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INVESTIGATIONS INTO THE REACTIVITY OF ALKYNES AND SULFUR OXIDES UNDER GOLD CATALYSIS

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Within this thesis sulfur oxides have been reacted under gold catalysis with alkynes allowing access to interesting and novel structures.

The gold catalysed oxyarylation of alkynes with aryl sulfides has been employed, developing conditions for the use of dibenzothiophene-*S*-oxide as the oxidant for the first time, to enable an efficient way to modify these useful structures. Encompassed within this work is the extension of the methodology allowing disubstitution of dibenzothiophenes and a novel oxyarylation-cycloisomerisation cascade. Overall the method showcases very mild conditions and good chemoselectivity.

Secondly a novel gold catalysed reaction of aromatic disulfur oxides with terminal and ester substituted internal alkynes has been developed. Fluorene and naphthalene derived sulfur oxides can be oxidised and functionalised in a single step with a range of terminal alkynes. The transformation successfully exploits rhodium carbene reactivity with alkynes and sulfur oxides.

Finally a large series of alkynyl sulfoxides have been synthesised which can undergo an efficient gold catalysed intramolecular cyclopropanation with an external oxidant affording fused sulfur heterocycles. This work presents the first example of accessing cyclopropanation from an α-diazo sulfoxide, or equivalent. Attempts to access other carbene reactivity modes are discussed as well as the synthesis of highly enantioenriched alkynyl sulfoxides and their treatment under gold catalysis.

Acknowledgements

Firstly, I would like to thank my supervisors, Dr Richard Grainger and Dr. Paul Davies, for their support, guidance and inspiration throughout my PhD, and for giving me the opportunity to work with them.

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Contents

List of abbreviations

Å	Amstrong
Au(I)	gold in oxidation state +1
Ac	Acetyl
Ar	Aromatic
C	Celsius
δ	chemical shift
d	doublet
DMF	dimethylformamide
DMSO	dimethylsulfoxide
dr	Diastereomeric ratio
E	Electrophile
EI	Electronic impact
eq	equivalent(s)
Eq	equation(s)
ESI	electronic spray ionisation
Et	ethyl
EWG	electron-withdrawing group
EtOAc	Ethyl acetate
G	gram(s)
h	Hour(s)
HRMS	high resolution mass spectrometry
Hz	hertz
IR	infrared

iPr	isopropyl
IPr	1,3-bis(2,6- diisopropylphenyl)imidazol-2-ylidene
J	coupling constant
LiHMDS	lithium bis(trimethylsilyl)amide
L	Litre(s)
M	metal
m	multiplet
m	meta
m-CPBA	m-chloroperbenzoic acid
Me	methyl
min	minute(s)
mol	Mole(s)
mp	Melting point
Ms	methansulfonyl
nBu	normal-butyl
NBS	N-bromosuccinimide
NMR	nuclear magnetic resonance
nOe	nuclear Overhauser effect
nPr	normal-propyl
Ns	nitrobenzenesulfonyl
Nu	nucleophile
n/z	mass/charge
o	ortho
p	para

Ph	phenyl
Piv	pivaloyl
ppm	part per million
Py	pyridine
q	quartet
RT	room temperature
s	singlet
T	temperature
t	triplet
TBAF	tetrabutylammonium fluoride
TBDPS	tert-butyldiphenylsilyl
Tf	trifluoromethanesulfonate
TBS	tert-butyldimethylsilyl
THF	tetrahydrofuran
TIPS	triisopropylsilyl
TLC	thin layer chromatography
TMEDA	tetramethylethylenediamine
TMS	trimethylsilyl
TOF	time of flight
THP	tetrahydropyran
Ts	4-toluenesulfonyl
ν	frequency
z	atomic number

Chapter 1: Introduction

1.1 Origins of gold reactivity in homogenous catalysis

1.1.1 Relativistic effects

The unique reactivity displayed by gold species and other π acids derives from relativistic effects. These effects explain the contraction of atomic s orbitals and the expansion of the d and f orbitals due to increased nuclear shielding. This phenomenon is most pronounced for gold and explains the gold ligand short bond lengths compared to other metals and the "soft" nature of the gold species.[1]

1.1.2 Alkynophilicity

Gold complexes to both alkenes and alkynes rendering them electrophilic and susceptible to nucleophilic attack. The strong preference for nucleophilic attack at the alkyne compared to the alkene allows for high selectivities.[2]

The Dewar-Chatt-Duncanson bonding model helps describe the bonding situation found between an alkyne and a gold complex.[3] Calculations have verified that for a 'naked' acetylene gold species the major bonding contributions are from the alkyne to metal σ bond which accounts for approximately 65% of the total (Fig 1). The other major bonding contribution is from the metal to ligand in plane π orbitals which constitutes 27% of the total interaction.[4,5] Half of the interaction is thought to be electrostatic in nature.[4,5]

In gold carbenoids strong π back donation occurs from the gold to the carbene, compared to the weak interaction observed with back donation to the alkyne. This difference in bonding helps to explain why gold is so effective at stabilising a carbene.[2]

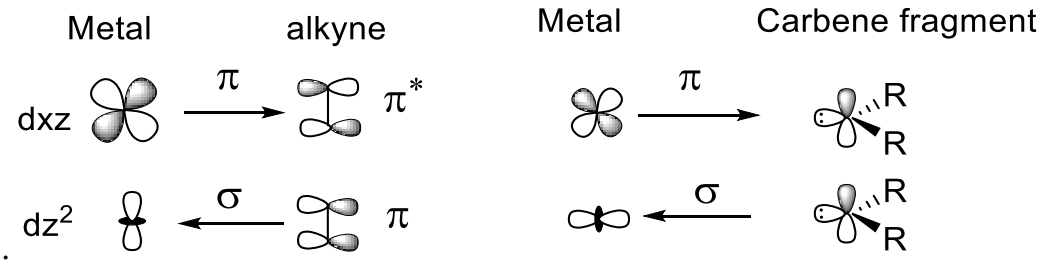
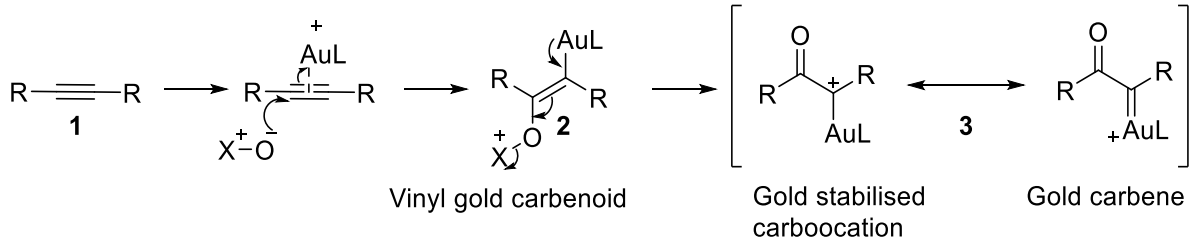


Fig 1. Major bonding interactions between gold and an alkyne and gold and a carbene.

1.2 Gold carbenoids

1.2.1 Generation of α-oxo gold carbenoids

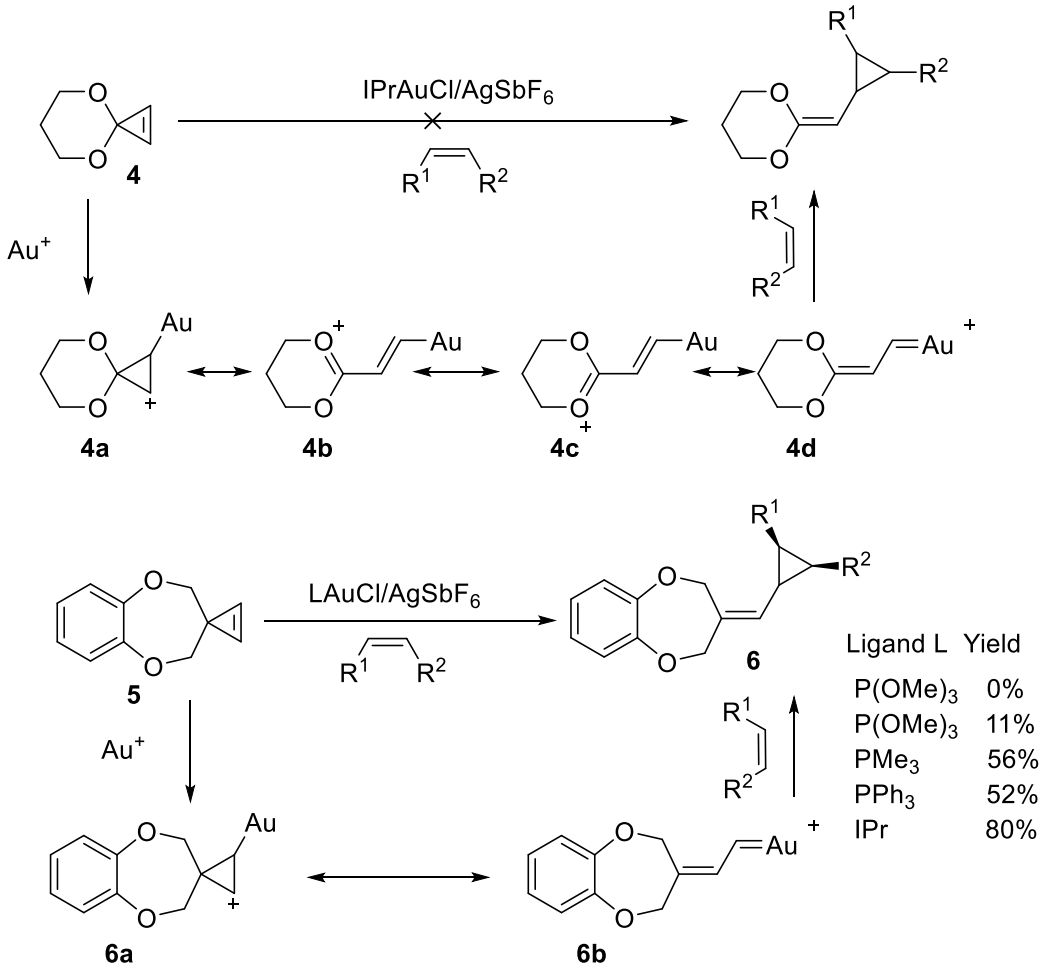
One area of particular recent interest involves gold activation of alkynes to access the reactivity patterns of α-oxo gold carbenes in a manner which avoids the use of diazo compounds and the issues associated with them. These concerns of extra synthetic steps and explosive nature make alternatives very attractive.[6] An improved method is realised using a nucleophilic oxidant, such as a sulfoxide, pyridine *N*-oxide or quinoline *N*-oxide and a gold species, where attack onto the activated alkyne **1** forms a vinyl gold carbenoid **2** (Scheme 1). Related species have been isolated and characterised in work by Hashmi.[7] Reaction of a nucleophile either intramolecularly or intermolecularly may occur next with loss of the leaving group. Alternatively extrusion of the nucleofuge may proceed first giving rise to an α-oxo gold carbene **3**. The nature of this species is widely proposed to be in between that of a metal carbene and a gold stabilised carbocation (Scheme 1).[8,9] The gold species can react with various nucleophiles intramolecularly or intermolecularly which permits an excellent range of diversity.



Scheme 1. Preparation of a gold carbene from an alkyne and an oxidant.

1.2.2 Bonding in gold carbenoids

Unearthing the nature of the bonding in gold carbenoids is vital to enable a good understanding of reactivity. The large differences in the bonding between a gold carbene and a gold stabilised carbocation need to be rationalised. Several studies have showed a range of theoretical and experimental evidence to suggest the bonding is best represented by a gold stabilised carbocation.[8] Successful intermolecular cyclopropanation by Echavaŕren and co-workers argued that an α-oxo gold carbene intermediate was more representative of the reactive intermediate.[9,10] Toste provided strong experimental evidence for this phenomenon by performing a gold catalysed cyclopropanation with a variety of different ligands on gold (Scheme 2).[11] In the first example, the proximity of the oxygen atoms on the dioxane **4** to the gold centre favour unproductive resonance contributions **4a** to **4c** with the positive charge stabilised on the oxygen and no reaction was observed. In a second example the influence of the ligand on gold was profound. Strongly σ-donating and weakly π-accepting ligands such as *N*-heterocyclic carbenes and alkyl substituted phosphines contribute electron density to the gold atom giving rise to the gold carbene **6b** which results in efficient cyclopropanation. Alternatively strongly π-accepting ligands such as phosphites deprive the gold centre of electron density and the cationic gold resonance form **6a** is preferred which is unreactive towards cyclopropanation. This seminal contribution which boasted theoretical studies backing up the experimental results, rationalises the reactivity changes observed with ligands on gold of varying electronic nature, which is an ongoing topic throughout the work in this field.



Scheme 2. Intermolecular cyclopropanation of cyclopropenes.

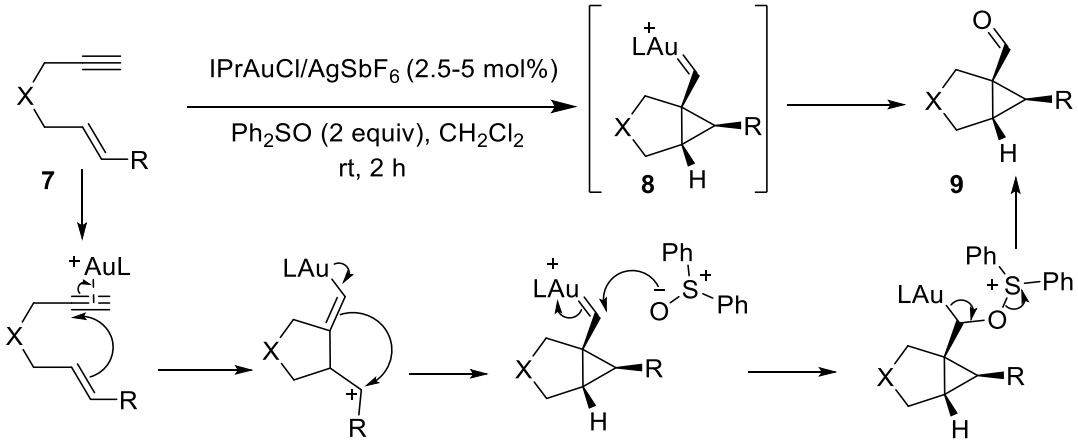
1.3 Developments in reactions of oxygen based nucleophiles with alkynes under gold catalysis

1.3.1 Use of sulfoxides as intermolecular and intramolecular oxidants

Sulfoxides have been employed as intramolecular and intermolecular oxidants in a limited range of gold catalysed processes with alkynes. They often provide complementary reactivity to nitrogen based oxidants, allowing access to unique reactivity modes.

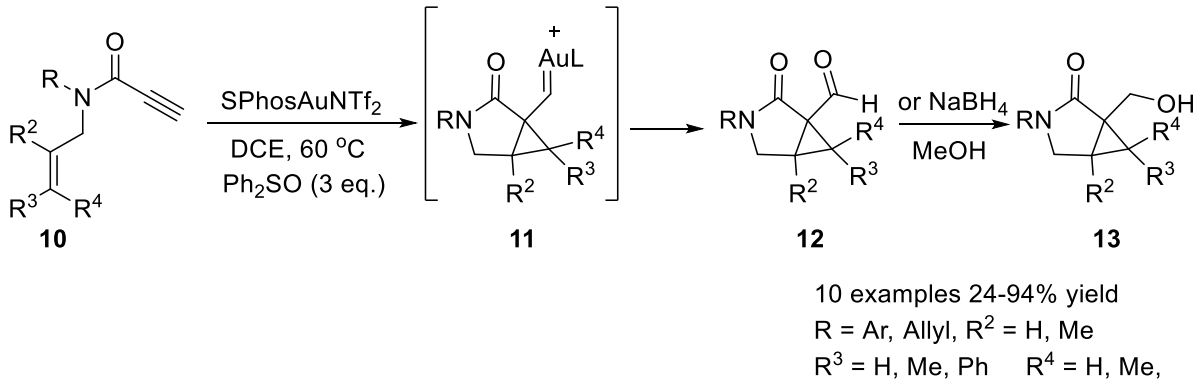
The gold catalysed cycloisomerisation of enynes is a well-known reaction in which complex structures can be generated from simple starting materials.[12] Toste *et al* set about trapping the

cyclopropane gold (I) carbene intermediate **8** formed in the cycloisomerisation of 1,6 enynes **7**. (Scheme 3). Diphenylsulfoxide was selected as the oxidant to achieve this after dimethylsulfoxide was found to be ineffective for the transformation.[13] A variety of 1,6-enynes **7** underwent cyclisation affording cyclopropyl aldehydes **9** in high yield. The work was also expanded to other systems starting from both diazo compounds and alkynes affording a variety of rearrangement products.



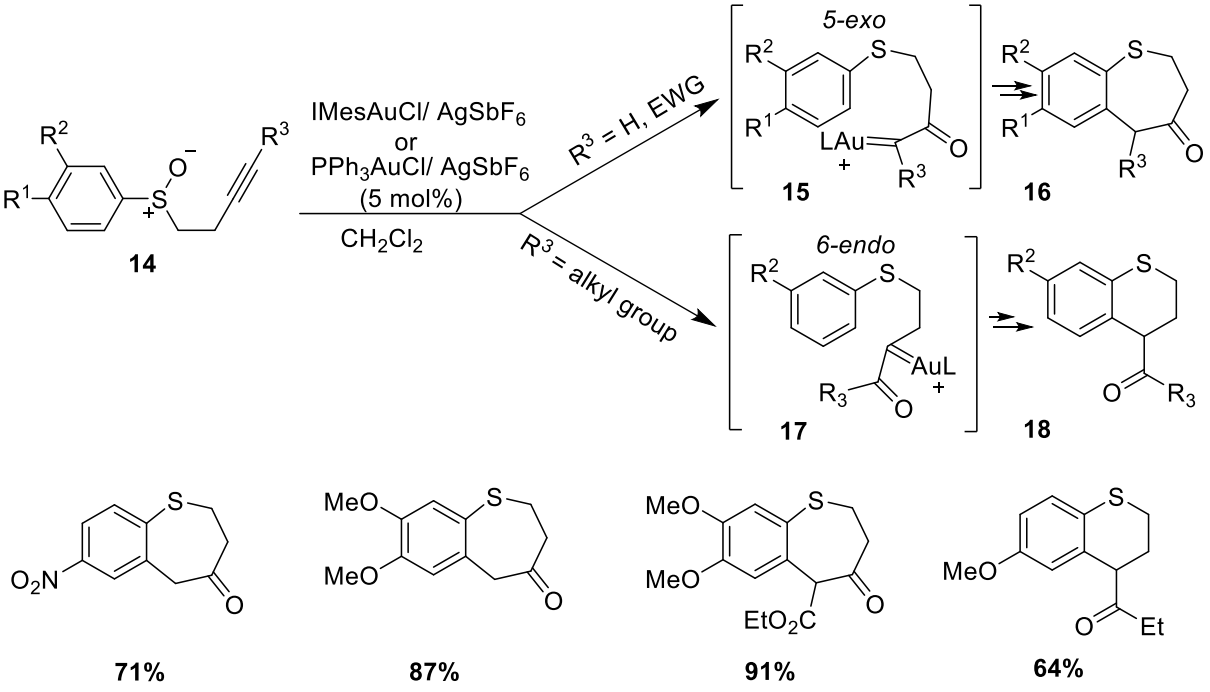
Scheme 3. Cyclopropyl aldehydes formation via trapping of a gold carbene

Shin, under modified conditions demonstrated similar reactivity of diphenylsulfoxide in the preparation of a variety of cyclopropane carboxaldehyde derivatives **12** (Scheme 4) some of which were directly transformed to their corresponding alcohol **13** due to isolation difficulties.[14] Shin had established that terminal enynes **10** react via a 5-exo dig cyclisation and an excess of diphenylsulfoxide as the oxidant enables the trapping of the gold carbene **11** and limits formation of the undesired alder-ene derived products. Substitution on the alkene was shown to be well tolerated and the protecting group on nitrogen could be readily switched. Choice of oxidant was critical for this transformation with various pyridine-*N*-oxides being unsuitable, giving low yields and undesired side products.



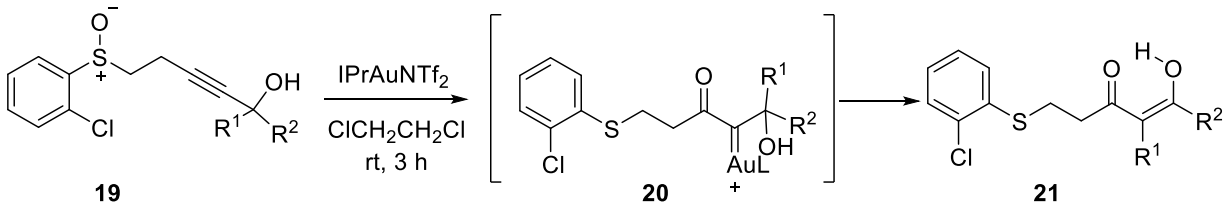
Scheme 4. Terminal 1,6 enynes as substrates for cyclopropanation.

Independently, both Toste[15] and L. Zhang[16] demonstrated that tethered sulfoxides **14** can add intramolecularly to a gold activated triple bond. The electronic bias on the alkyne can be varied to alter the regioselectivity of attack and allow the efficient formation of either benzothiepinones **16** or benzothiopines **18**. In these initial communications, the reaction was proposed to proceed via an α-oxo gold carbene with Friedel-Crafts type reaction leading to the products. High functional group tolerance was observed with substitution at the propargyl and homopropargyl positions allowed (Scheme 5).



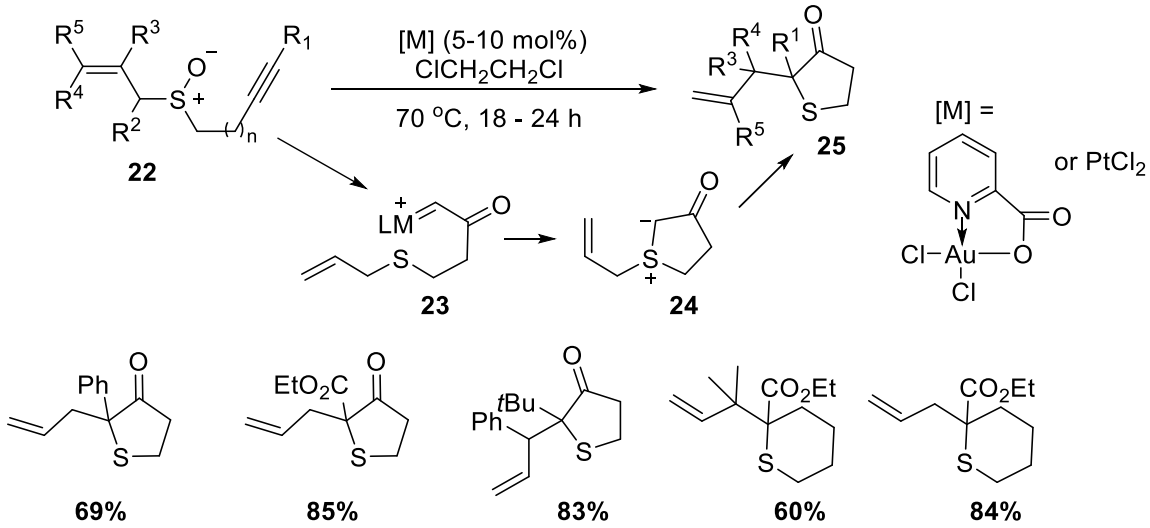
Scheme 5. Benzothiepinones or benzothiopines.

Zhang showed that an *o*-chloro benzene substituent **19** blocks the Friedel-Crafts pathway (now found to involve a [3,3]-sigmatropic rearrangement as the key step) exploring the synthesis of **21** utilising a semi pinacol rearrangement (Scheme 6).[16] The reaction was efficient and could be used to furnish a variety of different ketones **21**.



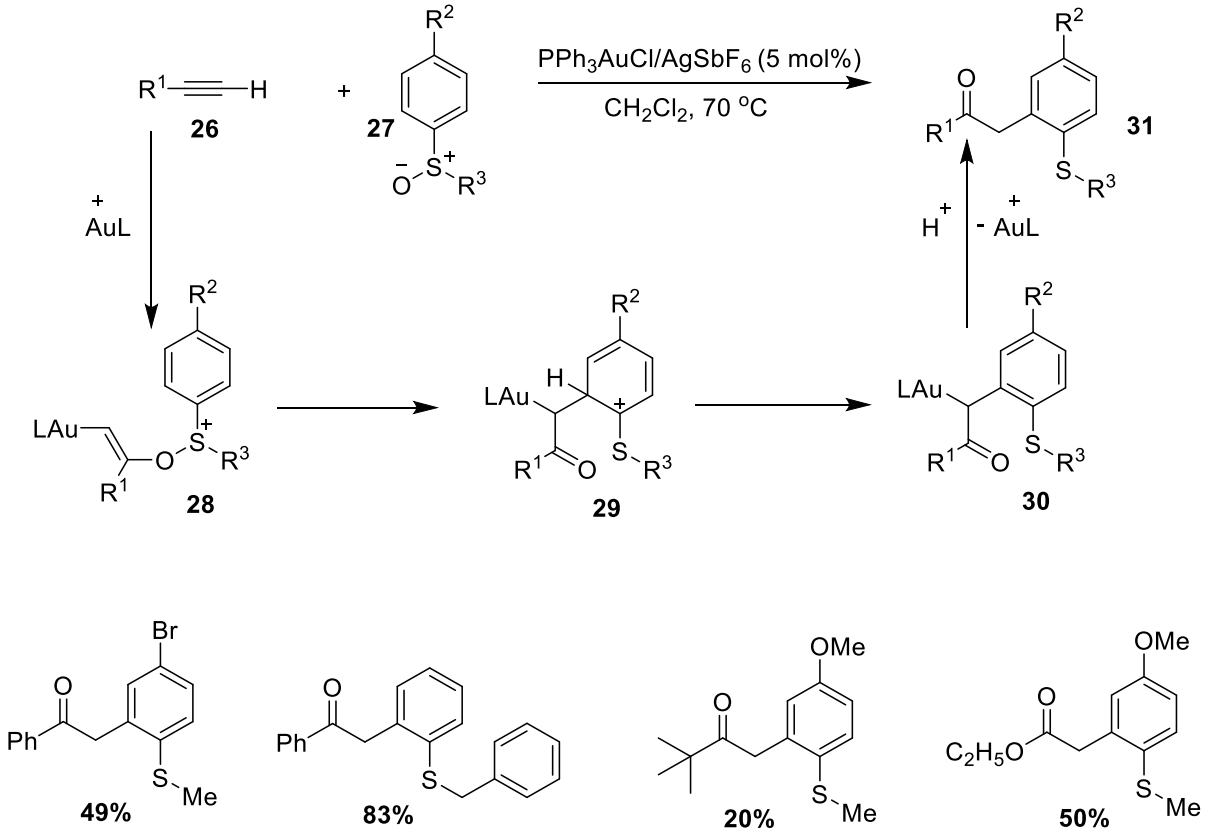
Scheme 6. Incorporating a semi pinacol rearrangement upon oxidation.

Davies and co-worker were able to successfully apply the intramolecular oxidation with sulfoxides **22** to generate sulfur ylides **24**, which underwent a facile [2,3]-sigmatropic rearrangement.[17] The reaction was proposed to proceed via an α-oxo metal carbene **23** with nucleophilic attack of the sulfur and [2,3]-rearrangement furnishing the 5 and 6 membered heterocycles **25** (Scheme 7). Either a Pt (II) or a Au (III) catalyst was employed with the choice important in some cases, substrate scope was good and yields were moderate to excellent.



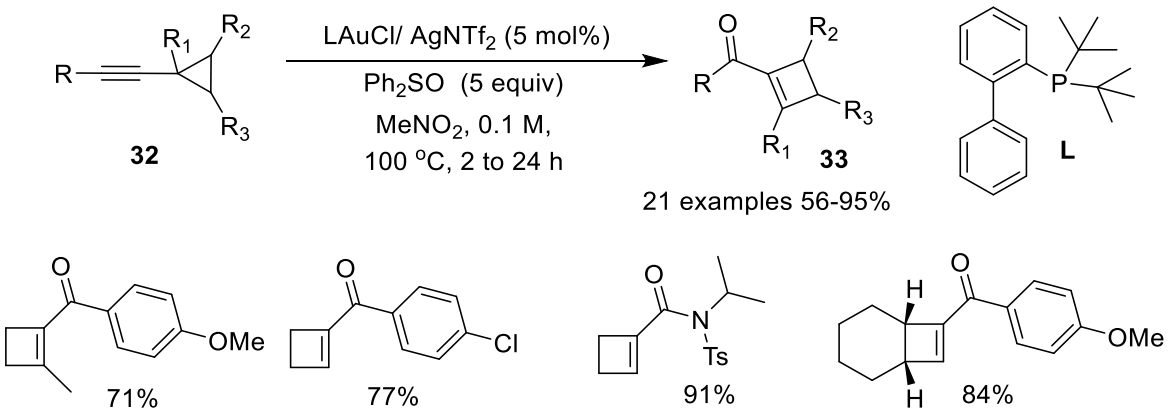
Scheme 7. Using oxidative gold catalysis to access a [2,3]-sigmatropic rearrangement.

Asensio *et al* investigated for the first time the intermolecular oxidation of terminal alkynes **26** with sulfoxides **27**.[18] The expected mechanistic pathway involved oxidation of the alkyne leading to an α-oxo gold carbene which would be trapped intramolecularly by a Friedel-Crafts type electrophilic aromatic substitution. The formation of only the *ortho* substituted regioisomer **31** led the research group to undertake DFT studies to confirm the reaction mechanism. Following the anti-addition of the sulfoxide, intermediate **28** is formed and this undergoes a [3,3]-sigmatropic rearrangement to afford **29**. Formation of **30** proceeds with protodeauration furnishing **31** giving a lower energy pathway than the alternate α-oxo gold carbene mechanism (Scheme 8). The overall result is a good method to selectively functionalise the *ortho* position of an aromatic sulfide. The study demonstrated the successful use of alternative aryl sulfoxides in an intermolecular reaction for the first time with electron deficient sulfoxides resulting in reduced reaction efficiency compared to electron neutral and electron rich sulfoxides.



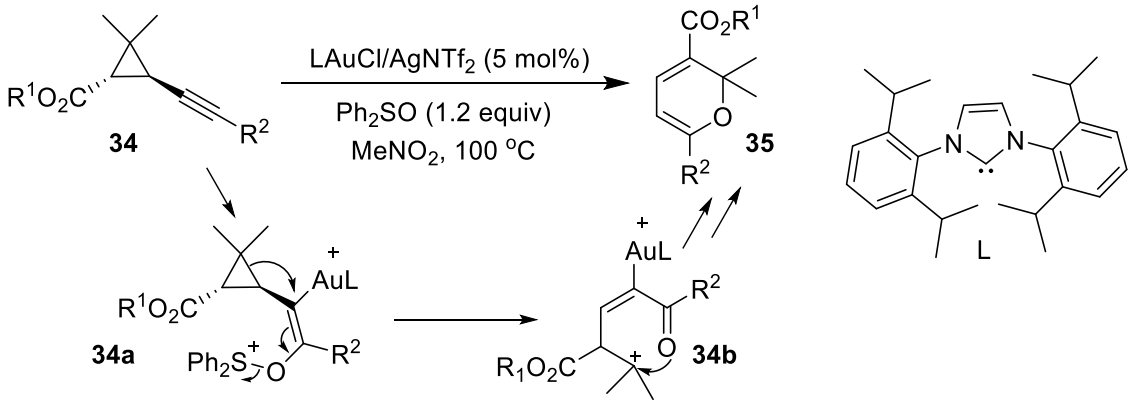
Scheme 8. The intermolecular gold catalysed oxidation with terminal alkynes.

An efficient method of preparing cyclobutene derivatives **33**, was reported by Liu utilising a gold catalysed oxidative ring expansion of cyclopropane derivatives **32** (Scheme 9).[19] Diphenylsulfoxide was found to be active unlike pyridine-*N*-oxide, amine oxide or imine oxide, with a large excess (5 equiv) required to achieve total conversion. Vitally the ring expansion of **32** was more favourable than oxyarylation of **32**. Although high temperatures were required the reaction was shown to be versatile with lots of functionality tolerated and aminocyclopropyl alkynes proved especially excellent reaction substrates.



Scheme 9. Formation of different cyclobutenyl compounds under gold catalysis.

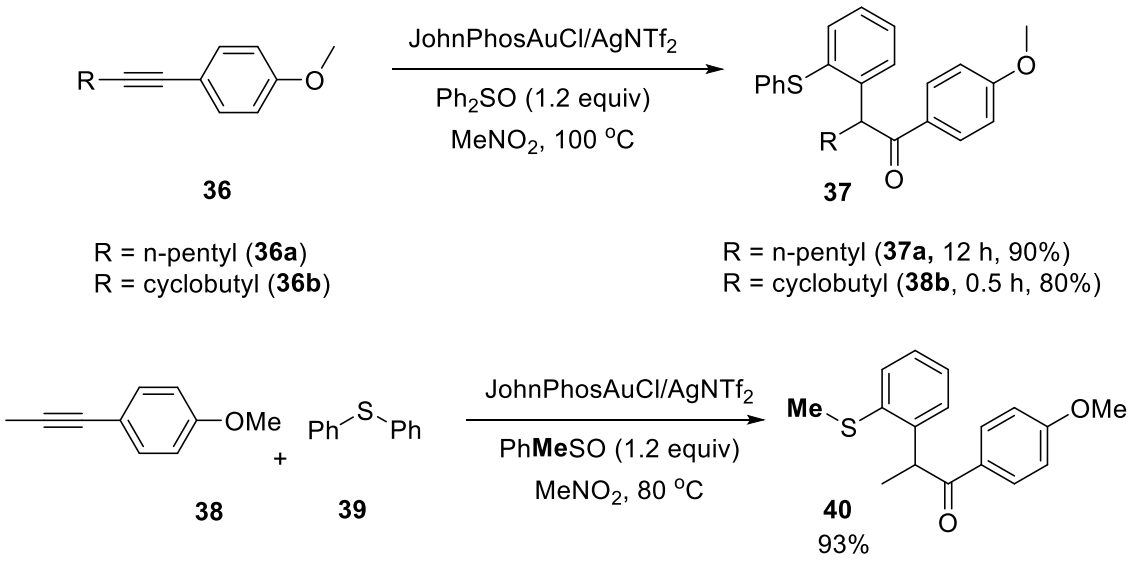
In the same report Liu exploited the known ring cleavage of cyclopropanes containing both donor and acceptor groups as vicinal substituents at the cyclopropane ring.[20] Accordingly substrates were designed and these smoothly underwent an oxidative cleavage on changing the gold catalyst to afford several functionalised 2H-pyrans (Scheme 10).[19] In the reaction mechanism a cyclopropyl migration occurs from intermediate **34a** forming a stabilised cation **34b**. Cyclisation of **34b** leads to the 2H-pyran **35**.



Scheme 10. Formation of different 2H pyrans.

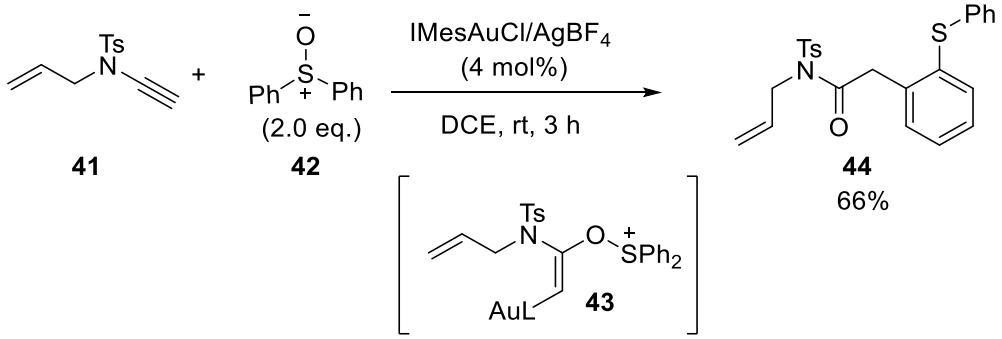
Liu attempted to expand the scope of this oxidative gold catalysed ring expansion by reacting *n*-pentyl and cyclobutyl aromatic alkynes **36**.[19] Instead though excellent yields of the *ortho* functionalised sulfides **37** were obtained (Scheme 11). These products result from the oxyarylation of alkynes and expand the reaction scope for that transformation with the

incorporation of internal alkynes. The reaction conditions employed for the oxyarylation were similar to those selected by Asensio, with higher temperatures and a more electron rich ligand than PPh_3 being employed. Crossover experiments were performed, with the addition of a sulfide **39** into the reaction mixture (Scheme 11). Only the product **40** incorporating the aryl sulfide from sulfoxide was formed, resulting from oxyarylation onto the sulfoxide.



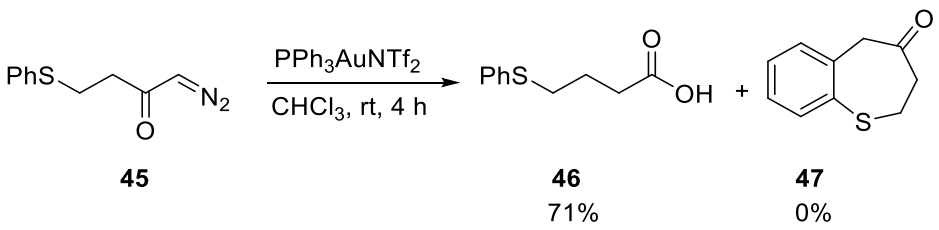
Scheme 11. Internal alkynes in the gold catalysed oxyarylation.

More recently, (in 2013) Li showed that treatment of a terminal ynamide **41** with diphenylsulfoxide **42** and a gold catalyst led to the formation of the oxyarylation product **44**, instead of the desired cyclopropanation product, in a moderate yield (Scheme 12).[21] The mechanism for the cyclopropanation was also proposed to proceed via the vinyl gold intermediate **43** (Scheme 12) suggesting aryl sulfoxides are incompatible oxidants for this process.



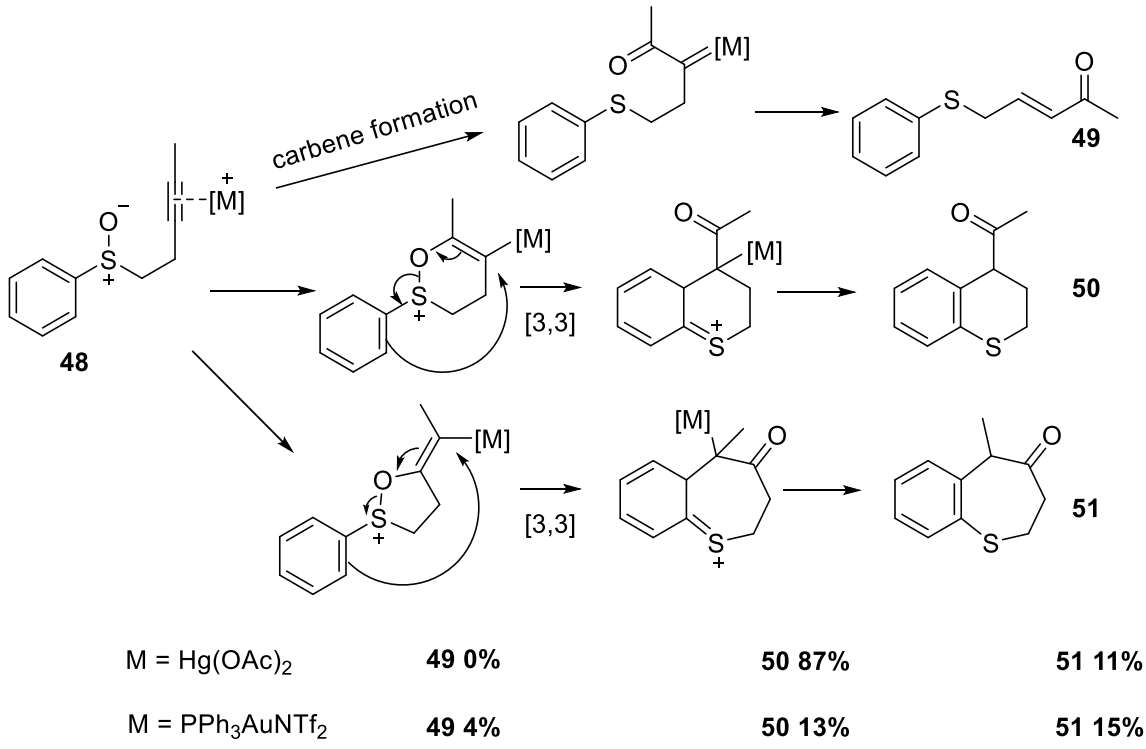
Scheme 12. Oxyarylation reaction of a terminal ynamide with diphenylsulfoxide.

In 2013 L. Zhang published a detailed study containing both experimental, and theoretical evidence using DFT studies to rule out α-oxo gold carbenes as fleeting intermediates in his earlier work on the synthesis of benzothiepines.[22] An alternative pathway, where intramolecular [3,3]-sigmatropic rearrangement is the key bond forming process was found to be significantly lower in energy. Diazo compound **45** was subjected to the optimised reaction conditions. In this case none of the benzothiepinone **47** was formed, instead a carboxylic acid **46** resulted, likely as the result of a Wolff rearrangement, followed by a hydration (Scheme 13).[22] Interestingly, these results are in contrast to Davies' work, where sulfur ylides were generated and underwent subsequent rearrangement (Scheme 12) with the only plausible mechanism involving metal carbenes.[17] In this case no aryl groups are present so the lower energy [3,3]-sigmatropic rearrangement is implausible and in the absence of a lower energy reaction pathway the reaction proceeds via a gold carbene.



Scheme 13. Reaction of a diazo compound showing the exclusion of the expected α-oxo gold carbene.

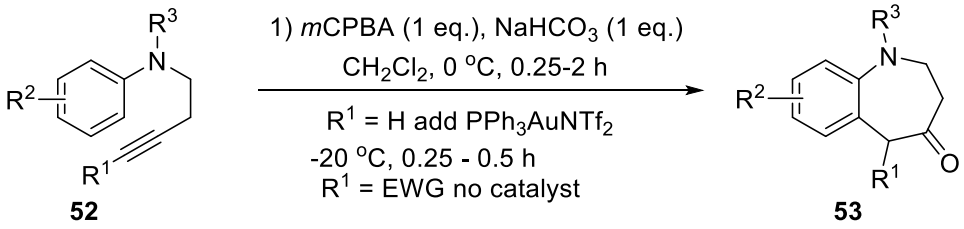
With this knowledge, the scope for the preparation of thiopineones **50** could be broadened and $Hg(OAc)_2$ was found to be a good alternative catalyst for certain substrates, including an internal alkyne (Scheme 14). Some α-oxo gold carbene formation arises with the gold catalyst and an internal alkyne which leads to unwanted α-β unsaturated ketones **49**.



Scheme 14. Reaction outcome dependence on metal.

1.3.2 Intramolecular nitrogen based oxidants in gold catalysis

Amine-*N*-oxides and nitrones have also proven to be excellent intramolecular oxidants for gold catalysed processes enabling the formation of a wide range of heterocycles.[23-32] An example of using an amine-*N*-oxide in this manner is displayed below where tetrahydrobenz(b)zepines **53** were prepared in a one pot sequence (Scheme 15).[32]



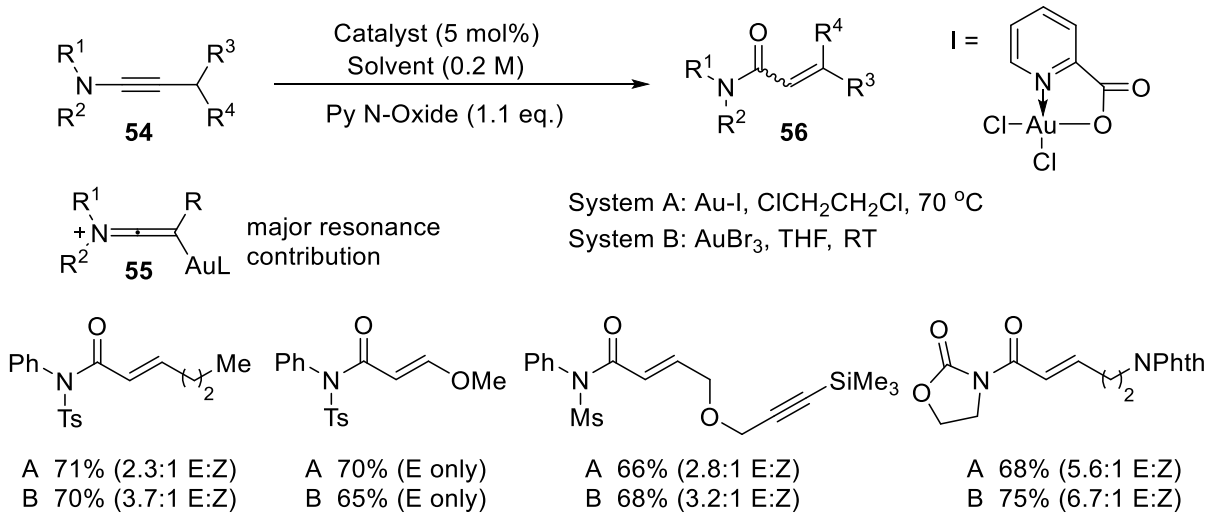
Scheme 15. Synthesis of tetrahydrobenz[b]azepin-4-ones.

1.3.3 Site specificity and double oxidation

An important control factor is the regioselectivity of addition by the intermolecular oxidant. Controlling the regioselectivity is of paramount importance in order to access viable synthetic reactions.

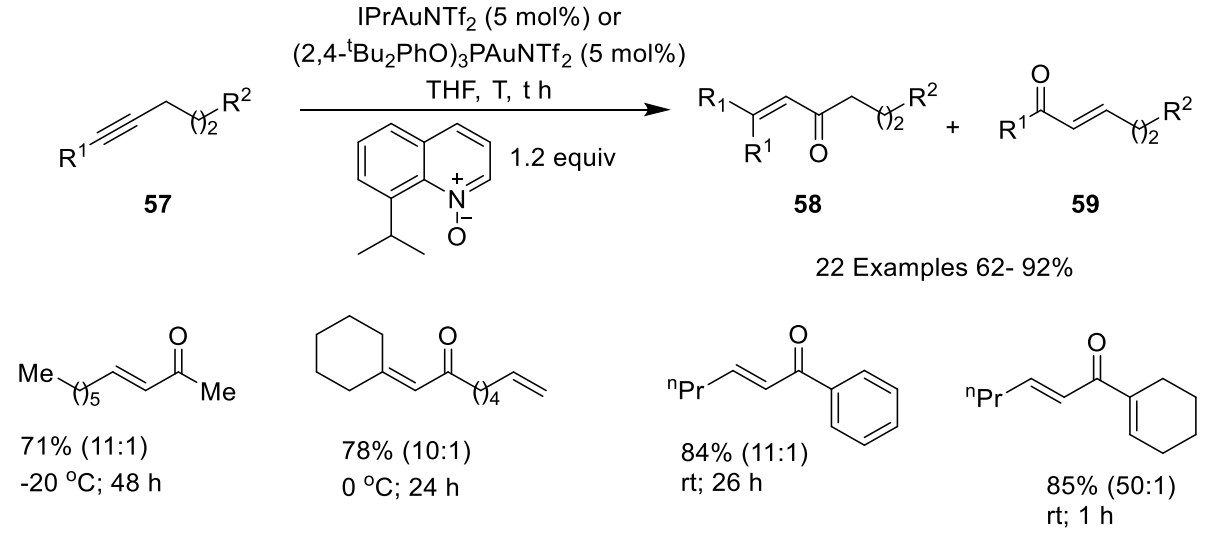
Additionally attack of a second oxidant molecule to the gold carbenoid can be considered as a double alkyne oxidation. This competing process when employing external oxidants also needs to be considered.

Ynamides **54** have been employed in acid free intermolecular gold catalysed oxidations in work undertaken by Davies and co-workers. Participation of the nitrogen lone pair gives a gold–keteneiminium resonance form **55** (Scheme 16). The highly electrophilic position allows site specific attack of the oxygen nucleophile.[33] A 1,2-hydrogen shift and elimination of gold then furnishes the α,β-unsaturated imide derivatives **56**. The tolerance of different functional groups is high (Scheme 15) and the yields are good (63 to 81%) with reasonable to excellent *E:Z* ratios of products. Furthermore ynol ethers are also suitable substrates. This method allows good access to α-imido and α-ester metal carbenoid reactivity. Notably a second transformation was achieved in the report, with an ynamide being doubly oxidised under alternative conditions. Later the same transformation was achieved under different conditions and extended to substituted diphenyl alkynes.[34]



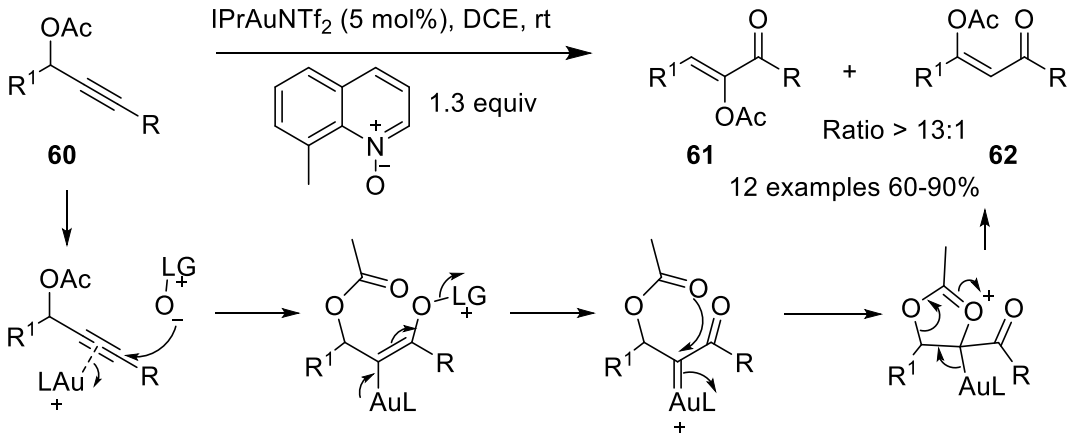
Scheme 16. Intermolecular oxidation of ynamides.

Achieving good regioselectivity with intermolecular oxidation of internal alkynes is a considerable challenge due to the small difference in electronic properties of the two alkyne carbons. Using a sterically bulky quinoline-*N*-oxide and a N-heterocyclic carbene ligand on the gold species, L. Zhang was able to address this issue and attained high regioselectivity in the preparation of α-β unsaturated carbonyls **59** from alkynes **57**.[35] The reaction proceeded with good chemoselectivity and in high yield. (Scheme 17).



Scheme 17. Gold-catalysed regioselective oxidation of alkynes without acid additives.

Propargylic acetates **60** were treated under gold catalysis with an oxidant and were shown to be excellent substrates for highly regioselective oxidation (Scheme 18).[36] Chemoselectivity was high with the regiocontrol attributed to the effect of the electron withdrawing carboxy group and the *E:Z* ratios were generally high. The α-acetoxyenones **61** formed were proposed to be the result of a two-step 2,4 acetoxy migration (Scheme 18).

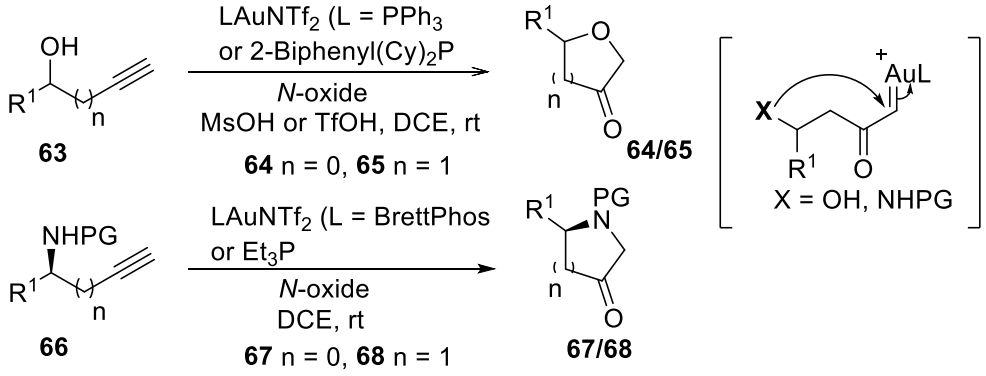


Scheme 18. Gold catalysed oxidation of propargylic acetates.

1.3.4 Intramolecular trapping of the α-oxo gold carbene

Trapping of the gold species generated after initial attack of the oxidant onto the activated alkyne by intramolecular attack of an alcohol or amine nucleophile, has proven to be an excellent approach, to conveniently and mildly prepare a wide range of heterocycles (Scheme 19).

The α-oxo gold carbene could be trapped by an alcohol in both the propargylic and homopropargylic postions giving rise to oxetan-3-ones **64** and dihydrofuran-ones **65**.[37,38] Acid additives were required to achieve high yields, but otherwise mild conditions could be employed. Chiral propargyl carboxamides and homopropargyl carboxamides synthesised from Ellman's chemistry also proved suitable substrates, delivering nitrogen heterocycles **67** and **68** in high yields and with excellent enantioselectivity.[39,40]

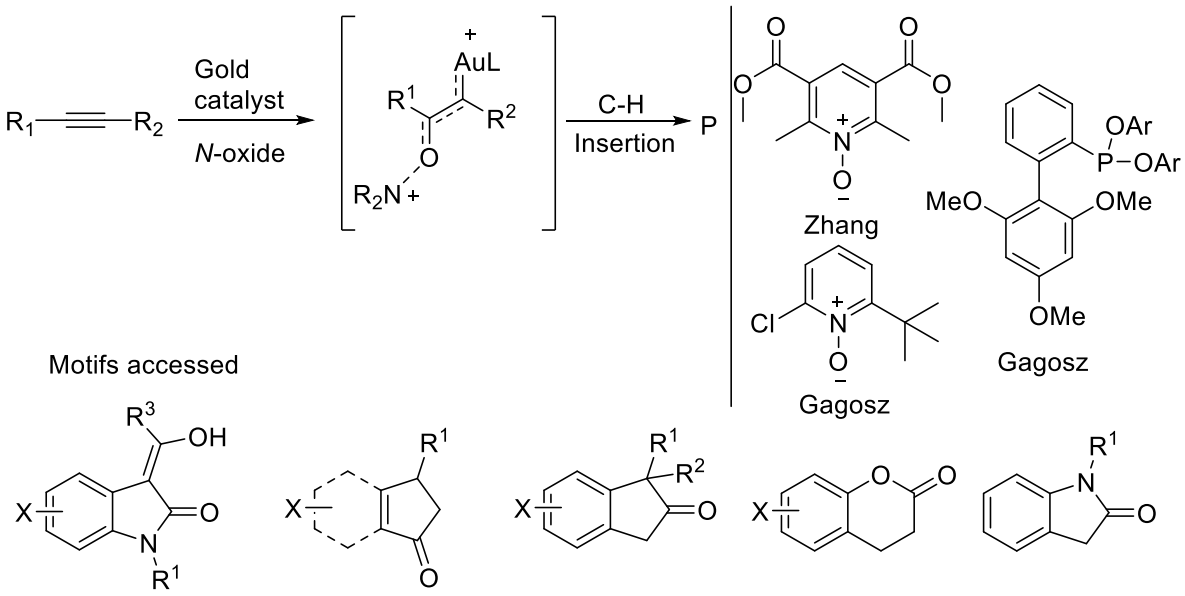


Scheme 19. Trapping of the α-oxo gold carbene with a pendant OH or NH nucleophile.

C-H insertions are another type of common reactions of metal carbenes.[41] In developing oxidative gold catalysed reactions involving a C-H insertion, exciting new structures have been prepared as well as novel catalysts and oxidants delivering further insight into this versatile field of organic chemistry (Scheme 20).[42-46] Side reactions caused problems in these trnasformations which including deactivation of the catalyst by the pyridine leaving group.

The solution involved further tuning of the catalyst and the oxidant. Very bulky oxidants were employed by Zhang and Gagosz to suppress unwanted reactions. After disappointing screening reactions with known catalysts Gagosz prepared a new class of ligands for gold which combined strong steric shielding of the gold centre with the required electron-withdrawing properties (Scheme 20).

Similar transformations allowing access to multiple products have been developed in the last few years. Alkynes were employed with an external oxidant and a gold catalyst showcasing efficient routes to functionalised heterocycles.[47-57]



Scheme 20. Trapping of the α-oxo gold carbene with a pendant CH nucleophile.

1.3.5 Gold catalysed intramolecular oxidative cyclopropanations

Cyclopropanations are among the most common reactivity pathways of metal carbenes, with many examples of cyclopropanation from copper or rhodium carbenes generated from diazo compounds.[58] This reactivity has been extended to gold more recently, using readily available alkynes and pyridine-or quinoline-based oxidants (Scheme 21).

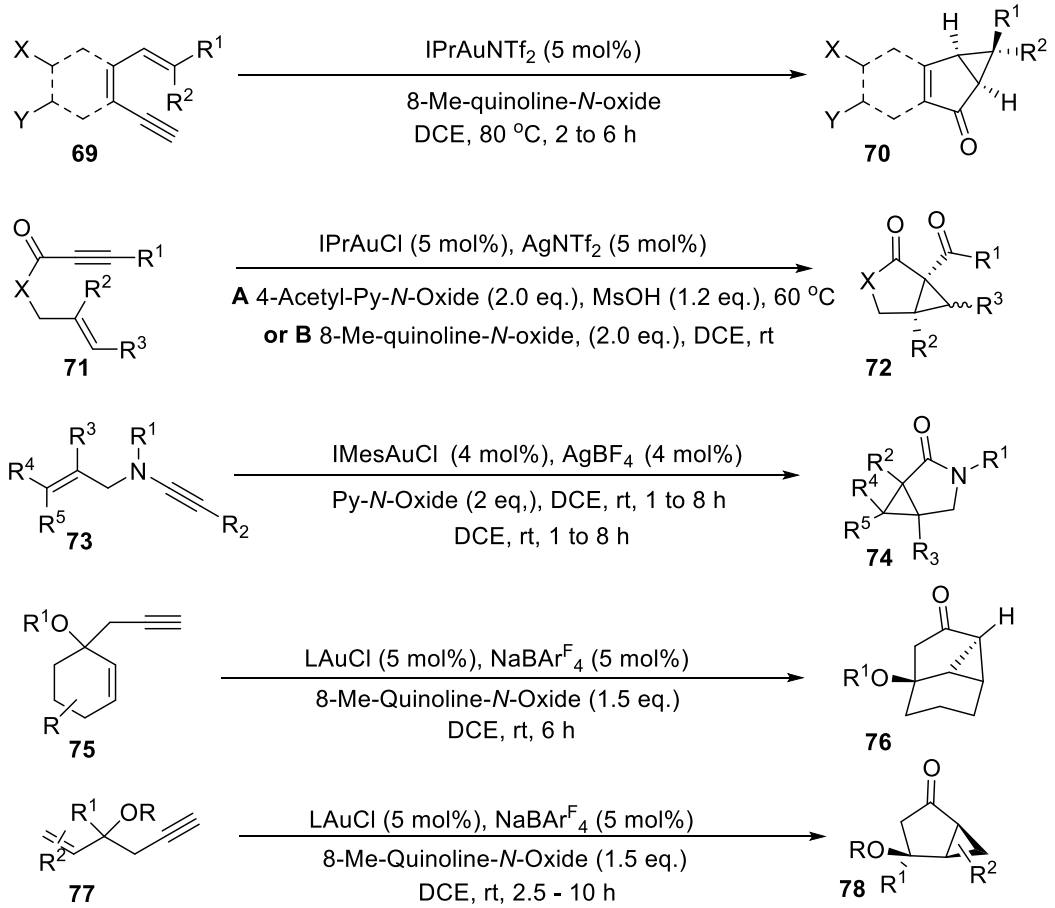
In 2011 Liu and co-workers reported a stereoselective oxidative cyclopropanation from 1,5 enynes **69**. The catalysis showed excellent chemoselectivity with benzene derived and non-benzene derived substituents working well (Scheme 21).[59]

J. Zhang and co-worker demonstrated in 2011 that electronically-biased 1,5 enynes **71** are capable of undergoing a gold catalysed oxidative intramolecular cyclopropanation sequence forming lactams and cyclopentanones **72**.[60] When an ester derived substrate was employed under conditions **A** no cyclopropanation was observed. Instead a product resulting from intermolecular trapping of the gold carbene with mesylate resulted. The highly charged gold carbene species would be preferentially attacked by a hard nucleophile such as mesylate

compared to the softer alkene nucleophile suggesting that the α-oxo gold carbene is the reactive intermediate in the catalysis.

Ynamides **73** were transformed efficiently by Li into 3-aza-bicyclo[3.1.0]hexan-2-ones **74** utilising gold catalysis.[21] A diazo compound which would be expected to lead to the same cyclopropanated product **74** via a gold carbene intermediate was prepared, but resulted in a poor yield of **74** when employed under the reaction conditions. If the reaction did proceed via an α-oxo gold carbene a high reaction efficiency would be expected. As this was not the case the observed vinyl gold carbenoid intermediate was deemed to be involved.

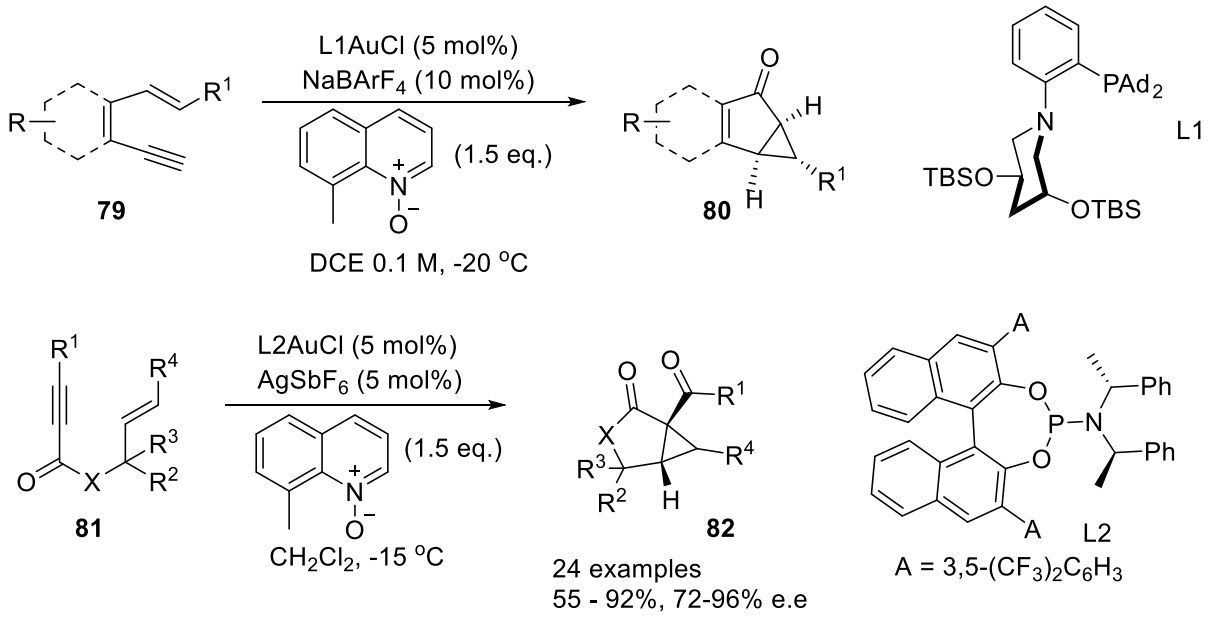
Alternative substrates were subjected to the intramolecular oxidative cyclopropanation by L. Zhang generating a wide range of bicyclic **76** and tricyclic cyclopropyl ketones **78** (Scheme 21).[61] For these transformations a P,N bidentate ligand was employed successfully.



Scheme 21. Gold catalysed oxidative intramolecular cyclopropanation reactions.

Diazo chemistry has proven very amenable to enantioselective catalysis reactions via a metal carbene employing chiral ligands, yet few reports demonstrate asymmetric oxidative gold transformations.

Choosing systems previously studied for oxidative cyclopropanation L. Zhang and co-workers and J. Zhang were able to effect a highly enantioselective reaction.[62,63] L. Zhang found success with a modified P,N-C2 symmetric bidentate ligand creating a chiral environment around the gold centre, employing 8-methylquinoline-*N*-oxide at low temperature.[62] J. Zhang on the other hand employed a phosphoramidite chiral catalyst under similar conditions which gave similarly impressive results (Scheme 22).[63] From experimental evidence the vinyl gold carbenoid (see **2**) is proposed to be the key intermediate, and this is the stage in which the enantioselectivity is determined.

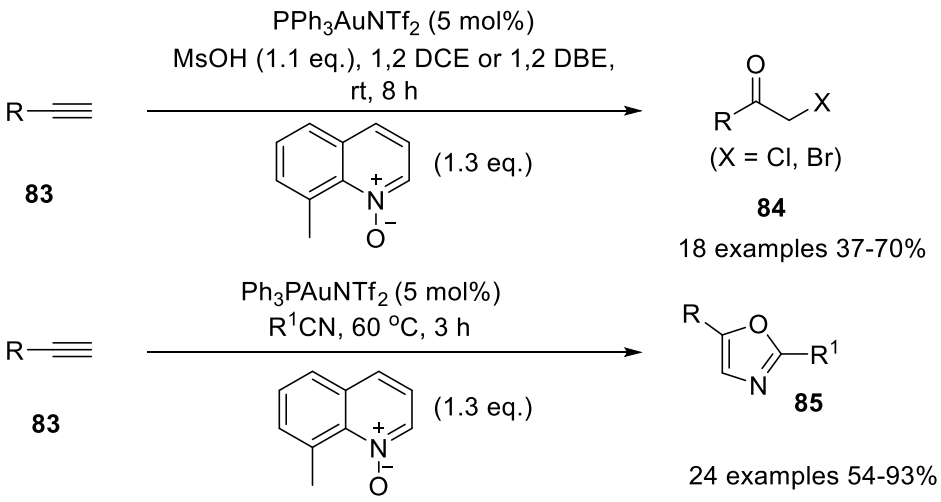


Scheme 22. Enantioselective cyclopropanation using a modified P, N based ligand and the use of a chiral phosphoramidite ligand.

1.3.6 Use of intermolecular nucleophiles to trap the gold carbenoid

Intermolecular trapping of the α-oxo gold carbene by halide abstraction was observed as early as 2009 by Davies.[17] L. Zhang and co-workers developed a one-step sequence to access α-halo methyl ketones **84** from terminal alkynes **83** under oxidative gold conditions (Scheme 23). The proposed reaction mechanism involves the abstraction of a halide from the solvent via a halonium ion.[65] The reaction efficiency was moderate due in part to the competitive trapping of the α-oxo gold carbene with mesylate.

A second synthetic transformation utilising intermolecular trapping of the gold carbene with the reaction solvent exploited the reactivity of nitriles as the solvent allowing a desirable and efficient [2+2+1] annulation with alkynes **83** (Scheme 23).[64] Most of the study was performed using the nitrile reagent in large excess as solvent. Limitations were observed when the substrate contained a functional group that could trap the metal carbene intramolecularly. Examples of this were seen with hydroxy substituted alkynes which preferentially afforded the dihydrofuranones prepared previously. Furthermore yields were poor with sterically bulky arylacetylenes. Employing 3 equivalents of nitrile still permitted moderate yields with longer reaction times.



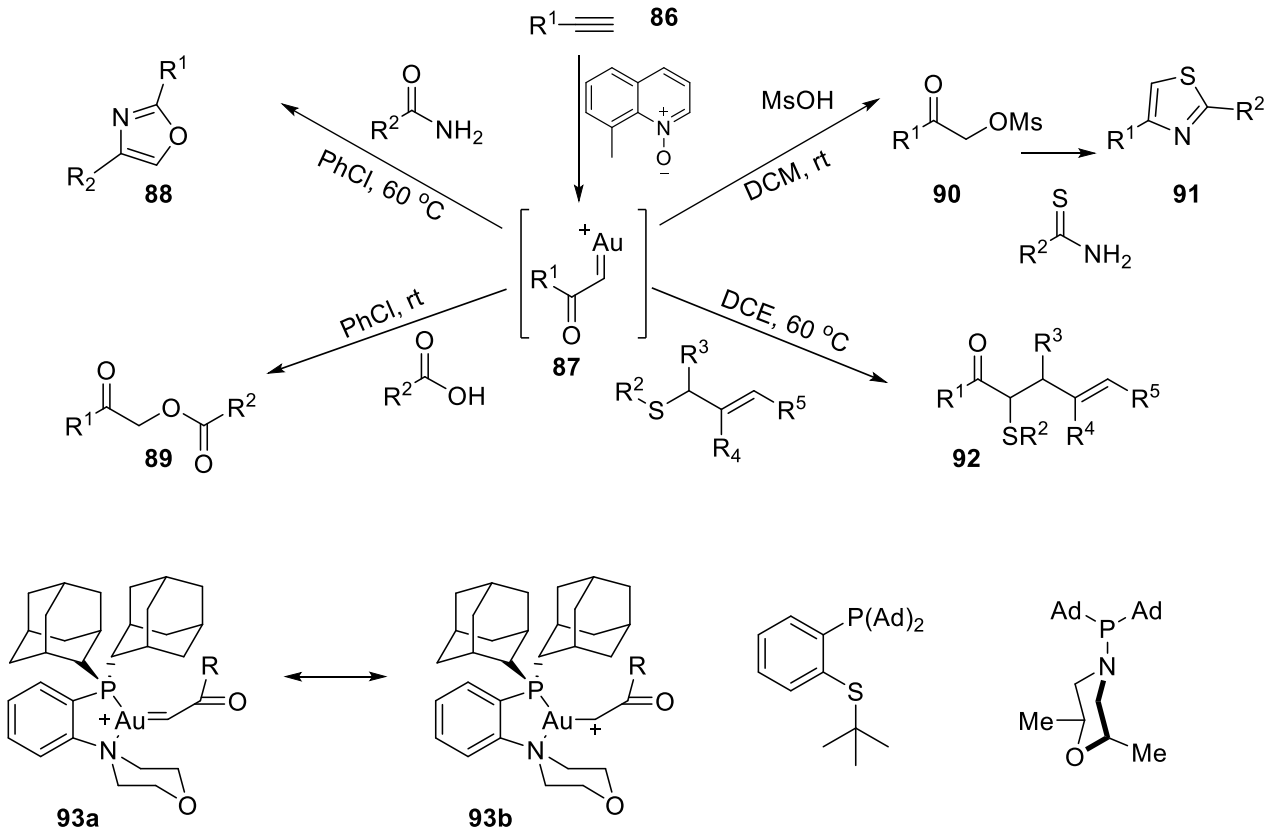
Scheme 23. 2,5 Disubstituted oxazoles via a gold-catalysed intermolecular alkyne oxidation.

Three main approaches have been employed in order to overcome the unwanted intramolecular reactivity, double oxidation and solvent interference for fully intermolecular reactions.

Zhang has been able to develop a number of transformations in which a quinoline based oxidant is used alongside a gold catalyst to generate an α-oxo gold carbene **87** from a terminal alkyne **86** which is subsequently trapped intermolecularly with a nucleophile (Scheme 24).[66-69] These reactions allow access to diverse heterocycles **88** and **91** and proceed with high efficency

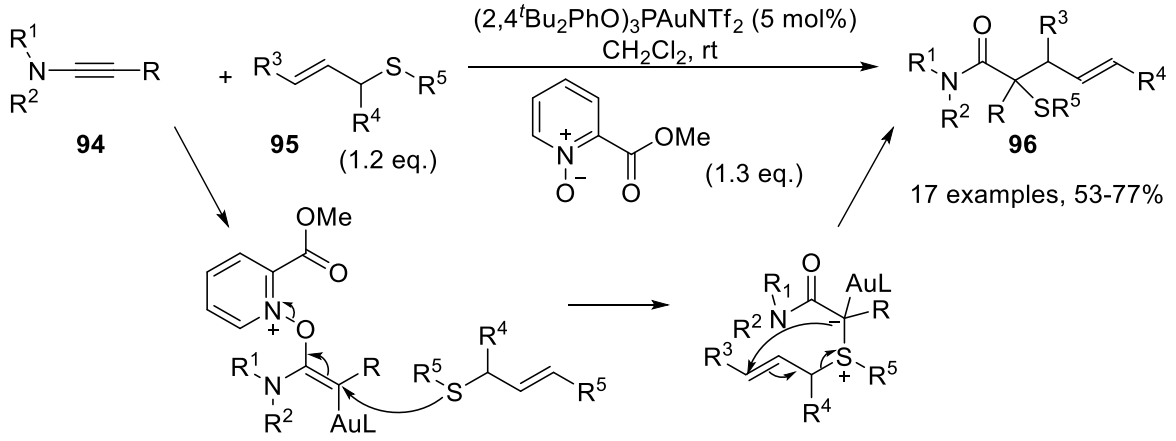
To overcome the inherent difficulties associated with controlling the reactivity of the α-oxo gold carbene, catalysts were employed such as MorDalPhos (Scheme 24). A tricoordinate species is proposed **93a**, **b**, creating a sterically shielded environment for the gold centre to suppress unwanted side reactions and allow high efficiency. Variations on these catalysts have been employed with a P,S analogue being the catalyst of choice in the sulfur ylide chemistry. Further catalyst optimisation highlighted that careful positioning of two methyl groups on the cyclohexyl ring lock the chair conformation of the complex, enabling strong steric crowding at all times and further reducing unwanted reactivity. As important as these new reports were, an

unsolved limitation was the requirement of the oxidant to be added by syringe pump over an extended period.



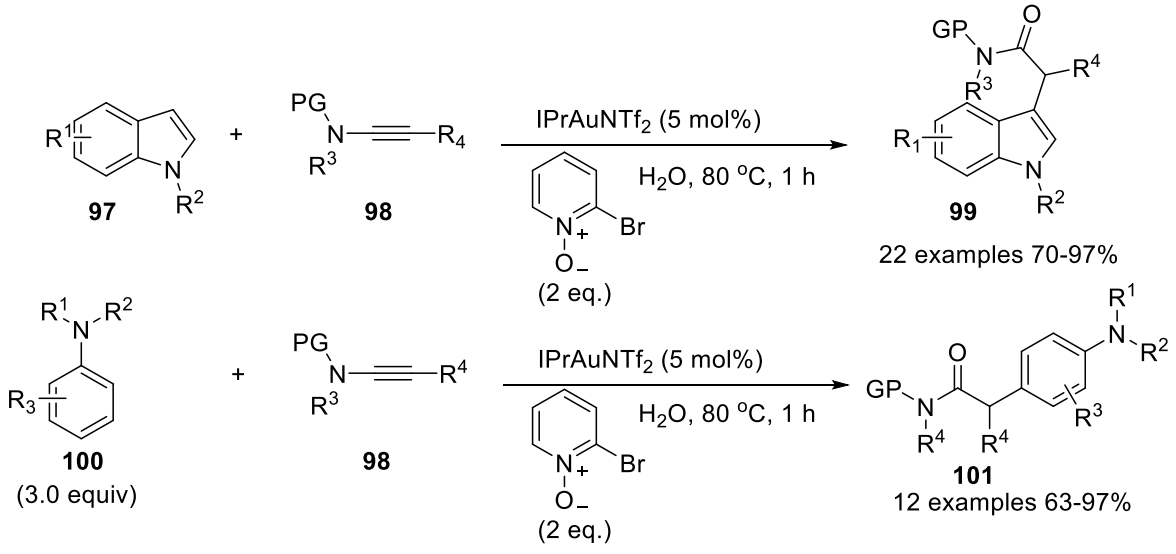
Scheme 24. Controlling the electrophilicity of the gold carbene in an oxazole synthesis.

Work by Davies and co-worker presented a second valid method for achieving intermolecular nucleophile addition to an α-oxo gold carbenoid.[70] Ynamides **94** (Scheme 25) were utilised as diazo equivalents in a gold catalysed sequence of oxidation, ylide formation and [2,3]-sigmatropic rearrangement to form highly functionalised sulfides **96**. This approach allowed the efficient formation of a C-O, C-S and C-C bond in a single step under mild and convenient conditions with the oxidant introduced in one portion (Scheme 25). Selectivity for ylide formation over double oxidation was proposed to be dependent on using a strongly electron withdrawing phosphite catalyst which would form a vinyl gold carbenoid species, favouring S over O attack (Scheme 25).



Scheme 25. Generation of complex quaternary centres from ynamides.

Ye successfully employed indoles **97** to trap α-oxo gold carbenes generated from an ynamide **98** and a pyridine-*N*-oxide in water (Scheme 26).[71] This report highlights a third successful approach to achieving high reaction efficiency in intermolecular carbene trapping. These conditions allow a slow release of the water soluble oxidant, preventing the formation of undesirable double oxidation products. The reaction is extremely efficient and the reaction could be extended to anilines **101** which again proved excellent substrates for the reaction.



Scheme 26. Trapping of α-oxo gold carbenes using nitrogen nucleophiles in water.

Conclusion

The reaction of a gold activated alkyne with an oxygen containing nucleophile affords a gold carbenoid species which can be trapped intramolecularly or intermolecularly to afford a diverse range of products. The choice of catalysts can favour α-oxo gold carbene or vinyl gold carbenoid type intermediates and the differences in reactivity of these two extreme forms can impart a major influence on the reaction outcome. The use of different oxidants can control the reactivity observed with milder sulfoxide oxidants used to oxidise the gold carbene formed on initial cycloisomerisation or as substrates for oxyarylation with alkynes. Quinoline and pyridine based oxidants are now much more widely used and can be tuned in many cases to maximise efficiency.

Various approaches have been successfully employed to control unwanted reactivity. These include limiting the rate of addition of the oxidant or its concentration by using its solubility, using more bulky catalysts which shield the gold centre and/ or employing electron-withdrawing groups on the ligands to form a less electrophilic vinyl gold species

The review clearly demonstrates a lack of investigations into the use of sulfoxides with alkynes in oxidative gold chemistry. This thesis will address these gaps in the literature with three different projects.

In chapter 2 the gold catalysed oxyarylation of alkynes is developed for use with dibenzothiophene-*S*-oxides. Investigations into substrate scope, an iterative process and a cascade are presented.

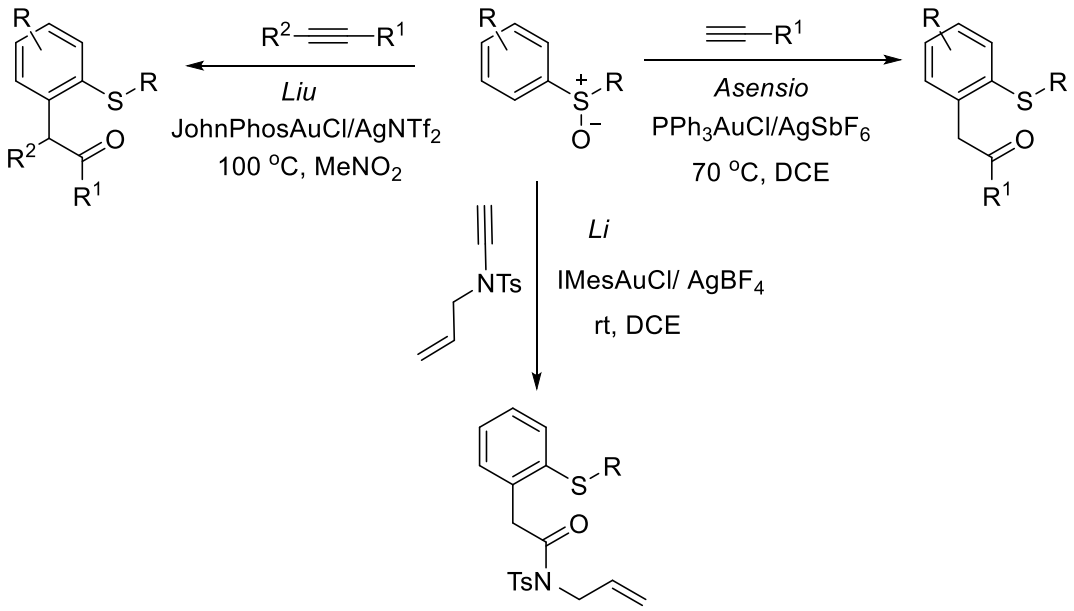
In chapter 3 disulfide oxides are investigated in gold catalysis with alkynes. Two systems are developed and the reactivity observed compared.

Chapter 4 uses alkynyl sulfoxides as α-carbene sulfoxide equivalents to develop an intramolecular gold catalysed cyclopropanation sequence.

Chapter 2: Oxyarylation of alkynes with dibenzothiophene-*S*-oxides

2.1 Introduction

Sulfoxides have been effectively employed as intermolecular oxidants in several gold catalysed reactions of alkynes including alkyne oxyarylation (Chapter 1). The mechanism for the gold catalysed oxyarylation has been modelled using DFT calculations and both internal and terminal alkynes have been successfully employed, although moderate to high temperatures are required (Scheme 27).[18,19] Despite this, further uses of this potentially powerful transformation have not been documented. Notably industry useful aryl sulfide motifs haven't been employed, generally simple sulfoxide nucleophiles have been used, only a limited range of alkynes have been employed and there are no reports on further modifications of the catalysis products.



Scheme 27. Recap of progress in the oxyarylation field.

Dibenzothiophenes are aromatic sulfides and could potentially be functionalised efficiently, mildly and selectively utilising a gold catalysed oxyarylation strategy.

These structures are of high importance in materials science due to their optical, redox and conducting properties.[72] Applications of dibenzothiophenes in medicinal chemistry are also

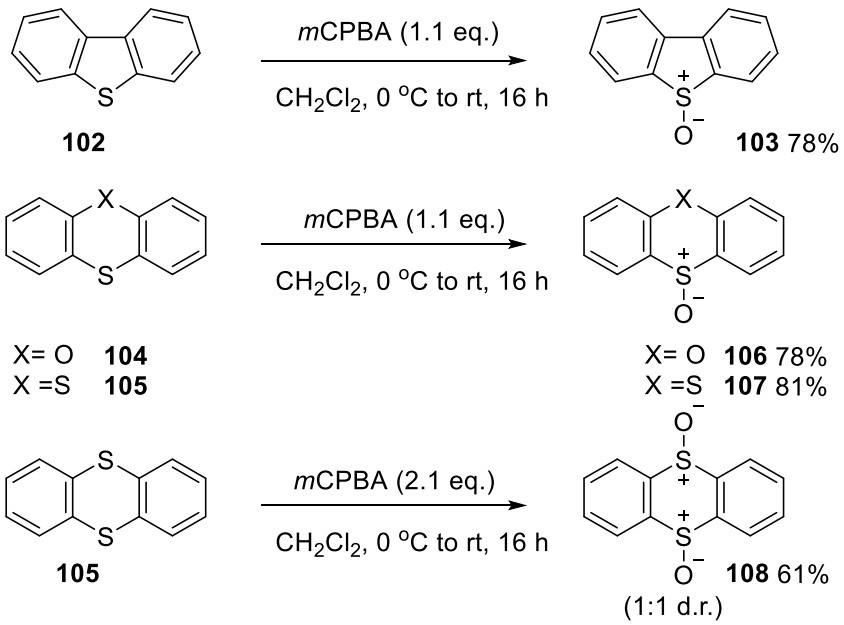
known.[73] Further to this, dibenzothiophenes have been employed as precursors to triphenylenes and as transfer reagents for reactive species such as nitrenes, carbenes and atomic oxygen.[74,75] The major routes to functionalised dibenzothiophenes involve a final step formation of the dibenzothiophene core,[76,77,78] or regioselective bromination of dibenzothiophene at the 2,8-positions[79] or the 3,7-positions of the corresponding *S,S*-dioxide.[80] Substitution at the 4- and 6-positions is possible but requires stoichiometric metallation using organolithium or organoaluminium reagents.[81,82]

2.2 Aim and Objectives

The aim was to investigate the oxyarylation reactions of dibenzothiophenes and related sulfoxides in order to probe structure activity relationships with sulfoxides as oxidants in gold catalysis and explore the wider synthetic potential of this method. The gold catalysed oxyarylation of alkynes with sulfoxides is of particular interest. Developing this reaction to incorporate synthetically useful aromatic sulfides may allow access to a novel strategy for functionalising these structures.

2.3 Preliminary reactions as oxidants

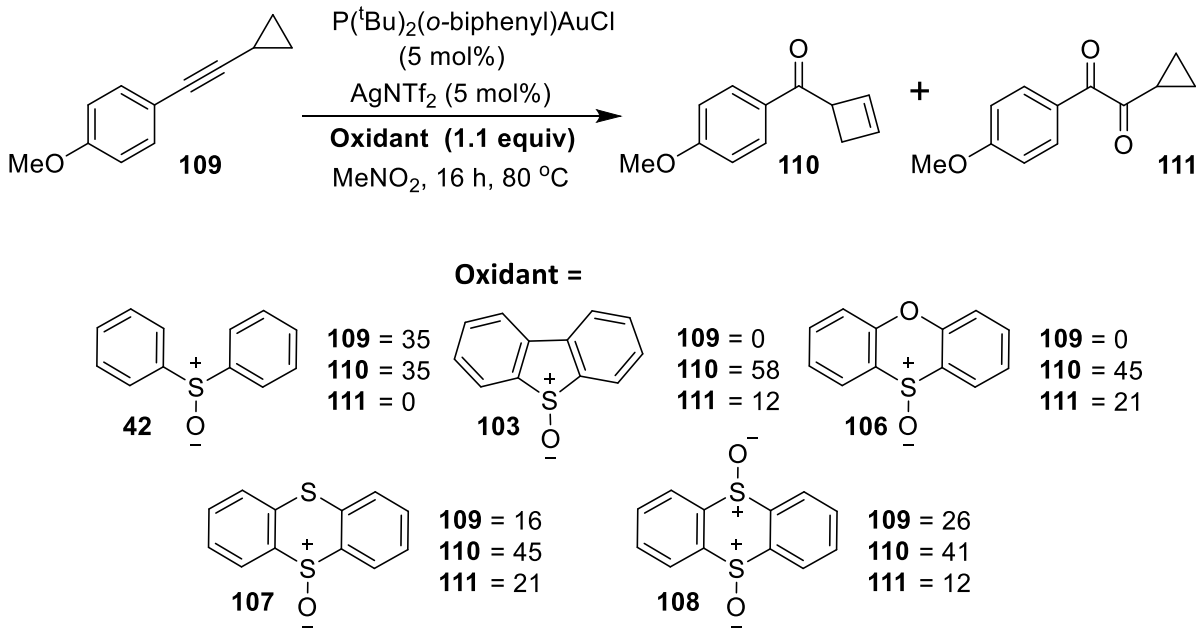
In order to begin the investigation several cyclic sulfoxides were synthesised by *m*CPBA oxidation of the relevant sulfide (Scheme 28). In the case of disulfide **105** both the mono **107** and di-oxo compounds **108** could be prepared.[83]



Scheme 28. Preparation of fused cyclic sulfoxides.

With the sulfoxides **103**, and **106-108** in hand, preliminary studies focused on employing these species with alkynes or ynamides in different reported transformations.

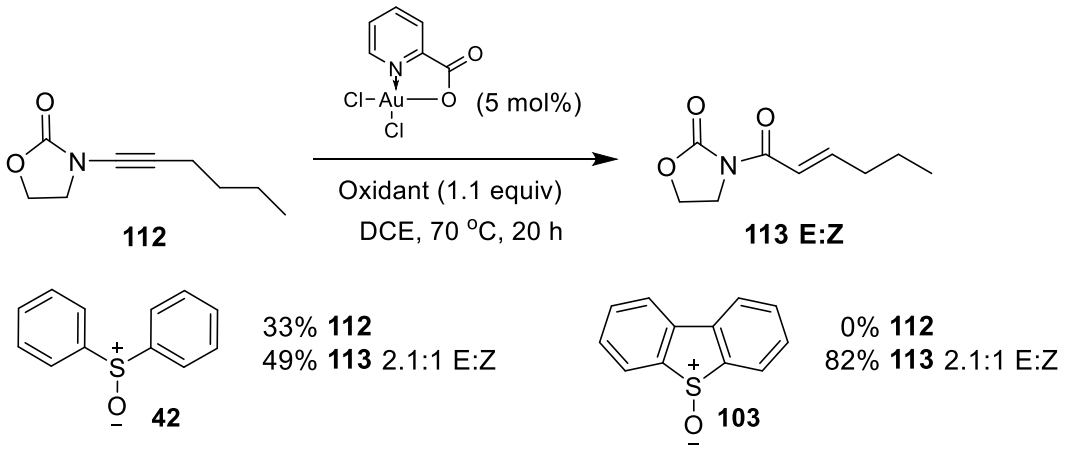
Liu's optimised conditions for the ring expansion of alkynyl cyclopropanes **109** were employed while reducing the oxidant stoichiometry to 1.1 equivalents.[19] Diphenyl sulfoxide **42** was then substituted for the prepared fused cyclic sulfoxides **103**, **106**, **107** and **108** in order to establish their activity. Dibenzothiophene-*S*-oxide **103** was shown to be a powerful oxidant for the reaction (Scheme 29). Diketone **111** was observed, however, originating as a product of the competing double oxidation. Other fused sulfoxides **106-108** were also tested and gave similar results to dibenzothiophene-*S*-oxide **103** but with lower conversion. These results were in contrast to diphenyl sulfoxide **42** where the alkyne was only converted to the desired cyclobutenyl ketone **110** under the catalysis conditions. This result showed dibenzothiophene-*S*-oxide **103** to be the most promising oxidant and other tests focused on this oxidant.



NMR yields determined using 1,2,4,5 tetramethylbenzene as an internal standard

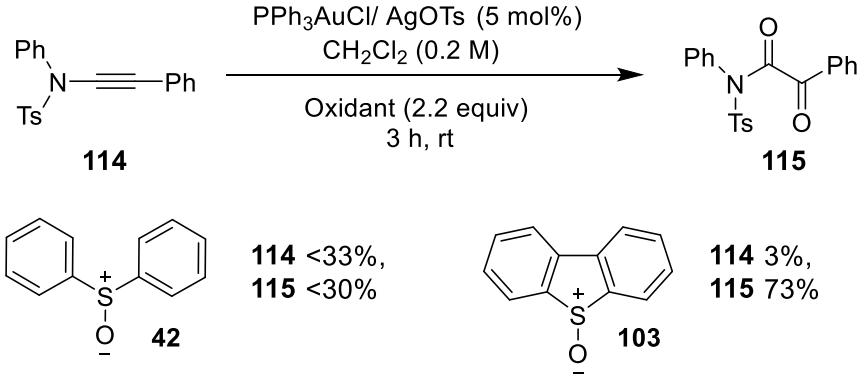
Scheme 29. Effectiveness of various sulfoxides as oxidants in a gold catalysed reaction.

The reaction of an ynamide **112** with a gold catalyst and an oxidant forming an α,β-unsaturated imide **113** was selected to compare the reactivity of the commonly used diphenyl sulfoxide **42** and dibenzothiophene-*S*-oxide **103** (Scheme 30).[33] Employing 1.1 equivalents of the oxidant resulted in complete conversion with dibenzothiophene-*S*-oxide **103**, compared to only moderate conversion with diphenyl sulfoxide **42**. In Davies' study pyridine-*N*-oxide was chosen as the oxidant and dibenzothiophene-*S*-oxide **103** delivers a parallel result, however the ratio of *E/Z* isomers in the product is lower with the sulfoxides trialled (2.1:1) compared to pyridine-*N*-oxide (3.2:1).[33]



Scheme 30. Effect of the oxidant in the site specific ynamide oxidation reaction.

A final comparison of the two sulfoxides was made by employing them as oxidants for the double oxidation of a phenyl substituted ynamide **114** to afford 2-oxo-*N*,2-diphenyl-*N*-tosylacetamide **115** (Scheme 31).[33] Once again dibenzothiophene-*S*-oxide **103** was much more active than diphenyl sulfoxide **42** and these latter results demonstrate that dibenzothiophene-*S*-oxide **103** may be considered as an alternative to pyridine-*N*-oxide for certain transformations.



Scheme 31. Effect of the oxidant in the double oxidation of an ynamide.

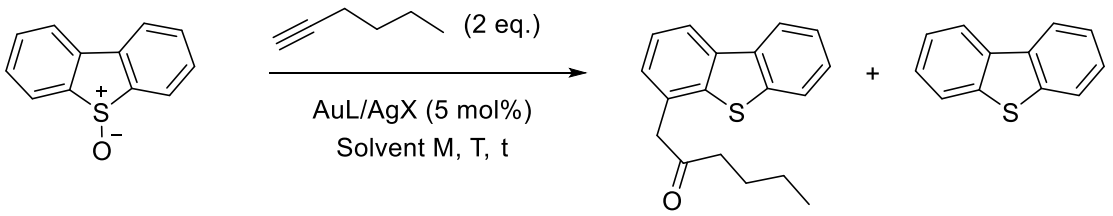
2.4 Optimisation of the oxyarylation reaction

Dibenzothiophene-*S*-oxide **103** was next employed using Asensio's optimal conditions for the gold-catalysed oxyarylation of alkynes with aryl sulfoxides.[18] Hex-1-yne was selected as the alkyne for the screening process and an encouraging 37% NMR yield of the desired *ortho*-

substituted dibenzothiophene **116** was observed (Table 1, entry 1). Conversion was excellent, however a large amount (49%) of dibenzothiophene **102** was present in the reaction mixture, potentially resulting from oxidation of the gold carbene (Scheme 32). The effect of solvent on the reaction conditions was then investigated. 1,2-Dichloroethane was employed to circumvent the requirement for a sealed tube, but this resulted in only a poor yield of the desired product **116** and lots of degradation (Table 1, entry 2). Nitromethane gave a similar result to dichloromethane but was preferred due to its higher boiling point allowing reactions to be performed in Schlenk tubes (Table 1, entry 3). The air stable silver tosylate was tested, providing a slightly enhanced yield of the desired product (Table 1, entry 4). Varying the gold species and employing AuCl (Table 1, entry 5) or ($AuPicCl_2$) (Table 1, entry 6) resulted in very low yields and significant formation of the unwanted dibenzothiophene **102**. A more electron-withdrawing phosphine gold species was employed with little change in yield of the desired product **116**, however a large decrease in yield of dibenzothiophene was seen (Table 1, entry 7). Electron-rich ligands XPhos and JohnPhos derived complexes instead favoured double oxidation (Table 1, entries 8 and 9). An electron-deficient phosphite catalyst, which would be expected to disfavour formation of gold carbene **118** from the vinyl gold species **117**, was employed, giving the best yield of the desired substituted dibenzothiophene **116** (Table 1, entry 10). Using the pre-formed air-stable acetonitrile complex of the gold species resulted in an enhanced yield, suggesting silver may retard the reaction to a small extent or result in other products being formed (Table 1, entry 11). The reaction time was shortened and the solvent was diluted resulting in a decrease in yield (Table 1, entry 12). When the temperature was reduced and the concentration reduced a large increase in yield was observed (Table 1, entry 13). Switching the solvent again at this stage to dichloromethane resulted in a large reduction in yield (Table 1, entry 14), with acetonitrile being an even less suitable solvent (Table 1, entry

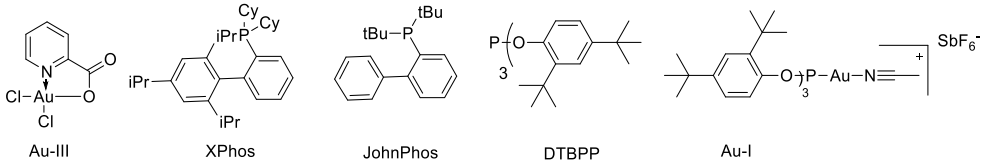
15). Toluene proved to be an excellent solvent (Table 1, entry 16), and upon a further decrease in reaction temperature, an excellent yield of the substituted dibenzothiophene **116** was obtained (Table 1, entry 17).

Table 1. Optimisation of the reaction conditions.

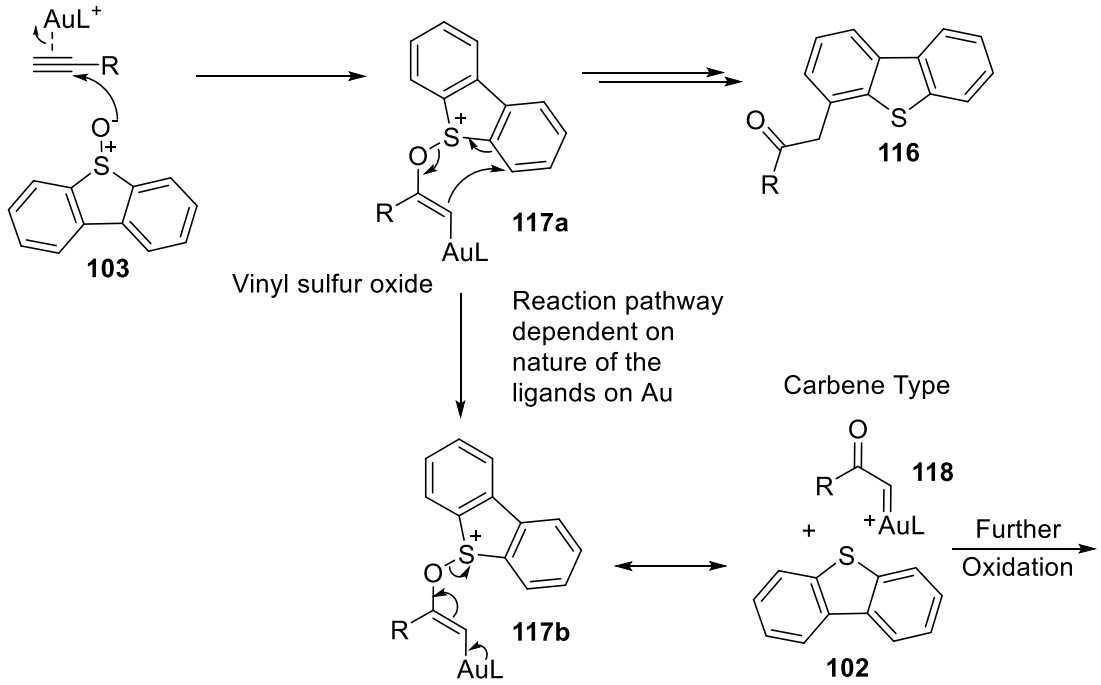


Entry	Gold catalyst	Silver salt	Solvent	Temp ^{o}C	Solvent conc M	Yield %[a] **103**	**116**	**102**
1	PPh_3AuCl	$AgSbF_6$	CH_2Cl_2	70	1	0	37	49
2	PPh_3AuCl	$AgSbF_6$	1,2 DCE	70	1	(5)[b]	20	30
3	PPh_3AuCl	$AgSbF_6$	CH_3NO_2	70	1	0	38	35
4	PPh_3AuCl	AgOTs	CH_3NO_2	70	1	10	41	25
5	AuCl	-	CH_3NO_2	70	1	51	4	17
6	Au-III	-	CH_3NO_2	70	1	45	4	20
7	$P(4CF_3Ph)_3AuCl$	AgOTs	CH_3NO_2	70	1	20	41	3
8	XPhosAuCl	AgOTs	CH_3NO_2	70	1	50	10	20
9	JohnPhosAuCl	AgOTs	CH_3NO_2	70	1	51	8	20
10	DTBPPAuCl	AgOTs	CH_3NO_2	70	1	0	44	16
11	Au-I	-	CH_3NO_2	70	1	5	49	16
12	Au-I	-	CH_3NO_2	70	0.1	8	43	16
13	Au-I	-	CH_3NO_2	RT	0.1	6	70	7
14	Au-I	-	CH_2Cl_2	RT	0.1	0	39	11
15	Au-I	-	CH_3CN	RT	0.1	0	28	3
16	Au-I	-	Toluene	RT	0.1	0	82	6
17	Au-I	-	Toluene	0	0.1	0	92	5

[a] Reactions performed on a 0.1 mmol scale and yields determined by crude NMR analysis using 1, 2, 4, 5 Tetramethylbenzene as an internal reference standard. [b] As a result of degradation it was only possible to estimate the percentage of remaining sm.



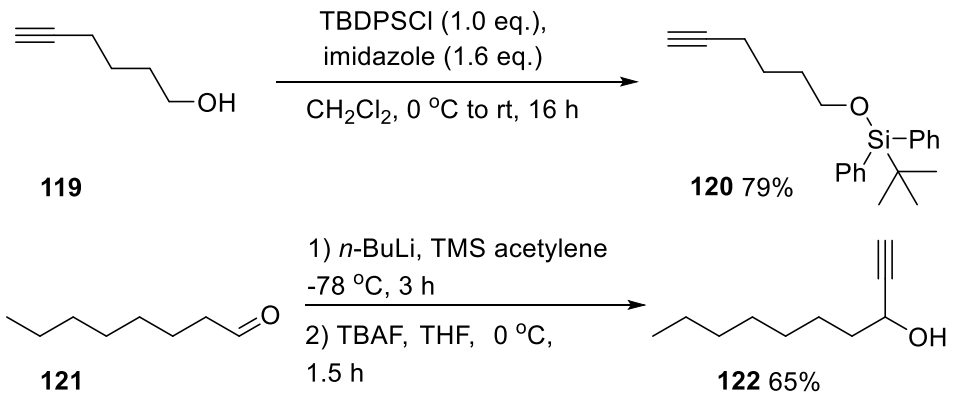
Scheme 32 shows the mechanism leading to the formation of the desired substituted dibenzothiophene **116**. Attack of the *S*-oxide **103** onto the internal position of the alkyne proceeds first. These catalysts are theorised to stabilise the gold carbene and favour its formation at the expense of the desired [3,3]-sigmatropic rearrangement and thus increasing the propensity for the unwanted nucleophilic attack of a second molecule of dibenzothiophene-*S*-oxide (Scheme 32).[70] Electron-rich ligands on the phosphine donate electron density to the π-accepting gold atom leading to the α-oxo gold carbenoid species which could be quenched by attack of a second molecule of dibenzothiophene-*S*-oxide. Alternatively π acidic ligands such as phosphites would favour the vinyl gold species which is in the conformation to undergo a productive [3,3]-sigmatropic rearrangement to furnish the oxyarylation product.[84] The substantial improvement in reaction outcome upon reducing the temperature could be related to the entropic cost associated with forming one molecule from two explained by the Gibbs free energy equation $\Delta G = \Delta H - T\Delta S$. As the temperature is reduced the entropy change is less relevant to the reaction outcome. Alternatively increased temperatures may promote rapid elimination of the dibenzothiophene nucleofuge in formation of an α-oxo gold carbene which prevents the productive [3,3]-sigmatropic rearrangement.[20]



Scheme 32. Rationale for observed reactivity

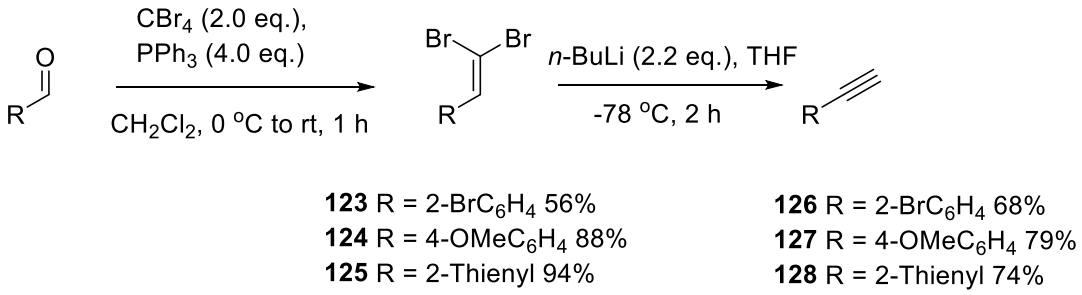
2.5 Preparation of the starting materials

The scope of the reaction was then explored requiring the preparation of several alkynes. Hex-1-yn-ol **119** was protected in a good yield using the method of Carreira to provide alkyne **120** (Scheme 33).[85] Octanal **121** was converted into dec-1-yn-ol **122** in two steps. TMS acetylene was deprotonated and reacted with aldehyde **121** to give the propargylic alcohol **122** after desilylation with TBAF.[27]



Scheme 33. Silyl protection and synthesis of a propargylic alcohol.

Three aryl alkynes were synthesised from the corresponding aldehydes by first preparing the dibromoolefins **123**-**125** and converting them into the alkynes **126**-**128** under strongly basic conditions (Scheme 34).[86]



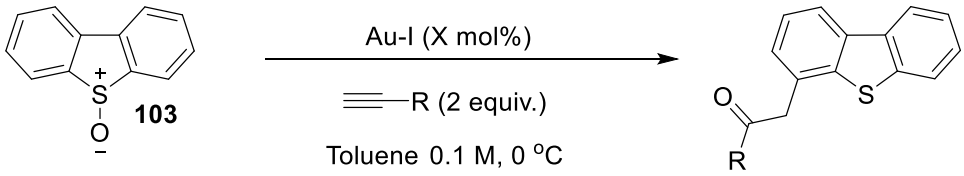
Scheme 34. Preparation of aryl substituted terminal alkynes.

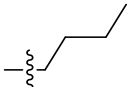
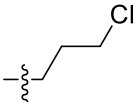
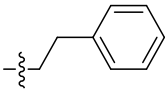
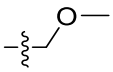
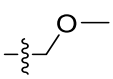
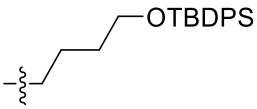
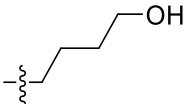
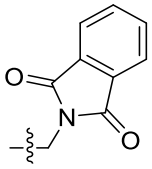
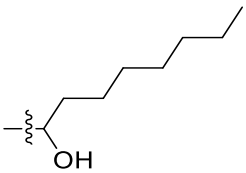
2.6 Preparation of 4-substituted dibenzothiophenes

The oxyarylation of different alkyl alkynes using dibenzothiophene-*S*-oxide **103** was then investigated. Chloro, ether and silyl-ether derived substituents were all well tolerated (Table 2, entries 2, 4, and 6) providing the substituted dibenzothiophene **129**, **131** and **132** in high yield. Hexyn-1-ol **119** was not a suitable alkyne however. Employment of a propargylic alcohol (Table 2, entry 9) could have been expected to result in significant formation of oxetan-3-one, however none was discovered upon analyzing the crude NMR spectrum which showed a high yield of substituted dibenzothiophene **135**.[27] An aryl-derived and phthalimido substituent were

also tolerated providing dibenzothiophenes **130** and **134** in a moderate yield (Table 2, entries 3 and 7). The reactions were mostly fast and lower catalyst loadings could be employed at higher scales without adverse effect beyond increased reaction time (Table 2, entry 5 versus 4). The higher scale reaction to form **131** (Table 2, entry 5) was carried out under an atmosphere of air and used technical grade solvent, highlighting the robust nature of the protocol.

Table 2. Incorporation of alkyl substituted terminal alkynes



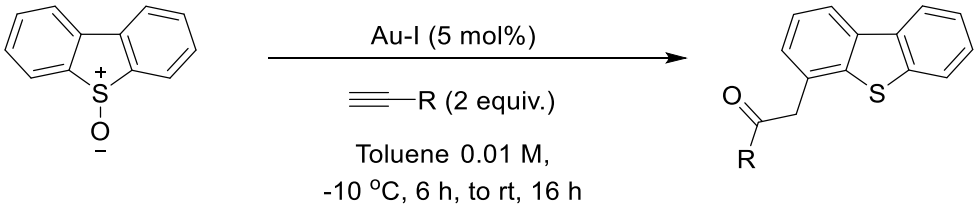
Entry	R =	Scale mmol	Catalyst Loading mol%	Reaction time h	Product	Yield %[a]
1		0.2	5	0.75	**116**	87
2		0.2	5	0.75	**129**	79
3		0.2	5	0.75	**130**	62
4		0.2	5	0.75	**131**	87
5[b]		2.0	1	2	**131**	84
6		0.5	2	2	**132**	82
7		0.2	5	2	**133**	0
8		2.0	2	16	**134**	52
9		0.2	5	16	**135**	76

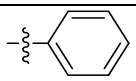
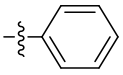
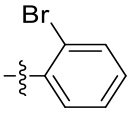
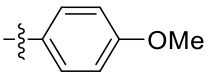
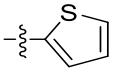
[a] Isolated yields. [b] Reaction performed under an atmosphere of air with technical grade toluene.

The use of phenylacetylene, in contrast to alkyl alkynes, resulted in significant quantities of dibenzothiophene **102** being formed under the standard conditions (Table 3, entry 1). To reduce the amount of this unwanted side product the temperature was reduced, requiring a higher dilution to maintain solubility of **103** (Table 3, entry 2). The NMR yield with phenylacetylene

was now good, however material was lost in the purification of the product **136**. The modified conditions were then employed with other arylalkynes. A sterically bulky *o*-bromobenzene could be incorporated to give product **137**. *p*-Methoxybenzene was a surprisingly poor substituent on the alkyne but still afforded a useful yield of the desired substituted dibenzothiophene **138**. A thiophene was also tolerated providing **139** in a reasonable yield (Table 3, entry 5)

Table 3. Incorporation of aryl substituted terminal alkynes.

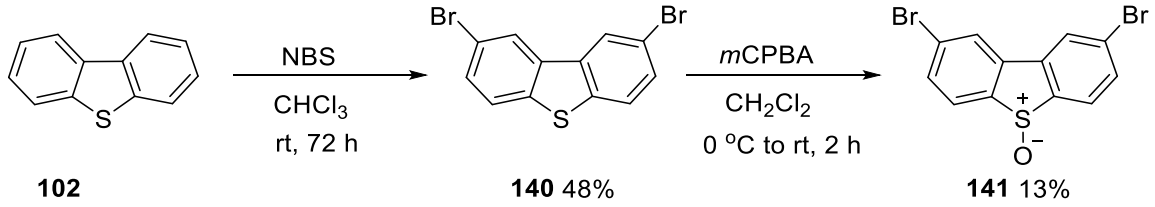


Entry	R =	Scale mmol	Product	Yield %
1[a]		0.1	**136**	47[b]
2		0.3	**136**	58 (74)[b]
3		0.2	**137**	40
4		0.2	**138**	42
5		0.2	**139**	62

[a] Reaction conditions: Au-I (5 mol%), toluene 0.1 M, 0 °C, 1.5 h. [b] yields determined by crude NMR analysis using 1, 2, 4, 5 tetramethylbenzene as an internal reference standard.

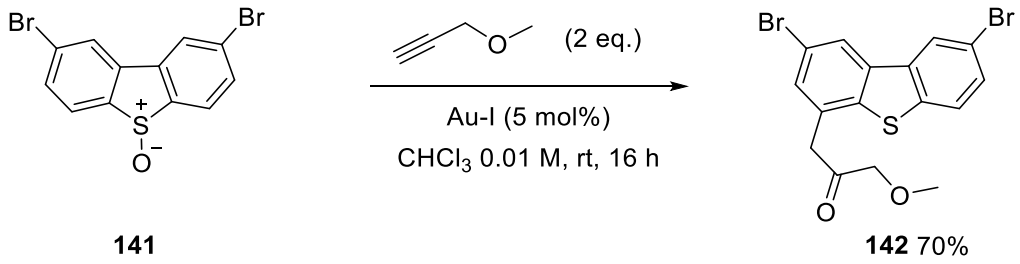
A functionalised dibenzothiophene-*S*-oxide **141** was prepared to test its suitability for the gold catalysed oxyarylation. 2,8-Dibromo dibenzothiophene-*S*-oxide **141** was selected as an important substrate as it could undergo further functionalization via metal coupling chemistry.[79]

Bromination of dibenzothiophene **102** proceeded in a satisfactory yield (Scheme 35) and a low yielding oxidation step provided the target *S*-oxide **141**.[87,88]



Scheme 35. Preparation of 2,8-dibenzothiophene-*S*-oxide.

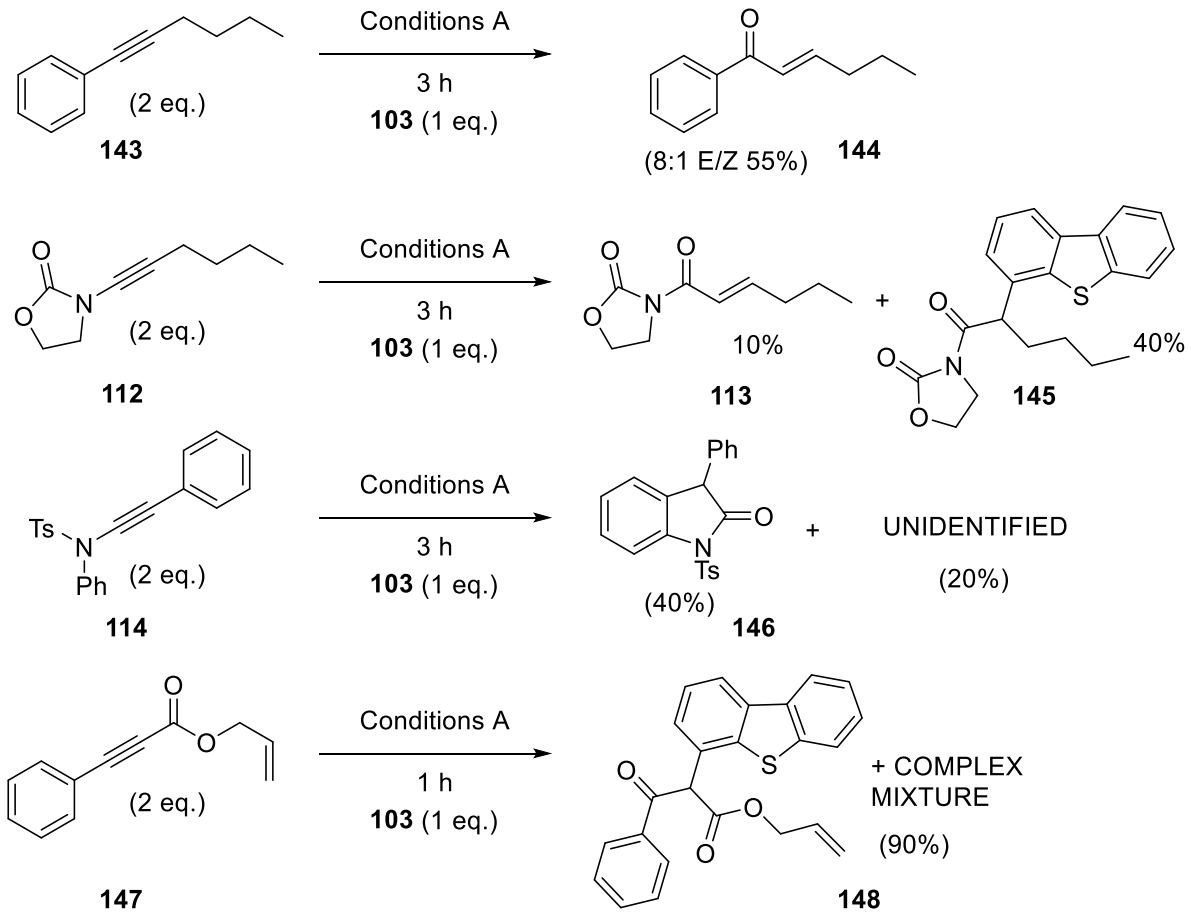
Subjecting sulfoxide **141** to a terminal alkyne under modified conditions to allow for the poor solubility of the starting material, resulted in a good yield of the desired oxyarylation product **142** (Scheme 36).



Scheme 36. Incorporation of a substituted dibenzothiophene into the catalysis.

Dibenzothiophene-*S*-oxide **103** was treated with internal alkyne **143** and complete conversion of starting material was observed after 3 hours although no oxyarylation product was observed. Instead a mixture of both *E* and *Z* isomers of the ene-one **144** was isolated (Scheme 37).[89] Upon initial attack onto the alkyne with the formation of the gold carbenoid 1,2 H-insertion is more favourable than the [3,3]-sigmatropic rearrangement. An alkyl substituted ynamide **112** was subjected to the catalysis conditions and upon reaction completion 1,2 insertion product **113** was isolated as well as oxyarylation product **145** which could not be sufficiently purified for full characterisation. When ynamide **114** was employed, no evidence of oxyarylation was seen, instead oxindole **146** was tentatively identified as well as an unidentified product. Finally when

an ester-substituted alkyne **147** was subjected to the catalysis conditions the reaction proceeded quickly and smoothly however, following purification, only a complex mixture of products were isolated.



Scheme 37. Reaction of dibenzothiophene-S-oxide 90 with internal alkynes and ynamides.

Other fused sulfoxides **106**, **107** and **108** were then employed under the catalysis conditions (Table 2) with hex-1-yne. Although these sulfoxides were effective oxidants in gold catalysed oxidation processes (Fig 2) only trace amounts of the oxyarylation products **149-151** were observed upon analysing the crude NMR. Therefore attempts to prepare derivatives of these fused heterocycles were abandoned.

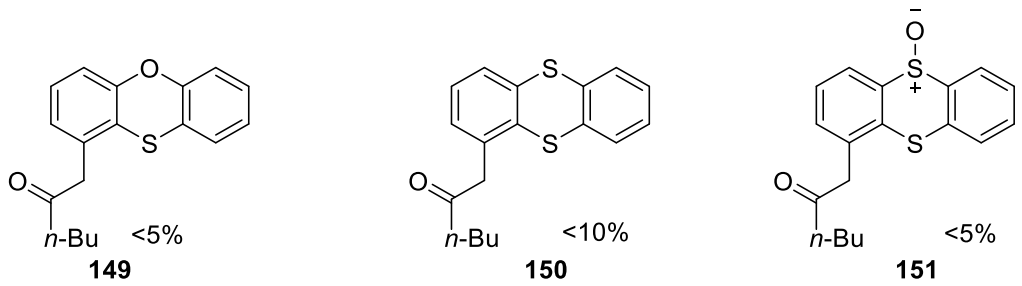
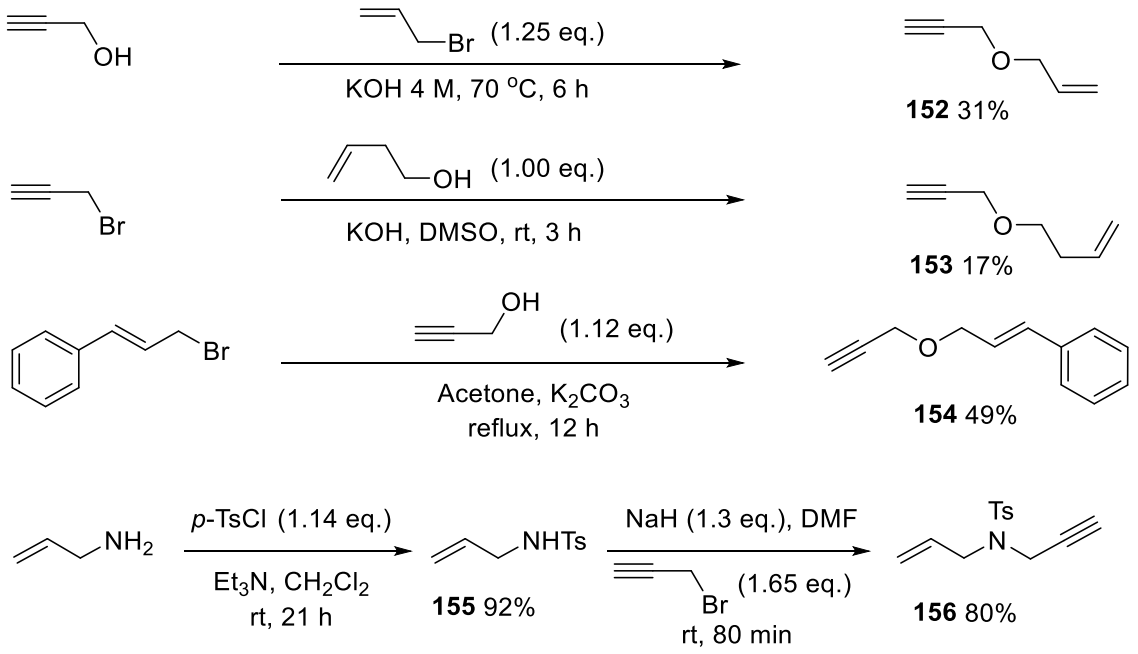


Figure 2. Catalysis products expected upon treatment of other cyclic sulfoxides under the optimised conditions.

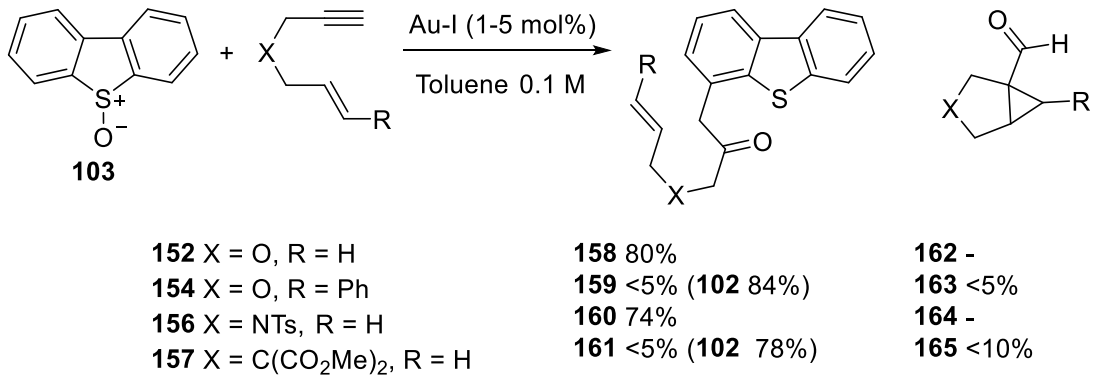
2.7 Cycloisomerisation vs oxyarylation

A small series of terminal alkyne based enynes were prepared in order to test their reactivity in the oxyarylation reaction with dibenzothiophene-*S*-oxide **103** compared to the enyne cycloisomerisation pathway. Oxygen containing enynes **152** and **153** were prepared, with the low yields resulting from the volatility of these componds.[90,91] Treatment of cinnamyl bromide with propargyl alcohol and potassium carbonate resulted in a moderate yield of the desired phenyl substituted enyne **154**.[92] *N*-Allyl-4-methyl-*N*-(prop-2-yn-1-yl)benzenesulfonamide **156** was prepared in two steps from allylamine (Scheme 38).[93] Tosylation to afford **155** proceeded in an excellent yield and propargylation using NaH also worked well providing the desired enyne 1**56** in high yield.[93]



Scheme 38. Preparation of 1,6 enynes.

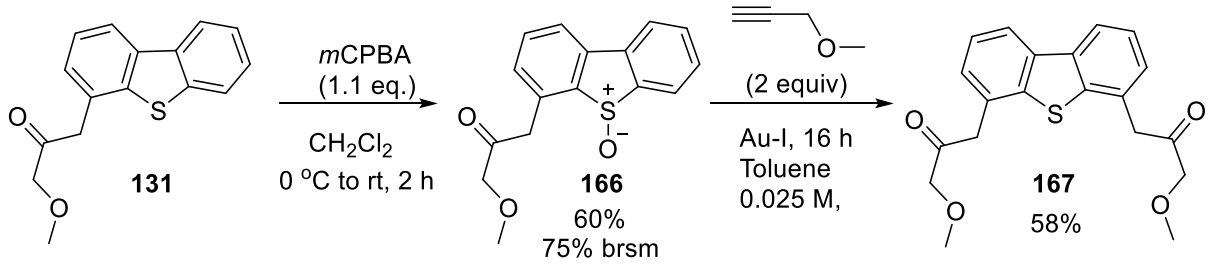
With the enynes in hand they were employed as substrates in the catalysis reaction. Enyne **152** with an oxygen linker and **156** with an *N*-tosyl linker efficiently underwent oxyarylation to afford functionalised dibenzothiophenes **158** and **160** with no evidence of competing cycloisomerisation (Scheme 39). Enyne **154** was one of the substrates employed by Toste with excess diphenyl sulfoxide **42** to effect cycloisomerisation followed by oxidation of the resultant carbene.[13] With dibenzothiophene-*S*-oxide **103** trace amounts of oxidised cycloisomerisation product **163** was observed with no oxyarylation products. A similar result was observed with enyne **157**. Shin had demonstrated cycloisomerisation and oxidation of the resultant carbene when employing enynes with a terminal alkyne and a propiolamide tether.[14] Enynes with a high tendency to cycloisomerise are poor choices for oxyarylation. The results further highlight the good functional group tolerance for the oxyarylation reaction.



Scheme 39. Oxyarylation with various enynes.

2.8 Iterative Processes

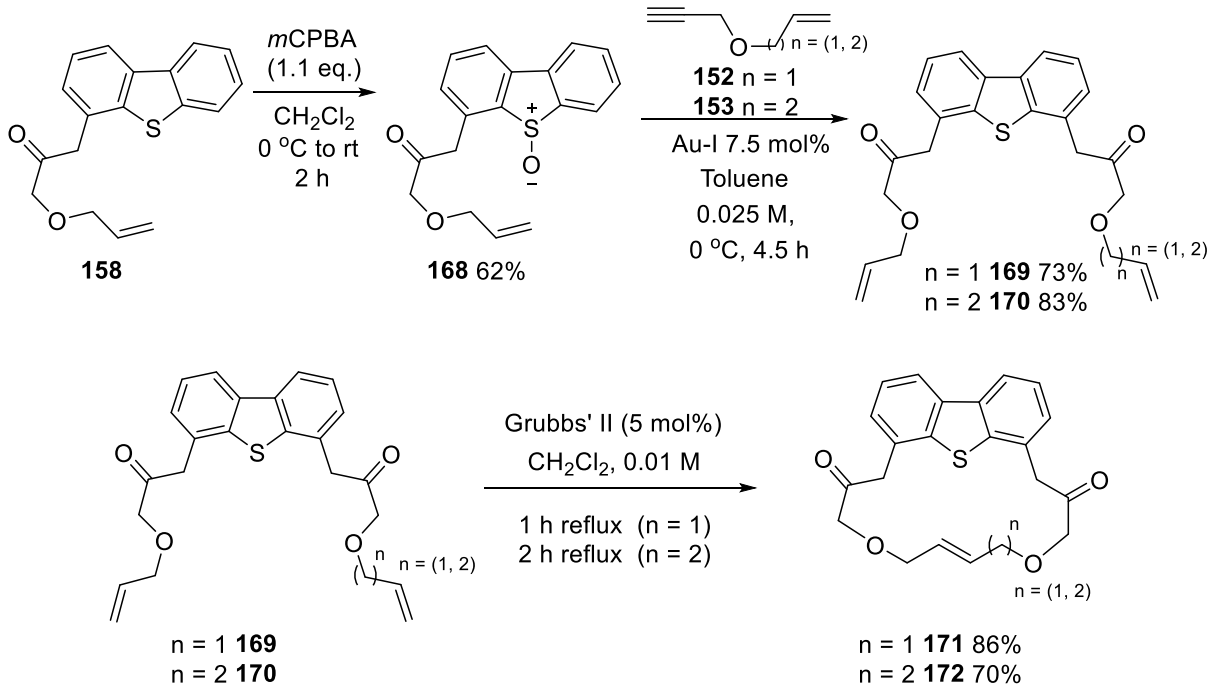
The feasibility of achieving selective functionalization of both 4- and 6-positions of dibenzothiophene by an iterative application of the gold catalyzed oxyarylation was explored Initial sulfoxide oxidation of **131** with urea hydrogen peroxide yielded predominantly the sulfone, and employing sodium metaperiodate resulted in only recovered starting material. Efficient oxidation of dibenzothiophene **131** was achieved with *m*CPBA providing sulfoxide **166**. Subjecting the sulfoxide under the standard oxyarylation conditions, with a higher dilution to allow for the reduced sulfoxide solubility furnished disubstituted dibenzothiophene **167** in a moderate yield (Scheme 40).



Scheme 40. Double functionalisation of dibenzothiophene.

158 was also selectively oxidized to sulfoxide **168** using *m*CPBA in a similarly high yield and pleasingly proved an effective reagent for oxyarylation (Scheme 41). Treatment of **168** with

enyne **152** furnished a functionalised, symmetrical 4,6-disubstituted dibenzothiophene **169** in high yield. Employment of enyne **153** with sulfoxide **168** resulted in formation of an unsymmetrical, disubstituted dibenzothiophene **170** in good yield. The reactions were slower than the comparable reactions with unsubstituted dibenzothiophene-*S*-oxide **103** but the high yields and mild conditions make this an attractive method of further functionalising these structures, especially considering the presence of keto and alkene functionality in the starting sulfoxide. Preparation of these disubstituted dibenzothiophenes allowed access to new and potentially interesting cyclic structures. Ring closing metathesis using Grubbs' 2nd generation catalyst was successfully applied to furnish symmetrical and unsymmetrical macrocycles **171** and **172** in high yields.



Scheme 41. Preparation of a symmetrical and unsymmetrical dialkylated dibenzothiophene and preparation of a macrocycle.

A crystal structure was obtained of the symmetrical macrocycle **171** (Fig 3). This confirmed that the geometry of the double bond was *E*. ^{1}H NMR data of the unsymmetrical macrocycle was consistent with *E* double bond geometry.

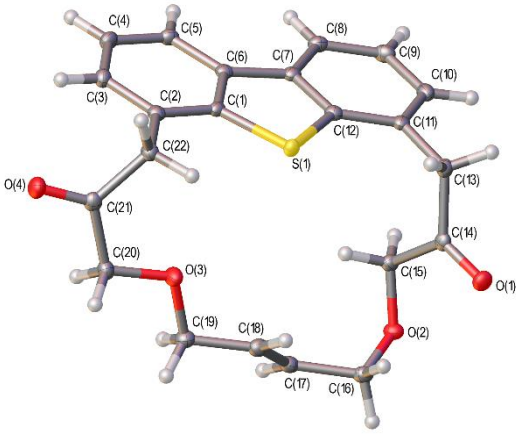
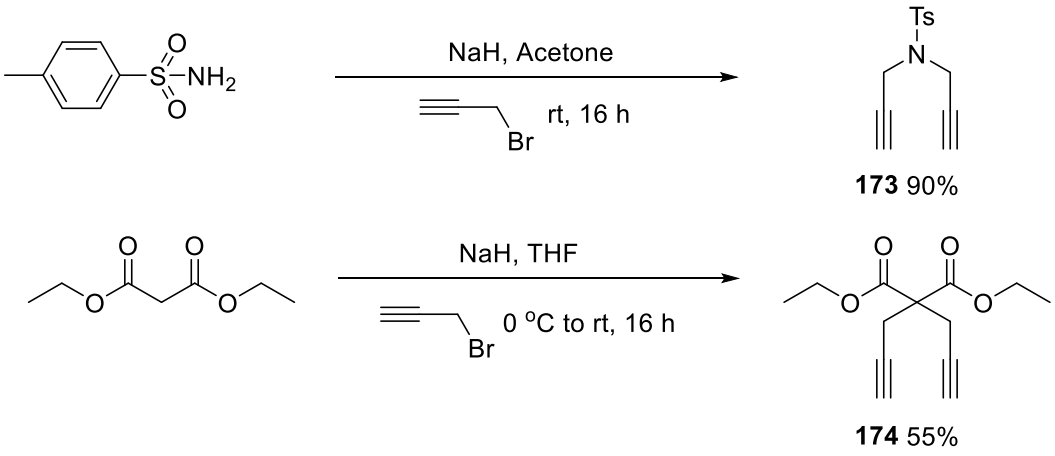


Fig 3. Crystal structure for macrocycle 160.

2.9 Further transformations

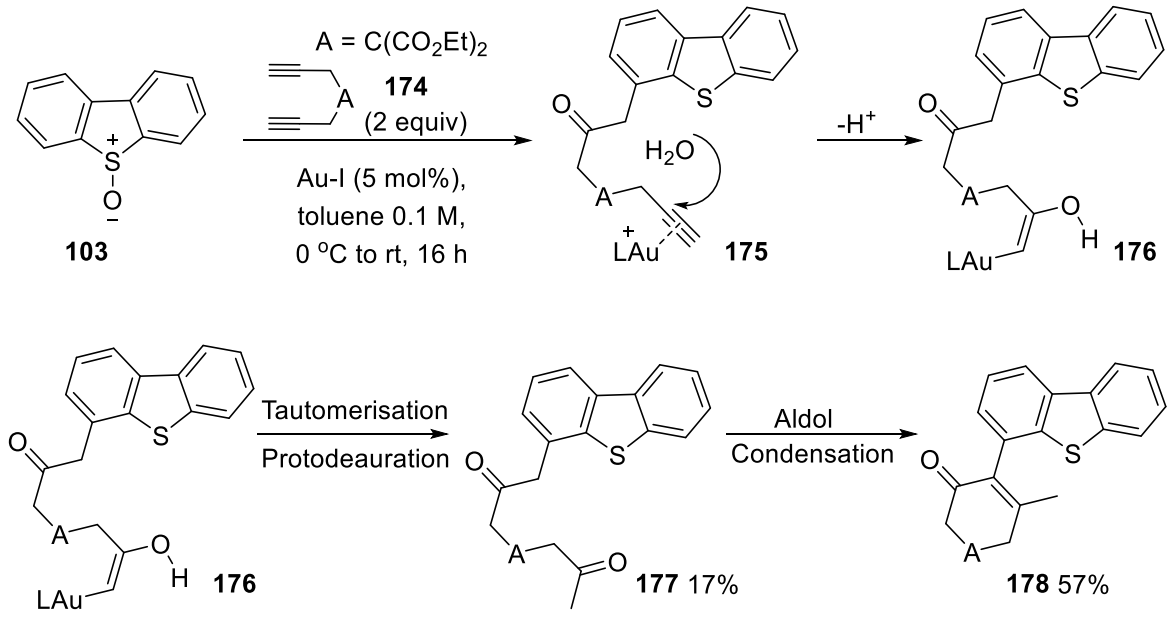
Diynes **173** and **174** were prepared (Scheme 15) according to the method of Hashmi (Scheme 42).[94]



Scheme 42. Preparation of diynes.

They were tested under the catalysis conditions in order to assess their reactivity and determine the effect of a second terminal alkyne group. Firstly diyne **173** was employed under the standard catalysis conditions with dibenzothiophene-*S*-oxide **103** and good conversion of starting material was observed. Unfortunately, however, the isolated spots from column chromatography degraded rapidly and no products were successfully isolated. On employing

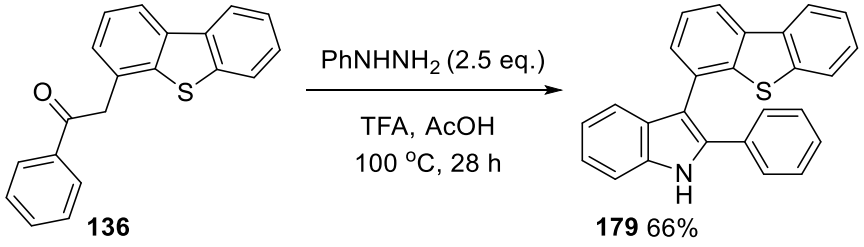
diyne **174**, two new spots were observed by TLC. Upon reaction completion these could be successfully isolated providing the diketone **177** in 17% yield and more interestingly the cyclohexanone **178** in 57% yield (Scheme 43). A likely explanation for this reaction outcome is consistent with the result observed by Davies and Detty-Mambo in their cycloisomerisation of alkynes tethered to unactivated enolisable ketones in the presence of cationic gold(I) species.[95] Oxyarylation with the diyne provides substituted dibenzothiophene **175**. Adventitious water in the reaction mixture hydrates the pendant alkyne **176** at which point tautomerisation and loss of the gold affords the diketone **177** which mostly reacts further participating in an intramolecular aldol condensation.



Scheme 43. Reacting dibenzothiophene-*S*-oxide with a diyne.

Preliminary screening was initiated in order to quickly determine if a number of other aryl based sulfoxides could be employed with diyne **174** to generate further functionalised cyclohexanones. While the cyclohexanone derived products were observed with diphenyl sulfoxide **42** poor reactivity was observed with methyl phenyl sulfoxide and no further exploration was done.

Treatment of dibenzothiophene **136** with phenyl hydrazine, TFA and acetic acid at a high temperature afforded indole **179** in a reasonably good unoptimised yield (Scheme 44). This reaction demonstrates that these products of catalysis can be readily further modified providing a new method to incorporate an indole in the 2- position.



Scheme 44. Preparation of an indole-derived dibenzothiophene.

2.10 Conclusion

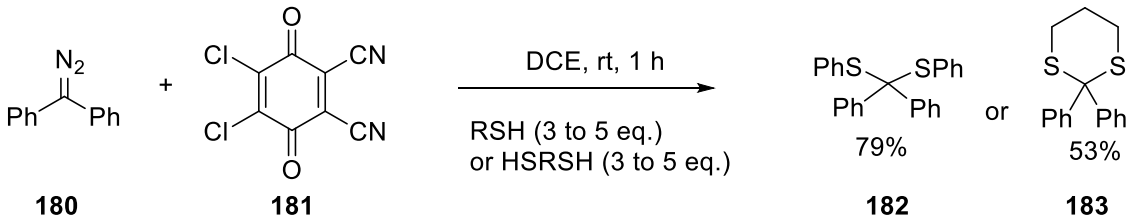
With dibenzothiophene-*S*-oxide **103** clear trends are observed with regard to the nature of the gold catalyst and the temperature influencing reaction outcome. Very different conditions have been successfully employed to efficiently facilitate the oxyarylation of various alkynes with other aryl sulfides.

Dibenzothiophene-*S*-oxide **103** has been shown to be a very effective substrate for oxyarylation with terminal alkynes under mild conditions and with excellent chemoselectivity. Investigations into other cyclic sulfoxides proved unsuccessful but an iterative process was used to allow the extension of the current methodology. Macrocycles could also be prepared easily using this method. Other progress included a novel oxyarylation cascade and functionalization of products. With the high interest in dibenzothiophenes, this method could find many uses and demonstrates the versatility of this oxyarylation reaction. Preliminary tests and unsuccessful attempts to incorporate internal alkynes in the oxyarylation suggest the high reactivity of dibenzothiophene-*S*-oxide **103** and relatively low selectivity limits its applications or the competing reactions are too rapid.

Chapter 3: Gold catalysed processes from alkynes and cyclic disulfide oxides

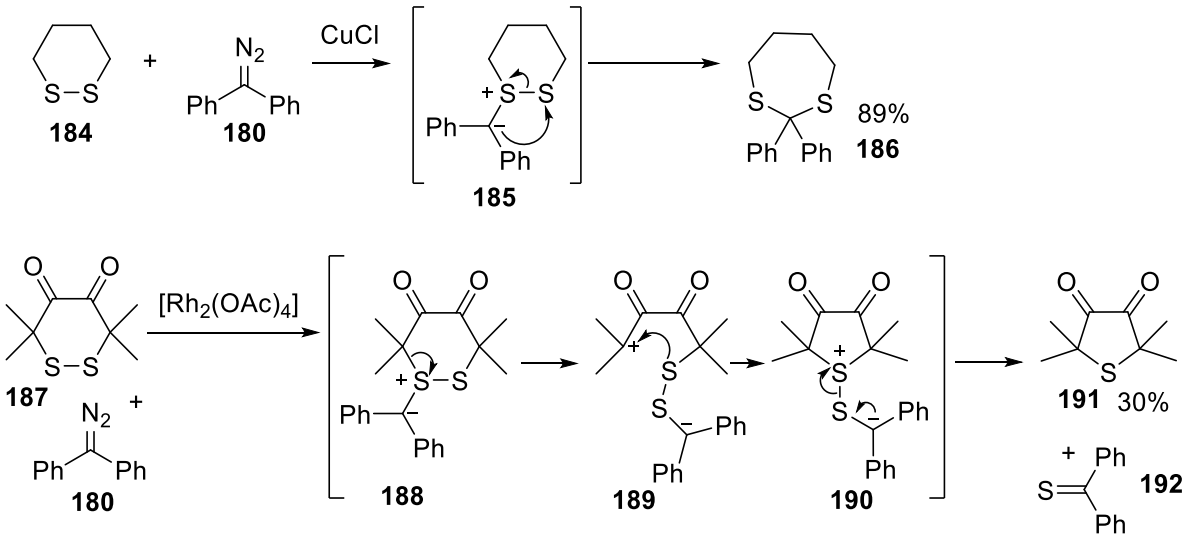
3.1 Introduction

Thioacetals are traditionally prepared by the reaction of carbonyl compounds with thiols or dithiols under acidic conditions.[96] Dithianes are used as carbonyl protecting groups and allow umpolung reactions to be performed. In the Corey-Seebach reaction 1,3 dithianes are employed as nucleophilic acylating reagents. An alternative preparation of thioacetals is by reaction of diazo compounds and thiols or dithiols. In the first report demonstrating this method, diphenyl diazomethane **180** was reacted with 2,3-dichloro-5,6-dicyanobenzoquinone (DDQ) **181** followed by addition of the thiol or dithiol (Scheme 45). Utilising the dehydrogenating power of DDQ good yields of an acyclic dithioacetal **182** or a cyclic dithioacetal **183** were achieved.[97]



Scheme 45. Preparation of thioacetals from diphenyl diazomethane and sulfides.

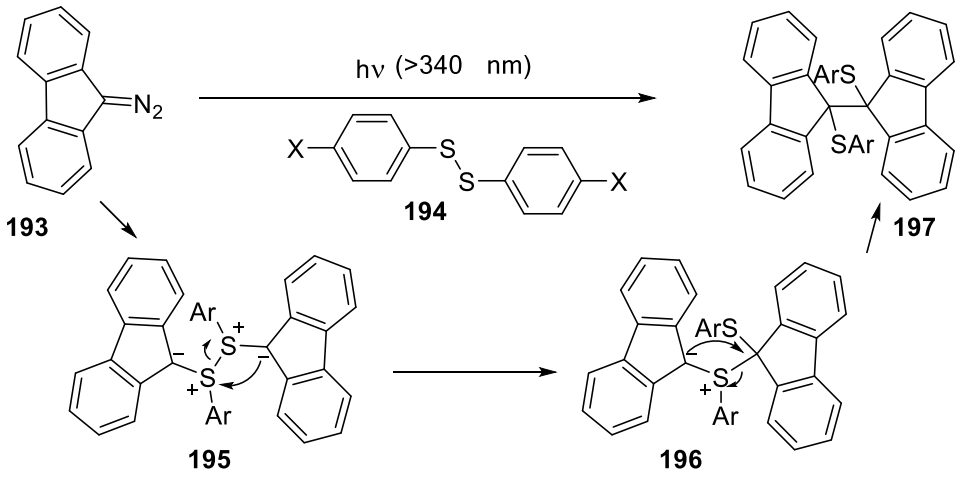
In 1985, various cyclic disulfides including **184** and **187** were treated with carbenes, generated by copper catalysis, rhodium catalysis and irradiation with light.[98] The study found that the method of carbene generation from the diazo species, had no effect on the reaction outcome. The factor found to determine the reaction outcome was the steric nature of both the carbene and the disulfide. In all cases sulfur ylide formation was proposed to proceed initially forming **185** and **188** (Scheme 46). In cases where the substrate was less bulky, 1,2-rearrangement and cleavage of the disulfide bond occurred forming dithioacetals such as **186**, often in high yield. On the other hand sterically congested substrates underwent desulfurisation through **188**-**190** in a low yield to form sulfur heterocycles such as **191**.



Scheme 46. Divergent reactivity of sulfur ylides from diazo compounds and cyclic disulfides.

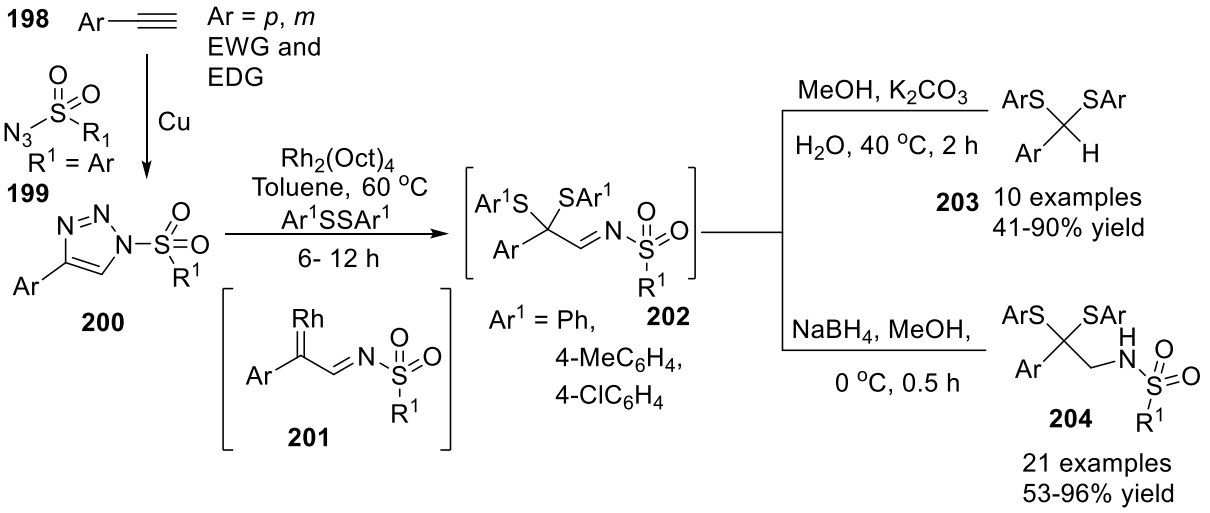
Generation of singlet carbenes is widely understood to be an important method for forming sulfur ylides.[99] The mechanism for the reaction of triplet carbenes (diphenylcarbene and fluorenylidene) with sulfides and disulfides was studied by Alberti using electron paramagnetic resonance spectroscopy.[100] Triplet diphenylcarbene was shown to react via its triplet state, undergoing a homolytic substitution process to yield the dithioacetal among other products. In contrast triplet fluorenylidene was found to access singlet carbene reactivity with the reaction proceeding proposedly via a sulfur ylide.

Kawamura employed **193** with diaryl disulfides **194** forming mostly **197**. The reaction was proposed to proceed via a double insertion, with monoinsertion products formed in negligible yield (Scheme 47).[101] The most probable mechanism involved a double Stevens rearrangement through intermediates **195** and **196** (Scheme 47).



Scheme 47. Double insertion of aryl disulfides

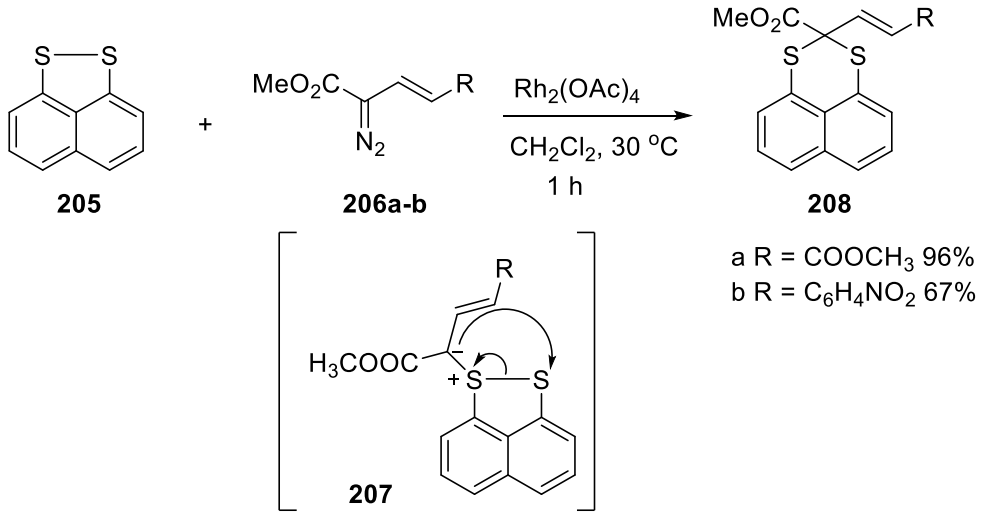
Very recently, terminal alkynes **198** were transformed into triazoles **200** under copper catalysis upon treatment with azides **199** (Scheme 48).[102] Addition of a rhodium catalyst led to nitrogen loss, and formation of a rhodium carbene **201** which reacted with aryl disulfides forming thioacetals **202** (Scheme 48). The imine moiety could be cleaved or reduced easily in situ to form either 1-(aryl(arylthio)methylthio)benzenes **203** or aryl-2,2-bis(arylthio)-*N*-sulfonylethanamine **204** in high yields.



Scheme 48. Generation of rhodium carbenes from triazoles in thioacetal formation.

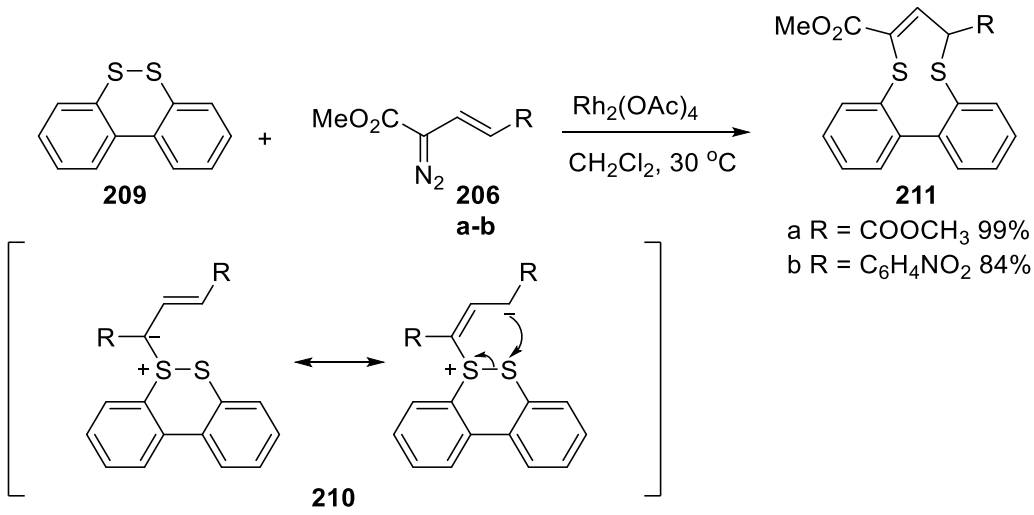
A report published in 1998 explored the reactions of two rigid aromatic cyclic disulfides **205** and **209** with vinyl diazo compounds **206** and a rhodium catalyst.[103]

1,2-Dithiaphenanthrene **205** was treated under rhodium catalysis with **206a-b** affording dithioacetals **208a-b** selectively and in high yield from these reactions (Scheme 49).[103] The reaction is proposed to proceed via a sulfonium ylide **207a-b** with sulfur migration forming the thioacetal **208**.



Scheme 49. Reaction of vinylcarbenoids with naphthalene disulfide.

In the same study Oshima reacted dibenzo[c,e][1,2]dithiin **209** with the same diazo compounds **206a-b** and rhodium acetate (Scheme 50). The isolated products were 1,3-insertion adducts **211a-b** resulting from 1,4-sulfur migration **210** which in this case is more favourable.[103]



Scheme 50. Reaction of 1,2-dithiaphenanthrene with a metal vinyl carbenoid.

3.2 Aim and objectives

The aim of this work was to explore the reactivity of disulfide oxides with alkynes under gold catalysis, led by a curiosity as to whether analogous insertion products to those formed with rhodium carbenes would be observed and whether selectivity could be achieved when several reasonable reaction pathways could be foreseen.

A number of disulfide oxides **212-216** have been reported to be stable compounds, including the ditert-butyl disulfide **215**,[105] and dibenzo[c,e][1,2]dithiin monoxide **216**,[106,107] while the Grainger group introduced a range of naphthalene derived disulfide oxides **212-214** the including the first stable *vic* disulfoxide **214** (Figure 4).[83,104]

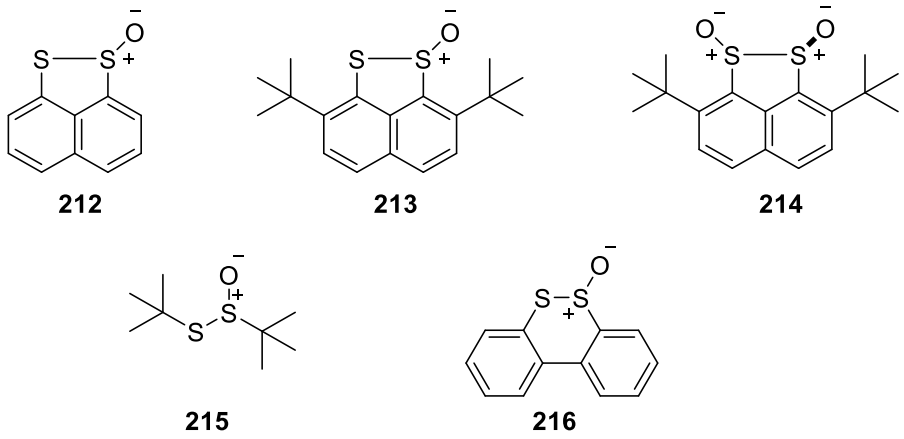
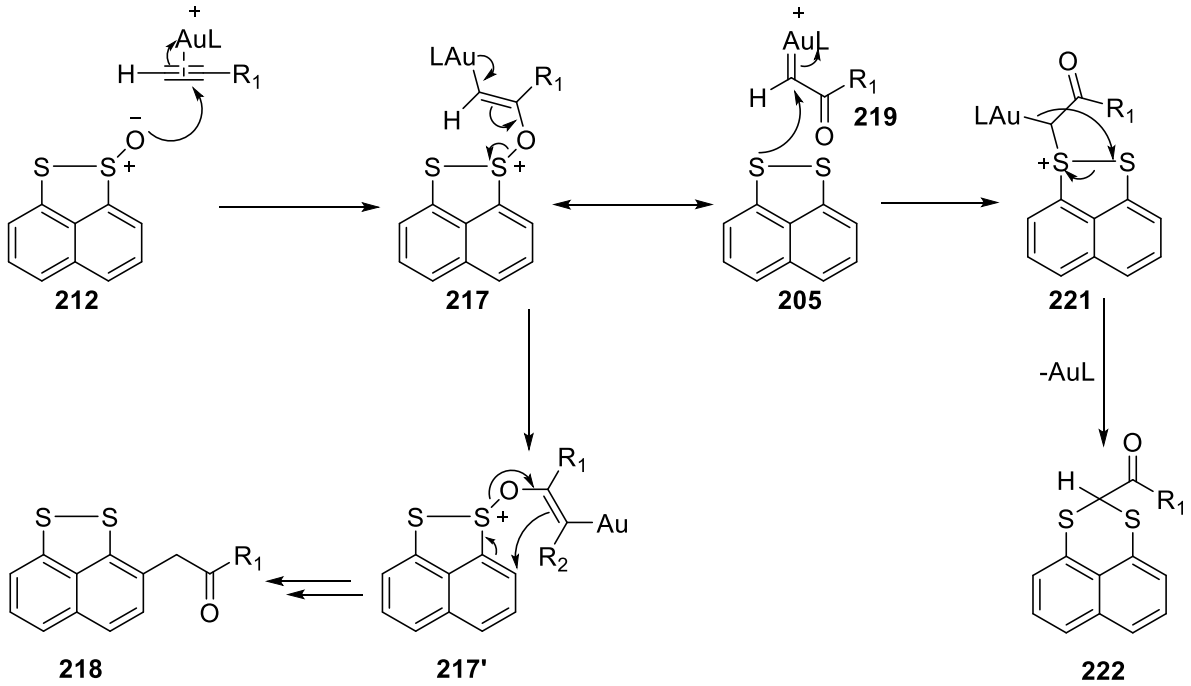


Figure 4. Disulfide oxides.

In this process it is desirable that the SO reacts with the alkyne to afford the gold carbene with release of disulfide (Scheme 51).[17,34] Regioselective nucleophilic attack of the disulfide oxide **212** onto the internal carbon of the activated alkyne would be expected to proceed initially.[26,27] The nature of the gold species could then be pivotal in determining reaction outcome. Vinyl gold species **217** may be expected to undergo [3,3]-sigmatropic rearrangement **218** to furnish the oxyarylation product **219** . Cleavage of the S-O bond would form the α-oxo gold carbene **220** and disulfide **205** which could then react analogously to afford the sulfur ylide **221** as observed with rhodium carbenes.[99,101,103] such formation from sulfoxides is often less effective than other competing pathways (oxyarylation/further oxidation), though in this case the disulfide nucleofuge may show a substantially different reactivity profile than a sulfide. Alternatively, sulfur ylide formation may proceed from the vinyl gold carbenoid **221** via attack of the second sulfur at the electrophilic carbon. Finally Stevens-type migration of the ylide carbon to sulfur would furnish the dithiane product **222**. Tuning of the reaction outcome was predicted to be possible by choice of reaction conditions, gold ligand sphere and also the disulfide oxide structure.

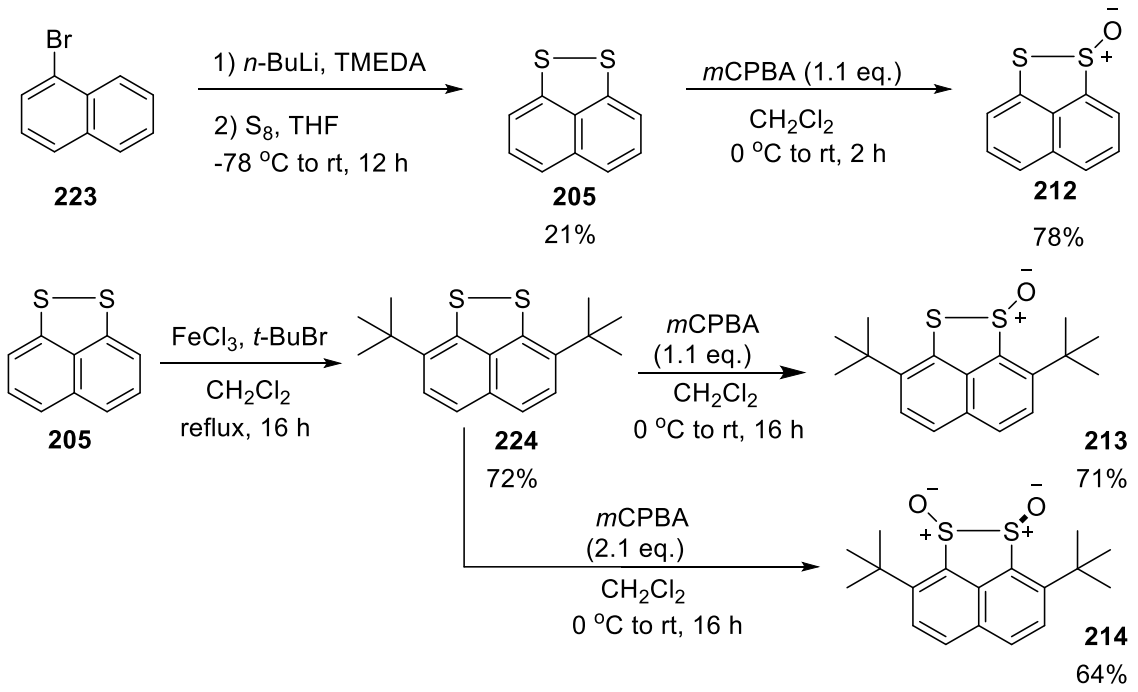


Scheme 51. Formation of products derived from an oxyarylation or an insertion.

3.3 Preliminary studies and reaction discovery

Three naphthalene derived disulfide oxides **212-214** (Fig 1) were chosen as initial test substrates. Naphthalene disulfide oxide **212** provides a direct comparison to naphthalene disulfide employed in Oshima's study. The two di-*tert* butyl substituted sulfur oxides **213** and **214** would be unable to undergo oxyarylation and also provide a sterically bulky environment.

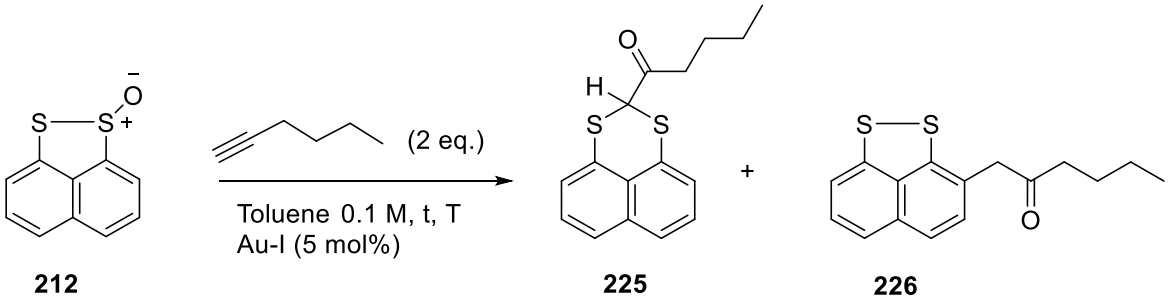
Disulfide **205** was prepared from 2-bromonaphthalene **223** using reported procedures by halogen metal exchange, followed by a selective deprotonation at the 8-position with heating, and subsequent quenching with sulfur (Scheme 52).[83] Oxidation with *m*CPBA afforded the sulfur oxide **212**. Friedel Crafts alkylation of naphthalene disulfide **205** proceeded smoothly and treatment of **224** with *m*CPBA afforded disulfide monoxide **213** and *vic* disulfoxide **214** selectively.



Scheme 52. Preparation of disulfide oxides.

The initial test towards the desired aim was performed using naphtho dithiole monoxide **212** and hex-1-yne under the oxyarylation conditions previously developed (Chapter 2). The formation of a 1,1-insertion product **225** was observed in a modest yield alongside oxyarylation product **226** resulting from [3,3]-sigmatropic rearrangement on the initially formed vinyl gold species (Table 4, entry 1). Reducing the temperature gave a poorer yield of **225** (Table 4, entry 2) which is consistent with the trends expected for oxyarylation. A small improvement in reaction outcome was observed at 40 °C (Table 4, entry 3). However, degradation was seen at higher temperatures (Table 4, entry 4). Changing from the phosphite-gold catalyst to a more electron-rich XPhosAuCl/$AgSbF_6$ system tried to decrease the lifetime of vinyl gold carbenoid (or increase the likely formation of the gold carbene). Overall lower conversion was seen though an improved ratio toward the desired product **225** over oxyarylation **226** was observed (Table 4, entry 5).

Table 4. Reaction discovery and preliminary screening results.



212 **225** **226**

Entry	Catalyst	Temp ^{o}C	Time h	Yield[a]		
				212	**225**	**226**
1	Au-I	rt	16	30	35	15
2	Au-I	0	16	27	28	20
3	Au-I	40	16	0	42	34
4	Au-I	70	5	0	24	13
5	XPhosAuCl/ $AgSbF_6$ (2.5 mol%)	50	16	60	20	8

[a] Reactions performed on a 0.1 mmol scale and yields determined by crude NMR analysis using 1,2,4,5 Tetramethylbenzene as an internal reference standard. Au-I = (2,4-di-*tert*-butyl$C_6H_3O)_3PAu(NCCH_3)SbF_6$.

3.4 Reaction Optimisation

With these promising results in hand, phenylacetylene was subsequently used for reaction optimisation as the degradation observed on moderate heating with hex-1-yne was not observed (Table 4, entry 4).

Initially the reaction solvent was varied. Excellent conversion was observed with toluene (Table 5, entry 1) yet the ratio of the two products was quite poor. Halogenated solvents proved suitable giving moderate conversion and a low yield of desired product **227** (Table 5, entries 2 and 4). 1,4-dioxane and acetonitrile shut down the reaction (Table 5, entry 3 and 5). No conversion was seen with only the gold at an elevated temperature (Table 5, entry 6), triflimidic acid solely resulted in degradation on employment (Table 5, entry 7) and silver hexafluoroantimonate did not promote any reaction (Table 5, entry 8).

The nature of the silver co-catalyst was instrumental in determining the reaction outcome. With the basic and tightly coordinating tosylate anion, no reaction was observed, and silver

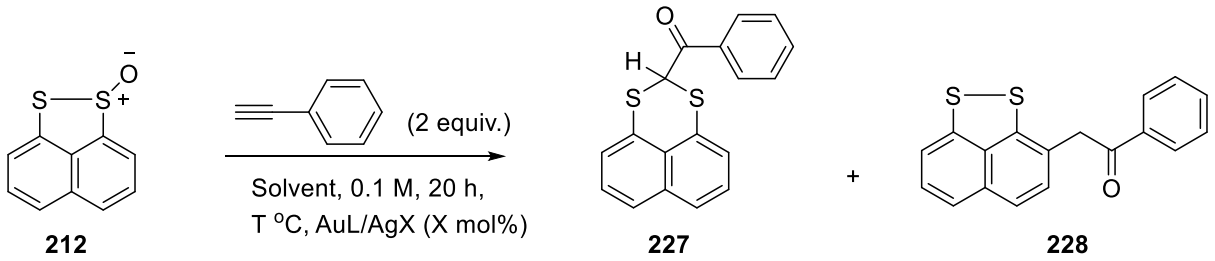
tetrafluoroborate and silver triflate were also poor choices (Table 5, entries 9 and 11). An improvement in ratio was observed with silver triflimidate (Table 5, entry 12), but only silver hexafluoroantimonate facilitated high reaction efficiency (Table 5, entry 2).

The electronic nature of the phosphine gold catalyst was not pivotal in determining the reactivity and selectivity of the system. Sterically bulky catalysts, such as XPhos and di-*tert* butyl phosphite, proved more effective (Table 5, entries 1 and 14), compared to triphenylphosphinegold(I) chloride (Table 5, entry 15). IPrAuCl was also ineffectual (Table 5, entry 18).

The addition of a catalytic quantity of 4-methyl di-*tert* butyl pyridine, a non-nucleophilic base, resulted in total loss of reactivity (Table 5, entry 19). A negligible difference in reaction outcome was observed on switching from the phosphite catalyst to the pre-formed acetonitrile complex Au-I (Table 5, entries 16 and 17). Addition of 1.1 equivalents of methanesulfonic acid resulted mostly in degradation (Table 5, entry 20).

Temperature was a less critical variable with complete conversion above 50 ^{o}C, and no change in the reaction outcome when the temperature was increased further (Table 5, entries 21 and 22). Small peaks at 10-11 ppm were observed in the crude ^{1}H NMR spectrum likely due to the small amount of regioisomeric product resultant from *S*-oxide attack at the external carbon of the activated alkyne.

Table 5. Screening of reaction conditions.



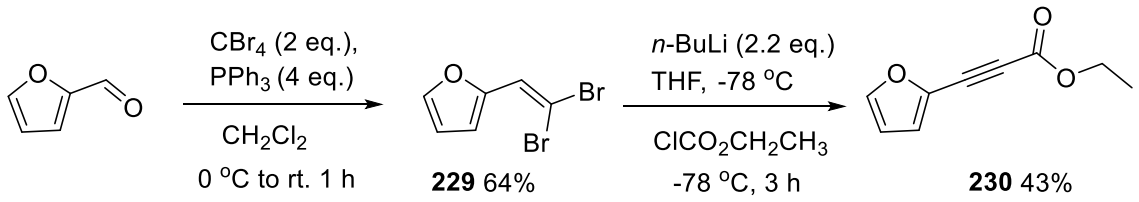
212 **227** **228**

Entry	Temperature °C	Gold Catalyst	Silver Co-catalyst	Loading mol%	Solvent	**212**[a]	**227**[a]	**228**[a]
1	50	XPhosAuCl	$AgSbF_6$	2.5	Toluene	0	52	38
2	50	XPhosAuCl	$AgSbF_6$	2.5	$CHCl_3$	25	42	29
3	50	XPhosAuCl	$AgSbF_6$	2.5	Dioxane	90	0	0
4	50	XPhosAuCl	$AgSbF_6$	2.5	DCE	24	33	22
5	50	XPhosAuCl	$AgSbF_6$	2.5	CH_3CN	90	8	3
6	100	XPhosAuCl	-	2.5	Toluene	100	0	0
7	50	$HNTf_2$		5	Toluene	88	<3	0
8	50		$AgSbF_6$	10	Toluene	90	0	0
9	50	XPhosAuCl	$AgBF_4$	2.5	Toluene	78	12	5
10	50	XPhosAuCl	AgOTs	2.5	Toluene	95	0	0
11	50	XPhosAuCl	AgOTf	2.5	Toluene	100	0	0
12	50	XPhosAuCl	$AgNTf_2$	2.5	Toluene	42	33	5
14	50	SPhosAuCl	$AgSbF_6$	2.5	Toluene	20	42	26
15	50	PPh_3AuCl	$AgSbF_6$	2.5	Toluene	23	30	16
16	50	L2AuCl	$AgSbF_6$	2.5	Toluene	42	39	12
17	50	Au-I	$AgSbF_6$	2.5	Toluene	17	43	28
18	50	IPrAuCl	$AgSbF_6$	2.5	Toluene	76	5	<3
19[b]	50	XPhosAuCl	$AgSbF_6$	2.5	Toluene	95	0	0
20[c]	50	XPhosAuCl	$AgSbF_6$	2.5	Toluene	12	8	<3
21	rt	XPhosAuCl	$AgSbF_6$	2.5	Toluene	12	44	32
22	100	XPhosAuCl	$AgSbF_6$	2.5	Toluene	1	51	37

[a] Reactions performed on a 0.2 mmol scale and yields determined by crude NMR analysis using 1, 2, 4, 5 Tetramethylbenzene as an internal reference standard. [b] Addition of 5 mol% 2,6-di-*tert*-butyl-4-methylpyridine. [c] Addition of 1.1 eq. methanesulfonic acid. L2 = Au-I = (2,4-di-*tert*-butyl$C_6H_3O)_3PAu(NCCH_3)SbF_6$.

3.5 Variation of the alkyne

Sulfur oxide **212** was treated with a range of alkynes in order to better understand the chemoselectivity and the scope for the transformation. Ester substituted alkyne **230** was prepared in two steps from furfural (Scheme 53).[108, 109]

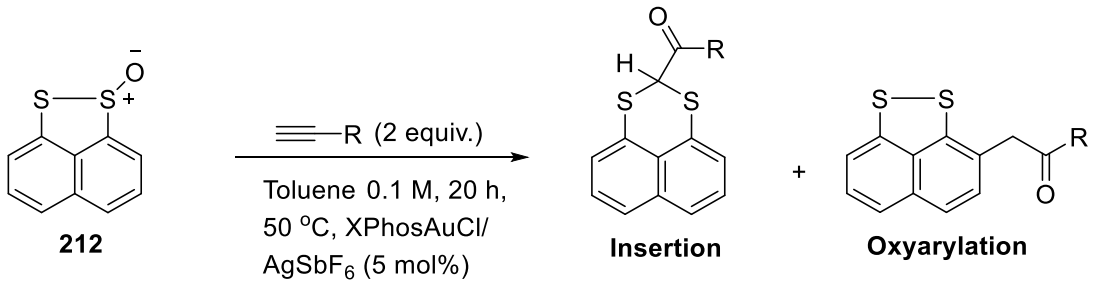


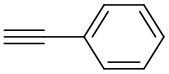
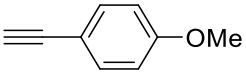
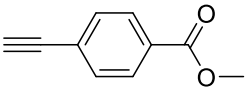
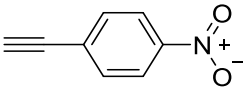
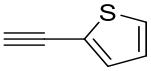
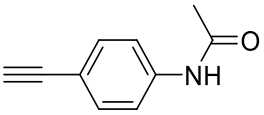
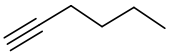
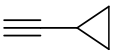
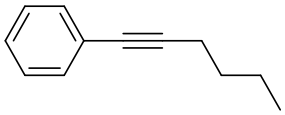
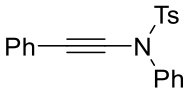
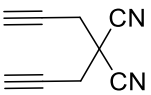
Scheme 53. Preparation of an internal alkyne.

Due to the difficulties involved in isolating the pure products, and the generally poor to modest yields encountered, only NMR yields were obtained, except for the phenyl derivative, with the insertion product **227** isolated in a moderate 46% yield and the rearrangement product **228** in a 9% isolated yield (Table 6. entry 1).

Both electron rich and electron poor aryl substituted terminal alkynes were tolerated with the ester working as well as phenyl (Table 6, entries 1-4). A heteroaromatic thiophene was employed successfully in a reduced yield (Table 6, entry 5). However, an acetamide was mostly unreacted (Table 6, entry 6) highlighting the limited substrate scope for this transformation. Under the conditions developed for aryl substituents, alkyl substituents were largely unreactive. Hex-1-yne worked poorly, with cyclopropyl even worse (Table 6, entries 7 and 8). No reactivity was observed with an internal alkyne or with an ynamide (Table 6, entries 9 and 10). A diyne was also not tolerated (Table 6, entry 11) underlining the sensitivity of this reaction.

Table 6. Treatment of naphtho dithiole monoxide with a variety of alkynes.



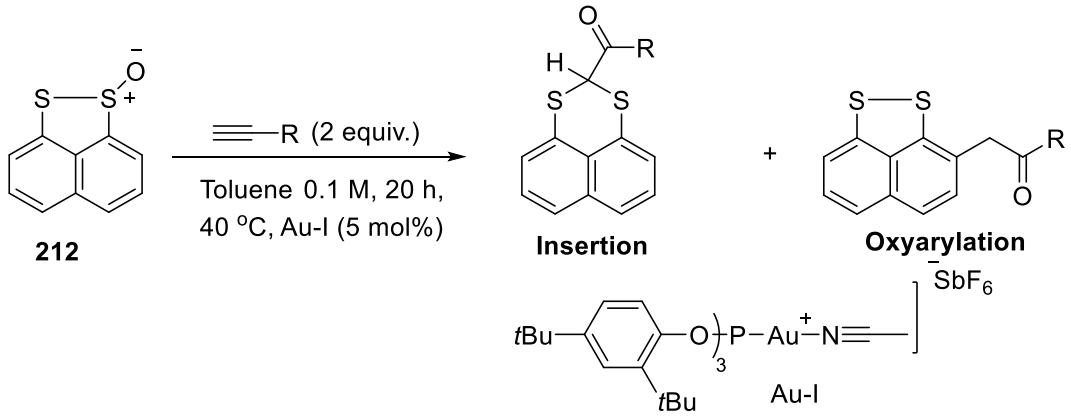
Entry	Alkyne	Yield **212**%	Insertion %	Oxyarylation %
1		0	**216** 46[b]	**217** 9[b]
2		55	**231** 35	**232** <3
3		0	**233** 54	**234** 36
4		50	**235** 35	**236** <3
5		55	**237** 28	**238** 3>
6		80	**239** 7	**240** 3>
7		60	**225** 20	**226** 10
8		71	**241** 15	**242** 4
9		90	**243** 0	**244** 0
10		90	**245** 0	**246** 0
11		70	**247** 3>	**248** 3>

[a] Reactions performed on a 0.1 mmol scale and yields determined by crude NMR analysis using 1, 2, 4, 5 Tetramethylbenzene as an internal reference standard. [b] Reaction performed on a 0.4 mmol scale and Isolated yields after flash column chromatography

Preliminary studies had showed hex-1-yne to be more reactive with the electron-withdrawing phosphite catalyst Au-I (Table 4, entry 4). These conditions were reinvestigated with secondary

and tertiary alkynes to see how that might affect the ratio of insertion products (**225**, **249** and **241**) and the oxyarylation products (**226**, **250** and **242**). In all cases there is little effect on reaction outcome upon changing the sterics of the alkyl group and product selectivity remains poor. While naphtho dithiole monoxide **212** proved to afford the desired reactivity and afforded high conversion with a range of terminal alkynes, selectivity between pathways was low with competing oxyarylation causing low yields.

Table 7. Preparation of alkyl substituted products.

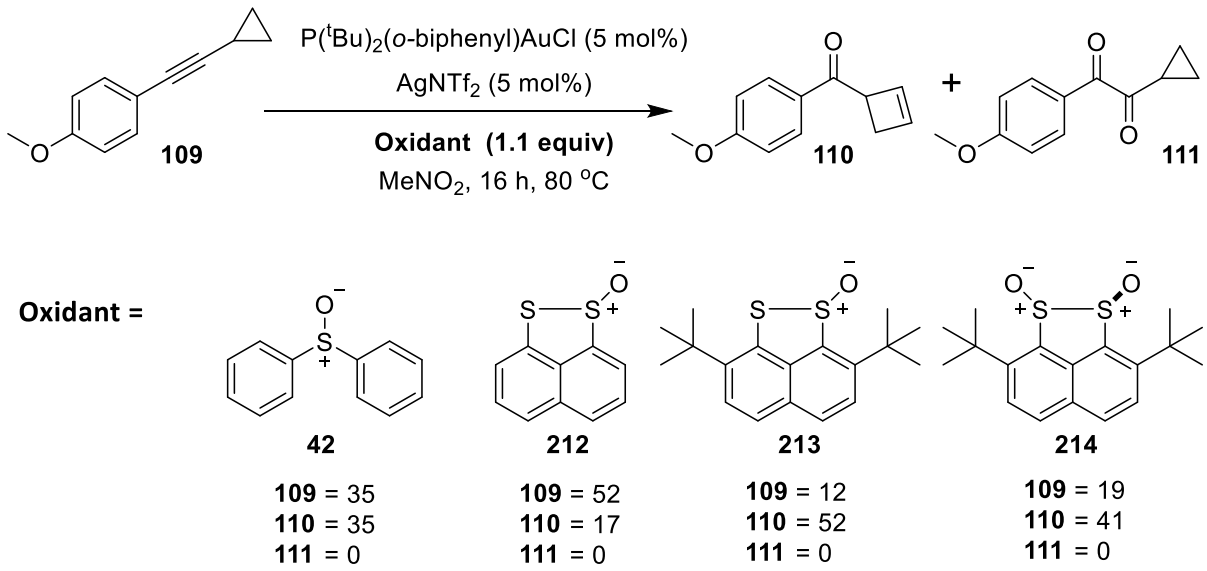


Alkyne	Scale (mmol)	Product	Yield[a] 207%	Product	Yield[a] 212%
	0.3	**225**	36	**226**	33
	0.2	**249**	46	**250**	26
	0.2	**241**	38	**242**	20

[a] Isolated yields after purification by silica gel chromatography.

3.6 Probing the reactivity of disulfide oxides

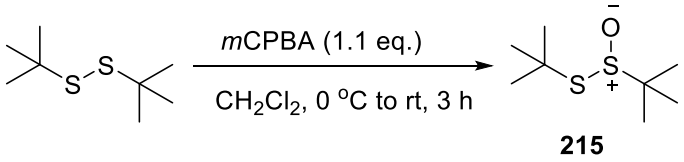
The reactivity of the disulfide oxides in gold catalysis was first probed employing them as oxidants to replace diphenyl sulfoxide **42** in Liu's oxidative ring-expansion of alkynyl cyclopropanes **109** to cyclobutenyl ketones **110**.[19] Interestingly, all three derivatives selectively transformed the cyclopropyl alkynes **109** into the desired cyclobutenyl ketones **110** under Liu's conditions (Scheme 54). The addition of the *tert* butyl groups resulted in much improved conversion with the crude yield of cyclobutenyl ketone **110** when employing sulfur oxide **214** being comparable to diphenyl sulfoxide **42**.



Scheme 54. Naphthalene based disulfide oxides as intermolecular oxidants in oxidative gold catalysis.

Other disulfide oxides were then explored to see how structure would impact on selectivity. It was hypothesised that by blocking the *ortho* positions on the naphthalene ring, the formation of the undesired oxyarylation product would be eliminated. Employing the di-*tert* butyl variant of the sulfur oxide **213** and the *vic* disulfoxide **214** under the previous best conditions (Table 5, entry 6) resulted in no reaction. These two sulfur oxides were suitable as intermolecular oxidants in the ring expansion of alkynyl cyclopropane **109**.

Di-*tert* butyl disulfide monoxide **215** was synthesised (Scheme 55) and tested under the reaction conditions. The starting material was consumed, although a complex mixture was observed.



215

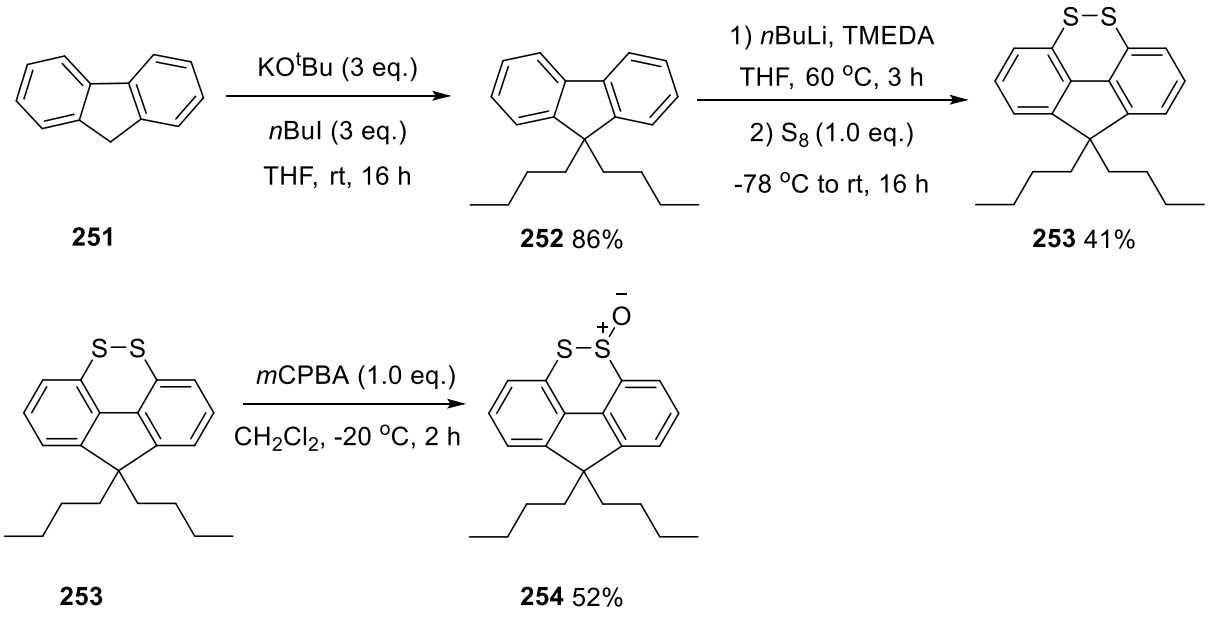
Scheme 55. Preparation of a more flexible disulfide oxide.

3.7 Reactivity of a fluorene derived disulfide monoxide

A system based on dibenzo[c,e][1,2]dithiin was considered as Oshima found success, generating different products to the naphthalene disulfide. The known preparation is many steps in length which is off-putting for a useful procedure.

Recently a cyclic disulfide derived from fluorene has been prepared for the first time.[110] Bonifácio demonstrated an efficient synthesis for this compound and this methodology was employed by Figliola who reduced the length of the alkyl chain in preparing **226** which was selected as a test case for the disulfide variation approach.[110,111]

Employing the aforementioned procedure, fluorene **251** was doubly alkylated upon treatment with KO^{t}Bu followed by the addition of butyl iodide in excellent yield. Combining **252** in refluxing THF with *n*-BuLi and TMEDA resulted in selective double deprotonation, and trapping with sulfur at low temperature furnished the required disulfide **253**. The disulfide **253** was then oxidised selectively to the target disulfide monoxide **254** in moderate yield using *m*CPBA at low temperature (Scheme 56).



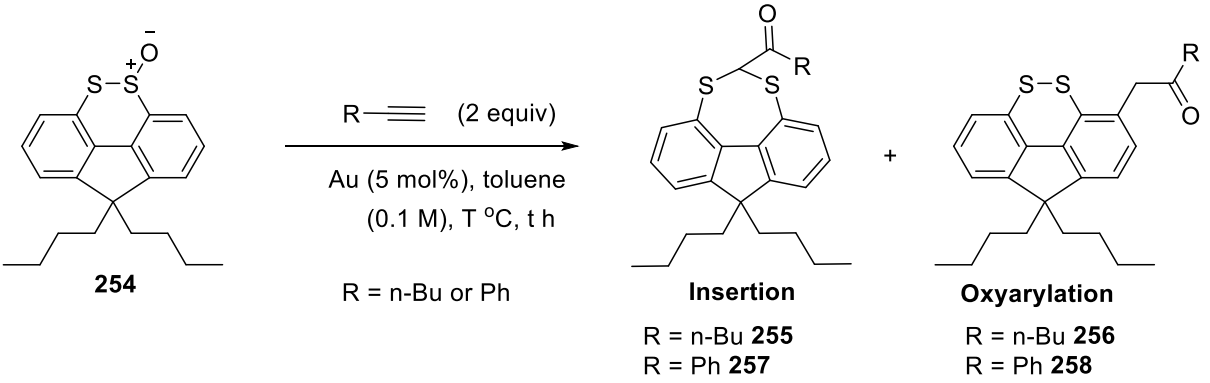
Scheme 56. Preparation of a novel disulfide oxide from fluorene.

Fluorene disulfide oxide **254** was then reacted with hex-1-yne under the best conditions found previously for naphthalene dithiole monoxide **212** with alkyl alkynes (Table 7). Formation of the 1,1 insertion product **255** was observed (Table 8, entry 1) with clear reduction in the proportion of the oxyarylation product **256** formed.

Employing phenylacetylene under the conditions found previously to be optimum for aryl alkynes (Table 6, entry 1) led to only a very low yield of insertion product **257** (Table 8, entry 2) but only traces of the undesired oxyarylation product **258**. Reactions were performed with phenylacetylene and phosphite catalyst Au-I and the temperature varied (Table 8, entries 3-6). As expected the ratio of product **257** to **258** increased upon increasing the temperature following the trends seen in chapter 2. Preparation of pre-formed gold complex Au-II and an increase in temperature led to a better yield of the insertion product with phenylacetylene and the oxyarylation product **258** was effectively eliminated (Table 5, entry 8). The results show the fluorene-derived sulfur oxide **254** is less reactive than the naphthalene derived sulfur oxide **212** but catalyst tuning effectively prevents formation of the undesired oxyarylation product **258**. Oxyarylation is eliminated using an electron-rich catalyst favouring the α-oxo gold carbene,

which would give rise to the desired insertion product (Table 5, entries 6 and 8). Small peaks at 10-11 ppm were observed in the crude NMR spectrum likely due to the small amount of regioisomeric product resultant from *S*-oxide attack at the external carbon of the activated alkyne.

Table 8. Optimisation of the desired reaction.



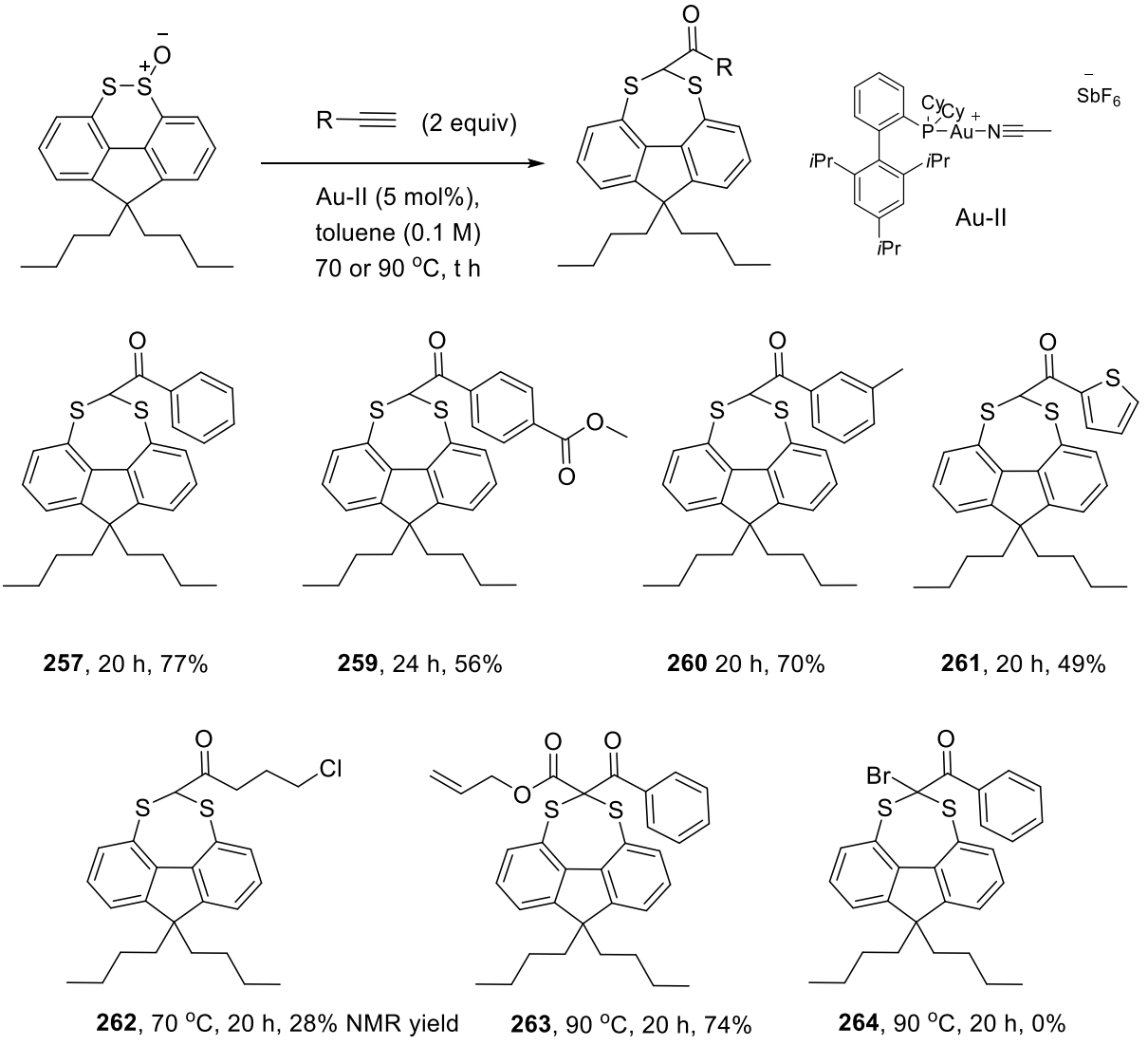
Entry	R	Catalyst	Temp °C	Time (h)	Yield% [a]		
					254	**255/7**	**256/8**
1	n-Bu	Au-I	40	28	45	40	10
2	Ph	XPhosAuCl/ $AgSbF_6$	50	40	70	17	<3
3	Ph	Au-I	rt	24	54	20	9
4	Ph	Au-I	40	24	46	32	12
5	Ph	Au-I	60	24	32	52	12
6	Ph	Au-I	80	24	<10	45	7
7	Ph	Au-II	60	24	30	59	0
8	Ph	Au-II	70	24	<10	71	0
9*	Ph	Au-II	90	24	<5	73	0

[a] Reactions performed on a 0.1 mmol scale and yields determined by crude NMR analysis using 1, 2, 4, 5 Tetramethylbenzene as an internal reference standard. * Reaction performed after the first 4 examples were obtained. Au-II = (Acetonitrile) Dicyclohexylphosphino-2′,4′,6′-triisopropylbiphenyl gold(I) hexafluoroantimonate.

3.8 Substrate elaboration

An investigation into the substrate scope for the transformation was carried out. First, several aryl based terminal alkynes were tested under the optimised conditions. Pleasingly, an ester, methyl and thienyl substituent were all well tolerated, providing the desired products **259** and **260**-**261** in moderate to good yields (Scheme 57).

Employment of 5-chloro-1-pentyne under the optimised reaction conditions resulted in poor reactivity with only a 28% proton NMR yield of **262** observed. Notably reactions from this point were performed at 90 °C, with this temperature increase rationalised by improved reactivity (Table 9, entry 9). Gratifyingly, an ester derived internal alkyne reacted in good yield affording thioacetal **263**. Bromophenylacetylene did not afford any desired product **264**. TLC analysis of the reaction mixture showed very little reactivity with some degradation.



Scheme 57. Preparation of a range of dithioacetals.

The structure of **263** was rationalised by comparing the ^{13}C NMR data of the carbonyl carbons against two known compounds **265** and **266** displaying the possible substitution patterns (Fig

5). [112,113] The difference in chemical shift suggests **263** rather than **267** is the correct compound. This conclusion also fits with the known literature where nucleophilic attack of the oxygen moiety occurs away from the internal ester carbon.[27,52] A comparison was made of the ^{13}C resonances of the carbonyl carbon across the series of compounds **255, 257**, **268**, **259-262**, **269-270**. For the phenyl substituted products the carbonyl peak appears at around 192 ppm. A thiophene substituent results in a decrease in chemical shift whereas the carbonyl is significantly more deshielded with a hexyl substituent resonating at 202 ppm.

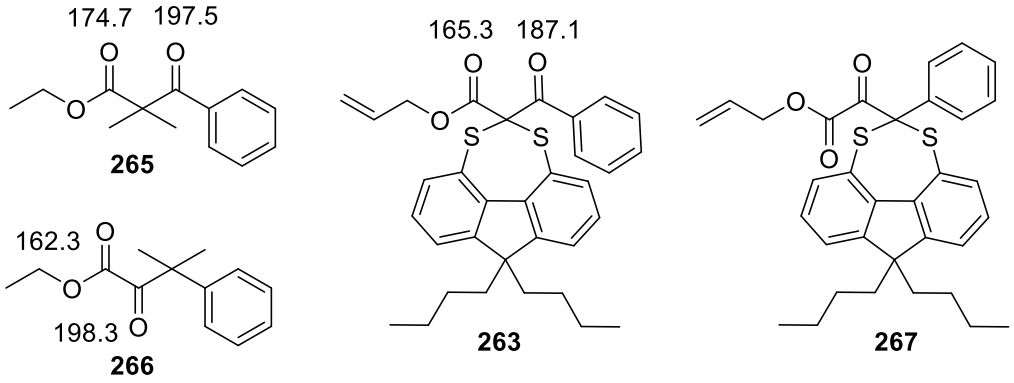


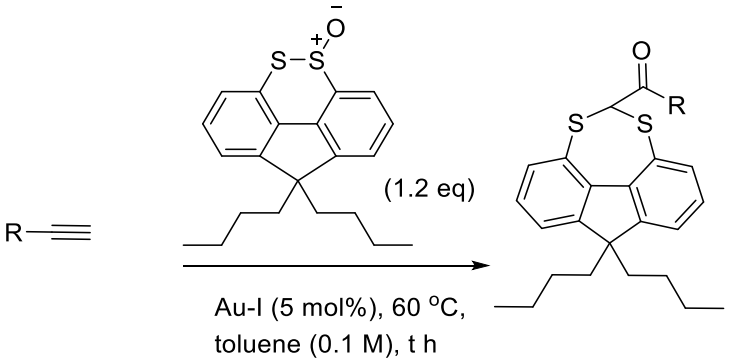
Fig 5. Characteristic carbonyl peaks in the ^{13}C NMR spectrum.

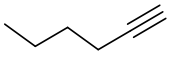
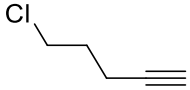
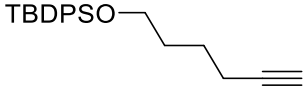
Table 9. Comparison of chemical shifts of the C=O bond in the catalysis products

Substituent	C=O Chemical shift
Ph	191.9
3-$OMeC_6H_4$	191.7
3-MeC_6H_4	192.1
4-$CO_2MeC_6H_4$	191.1
4-BrC_6H_5	190.8
2-Thienyl	184.5
Hexyl	201.2
$(CH_2)_3Cl$	201.1
$(CH_2)_4OTBDPS$	199.8

Alkylalkynes were studied using modified conditions providing a strategy to efficiently oxidise and functionalise alkynes in a single step because of the poor result observed using the conditions in Scheme 57. Under these conditions 5-chloro-1-pentyne was well tolerated (Table 10, entry 2). Hex-1-yne was also incorporated to give **255** in a moderate yield (Table 11, entry 1) and a silyl protected alcohol was also allowed **268**, albeit in a lower 44% yield (Table 11, entry 3).

Table 10. Preparation of alkyl substituted insertion products.



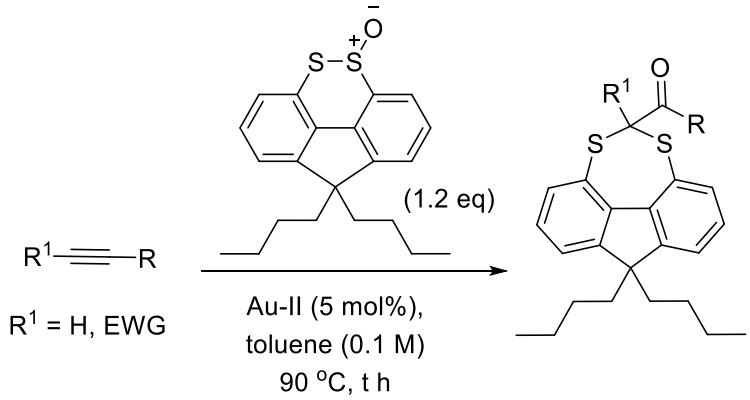
Entry	Alkyne	Time h	Product	Yield[a]
1		22	**255**	57
2		22	**262**	66
3		22	**268**	44

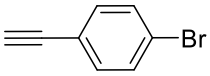
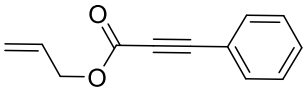
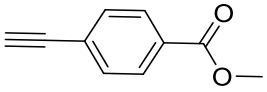
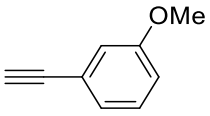
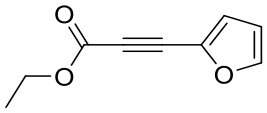
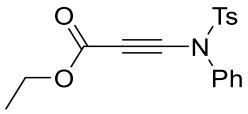
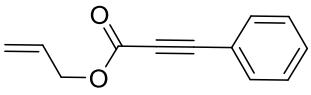
Reactions performed on a 0.1 mmol scale. [a] Isolated yield after purification by silica gel chromatography.

In addition to the interesting reactivity, this transformation potentially provides a strategy to efficiently oxidise and functionalise alkynes in a single step. To enhance this, the reagent stoichiometry was altered in order to make the alkyne the limiting reagent. 4-Bromo phenylacetylene proved to be a good substrate, delivering the insertion product **269** in high yield (Table 11 entry 1). The ester substituted alkyne tested previously provided a similar reaction outcome (Table 11, entry 2) and a 3-methoxy-substituent **270** was incorporated in a moderate yield (Table 11, entry 4). The most exciting results were obtained utilising the ester substituted internal alkynes. An excellent yield was obtained of dithioacetal **263** (Table 11, entry 3), higher than when the alkyne was employed in excess (Scheme 57). Alkyne **230** with a furan heterocycle attached was also incorporated, providing **271** in a good yield (Table 11, entry 5). Unfortunately attempts to incorporate an ester substituted ynamide were unsuccessful (Table 11, entry 6).

With ester substituted alkynes an alternative reaction mechanism can be envisaged without the requirement for a π-acid. The nucleophilic sulfur oxide could undergo a conjugate addition to the alkyne. This pathway was ruled out as no reaction was observed on omission of the gold catalyst (Table 11, entry 7).

Table 11. Thioacetal preparation using aryl based alkynes as the limiting reagent.



Entry	Alkyne	Time h	Product	Yield[a]
1		22	**269**	70
2		20	**263**	83
3		20	**259**	52
4		20	**270**	67
5		14	**271**	75
6		20	**272**	0
7[b]		20	**263**	0

Reactions performed on a 0.1 mmol scale. [a] Isolated yield after purification by silica gel chromatography. [b] No catalyst added into the reaction mixture.

3.9 Crystal structure comparisons of the insertion products

A crystal structure was successfully obtained for the insertion products **227** and **257** using single crystal X-ray diffractometry (Fig 7). Naphthalene based **227** (Fig 6) comprised of two crystallographically independent molecules of which the right hand structure was used for analysis.

In **227** the 1,3 dithiane ring sits in a sofa conformation.[83,114] Ring strain is observed with the C1-C9-C8 bond angle of 124.5^{o} compared to the expected 120^{o}. The naphthalene ring is almost planar with the C1C9-C10C5 dihedral angle at 178.69(10)^{o}. One of the sulfur atoms is out of the plane with a S1C1C9C8 bond angle of 5.7^{o}.

The bond lengths of the carbon sulfur bonds in compounds **227** and **257** are virtually identical. The S1C11 and S2C11 of **227** and the S1C14 and S2C14 of **257** are 1.81 which is significantly longer than the C1-S1 and the C8-S2 t 1.7669(15) and 1.7690(11) lengths for **227** and **257**.

Other interesting features are the S1C14S2 bond angle of 114.52(0)^{o} which is in between tetrahedral and planar. With the fluorene derivative the S1C1C2 and S1C1C13 bond angles are shifted significantly from the expected 120^{o} at 112.491(13)^{o} and 128.55^{o} compared to the S1C1C2 and S1C1C9 angles of 114.84(11)^{o} and 124.14(11)^{o} in the naphthalene derivative 124.5^{o}. Clearly ring strain is present in both molecules but the data is not sufficient enough or convincing to explain the differences in selectivity between the two systems.

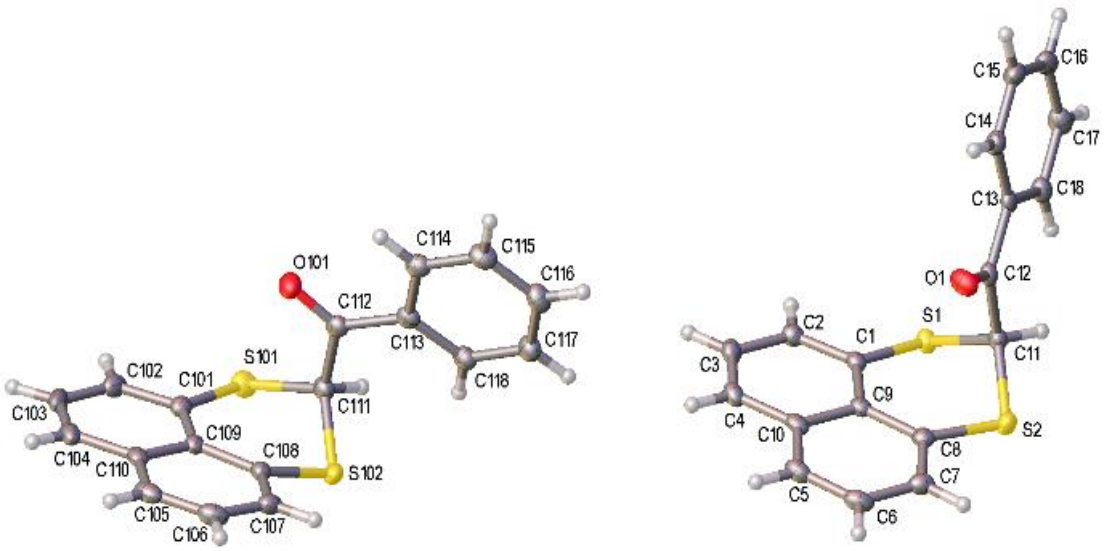


Figure 6. Crystal structure of 227

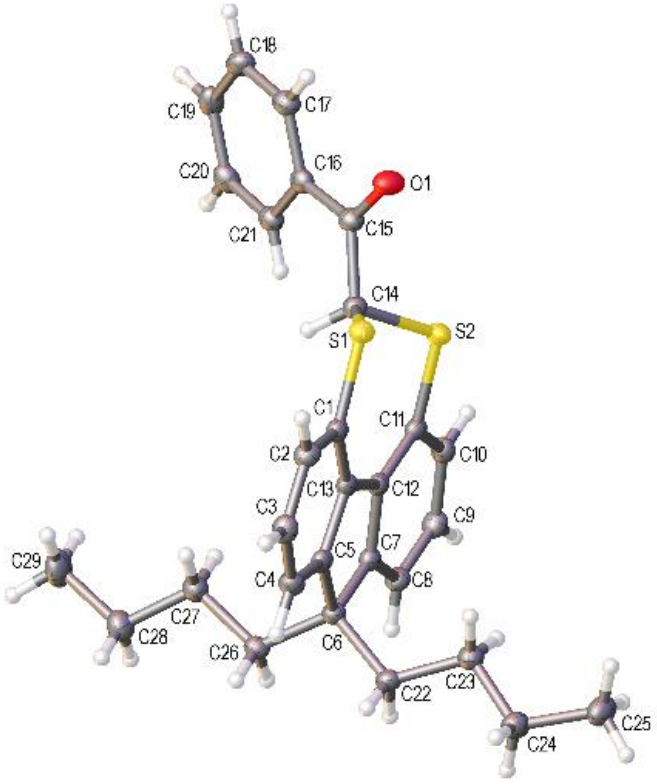


Figure 7. Crystal structures of 257.

3.10 Conclusion

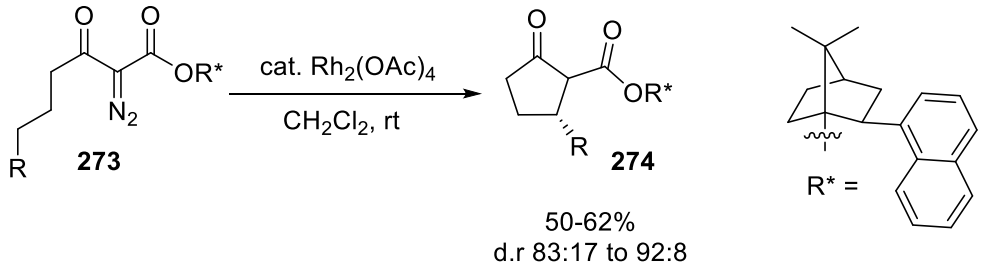
Several disulfide oxides have been investigated in this study exploring the chemistry of these species with alkynes. Two, naphthalene dithiole monoxide **212** and 9,9-dibutyl-9H-fluoreno[4,5-cde][1,2]dithiine 4-oxide **254**, have undergone insertion chemistry with alkynes. These results resemble the reactivity of cyclic disulfides with rhodium carbenes in Oshima's study.[101] Naphthalene disulfide oxide **212**, on the one hand displayed good reactivity however the competing oxyarylation pathway adversely affected the yield. Selectivity could not be achieved upon screening a range of reaction conditions. 9,9-Dibutyl-9H-fluoreno[4,5-cde][1,2]dithiine 4-oxide **254** proved less reactive but the reaction outcome could be tuned with the appropriate catalyst. Using this disulfide oxide a range of novel dithioacetals were prepared and terminal and ester substituted alkynes could be efficiently oxidised and functionalised in a single step. In all cases regioselectivity in the initial attack of the sulfur oxide was good with only trace amounts of the aldehyde observed. A limitation of this approach is the lack of reactivity with ynamides and internal alkynes.

Chapter 4: Alkynyl sulfoxides as diazo equivalents in gold catalysis

4.1 Introduction

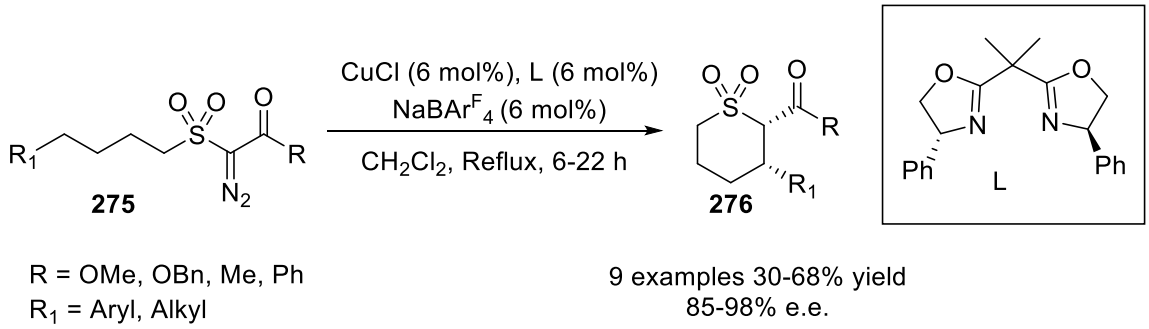
4.1.1 Preparation and reactions of α-diazo sulfoxides

Reactions at metal carbene centres offer substantial variety in formation of stereogenic centres. Ligand choice offers a good method to form stereogenic centres however this is still a considerable challenge.[115,116] An alternative method is to employ a chiral auxiliary within the substrate to control the stereochemistry. Taber utilised this method by employing a chiral ester group near to the reaction centre in **273**, in order to obtain high diastereoselectivity in a synthesis of cyclopentanones **274** (Scheme 58).[117]



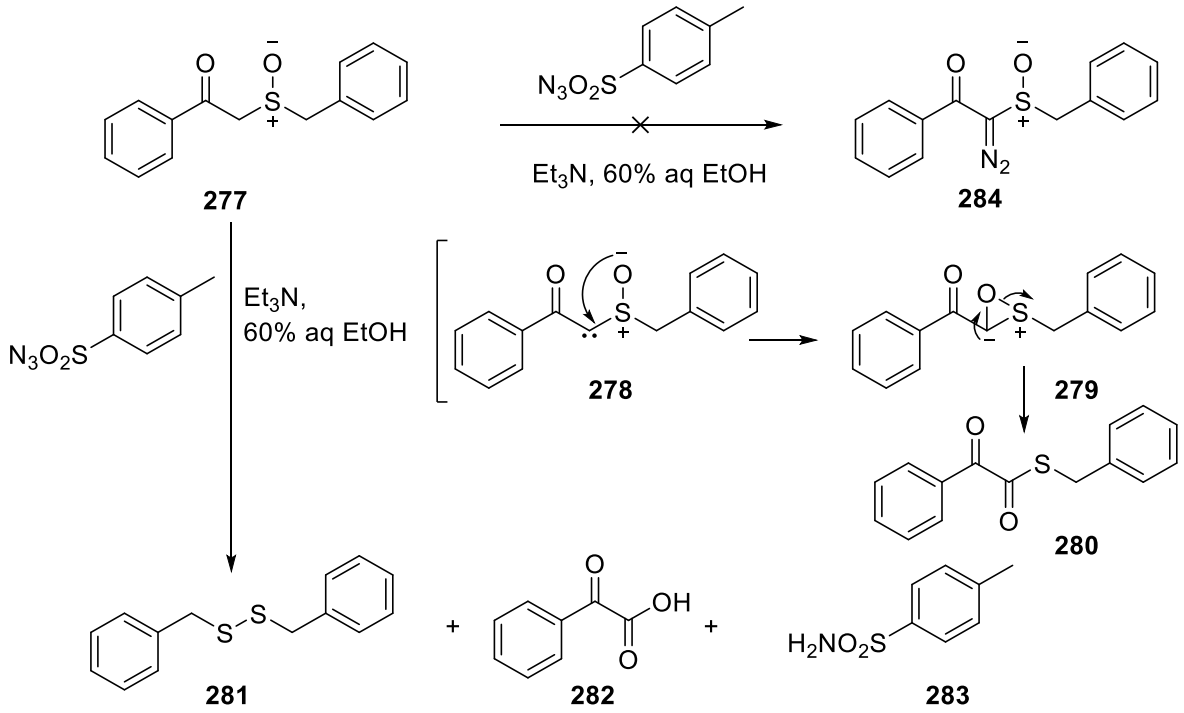
Scheme 58 Diastereocontrol in a C-H insertion from a diazo compound.

α-Diazo sulfoxides may be expected to be excellent candidates for asymmetric synthesis due to the fact that sulfoxides can be prepared in enantiopure form relatively easily.[118] Furthermore the proximity of the sulfoxide functionality to the reaction centre could facilitate good stereocontrol.[119] In reality α-diazo sulfoxides are difficult to prepare, and their reactivity is hard to control and mostly follows undesirable pathways. This is in complete contrast to α-diazo sulfones which can be prepared easily and display the normal reactivity modes for diazo species.[115,116] An illustrative example from Maguire used α-diazo sulfones **275** in a highly enantioselective copper catalysed synthesis of thiopyrans **276**.[116] A combination of copper chloride, a boronate counter ion and a chiral ligand promoted the C-H insertion process (Scheme 59).



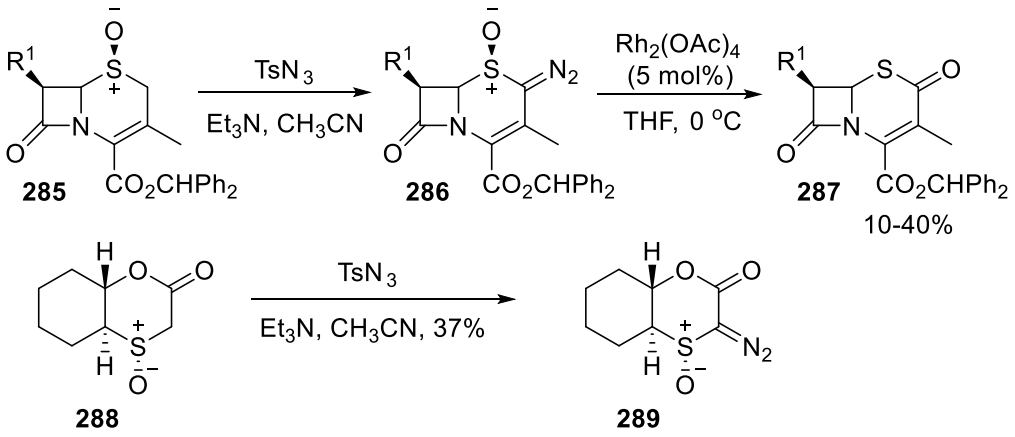
Scheme 59. Enantioselective C-H insertion reactions with α-diazo sulfones.

In 1968 Hodgson and Holt reported that under diazo transfer conditions β-keto sulfoxides exhibit unusual reactivity patterns compared to β-keto sulfones.[120,121] Upon treatment of (benzylsulfinyl)acetophenone **277** with a well-used diazo transfer reagent *p*-toluenesulfonyl azide and triethylamine, no α-diazosulfoxide **284** was isolated. Instead dibenzyl disulfide **281**, benzoylformic acid **282** and *p*-toluenesulfonamide **283**, were obtained as the products (Scheme 60). The isolation of these products can be explained through initial formation of the α-diazo sulfoxide **284**, which undergoes decomposition via an intermediate carbene **278**. It was postulated that the first step involved an oxygen transfer from the sulfur to the carbene centre **278** providing the corresponding thiol ester **280**. The keto-acid **282** and disulfide **281** were formed by hydrolysis of the thiol ester **280**.



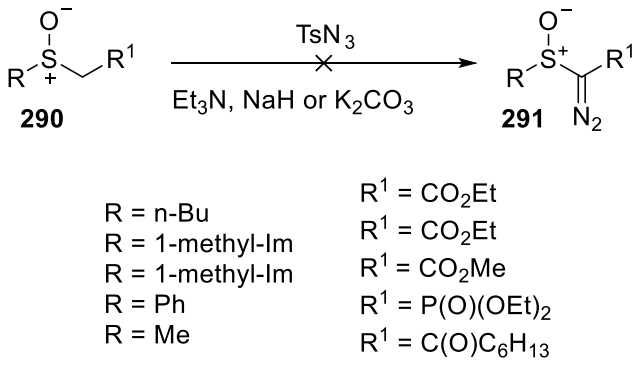
Scheme 60. Attempted diazo transfer to an acyclic sulfoxide.

Rosati was the first to demonstrate the preparation a stable cyclic α-diazo sulfoxide **286**, achieved while synthesising cephalosporin derivatives.[122] Treatment of **286** with a rhodium catalyst resulted in a low yield of an oxygen transfer product **287** (Scheme 61). Maguire also demonstrated the preparation of a stable cyclic α-diazo sulfoxide **289**.



Scheme 61. First successful isolation of diazo sulfoxides.

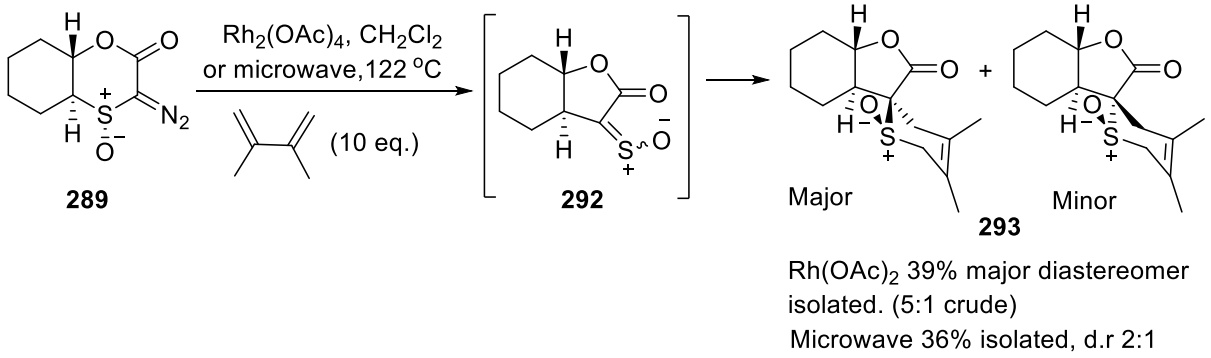
Constrainment of the sulfoxide within a ring was revealed to be essential in order for the α-diazo sulfoxide to be stable. A broad range of acyclic sulfoxides **290** were prepared and subjected to diazo transfer conditions with no α-diazo sulfoxides **291** isolated (Scheme 62).[127]



Scheme 62. Unsuccessful isolation of diazo sulfoxides.

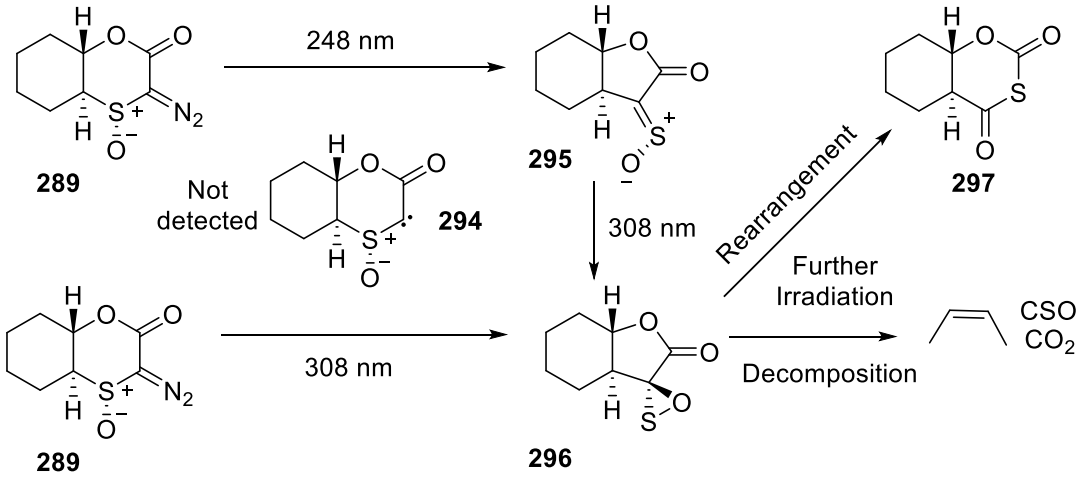
Maguire then reacted **289** with $Rh_2(OAc)_4$ in order to evaluate its reactivity (Scheme 63).[123] It was found that a Wolff rearrangement was proceeding, delivering a dimerization product, but which could be trapped by a diene affording a Diels-Alder adduct **293** (Scheme 63).

Microwave irradiation was found to promote the Wolff rearrangement without the requirement for a transition metal catalyst (Scheme 63).[124] A single stereoisomer of the Diels-Alder adduct **293** could be prepared by thermodynamic equilibration of the *Z* sulfine to the *E* sulfine prior to diene addition (not shown).



Scheme 63. Successful diazo transfer and subsequent reactivity.

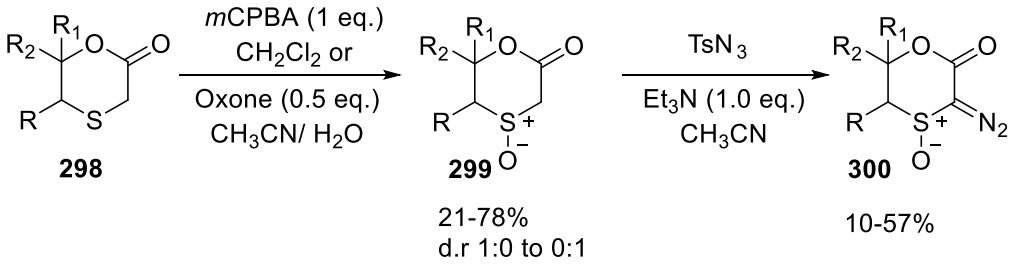
Maguire and co-workers undertook photochemical studies with α-diazo sulfoxide **289** (Scheme 64), in order to understand more about the reactions of these species.[125] The sulfoxide was stabilised in an argon matrix at an extremely low temperature (10 K) and product formation was analysed using infra-red spectroscopy. Irradiation with light at 248 nm resulted in a good yield of *E* sulfine **295**, whereas irradiation of light at 308 nm resulted in the direct formation of an oxithiirane **296**, with the configuration shown (Scheme 64), calculated to be the most stable. The *E* sulfine **295** was converted into the oxithiirane **296** with irradiation at 308 nm and further irradiation led to rearrangement product **297** or decomposition. The group were unable to isolate the carbene intermediate, yet the results strongly support the experimental evidence, that upon nitrogen loss a sulfine intermediate is formed by Wolff rearrangement.



Scheme 64. Reactions of a diazo sulfoxide upon irradiation with light.

Maguire's earlier studies on cyclic α-diazo sulfoxides were inhibited by the inefficiency of the sulfide precursor synthesis, where Baker's yeast was employed in a low yielding carbonyl reduction.[126] An efficient sulfide preparation was developed, which permitted synthesis of a library of chiral cyclic sulfoxides **299** from sulfides **298**.[127] Upon screening to establish the best diazo transfer agent, a wide variety of monocyclic and bicyclic α-diazo sulfoxides **300** were prepared (Scheme 65). Maguire rationalised that the diazo sulfoxide stability is dependant upon

the overlap of the sulfinyl lone pair of electrons with the unsaturated diazo moiety. This helped to explain why "axial" α-diazo sulfoxides showed greater stability than the "equatorial" α-diazo sulfoxides.[127]

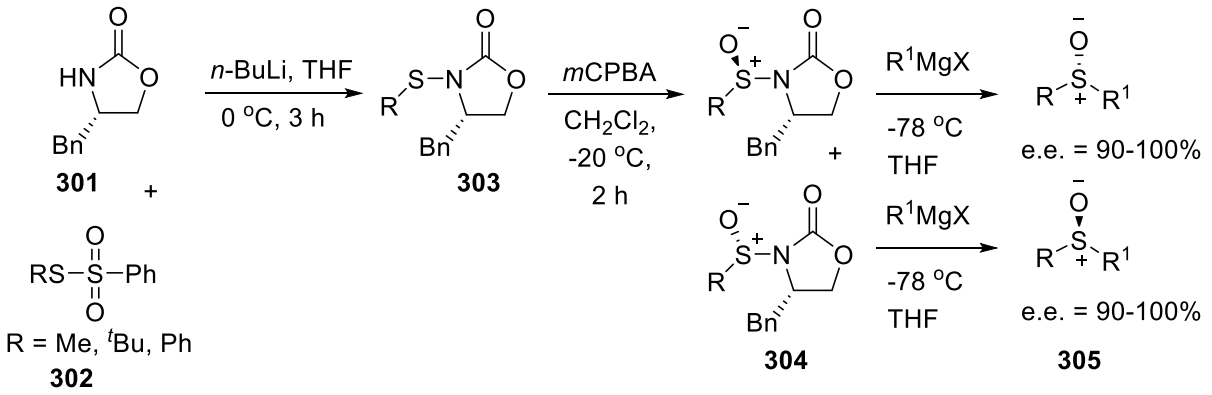


Scheme 65. Synthesis of a library of α-diazo sulfoxides.

4.1.2 Synthesis and applications of alkynyl sulfoxides

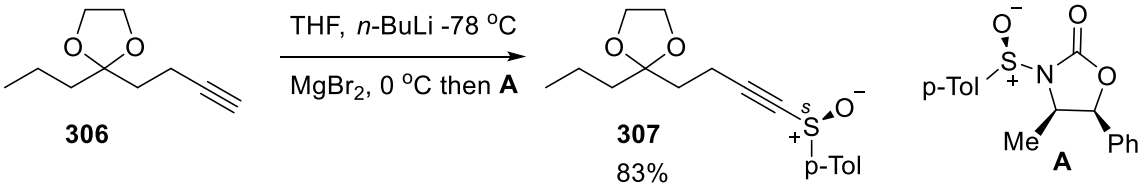
Many methods have been successfully employed to allow the facile preparation of enantioenriched sulfoxides in high yields, as mentioned earlier.[118] An important example which allows a variety of enantiopure sulfoxides to be easily prepared is discussed below.

An efficient asymmetric preparation of sulfoxides was demonstrated in Evans' synthesis of chiral organosulfur compounds, utilising oxazolidinones derived from norepherdrin and *L*-phenylalanine (Scheme 66).[128] This method promoted a facile entry into enantiopure sulfoxides for use in asymmetric synthesis, due to readily available starting materials and no requirement for multiple recrystallizations. Oxazolidinone **301** was alkylated at nitrogen using *n*-BuLi affording **303**. *m*CPBA oxidation afforded separable diastereomers **304a** and **304b** and these could be transformed to asymmetric sulfoxides **305** using Grignard reagents (Scheme 66). Yields and enantioselectivities were high and the nucleophilic displacement occurred with inversion at the sulfur centre. These transfer reagents were shown to react over 100 times faster than the commonly used menthol derived reagents.[128]



Scheme 66. Synthesis of sulfinyl transfer reagents from Evans' auxiliary.

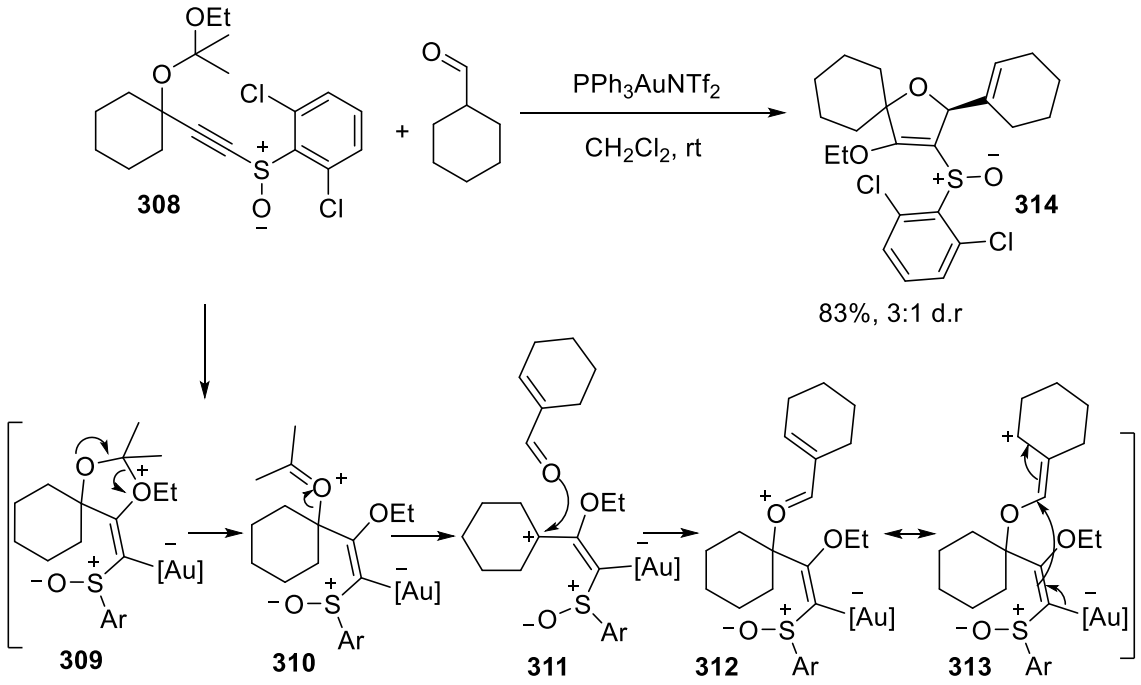
An example showcasing the preparation of an enantiopure sulfoxide and its subsequent use in synthesis is Marino's enantiospecific synthesis of an aspidosperma alkaloid.[129] The key step introduces a chiral alkynyl sulfoxide **307** using Evans' sulfinyl transfer reagent, which directs the selectivity in later stages of the synthesis (Scheme 67). Preparation of the sulfoxide **307** was achieved with initial deprotonation of the alkyne **306** CH followed by transmetalation and introduction of the auxiliary **A**.



Scheme 67. Preparation of an enantiopure alkynyl sulfoxide.

The only previous example of using an alkynyl sulfoxide as a substrate in gold catalysis was in the preparation of [3 + 2] cycloaddition products **314** from ketal esters **308** (Scheme 68).[130] Zhang designed substrates which favoured the 1,3 all-carbon dipole resonance form, on coordination of the gold species, allowing a chemoselective cycloaddition with aldehydes and ketones. 2,6-dichlorophenyl-substituted sulfoxide was an efficient electron withdrawing group promoting the reaction in an excellent yield. Initial attack of the ethoxy substituent onto the activated alkyne giving **309**. Rearrangement to **310** occurs and loss of acetone which is favoured

over a 5-endo trig cyclisation gives the 1,3 dipolar compound **311**. Cyclohexanone attack followed by a favourable 5-exo trig cyclisation via resonance form **312** and **313** furnishes **314**. The substrate design allows the reaction to proceed without any competing reactivity from the gold carbene.

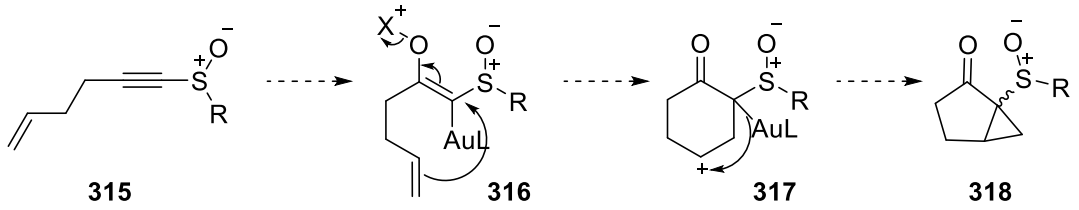


Scheme 68. Effective use of an alkynyl sulfoxide in gold catalysis.

4.2 Aims and objectives

The aim is to employ alkynyl sulfoxides, an external oxidant and a gold species in order to access the α-sulfoxy metal carbene reactivity patterns that can not be accessed in a controlled fashion when using α-diazo sulfoxides. Reactions in which an intramolecular or intermolecular nucleophile trap a vinyl gold carbenoid would provide an alternative reaction pathway to avoid the unwanted Wolff rearrangement pathway which would be expected to occur if the gold carbene dominated.

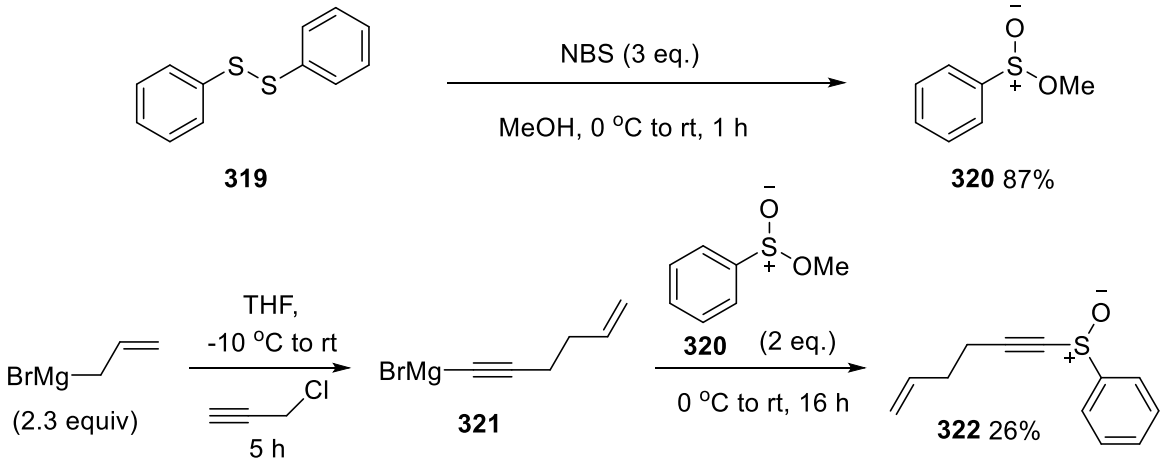
Initially an alkynyl sulfoxide **315** was conceived with the potential to undergo cyclopropanation upon addition of a nucleophilic oxidant to the gold activated alkyne **316** (Scheme 69) to afford **318**.



Scheme 69. Substrate design for gold catalysed cyclopropanation of alkynyl sulfoxides.

4.3 Preliminary studies

Synthesis of the required alkynyl sulfoxide **322** was achieved by adapting a literature procedure.[132] Allyl magnesium bromide was treated with propargyl chloride forming the deprotonated 1,6 enyne *in situ* and quenching with the sulfinic ester **320**, itself prepared in high yield from disulfide **319** (Scheme 70).[131]



Scheme 70. Preparation of an alkene substituted alkynyl sulfoxide.

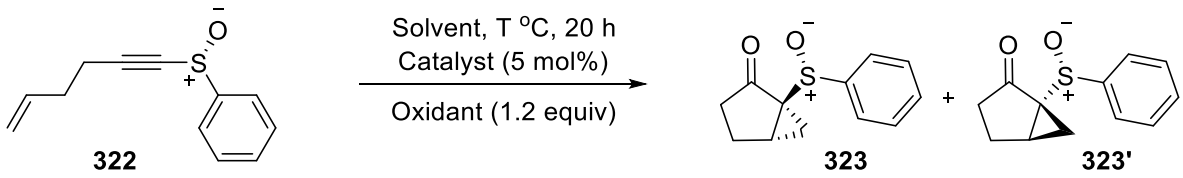
4.4 Formation of cyclopentanones

Alkynyl sulfoxide **322** was next subjected to a number of reaction conditions with a gold catalyst and an oxidant in an attempt to prepare products **318**. Throughout the chapter sulfoxides are drawn as one enantiomer to help show the diastereoselectivity.

Cyclopropanation products **323** and **323'** were observed upon treatment of the alkynyl sulfoxide **322** with pyridine-*N*-oxide and a gold catalyst in DCE (Table 12, entries 1-3) with a 1:1 diastereomeric ratio. With the promising reactivity seen, a change in solvent and increase in reaction temperature was tried and this led to improved reactivity (Table 12, entry 4 *vs* entry 5). A small solvent screen at this juncture revealed nitromethane to be the most suitable solvent (Table 12, entries 5-7). A reduction in temperature to 80 ^{o}C resulted in no change (Table 12, entry 8). Various oxidants were trialled. The use of diphenyl sulfoxide resulted mostly in degradation (Table 12, entry 9), whereas halogen substituted pyridine-*N*-oxides resulted in improved conversion and yields (Table 12, entries 10 to 13). The diastereomeric ratio improved with *ortho* and *meta* substituted *N*-oxides suggesting its involvement in the diastereoselectivity determining step (Table 12, entries 10, 11 and 13). The improvement was very modest, however, and the bulky 2,6-dichloro pyridine-*N*-oxide did not give any improvement and conversion was reduced (Table 12, entry 17). A preformed catalyst system was selected with SPhosAuNTf$_2$ superior to XPhosAuNTf$_2$ (Table 12, entries 14 and 15). 1,4-Dioxane provided similar yields to nitromethane but afforded increased diastereoselectivity (Table 12, entry 16). Further modest advances in the diastereomeric ratio of the products were achieved by reducing the temperature (Table 12, entry 18), however this resulted in poor conversion. MorDalPhosAuCl which was found to be an excellent catalyst by Zhang for an intermolecular prearation of methanesulfonyloxymethyl ketones was ineffective for this transformation (Table

12, entry 19).[61] Unfortunately the diastereoselectivity achieved was quite low, and synthesis of other alkynyl sulfoxides was initiated in an effort to improve the reaction outcome.

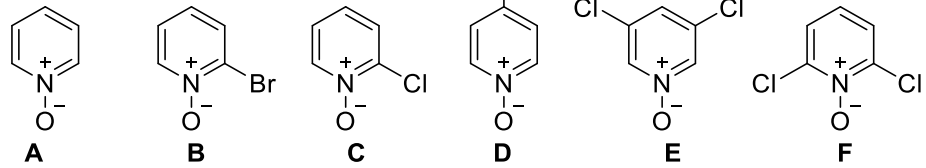
Table 12. Optimisation table for cyclopentanone formation.



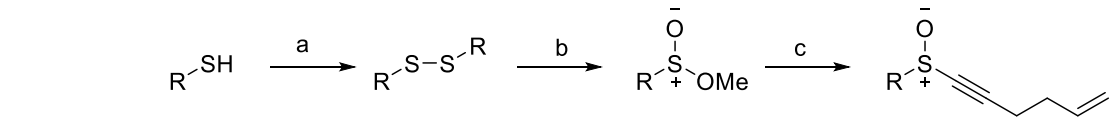
Entry	Catalyst	Co-catalyst	Solvent	T °C	*N*-Oxide	Yield **322**%[a]	Yield **323**%[a]	d.r.
1	DTBPAuCl	$AgNTf_2$	DCE	60	A	9	16	1:1
2	PPh_3AuCl	$AgNTf_2$	DCE	60	A	30	14	1:1
3	IPrAuCl	$AgNTf_2$	DCE	60	A	30	16	1:1
4	XPhosAuCl	$AgNTf_2$	DCE	60	A	77	20	1:1
5	XPhosAuCl	$AgNTf_2$	$MeNO_2$	100	A	30	36	1:1
6	XPhosAuCl	$AgNTf_2$	Toluene	100	A	30	24	1:1
7	XPhosAuCl	$AgNTf_2$	C_6H_5Cl	100	A	30	24	1:1
8	XPhosAuCl	$AgNTf_2$	$MeNO_2$	80	A	30	38	1:1
9	XPhosAuCl	$AgNTf_2$	$MeNO_2$	80	Ph_2SO	30	15	-
10	XPhosAuCl	$AgSbF_6$	$MeNO_2$	80	B	40	49	1.4:1
11	XPhosAuCl	$AgSbF_6$	$MeNO_2$	80	C	42	45	1.3:1
12	XPhosAuCl	$AgSbF_6$	$MeNO_2$	80	D	83	20	1:1
13	XPhosAuCl	$AgSbF_6$	$MeNO_2$	80	E	26	65	1.4:1
14	$XPhosAuNTf_2$	-	$MeNO_2$	80	E	40	52	1.4:1
15	$SPhosAuNTf_2$	-	$MeNO_2$	80	E	30	59	1.2:1
16	SPhosAuCl	$AgSbF_6$	1,4-dioxane	80	E	35	66	1.6:1
17	$SPhosAuNTf_2$	-	1,4-dioxane	80	F	48	34	1.6:1
18	$SPhosAuNTf_2$	-	1,4-dioxane	rt	E	60	28	2.3:1
19	MorDalPhosAuCl	$AgSbF_6$	$MeNO_2$	80	A	66	7	1:1

[a] Reactions performed on a 0.1 mmol scale and yields determined by crude ^1H NMR analysis using 1,2,4,5 tetramethylbenzene as an internal reference standard. [b] 5 equivalents were used

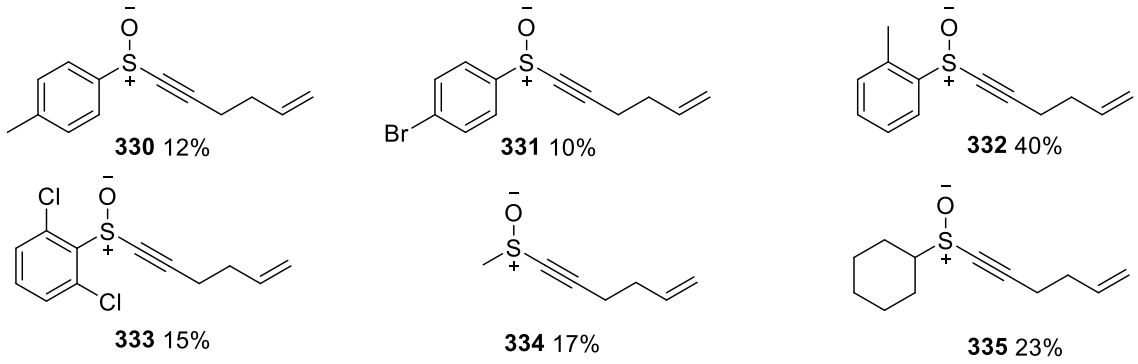
Oxidants used



Substituted alkynyl sulfoxides **330-335** were synthesised over 3 steps (Scheme 71). The relevant thiol was oxidised to the disulfide quantitatively using sodium perborate.[133] NBS was employed to convert the disulfide into the sulfinate ester **324-329** which proceeded in high yields.[131] Finally the sulfinate ester was added to the deprotonated 1,6-enyne *in situ* to afford the alkynyl sulfoxide in variable but generally poor yield (Scheme 71).[132] Aryl **330-333** and alkyl groups **334** and **335** were tolerated, including the sterically bulky 2,6-dichlorophenyl substituent **333**.



Conditions: a .Sodium perborate, MeOH, H_2O, 2 h, rt. b. NBS 3 eq., MeOH, 0 °C to rt. **70-90% over 2 steps.** c. AllylMgBr, Propargyl chloride 16 h. Yields are isolated yields for step c,

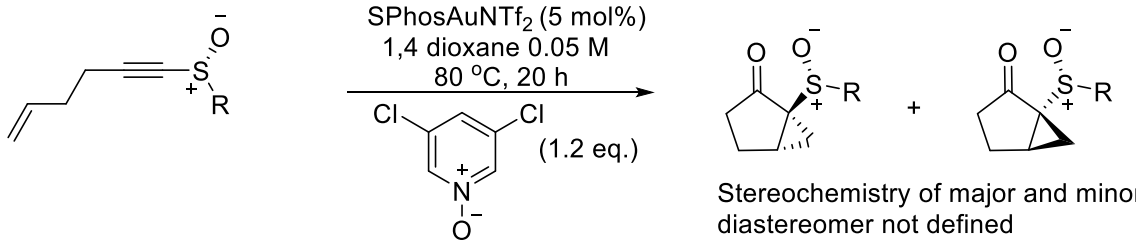


Scheme 71. Preparation of sulfinyl substituted 1,5 enynes.

A variety of substituents were positioned next to the sulfoxide to probe the effect of varying the electronic and steric nature of the substrate on the diastereoselectivity. On testing the alkynyl sulfoxides in the cyclopropanation, the substitution on the aryl group was found to moderately influence the diastereoselectivity (Table 13). With weakly electron-withdrawing and -donating bromo and methyl substituents on the aryl alkynyl sulfoxides **330** and **331** respectively, the crude yield of products **336** and **337** was almost unchanged compared to the phenyl derivative **323** (Table 13, entry 1 vs entries 2 and 3), and the diastereomeric ratio remianed roughly the

same. With alkynyl sulfoxide **332** containing steric bulk in the *ortho*-position (Table 13, entry 4) the diastereoselectivity was further enhanced but at the price of a reduction in yield of product **338**. The best diastereoselectivity was achieved with the 2,6-dichloro-substituted alkynyl sulfoxide **333** (Table 13, entry 5) however the yield of product **339** was significantly lower than for the other examples. These results show that the diastereoselectivity cannot be easily controlled by varying the reaction conditions and is more dependent on the sulfoxide substituent. Replacing aryl with alkyl groups led to poorer results. The cyclohexane-substituted alkynyl sulfoxide **335** was inactive under the reaction conditions employed (Table 13, entry 6) and the methyl-substituted derivative **334** gave a low yield of product **340** (Table 13, entry 7) as a 1:1 mix of diastereomers. These substrates were reacted under conditions previously found to be the most effective for cyclopropanation (Table 12). NMR yields were moderate at best, diastereoselectivity modest and hence alternative substrates were sought.

Table 13. The effect of the R group on reaction outcome.



Entry	R	SM	Catalysis Product	Alkynyl Sulfoxide[a]	Major diastereomer[a]	Minor diastereomer[a]	dr
1	Ph	**322**	**323**	35	38	24	1.6:1
2	*p*-Tol	**330**	**336**	36	43	22	2.0:1
3	4-BrC_6H_4	**331**	**337**	39	45	21	2.1:1
4	2-Me C_6H_4	**332**	**338**	43	40	13	3.2:1
5	2,6 - DiClC_6H_3	**333**	**339**	60	28	7	4.0:1
6[b]	Cy	**335**	**341**	90	0	0	-
7[b]	Me	**334**	**340**	60	15	15	1:1

[a] Yields calculated by ^{1}H NMR against a known quantity of internal reference standard 1,2,4,5 tetramethylbenzene. Other conditions used [b] $MeNO_2$, SPhosAuCl/ $AgSbF_6$

4.5 Reaction screening to afford sulfur heterocycles

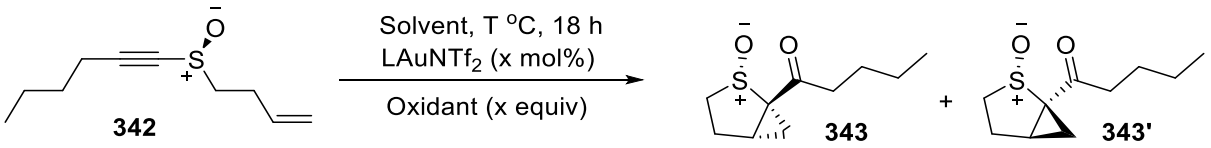
An alternative alkynyl sulfoxide substrate for cyclopropanation was devised, with the alkene tether directly attached to the sulfoxide functionality. In work undertaken by Fatima Khan, a postgraduate masters student working in the Davies and Grainger research groups this new alkynyl sulfoxide was subjected to gold catalysis.

Using the hex-1-yne-derived alkynyl sulfoxide **342**, the diastereomeric ratio of the cyclopropanation products (**343** and **343'**) in the crude ^{1}H NMR spectrum could not be successfully determined, due to the highly crowded alkyl region. Isolation of **342** provided a 6:1 ratio of inseparable diastereomers **343** and **343'**. A characteristic peak of the major

diastereomeric product **343** from the SOC*H*H hydrogen at 3.54 ppm enabled NMR yields to be accurately calculated (Table 13).

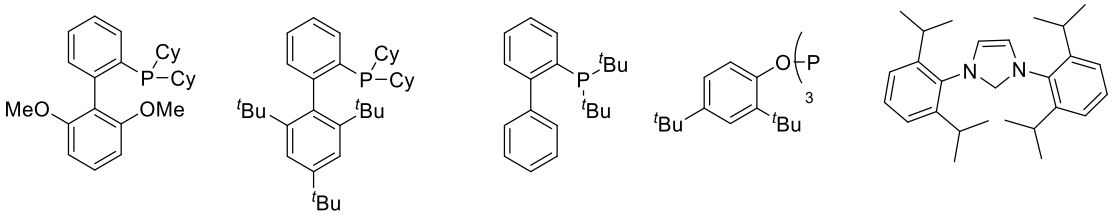
The starting point for the reaction optimisation was based on the best results obtained in the cyclopentanone synthesis (Table 12, entry 16). A good yield (69%) of the major diastereomer was observed (Table 14, entry 1). Solvents were screened initially, with toluene, DCE and THF being significantly inferior to 1,4-dioxane (Table 14, entries 2 to 5). DCM at rt was also tested, with only low conversion observed (Table 14, entry 4). Variation of the gold species was performed, testing a range of catalysts with very different steric and electronic properties (Table 14, entries 7-10). An acceptable yield was observed in all cases, with only L2 providing a similar result to the best (Table 14, entry 10). There were negligible differences in reaction outcome on varying the temperature between 50 and 80 degrees (Table 14, entries 1, 6 and 24), and lower yields were obtained with varied reaction concentrations (Table 14, entries 12-14). Increasing the amount of oxidant or employing other nitrogen based oxidants provided inferior results (Table 14, entries 15-21) and finally lowing the catalyst gave poorer yields (Table 14, entries 22 and 23).

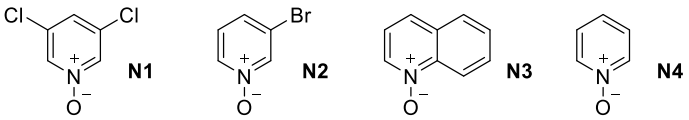
Table 14. Reaction screening to afford fused cyclic sulfoxides from a gold catalysed cyclopropanation (Reactions performed by Ghulam Khan).



Entry	Ligand	Cat mol %	Solvent	T °C	Oxidant	*N*-Oxide eq	C (M)	Yield %[a]
1	SPhos	5	Dioxane	80	N1	1.2	0.05	69
2	SPhos	5	1,2 DCE	60	N1	1.2	0.05	45
3	SPhos	5	THF	60	N1	1.2	0.05	37
4	SPhos	5	CH_2Cl_2	rt	N1	1.2	0.05	26
5	SPhos	5	Toluene	60	N1	1.2	0.05	39
6	SPhos	5	Dioxane	65	N1	1.2	0.05	66
7	L3	5	Dioxane	65	N1	1.2	0.05	42
8	L4	5	Dioxane	65	N1	1.2	0.05	45
9	L1	5	Dioxane	65	N1	1.2	0.05	47
10	L2	5	Dioxane	65	N1	1.2	0.05	59
11	SPhos	5	Dioxane	80	N1	1.2	0.05	69
12	SPhos	5	Dioxane	80	N1	1.2	0.10	52
13	SPhos	5	Dioxane	80	N1	1.2	0.20	42
14	SPhos	5	Dioxane	80	N1	1.2	0.025	65
15	SPhos	5	Dioxane	80	N1	2.0	0.05	54
18	SPhos	5	Dioxane	80	N1	1.2	0.05	66
19	SPhos	5	Dioxane	80	N2	1.2	0.05	63
20	SPhos	5	Dioxane	80	N3	1.2	0.05	59
21	SPhos	5	Dioxane	80	N4	1.2	0.05	70
22	SPhos	2.5	Dioxane	80	N1	1.2	0.05	62
23	SPhos	1	Dioxane	80	N1	1.2	0.05	27
24	SPhos	5	Dioxane	50	N1	1.2	0.05	69

[a] Reactions performed on a 0.1 mmol scale and yields of the major diastereomer determined by crude NMR analysis using 1, 2, 4, 5 Tetramethylbenzene as an internal reference standard.





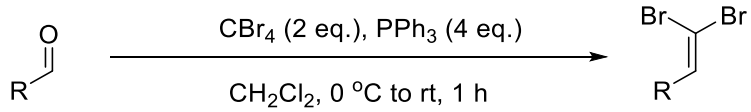
4.6 Starting material preparation

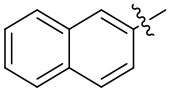
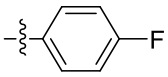
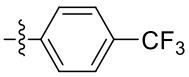
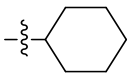
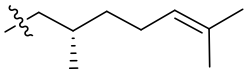
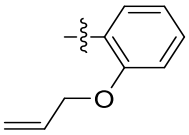
4.6.1 Precursor preparation

Synthesis of a range of alkynyl sulfoxides was required in order to examine the substrate scope of the reaction. The first synthetic step involved the preparation of dibromoolefins or alkynes.

A variety of dibromoolefins **344-349** were easily and conveniently prepared using the method of Shastin (Table 15, entries 1-6).[108]

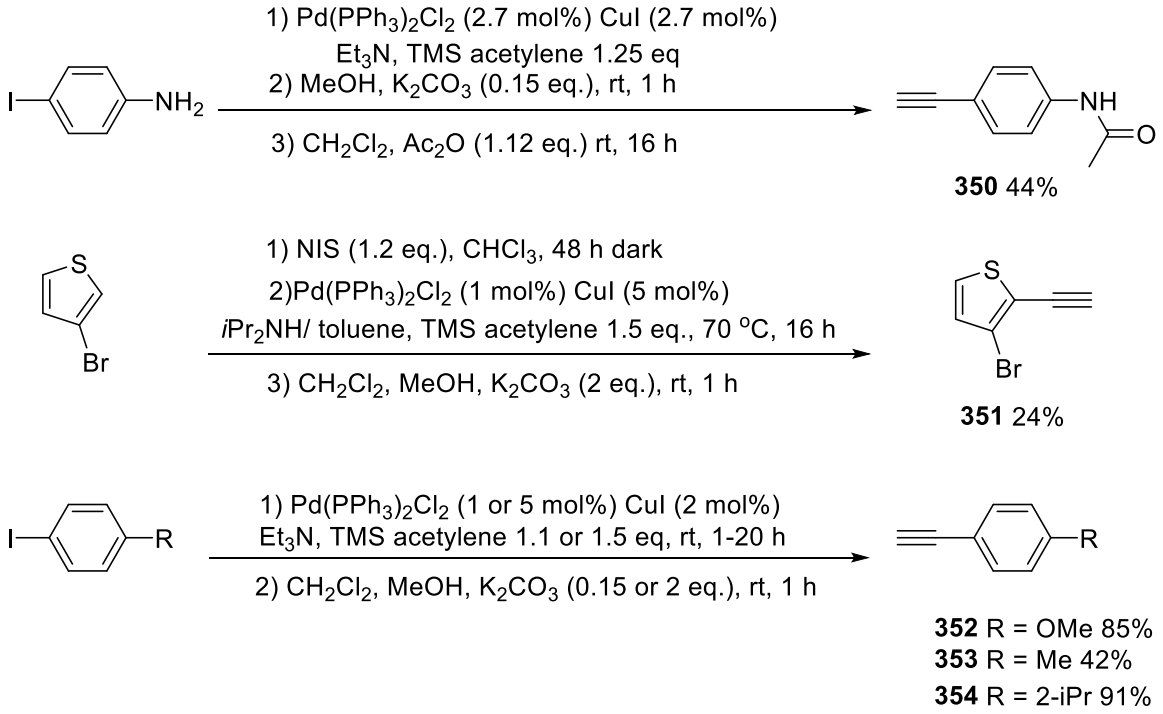
Table 15. Preparation of dibromoolefins



Entry	R =	Product	Yield %
1		**344**	84
2		**345**	79
3		**346**	74
4		**347**	47
5		**348**	71
6		**349**	95

Alkynes **350-354** were synthesised using the Sonagashira reaction with TMS acetylene followed by desilylation (Scheme 72).[134-137] Amide formation to afford **350** from the aniline

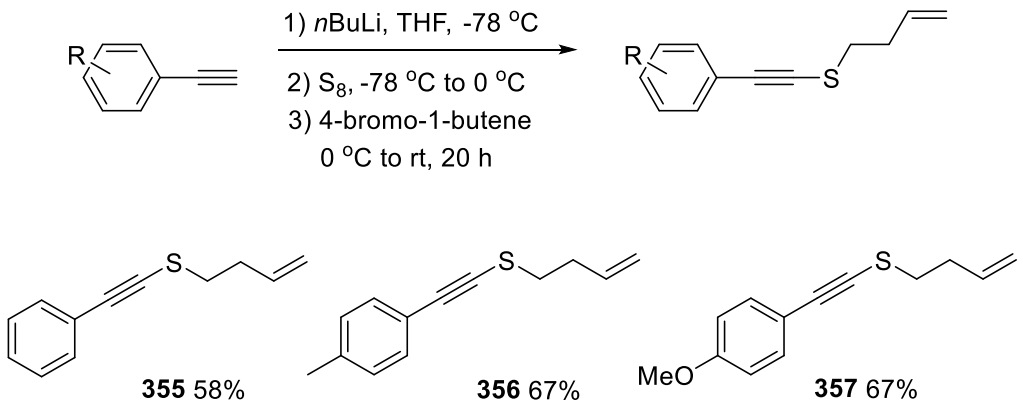
proceeded well and 3-bromothiophene was readily iodinated in the dark prior to alkyne formation affording **351**.[138,139]



Scheme 72. Preparation of alkynes.

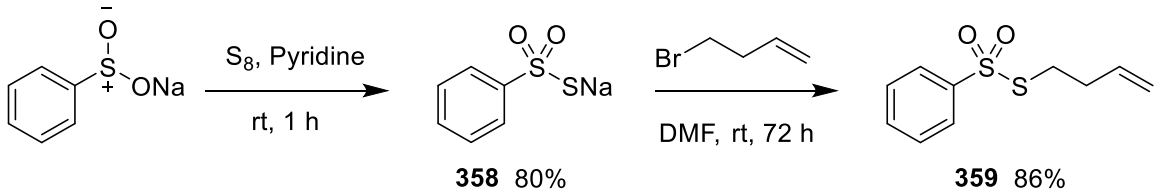
4.6.2 Sulfide preparation

Alkynyl sulfides **355-357** were initially prepared using the method of Hu in moderate yields (Scheme 73).[140]



Scheme 73. Preparation of alkynyl sulfides using Hu's procedure.

As this procedure afforded moderate yields and was time-consuming, an improved procedure was required to ensure the starting material synthesis was attractive. An electrophilic sulfur compound **359** was targeted to simplify the synthesis. Thiosulfonate **359** was prepared easily, on a large scale and in a high yield over 2 steps (Scheme 74).[141,142]

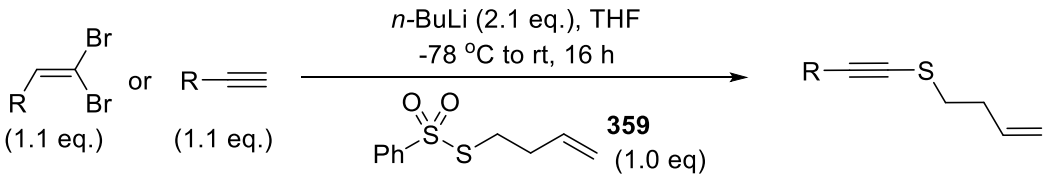


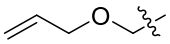
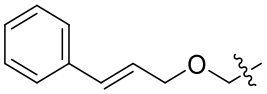
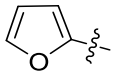
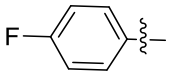
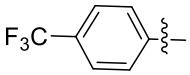
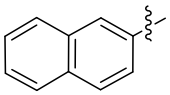
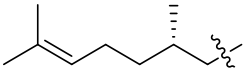
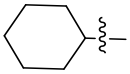
Scheme 74. Preparation of a thiosulfonate.

In the modified sulfide preparation, thiosulfonate **359** was added directly to the deprotonated alkyne, resulting in a more convenient reaction to prepare alkynyl sulfides **360** and **361** (Table 16, entries 1 and 2).

Thiosulfonate **359** was then found to be compatible for use with dibromoolefins as reaction partners. This procedure offered an alternative route to alkynyl sulfides **362-367** (Table 16, entries 3-8), especially useful when the alkynes were volatile (Table 16, entries 3-5) and resulted in much better yields for the synthetic sequence. Alkynyl sulfides **363** and **365** were not obtained as pure compounds (Table 16, entries 4 and 5), but after subjection to *m*CPBA the pure alkynyl sulfoxides were obtained.

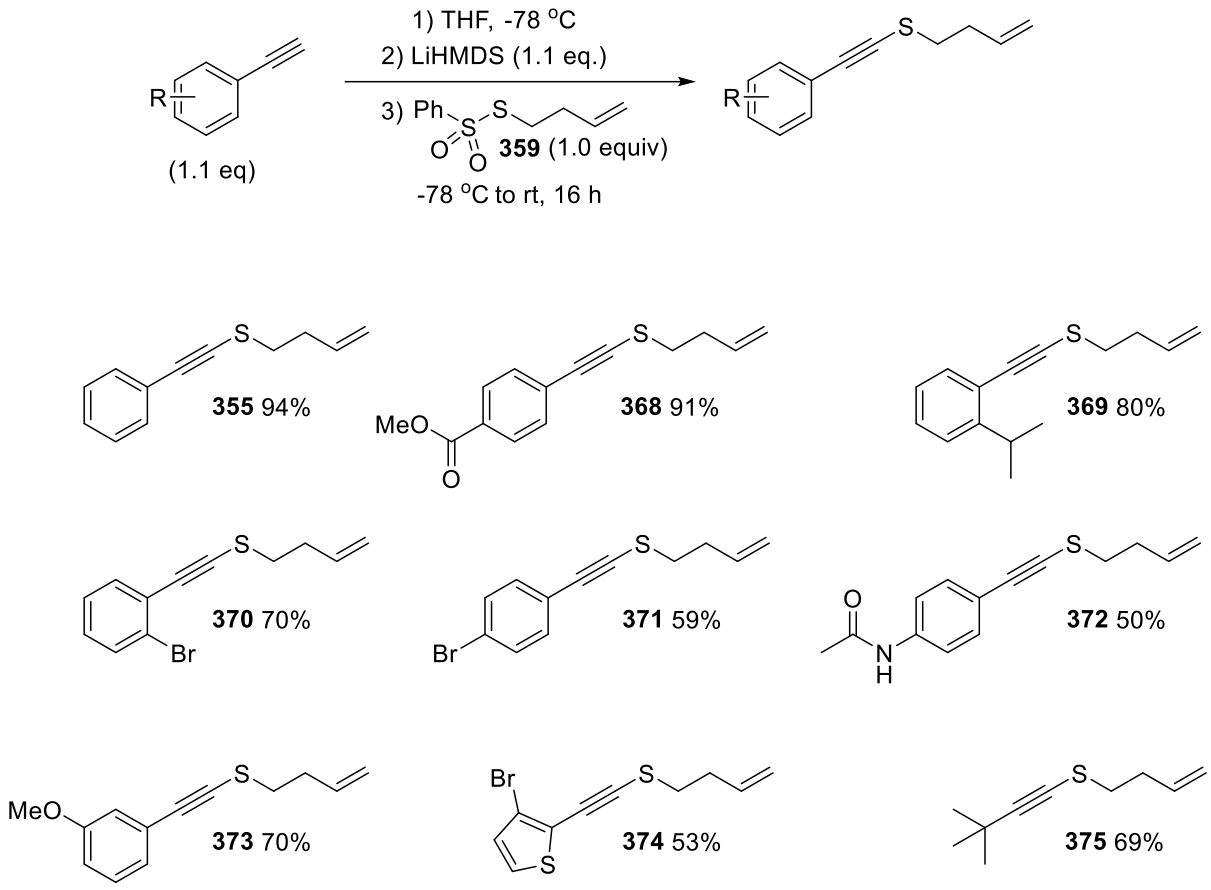
Table 16. Preparation of alkynyl sulfides from dibromoolefins and alkynes.



Entry	R	Product	Yield%
1		**360**	57[a]
2		**361**	66[a]
3		**362**	44
4		**363**	65 (~90%)[b]
5		**364**	50 (~90%)[b]
6		**365**	65
7		**366**	62
8		**367**	55

[a] Sulfide prepared from the terminal alkyne and *n*-BuLi (1.2 eq.) was used. [b] Sulfides isolated with a purity of approximately 90% from ^{1}H NMR analysis

The use of *n*-BuLi limited the functionality which could be tolerated and led to messy reactions (Table 15, entries 4 and 5). A test using LiHMDS to deprotonate the alkyne followed by trapping with **359** afforded a substantially improved yield in the synthesis of sulfide **355** compared to the original protocol using *n*-BuLi (Scheme 75). This new procedure was employed in the preparation of sulfides **368-375** (Scheme 75). In addition, the sulfide purification was generally straightforward compared to that with *n*-BuLi due to the lack of side products formed.

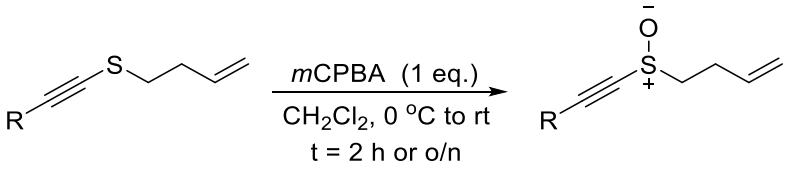


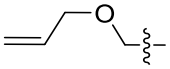
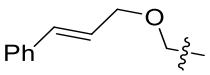
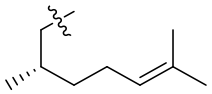
Scheme 75. Preparation of alkynyl sulfides using LiHMDS.

4.6.3 Sulfoxide preparation

Oxidation of the alkynyl sulfides **355-357** and **368-375** to their corresponding alkynyl sulfoxides was achieved using a general *m*CPBA oxidation method. Addition of 1 equivalent of *m*CPBA to the sulfide in CH_2Cl_2 at 0 °C resulted in good to excellent yields of the sulfoxides **376-394**, after aqueous workup and purification by column chromatography (Table 17, entries 1-18). When aryl groups were positioned next to the alkyne, the sulfoxides were unstable at room temperature and careful handling was required. Heteroaryl alkynyl sulfoxides **389** and **390** degraded particularly quickly and were used directly in the catalysis reactions after solvent evaporation.

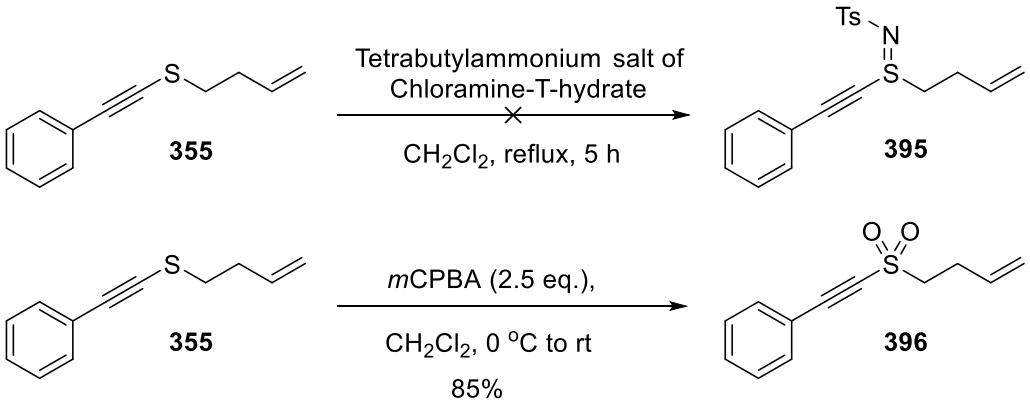
Table 17. Preparation of alkynyl sulfoxides from alkynyl sulfides.



Entry	R	Product	Yield %	Entry	R	Product	Yield %
1	C_6H_5	**376**	77	10	Cyclohexyl	**385**	57
2	4-$MeOC_6H_4$	**377**	75	11	2-*i*PrC_6H_4	**386**	89
3	4-MeC_6H_4	**378**	74	12	4-$CO_2MeC_6H_4$	**387**	77
4	4-FC_6H_4	**379**	73	13	4-$NHCOMeC_6H_4$	**388**	74
5	4-$CF_3C_6H_4$	**380**	50	14	2-furyl	**389**	70*
6	4-BrC_6H_4	**381**	80	15	3-bromo-2-thienyl	**390**	70*
7	2-BrC_6H_4	**382**	85	16		**391**	80
8	3-$MeOC_6H_4$	**383**	72	17		**392**	66
9	^{t}Bu	**384**	72	18		**393**	71
				19	2-Napthyl	**394**	79

*Used directly and not characterised

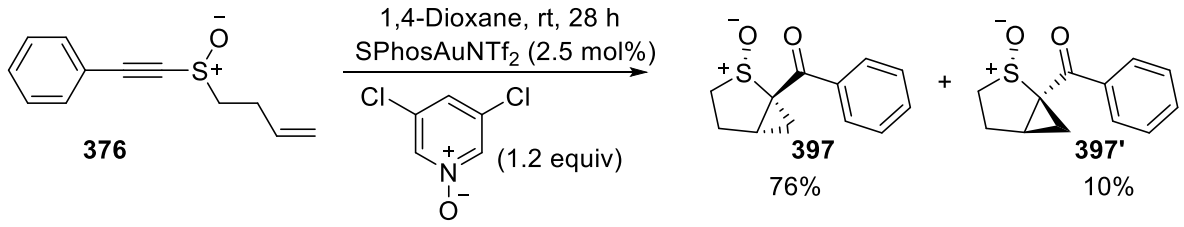
Other functionalization at sulfur was of interest to potentially generate more structurally varied catalysis products, and in order to gain a wider understanding of the catalysis. Firstly preparation of a sulfilimine **395** from alkynyl sulfide **355** was attempted with a commonly used literature method.[143] Unfortunately no product formation was observed by TLC (Scheme 76). An alkynyl sulfone **396** was also targeted, to compare its reactivity to that of an alkynyl sulfoxide under gold catalysis. Sulfone **396** was prepared readily from sulfide **355** using excess *m*CPBA (Scheme 76).



Scheme 76. Preparation of a sulfone and attempted preparation of a sulfilimine.

4.7 Substrate Scope for the cyclopropanation reaction

Phenyl substituted alkynyl sulfoxide **376** was subjected to gold catalysis. The reaction was faster and more efficient than for hex-1-yne substituted alkynyl sulfoxide **342**, permitting reduced catalyst loading and a lower reaction temperature for the transformation (Scheme 77).



Scheme 77. Efficient cyclopropanation under milder conditions (NMR yields).

A crystal structure was successfully determined for major diastereomer **397** using single crystal X-ray diffraction analysis (Fig 8).

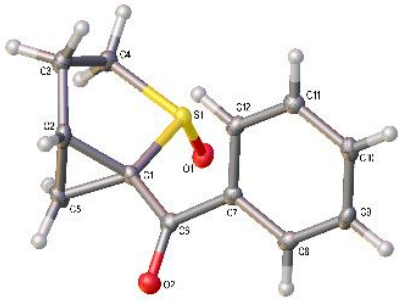


Fig 8. Crystal structure of 397.

The ^{1}H NMR spectrum for the major diastereomer of the catalysis product **397** is distinctive and remains consistent with modifications on the sulfoxide substituent. In each case a distinctive proton α to the sulfoxide resonates between 3.52 and 3.58 ppm. This constitutes a shift of 0.4 ppm downfield compared to the same proton in the NMR spectrum of the minor diastereomer. Figure 9 shows a 3D representation of the major and minor diastereomer for catalysis products **397** and **397'**. By comparing these results to literature values the deshielded proton can be identified.[145] The large deshielding effect is derived from the strong overlap between the C-H σ and the sulfoxide lone pair. In the minor diastereomer neither C-H overlaps with the lone pair of electrons and hence the peak is found upfield experiencing significant through space deshielding from the sulfoxide oxygen. The cyclopropyl hydrogens are shifted downfield significantly as they are in closer proximity to the sulfoxide bond (Fig 9). The minor diastereomer has markedly different chemical shifts. The more shielded SOC*H*H hydrogen is shifted 0.4 ppm upfield. The cyclopropane hydrogens are shifted upfield to an even greater degree.

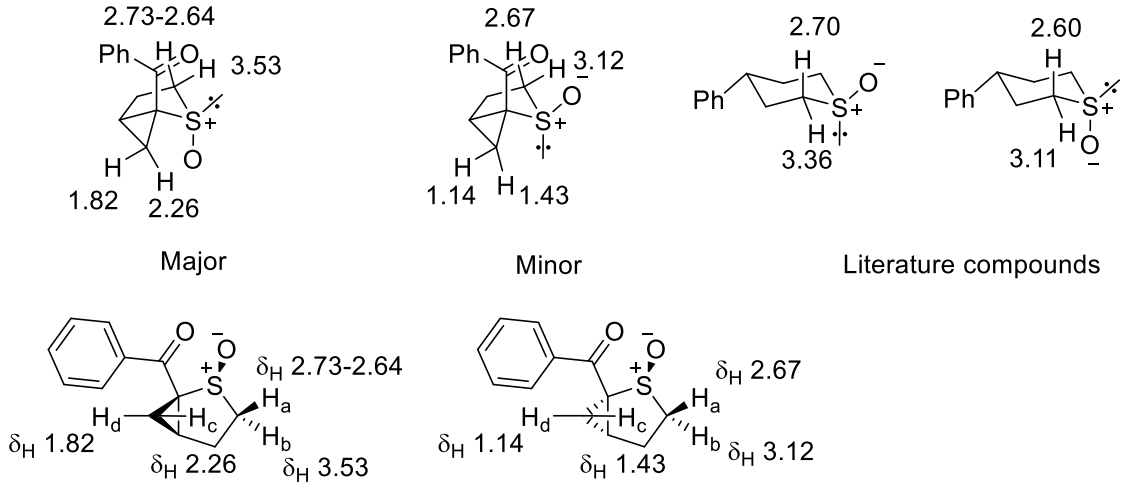


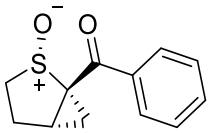
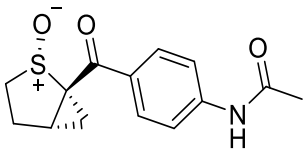
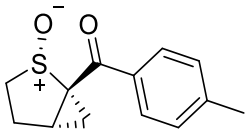
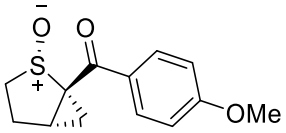
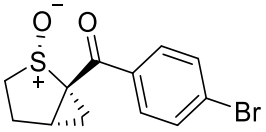
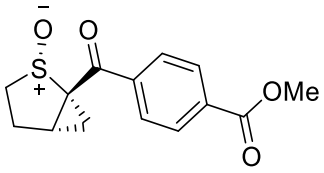
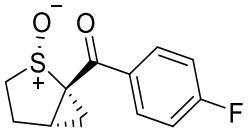
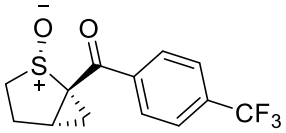
Fig 9. Key ^{1}H NMR shifts in catalysis product 397

The two identified sets of reaction conditions, **A** 2.5 mol% SPhosAuNTf$_2$ at rt and **B** 5 mol% SPhosAuNTf$_2$ at 50 ^{o}C (Table 14, entry 24) were employed with the alkynyl sulfoxide to help decipher how the electronic nature of the substituents affected the reactivity of the system but in two cases .the temperature was altered.

A study on the effect of the electronic nature of the substituent was undertaken by varying the group at the *para* position on the phenyl ring. Electron-rich substrates **398-400** with methyl, methoxy and acetamido substituents performed well in the catalysis (Table 18, entries 1 to 3). Good yields could be obtained under the milder conditions, with the more forcing conditions giving slightly better yields. With no substituent on the phenyl ring the yield of catalysis product **397** was reduced slightly on employing the mild conditions (Table 18, entry 4). Reactions with the more electron-poor alkynyl sulfoxides were generally slower giving reduced yields. The employment of conditions A resulted in moderate yields for the 4-bromo **401** and the ester **402** as well as the 4-fluoro-substituted derivative **403** (Table 18, entries 5, 6 and 7). Employing the strongly electron-withdrawing 4-(trifluoromethyl)phenyl substituted alkynyl sulfoxide under the milder conditions resulted in a poor yield of the catalysis product **404**. The electronic nature of the substituents is important in determining the reaction outcome with electron-withdrawing

groups slowing the reaction considerably with incomplete conversion and some degradation observed. Employing the more forcing conditions B promotes moderate to good yields in all cases (Table 18, entries 5, 6 and 8). Notably the ratio of diastereomers formed in the catalysis reaction was approximately 8:1 in all cases, suggesting the nature of the aryl group is inconsequential to the diastereomeric outcome. In all of the cases below, only the major diastereomer was isolated which eluted first on the column because of co-elution with the major diastereomer, however, the minor diastereomer could also be isolated on larger scale runs.

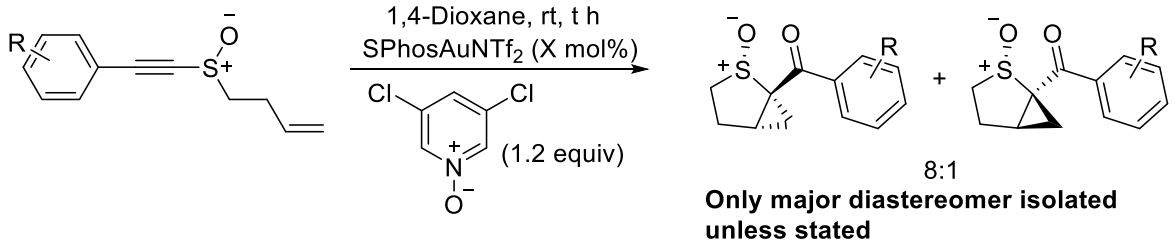
Table 18. An electronic study of 4-substituted aromatics in the gold catalysis

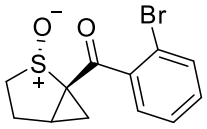
Entry	Product	Heterocycle	Yield[a] Cond: A	Yield[a] Cond: B
1	**397**		73[b]	80[d]
2	**398**		79 (20 h)	79 (4 h)
3	**399**		75[b]	-
4	**400**		74[b]	78[d]
5	**401**		54[b]	74 (3 h)
6	**402**		54[b]	64 (20 h)
7	**403**		54[b]	68 (17 h)
8	**404**		30[b]	63 (17 h)

Conditions A: rt, 2.5 mol% $SPhosAuNTf_2$, 1.2 eq. 3,5 Cl_2-Py-*N*-Oxide, 1,4-dioxane 0.05 M. Conditions B: 50 °C, 5 mol% $SPhosAuNTf_2$, 2 eq. 3,5 Cl_2-Py-*N*-Oxide, 1,4-dioxane 0.05 M. [a] Isolated yields. [b] reaction time 28 hours. [c] 40 °C, 2.5 mol% $SPhosAuNTf_2$, 1 h [d] 65 °C, 5 mol% $SPhosAuNTf_2$, 0.75 h

Further structural variations were investigated in the catalysis (Scheme 78). A sterically bulky *o*-bromo substituent led to a moderate yield of catalysis product **405**. A naphthyl derivative was well tolerated **406** and placing a methoxy substituent *meta* resulted in a significantly reduced

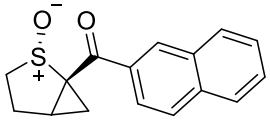
yield compared to the *para* derivative, however, a good yield of **407** was achieved with conditions B. Replacing the phenyl ring with a heterocycle successfully resulted in good yields of the fused sulfoxides **408** and **409**. With an *ortho* isopropyl group the yield of the desired product of cyclopropanation **410** was considerably lower mainly due to a side reaction. The diastereoselectivity for these reactions remained consistently at 8:1.





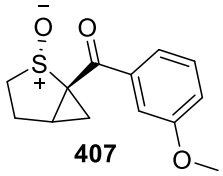
405

50%, rt, X = 2.5, 28 h



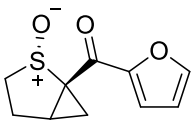
406

65%, rt, X = 2.5, 28 h
70%, 50 °C, X = 5, 28 h



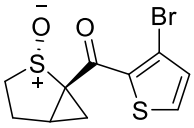
407

54%, rt, X = 2.5, 28 h
70%, 50 °C, X = 5, 18 h



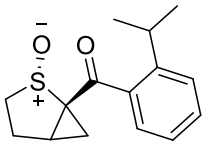
408

46%, rt, X = 2.5, 20 h
74%, 50 °C, X = 5, 28 h



409

73%, 50 °C, X = 2.5, 28 h



410

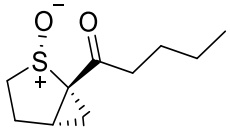
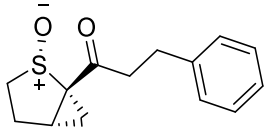
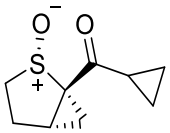
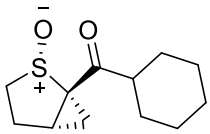
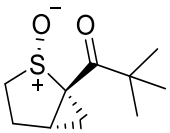
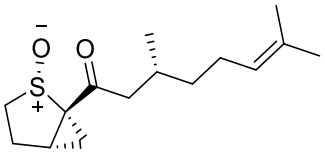
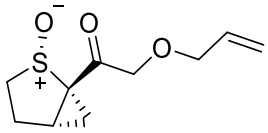
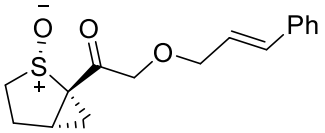
50%, rt, X = 2.5, 28 h
52%, 50 °C, X = 5, 28 h (10:1 d.r)

Scheme 78. Additional aryl and heteroaryl derived catalysis products.

Alkyl substituted alkynyl sulfoxides were employed under optimised catalysis conditions B (Table 14, entry 24) due to the reduced reactivity observed compared to aryl-derivatives. In each case, the catalysis products **343** and **411-417** were isolated as a mixture of diastereomers as they were not separable by column chromatography (Table 19). The hex-1-yne derived sulfoxide worked well, providing the cyclic sulfoxide **343** in a 72% yield (Table 19, entry 1). A but-3-enyl derivative **411** was formed in a slightly reduced yield (Table 19, entry 2). The

cyclopropyl substituted sulfoxide worked excellently in the catalysis with no loss of yield of product **412** on reducing the temperature (Table 19, entry 3). A cyclohexyl group **413** was tolerated however the yield was much lower due to poor reactivity (Table 19, entry 4) and significant starting material remained. An alkynyl sulfoxide with a *tert*-butyl group was also employed in the catalysis resulting in an improved diastereomeric ratio and a surprisingly high yield for such a sterically bulky substituent **414** (Table 19, entry 5). A 1:1 diastereomeric ratio of citronellal derived sulfoxide **393** was successfully transformed providing **415** (Table 19, entry 9). Two alkynyl sulfoxides incorporating a tethered 1,6-enyne with an oxygen linker were employed under the catalysis conditions (Table 19, entries 7 and 8). The alkene could potentially compete in an alternative cyclopropanation pathway providing a fused dihydropyranone, however this was not observed and products **416** and **417** were furnished in a moderate yield.

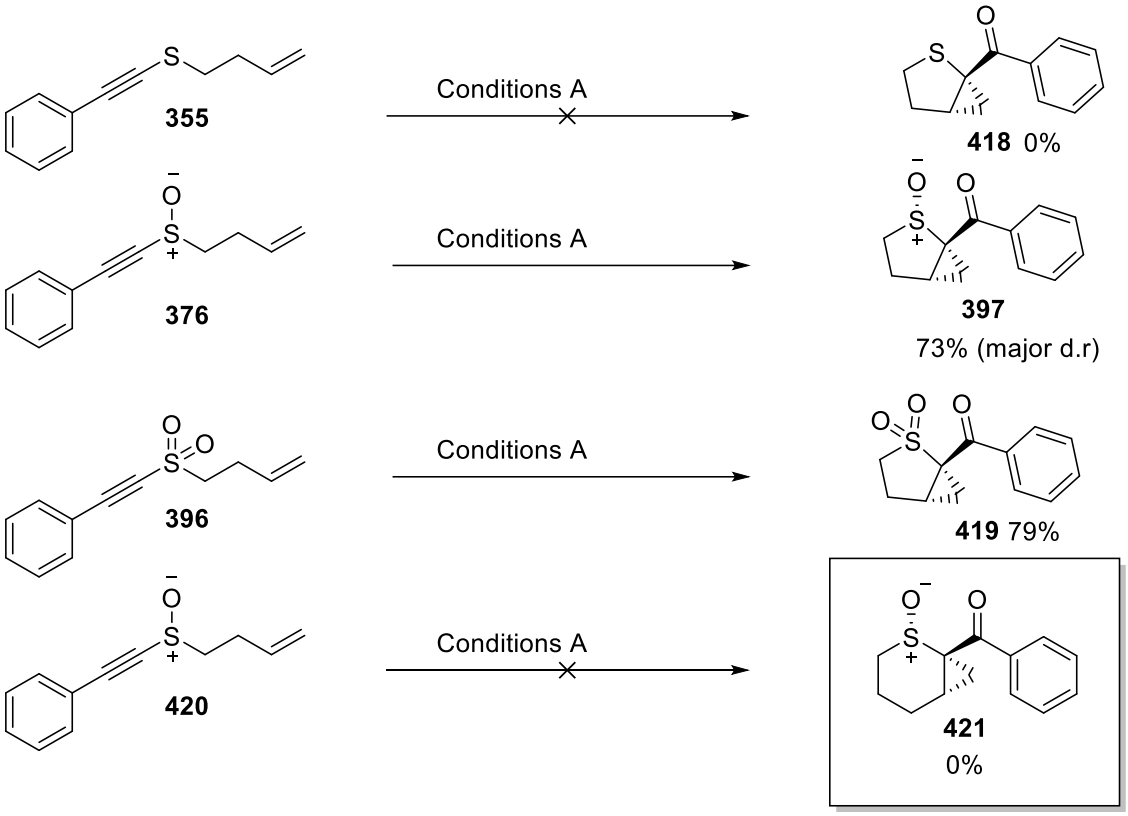
Table 19. Preparation of alkyl substituted fused sulfur heterocycles.

Entry	Product	Heterocycle	Time (h)	Yield Cond B	d.r isolated
1[M, F]	**343**		17	72	6:1
2[F]	**411**		17	65	10:1
3[F]	**412**		17	85(85)[a]	10:1
4[M]	**413**		24	45	7:1
5[M]	**414**		25	70	12:1
6[M]	**415**		21	70	10:10:1:1
7[M]	**416**		21	65	10:1
8[M]	**417**		21	68	10:1

[M] Reactions performed by Matthew Barrett. [F] Reactions performed by Ghulam Fatima Khan.
Conditions B: 50 °C, 5 mol% $SPhosAuNTf_2$, 2 eq. 3,5 Cl_2-Py-*N*-Oxide, 1,4-dioxane 0.05 M.
[a] rt, 5 mol% $SPhosAuNTf_2$ 1.2 eq., 3,5 Cl_2-Py-*N*-Oxide, 1,4-dioxane 0.05 M, 17 h.

The reactivity of sulfoxide **376** was compared with that of the corresponding sulfide **355** and sulfone **396** under the milder optimised catalysis conditions (Scheme 79). Both the sulfoxide and sulfone were transformed efficiently into products **397** and **419**. The sulfide however did not undergo any reaction. The sulfoxide and sulfone are very electron-withdrawing, facilitating external nucleophilic attack on coordination of the gold species. The electron donating nature

of the sulfide renders the alkyne too weakly electrophilic to allow the initial intermolecular oxidant attack. Finally a 1,6-enyne substituted alkynyl sulfoxide **392** was prepared by Fatima and employed under the standard conditions, unfortunately no cyclopropanation product **393** was isolated with lots of degradation observed.

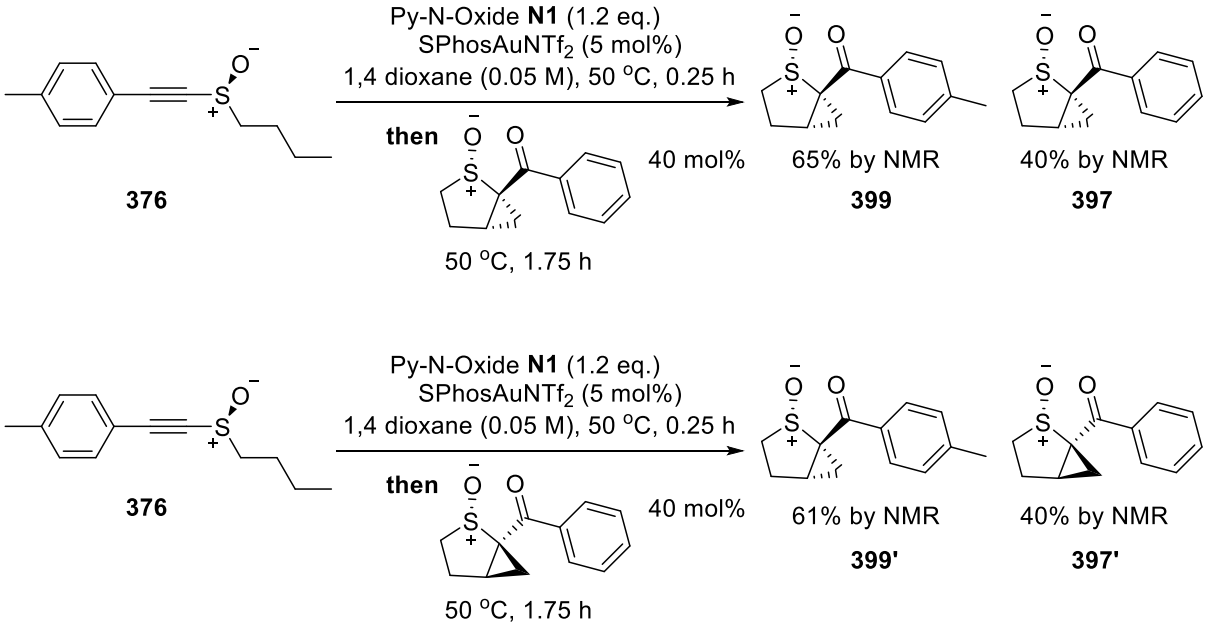


Scheme 79. Comparison of oxidation states at sulfur and failed formation of the 6 membered ring containing fused heterocycle.

4.8 Origin of the diastereoselectivity

An additional control experiment was performed to see whether epimerisation was taking place under the reaction conditions. If this was proceeding the ratio of products would be partially determined by thermodynamic control rendering the kinetic model redundant. Two catalysis reactions were set up as usual with sulfoxide **378**. Upon some conversion of the sulfoxide to product **399** one was doped with 40 mol% of minor d.r **397'** and to the other was added 40 mol% of major d.r **397**. After 2 hours the reaction was complete by TLC and the crude residue

was analysed. In both cases the dopant sulfoxides were present without any epimerisation demonstrating that no interconversion occurs under the reaction conditions (Scheme 80).



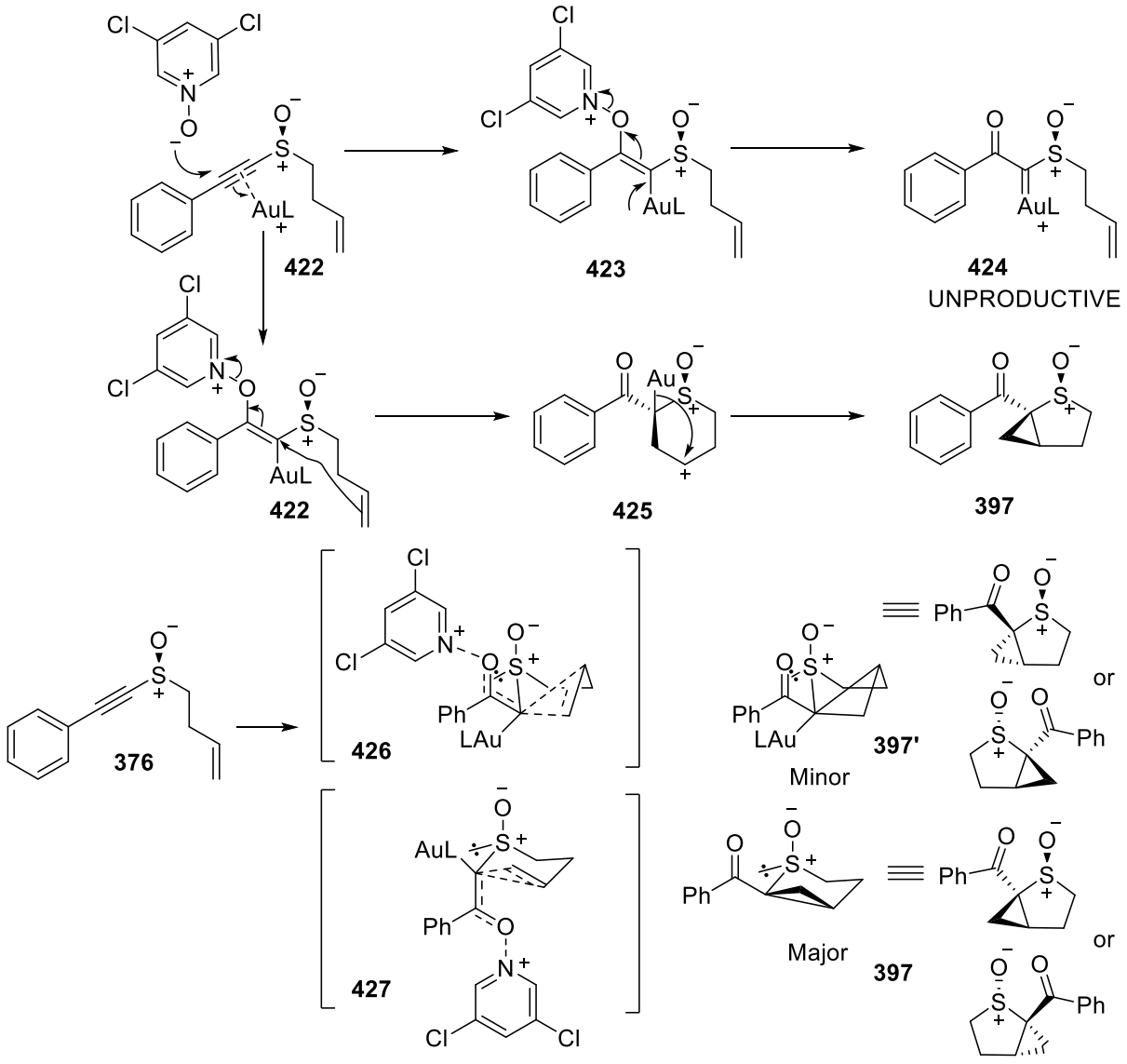
Scheme 80. Control experiment to monitor epimerisation under the reaction conditions.

Scheme 81 depicts a stepwise mechanism for the intramolecular cyclopropanation of alkynyl sulfoxides. Formation of the α-oxo gold carbene **424** is unlikely to be productive considering the reactivity of similar α-oxo rhodium carbenes, and would be expected to lead to degradation products potentially via a Wolff rearrangement.[123,126,127]

Scheme 81 also suggests a reasonable model for the diastereoselectivity observed. The reaction step in which the diastereoselectivity is determined is the nucleophilic attack of the alkene onto the β-gold vinyloxypyridium intermediate **423**. Anti addition of the pyridine-*N*-oxide onto the activated alkyne is widely proposed to proceed.[32] Coordination of the sulfoxide oxygen to the gold is unlikely as no vacant coordination sites are present on gold.[33]

Minimisation of dipole-dipole interactions explained the stereocontrol in Soladie's study into the reduction of β-keto sulfoxides without the addition of a Lewis acid for chelation and this may help to explain the observed stereoselectivity.[146] The reaction can be represented using two

transition state models. **426** shows the transition state leading to the minor diastereomer product **397'** via a concerted mechanism. Reaction leading to the minor diastereomer may be expected to proceed through a high energy boat transition state where there is good overlap of the C-Au σ-bond with the π^* of the alkene. A lower energy chair conformation transition state **427** leads via a concerted pathway to major diastereomer **397**. Unfavourable dipole-dipole interactions are avoided and there is the potential for a stabilising Au-O interaction

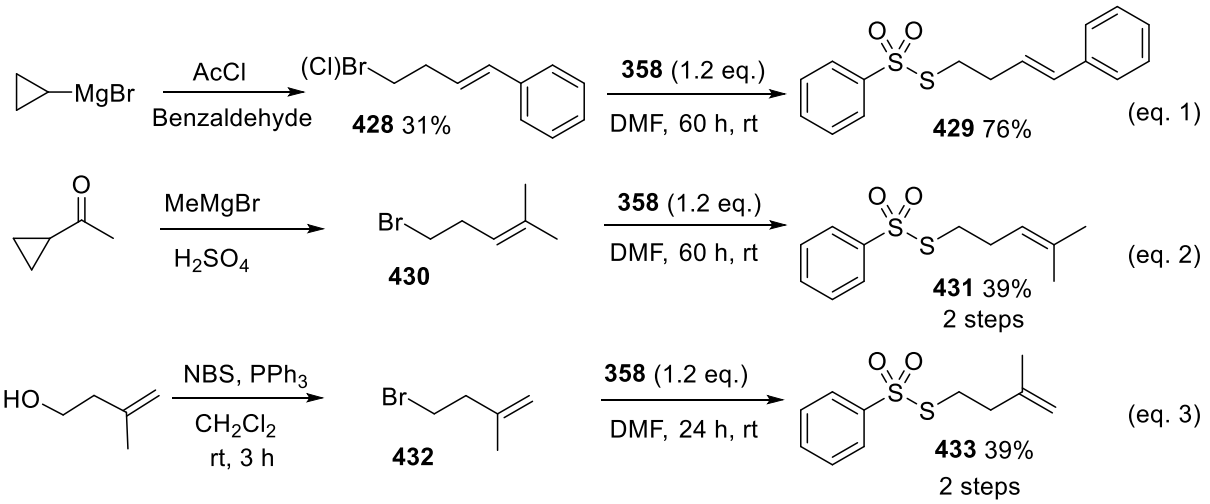


Scheme 81. Mechanism and diastereochemical model for the intramolecular cyclopropanation.

4.9 Variation of the alkene

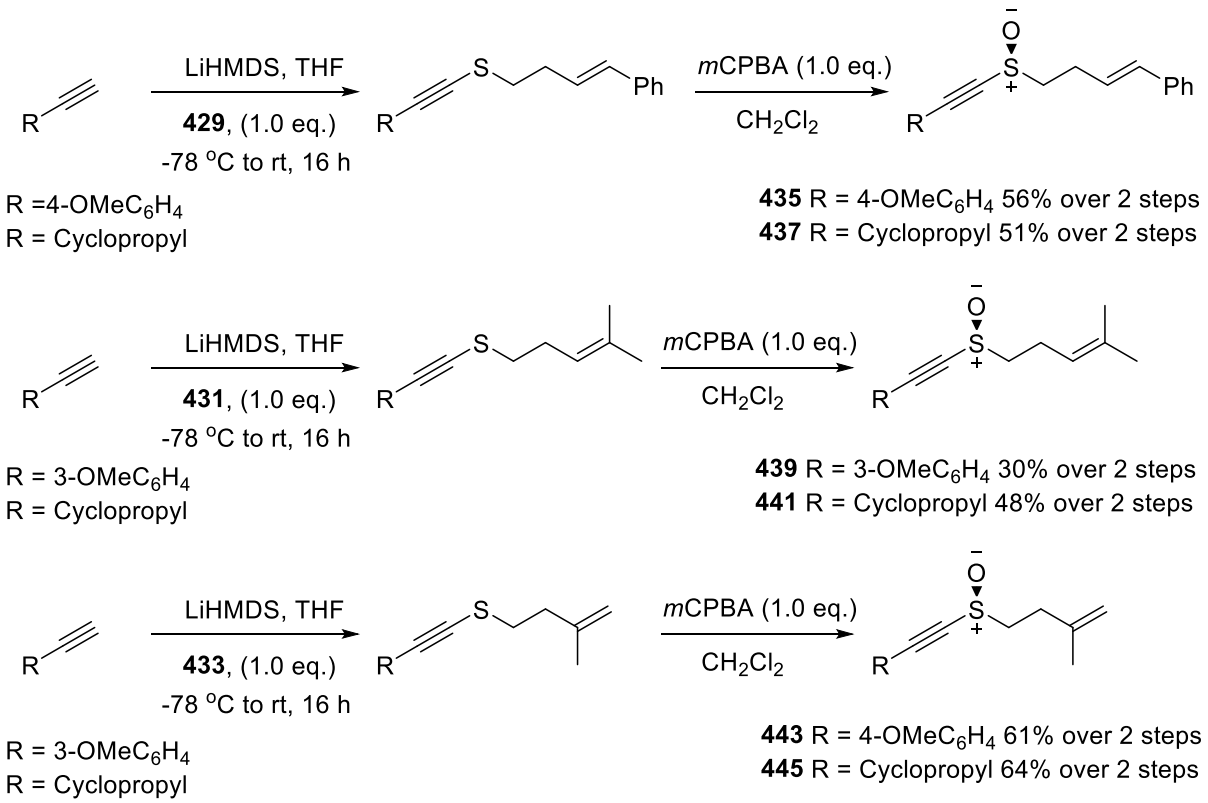
Three variations of the alkene component of the alkynyl sulfoxide were considered in order to expand the reaction scope for the cyclopropanation and to perceive any change in reactivity.

Firstly, an *E*-phenyl substituted alkene **428** was prepared following the method reported by Procter.[147] Cyclopropylmagnesium bromide was treated with cinnamyl bromide and acetyl chloride to furnish the reported (3:1) mixture of halides **428** (Scheme 82). The thiosulfonate **429** was then synthesised in a 76% yield using the method of Sharma (Scheme 82, eq. 1).[148] A dimethyl group was introduced on the terminal alkene position, commencing from cyclopropylmethyl ketone. This was treated with MeMgBr before addition of sulfuric acid providing the crude bromide **430**, which was transformed to the thiosulfonate **431** in a 39% yield over 2 steps (Scheme 82, eq. 2).[142] Finally the internal methyl derivative **433** was obtained utilising an Appel reaction on the corresponding alcohol (Scheme 82, eq. 3).[149] The yield over the two steps to the thiosulfonate **433** was 39%.



Scheme 82. Preparation of a range of thiosulfonates.

Aryl and alkyl derived alkynyl sulfoxides **435, 437, 439, 441, 443** and **445** were prepared to provide a series of substrates encompassing each alkene modification to test in the catalysis reaction. Yields were moderate to high over the two step sequence.

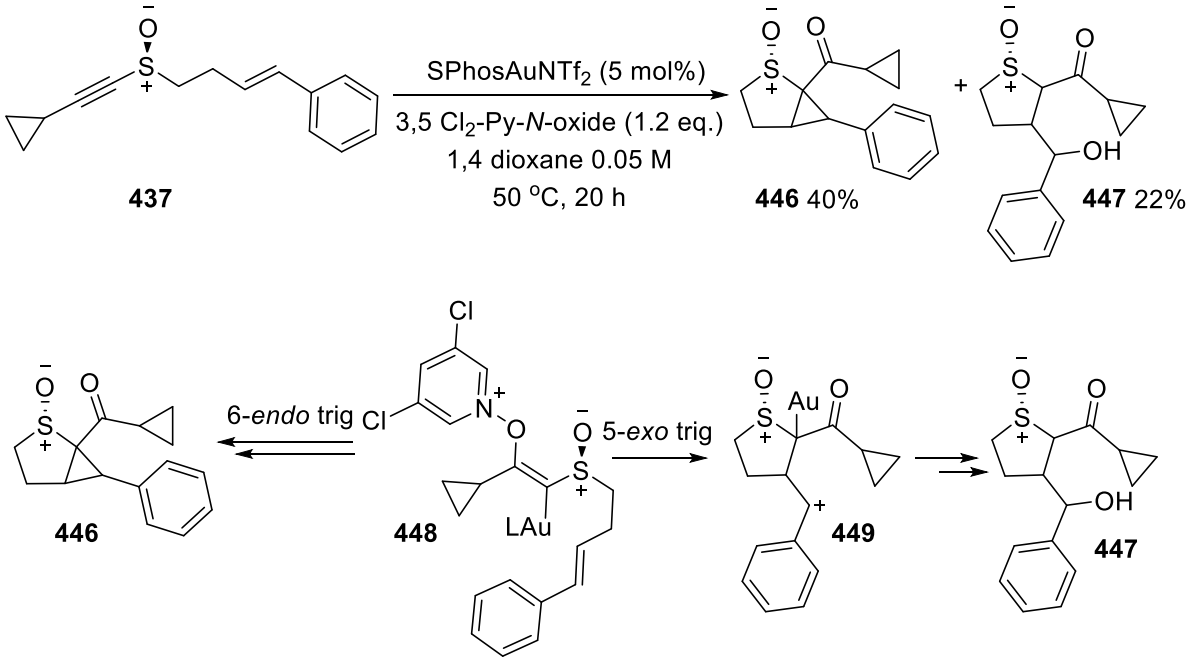


Scheme 83. Preparation of alkynyl sulfoxides containing substituted alkenes.

Using 4-methoxyphenyl substituted sulfoxide **435** under the standard catalysis conditions resulted in a messy reaction and pure products could not be isolated. Conversely with the less sterically cumbersome cyclopropyl substituent **437** two novel products were isolated, in a moderate combined yield (Scheme 84). Cyclopropanation product **439** was identified by the characteristic peak at 3.58 observed in the other cyclopropanation products, the 4 separate CH peaks of the non-identical cyclopropyl substituent protons was also observed. Hydration product **447** was identified by the downfield OH peak at 4.86 ppm which was not attached to any carbons from the HSQC. The C*H*OH doublet at 3.77 ppm was also characteristic.

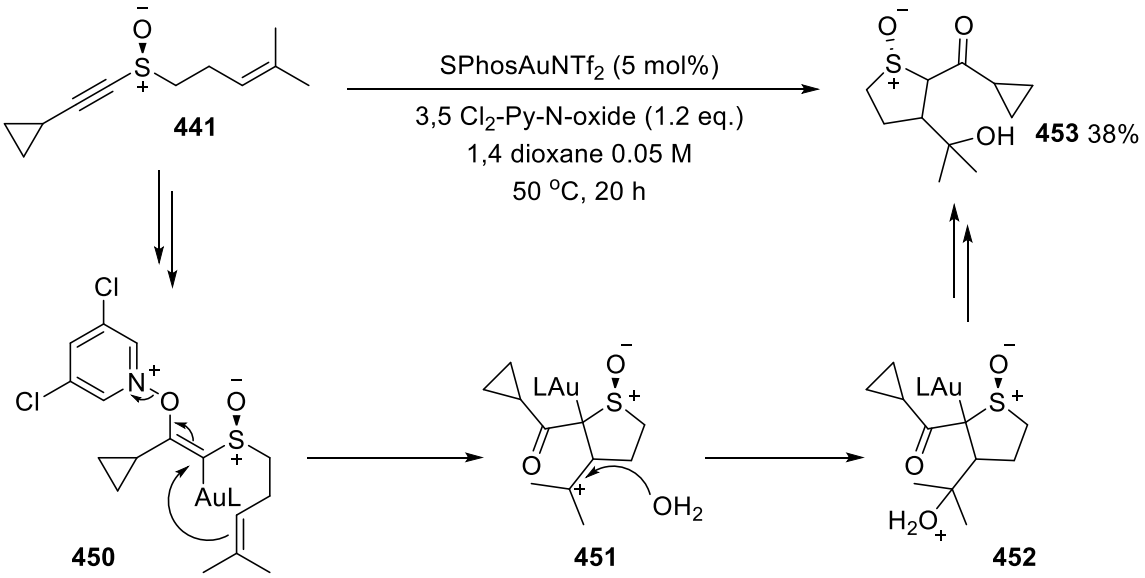
Other products were present from NMR analysis of the crude reaction mixture, however, isolation was unsuccessful. 6-*exo* trig cyclisation would be expected to lead through to the expected cyclopropanation product whereas upon a 5-*exo* trig cyclisation, trapping of the carbocation by adventitious water is perhaps more favourable (Scheme 84).[150] The

stereochemistry of the products was not identified but only one set of peaks were present in the proton and carbon NMR of compound **446** and **447**.



Scheme 84. Phenyl substituted alkene derived alkynyl sulfoxides.

Treatment of the aryl substituted sulfoxide **439** under the catalysis conditions led to many spots being observed on the TLC plate and no products could be isolated. When the cyclopropyl derived sulfoxide **441** was employed, the product **453** was isolated in a modest 38% yield (Scheme 85). The product is derived from quenching of the cation with adventitious water and provides an increase in molecular complexity.[150] Furthermore only a single set of peaks were observed in the ^{13}C NMR spectrum which may suggest the product was isolated as a single diastereomer. Crude NMR analysis suggested cyclopropanation products were also formed and conversion was high, however these could not be isolated in a pure form. Repeating the experiment with the addition of ten equivalents of MeOH to the reaction mixture in an attempt to quench the carbocation **451** led to reduced reactivity and the expected product could not be isolated.

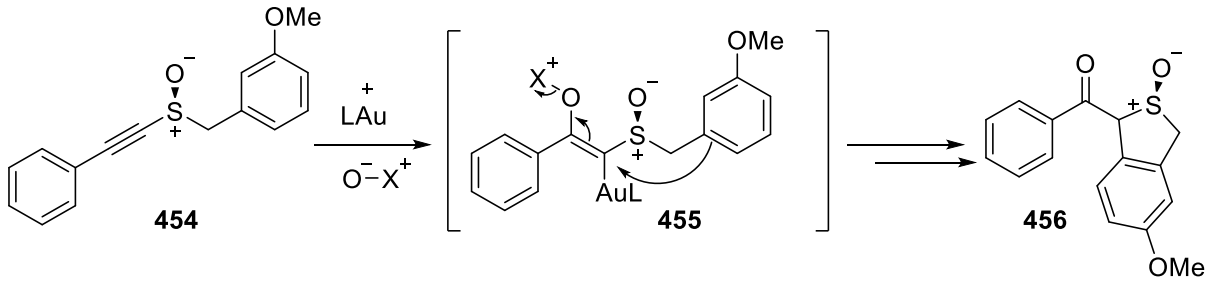


Scheme 85. Catalysis reaction of a prenyl-derived alkynyl sulfoxide.

Finally the alkynyl sulfoxides **443** and **445** incorporating an internal methyl substituent on the alkene were tested. Reaction of **443** and **445** proceeded well by TLC under the reaction conditions, but the products could not be successfully purified.

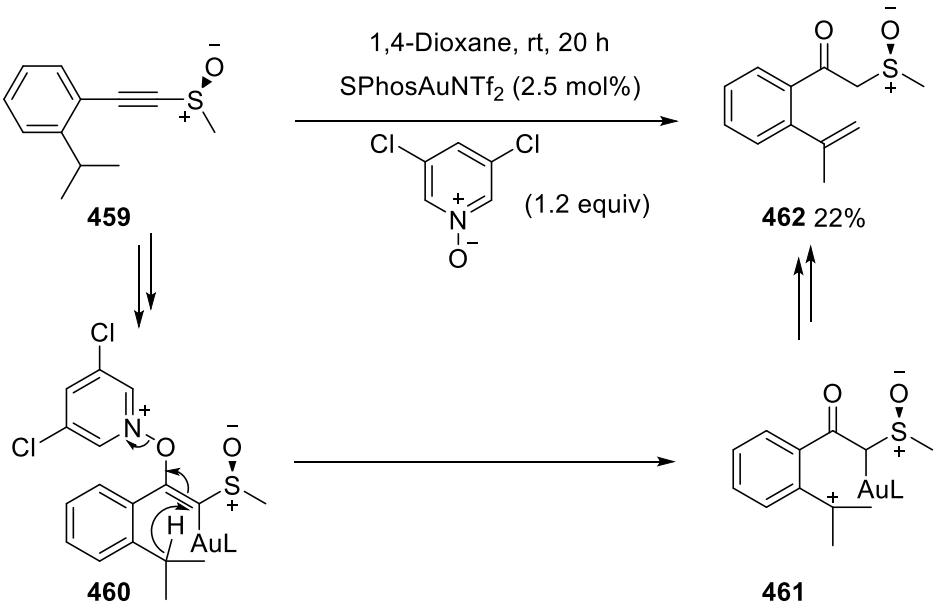
4.10 Exploring other reactivity modes of gold carbenoids with alkynyl sulfoxides

In work undertaken by Fatima Khan the alkene component for the cyclopropanation reaction was replaced with a benzyl group. Trapping of the gold carbenoid, formed upon addition of the oxidant to the activated alkyne, in a Friedel-Crafts type reaction would allow synthesis of a range of novel products (Scheme 86). To enhance the likelihood of reaction success, the phenyl ring was activated with methoxy groups in the 2 position, increasing the nucleophilicity of the phenyl ring. Unfortunately, competing reactivity rendered the reaction unsuccessful with only degradation products visible in the crude NMR spectrum.



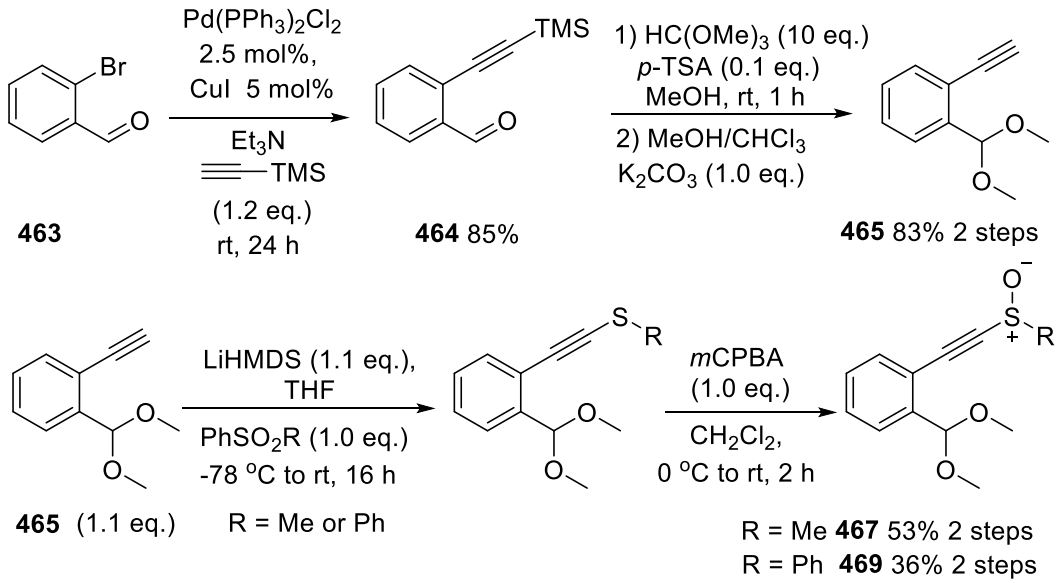
Scheme 86. Attempted C-H insertion trapping from alkynyl sulfoxides.

During investigations into finding the substrate scope for the intramolecular cyclopropanation reaction a side product was identified when employing *ortho* isopropyl substituted alkynyl sulfoxide **386** (Scheme 87). The side product co-eluted with the oxidant prompting the testing of **459**, a modified sulfoxide with a methyl substituent, prepared from the sulfide **458**. Subjection of sulfoxide **459** to catalysis conditions A for 20 hours resulted in starting material remaining (40%) and significant degradation (30%). Product **462** was isolated in a 22% yield, similar to the NMR yield observed with alkynyl sulfoxide **386** (Scheme 77). The product is proposed to form via the gold carbenoid **460** and a 1,5-hydride shift results in the formation of a stabilised carbocation **461** which is quenched by elimination (Scheme 87).



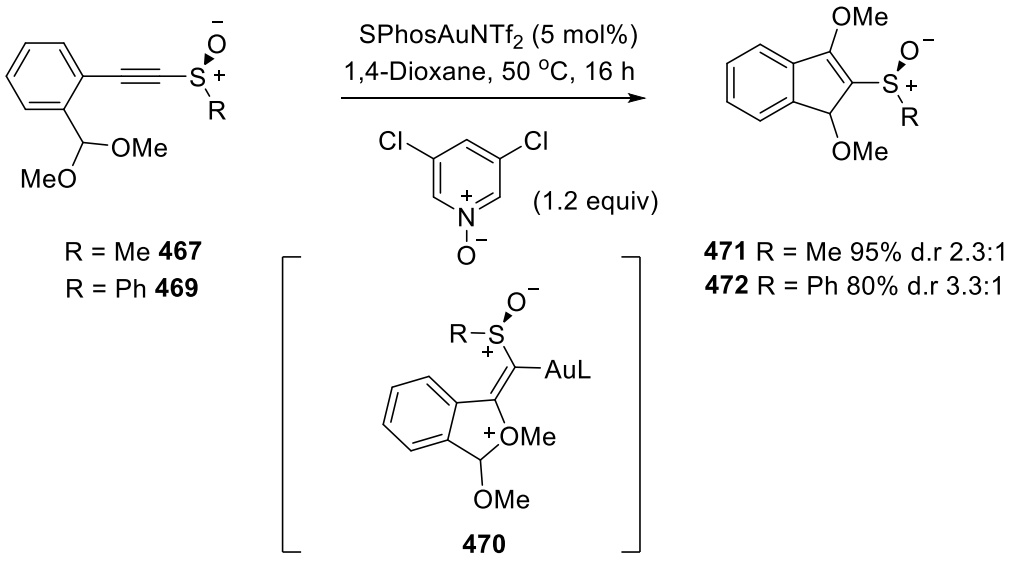
Scheme 87. Unoptimised synthesis of alkene 462.

Two *ortho* acetal substituted alkynyl sulfoxides **468** and **470** were prepared from 2-bromo benzaldehyde **463** (Scheme 88).[151,152] These substrates were prepared to explore further oxidative reactions of alkynyl sulfoxides. Acetal formation proceeded well and formation of the sulfoxides was satisfactory, with the sulfides **467** and **469** transformed into the sulfoxides without purification.



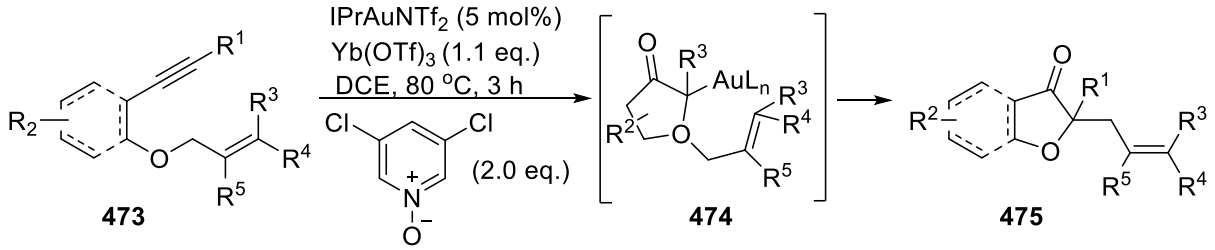
Scheme 88. Preparation of acetal substituted alkynyl sulfoxides.

Treatment of sulfoxide **467** and **469** under optimised reaction conditions B for the cyclopropanation resulted in complete conversion after 16 hours although significant consumption was observed after 15 minutes (Scheme 89). Upon product isolation and subsequent data collection it became clear that the products were derived from a dominant carboalkoxylation pathway proceeding through intermediate **470**. No products were observed from oxidative pathways suggesting intramolecular oxygen attack from the acetal onto the gold activated alkyne is a much faster process than formation of the gold carbenoid. The novel sulfoxides **471** and **472** were afforded, under mild conditions and in excellent yield. Compound **471** is analogous to the methyl ester reported by Toste.[152]



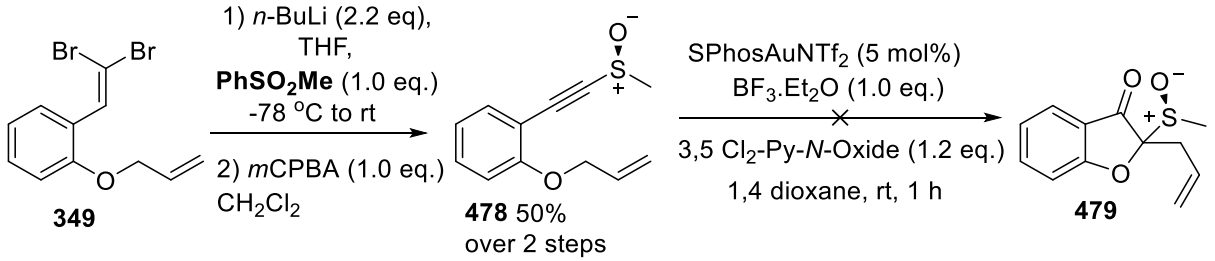
Scheme 89. Carboalkoxylation reactions of alkynyl sulfoxides.

Tang and co-workers developed an efficient synthesis of complex dihydrofuranones **475** from easily prepared starting materials **473** (Scheme 90).[52] Addition of a Lewis acid catalyst greatly speeds up the rearrangement after cyclisation. The reaction showed excellent chemoselectivity although the exact mechanism was debated.



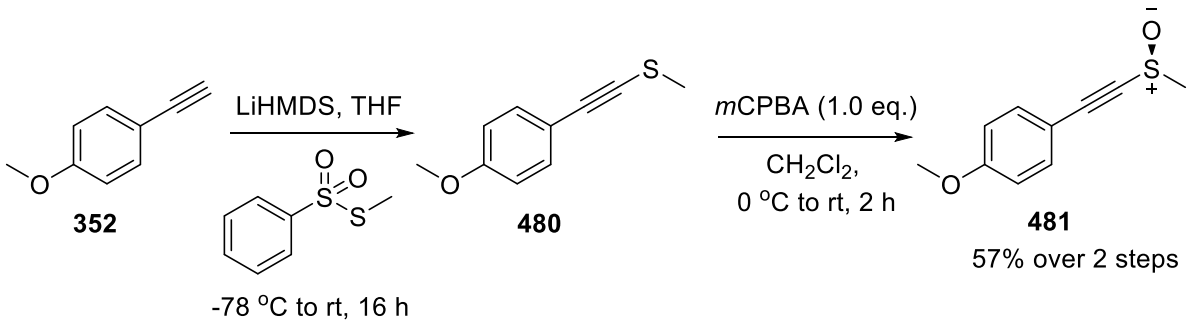
Scheme 90. Rearrangement of oxonium ylides generated under oxidative gold conditions.

Tang's system was selected to explore whether alkynyl sulfoxides would be suitable for this type of oxidative transformation to form dihydrofuranones **479**. An analogous substrate **478** was synthesised, replacing the alkynyl ester Tang employed for an alkynyl sulfoxide. A Lewis acid with good activity in Tang's work was selected. In the catalysis reaction the alkynyl sulfoxide was consumed with a new spot formed which faded over time. Multiple isolation attempts proved fruitless (Scheme 91).



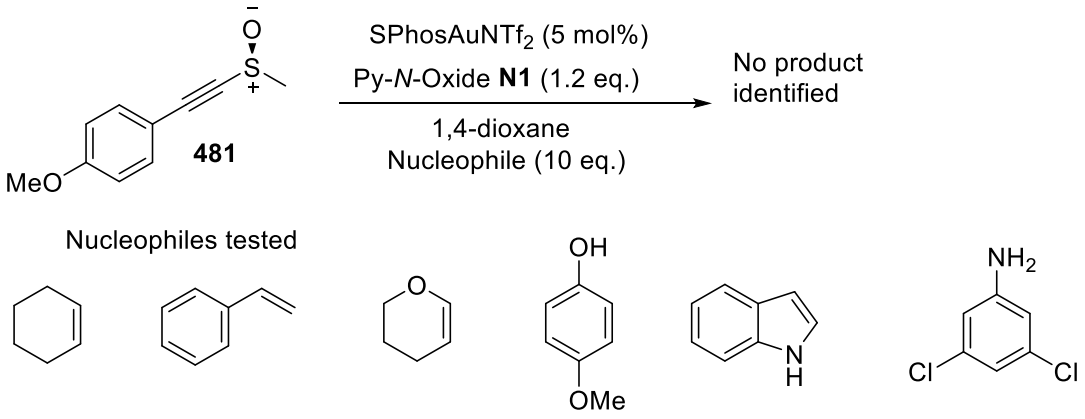
Scheme 91. Attempted dihydrofuranone preparation via an oxonium ylide.

An alkynyl sulfoxide lacking the functionality to undergo intramolecular reactions was prepared as a test substrate for attempts to achieve intermolecular reactivity. Methyl substituted alkynyl sulfoxide **481** was prepared successfully (Scheme 92), however, with a phenyl substituent the sulfoxide degraded too rapidly to use.



Scheme 92. Preparation of a sulfoxide to test for intermolecular reactions.

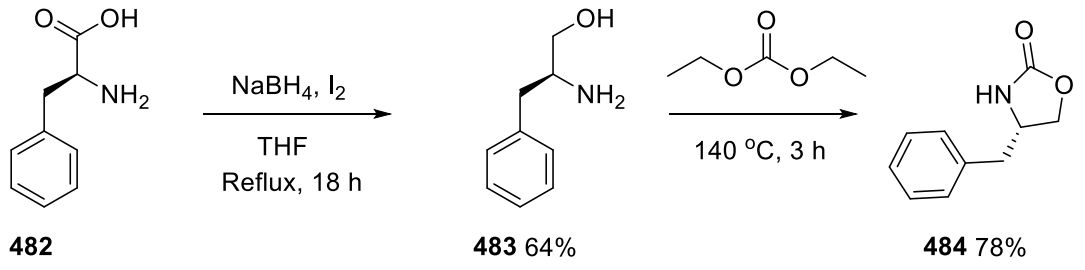
Sulfoxide **481** was treated under the standard catalysis conditions for intramolecular cyclopropanation with 10 equivalents of styrene and cyclohexene (Scheme 93). The pyridine-*N*-oxide was consumed within 10 minutes and a new spot formed on the baseline of the TLC plate. Attempts to isolate the spot were unsuccessful. In the absence of a good competing pathway degradation occurs potentially via an oxygen-transfer process.



Scheme 93. Attempted intermolecular reactions of alkynyl sulfoxides with various nucleophiles.

4.11 Preparation of an enantiopure alkynyl sulfoxide and its application

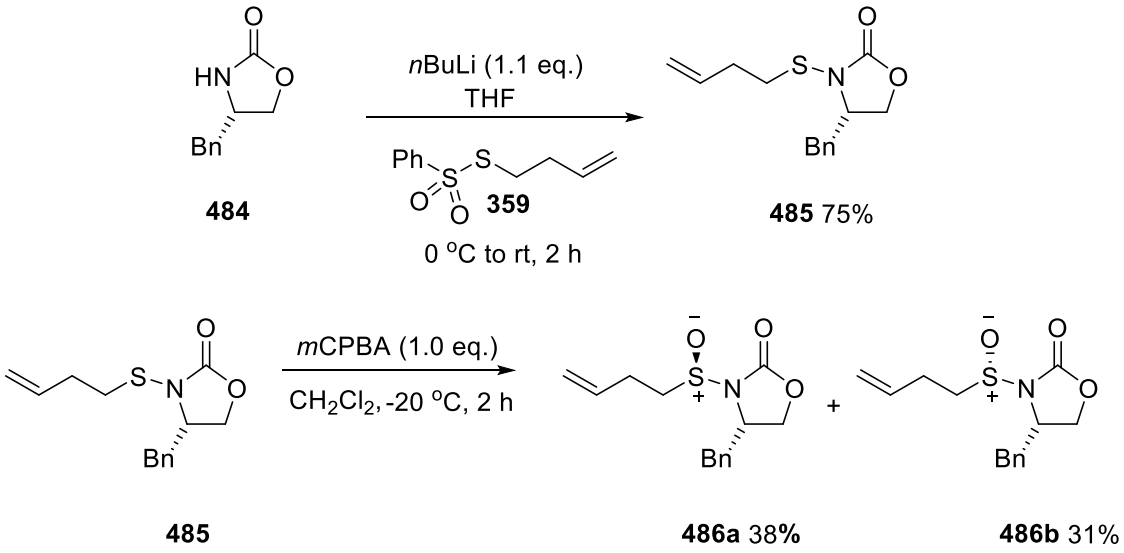
It was desirable to prepare enantiopure sulfoxides as this would showcase a novel route to achieve assymetric products in gold catalysis. A route to synthesise an enantiopure alkynyl sulfoxide was envisaged, commencing from Evans' phenylalanine derived oxazolidinone auxiliary. Auxiliary **484** was prepared in two steps from cheap *L*-phenylalanine **482** (Scheme 94). Firstly *L*-phenylalanine was reduced to an amino alcohol **483** in 64% yield.[153] Reaction of the amino alcohol **484** with diethyl carbonate at high temperature provided oxazolidinone **484** in 78% yield.[154]



Scheme 94. Preparation of an Evans auxiliary.

Auxiliary **484** was deprotonated at nitrogen with *n*-BuLi, before the addition of the thiosulfonate electrophile **359**, which provided the adduct **485** in a 75% yield (Scheme 95). *m*CPBA oxidation of **485** proceeded well at low temperature to afford a separable mixture of

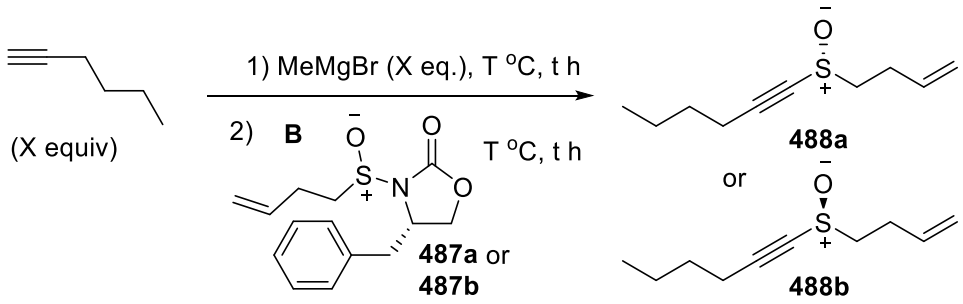
diastereomers of the two sulfinyl carbamate products **486a** and **486b** which were assigned on the basis of Evans' report.[150]



Scheme 95. Preparation of the sulfinyl transfer reagent.

Different conditions were employed in order to find an efficient preparation of the desired enantiopure sulfoxide. Hex-1-yne was treated with MeMgBr in THF. Upon addition of auxillary **486a** a modest yield could be achieved keeping the temperature at -20 °C (Table 20, entry 1). Refluxing was required to ensure complete deprotonation (Table 20, compare entries 2 and 3 vs 4). Addition of the auxiliary derived sulfinyl compound **486b** at low temperature facilitated a moderate yield of the target alkynyl sulfoxide **487a**. The reaction was proposed to proceed with complete inversion at sulfur which was seen by Evans.[128] Alternative conditions employed by Marino where a transmetalation approach was employed were unsuccessful (not shown).[129]

Table 20. Optimisation of reaction conditions in forming an enantiomerically pure alkynyl sulfoxide.

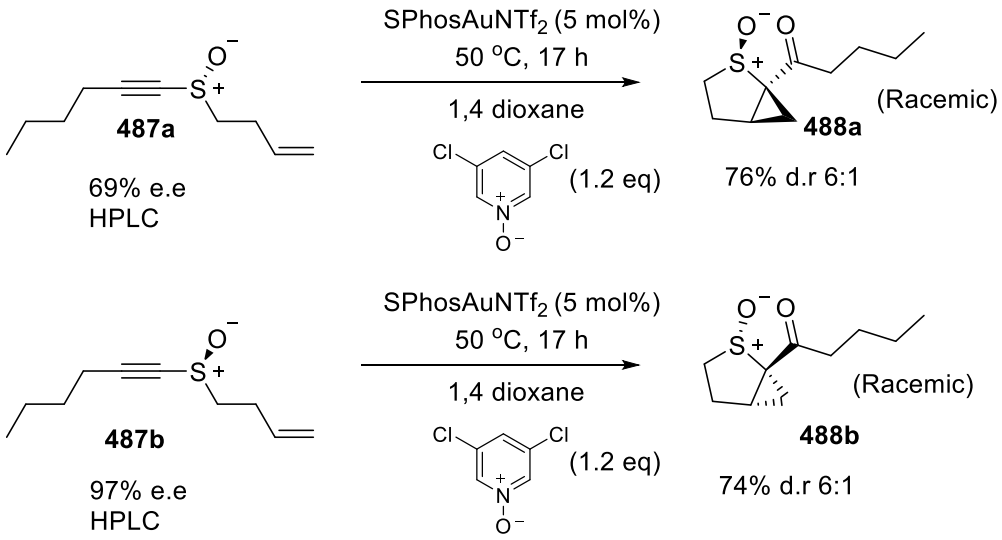


Entry	Hex-1-yne eq	Auxiliary	MeMgBr (equiv)	Conditions	Side products	Yield %
1	2.0	**486b**	1.0	reflux, 1 h, **B** - 20 °C, 4 h	-	33 **487a**
2	2.0	**486a**	1.0	rt, 2 h **B** -20 °C to 0 °C, 4 h	-	16 **487b**
3	1.3	**486b**	1.2	rt,1 h, **B** -20 °C to rt, 16 h	Methyl homoallyl sulfoxide (~60%)	<10 **487a**
4	1.5	**486a**	1.1	1 h reflux, 4 h, -20 °C to 0 °C		67 **487b**

HPLC analysis of the chiral sulfoxides was performed showing **487a** had a 69% e.e. and **487b** 97% e.e. from the chiral transfer reagent **486a**. The two enantiomers could be separated using an amylose 1 chiral column and eluting with 25%MeCN/H_2O (see appendix).

The enantioenriched sulfoxides were then tested under the optimal catalysis conditions and delivered the catalysis products in comparable yields to the racemic sulfoxide (Scheme 94).

The two enantiomers of the catalysis product were inseparable using a number of HPLC chiral columns and conditions. Chiral gas chromatography ensured the clean separation of the enantiomers but demonstrated that both diastereomers of the two catalysis products derived from the enantiomerically enriched sulfoxides were racemic.



Scheme 94. Treatment of alkynyl sulfoxides derived from Evans' auxiliary under catalysis conditions.

Racemisation of the sulfoxide clearly proceeds rapidly, however the mechanism for this racemisation and at which point it occurs remains undetermined.

Sulfoxide racemisation is known to proceed in the presence of strong acid[155], or thermally often at high temperatures where a bipyrimidal inversion mechanism is accountable.[156] Benzyl substituted sulfoxides are known to racemise at lower temperatures (130-150 °C) via a homolytic scission and cage recombination mechanism.[157] Racemisation of allyl substituted sulfoxides is much more facile undergoing a reversible rearrangement mechanism via allyl sulfenates.[158] Prior to this study no homoallyl substituted sulfoxides have been reported and they may undergo facile racemisation, however this is only speculation.

Alkynyl sulfoxides have been used as precursors to vinyl sulfoxides[159] and in Diels-Alder reactions.[160] In the reactions transforming chiral alkynyl sulfoxides to chiral vinyl sulfoxides metals complexes including rhodium complexes, copper species and zinc have been employed.[161,162] These observations and the fact no racemisation has been reported for alkynyl sulfoxides suggest that the unique reactivity of gold could be the cause of the racemisation.

The sulfoxides **487a** and **487b** are stable to racemisation at rt neat for several days, and no degradation products can be seen by TLC upon heating at 50 ^{o}C in 1,4-dioxane or after the addition of the gold catalyst. Inconclusive HPLC results suggest the racemisation may occur upon addition of the gold. The utility of chiral sulfoxides is that they do not racemise over most common reaction conditions, as already described. Diazo chemistry performed by Maguire showed no racemisation on reaction via the metal carbene.

Another possibility is that the racemisation occurs upon formation of the gold carbenoid. The behaviour of the chiral sulfur centre when adjacent to the gold carbenoid is completely unknown, yet this is only speculation.

Finally racemisation could potentially occur upon formation of the sulfur heterocycle product **488a** and **488b**. The experiment (p.110) shows that epimerization does not occur under the reaction conditions. This would suggest that these products are stable to racemisation.

4.12 Conclusions and future work

The work presented within this chapter showcases the successful use of gold catalysis to access an intramolecular cyclopropanation reaction from an α-diazo sulfoxide equivalent. Two related alkynyl sulfoxide systems have been shown to undergo cyclopropanation. In the first case, forming fused cyclopentanone derived structures, yields were moderate diastereoselectivity was modest and heavily influenced by the substituent. A second system was much more successful where high yields of single diastereomers could be obtained in many cases, substrate scope was good and an efficient preparation of precursors was designed and realised. A model for the observed diastereoselectivity was given. Limited success was observed on changing the alkene component in the cyclopropanation, mostly due to competing reactivity however further reaction optimisation would be expected to solve this problem. Attempts to access other

‘carbene’ reactivity modes were mostly unproductive but some promising reactivity suggest this should be explored further. Finally an alkynyl sulfoxide was prepared asymmetrically but racemic products were obtained in the gold catalysed reaction.

The basis for this is yet to be determined and is in itself interesting given the other uses of alkynylsulfoxides. A systematic approach to determine the cause and reasons for the racemisation between enantioenriched sulfoxides and racemic products should be performed. This would determine whether any practical solutions could be implemented. Further reaction screening may be expected to produce improved results from the substituted alkenes. Trapping of the gold carbenoid by an intramolecular nucleophile could be explored further. An alternative system such as Zhang’s oxetan-one formation may provide improved results.

Chapter 5: Experimental section

General Experimental

Commercially available chemicals/reagents were purchased from Sigma Aldrich, Acros, Strem, Alfa Aesar and used without further purification, unless reported. All catalysis reactions were carried out under argon in heat gun-dried glassware unless otherwise stated. Solvents were purified using a Pure Solv-MD solvent purification system except for $CHCl_3$, 1,4-dioxane which was dried over activated 4Å molecular sieves, and were transferred under argon. Asynt DrySyn heating blocks on stirrer hotplates were employed for reactions with temperature controlled *via* external probe. The following cooling baths were used: 0 ºC (ice/water), -10 ºC (NaCl/ice) and -78 ºC (dry ice/acetone). Flash column chromatography: Fluorochem silica gel 60 (0.043-0.063 mm). Thin layer chromatography (TLC): Macherey Nagel silica gel $60F_{254}$ analytical plates which were developed using standard visualizing agents: UV fluorescence (254 and 366 nm), phosphomolybdic acid /Δ, potassium permanganate /Δ and vanillin /Δ. IR was recorded using a Perkin–Elmer Spectrum 100 FTIR spectrometer. Only selected absorbencies (υ_{max}) are reported in cm^{-1}. MS and HRMS (EI): VG ProSpec or VG-ZabSpec at 70 eV. High resolution EI spectra were measured using perfluorokerosene (PFK) as an internal calibrant. MS and HRMS (ES): Waters LCT, Time of Flight. HRMS was obtained using leucineenkephalin as lock-mass.

NMR: Spectra were recorded on Bruker AVIII300 (^1H = 300 MHz, ^{13}C = 75.5 MHz) and Bruker AVIII400 (^1H = 400 MHz, ^{13}C = 101 MHz) in the solvents indicated; $CDCl_3$ purchased from Sigma Aldrich and DMSO-d_6 from Goss Scientific. ^{13}C NMR spectra were recorded using the UDEFT or PENDANT pulse sequences from the Bruker standard pulse program library. HSQC and HMBC spectra were recorded using the Bruker standard pulse program library. Chemical shifts (δ) are given in ppm relative to TMS. The solvent signals were used as references and the chemical shifts converted to the TMS scale ($CDCl_3$: δ_c = 77.16 ppm; residual $CHCl_3$ in $CDCl_3$:

δ_c = 7.26 ppm). Coupling constants (*J*) are reported in Hz. Multiplicity is denoted in ^{1}H NMR by: s (singlet), d (doublet), t (triplet), q (quadruplet), m (multiplet). 1D

Various alkynes and other precursors were kindly donated by members of the Davies group for use in this research.

m-CPBA was purified by washing with a pH 7 phosphate buffer unless otherwise stated: A buffer solution was prepared from 0.1 M NaOH (154 mL) and 0.2 M KH_2PO_4 (94 mL) and made up to 376 mL with distilled water. *m*-CPBA (77% w/w, 10 g) was dissolved in diethyl ether (100 mL) and washed four times with the buffer solution. The organic extract was dried over $MgSO_4$ and carefully evaporated under reduced pressure to yield pure *m*-CPBA (7.3 g).[83]

5.1 General experimental procedures

General Procedure 1 (GP1) Preparation of dibromoolefins

The general procedure follows a literature procedure.[108]

PPh_3 (4 eq.) was added to a solution of CBr_4 (2 eq.) in dry CH_2Cl_2 (0.05 M based on the aldehyde) at 0 ^oC. After stirring for 10 minutes the aldehyde (1 eq.) was added and the reaction was stirred for 1 hour. Water was added and the mixture was extracted with Et_2O, dried over Na_2SO_4, filtered and concentrated under reduced pressure. The residue was purified by column chromatography to afford the corresponding dibromoolefin.

General Procedure 2 (GP2)

Dibenzothiophene-*S*-oxide (1 eq.) and alkyne (2 eq.) were stirred in toluene (0.1 M) until dissolved in a heat gun dried schlenk tube. The mixture was then cooled in an ice bath at 0 ^oC and Au-I (1-5 mol%) was added. The reaction mixture was stirred until TLC showed consumption of dibenzothiophene-*S*-oxide, filtered through a pad of silica, washing with CH_2Cl_2 before being concentrated and the residue purified by column chromatography.

General Procedure 3 (GP3)

Dibenzothiophene-*S*-oxide (1 eq.) and alkyne (2 eq.) were stirred in toluene (0.01 M) until dissolved in a heat gun dried schlenk tube. The mixture was then cooled in a (NaCl/ice) bath to -10 ^{o}C and Au-I (5 mol%) was added. The reaction mixture was stirred until TLC showed consumption of dibenzothiophene-*S*-oxide, filtered through a pad of silica washing with CH_2Cl_2 before being concentrated and the residue purified by column chromatography.

General Procedure 4 (GP4)

To a flame dried Radleys tube under argon was added Naphtho dithiole monoxide **212** (1.0 eq.), alkyne (2.0 eq.) and toluene (0.1 M). Au-I (5 mol%) was added and the mixture was transferred to a hot plate at 40 ^{o}C and the reaction mixture was stirred at this temperature until completion was observed by TLC or no further reaction occurred. On completion the mixture was filtered through a pad of silica and purified by column chromatography.

General Procedure 5 (GP5)

To a Radleys tube under argon was added sulfur oxide **254** (1.0 eq.) and alkyne (2.0 eq.). Toluene (0.2 M) was added followed by Au-II (5 mol%) a further (0.2 M) toluene was added and the tube was transferred to a heating block at 70 ^{o}C. The reaction was stirred until completion or no further reaction was observed by TLC analysis. The mixture was filtered through a pad of silica, washing with EtOAc, concentrated and purified by column chromatography.

General Procedure 6 (GP6)

To a Radleys tube under argon was added alkyne (1.0 eq.) and disulfide oxide **254** (1.2 eq.) Toluene (0.2 M) was added followed by Au-II (5 mol%). A further (0.2 M) toluene was added and the tube was transferred to a heating block at 90 ^{o}C. The reaction was stirred until

completion or no further reaction was observed by TLC analysis. The mixture was filtered through a pad of silica, washing with EtOAc, concentrated and purified by column chromatography.

General Procedure 7 (GP7)

To a Radleys tube under argon was added alkyne (1.0 eq.) and sulfur oxide **254** (1.2 eq.) Toluene (0.2 M) was added followed by Au-I (5 mol%) a further (0.2 M) toluene was added and the tube was transferred to a heating block at 60 ^{o}C. The reaction was stirred until completion or no further reaction was observed by TLC analysis. The mixture was filtered through a pad of silica, washing with EtOAc, concentrated and purified by column chromatography

General Procedure 8 (GP 8) Preparation of Sulfinic esters

The disulfides were prepared according to a literature procedure.[133] To a RBF was added thiol (20 mmol), water (20 mL) and MeOH (50 mL). Sodium perborate was added and the mixture was stirred at rt for 2 hours. The mixture was added to a separating funnel and extracted with CH_2Cl_2 (3 × 50 mL). The organic layers were dried Na_2SO_4, filtered, concentrated under reduced pressure affording a solid which was used directly.

The sulfinic esters were prepared according to a literature procedure.[131] To a RBF containing disulfide (18.0 mmol) was added anhydrous MeOH (80 mL) and the mixture was cooled to 0 ^{o}C. *N*-bromosuccinimide (54.0 mmol, 3.0 eq) was added in one portion. The ice bath was removed and the mixture stirred for 1 hour. After this time the mixture was diluted with CH_2Cl_2 (100 mL) and washed with $NaHCO_3$ (2 × 50 mL) and water (50 mL). The organic layer was dried Na_2SO_4, filtered, concentrated under reduced pressure and purified by column chromatography (1:1 CH_2Cl_2:hexane) to (CH_2Cl_2) to afford the sulfinic ester.

General Procedure 9 (GP 9) Preparation of Alkynyl Sulfoxides

The general procedure is adapted from a literature procedure.[132]

To a 2 neck RBF under argon fitted with a condenser was added Mg turnings (2.3 eq.) and a pellet of iodine and the mixtue was purged with argon. Et_2O (1 M) was added followed by slow addition of allyl bromide (2.3 eq.). The grignard was stirred for 2 hours at rt.

The reaction mixture was cooled to -10 ^oC, propargyl chloride (1.0 eq.) was added slowly and the solution was stirred for 5 hours allowing to warm to rt. After cooling to 0 ^oC, sulfinate (2.0 eq.) was added dropwise and the solution was stirred at rt for 14 hours. The reaction was quenched by the addition of sat. NH_4Cl solution at 0 ^oC and the aqueous layer was extracted with Et_2O (5 × 0.2 M with respect to propargyl chloride), washed with brine (0.2M) and the organic layers were dried over Na_2SO_4, filtered, concentrated under reduced pressure and purified by column chromatography to afford the alkynyl sulfoxide.

General Procedure 10 (GP10) Preparation of alkynyl sulfides

To a flame dried 2 neck RBF under argon was added dibromoolefin (1.1 eq.) and anhydrous THF (0.2 M). The flask was cooled to -78 ^oC using a dry ice/ acetone cool bath. *n*-BuLi (2.5 M in hexane) (2.3 eq.) was added dropwise and on complete addition the mixture was stirred at -78 ^oC for an hour before *S*-(but-3-en-1-yl) benzenesulfonothioate (1.0 eq.) was added dropwise. The reaction was allowed to warm to rt o/n. The reaction was quenched with NH_4Cl (sat) (0.2 M with respect to alkyne added) and the mixture was extracted Et_2O (3 × 0.2 M), the organics were washed with brine (0.2 M), dried Na_2SO_4, filtered, concentrated under reduced pressure and the residue was purified by column chromatography.

General Procedure 11 (GP11) Preparation of alkynyl sulfides

Alkyne (1.1 eq.) and anhydrous THF (0.2 M) were added to a flame dried two neck RBF under argon. The flask was cooled to -78 ^oC using a dry ice/ acetone bath. LiHMDS (1 M in

ethylbenzene) (1.1 eq.) was added dropwise and on complete addition the mixture was stirred at -78 ^{o}C for an hour before *S*-(but-3-en-1-yl) benzenesulfonothioate (1.0 eq.) was added dropwise. The reaction was allowed to warm to rt o/n. The reaction was quenched with NH_4Cl (sat) (0.2 M with respect to alkyne added) and the mixture was extracted Et_2O (3 × 0.2 M), the organics were washed with brine (0.2 M), dried over Na_2SO_4, filtered, concentrated under reduced pressure and the residue was purified by column chromatography.

General Procedure 12 (GP 12) Preparation of alkynyl sulfoxides

To a RBF equipped with a stirrer bar under argon was added alkynyl sulfide (1.0 eq.) and CH_2Cl_2 (0.1 M). The mixture was cooled to 0 ^{o}C and *m*CPBA (1.0 eq.) was added in 5 portions over 10 mins. The reaction was allowed to warm to rt. On reaction completion the mixture was washed with $NaHCO_3$ (3 × 10 mL) and the aqueous phase was extracted with CH_2Cl_2 (3 × 10 mL). The combined organic layers were dried over Na_2SO_4, filtered, concentrated and purified by column chromatography (using 3-5 inches of silica) to provide the alkynyl sulfoxide.

General procedure 13 (GP13)

To a Radleys tube under argon was added 3,5-dichloropyridine-*N*-oxide (1.2 eq.) and alkynyl sulfoxide (1.0 eq.) as a 0.2 M solution in 1,4-dioxane. $SPhosAuNTf_2$ (2.5 mol%) was added followed by 1,4-dioxane (0.067 M) and the reaction was stirred until completion or no further reaction was observed by TLC analysis. The mixture was filtered through a pad of silica, washing with EtOAc, concentrated and purified by column chromatography.

General procedure 14 (GP14)

To a Radleys tube under argon was added 3,5-dichloropyridine-*N*-oxide (1.2 eq.) and alkynyl sulfoxide (1 eq.) as a 0.2 M solution in 1,4-dioxane. The flask was placed in an oil bath at 50 ^{o}C and $SPhosAuNTf_2$ (5 mol%) was added followed by 1,4-dioxane (0.067 M) and the reaction was stirred until completion or no further reaction was observed by TLC analysis. The mixture

was filtered through a pad of silica, washing with EtOAc, concentrated and purified by column chromatography.

Preparation of gold catalysts and a pyridine-N-oxide

Chloro[tris(2,4-di-tert-butylphenyl)phosphite]gold

Prepared according to a literature procedure.[163] Thiodiethanol (114.9 mg, 1.11 mmol) was added dropwise to a solution of $KAuCl_4$ (150 mg, 0.397 mmol) in H_2O (3.5 mL) cooled to 0 ^oC. Upon stirring for a further 30 mins, 2,4 di-tertbutylphenyl phosphite (205.5 mg, 0.318 mmol) was added dropwise at 0 ^oC. Upon complete addition the mixture was stirred for a further 30 mins, filtered and washed with pentane to afford the catalyst (250 mg); ^{1}H-NMR (300 MHz, $CDCl_3$): δ = 7.40 (dd, *J* = 8.5 and 1.4, 2H), 7.12 (dd, *J* = 8.6 and 2.5, 1H), 1.44 (s, 9H), 1.28 (s, 9H); ^{31}P-NMR (131 MHz, $CDCl_3$): δ = 100.5. Data matches that reported in the literature.[163]

(2,4-di*-tert-*butylC$_6$H$_3$O)$_3$PAu(NCCH$_3$)SbF$_6$

Prepared according to a literature procedure.[164] Chloro[tris(2,4-di-tert-butylphenyl)phosphite]gold (87.8 mg, 0.10 mmol) was added to a 25 ml 2 neck RBF. The flask was covered in foil, CH_3CN (7 mL) was added followed by $AgSbF_6$ (41.2 mg, 0.12 mmol) and the reaction was stirred at rt for 16 hours. MeCN was removed under reduced pressure, CH_2Cl_2 (5 mL) was added and the mixture was filtered under argon through celite. Evaporation of the solvent afforded the gold catalyst (100.8 mg, 90%) as a white solid. Sata matches the literature.[164] ^{1}H-NMR (300 MHz, $CDCl_3$): δ = 7.49 – 7.44 (m, 1H), 7.35 (dd, *J* 8.5 and 1.4, 1H), 7.23 (dd, *J* 8.6 and 2.4, 1H), 2.47 (s, 1H), 1.44 (s, 9H), 1.30 (s, 9H); ^{31}P-NMR (122 MHz, $CDCl_3$): δ = 87.8; IR (neat): ν = 2961, 2870, 1489, 1399, 1363, 1175, 1073, 947, 890, 656;

XPhosAuCl

Prepared according to a literature procedure.[165] $KAuCl_4$ (200 mg, 0.53 mmol) was dissolved in MeOH (3.2 mL), before the dropwise addition of dimethylsulfide (115 µL, 1.57 mmol, 2.9 eq.) as a solution in MeOH (0.8 mL) minimising exposure to light. After stirring for 30 minutes the white solid was filtered under vacuum washing with MeOH, Et_2O and pentane affording a white solid (quant) which was used directly.

Me_2SAuCl (88.4 mg, 0.30 mmol) was combined with XPhos (143 mg, 0.30 mmol, 1 eq.). CH_2Cl_2 (5 mL) was added and the solution stirred for 2 hours at rt. The solvent was mostly removed under reduced pressure before the addition of hexane and the product crashed out as white crystals (166 mg, 78%) which were collected by vacuum filtration washing with hexane.

^{1}H NMR (300 MHz, $CDCl_3$): δ = 7.67 – 7.58 (m, 1H), 7.56 – 7.46 (m, 2H), 7.32 – 7.26 (m, 1H), 7.10 (s, 2 H), 3.00 (dt, *J* = 13.8, 6.9 Hz, 1H), 2.25 (dt, *J* = 13.5, 6.8 Hz, 2H), 2.17 – 2.02 (m, 4H), 1.91 – 1.75 (m, 6H), 1.73 – 1.64 (m, 2H), 1.56 – 1.45 (m, 2H), 1.39 (d, *J* = 6.9 Hz, 6H), 1.32 (d, *J* = 6.9 Hz, 6H), 1.40 – 1.15 (m, 8H), 0.96 (d, *J* = 6.7 Hz, 6H); 31P-NMR (122 MHz, $CDCl_3$): δ = 35.6; Data matches that reported in the literature.[165]

XPhosAu(NCCH$_3$)SbF$_6$

Prepared according to a literature procedure.[166] XPhosAuCl (70.9 mg, 0.10 mmol) was added to a 25 ml 2 neck RBF. The flask was covered in foil, CH_3CN (7 mL) was added followed by $AgSbF_6$ (41.2 mg, 0.12 mmol) and the reaction was stirred at rt for 16 hours. MeCN was removed under reduced pressure, CH_2Cl_2 (5 mL) was added and the mixture was filtered under argon through celite. Evaporation of the solvent afforded the gold catalyst (71.5 mg, 75%) as a white solid. ^{1}H-NMR (300 MHz, $CDCl_3$): δ = 7.49 – 7.44 (m, 1H), 7.35 (dd, *J* 8.5 and 1.4, 1H), 7.23 (dd, *J* 8.6 and 2.4, 1H), 2.47 (s, 1H), 1.44 (s, 9H), 1.30 (s, 9H); IR (neat): ν = 2961, 2870, 1489, 1399, 1363, 1175, 1073, 947, 890, 656; ^{31}P-NMR (121 MHz, $CDCl_3$): δ = 87.8; ^{1}H NMR (300 MHz, $CDCl_3$): δ = 7.71 (t, *J* = 8.8 Hz, 1H), 7.57 (dt, *J* = 14.8, 5.7 Hz, 2H), 7.21 (s, 1H), 7.00 (s, 2H), 2.94 (dt, *J* = 13.7, 6.9 Hz, 1H), 2.20 (dt, *J* = 13.4, 6.8 Hz, 4H), 2.10 – 1.98 (m, 2H), 1.90 – 1.67 (m, 5H), 1.35 (d, J = 6.8 Hz, 6H), 1.43-1.11 (m, 13H), 1.21 (d, J = 6.7 Hz, 6H), 0.93 (d, J = 6.8 Hz, 6H); ^{31}P-NMR (122 MHz, $CDCl_3$): δ = 36.4; IR (neat): ν = 2929, 2856, 1448, 1428, 1383, 1270, 1178, 1124, 920, 883, 876, 854, 770, 743. Data matches that reported in the literature.[166]

SPhosAuCl

Prepared according to a literature procedure.[167] $KAuCl_4$ (200 mg, 0.53 mmol) was dissolved in MeOH (3.2 mL), before the dropwise addition of dimethylsulfide (115 µL, 1.57 mmol, 2.9

eq.) as a solution in MeOH (0.8 mL) minimising exposure to light. After stirring for 30 minutes the white solid was filtered under vacuum washing with MeOH, Et_2O and pentane affording a white solid (quant) which was used directly.

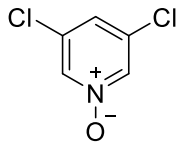
Me_2SAuCl (0.204 mmol, 60 mg) was combined with SPhos (83.7 mg, 0.204 mmol, 1 eq.). CH_2Cl_2 (5 mL) was added and the solution stirred for 2 hours at rt. The solvent was mostly removed under reduced pressure before the addition of hexane and the product crashed out as white crystals (99.6 mg, 80%) which were collectd by vacuum filtration washing with hexane. ^1H NMR (300 MHz, $CDCl_3$): δ = 7.60 – 7.41 (m, 4H), 7.24 – 7.17 (m, 1H), 6.66 (d, *J* = 8.4 Hz, 2H), 3.69 (s, 6H), 2.21 – 2.07 (m, 2H), 2.01 – 1.89 (m, 2H), 1.86 – 1.55 (m, 8H), 1.53 – 1.38 (m, 2H), 1.37 – 1.11 (m, 8H); ^{31}P NMR (122 MHz, $CDCl_3$): δ = 38.5; IR (neat): *v* = 2924, 2851, 1589, 1472, 1428, 1249, 1110, 1000, 759, 723. Data matches that reported in the literature.[167]

SPhosAuNTf$_2$

Prepared according to a literature procedure.[168] To SPhosAuCl (53.6 mg, 0.083 mmol) in CH_2Cl_2 (4 mL) in a RBF wrapped in foil was added $AgNTf_2$ (32.3 mg, 0.083 mmol) and the mixture was stirred at rt for 1 hour. The mixture was filtered through a pad of celite, washing with CH_2Cl_2, and concentrated under reduced pressure to afford $SPhosAuNTf_2$ (62.6 mg, 85%) as white crystals. Data matches that reported in the literature.[168]

^1H NMR (300 MHz, $CDCl_3$): δ = 7.64 – 7.54 (m, 2H), 7.53 – 7.46 (m, 1H), 7.43 (t, *J* = 8.4 Hz, 1H), 7.21 (ddd, *J* = 8.3, 4.6, 1.5 Hz, 1H), 6.71 (d, *J* = 8.4 Hz, 2H), 3.69 (s, 6H), 2.25 – 1.93 (m, 4H), 1.92 – 1.60 (m, 8H), 1.46 – 1.00 (m, 10H); ^{31}P NMR (122 MHz, $CDCl_3$): δ = 37.9; IR (neat): *v* = 2930, 2863, 1600, 1590, 1474, 1389, 1371, 1213, 1186, 1128, 1112, 962, 811, 658. Data matches that reported in the literature.[169]

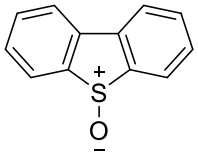
3,5-Dichloropyridine 1-oxide



74 was prepared according to a literature procedure.[1] To a RBF was added 3,5-dichloropyridine (740 mg, 5.00 mmol) and CH_2Cl_2 (50 mL). The mixtue was cooled to 0 °C, *m*CPBA (1.06 g, 6.15 mmol, 1.23 eq.) was added and the reaction was allowed to warm to rt over 16 hours. The mixture was quenched with $NaHCO_3$ (5 mL of a saturated aqueous solution) and extracted with CH_2Cl_2 (4 × 10 mL). The organics were combined, dried over $MgSO_4$, concentrated under reduced pressure and purified by column chromatography (EtOAc) to afford the title compound (686 mg, 84%) as a white solid; mp: 108-110 °C; ^{1}H NMR (300 MHz, $CDCl_3$): δ = 8.14 (d, *J* = 1.6 Hz, 2H), 7.31 (t, *J* = 1.6 Hz, 1H); IR (neat): ν = 3290, 3032, 2858, 2117, 1496, 1455, 1355, 1074, 1027, 739, 697. Data matches that reported in the literature.[169]

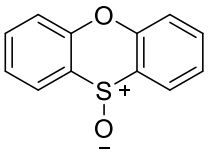
5.2 Experimental section:Chapter 2

Dibenzothiophene-5-oxide (103)



Sulfoxide **103** was prepared from a literature procedure.[83] Dibenzothiophene **102** (2.00 g, 10.9 mmol) in CH_2Cl_2 (46 mL) was cooled to 0 °C. *m*CPBA (2.06 g, 11.9 mmol) in CH_2Cl_2 (80 mL) was added over 20 minutes. The reaction was left to warm to rt and stirred for 16 hours. The reaction mixture was washed with $NaHCO_3$ (3 × 30 mL of a 0.1 M aqueous solution) and extracted with CH_2Cl_2 (3 × 30 mL), dried over $MgSO_4$, filtered, concentrated under reduced pressure and purified by column chromatography (petroleum ether:EtOAc 9:1) to yield **103** (1.70 g, 78%) as a white solid; R_f 0.36 (1:1 petroleum ether:EtOAc); mp: 184-186 °C; ^{1}H NMR (300 MHz, $CDCl_3$): δ = 8.00 (d, *J* = 7.2 Hz, 2H), 7.82 (d, *J* = 8.0 Hz, 2H), 7.61 (td, *J* = 7.5, 1.1 Hz, 2H), 7.51 (td, *J* = 7.5, 1.1 Hz, 2H); *m/z* (ES) 223 $(M + Na)^+$ (100), 224 (8), 255 (15). Data matches that reported in the literature.[170]

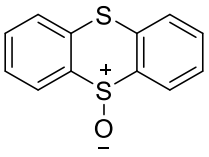
Phenoxathiin-10-oxide (106)



Sulfoxide **106** was prepared from a literature procedure.[83] Phenoxathiin **104** (500 mg, 2.50 mmol) in CH_2Cl_2 (18 mL) was cooled to 0 °C. *m*CPBA (475 mg, 2.75 mmol) in CH_2Cl_2 (24 mL) was added by syringe over 20 minutes, the reaction was left to warm to rt and stirred for 16 hours. The reaction mixture was washed with $NaHCO_3$ (3 × 10 mL of a 0.1 M aqueous solution), extracted with CH_2Cl_2 (3 × 10 mL), dried over $MgSO_4$, filtered, concentrated under reduced pressure and purified by column chromatography (hexane:EtOAc 1:1) to yield **106** (433 mg, 78%) as a white solid; R_f 0.38 (hexane:EtOAc 1:1); mp: 138-139 °C; ^{1}H NMR (300 MHz, $CDCl_3$): δ = 7.92 (dd, *J* = 7.8, 1.6 Hz, 2H), 7.61 (ddd, *J* = 8.7, 7.3, 1.6 Hz, 2H), 7.42 (dd, *J* = 8.4, 1.0 Hz, 2H), 7.37 (t, *J* = 7.5

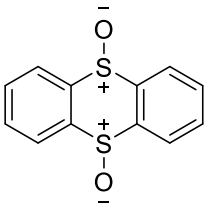
Hz, 2H); IR (neat): ν = 3074, 1586, 1452, 1435, 1223, 1023, 1032, 770, 755. Data matches that reported in the literature.[172]

Thianthrene-5-oxide (107)



Sulfoxide **107** was prepared from a literature procedure.[83] Thianthrene **105** (604 mg, 2.79 mmol) in CH_2Cl_2 (18 mL) was cooled to 0 °C. *m*CPBA (530 mg, 3.07 mmol) in CH_2Cl_2 (24 mL) was added by syringe over 20 minutes, the reaction was left to warm to rt and stirred for 16 hours. The reaction mixture was washed with $NaHCO_3$ (3 × 10 mL of a 0.1 M aqueous solution) and extracted with CH_2Cl_2 (3 × 10 mL), dried over $MgSO_4$, filtered, concentrated under reduced pressure and purified by column chromatography (hexane:EtOAc 85:15) to yield **107** (530 mg, 81%) as a white solid; R_f 0.21 (1:10 EtOAc:hexane); mp: 138-139 °C; ^{1}H NMR (300 MHz, $CDCl_3$): δ = 7.86 (d, J = 7.8 Hz, 2H), 7.57 (d, J = 8.5 Hz, 2H), 7.50 (t, J = 8.2 Hz, 2H), 7.37 (t, J = 7.5 Hz, 2H); IR (neat): ν = 1569, 1434, 1248, 1117, 1075 (S=O), 1033, 747. Data matches that reported in the literature.[172,173]

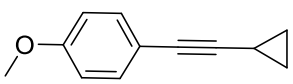
Thianthrene 5,10-dioxide (108)



Sulfoxide **108** was prepared from a literature procedure.[83] Thianthrene **105** (100 mg, 0.46 mmol) in CH_2Cl_2 (3 mL) was cooled to 0 °C. *m*CPBA (160 mg, 0.92 mmol) in CH_2Cl_2 (4 mL) was added by syringe over 20 minutes, the reaction was left to warm to rt and stirred for 16 hours. The reaction mixture was washed with $NaHCO_3$ (3 × 5 mL of a 0.1 M aqueous solution) and extracted with CH_2Cl_2 (3 × 5 mL), dried over Na_2SO_4, filtered, concentrated under reduced pressure and purified by column chromatography (hexane:EtOAc 1:3) to yield **108** (70 mg, 61%) as a white solid as a 1:1 mixture of diastereomers; R_f 0.39 (1:3 hexane:EtOAc); mp: 253-255 °C; ^{1}H NMR (300MHz,

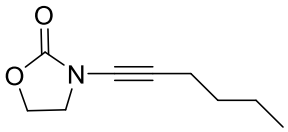
$CDCl_3$): δ = 8.04 (dd, *J* = 5.6, 3.3Hz, 4H), 7.60 (dd, *J* = 5.6, 3.3 Hz, 4H); IR (neat): *ν* = 3056, 1571, 1436, 1072, 1037, 1023, 779, 763. Data matches that reported in the literature.[172,173]

1-(Cyclopropylethynyl)-4-methoxybenzene (109)



Alkyne **109** was prepared according to the literature procedure.[19] To a stirring solution of of CuI (38 mg, 0.46 mmol) and $Pd(PPh_3)_2Cl_2$ (69 mg, 0.98 mmol) in diethylamine (25 ml) was added 4-methoxy iodobenzene (1.15 g, 4.9 mmol). After stirring for 10 min, cyclopropylacetylene (389 mg, 5.88 mmol) was added. The reaction mixture was stirred for 16 hours, concentrated under reduced pressure and purified by column chromatography (hexane) to give **109** (0.513 g, 64%) as a colourless oil; R_f 0.19 (hexane); ^{1}H NMR (300MHz, $CDCl_3$): δ = 7.31 (d, *J* = 8.9 Hz, 2H), 6.80 (d, *J* = 8.9 Hz, 2H), 3.79 (s, 3H), 1.42 (m, 1H), 0.81 (m, 4H); ^{13}C NMR (100 MHz, $CDCl_3$): δ = 159.0 (C), 133.0 (2CH), 116.0 (C), 113.8 (2CH), 91.7 (C), 75.5 (C), 55.2 (CH_3), 8.5 ($2CH_2$), 0.1 (CH). IR (neat): ν = 3009, 2957, 2837, 2234, 1605. Data matches the literature.[19]

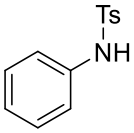
3-(Hex-1-yn-1-yl)oxazalidin-2-one (112)



Ynamide **112** was prepared according to the literature procedure.[35] To a 500 ml 3 neck RBF flame dried under argon was added $CuCl_2$ (81 mg, 0.6 mmol), oxazalidin-2-one (1.37 g, 15.7 mmol) and Na_2CO_3 (636 mg, 6.0 mmol). The flask was purged with oxygen for 15 minutes and a balloon of oxygen was attached. The reaction mixture was heated to 70 ^{o}C and toluene (10 ml) and pyridine (475 mg, 6.0 mmol) were added. 1-Hexyne (0.35 ml, 3.0 mmol) in toluene (10 ml) was added by syringe pump over 4 hours stirring at 70 ^{o}C. On complete addition the reaction was left stirring at 70 ^{o}C for 14 h. The reaction mixture was allowed to cool to rt and the inorganics were removed by filtration. The filtrate was concentrated under reduced pressure and purified by column chromatography (Hexanes:EtOAc 7:3) to yield **112** (293 mg, 59%) as a clear oil. ^{1}H NMR (300 MHz, $CDCl_3$):

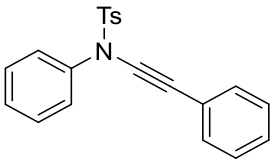
δ = 4.41 (t, *J* = 10.9 Hz, 2H), 3.87 (t, *J* = 8.2 Hz, 2H), 2.30 (t, *J* = 7.0 Hz, 2H), 1.54-1.31 (m, 4H), 0.91 (t, *J* = 7.0 Hz, 3H); IR (neat): ν = 2959, 2932, 2873, 2274, 1759, 1480, 1413, 1298, 1201, 1113, 1033, 973, 750, 730, 614. Data matches the literature.[35]

4-Methyl-N-phenylbenzenesulfonamide (114a)



Sulfonamide was prepared according to a literature procedure.[35] To a 100 ml RBF stirring at rt under argon was added aniline (3.00 g, 32.2 mmol) and CH_2Cl_2 (70 ml). Pyridine (15.3 ml, 193 mmol) was added and TsCl (6.20 g, 38.7 mmol) was added in portions over 1 hour. The reaction was stirred at rt for 16 hours. The reaction mixture was concentrated to half its volume, washed with 5% HCl (3 × 25 ml) and purified by column chromatography (Hexanes:EtOAc 2:1) to give the title compound (7.50 g, 95%) as a white solid; R_f 0.68 (Hexanes:EtOAc 2:1); ^{1}H NMR (300MHz, $CDCl_3$): δ = 7.64 (d, *J* = 8.3 Hz, 2H), 7.25-7.19 (m, 4H), 7.12-7.01 (m, 3H), 2.38 (s, 3H); IR (neat): ν = 2962, 2930, 2875, 1770, 1682, 1631, 1479, 1386, 1362, 1286, 1262, 1204, 1120, 1038, 984, 759, 706, 649, 637, 620, 611. Data matches the literature.[35]

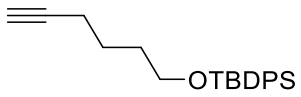
4-Methyl-N-phenyl-N-(phenylethynyl)benzenesulfonamide (114)



Ynamide **114** was prepared according to the literature procedure.[35] To a 500 ml 3 neck RBF flame dried under argon was added $CuCl_2$ (53.8 mg, 0.4 mmol), sulfonamide **114a** (2.47 g, 10 mmol) and Na_2CO_3 (424 mg, 4 mmol). The flask was purged with oxygen for 15 minutes and a balloon of oxygen was attached. The reaction mixture was heated to 70 ^oC and toluene (10 ml) and pyridine (316 mg, 4 mmol) were added. Phenylacetylene (0.22 ml, 2 mmol) in toluene (10 ml) was added by syringe pump over 4 hours stirring at 70 ^oC. On complete addition the reaction was left stirring at 70 ^oC for 14 h. The reaction mixture was allowed to cool to rt and the inorganics were removed by filtration. The filtrate was concentrated under reduced pressure and purified by

column chromatography (Hexanes:EtOAc 20:1) to yield **114** (500 mg, 68%) as a pale yellow solid; R_f 0.36 (Hexanes:EtOAc 20:1); ^{1}H NMR (300MHz, $CDCl_3$): δ = 7.62 (d, *J* = 8.3 Hz, 4H), 7.43-7.35 (m, 3H), 7.34-7.28 (m, 9H), 2.44 (s, 3H); IR (neat): ν = 3235, 1597, 1482, 1415, 1336, 1155, 1090, 909, 818, 753, 694, 656, 622. Data matches the literature.[35]

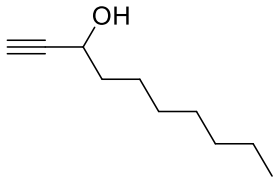
Tert-butyl(hex-5-yn-1-yloxy)diphenylsilane (120)



Alkyne **120** was prepared according to a literature procedure.[85]

To a RBF under argon containing CH_2Cl_2 (5 mL) was added 5-hexyn-1-ol **119** (0.14 mL, 1.27 mmol) followed by imidazole (0.14 g, 2.05 mmol) and TBDPSCl (0.33 mL, 1.27 mmol) at 0 ºC. The reaction was allowed to warm to rt stirring for 16 hours. CH_2Cl_2 (12 mL) was added followed by NH_4Cl (20 mL of a saturated solution). The organic layer was collected and the aqueous extracted with CH_2Cl_2 (15 mL), dried over Na_2SO_4, filtered, concentrated under reduced pressure and purified by column chromatography (98:2 hexanes:EtOAc) to afford **120** (330 mg, 79%) as a clear oil; R_f 0.33 (98:2 hexane:EtOAc); ^{1}H-NMR (300 MHz, $CDCl_3$): δ = 7.72 – 7.62 (m, 4H), 7.47 – 7.34 (m, 6H), 3.67 (t, *J* = 5.5 Hz, 2H), 2.20 (dt, *J* = 5.6, 2.8 Hz, 2H), 1.97– 1.91 (m, 1H), 1.74 – 1.59 (m, 4H), 1.04 (s, 9H); IR (neat): ν = 3308, 3072, 2932, 2858, 1590, 1428, 1106, 700. Data matches that reported in the literature.[85]

Dec-1-yn-3-ol (122)



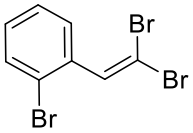
Alkyne **122** was prepared according to a literature procedure.[27]

A flame dried RBF containing a stirrer bar, TMS acetylene (1.11 ml, 8.00 mmol, 1.5 eq.) and THF (20 mL) was placed in a dry ice/ acetone bath at -78 ºC. *n*-BuLi (1.6 M) (5.3 mL, 8.5 mmol, 1.6 eq.) was added dropwise over 30 minutes. After stirring for an additional 15 minutes, octanal (828 µL, 5.3 mmol, 1.0 eq.) in THF (20 mL)

was added dropwise over 30 minutes and the reaction was stirred at -78 °C for an additional 3 hours. The reaction mixture was quenched with NH_4Cl (20 mL of a saturated solution), extracted with Et_2O (4 × 20 mL), dried over Na_2SO_4, filtered and concentrated under reduced pressure affording the TMS protected propargylic alcohol (1.10 g) which was used crude.

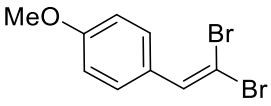
To a flame dried RBF equipped with a stirrer bar, was added THF (35 mL) and crude TMS protected alcohol (1.10 g, 4.0 mmol). The solution was cooled to 0 °C and TBAF (1.0 M) (4.0 ml, 4.0 mmol, 1.0 eq.) was added dropwise over a period of 15 minutes and the reaction was stirred for a further 90 minutes. NH_4Cl (50 mL of a saturated solution) was added and the mixture was extracted with Et_2O (3 × 25 mL), dried over Na_2SO_4, filtered, concentrated under reduced pressure and purified by column chromatography (10-20% EtOAc:hexanes) affording **122** (540 mg, 66%) as a pale yellow oil; R_f 0.38 (9:1 hexane:EtOAc); ^{1}H-NMR (300 MHz, $CDCl_3$): δ = 4.39-4.35 (m, 1H), 2.46 (d, *J* 2.1, 1H), 1.76-1.68 (m, 4H), 1.62 (s, 2H), 1.50-1.41 (m, 2H), 1.34–1.23 (m, 8H), 0.88 (t, *J* 6.8, 3H); IR (neat): v = 3312, 2925, 2857, 1465, 1379, 1302, 1118, 1045, 1021, 722, 652, 624. Data matches that reported in the literature.[174]

1-Bromo-2-(2,2-dibromovinyl)benzene (123)



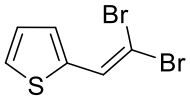
Prepared according to **GP1**, using 2-bromo benzaldehyde (0.48 mL, 5.0 mmol), CBr_4 (3.30 g, 10.0 mmol), PPh_3 (5.25 g, 20.0 mmol) and CH_2Cl_2 (15 mL). The reaction time was 16 hours. Aqueous workup and purification by column chromatography afforded **123** (750 mg, 56%) as a pale yellow oil. ^{1}H NMR (300 MHz, $CDCl_3$): δ = 7.59 (d, *J* = 8.0 Hz, 2H), 7.51 (s, 1H), 7.34 (td, *J* = 7.6, 1.2 Hz, 1H), 7.21 (td, *J* = 7.6, 1.6 Hz, 1H); 3064, 3019, 2922, 2855, 1606, 1589, 1463, 1428, 1317, 1277, 1161, 1118, 1046, 1025, 946, 854, 830, 790. Data matches that reported in the literature.[86]

1-(2,2-Dibromovinyl)-4-methoxybenzene (124)



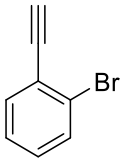
Prepared according to **GP1**, using *p*-methoxybenzaldehyde (0.61 mL, 5.0 mmol), CBr_4 (3.30 g, 10.0 mmol), PPh_3 (5.25 g, 20.0 mmol) and CH_2Cl_2 (15 mL). The reaction time was 16 hours. Aqueous workup and purification by column chromatography afforded **124** (1.20 g, 88%) as a pale orange solid. mp: 34-36 ^oC; ^1H NMR (300 MHz, $CDCl_3$): δ = 7.51 (d, *J* = 8.6 Hz, 2H), 7.41 (s, 1H), 6.89 (d, *J* = 8.9 Hz, 2H), 3.82 (s, 3H); IR (neat): ν = 3006, 2965, 2934, 2840, 1898, 1603, 1507, 1254, 1177, 1026, 864. Data matches that reported in the literature.[86]

2-(2,2-Dibromovinyl)thiophene (125)



Prepared according to **GP1**, using thiophene carboxaldehyde (0.47 mL, 5.0 mmol), CBr_4 (3.30 g, 10.0 mmol), PPh_3 (5.25 g, 20.0 mmol) and CH_2Cl_2 (15 mL). The reaction time was 1 hour. Aqueous workup and purification by column chromatography afforded **125** (1.26 g, 94%) as a light brown solid. mp: 53-55 ^oC; ^1H NMR (300 MHz, $CDCl_3$): δ = 7.66 (s, 1H), 7.39 (d, *J* = 4.8 Hz, 1H), 7.25 (s, 1H), 7.08 – 7.00 (m, 1H); IR (neat): ν = 3101, 3007, 2162, 1634, 1605, 1420, 1209, 1076, 1051, 856, 817, 741, 703; Data matches that reported in the literature.[175]

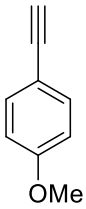
1-Bromo-2-ethynylbenzene (126)



Prepared according to a literature method.[86] To a RBF was added dibromalkene **123** (800 mg, 2.35 mmol) and Et_2O (10 mL). The mixture was cooled to -78 ^oC. *n*-BuLi (2.5 M in hexanes) (2.36 mL, 5.89 mmol, 2.3 eq.) was added dropwise over 1 hour, the reaction was stirred at -78 ^oC for 1 hour before the addition of NH_4Cl (10 mL). The mixture was warmed to rt, the organic layer separated, the aqueous layer extracted Et_2O (3 × 10 mL). The combined organics were dried over Na_2SO_4, filtered, concentrated under reduced pressure

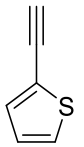
and purified by column chromatography (hexane) affording the title compound **126** as a light brown oil; ^{1}H NMR (300 MHz, $CDCl_3$): δ = 7.59 (dd, *J* = 7.8, 1.5 Hz, 1H), 7.53 (dd, *J* = 7.6, 1.8 Hz, 1H), 7.28 (td, *J* = 7.5, 1.4 Hz, 1H), 7.21 (td, *J* = 7.7, 1.9 Hz, 1H), 3.38 (s, 1H); IR (neat): v = 3291, 1465, 1026. Data matches that reported in the literature.[175]

1-Ethynyl-4-methoxybenzene (127)



Prepared according to a literature method.[86] To a RBF was added dibromalkene **124** (730 mg, 2.50 mmol) and Et_2O (10 mL). The mixture was cooled to -78 ^{o}C. *n*-BuLi (2.5 M in hexanes) (2.40 mL, 6.0 mmol, 2.4 eq.) was added dropwise over 1 hour, the reaction was stirred at -78 ^{o}C for 1 hour before the addition of NH_4Cl (10 mL). The mixture was warmed to rt, the organic layer separated, the aqueous layer extracted Et_2O (3 × 10 mL). The combined organics were dried over Na_2SO_4, filtered, concentrated under reduced pressure and purified by column chromatography (hexane) affording the title compound **127** (261 mg, 79%) as a colourless oil; ^{1}H-NMR (300 MHz, $CDCl_3$): δ = 7.47 – 7.40 (m, 2H), 6.87 – 6.81 (m, 2H), 3.81 (s, 3H), 3.00 (s, 1H); IR (neat): v = 3286, 2960, 2540, 2106, 1606, 1505, 1290, 1245, 1169, 1029, 830. Data matches that reported in the literature.[86]

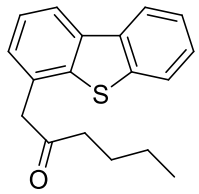
2-Ethynylthiophene (128)



Prepared according to a literature method.[86] To a RBF was added dibromalkene **125** (669 mg, 2.50 mmol) and Et_2O (10 mL). The mixture was cooled to -78 ^{o}C. *n*-BuLi (2.5 M in hexanes) (2.40 mL, 6.0 mmol, 2.4 eq.) was added dropwise over 1 hour, the reaction was stirred at -78 ^{o}C for 1 hour before the addition of NH_4Cl (10 mL). The mixture was warmed to rt, the organic layer separated, the aqueous layer extracted Et_2O (3 × 10 mL). The combined organics were dried over Na_2SO_4, filtered, concentrated under reduced pressure and purified by column chromatography (hexane) affording **128** as a light brown oil; ^{1}H-NMR (300 MHz,

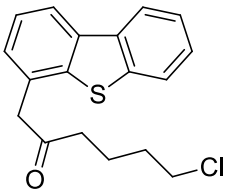
$CDCl_3$): δ =7.28 (dd, *J* = 3.5, 1.1 Hz, 2H), 6.98 (dd, *J* = 5.1, 3.6 Hz, 1H), 3.34 (s, 1H); IR (neat): v = 3294, 2928, 1240, 928, 852. Data matches that reported in the literature.[175]

1-(Dibenzo[b,d]thiophen-4-yl)hexan-2-one (116)



116 was prepared according to **GP2** using dibenzothiophene-*S*-oxide (40.0 mg, 0.20 mmol), 1-hexyne (23 µl, 0.40 mmol), toluene (2 mL) and Au-I (11.2 mg, 0.02 mmol, 5 mol%). The reaction was stirred for 45 minutes at 0 ºC. Column chromatography (1:19 EtOAc:hexane) afforded **116** (49 mg, 87%) as a white solid; R_f 0.28 (1:19 EtOAc:hexane) mp: 43-45 ºC; ^{1}H-NMR (300 MHz, $CDCl_3$): δ = 8.20–8.13 (m, 1H), 8.10 (d, *J* = 7.2 Hz, 1H), 7.92–7.82 (m, 1H), 7.51-7.43 (m, 3H), 7.32 (d, *J* = 7.2 Hz, 1H), 3.96 (s, 2H), 2.51 (t, *J* = 7.4 Hz, 2H), 1.63–1.50 (m, 2H), 1.33-1.19 (m, 2H), 0.85 (t, *J* = 7.3 Hz, 3H); ^{13}C-NMR (101 MHz, $CDCl_3$): δ = 207.5 (C), 140.0 (C), 139.1 (C), 136.1 (C), 136.0 (C), 129.2 (C), 128.0 (CH), 127.0 (CH), 125.2 (CH), 124.7 (CH), 123.0 (CH), 122.0 (CH), 120.6 (CH), 49.4 (CH_2), 42.0 (CH_2), 26.0 (CH_2), 22.3 (CH_2), 14.0 (CH_3); IR (neat): *v* = 3057, 2957, 2930, 2872, 1708, 1584, 1404, 749; HR-MS (ES-TOF): *m/z*: calcd for $C_{18}H_{18}ONaS$: 305.0976, found 305.0978 $[M + Na]^+$.

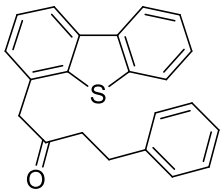
6-Chloro-1-(dibenzo[b,d]thiophen-4-yl)hexan-2-one (129)



129 was prepared according to **GP2** using dibenzothiophene-*S*-oxide (40.0 mg, 0.20 mmol), 6-chloro-1-hexyne (48.5 µL, 0.40 mmol), toluene (2 mL) and Au-I (11.2 mg, 0.02 mmol, 5 mol%). The reaction was stirred for 40 minutes at 0 ºC. Column chromatography (9:11 CH_2Cl_2: hexane) afforded **129** as a yellow oil (50 mg, 79%); R_f 0.44 (9:11 CH_2Cl_2:hexane); ^{1}H-NMR (300 MHz, $CDCl_3$): δ = 8.18–8.12 (m, 1H), 8.09 (dd, *J* = 7.9, 0.9 Hz, 1H), 7.91–7.83 (m, 1H), 7.54–7.42 (m, 3H), 7.32 (d, *J* = 7.2 Hz, 1H), 3.95 (s, 2H), 3.50–3.42 (m, 2H), 2.59–2.50 (m, 2H), 1.76–1.66 (m, 4H);

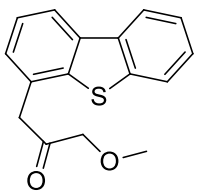
^{13}C-NMR (101 MHz, $CDCl_3$): δ = 206.6 (C), 139.9 (C), 139.0 (C), 136.2 (C), 136.1 (C), 129.0 (C), 128.0 (CH), 127.0 (CH), 125.2 (CH), 124.8 (CH), 123.0 (CH), 122.0 (CH), 120.7 (CH), 49.4 (CH_2), 44.7 (CH_2), 41.1 (CH_2), 31.8 (CH_2), 21.1 (CH_2); IR (neat): *v* = 3060, 2953, 1711, 1584, 1443, 1401, 749; HR-MS (ES-TOF): *m/z*: calcd for $C_{18}H_{17}ONaS^{35}Cl^3$: 339.0586, found 339.0574 $[M + Na]^+$.

1-(Dibenzo[b,d]thiophen-4-yl)-4-phenylbutan-2-one (130)



130 was prepared according to **GP2** using dibenzothiophene-*S*-oxide (40.0 mg, 0.20 mmol), 4-phenyl-1-butyne (56 µl, 0.40 mmol), toluene (2 mL) and Au-I (11.2 mg, 0.02 mmol, 5 mol%). The reaction was stirred for 45 minutes at 0 ºC. Column chromatography (1:1 hexane: CH_2Cl_2) afforded **130** (43 mg, 65%) as a white solid; R_f 0.78 (3:7 EtOAc: hexane); mp: 102-104 ºC; ^{1}H-NMR (300 MHz, $CDCl_3$): δ = 8.04-7.96 (m, 1H), 7.93 (d, *J* = 7.8 Hz, 1H), 7.74-7.66 (m, 1H), 7.38–7.26 (m, 3H), 7.15–6.93 (m, 6H), 3.78 (s, 2H), 2.79–2.63 (m, 4H); ^{13}C-NMR (101 MHz, $CDCl_3$): δ = 206.3 (C), 140.9 (C), 140.0 (C), 139.0 (C), 136.2 (C), 136.1 (C), 128.9 (C), 128.6 (2CH), 128.5 (2CH), 128.0 (CH), 127.0 (CH), 126.2 (CH), 125.2 (CH), 124.7 (CH), 123.0 (CH), 122.0 (CH), 120.7 (CH), 49.6 (CH_2), 43.7 (CH_2), 29.9 (CH); IR (neat): *v* = 3058, 3027, 2877, 1706, 1601, 1583, 1403, 1046, 746; HR-MS (ES-TOF): *m/z*: calcd for $C_{22}H_{18}ONaS$: 353.0976, found 353.0991 $[M + Na]^+$.

1-(Dibenzo[b,d]thiophen-4-yl)-3-methoxypropan-2-one (131)



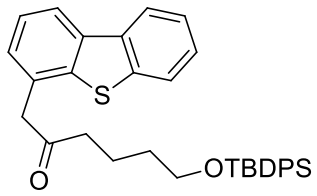
131 was prepared according to **GP2** using dibenzothiophene-*S*-oxide (40.0 mg, 0.20 mmol), monomethyl propargyl ether (33.8 µl, 0.40 mmol), toluene (2 mL) and Au-I (11.2 mg,

0.02 mmol, 5 mol%). The reaction was stirred for 45 minutes at 0 °C. Column chromatography (CH_2Cl_2) afforded **131** (47 mg, 87%) as a yellow solid; mp: 51–53 °C; R_f 0.31 (3:7 EtOAc: hexane); ^{1}H-NMR (300 MHz, $CDCl_3$): δ = 8.19–8.13 (m, 1H), 8.10 (d, *J* = 7.7 Hz, 1H), 7.91–7.83 (m, 1H), 7.52–7.43 (m, 3H), 7.34 (d, *J* = 7.2 Hz, 1H), 4.13 (s, 2H), 4.03 (s, 2H), 3.41 (s, 3H); ^{13}C-NMR (101 MHz, $CDCl_3$): δ = 204.7 (C), 140.0 (C), 138.9 (C), 136.2 (C), 136.1 (C), 128.2 (C), 128.1 (CH), 127.1 (CH), 125.2 (CH), 124.7 (CH), 123.0 (CH), 122.0 (CH), 122.0 (CH), 77.3 (CH_2), 59.5 (CH_3), 45.5 (CH_2); IR (neat): *v* = 2903, 1712, 1590, 1427, 1394, 1316, 1102, 759; HR-MS (ES-TOF): *m/z*: calcd for $C_{16}H_{14}O_2NaS$: 293.0612, found 293.0610 [M + Na]$^+$.

Open flask protocol

To a 25 mL RBF under an atmosphere of air was added dibenzothiophene-*S*-oxide (401 mg, 2 mmol), monomethyl propargyl ether (338 µl, 4 mmol) and toluene (technical grade) (20 mL). The flask was placed in an ice bath and Au-I (22.4 mg, 0.002 mmol, 1 mol%) was added. The reaction was stirred at this temperature for 2 hours until TLC indicated reaction completion. Column chromatography (CH_2Cl_2) afforded **131** (456 mg, 84%).

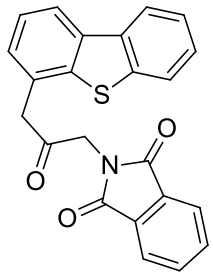
6-((tert-Butyldiphenylsilyl)oxy)-1-(dibenzo[b,d]thiophen-4-yl)hexan-2-one (132)



132 was prepared according to **GP2** using dibenzothiophene-*S*-oxide (100 mg, 0.50 mmol), alkyne **120** (336 mg, 1.0 mmol), toluene (5 mL) and Au-I (11.2 mg, 2 mol%). The reaction was stirred for 2 hours at 0 °C. Column chromatography (3:2 hexane:CH_2Cl_2) afforded **132** (222 mg, 83%) as a viscous oil; R_f 0.31 (3:2 hexane:CH_2Cl_2); ^{1}H-NMR (300 MHz, $CDCl_3$): δ = 8.20–8.13 (m, 1H), 8.09 (dd, *J* = 7.9, 0.9 Hz, 1H), 7.88-7.82 (m, 1H), 7.67–7.59 (m, 4H), 7.51–7.32 (m, 9H), 7.30 (d, *J* = 7.3 Hz, 1H), 3.93 (s, 2H), 3.60 (t, *J* = 6.2 Hz, 2H), 2.51 (t, *J* = 7.3 Hz, 2H), 1.77–1.60 (m, 2H), 1.53–1.40 (m, 2H), 1.01 (s, 9H); ^{13}C-NMR (101 MHz, $CDCl_3$): δ = 207.2 (C), 140.0

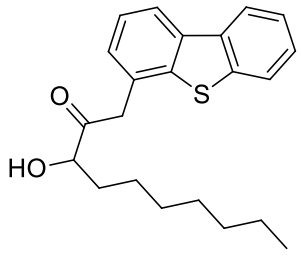
(C), 139.1 (C), 136.2 (C), 136.1 (C), 135.7 (4CH), 134.1 (2C), 129.7 (2CH) 129.2 (C), 128.0 (CH), 127.7 (4CH), 127.0 (CH), 125.2 (CH), 124.7 (CH), 123.0 (CH), 122.0 (CH), 120.6 (CH), 63.6 (CH_2), 49.4 (CH_2), 42.0 (CH_2), 32.0 (CH_2), 27.0 ($3CH_3$), 20.4 (CH_2), 19.4 (C); IR (neat): *v* = 2930, 2856, 1713, 1588, 1427, 1105; HR-MS (ES-TOF): *m/z*: calcd for $C_{34}H_{36}O_2NaSiS$: 559.2103, found 559.2102 $[M + Na]^+$.

2-(3-(Dibenzo[b,d]thiophen-4-yl)-2-oxopropyl)isoindoline-1,3-dione (134)



134 was prepared according to **GP2** using dibenzothiophene-*S*-oxide (200 mg, 1.0 mmol), N-propargylphthalimide (370 mg, 2.0 mmol) and Au-I (22.4 mg, 0.04 mmol, 2 mol%) for 4 hours at 0 °C and stirring for a further 16 hours. The precipitate formed was washed with toluene and then recrystallized from hot EtOH affording **134** as yellow crystals (201 mg, 52%); R_f 0.65 (3:7 EtOAc:hexane); mp: 190-192 °C (EtOH); ^{1}H-NMR (300 MHz, $CDCl_3$): δ = 8.20-8.15 (m, 1H), 8.13 (dd, *J* = 7.9, 1.0 Hz, 1H), 7.90–7.85 (m, 1H), 7.85–7.78 (m, 2H), 7.75–7.67 (m, 2H), 7.54–7.44 (m, 3H), 7.40 (d, *J* = 7.3 Hz, 1H), 4.56 (s, 2H), 4.11 (s, 2H); ^{13}C-NMR (101 MHz, $CDCl_3$): δ = 199.0 (C), 167.7 (C), 140.0 (C), 139.0 (C), 136.5 (C), 136.1 (C), 134.2 (2CH), 132.1 (2C), 128.0 (CH), 127.5 (C), 127.2 (CH), 125.4 (CH), 124.8 (CH), 123.6 (2CH), 123.1 (CH), 122.0 (CH), 121.1 (CH) 46.7 (CH_2), 46.3 (CH_2); IR (neat): *v* = 2970, 1769, 1735, 1698, 1470, 1409, 1067; HR-MS (ES-TOF): *m/z*: calcd for $C_{23}H_{15}NO_3NaS$: 408.0670, found 408.0667 $[M + Na]^+$.

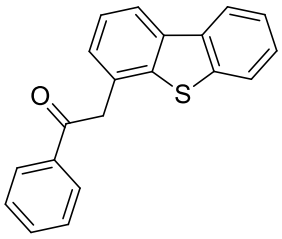
1-(Dibenzo[b,d]thiophen-4-yl)-3-hydroxydecan-2-one (135)



135 was prepared following **GP2** using dibenzothiophene-*S*-oxide (40 mg, 0.20 mmol), alkyne **122** (64 µl, 0.40 mmol), toluene (2 mL) and Au-I (11.2 mg, 5 mol%). Purification of the reaction mixture with column chromatography (9:1 hexane:EtOAc), followed by

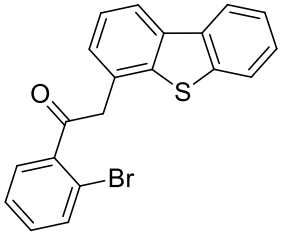
recrystallization from hot MeOH afforded **135** (54 mg, 76%); R_f 0.25 (9:1 hexane:EtOAc); mp: 52-54 °C; ^{1}H-NMR (300 MHz, $CDCl_3$): δ = 8.21– 8.14 (m, 1H), 8.11 (d, *J* = 7.9 Hz, 1H), 7.91–7.82 (m, 1H), 7.54–7.43 (m, 3H), 7.33 (d, *J* = 7.2 Hz, 1H), 4.38 (dd, *J* = 7.4, 3.6 Hz, 1H), 4.07 (s, 2H), 3.33 (s, 1H), 2.02–1.88 (m, 1H), 1.75–1.62 (m, 1H), 1.59–1.16 (m, 10H), 0.88 (t, *J* = 6.6 Hz, 3H); ^{13}C-NMR (101 MHz, $CDCl_3$): δ = 208.9 (C), 139.9 (C), 138.9 (C), 136.3 (C), 136.1 (C), 128.1 (CH), 127.9 (C), 127.1 (CH), 125.2 (CH), 124.8 (CH), 123.0 (CH), 122.0 (CH), 121.0 (CH), 76.4 (CH), 44.3 (CH_2), 34.0 (CH_2), 31.9 (CH_2), 29.5 (CH_2), 29.2 (CH_2), 24.9 (CH_2), 22.8 (CH_2), 14.2 (CH_2); IR (neat): *v* = 3446, 2924, 2854, 1714, 1585, 1443, 1402, 1047, 749; HR-MS (ES-TOF): *m/z*: calcd for $C_{22}H_{26}O_2NaS$: 377.1551, found 377.1565 $[M + Na]^+$.

2-(Dibenzo[b,d]thiophen-4-yl)-1-phenylethanone (136)



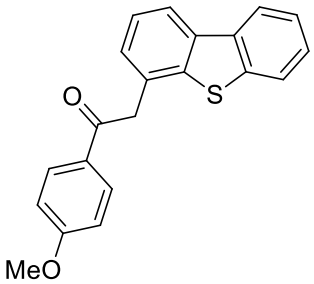
136 was prepared following **GP3** using dibenzothiophene-*S*-oxide (60.0 mg, 0.30 mmol), phenylacetylene (65 µl, 0.60 mmol), toluene (0.01 M, 30 mL) and Au-I (16.8 mg, 0.03 mmol, 5 mol%). Column chromatography (19:1 hexane:EtOAc), followed by recrystallization from hot EtOAc afforded **136** (53 mg, 58%) as a white solid; R_f 0.33 (19:1 hexane:EtOAc); mp: 127-129 °C; ^{1}H-NMR (300 MHz, $CDCl_3$): δ = 8.19–8.12 (m, 1H), 8.12–8.05 (m, 3H), 7.89–7.82 (m, 1H), 7.63– 7.54 (m, 1H), 7.52–7.40 (m, 5H), 7.34 (d, *J* = 6.9 Hz, 1H), 4.55 (s, 2H); ^{13}C-NMR (101 MHz, $CDCl_3$): δ = 196.4 (C), 139.9 (C), 139.1 (C), 136.7 (C), 136.2 (2C), 133.5 (CH), 129.5 (C), 128.9 (2CH), 128.7 (2CH), 127.9 (CH), 127.0 (CH), 125.1 (CH), 124.7 (CH), 123.0 (CH), 122.0 (CH), 120.6 (CH), 44.7 (CH_2); IR (neat): *v* = 3056, 2924, 2856, 1685, 1580, 1440, 1206, 908; HR-MS (ES-TOF): *m/z*: calcd for $C_{20}H_{14}ONaS$: 325.0663, found 325.0660 $[M + Na]^+$.

1-(2-Bromophenyl)-2-(dibenzo[b,d]thiophen-4-yl)ethanone (137)



137 was prepared following **GP3** using dibenzothiophene-*S*-oxide (40.0 mg, 0.20 mmol), alkyne **126** (50 µL, 0.40 mmol), toluene (20 mL, 0.01 mmol) and Au-I (11.2 mg, 0.02 mmol, 5 mol%). Column chromatography (19:1 hexane:EtOAc) followed by recrystallization with EtOH afforded **137** (30.5 mg, 40%) as white needles; R_f 0.20 (19:1 hexane:EtOAc); mp: 93-95 ^oC; ^{1}H-NMR (300 MHz, $CDCl_3$): δ = 8.18–8.12 (m, 1H), 8.09 (dd, *J* = 7.7, 1.1 Hz, 1H), 7.89–7.82 (m, 1H), 7.64–7.59 (m, 1H), 7.51–7.42 (m, 3H), 7.41–7.35 (m, 2H), 7.35–7.24 (m, 2H), 4.53 (s, 2H); ^{13}C-NMR (101 MHz, $CDCl_3$): δ = 200.2 (C), 141.4 (C), 140.2 (C), 139.1 (C), 136.2 (C), 136.1 (2C), 133.7 (CH), 131.8 (CH), 128.8 (CH), 128.3 (CH), 127.6 (CH), 127.0 (CH), 125.1 (CH), 124.7 (CH), 123.0 (CH), 122.0 (CH), 120.8 (CH), 118.8(C), 48.7 (CH_2); IR (neat): *v* = 3054, 2940, 1703, 1591, 1441, 1332, 989, 742; HR-MS (ES-TOF): *m/z*: calcd for $C_{20}H_{14}OS^{79}Br$: 380.9949, found 380.9948 $[M + H]^+$.

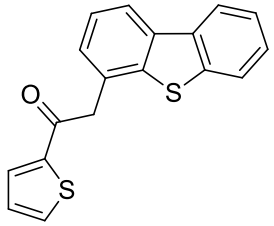
2-(Dibenzo[b,d]thiophen-4-yl)-1-(4-methoxyphenyl)ethanone (138)



138 was prepared following **GP3** using dibenzothiophene-*S*-oxide (40.0 mg, 0.20 mmol), alkyne **127** (52 µl, 0.40 mmol), toluene (20 mL) and Au-I (11.2 mg, 0.02 mmol, 5 mol%). Column chromatography (19:1 hexane:EtOAc) afforded **138** (28 mg, 42%) as a white solid; R_f 0.18 (19:1 hexane:EtOAc); mp: 113-115 ^oC; ^{1}H-NMR (300 MHz, $CDCl_3$): δ = 8.19–8.12 (m, 1H), 8.11–8.01 (m, 3H), 7.90–7.82 (m, 1H), 7.51–7.39 (m, 3H), 7.34 (d, *J* = 7.2 Hz, 1H), 6.98–6.89 (m, 2H), 4.49 (s, 2H), 3.86 (s, 3H); ^{13}C-NMR (101 MHz, $CDCl_3$): δ = 195.0 (C), 163.8 (C), 139.8 (C), 139.1 (C), 136.3 (C), 136.2 (C), 131.0 (2CH), 129.9 (C), 129.7 (C), 127.8 (CH), 126.9 (CH), 125.1 (CH), 124.7 (CH), 123.0 (CH), 122.0 (CH), 120.4 (CH),

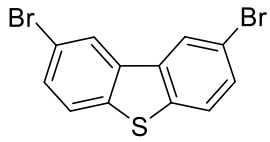
114.0 (2CH), 55.6 (CH_3), 44.4 (CH_2); IR (neat): ν = 2910, 1717, 1593, 1508, 1400, 1167, 751; HR-MS (ES-TOF): *m/z*: calcd for $C_{21}H_{17}O_2NS$: 333.0949, found 333.0950 $[M + H]^+$.

2-(Dibenzo[b,d]thiophen-4-yl)-1-(thiophen-2-yl)ethanone (139)



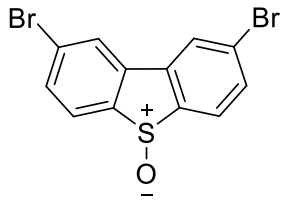
139 was prepared following **GP3** using dibenzothiophene-*S*-oxide (40 mg, 0.20 mmol), alkyne **128** (44 µl, 0.40 mmol), toluene (20 mL, 0.01 mmol) and Au-I (11.2 mg, 0.02 mmol, 5 mol%). Purification of the reaction mixture with column chromatography (9:1 hexane:EtOAc) afforded **139** (38 mg, 62%) as an orange oil; R_f 0.65 (9:1 hexane:EtOAc); ^{1}H-NMR (300 MHz, $CDCl_3$): δ = 8.19–8.11 (m, 1H), 8.09 (dd, *J* = 7.5, 1.2 Hz, 1H), 7.90–7.82 (m, 2H), 7.65 (dd, *J* = 4.9, 0.7 Hz, 1H), 7.51–7.38 (m, 4H), 7.11 (dd, *J* = 4.9, 4.0 Hz, 1H), 4.46 (s, 2H); ^{13}C-NMR (101 MHz, $CDCl_3$): δ = 189.2 (C), 143.9 (C), 139.9 (C), 138.9 (C), 136.2 (C), 136.2 (C), 134.4 (CH), 132.9 (CH), 129.2 (C), 128.4 (CH), 127.8 (CH), 127.0 (CH), 125.1 (CH), 124.7 (CH), 123.0 (CH), 122.0 (CH), 120.7 (CH), 45.5 (CH_2); IR (neat): ν = 3092, 3074, 1641, 1410, 1276, 1057, 750; HR-MS (EI-TOF): *m/z*: calcd for $C_{18}H_{12}OS_2$: 308.0330, found 308.0329 $[M + H]^+$.

2,8-Dibromodibenzothiophene (140)



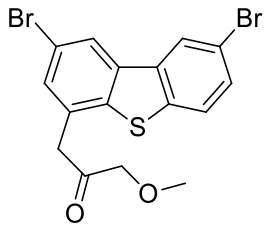
140 was prepared according to the literature procedure.[87] To dibenzothiophene (2.16 g, 10.8 mmol) in a RBF was added $CHCl_3$ (60 mL). The mixture was stirred and cooled to 0 °C. Bromine (1.56 mL, 61 mmol) was added over 15 minutes and the reaction was stirred for 72 hours. The white precipitate formed was filtered off under vacuum and washed with ethanol affording **140** (1.60 g, 43%) as a white solid; mp: 218-221 °C; ^{1}H NMR (300 MHz, $CDCl_3$): δ = 8.24 (m, 2H), 7.71 (m, 2H), 7.57 (m, 2H); Data matches that reported in the literature.[87]

2,8-Dibromodibenzo[b,d]thiophene 5-oxide (141)



141 was prepared according to a modified literature procedure.[88] 2,8 dibromodibenzothiophene **140** (3.65 mmol, 1.25 g) was added to a 250 mL RBF under argon, followed by CH_2Cl_2 (75 mL). The reaction was cooled to 0 ^oC and *m*CPBA (630 mg, 3.65 mmol), in CH_2Cl_2 (75 mL) was added over 25 minutes. The reaction was allowed to warm to rt and was worked up after 7 hours. The reaction mixture was washed with $NaHCO_3$ (3 × 50 mL), extracted with CH_2Cl_2 (3 × 50 mL), dried over Na_2SO_4, filtered, concentrated and purified by column chromatography (1:1 EtOAc: hexane) to afford the title compound as a white solid (170 mg, 13%); mp: >350 ^oC; ^1H NMR (300 MHz, $CDCl_3$): δ = 7.94 (d, *J* = 1.7 Hz, 2H), 7.86 (d, *J* = 8.1 Hz, 2H), 7.67 (dd, *J* = 8.1, 1.7 Hz, 2H); ^{13}C NMR (101 MHz, $CDCl_3$): δ = 144.5, 138.0, 133.3, 129.1, 127.8, 125.7; IR (neat): *ν* = 3073, 3047, 3012, 1575, 1557, 1455, 1404, 1382, 1056, 1025, 811. Data matches that reported in the literature.[88]

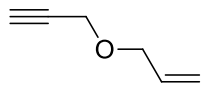
1-(2,8-Dibromodibenzo[b,d]thiophen-4-yl)-3-methoxypropan-2-one (142)



Sulfoxide **141** (71.6 mg, 0.20 mmol) was added to a 50 mL RBF with monomethyl propargyl ether (33.8 µl, 0.40 mmol) and $CHCl_3$ (30 mL). Au-I (11.2 mg, 0.01 mmol, 5 mol%) was added and the mixture was stirred at rt for 17 hours. Purification by column chromatography (CH_2Cl_2) afforded **142** (58 mg, 70%) as a white solid; R_f 0.07 (1:19 EtOAc:Hexane); mp: 139-141 ^oC; ^1H-NMR (300 MHz, $CDCl_3$): δ = 8.18 (s, 1H), 8.12 (s, 1H), 7.68 (d, *J* = 8.5 Hz, 1H), 7.56 (dd, *J* = 8.5 Hz, 1H), 7.46 (s, 1H), 4.12 (s, 2H), 4.00 (s, 2H), 3.45 (s, 3H); ^{13}C-NMR (101 MHz, $CDCl_3$): δ = 204.1 (C), 139.4 (C), 138.0 (C), 136.6 (C), 136.4 (C), 131.5 (CH), 130.6 (CH), 130.0 (C), 125.0 (CH), 124.3 (CH), 123.8 (CH), 119.1 (C), 119.0 (C), 77.6 (CH_2), 59.6

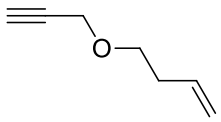
(CH_3), 44.8 (CH_2); IR (neat): *v* = 3067, 2901, 1723, 1567, 1410, 1319, 1072, 1042, 746; HR-MS (ES-TOF): *m/z*: calcd for $C_{16}H_{12}O_2NaS^{79}Br^{81}Br$: 450.8802, found 450.8801 $[M + Na]^+$.

3-(Prop-2-yn-1-yloxy)prop-1-ene (152)



Terminal alkyne **152** was prepared according to a literature procedure.[90] Propargyl alcohol (1.75 g, 31.0 mmol, 1.0 eq.) and allyl bromide (3.10 g, 38.8 mmol, 1.25 eq.) were added to a 25 mL RBF and the mixture was cooled to 0 °C. KOH (4 M) (8 mL) was added dropwise over 10 minutes. The mixture was refluxed at 70 °C for 6 hours. On cooling the mixture was extracted with Et_2O (20 mL), washed with water (3 × 10 mL), dried over Na_2SO_4, filtered and concentrated affording the title compound (2.00 g, 36%, (54% in Et_2O)) as a colourless oil; ^{1}H-NMR (300 MHz, $CDCl_3$): δ = 5.91 (ddt, *J* =17.2, 10.3, 5.8 Hz, 1H), 5.31 (dd, *J* = 17.2, 1.4 Hz, 2H), 5.24 (dd, *J* = 10.3, 1.4 Hz, 2H), 4.16 (d, *J* = 2.4 Hz, 2H), 4.08 (dt, *J* = 5.8, 1.3 Hz, 2H), 2.43 (t, *J* = 2.4 Hz, 1H); ^{13}C NMR (101 MHz, $CDCl_3$): δ = 133.9 (CH), 118.2 (CH_2), 79.8 (C), 74.6 (CH), 70.7 (CH_2), 57.2 (CH_2); IR (neat): v = 2920, 1076, 631. Data matches that reported in the literature.[90]

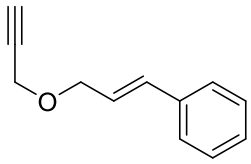
4-(Prop-2-yn-1-yloxy)but-1-ene (153)



Terminal alkyne **153** was prepared according to a literature procedure.[91] To a suspension of KOH in DMSO (25 mL), was added 3-buten-1-ol (1.08 mL, 12.5 mmol, 1.0 eq.) at 0 °C. After 10 minutes propargyl bromide (1.39 mL, 12.5 mmol, 1.0 eq.) was added. The reaction mixture was stirred at rt for 3 hours, diluted with water (50 mL) and extracted with Et_2O (3 × 30 mL). The organics were washed with water (4 × 20 mL), brine, dried Na_2SO_4, filtered, concentrated under reduced pressure and purified by column chromatography (2% Et_2O/Petroleum ether) affording **153** (430 mg, 17% (77% in Et_2O)) as a colourless oil; ^{1}H-NMR (300 MHz, $CDCl_3$): δ = 5.83 (ddt, *J* = 17.0, 10.2, 6.7 Hz, 1H), 5.12 (dd,

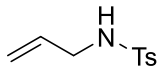
J = 17.0, 1.5 Hz), 5.06 (dd, *J* = 10.2, 1.5 Hz), 4.16 (d, *J* = 2.4 Hz, 2H), 3.59 (t, *J* = 6.7 Hz, 2H), 2.43 (t, *J* = 2.4 Hz, 1H), 2.41 – 2.32 (m, 2H); IR (neat): ν = 3289, 2923, 1722, 1679, 1434, 1359, 1047, 918, 789, 637. Data matches that reported in the literature.[91]

E)-(3-(prop-2-yn-1-yloxy)prop-1-en-1-yl)benzene (154)



154 was prepared according to a literature procedure.[92] To a 50 mL RBF was added propargyl alcohol (2.02 g, 36.0 mmol, 1.2 eq.), acetone (15 mL) and K_2CO_3 (4.98 g, 36.0 mmol). Cinnamyl bromide (5.92 g, 30.0 mmol, 1.0 eq.) was added and the mixture was heated to reflux for 12 hours. The mixture was cooled to rt, water was added and the mixture was extracted with EtOAc (3 × 20 mL), dried over Na_2SO_4, filtered and concentrated under reduced pressure. Purification by column chromatography (9:1 hexane:EtOAc) yielded the title compound (2.70 g, 49%) as a pale yellow oil; R_f 0.83 (7:3 hexane:EtOAc); ^{1}H NMR (300 MHz, $CDCl_3$): δ = 7.46 – 7.19 (m, 6H), 6.65 (d, *J* = 15.9 Hz, 1H), 6.28 (dt, *J* = 15.9, 6.2 Hz, 1H), 4.25 (dd, *J* = 6.2, 1.4 Hz, 2H), 4.21 (d, *J* = 2.4 Hz, 2H), 2.47 (t, *J* = 2.4 Hz, 1H); IR (neat): ν = 2852, 2117, 1735, 1495, 1449, 1356, 1242, 1116, 1073, 966, 743. 691. Data matches that reported in the literature.[92]

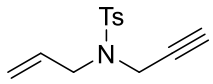
N-allyl-4-methylbenzenesulfonamide (155)



155 was prepared according to a literature procedure.[93] To a RBF under argon containing CH_2Cl_2 (32 mL) was added *p*-toluenesulfonyl chloride (2.17 g, 1.40 mmol, 1.14 eq.) followed by triethylamine (1.56 mL, 11.2 mmol) at 0 ºC. Allyl amine (0.75 mL, 10.0 mmol) was added dropwise and the reaction was stirred ar rt for 21 hours. To the reaction mixture was added NH_4Cl (60 mL of a saturated solution), the organic layer was separated, dried over Na_2SO_4, filtered, concentrated under reduced pressure and purified by column chromatography (9:1 hexane:EtOAc) to afford the title compound (1.95 g, 92%) as a

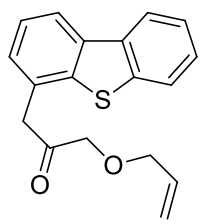
white solid; mp: 61-63 °C; ^{1}H NMR (300 MHz, $CDCl_3$): δ = 7.75 (d, *J* = 8.2 Hz, 2H), 7.32 (d, *J* = 8.2 Hz, 2H), 5.72 (ddt, *J* = 17.1, 10.2, 5.8 Hz, 1H), 5.16 (dd, *J* = 17.1, 1.4 Hz, 1H), 5.10 (dd, *J* = 10.2, 1.4 Hz, 1H), 4.38 (t, *J* = 6.0 Hz, 1H), 3.59 (tt, *J* = 6.2, 1.4 Hz, 2H), 2.43 (s, 3H); IR (neat): ν = 3246, 3046, 2926, 2854, 1649, 1596, 1494, 1423, 1318, 1157, 1092, 936, 811, 665. Data matches that reported in the literature.[93]

N-allyl-4-methyl-N-(prop-2-yn-1-yl)benzenesulfonamide (156)



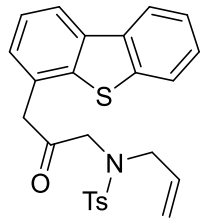
156 was prepared according to a literature procedure.[93] To a flame dried 2 neck flask containing a stirrer bar was added amine **155** (1.91 g, 9.04 mmol, 1.00 eq.). Anhydrous DMF (17 mL) was added, followed by the careful portionwise addition of NaH (60% in mineral oil) (470 mg, 11.8 mmol, 1.30 eq.). The mixture was stirred at rt for 1 hour, before the dropwise addition of propargyl bromide (80% in toluene) (1.66 mL, 14.9 mmol, 1.65 eq.) The reaction was then stirred for a further 80 minutes. The reaction mixture was then quenched with water (30 mL) and the product was extracted with diethyl ether (4 × 20 mL). The organic layer was dried over Na_2SO_4, filtered and concentrated under reduced pressure. Column chromatography (8:2 hexane:Et_2O) provided the title compound as a white solid; R_f 0.33 (8:2 hexane:Et_2O); mp: 61-62 °C; ^{1}H NMR (300 MHz, $CDCl_3$): δ = 7.76 (d, *J* = 8.3 Hz, 2H), 7.32 (d, *J* = 8.0 Hz, 2H), 5.75 (ddt, *J* = 16.5, 10.0, 6.5 Hz, 1H), 5.31 (dd, *J* = 16.5, 1.4 Hz, 1H), 5.26 (d, *J* = 10.0, 1.4 Hz, 1H), 4.11 (d, *J* = 2.4 Hz, 2H), 3.84 (d, *J* = 6.5 Hz, 2H), 2.45 (s, 3H), 2.02 (t, *J* = 2.5 Hz, 1H); IR (neat): ν = 3268, 2907, 2119, 1644, 1599, 1340, 1324, 1157, 928, 892, 752, 663. Data matches that reported in the literature.[93]

1-(Allyloxy)-3-(dibenzo[b,d]thiophen-4-yl)propan-2-one (158)



158 was prepared according to **GP2** using dibenzothiophene-*S*-oxide (100 mg, 0.50 mmol), 3-(prop-2-yn-1-yloxy)prop-1-ene **152** (54% wt% in Et_2O 177 mg, 1.0 mmol), and Au-I (11.2 mg, 0.02 mmol, 2 mol%). The reaction mixture was stirred for 2 hours at 0 °C and left to warm to rt for a further 14 hours. Column chromatography (CH_2Cl_2) afforded **158** (119 mg, 80%) as a yellow oil; R_f 0.34 (CH_2Cl_2); ^{1}H-NMR (300 MHz, $CDCl_3$): δ = 8.19–8.14 (m, 1H), 8.10 (dd, *J* = 7.9, 1.0 Hz, 1H), 7.90–7.83 (m, 1H), 7.52–7.43 (m, 3H), 7.35 (d, *J* = 7.2 Hz, 1H), 5.89 (ddt, *J* = 17.2, 10.4, 5.8 Hz, 1H), 5.27 (dd, *J* = 17.2, 1.5 Hz, 1H), 5.21 (dd, *J* = 10.4, 1.5 Hz 1H), 4.18 (s, 2H), 4.06 (s, 2H), 4.06–4.02 (m, 2H); ^{13}C-NMR (101 MHz, $CDCl_3$): δ = 205.0 (C), 140.0 (C), 139.0 (C), 136.2 (C), 136.1 (C), 133.8 (CH), 128.3 (C), 128.1 (CH), 127.0 (CH), 125.2 (CH), 124.7 (CH), 123.0 (CH), 122.0 (CH), 120.8 (CH), 118.3 (CH_2), 74.8 (CH_2), 72.6 (CH_2), 45.6 (CH_2); IR (neat): *v* = 2901, 1726, 1554, 1443, 1402, 1096, 912; HR-MS (ES-TOF): *m/z*: calcd for $C_{18}H_{16}O_2SNa$: 319.0769, found 319.0775 $[M + Na]^+$.

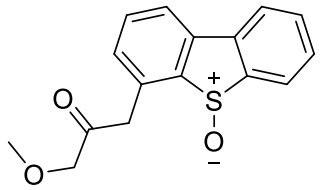
N-allyl-N-(3-(dibenzo[b,d]thiophen-4-yl)-2-oxopropyl)-4-methylbenzenesulfonamide (160)



160 was prepared according to **GP2** using dibenzothiophene-*S*-oxide (40 mg, 0.20 mmol), *N*-allyl-4-methyl-*N*-(prop-2-yn-1-yl)benzenesulfonamide **156** (96 mg, 0.40 mmol), and Au-I (11.2 mg, 0.02 mmol, 5 mol%). The reaction mixture was stirred for 2 hours 30 mins at 0 °C. Column chromatography (9:1 hexane:EtOAc) followed by recrystallization from hot MeOH afforded **160** (66 mg, 74%) as a white solid; R_f 0.31 (9:1 hexane:EtOAc); mp: 104-106 °C; ^{1}H NMR (300 MHz, $CDCl_3$): δ = 8.21 – 8.14 (m, 1H), 8.11 (dd, *J* = 8.1, 0.9 Hz, 1H), 7.91 – 7.82 (m, 1H), 7.65 (d, *J* = 8.3 Hz, 2H), 7.53 – 7.43 (m, 3H), 7.32 (d, *J* = 7.2 Hz, 1H), 7.21 (d, *J* = 8.1 Hz, 2H), 5.58 (ddt, *J* = 16.9, 10.1, 6.8 Hz, 1H), 5.03 (dd, *J* = 10.1, 1.1 Hz, 1H), 4.96 (dd, *J* = 16.9, 1.1 Hz, 1H), 4.10 (s,

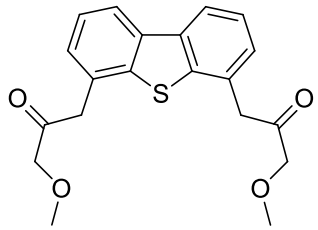
2H), 4.01 (s, 2H), 3.78 (d, *J* = 6.7 Hz, 2H), 2.36 (s, 3H); ^{13}C-NMR (101 MHz, $CDCl_3$): δ = 201.9 (C), 143.7 (C), 140.0 (C), 139.0 (C), 136.3 (C), 136.2 (C), 136.0 (C), 132.1 (CH), 129.8 (2CH), 128.2 (CH), 128.0 (C), 127.6 (2CH), 127.1 (CH), 125.3 (CH), 124.8 (CH), 123.0 (CH), 122.0 (CH), 120.9 (CH), 120.5 (CH_2) 54.4 (CH_2), 51.4 (CH_2), 46.4 (CH_2), 21.6 (CH_3); IR (neat): *v* = 1731, 1443, 1397, 1153, 1045, 924, 752; HR-MS (ES-TOF): *m/z*: calcd for $C_{25}H_{24}NO_3S_2$: 450.1198, found 450.1180 $[M + H]^+$.

1-Methoxy-3-(5-oxidodibenzo[b,d]thiophen-4-yl)propan-2-one (166)



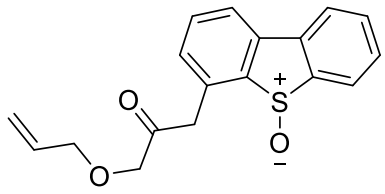
*m*CPBA (129 mg, 0.75 mmol, 1.1 equiv.) was added in 5 portions over 10 minutes to a solution of **131** (184 mg, 0.68 mmol) in CH_2Cl_2 (15 mL) at 0 °C. The reaction was allowed to warm to rt over 2 hours, worked up, washed with $NaHCO_3$ (4 × 10 mL), extracted with CH_2Cl_2 (4 × 10 mL), dried over Na_2SO_4, filtered and concentrated under reduced pressure. Purification by column chromatography (8:2 hexane:EtOAc to EtOAc) afforded firstly **131** (37 mg, 20%) and then **166** (120 mg, 61%) as a white solid; R_f 0.25 (EtOAc); mp: 110-112 °C ; ^{1}H-NMR (300 MHz, $CDCl_3$): δ = 7.95 (d, *J* = 7.5 Hz, 1H), 7.79 (d, *J* = 7.6 Hz, 1H), 7.73 (d, *J* = 7.2 Hz, 1H), 7.59 (td, *J* = 7.6, 1.1 Hz, 1H), 7.56 (t, *J* = 7.6 Hz, 1H), 7.49 (td, *J* = 7.6, 1.1 Hz, 1H), 7.29 (d, *J* = 7.6 Hz, 1H), 4.34–4.15 (m, 4H), 3.46 (s, 3H); ^{13}C-NMR (101 MHz, $CDCl_3$): δ = 204.4 (C), 144.6 (C), 143.9 (C), 137.7 (C), 137.2 (C), 134.9 (C), 133.1 (CH), 132.8 (CH), 131.6 (CH), 129.7 (CH), 127.5 (CH), 122.2 (CH), 121.1 (CH), 77.6 (CH_2), 59.6 (CH_3), 42.4 (CH_2); IR (neat): *v* = 3047, 2925, 2827, 1725, 1448, 1049, 1012; HR-MS (ES-TOF): *m/z*: calcd for $C_{16}H_{14}O_3SNa$: 309.0561, found 309.0556 $[M + Na]^+$.

3,3'-(Dibenzo[b,d]thiophene-4,6-diyl)bis(1-methoxypropan-2-one) (167)



Sulfoxide **167** (85.9 mg, 0.30 mmol) and monomethyl propargyl ether (51 µl, 0.6 mmol) were dissolved in toluene (3 mL). Au-I (16.8 mg, 0.015 mmol) was added and the reaction was stirred at rt for 16 hours. The reaction mixture was filtered through a plug of silica and washed with CH_2Cl_2 (10 mL). The reaction mixture was concentrated under reduced pressure and purified by column chromatography (1:1 hexane:EtOAc) to afford **167** (60.5 mg, 58%) as a yellow crystalline solid; R_f 0.25 (1:1 hexane:EtOAc); mp: 70–72 ^oC; ^1H-NMR (300 MHz, $CDCl_3$): δ = 8.10 (dd, *J* = 7.9, 0.9 Hz, 2H), 7.48 (appt, *J* = 7.6 Hz, 2H), 7.35 (d, *J* = 7.2 Hz, 2H), 4.13 (s, 4H), 4.05 (s, 4H), 3.42 (s, 6H); ^{13}C-NMR (101 MHz, $CDCl_3$): δ = 204.7 (C), 139.5 (C), 136.7 (C), 128.3 (CH), 128.2 (C), 125.4 (CH), 121.1 (CH), 77.3 (CH_2), 59.5 (CH_3), 45.5 (CH_2); IR (neat): *v* = 2927, 1721, 1572, 1049, 912, 778, 727; HR-MS (ES-TOF): *m/z*: calcd for $C_{20}H_{20}O_4NaS$: 379.0980, found 379.0999 $[M + Na]^+$.

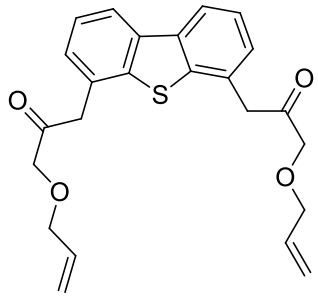
1-(Allyloxy)-3-(5-oxidodibenzo[b,d]thiophen-4-yl)propan-2-one (168)



*m*CPBA (72.3 mg, 0.42 mmol, 1.1 equiv) was added portionwise to a solution of **158** (113 mg, 0.38 mmol) in CH_2Cl_2 (10 mL) at 0 ^oC. The reaction was allowed to warm to rt over 2 hours, worked up, washed with $NaHCO_3$ (4 × 10 mL), extracted with CH_2Cl_2 (4 × 10 mL), dried over Na_2SO_4, filtered and concentrated under reduced pressure. Purification by column chromatography (1:4 EtOAc:hexane) to (EtOAc) afforded firstly **158** (25 mg, 22%) and **168** (74 mg, 62%) as a white solid; R_f 0.37 (7:3 EtOAc:hexane); mp: 98-100 ^oC; ^1H-NMR (300 MHz, $CDCl_3$): δ = 7.96 (d, *J* = 7.5 Hz, 1H), 7.80 (d, *J* = 7.6 Hz, 1H), 7.74 (d, *J* = 7.5 Hz, 1H), 7.64–7.53 (m, 2H), 7.50 (td, *J* = 7.5, 0.9 Hz, 1H), 7.29 (d, *J* = 7.6 Hz, 1H), 5.94 (ddt, *J* = 17.2, 10.5, 5.7 Hz, 1H), 5.32 (dd, *J* = 17.2, 1.5 Hz, 1H), 5.24 (dd, *J* = 10.5, 1.2 Hz, 1H), 4.38–4.17

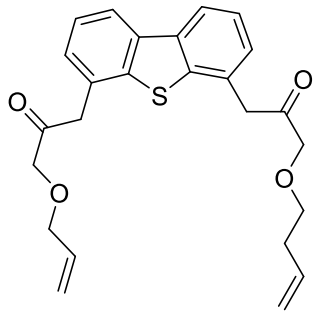
(m, 4H), 4.11 (d, *J* = 5.8 Hz, 2H); ^{13}C-NMR (101 MHz, $CDCl_3$): δ = 204.6 (C), 144.7 (C), 144.0 (C), 137.7 (C), 137.3 (C), 135.0 (C), 133.9 (CH), 132.7 (CH), 132.7 (CH), 131.7 (CH), 129.7 (CH), 127.5 (CH), 122.2 (CH), 121.0 (CH), 118.3 (CH_2), 75.1 (CH_2), 72.7 (CH_2), 42.5 (CH_2); IR (neat): *v* = 3050, 2857, 1725, 1551, 1485, 1424, 1321, 1161, 1145, 1070, 1045, 1012, 762; HR-MS (ES-TOF): *m/z*: calcd for $C_{18}H_{17}O_3S$: 313.0898, found 313.0906 $[M + H]^+$.

3,3'-(Dibenzo[b,d]thiophene-4,6-diyl)bis(1-(allyloxy)propan-2-one) (169)



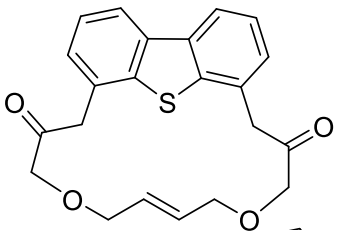
Sulfoxide **168** (68 mg, 0.22 mmol) and enyne **152** (54 wt% in Et_2O, 78.3 mg, 0.44 mmol) were dissolved in toluene (8.8 mL, 0.025 M). After stirring for 20 minutes the reaction mixture was transferred to an ice bath at 0 ºC. Au-I (12.3 mg, 0.011 mmol, 5 mol%) was added and after 3 hours Au-I (6.1 mg, 0.0055 mmol, 2.5 mol%) was added and the reaction mixture was stirred for a further 1 hour at 0 ºC. The reaction mixture was filtered through a plug of silica and washed with CH_2Cl_2 (10 mL). The reaction mixture was concentrated under reduced pressure and purified by column chromatography (4:1 hexane:EtOAc) providing **169** (65 mg, 73%) as a white solid; R_f 0.58 (1:1 EtOAc: hexane); mp: 77-80 ºC; ^{1}H-NMR (300 MHz, $CDCl_3$): δ = 8.08 (d, *J* = 7.7 Hz, 2H), 7.47 (appt, *J* = 7.6 Hz, 2H), 7.34 (d, *J* = 7.2 Hz, 2H), 5.90 (ddt, *J* = 17.2, 10.4, 5.7 Hz, 1H), 5.27 (app d, *J* = 17.2 Hz, 1H), 5.21 (app d, *J* = 10.4 Hz, 1H) 4.17 (s, 4H), 4.11-4.01 (m, 8H); ^{13}C-NMR (101 MHz, $CDCl_3$): δ = 204.8 (2C), 139.5 (2C), 136.6 (2C), 133.8 (2CH), 128.3 (2CH), 128.3 (2C), 125.4 (2CH), 121.0 (2CH), 118.3 ($2CH_2$), 74.8 (CH_2), 72.6 (CH_2), 45.6 ($2CH_2$); IR (neat): *v* = 2855, 1722, 1574, 1426, 1390, 1331, 1164, 1060, 1045; HR-MS (ES-TOF): *m/z*: calcd for $C_{24}H_{24}O_4NaS$: 431.1293, found 431.1288 $[M + Na]^+$.

1-(Allyloxy)-3-(6-(3-(but-3-en-1-yloxy)-2-oxopropyl)dibenzo[b,d]thiophen-4-yl)propan-2-one (170)



Sulfoxide **168** (60 mg, 0.192 mmol) and ene-yne **153** (77% wt% in Et_2O, 50 mg, 0.348 mmol) were dissolved in toluene (0.025 M, 10 mL). After stirring for 20 minutes at rt the reaction was transferred to an ice bath at 0 ^oC and Au-I (7.5 mol%) was added. The reaction was stirred for 4 hours filtered through a pad of silica washing with CH_2Cl_2, concentrated and purified by column chromatography (1:4 EtOAc:hexane) to afford **170** (68 mg, 83%) as an off white solid; R_f 0.81 (1:1 EtOAc:hexane); mp: 57-59 ^oC; ^{1}H-NMR (300 MHz, $CDCl_3$): δ = 8.02 (dd, *J* = 7.9, 0.8 Hz, 2H), 7.40 (app t, *J* = 7.6, 2H), 7.28 (d, *J* = 7.3 Hz, 2H), 5.91–5.68 (m, 2H), 5.21 (dd, *J* = 17.2, 1.6 Hz, 1H), 5.15 (dd, *J* = 10.2, 1.6 Hz, 1H), 5.04 (dd, *J* = 17.2, 1.6 Hz, 1H), 4.97 (dd, *J* = 10.2, 1.6 Hz, 1H), 4.10 (s, 4H), 4.02–3.96 (m, 6H), 3.48 (t, *J* = 6.7 Hz, 2H), 2.37–2.27 (m, 2H); ^{13}C-NMR (101 MHz, $CDCl_3$): δ = 205.1 (C), 204.9 (C), 139.6 (2C), 136.7 (2C), 134.9 (CH), 133.8 (CH), 128.3 (2CH), 128.2 (2C), 125.4 (2CH), 121.0 (2CH), 118.3 (CH_2), 117.0 (CH_2), 75.9 (CH_2), 74.8 (CH_2), 72.6 (CH_2), 71.3 (CH_2), 45.6 ($2CH_2$), 34.2 (CH_2); IR (neat): ν = 2860, 1721, 1644, 1575, 1476, 143, 1061, 913, 776; HR-MS (ES-TOF): *m/z*: calcd for $C_{25}H_{26}O_4NaS$: 445.1450, found 445.1429 $[M + Na]^+$.

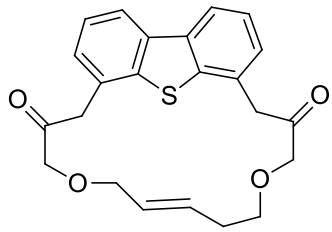
Macrocycle 1 (171)



To a solution of **169** (100 mg, 0.245 mmol) in CH_2Cl_2 (25 mL) was added Grubbs 2nd generation catalyst (10.4 mg, 0.012 mmol). The reaction mixture was heated to reflux for 1 hour, allowed to cool, concentrated and purified by column chromatography (3:7 EtOAc:hexane) to afford **171** (80 mg, 86%) as a white solid; R_f 0.58 (1:1 EtOAc:hexane); mp: 165-167 ^oC; ^{1}H-NMR (300 MHz, $CDCl_3$): δ = 8.08 (d, *J* = 7.2 Hz, 2H), 7.48 (app t, *J* = 7.6 Hz,

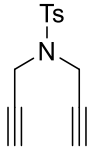
2H), 7.39 (d, *J* = 7.0 Hz, 2H), 5.74–5.60 (m, 2H), 4.19 (s, 4H), 4.02 (s, 4H), 3.96 (dd, *J* = 3.0, 1.3 Hz, 4H); ^{13}C-NMR (101 MHz, $CDCl_3$): δ = 205.0 (2C), 139.2 (2C), 136.7 (2C), 130.2 (2CH), 128.1 (2CH), 128.1 (2C), 125.7 (2CH), 121.1 (2CH), 74.3 ($2CH_2$), 71.1 (CH_2), 45.6 (CH_2); IR (neat): *v* = 2855, 1722, 1574, 1426, 1390, 1331, 1144, 1060, 1045, 919, 776, 731; HR-MS (ES-TOF): *m/z*: calcd for $C_{22}H_{20}O_4NaS$: 403.0980, found 403.0996 $[M + Na]^+$.

Macrocycle 2 (172)



To a solution of **170** (50 mg, 0.118 mmol) in CH_2Cl_2 (25 mL) was added Grubbs 2nd generation catalyst (5.0 mg, 0.006 mmol). The reaction mixture was heated to reflux for 2 hours, concentrated and purified by column chromatography (7:3 EtOAc:hexane) to afford **172** (35 mg, 70%) as a white solid; R_f 0.48 (1:1 EtOAc:hexane); mp: 138-139 ^oC ; ^{1}H-NMR (300 MHz, $CDCl_3$): δ = 8.07 (d, *J* = 7.8 Hz, 2H), 7.48 (td, *J* = 7.6, 3.1 Hz, 2H), 7.37 (d, *J* = 5.1 Hz, 2H), 6.11–5.95 (m, 1H), 5.69 (dt, *J* = 15.0, 5.6 Hz, 1H), 4.18 (s, 4H), 4.15-4.05 (m, 6H), 3.64 (t, *J* = 5.8 Hz, 2H), 2.42 (dd, *J* = 11.6, 5.6 Hz, 2H); ^{13}C-NMR (101 MHz, $CDCl_3$): δ = 206.6 (C), 205.8 (C), 139.2 (C), 139.1 (C), 136.7 (C), 136.6 (C), 132.0 (CH), 128.7 (CH), 128.7 (CH), 128.4 (C), 127.4 (CH), 125.4 (2CH), 121.0 (CH), 120.9 (CH), 76.3 (CH_2), 74.4 (CH_2), 71.7 (CH_2), 71.2 (CH_2), 44.7 (CH_2), 44.2 (CH_2), 32.8 (CH_2); IR (neat): *v* = 2861, 1720, 1644, 1575, 1426, 1143, 1062, 914, 775; HR-MS (ES-TOF): *m/z*: calcd for $C_{23}H_{22}O_4NaS$: 417.1137, found 417.1136 $[M + Na]^+$.

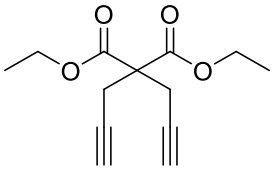
4-Methyl-N,N-di(prop-2-yn-1-yl)benzenesulfonamide (173)



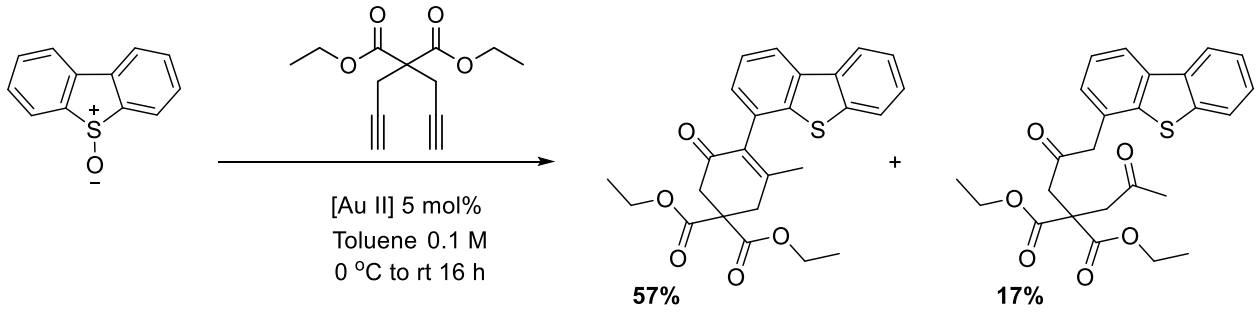
173 was prepared according to a literature procedure.[94] A RBF under argon was charged with *p*-toluenesulfonamide (399 mg, 2.33 mmol, 1.0 eq.) and acetone (10 mL). Upon dissolving, cesium carbonate (2.28 g, 7.00 mmol, 3.0 eq.) was added. Propargyl bromide

(0.92 mL, 7.00 mmol, 3.0 eq.) was added and the mixture was stirred at rt for 16 hours. The solvent was removed under reduced pressure, the residual solid was dissolved in water (10 mL) and CH_2Cl_2 (10 mL) was added. The layers were separated and the aqueous layer was extracted with CH_2Cl_2 (10 mL). The combined organic layers were dried over Na_2SO_4, filtered, concentrated under reduced pressure and purified by column chromatography (5:1 petroleum ether:EtOAc) to afford the title compound (508 mg, 88%) as a pale yellow solid; R_f 0.18 (5:1 petroleum ether:EtOAc); mp: 57-59 ºC; ^{1}H NMR (300 MHz, $CDCl_3$): δ = 7.72 (d, *J* = 8.1 Hz, 2H), 7.30 (d, *J* = 8.1 Hz, 2H), 4.16 (d, *J* = 2.2 Hz, 4H), 2.43 (s, 3H), 2.15 (t, *J* = 2.2 Hz, 2H); ^{13}C NMR (101 MHz, $CDCl_3$): δ = 144.1 (C), 135.3 (C), 129.7 (2CH), 128.0 (2CH), 76.3 (2C), 74.2 (2CH), 36.3 (CH_2), 21.7 (CH_3); IR (neat): ν = 3278, 3065, 1699, 1410, 1341, 1305, 1093, 957, 751. Data matches that reported in the literature.[94]

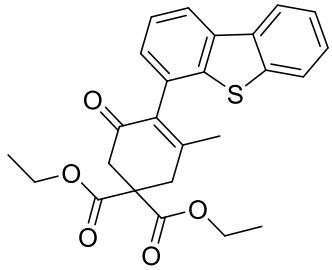
Diethyl 2,2-di(prop-2-yn-1-yl)malonate (174)



174 was prepared according to a literature procedure.[94] A RBF containing dry Et_2O (10 mL) in ice was charged with NaH (304 mg, 9.08 mmol, 2.0 eq.) in small portions. Diethyl malonate (727 mg, 4.54 mmol, 1.0 eq.) was added dropwise. Propargyl bromide (1.18 g, 9.08 mmol, 2.0 eq.) was added dropwise and the reaction mixture was stirred for 16 hours at rt. Water (20 mL) was added slowly, the organic layer was separated, the aqueous layer was washed with EtOAc (15 mL × 3), dried over Na_2SO_4, evaporated under reduced pressure and purified by column chromatography (5:1 petroleum ether:EtOAc) to afford the title compound (538 mg, 50%) as a white solid; ^{1}H NMR (300 MHz, $CDCl_3$): δ = 4.23 (q, *J* = 7.1 Hz, 2H), 2.99 (d, *J* = 2.6 Hz, 2H), 2.03 (t, *J* = 2.6 Hz, 1H), 1.26 (t, *J* = 7.1 Hz, 3H); IR (neat): ν = 3289, 2984, 1734, 1447, 1368, 1288, 1189, 1055, 856. Data matches that reported in the literature.[94, 176]

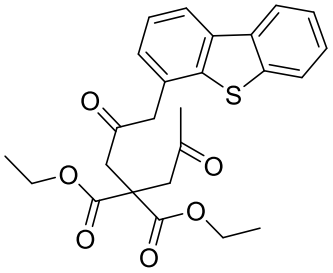


Diethyl 4-(dibenzo[b,d]thiophen-4-yl)-3-methyl-5-oxocyclohex-3-ene-1,1-dicarboxylate (178)



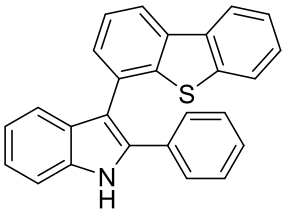
178 was prepared according to **GP2** using dibenzothiophene-*S*-oxide (40 mg, 0.20 mmol), diyne **174** (48.6 mg, 0.40 mmol), toluene (2 mL) and Au-I (11.2 mg, 5 mol%). The reaction was stirred for 2 hours at 0 °C before allowing to warm to rt for 16 hours. Column chromatography (3:7 hexane:CH_2Cl_2 to CH_2Cl_2) afforded **178** (49 mg, 57%) as a clear oil; R_f 0.48 (3:7 EtOAc:hexane); ^{1}H NMR (300 MHz, $CDCl_3$): δ = 8.13 (ddd, *J* = 12.9, 5.7, 2.4 Hz, 2H), 7.83 – 7.75 (m, 1H), 7.55–7.37 (m, 3H), 7.11 (dd, *J* = 7.2, 1.0 Hz, 1H), 4.44–4.21 (m, 4H), 3.32-2.94 (m, 2H), 1.85 (s, 3H), 1.32 (t, *J* = 7.1 Hz, 3H), 1.31 (t, *J* = 7.1 Hz, 3H); ^{13}C NMR (101 MHz, $CDCl_3$): δ = 192.4 (C), 169.9 (C), 156.3 (C), 140.1 (C), 139.4 (C), 136.1 (C), 135.8 (C), 128.2 (CH), 126.8 (CH), 124.7 (CH), 124.5 (CH), 122.8 (CH), 121.8 (CH), 121.0 (CH), 62.6 (CH_2), 62.4 (CH_2), 55.0 (C), 42.6 (CH_2), 37.5 (CH_2), 22.7 (CH_3), 14.2 ($2CH_3$); IR (neat): *v* = 2982, 1729, 1673, 1302, 1250, 1167, 752; HR-MS (ES-TOF): *m/z*: calcd for $C_{25}H_{24}O_5{}^{23}NaS$: 459.1242, found 459.1229 $[M + Na]^+$.

Diethyl 2-(3-(dibenzo[b,d]thiophen-4-yl)-2-oxopropyl)-2-(2-oxopropyl)malonate (177)



177 (15 mg, 17%) eluted second (CH_2Cl_2) in the above reaction as a clear oil; R_f 0.42 (3:7 EtOAc:hexane); ^{1}H NMR (300 MHz, $CDCl_3$): δ = 8.18–8.12 (m, 1H), 8.09 (dd, *J* = 7.9, 0.9 Hz, 1H), 7.87–7.81 (m, 1H), 7.50–7.42 (m, 3H), 7.31 (d, *J* = 7.0 Hz, 1H), 4.13 (q, *J* = 7.1 Hz, 2H), 4.12 (q, *J* = 7.1 Hz, 2H), 3.97 (s, 2H), 3.50 (s, 2H), 3.31 (s, 2H), 1.99 (s, 3H), 1.17 (t, *J* = 7.0 Hz, 6H); ^{13}C NMR (101 MHz, $CDCl_3$): δ = 206.0 (C), 204.6 (C), 169.5 (2C), 139.9 (C), 139.1 (C), 136.3 (C), 136.0 (C), 128.4 (CH), 128.2 (C), 127.1 (CH), 125.3 (CH), 124.8 (C), 122.9 (C), 122.0 (CH), 120.8 (CH), 62.1 ($2CH_2$), 53.2 (C), 49.4 (CH_2), 45.8 (CH_2), 44.9 (CH_2), 30.2 (CH_3), 14.0 ($2CH_3$); IR (neat): *ν* = 2982, 2930, 1719, 1444, 1403, 1364, 1201, 1096, 754; HR-MS (ES-TOF): *m/z*: calcd for $C_{25}H_{26}O_6SNa$: 477.1348, found 477.1339 $[M + Na]^+$.

3-(Dibenzo[b,d]thiophen-4-yl)-2-phenyl-1H-indole (179)

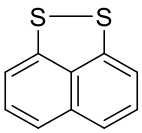


To substituted dibenzothiophene **136** (55 mg, 0.183 mmol, 1.0 eq.) was added AcOH (0.80 ml), TFA (0.28 ml) and phenylhydrazine (45 µL, 0.46 mmol, 2.5 eq.) in a sealed (ace) tube. The reaction was stirred at 100 ^{o}C for 28 hours at which point reaction completion was observed by TLC. The mixture was added to 10 mL ice/water, the mixture was extracted with with CH_2Cl_2 (10 mL × 3) and the organic portions were washed with HCl (1M, 5 mL), water (5 mL), dried over Na_2SO_4, concentrated and purified by column chromatography (1:9 EtOAc:hexane) to afford **179** (45.6 mg, 66%) as a viscous orange oil; R_f 0.31 (1:9 EtOAc:hexane); ^{1}H-NMR (300 MHz, $CDCl_3$): δ = 8.46 (s, 1H), 8.21 (ddd, *J* = 7.6, 5.6, 1.4 Hz, 2H), 7.77–7.70 (m, 1H), 7.59–7.48 (m, 3H), 7.48–7.41 (m, 3H), 7.40–7.34 (m, 2H), 7.33–7.20 (m, 4H), 7.13 (td, *J* = 7.6, 0.9 Hz, 1H); ^{13}C-NMR (101 MHz, $CDCl_3$): δ = 141.4 (C), 140.1 (C), 136.1 (C), 136.0 (2C),

134.8 (C), 132.5 (C), 130.5 (C), 129.3 (CH), 128.9 (2CH), 128.8 (C), 127.9 (CH), 127.3 (2CH), 126.7 (CH), 125.0 (CH), 124.3 (CH), 123.0 (CH), 122.9 (CH), 121.8 (CH), 120.4 (CH), 120.4 (CH), 120.3 (CH), 113.5 (C), 111.1 (CH); IR (neat): ν = 3408, 3057, 1578, 1487, 1442, 1384, 1253, 905, 742, 693; HR-MS (ES-TOF): *m/z*: calcd for $C_{26}H_{18}NS$: 376.1160, found 376.1170 $[M + H]^+$.

5.3 Experimental section:Chapter 3

Naphtho [1,8-cd][1,2]dithiole (205)

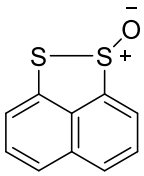


Disulfide **205** was prepared according to the literature procedure.[83] A 500 mL 3 neck RBF was fitted with a reflux condenser, a thermometer and a septa. The flask was purged with argon, *n*-BuLi in hexanes (73.6 mL, 120 mmol, 1.2 eq.) was added and was diluted with dry Et_2O (80 mL). The mixture was cooled to 0 ^oC and 1-bromo naphthalene (20.0 g, 100 mmol, 1.0 eq.) was added over 20 min preventing the temperature from rising above 10 ^oC. After stirring for an additional 15 min the reaction was cooled to -10 ^oC and stirring was stopped. On standing for 10 min the supernatant was removed by cannula. Hexane (250 mL) was added and stirring continued at -20 ^oC for 10 min. On standing for a further 10 min the supernatant was removed by cannula. This was repeated twice.

n-BuLi in hexanes (79.8 mL, 130 mmol, 1.3 eq.) followed by TMEDA (16.3 g, 140 mmol, 1.4 eq.) was added to the suspension. The mixture was heated at reflux for 3 h and left to cool to room temperature. The reaction was cooled to -78 ^oC and THF (80 mL) was added to dissolve the solid. The mixture was stirred for 20 minutes at -78 ^oC before addition of sulfur (202 mmol 6.54 g, 2.02 eq.) and the reaction mixture was stirred for 16 hours. The reaction was quenched with HCl (30 mL of a 1 M solution) followed by filtration through a pad of celite. The organic phase was separated and the aqueous phase acidified to pH 1. The aqueous layer was then extracted with diethyl ether (3 × 30 mL). The organic fractions were combined, dried over $MgSO_4$ and the solvent was concentrated under reduced pressure giving a red-brown oil. The product was purified by column chromatography (petroleum ether), and recrystallised in EtOH to give **205** (4.00 g, 21.0%) as bright red crystals; R_f 0.65 (petroleum ether): mp: 108-110 ^oC; ^1H NMR (300 MHz, $CDCl_3$): δ = 7.36 (d, *J* = 8.1, 0.7 Hz, 2H), 7.27 (t, *J* = 7.3 Hz, 2H), 7.15 (dd, *J* = 7.3, 0.7 Hz, 2H); ^{13}C NMR (100 MHz, $CDCl_3$): δ = 144.0 (2C), 135.6 (C), 134.7 (C),

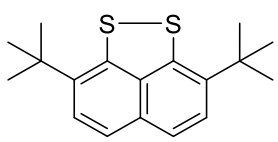
127.8 (2CH), 121.6 (2CH), 115.9 (2CH); m/z (EI) 190 (M^+, 100). Data matches that reported in the literature.[83,177]

Naphtho [1,8-cd][1,2]dithiole-1-oxide (212)



Disulfide monoxide **212** was prepared according to the literature procedure.[83] A solution of *m*CPBA (998 mg, 5.78 mmol) dissolved in CH_2Cl_2 (42 mL) was added dropwise over 30 minutes to a stirred solution of **205** (1.00 g, 5.26 mmol) in CH_2Cl_2 (21 mL) at 0 °C. The reaction mixture was allowed to warm to rt over 2 h. The mixture was quenched with $NaHCO_3$ (5 mL of a saturated aqueous solution) and extracted with CH_2Cl_2 (4 × 10 mL). The organics were combined, dried over $MgSO_4$, concentrated under reduced pressure, purified by column chromatography (6:4 hexane:Et_2O) and recrystallised (ethanol) to give **212** (850 mg, 79%); R_f 0.25 (6:4 hexanes:EtOAc); mp: 84-86 °C (ethanol); ^{1}H NMR (300 MHz, $CDCl_3$): δ = 8.21 (dd, *J* = 7.3, 0.9 Hz, 1H), 8.16 (d, *J* = 8.1, 0.9 Hz, 1H), 7.82 (app t, *J* = 8.1 Hz, 1H), 7.84 (dd, *J* = 8.1, 0.9 Hz, 1H), 7.67 (t, *J* = 7.6 Hz, 1H), 7.61 (dd, *J* = 8.1, 0.9 Hz, 1H); m/z (EI) 190 $[M - O]^+$(100), 192 (9), 114 (8). Data matches that reported in the literature.[178,179]

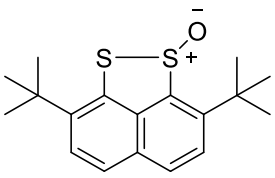
3,8-Di-tert-butylnaphtho[1,8-c,d][1,2]dithole (224)



Disulfide **224** was prepared according to the literature procedure.[83] *t*-BuBr (2.89 g, 21.0 mmol) was added to a solution of **205** (2.00 g, 10.50 mmol) in CH_2Cl_2 (4 mL). $FeCl_3$ (341 mg, 2.102 mmol. 0.2 eq.) was added and the reaction mixture was heated at reflux for 16 hours. The reaction mixture was allowed to cool to rt and filtered through a silica plug (petroleum ether). The solution was concentrated under reduced pressure and recrystallized from hot acetone yielding **224** (2.32 g, 73%) as orange crystals; R_f 0.96 (95:5 petroleum ether:Et_2O); mp: 153-155 °C (acetone); ^{1}H NMR (300 MHz, $CDCl_3$): δ

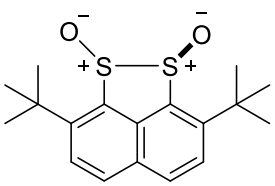
= 7.40 (d, *J* = 8.6 Hz, 2H), 7.35 (d, *J* = 8.6 Hz, 2H), 1.50 (s, 18H); ^{13}C NMR (100 MHz, $CDCl_3$): δ = 139.4 (2C), 138.9 (2C), 133.1 (2C), 125.7 (2CH), 121.9 (2CH), 35.6 (2C), 28.4 ($2CH_3$); *m/z* (EI) 287 $[M - CH_3]^+$ (100), 288 (18), 289 (10), 302 (70), 303 (13). Data matches that reported in the literature.[180]

3,8-Di-tert-butylnaphtho[1,8-c,d][1,2]dithole 1-oxide (213)



Disulfide monoxide **213** was prepared according to the literature procedure.[83] **224** (230 mg, 0.761 mmol) in CH_2Cl_2 (8 mL) was cooled to 0°C. *m*CPBA (144 mg, 0.836 mmol) in CH_2Cl_2 (16 mL) was added by syringe over 20 min. The reaction was left to warm to rt and stirred for 16 hours. The reaction mixture was washed with NaOH (3 × 5 mL of a 0.1 M aqueous solution) and extracted with CH_2Cl_2 (3 × 5 mL), dried $MgSO_4$, filtered, concentrated under reduced pressure and purified by column chromatography (9:1 hexanes:EtOAc) giving **213** (171 mg, 71%) as a light yellow solid**.** R_f 0.32 (9:1 hexanes:EtOAc); mp: 153-155 °C; ^{1}H NMR (300MHz, $CDCl_3$): δ = 8.03 (d, *J* = 8.7 Hz, 1H), 7.83 (d, *J* = 8.7 Hz, 1H), 7.76 (app q, *J* = 8.7 Hz, 2H), 1.75 (s, 9H,), 1.59 (s, 9H); ^{13}C NMR (100 MHz, $CDCl_3$): δ = 151.7 (C), 146.2 (C), 145.5 (C), 131.7 (CH), 131.5 (C), 131.3 (C), 131.0 (C), 127.1 (CH), 126.8 (CH), 125.4 (CH), 38.2 (C), 36.4 (C), 33.3 (CH_3), 30.5 $(CH)_3$; *m/z* (ES) 341 $(M + Na)^+$ (100), 319.1 (8), 357.1 (14), 373.2 (13), 425.2 (6). Data matches that reported in the literature.[83]

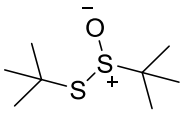
3,8-Di-tert-butylnaphtho[1,8-c,d][1,2]dithole 1,2-dioxide (214)



Vic-disulfoxide **214** was prepared according to the literature procedure.[83] **224** (500 mg, 1.65 mmol) in CH_2Cl_2 (15 mL) was cooled 0 °C. *m*CPBA (598 mg, 3.47 mmol) in CH_2Cl_2 (70 mL) was added by syringe over 20 minutes, the reaction was left to warm to rt and stirred for 16 hours. The reaction

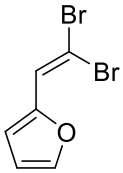
mixture was washed with NaOH (3 × 10 mL of a 0.1 M aqueous solution) and extracted with CH_2Cl_2 (3 × 10 mL), dried over $MgSO_4$, filtered, concentrated under reduced pressure and purified by column chromatography (8:2 hexanes:EtOAc) to give **214** (353 mg, 64%) as a yellow solid; R_f 0.29 (8:2 hexanes:EtOAc); mp: 172-174 °C; ^{1}H NMR (300 MHz, $CDCl_3$): δ = 8.06 (d, *J* = 8.7 Hz, 2H), 7.85 (d, *J* = 8.7 Hz, 2H), 1.71 (s, 18H); ^{13}C NMR (100 MHz, $CDCl_3$): δ = 155.2 (2C), 139.5 (2C), 138.8 (C), 132.7 (C), 132.3 (2CH), 127.4 (2CH), 38.0 (2C), 33.2 ($2CH_3$); m/z (ES) 357 $[M + Na]^+$ (100), 389 (25), 358 (18), 355 (7), 341 (7). Data matches that reported in the literature.[83]

S-tert-butyl 2-methylpropane-2-sulfinothioate (215)



Monoxide **215** was prepared according to the literature procedure.[83] To a RBF was added di-*tert* butyl disulfide (966 µL, 5.0 mmol, 1.0 eq.) and CH_2Cl_2 (20 mL). *m*CPBA (949 mg, 5.5 mmol, 1.1 eq.) in CH_2Cl_2 (30 mL) was added by syringe over 20 minutes and the reaction was left to warm to rt and stirred for 3 hours. The reaction mixture was washed with NaOH (3 × 10 mL of a 0.1 M aqueous solution) and extracted with CH_2Cl_2 (3 × 10 mL), dried over $MgSO_4$, filtered, concentrated under reduced pressure and purified by column chromatography (5:1 hexanes:EtOAc) to give **215** (567 mg, 58%) as a colourless oil; R_f 0.48 (8:2 hexanes:EtOAc); ^{1}H NMR (300 MHz, $CDCl_3$): δ = 1.55 (s, 9H), 1.38 (s, 9H); ^{13}C NMR (101 MHz, $CDCl_3$): δ = 59.5 (C), 48.8 (C), 32.5 ($3CH_3$), 24.4 ($3CH_3$); IR (neat): ν = 2962, 2925, 2900, 2866, 1471, 1456, 1393, 1365, 1163, 1070. Data matches that reported in the literature.[181]

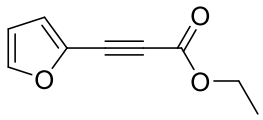
2-(2,2-Dibromovinyl)furan (229)



Prepared using **GP1**, with furfural (331 µl, 4.00 mmol), CBr_4 (2.63 g, 8.00 mmol), and PPh_3 (4.63g, 16.0 mmol) in dry CH_2Cl_2 (12 mL). The reaction time was 1 hour. Aqueous work-up and purification by column chromatography (hexane), yielded

dibromoalkene **229** (750 mg, 64%); ^{1}H NMR (300 MHz, $CDCl_3$): δ = 7.44 (dd, *J* = 1.7, 0.5 Hz, 1H), 7.40 (s, 1H), 6.95 (d, *J* = 3.4 Hz, 1H), 6.46 (dd, *J* = 3.4, 1.7 Hz, 1H); ^{13}C NMR (101 MHz, $CDCl_3$): δ = 150.1 (C), 142.7 (CH), 126.6 (CH), 111.7 (CH), 111.6 (CH), 87.2 (C); IR (neat): ν = 3147, 3031, 1705, 1561, 1481, 1142, 1019, 834, 737. Data matches that reported in the literature.[182]

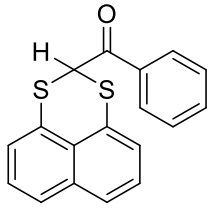
Ethyl 3-(furan-2-yl)propiolate (230)



230 was prepared according to a literature procedure.[109] Dibromoolefin **229** (470 mg, 1.74 mmol) was added to a flame dried RBF. THF (10 mL) was added and the mixture was cooled to -78 ^{o}C. *n*-BuLi (2.19 mL, 3.48 mmol, 2.0 eq.) was added dropwise and the reaction was stirred at -78 ^{o}C for 1 hour. Ethyl chloroformate (239 µL, 2.61 mmol, 1.5 eq.) was dropwise and the mixture was stirred for a further hour. The mixture was quenched with NH_4Cl (20 mL), the organic layer separeated and the aqueous layer washed with Et_2O (3 × 10 mL), the combined organics washed with brine (10 mL), dried over Na_2SO_4, filtered, concentrated under reduced pressure and purified by column chromatohgraphy (95:5 hexane:EtOAc) to afford the title compound (126 mg, 44%) as a colourless oil.

R_f 0.33 (9:1 hexane:EtOAc); ^{1}H NMR (300 MHz, $CDCl_3$): δ = 7.51 (m, 1H), 6.93 (d, = 3.5 Hz, 1H), 6.47 (dd, *J* = 3.5 Hz, *J* = 1.8 Hz, 1H), 4.30 (q, *J* = 7.1 Hz, 2H), 1.35 (t, *J* = 7.1 Hz, 3H); IR (neat): ν =3135, 3106, 2996, 2970, 2210. 1702, 1475, 1281, 1200, 1024, 767, 740; Data matches that reported in the literature.[109]

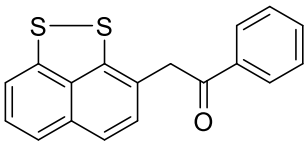
Naphtho[1,8-de][1,3]dithiin-2-yl(phenyl)methanone (227)



To a Radleys tube under argon was added sulfur oxide **212** (82.4 mg, 0.40 mmol), phenylacetylene (87.0 µl, 0.80 mmol) and toluene 3.2 ml. The mixture was heated to 50 ^{o}C and after 20 minutes XPhosAuCl (7.0 mg, 2.5

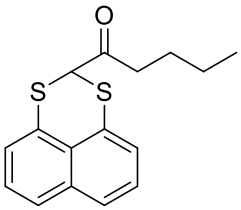
mol%) was added followed by $AgSbF_6$ (3.4 mg, 2.5 mol%). Toluene (0.8 ml) was added and the reaction was kept at this temperature for 20 hours before being filtered through a plug of silica, concentrated and purified by column chromatography (3:7 hexane:CH_2Cl_2) to afford **212** (56.0 mg, 46%) as a pale yellow solid; R_f 0.42 (1:9 hexane:EtOAc); mp: 126-127 ^oC (EtOH); ^1H NMR (400 MHz, $CDCl_3$): δ = 8.02 (d, *J* = 7.8 Hz, 2H), 7.73 (d, *J* = 8.2 Hz, 2H), 7.62 (app t, *J* = 7.5 Hz, 1H), 7.50 (app t, *J* = 7.5 Hz, 4H), 7.40 (t, *J* = 7.8 Hz, 2H), 5.83 (s, 1H); ^{13}C NMR (101 MHz, $CDCl_3$): δ = 190.0 (C), 134.6 (C), 134.0 (C), 133.9 (CH), 129.1 (2CH), 128.8 (2CH), 128.2 (2CH), 127.9 (2C), 126.6 (2CH), 125.6 (2CH), 125.5 (C), 44.7 (CH); IR (neat): ν = 2922, 2853, 1689, 1593, 1578, 1551, 1447, 1262, 1209, 1193, 986, 812, 759, 728, 681, 654; HR-MS (ES-TOF): *m/z*: calcd for $C_{18}H_{12}ONaS_2$: 331.0227, found 331.0230 $[M + Na]^+$.

2-(Naphtho[1,8-cd][1,2]dithiol-3-yl)-1-phenylethan-1-one (228)



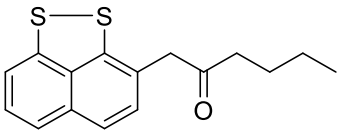
228 was also isolated from the reaction above eluting second with (3:7 hexane:CH_2Cl_2) providing (11.0 mg, 9%) as a red solid; R_f 0.53 (4:6 hexanes:CH_2Cl_2); mp: 87-89 ^oC; ^1H NMR (300 MHz, $CDCl_3$): δ = 8.09 – 8.03 (m, 2H), 7.65 – 7.57 (m, 1H), 7.55 – 7.47 (m, 2H), 7.41 – 7.36 (m, 2H), 7.29 (t, *J* = 7.7 Hz, 1H), 7.24 – 7.17 (m, 2H), 4.26 (s, 2H); ^{13}C NMR (101 MHz, $CDCl_3$): δ = 195.5 (C), 144.0 (C), 143.7 (C), 136.5 (C), 135.0 (C), 134.9 (C), 133.7 (CH), 129.9 (CH), 128.9 (2CH), 128.7 (2CH), 127.6 (CH), 123.3 (C), 122.8 (CH), 121.7 (CH), 116.4 (CH), 44.5 (CH); IR (neat): ν = 3039, 2926, 1679, 1544, 1447, 1320, 1205, 986, 806, 747,683, 667; HR-MS (ES-TOF): *m/z*: calcd for $C_{18}H_{12}ONaS_2$: 331.0227, found 331.0238 $[M + Na]^+$.

1-(Naphtho[1,8-de][1,3]dithiin-2-yl)pentan-1-one (225)



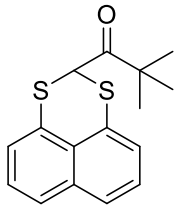
225 was prepared according to **GP4** using **212** (61.8 mg, 0.30 mmol), hex-1-yne (68.9 µl, 0.60 mmol), Au-I (11.2 mg, 5 mol%) and toluene (3.0 ml). The reaction time was 18 hours. Purification by column chromatography (6:4 hexane:CH_2Cl_2) afforded **225** (30.0 mg, 36%) as a colourless oil; R_f 0.25 (6:4 hexane:CH_2Cl_2); ^{1}H NMR (300 MHz, $CDCl_3$): δ = 7.69 (dd, *J* = 8.2, 1.2 Hz, 2H), 7.49 (dd, *J* = 7.3, 1.2 Hz, 2H), 7.42 – 7.35 (m, 2H), 4.87 (s, 1H), 2.66 (t, *J* = 7.2 Hz, 2H), 1.59 – 1.49 (m, 2H), 1.31 – 1.18 (m, 2H), 0.83 (t, *J* = 7.3 Hz, 3H); ^{13}C NMR (101 MHz, $CDCl_3$): δ = 200.6 (C), 134.7 (C), 128.3 (2CH), 127.3 (2C), 126.6 (2CH), 125.8 (2CH), 125.6 (C), 47.9 (CH), 39.3 (CH_2), 26.1 (CH_2), 22.2 (CH_2), 13.9 (CH_3); IR (neat): *v* = 3054, 2955, 2929, 2870, 1713, 1554, 1209, 1039, 900, 812, 757; HR-MS (ES-TOF): *m/z*: calcd for $C_{12}H_{16}OS_2$: 288.0659, found 288.0668 $[M + H]^+$.

1-(Naphtho[1,8-cd][1,2]dithiol-3-yl)hexan-2-one (226)



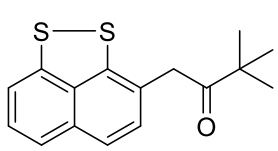
226 was also isolated from the reaction above eluting second with (6:4 hexane:CH_2Cl_2) to afford the title compound (28.4 mg, 33%) as a colourless oil; R_f 0.21 (6:4 hexane:CH_2Cl_2); ^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.37 (dd, *J* = 8.1, 3.9 Hz, 2H), 7.27 (t, *J* = 7.7 Hz, 1H), 7.19 – 7.15 (m, 1H), 7.14 (d, *J* = 8.3 Hz, 1H), 3.64 (s, 2H), 2.49 (t, *J* = 7.4 Hz, 2H), 1.62 – 1.53 (m, 2H), 1.34 – 1.23 (m, 2H), 0.87 (t, *J* = 7.3 Hz, 3H); ^{13}C NMR (101 MHz, $CDCl_3$): δ = 206.7 (C), 144.0 (C), 143.7 (C), 135.0 (C), 134.9 (C), 130.1 (CH), 127.6 (CH), 123.0 (C), 122.9 (CH), 121.7 (CH), 116.4 (CH), 49.1 (CH_2), 42.2 (CH_2), 23.0 (CH_2), 22.4 (CH_2), 14.0 (CH_3); IR (neat): *v* = 2956, 2927, 2871, 1708, 1607, 1543, 1493, 1331, 1048, 810, 751; HR-MS (ES-TOF): *m/z*: calcd for $C_{12}H_{16}OS_2$: 288.0643 found 288.0645 $[M + H]^+$.

2,2-Dimethyl-1-(naphtho[1,8-de][1,3]dithiin-2-yl)propan-1-one (249)



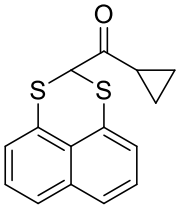
249 was prepared according to **GP4** using **212** (41.2 mg, 0.20 mmol), 3,3-dimethyl-1-butyne (49.2 µl, 0.40 mmol), Au-I (11.2 mg, 5 mol%) and toluene (2.0 ml). The reaction time was 23 hours. Purification by column chromatography (2:1 hexane:CH_2Cl_2) afforded **249** (26.3 mg, 46%) as a colourless oil; R_f 0.51 (6:4 hexane:CH_2Cl_2); ^{1}H NMR (300 MHz, $CDCl_3$): δ = 7.71 (dd, *J* = 8.2, 1.2 Hz, 2H), 7.48 (dd, *J* = 7.3, 1.2 Hz, 2H), 7.43 – 7.34 (m, 2H), 5.23 (s, 1H), 1.29 (s, 9H); ^{13}C NMR (101 MHz, $CDCl_3$): δ = 205.7 (C), 134.5 (C), 128.3 (2CH), 127.7 (2C), 126.7 (2CH), 125.7 (2CH), 125.4 (C), 45.0 (C), 41.2 (CH), 27.1 ($3CH_3$); IR (neat): *v* = 3054, 2966, 2868, 1704, 1554, 1475, 1365, 1209, 1053, 995, 813, 757; HR-MS (ES-TOF): *m/z*: calcd for $C_{16}H_{16}ONaS_2$: 311.0540 found 311.0539 $[M + Na]^+$.

3,3-Dimethyl-1-(naphtho[1,8-cd][1,2]dithiol-3-yl)butan-2-one (250)



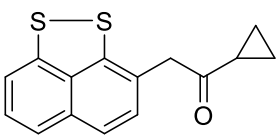
250 was also isolated from the reaction above eluting second with (2:1 hexane:CH_2Cl_2) affording the title compound (14.8 mg, 26%) as an orange solid; R_f 0.46 (6:4 hexane:CH_2Cl_2); mp 73-74 ºC; ^{1}H NMR (300 MHz, $CDCl_3$): δ = 7.36 (dd, *J* = 8.1, 1.2 Hz, 2H), 7.26 (t, *J* = 7.7 Hz, 1H), 7.18 – 7.08 (m, 2H), 3.79 (s, 2H), 1.26 (s, 9H); ^{13}C NMR (101 MHz, $CDCl_3$): δ = 211.5 (C), 143.9 (C), 143.4 (C), 134.9 (C), 134.8 (C), 130.4 (CH), 127.4 (CH), 123.9 (C), 122.5 (CH), 121.7 (CH), 116.2 (CH), 44.8 (C), 42.4 (CH_2), 26.6 ($3CH_3$); IR (neat): *v* = 2964, 2930, 2868, 1708, 1544, 1315, 1209, 1060, 1002, 902, 750; HR-MS (ES-TOF): *m/z*: calcd for $C_{16}H_{16}ONaS_2$: 311.0540 found 311.0538 $[M + Na]^+$.

Cyclopropyl(naphtho[1,8-de][1,3]dithiin-2-yl)methanone (241)



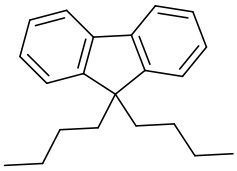
241 was prepared according to **GP4** using **212** (41.2 mg, 0.20 mmol), cyclopropylacetylene (33.9 µl, 0.40 mmol), Au-I (11.2 mg, 5 mol%) and toluene (2.0 ml). The reaction time was 23 hours. Purification by column chromatography (6:4 hexane:CH_2Cl_2) afforded **241** (20.8 mg, 38%) as a pale orange oil; R_f 0.24 (6:4 hexane:CH_2Cl_2): ^{1}H NMR (300 MHz, $CDCl_3$): δ = 7.69 (dd, *J* = 8.2, 1.1 Hz, 2H), 7.51 (dd, *J* = 7.3, 1.1 Hz, 2H), 7.43 – 7.34 (m, 2H), 5.10 (s, 1H), 2.21 (tt, *J* = 7.8, 4.6 Hz, 1H), 1.09 – 1.00 (m, 2H,), 0.98 – 0.90 (m, 2H); ^{13}C NMR (101 MHz, $CDCl_3$): δ = 200.8 (C), 134.8 (C), 128.2 (2CH), 127.7 (2C), 126.6 (2CH), 125.8 (2CH), 125.7 (C), 49.3 (CH), 19.0 (CH), 12.4 ($2CH_2$); IR (neat): *v* = 3054, 2926, 1698, 1554, 1496, 1375, 1209, 1193, 1059, 903, 812, 757, 727; HR-MS (ES-TOF): *m/z*: calcd for $C_{15}H_{12}ONaS_2$: 295.0227 found 295.0232 $[M + Na]^+$.

1-Cyclopropyl-2-(naphtho[1,8-cd][1,2]dithiol-3-yl)ethan-1-one (242)



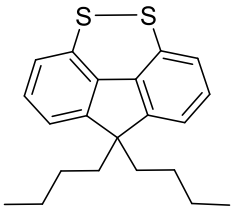
242 was also isolated from the above reaction eluting second with (6:4 hexane:CH_2Cl_2) affording the title compound (11.1 mg, 20%) as a red solid; R_f 0.19 (6:4 hexane:CH_2Cl_2); mp: 83-85 ^{o}C; ^{1}H NMR (300 MHz, $CDCl_3$): δ = 7.43 – 7.33 (m, 2H), 7.28 (app t, *J* = 7.7 Hz, 1H), 7.17 (d, *J* = 8.2 Hz, 2H), 3.79 (s, 2H), 2.01 (tt, *J* = 7.8, 4.5 Hz, 1H), 1.12 – 1.05 (m, 2H), 0.88 (dq, *J* = 11.1, 3.6 Hz, 2H); ^{13}C NMR (101 MHz, $CDCl_3$): δ = 206.3 (C), 144.1 (C), 143.9 (C), 135.0 (C), 134.9 (C), 130.1 (CH), 127.6 (CH), 123.1 (C), 122.9 (CH), 121.7 (CH), 116.5 (CH), 49.7 (CH_2), 20.4 (CH), 11.8 ($2CH_2$); IR (neat): *v* = 3050, 3006, 2924, 1691, 1543, 1492, 1378, 1207, 1067, 900, 813, 750, 671; HR-MS (ES-TOF): *m/z*: calcd for $C_{15}H_{12}ONaS_2$: 295.0227 found 295.0229 $[M + Na]^+$.

9,9-Dibutyl-9H-fluorene (252)



252 was prepared according to an adapted literature procedure.[110] To fluorene **251** (4.00 g, 24.4 mmol) in a RBF under argon was added anhydrous THF (160 mL). Potassium *tert*-butoxide (10.8 g, 96.0 mmol) was added in one portion. 1-Butyl iodide (8.19 mL, 72.0 mmol) was added over 10 mins and the reaction was stirred at rt for 16 hours. NH_4Cl was added and the organic layer was separated. The aqueous layer was extracted CH_2Cl_2 (3 × 30 mL). The combined organics were washed with brine (30 mL), dried over Na_2SO_4, filtered and purified by column chromatography (hexane) to give the title compound (5.83 g, 86%) as a white solid; mp: 48–50 ^oC; ^1H NMR (300 MHz, $CDCl_3$): δ = 7.74 – 7.68 (m, 1H), 7.39 – 7.27 (m, 3H), 1.97 (dd, *J* = 10.1, 6.6 Hz, 2H), 1.19 – 0.99 (m, 2H), 0.67 (t, *J* = 7.3 Hz, 3H), 0.64 – 0.52 (m, 2H); IR (neat): *v* = 3065, 2957, 2927, 2856, 1447, 771, 734. Data matches that reported in the literature.[111]

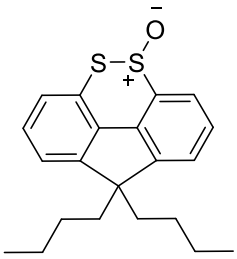
9,9-dibutyl-9H-fluoreno[4,5-cde][1,2]dithiine (253)



Disulfide **253** was prepared according to the literature procedure.[110,111] A 250 mL flask was equipped with a reflux condenser and flame dried. **252** (3.90 g, 14.0 mmol, 1.0 eq.) was added followed by *n*-BuLi (1.6 M in hexanes) (35 mL, 56 mmol, 4.0 eq.) and TMEDA (9.1 mL, 56 mmol, 4.0 eq.) The reaction was then heated to 60 ^oC and stirred at this temperature for 3 hours. The mixture was cooled to -78 ^oC and diluted with THF (80 mL). S_8 (3.61 g, 1.75 mmol, 1.0 eq.) was added and the mixture was allowed to warm to rt over 16 hours. The reaction was quenched with water (20 mL) and NaOH (20 mL of a 5% solution). The aqueous layer was extracted with Et_2O (3 × 100 mL), the combined organic layers washed with brine (100 mL), dried over Na_2SO_4, filtered and concentrated under reduced pressure. Purification by column chromatography (hexane) afforded the title compound **253** (2.10 g, 41%) as a light orange solid; mp: 76-77 ^oC; ^1H NMR

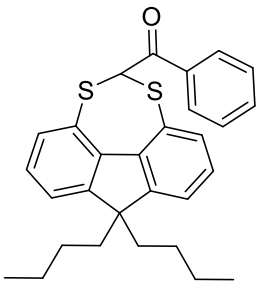
(300 MHz, $CDCl_3$): δ = 7.21 (t, *J* = 7.5 Hz, 3H), 7.12 (dd, *J* = 7.5, 0.8 Hz, 2H), 7.05 (dd, *J* = 7.6, 0.8 Hz, 2H), 1.96-1.87 (m, 4H), 1.17-1.04 (m, 4H), 0.71 (t, *J* = 7.3 Hz, 6H), 0.68-0.63 (m, 4H); IR (neat): *v* = 3046, 2955, 2927, 2855, 1567, 1463, 1464, 1406, 1376, 1187, 1164, 1120, 787; Data matches that reported in the literature.[111]

9,9-Dibutyl-9H-fluoreno[4,5-cde][1,2]dithiine 4-oxide (254)



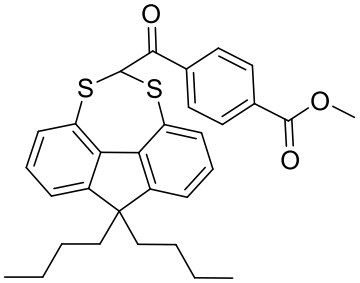
A flask under argon was charged with **253** (900 mg, 2.65 mmol) and CH_2Cl_2 (27 mL). The mixture was cooled to -20 ºC, *m*CPBA (458 mg, 2.65 mmol) was added portionwise over 10 minutes. The reaction was stirred at this temperature for 2 hours then quenched with $NaHCO_3$ (5 mL of a saturated aqueous solution) and extracted with CH_2Cl_2 (4 × 10 mL). The organics were combined, dried over Na_2SO_4, concentrated under reduced pressure, purified by column chromatography (8:2 hexane:Et_2O) to give **254** (495 mg, 52%) as a yellow solid; R_f 0.45 (6:4 hexane:Et_2O); mp: 145-146 ºC; ^{1}H NMR (300 MHz, $CDCl_3$): δ = 7.75 (dd, *J* = 6.5, 2.1 Hz, 1H), 7.67 – 7.59 (m, 2H), 7.55 – 7.48 (m, 1H), 7.40 (dd, *J* = 9.7, 0.8 Hz, 2H), 2.15 – 1.96 (m, 4H), 1.19 – 1.02 (m, 4H), 0.91 – 0.44 (m, 4H), 0.69 (q, *J* = 7.4 Hz, 6H); ^{13}C NMR (101 MHz, $CDCl_3$): δ = 152.6 (C), 151.5 (C), 132.9 (C), 132.2 (C), 131.8 (C), 130.1 (CH), 129.0 (CH), 126.5 (CH), 124.7 (CH), 124.4 (CH), 121.5 (CH), 120.2 (C), 57.0 (C), 39.5 (CH_2), 39.2 (CH_2), 26.3 (CH_2), 26.3 (CH_2), 23.1 (CH_2), 23.1 (CH_2), 13.9 ($2CH_3$); IR (neat): *v* = 2956, 2929, 2858, 1573, 1464, 1412, 1087, 790, 734; HR-MS (ES-TOF): *m/z*: calcd for $C_{21}H_{24}OS_2$: 356.1269 found 356.1269 $[M + H]^+$.

(4,4-Dibutyl-4H-fluoreno[4,5-def][1,3]dithiepin-9-yl)(phenyl)methanone (257)



257 was prepared according to **GP5** using **254** (71.2 mg, 0.20 mmol), phenylacetylene (43 µl, 0.40 mmol) and Au-II (9.8 mg, 5 mol%). The reaction time was 20 hours. Purification by column chromatography (95:5 hexane:Et_2O) afforded the title compound (70.3 mg, 77%) as a white solid; R_f 0.66 (8:2 hexane:Et_2O); mp: 155-156 ^oC; ^1H NMR (300 MHz, $CDCl_3$): δ = 7.99 (dd, *J* = 5.2, 3.3 Hz, 2H), 7.62 – 7.55 (m, 1H), 7.50 – 7.42 (m, 2H), 7.29 (dd, *J* = 7.0, 2.0 Hz, 2H), 7.26 – 7.18 (m, 4H), 5.73 (s, 1H), 2.04 – 1.90 (m, 4H), 1.16 – 0.97 (m, 4H), 0.73 – 0.58 (m, 8H), 0.55 – 0.37 (m, 2H); ^{13}C NMR (101 MHz, $CDCl_3$): δ = 191.9 (C), 154.0 (2C), 139.3 (2C), 134.2 (CH), 134.1 (C), 131.6 (2C), 129.4 (2CH), 129.0 (2CH), 128.3 (2CH), 127.0 (2CH), 121.0 (2CH), 56.6 (CH), 54.4 (C), 41.3 (CH_2), 41.0 (CH_2), 25.9 (CH_2), 25.7 (CH_2), 23.1 ($2CH_2$), 13.9 ($2CH_3$); IR (neat): *v* = 2951, 2925, 2857, 1678, 1580, 1450, 1401, 1274, 1174, 987, 792, 738, 686; HR-MS (ES-TOF): *m/z*: calcd for $C_{29}H_{30}ONaS_2$: 481.1636 found 481.1634 $[M + Na]^+$.

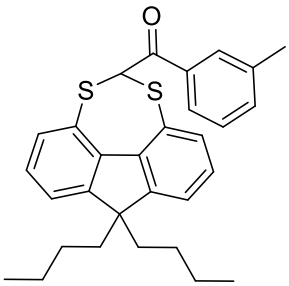
Methyl 4-(4,4-dibutyl-4H-fluoreno[4,5-def][1,3]dithiepine-9-carbonyl)benzoate (259)



259 was prepared according to **GP5** using **254** (72.8 mg, 0.20 mmol), methyl 4-ethynylbenzoate (64.7 mg, 0.40 mmol) and Au-II (9.8 mg, 5 mol%). The reaction time was 26 hours. Purification by column chromatography (95:5 hexane:Et_2O) afforded the title compound (58.1 mg, 56%) as a bright yellow solid. **259** was also prepared according to **GP6** using methyl 4-ethynylbenzoate (16.2 mg, 0.10 mmol), **254** (42.7 mg, 0.12 mmol) and Au-II (9.8 mg, 5 mol%). The reaction time was 20 hours. Purification by column chromatography (95:5 hexane:Et_2O) afforded the title compound (26.9 mg, 52%) as a bright yellow solid; R_f 0.40 (8:2 hexane:Et_2O); mp: 158-160 ^oC; ^1H NMR (300 MHz, $CDCl_3$): δ = 8.16 (d, *J* = 8.7 Hz,

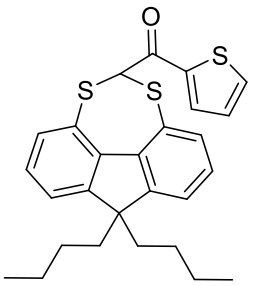
2H), 8.07 (d, *J* = 8.7 Hz, 2H), 7.35 – 7.23 (m, 6H), 5.79 (s, 1H), 3.97 (s, 3H), 2.08 – 1.94 (m, 4H), 1.18 – 1.02 (m, 4H), 0.78 – 0.64 (m, 8H), 0.55 – 0.45 (m, 2H); ^{13}C NMR (101 MHz, $CDCl_3$): δ = 191.1 (C), 166.1 (C), 154.0 (2C), 139.3 (2C), 137.6 (C), 134.7 (C), 131.2 (2C), 130.1 (2CH), 129.3 (2CH), 128.3 (2CH), 127.1 (2CH), 121.2 (2CH), 56.4 (CH), 54.5 (C), 52.7 (CH_3), 41.2 (CH_2), 41.0 (CH_2), 25.9 (CH_2), 25.7 (CH_2), 23.3 ($2CH_2$), 13.9 ($2CH_3$); IR (neat): *v* = 2929, 2858, 1718, 1681, 1401, 1268, 1105, 995, 872, 797, 737; HR-MS (ES-TOF): *m/z*: calcd for $C_{31}H_{32}O_3NaS_2$: 539.1961 found 539.1989 $[M + Na]^+$.

(4,4-Dibutyl-4H-fluoreno[4,5-def][1,3]dithiepin-9-yl)(3-methoxyphenyl)methanone (260)



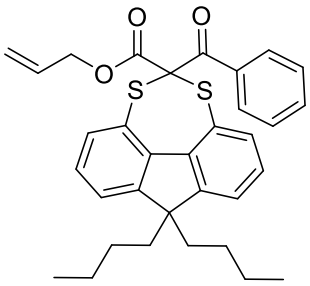
260 was prepared according to **GP5** using **254** (71.2 mg, 0.20 mmol), 3-methylphenylacetylene (46.5 mg, 0.40 mmol) and Au-II (11.2 mg, 5 mol%). The reaction time was 20 hours. Purification by column chromatography (95:5 hexane:Et_2O) afforded the title compound (70.3 mg, 70%) as a white solid; mp: 79-81 ^oC; R_f 0.79 (8:2 hexane:Et_2O); ^{1}H NMR (300 MHz, $CDCl_3$): δ = 7.64 (s, 1H), 7.60 (d, *J* = 7.8 Hz, 1H), 7.31 – 6.92 (m, 8H), 5.52 (s, 1H), 2.21 (s, 3H), 1.89 – 1.68 (m, 4H), 1.01 – 0.79 (m, 4H), 0.59 – 0.39 (m, 8H), 0.41 – 0.22 (m, 2H); ^{13}C NMR (101 MHz, $CDCl_3$): δ = 192.1 (C), 154.0 (2C), 139.3 (2C), 138.9 (C), 135.1 (CH), 134.1 (C), 131.7 (2C), 129.8 (CH), 128.8 (CH), 128.3 (2CH), 126.9 (2CH), 126.7 (CH), 121.0 (2CH), 56.7 (CH), 54.4 (C), 41.4 (CH_2), 41.0 (CH_2) 26.0 (CH_2), 25.7 (CH_2), 23.1 ($2CH_2$), 21.5 (CH_3), 14.0 ($2CH_3$); IR (neat): *v* = 2954, 2929, 2859, 1677, 1602, 1451, 1400, 1278, 1173, 791, 737, 685; HR-MS (ES-TOF): *m/z*: calcd for $C_{30}H_{32}ONaS_2$: 495.1792 found 495.1790 $[M + Na]^+$.

(4,4-Dibutyl-4H-fluoreno[4,5-def][1,3]dithiepin-9-yl)(thiophen-2-yl)methanone (261)



261 was prepared according to **GP5** using **254** (72.8 mg, 0.20 mmol), 2-ethynylthiophene (43.3 mg, 0.40 mmol) and Au-II (11.2 mg, 5 mol%). The reaction time was 24 hours. Purification by column chromatography (95:5 hexane:Et_2O) and recrystallisation from Et_2O afforded the title compound (45.8 mg, 49%) as a bright yellow solid; R_f 0.68 (8:2 hexane:Et_2O); mp: 138-139 ^oC; ^1H NMR (300 MHz, $CDCl_3$): δ = 7.88 (dd, *J* = 4.0, 1.0 Hz, 1H), 7.76 (dd, *J* = 4.9, 1.0 Hz, 1H), 7.38 – 7.22 (m, 6H), 7.18 (dd, *J* = 4.9, 4.0 Hz, 1H), 5.58 (s, 1H), 2.11 – 1.92 (m, 4H), 1.23 – 1.00 (m, 4H), 0.78 – 0.59 (m, 8H), 0.58 – 0.43 (m, 2H); ^{13}C NMR (101 MHz, $CDCl_3$): δ = 184.5 (C), 154.0 (2C), 140.6 (C), 139.1 (2C), 135.8 (CH), 134.5 (CH), 131.5 (2C), 128.6 (CH), 128.2 (2CH), 127.0 (2CH), 121.1 (2CH), 57.6 (CH), 54.4 (C), 41.3 (CH_2), 41.0 (CH_2), 25.9 (CH_2), 25.7 (CH_2), 23.1 ($2CH_2$), 13.9 (CH_3), 13.9 (CH_3); IR (neat): *v* = 2953, 2928, 2857, 1678, 1584, 1451, 1400, 1280, 1174, 989, 851, 791, 731; HR-MS (ES-TOF): *m/z*: calcd for $C_{27}H_{28}ONaS_3$: 487.1200 found 487.1188 $[M + Na]^+$.

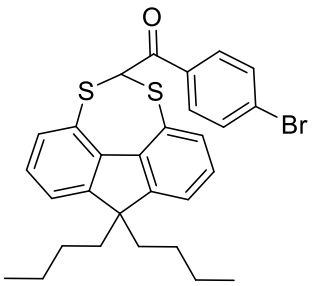
Allyl 9-benzoyl-4,4-dibutyl-4H-fluoreno[4,5-def][1,3]dithiepine-9-carboxylate (263)



263 was prepared according to **GP5** using **254** (35.6 mg, 0.10 mmol), allyl 3-phenylpropiolate (37.2 mg, 0.20 mmol) and Au-I (5 mol%) but at 90 ^oC. The reaction time was 20 hours. Purification by column chromatography afforded the title compound (41.3 mg, 74%) as a white solid. **263** was also prepared according to **GP6** using allyl 3-phenylpropiolate (18.6 mg, 0.10 mmol), **254** (42.7 mg, 0.12 mmol), and Au-II (4.8 mg, 5 mol%). The reaction time was 20 hours. Purification by column chromatography (95:5 hexane:Et_2O) afforded the title compound **263** (46.5 mg, 83%) as a yellow solid; R_f 0.46 (8:2 hexane:Et_2O); mp: 114-115 ^oC; ^1H NMR (300 MHz, $CDCl_3$): δ = 8.11 (d, *J* = 7.6 Hz, 2H), 7.57 (app t, *J* = 7.4 Hz, 1H), 7.42 (t, *J* = 7.7

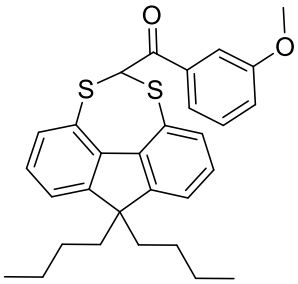
Hz, 2H), 7.35 – 7.13 (m, 6H), 5.49 (ddt, *J* = 16.4, 10.5, 5.9 Hz, 1H) 5.21 – 4.94 (m, 2H), 4.40 (d, *J* = 5.9 Hz, 2H), 2.22 – 1.86 (m, 4H), 1.21 – 1.00 (m, 4H), 0.77 – 0.63 (m, 6H), 0.60 – 0.42 (m, 4H); ^{13}C NMR (101 MHz, $CDCl_3$): δ = 187.1 (C), 165.3 (C), 153.1 (2C), 140.5 (2C), 133.9 (C), 133.8 (CH), 130.6 (CH), 130.1 (2CH), 129.0 (2C), 128.5 (2CH), 128.4 (2CH), 127.2 (2CH), 121.1 (2CH), 119.7 (CH_2), 72.2 (C), 67.8 (CH_2), 54.6 (C), 41.2 (CH_2), 41.0 (CH_2), 25.7 (CH_2), 25.6 (CH_2), 23.1 (CH_2), 23.1 (CH_2), 14.0 (CH_3), 13.9 (CH_3); IR (neat): *v* = 2956, 2930, 2859, 1742, 1686, 1596, 1448, 1402, 1231, 1199, 988, 792, 737, 688; HR-MS (ES-TOF): *m/z*: calcd for $C_{33}H_{34}O_3NaS_2$: 565.1847 found 565.1835 $[M + Na]^+$.

(4-Bromophenyl)(4,4-dibutyl-4H-fluoreno[4,5-def][1,3]dithiepin-9-yl)methanone (269)



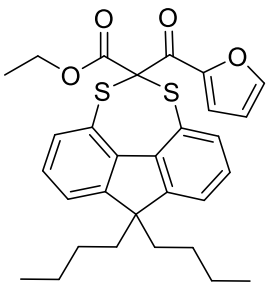
269 was prepared according to **GP6** using 1-bromo-4-ethynylbenzene (18.1 mg, 0.10 mmol), **254** (42.7 mg, 0.12 mmol), and Au-II (4.8 mg, 5 mol%). The reaction time was 24 hours. Purification by column chromatography (95:5 hexane:Et_2O) and recrystallisation from hot Et_2O afforded the title compound (42.6 mg, 70%) as a pale yellow solid; R_f 0.68 (8:2 hexane:Et_2O); mp: 82-83 °C; ^{1}H NMR (300 MHz, $CDCl_3$): δ = 7.89 (d, *J* = 8.5 Hz, 2H), 7.64 (d, *J* = 8.5 Hz, 2H), 7.35 – 7.23 (m, 6H), 5.71 (s, 1H), 2.15 – 1.89 (m, 4H), 1.18 – 1.02 (m, 4H), 0.71 (dt, *J* = 11.8, 7.4 Hz, 8H), 0.57 – 0.45 (m, 2H); ^{13}C NMR (101 MHz, $CDCl_3$): δ = 190.8 (C), 154.0 (2C), 139.3 (2C), 132.9 (C), 132.3 (2CH), 131.3 (2C), 130.9 (2CH), 129.5 (C), 128.3 (2CH), 127.1 (2CH), 121.1 (2CH), 56.4 (CH), 54.4 (C), 41.2 (CH_2), 41.0 (CH_2), 25.9 (CH_2), 25.7 (CH_2), 23.1 ($2CH_2$), 13.9 ($2CH_3$); IR (neat): *v* = 2954, 2928, 2857, 1678, 1584, 1399, 1280, 1174, 1070, 990, 851, 791, 731; HR-MS (ES-TOF): *m/z*: calcd for $C_{29}H_{29}ONaS_2{}^{79}Br$: 559.0741, found 559.0733 $[M + Na]^+$.

(4,4-Dibutyl-4H-fluoreno[4,5-def][1,3]dithiepin-9-yl)(thiophen-2-yl)methanone (270)



270 was prepared according to **GP6** using 3-methoxybenzene (13.2 mg, 0.10 mmol), **254** (42.7 mg, 0.12 mmol), and Au-II (4.8 mg, 5 mol%). The reaction time was 20 hours. Purification by column chromatography (97:3 hexane:Et_2O) and recrystallization from Et_2O afforded the title compound (32.7 mg, 67%) as yellow crystals; R_f 0.75 (8:2 hexane:Et_2O); mp: 145-147 ^oC; ^1H NMR (400 MHz, $CDCl_3$): δ = 7.59 (d, *J* = 7.8 Hz, 1H), 7.56 – 7.53 (m, 1H), 7.38 (app t, *J* = 8.0 Hz, 1H), 7.31 (dd, *J* = 7.2, 1.7 Hz, 2H), 7.29 – 7.21 (m, 4H), 7.18 – 7.13 (m, 1H), 5.71 (s, 1H), 3.83 (s, 3H), 2.05 – 1.91 (m, 4H), 1.17 – 1.00 (m, 4H), 0.69 (dt, *J* = 14.9, 7.4 Hz, 6H), 0.69 – 0.59 (m, 2H), 0.55 – 0.42 (m, 2H); ^{13}C NMR (101 MHz, $CDCl_3$): δ = 191.7 (C), 160.1 (C), 154.0 (2C), 139.2 (2C), 135.4 (C), 131.6 (2C), 129.9 (CH), 128.3 (2CH), 127.0 (2CH), 122.0 (CH), 121.0 (2CH), 121.0 (CH), 113.4 (CH), 56.7 (CH), 55.6 (CH_3), 54.4 (C), 41.3 (CH_2), 41.0 (CH_2), 25.9 (CH_2), 25.7 (CH_2), 23.1 ($2CH_2$), 13.9 ($2CH_3$); IR (neat): *v* = 2955, 2927, 2857, 1678, 1596, 1582, 1486, 1451, 1273, 1172, 1119, 1044, 873, 767, 791, 735, 682; HR-MS (ES-TOF): *m/z*: calcd for $C_{30}H_{32}O_2NaS_2$: 511.1735, found 511.1741 $[M + Na]^+$.

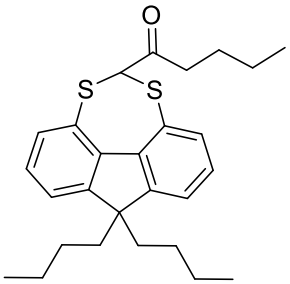
Ethyl 4,4-dibutyl-9-(furan-2-carbonyl)-4H-fluoreno[4,5-def][1,3]dithiepine-9-carboxylate (271)



271 was prepared according to **GP6** using **254** (16.0 mg, 0.10 mmol), **230** (42.7 mg, 0.12 mmol), and Au-II (4.8 mg, 5 mol%). The reaction time was 14 hours. Purification by column chromatography (15:1 hexane:Et_2O) afforded the title compound (38.6 mg, 75%) as a pale yellow solid; R_f 0.28 (8:2 hexane:Et_2O); mp: 128-130 ^oC; ^1H NMR (300 MHz, $CDCl_3$): δ = 7.66 (dd, *J* = 1.6, 0.6 Hz, 1H), 7.45 (dd, *J* = 3.7, 0.6 Hz, 1H), 7.34 – 7.28 (m, 2H), 7.27 – 7.22

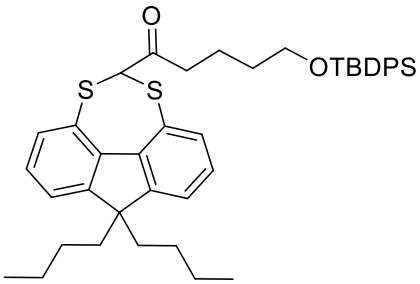
(m, 4H), 6.56 (dd, *J* = 3.7, 1.6 Hz, 1H), 4.04 (q, *J* = 7.1 Hz, 2H), 2.04 – 1.93 (m, 4H), 1.12 – 1.01 (m, 4H), 0.97 (t, *J* = 7.1 Hz, 3H), 0.68 (q, *J* = 7.4 Hz, 6H), 0.58 – 0.42 (m, 4H); ^{13}C NMR (101 MHz, $CDCl_3$): δ = 175.3 (C), 164.8 (C), 153.2 (2C), 149.1 (C), 147.7 (CH), 140.5 (2C), 129.0 (2C), 128.3 (2CH), 127.2 (2CH), 121.7 (CH), 121.0 (2CH), 112.7 (CH), 71.4 (C), 63.5 (CH_2), 54.6 (C), 41.1 (CH_2), 41.0 (CH_2), 25.7 ($2CH_2$), 23.1 ($2CH_2$), 13.9 (CH_3), 13.9 ($2CH_3$); IR (neat): *v* = 2955, 2928, 2857, 1745, 1670, 1562, 1456, 1270, 1200, 1031, 791, 764, 735; HR-MS (ES-TOF): *m/z*: calcd for $C_{30}H_{32}O_4NaS_2$: 543.1640, found 543.1646 $[M + Na]^+$.

1-(4,4-Dibutyl-4H-fluoreno[4,5-def][1,3]dithiepin-9-yl)pentan-1-one (255)



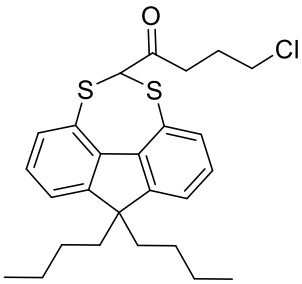
255 was prepared according to **GP7** using 1-hexyne (8.4 mg, 0.10 mmol), **254** (42.7 mg, 0.12 mmol) and Au-I (5.6 mg, 5 mol%). The reaction time was 20 hours. Purification by column chromatography (95:5 hexane:Et_2O) afforded the title compound (25.1 mg, 57%) as a colourless oil; R_f 0.71 (8:2 hexane:Et_2O); ^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.32 (p, *J* = 3.7 Hz, 2H), 7.25 – 7.19 (m, 4H), 5.02 (s, 1H), 2.83 (t, *J* = 7.3 Hz, 2H), 2.00 – 1.92 (m, 4H), 1.66 – 1.55 (m, 2H), 1.37 – 1.23 (m, 2H), 1.13 – 0.97 (m, 4H), 0.89 (t, *J* = 7.3 Hz, 3H), 0.73 – 0.62 (m, 6H), 0.61 – 0.52 (m, 2H), 0.48 – 0.38 (m, 2H); ^{13}C NMR (101 MHz, $CDCl_3$): δ = 201.2 (C), 153.8 (2C), 139.3 (2C), 131.3 (2C), 128.3 (2CH), 127.0 (2CH), 120.9 (2CH), 59.1 (CH), 54.4 (C), 41.2 ($2CH_2$), 40.6 (CH_2), 26.0 ($2CH_2$), 25.9 (CH_2), 25.6 (CH_2), 23.1 (CH_2), 22.3 (CH_2), 13.9 (CH_3), 13.9 ($2CH_3$); IR (neat): ν = 2956, 2928, 2854, 1715, 1455, 1400, 1172, 1054, 791; HR-MS (ES-TOF): *m/z*: calcd for $C_{27}H_{34}ONaS_2$: 461.1949 found 461.1949 $[M + Na]^+$.

5-((Tert-butyldiphenylsilyl)oxy)-1-(4,4-dibutyl-4H-fluoreno[4,5-def][1,3]dithiepin-9-yl)pentan-1-one (268)



268 was prepared according to **GP7** using alkyne **120** (33.6 mg, 0.10 mmol), **254** (42.7 mg, 0.12 mmol) and Au-I (5.6 mg, 5 mol%). The reaction time was 20 hours. Purification by column chromatography (95:5 hexane:Et_2O) afforded the title compound (30.0 mg, 44%) as a viscous oil; R_f 0.74 (8:2 hexane:Et_2O); ^{1}H NMR (300 MHz, $CDCl_3$): δ = 7.68 – 7.61 (m, 4H), 7.41 – 7.32 (m, 6H), 7.32 – 7.28 (m, 2H), 7.25 – 7.19 (m, 4H), 4.97 (s, 1H), 3.64 (t, *J* = 6.1 Hz, 2H), 2.80 (t, *J* = 7.2 Hz, 2H), 2.03 – 1.90 (m, 4H), 1.78 – 1.65 (m, 2H), 1.59 – 1.49 (m, 4H), 1.15 – 0.95 (m, 4H), 1.03 (s, 9H), 0.69 (t, *J* = 6.3 Hz, 3H), 0.64 (t, *J* = 6.3 Hz, 3H), 0.61 – 0.51 (m, 2H), 0.49 – 0.37 (m, 2H); ^{13}C NMR (101 MHz, $CDCl_3$): δ = 201.1 (C), 153.9 (2C), 139.4 (2C), 135.8 (2CH), 134.1 (2C), 131.3 (2C), 129.8 (2CH), 128.4 (2CH), 127.8 (4CH), 127.0 (2CH), 121.0 (2CH), 63.5 (CH_2), 59.1 (CH), 54.4 (C), 41.3 (CH_2), 40.6 (CH_2), 31.8 (CH_2), 27.1 ($3CH_3$), 25.9 (CH_2), 25.7 (CH_2), 23.1 (CH_2), 20.5 (CH_2), 19.4 (CH_2), 14.0 ($2CH_3$); IR (neat): *v* = 3053, 2956, 2929, 2857, 1716, 1590, 1562, 1454, 1428, 1400, 1108, 908, 734, 700, 613; HR-MS (ES-TOF): *m/z*: calcd for $C_{43}H_{52}O_2Na^{28}SiS_2$: 715.3068, found 715.3076 $[M + Na]^+$.

4-Chloro-1-(4,4-dibutyl-4H-fluoreno[4,5-def][1,3]dithiepin-9-yl)butan-1-one (262)

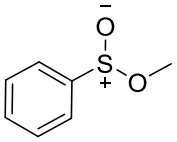


262 was prepared according to **GP7** using 5-chloro-1-pentyne (10.3 mg, 0.10 mmol), **254** (42.7 mg, 0.12 mmol) and Au-I (5.6 mg, 5 mol%). The reaction time was 20 hours. Purification by column chromatography (95:5 hexane:Et_2O) afforded the title compound (30.5 mg, 66%) as a colourless viscous oil; R_f 0.55 (8:2 hexane:Et_2O); ^{1}H NMR (300 MHz, $CDCl_3$): δ = 7.38 – 7.32 (m, 2H), 7.28 – 7.23 (m, 4H), 5.08 (s, 1H), 3.53 (t, *J* = 6.3 Hz, 2H),

3.07 (t, *J* = 6.8 Hz, 2H), 2.08 (dq, *J* = 13.2, 6.6 Hz, 2H), 2.02 – 1.93 (m, 4H), 1.20 – 0.97 (m, 4H), 0.71 (t, *J* = 5.2 Hz, 3H), 0.66 (t, *J* = 5.2 Hz, 3H), 0.63 – 0.52 (m, 2H), 0.50 – 0.37 (m, 2H); ^{13}C NMR (101 MHz, $CDCl_3$): δ = 199.8 (C), 153.8 (2C), 139.4 (2C), 130.9 (2C), 128.3 (2CH), 127.1 (2CH), 121.0 (2CH), 58.6 (CH), 54.4 (C), 44.1 (CH_2), 41.3 ($2CH_2$), 41.1 (CH_2), 37.5 (CH_2), 26.7 (CH_2), 25.8 (CH_2), 25.6 (CH_2), 23.1 (CH_2), 13.9 ($2CH_3$); IR (neat): *v* = 2957, 2929, 2858, 1718, 1563; HR-MS (ES-TOF): *m/z*: calcd for $C_{26}H_{31}ONaS_2Cl$: 481.1403 found 481.1419 $[M + Na]^+$.

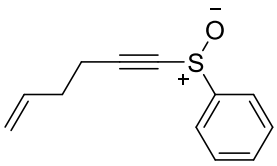
5.4 Experimental section: Chapter 4

Methyl benzenesulfinate (320)



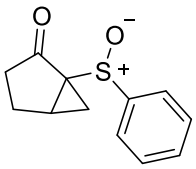
320 was prepared according to **GP8** using diphenyl disulfide (1.31 g, 6.00 mmol), *N*-bromosuccinimide (3.24 g, 18.0 mmol) and MeOH (30.0 mL). The reaction time was 2 hours. Column chromatography (CH_2Cl_2) provided the title compound (1.56 g, 83%) as a colourless oil; R_f 0.33 (CH_2Cl_2); ^{1}H NMR (300 MHz, $CDCl_3$): δ = 7.71 (dt, *J* = 5.5, 2.1 Hz, 2H), 7.60 – 7.50 (m, 3H), 3.48 (s, 3H); ^{13}C NMR (101 MHz, $CDCl_3$): δ = 144.0 (C), 132.4 (CH), 129.2 (2CH), 125.5 (2CH), 49.8 (CH_3); IR (neat): ν = 3060, 2942, 1478, 1445, 1307, 1124, 1082, 1067, 958, 755, 672, 689. Data matches that reported in the literature.[131]

(Hex-5-en-1-yn-1-ylsulfinyl)benzene (322)



322 was prepared according to **GP9** with magnesium (1.73 g, 72.0 mmol), allyl bromide (6.14 mL, 72.0 mmol), propargyl chloride (3.45 mL, 30 mmol) and **320** (9.37 g, 60 mmol). The reaction time was 16 hours. Subsequent workup and purification by column chromatography (9:1 hexane:EtOAc) afforded **322** as a yellow oil (1.23 g, 26%); R_f 0.27 (9:1 hexane:EtOAc); ^{1}H NMR (300 MHz, $CDCl_3$): δ = 7.85 – 7.75 (m, 2H), 7.59 – 7.50 (m, 3H), 5.79 (ddt, *J* = 17.0, 10.2, 6.6 Hz, 1H,), 5.06 (dd, *J* = 17.0, 1.4 Hz, 1H), 5.06 (dd, *J* = 10.2, 1.4 Hz, 1H), 2.52 (t, *J* = 7.2 Hz, 2H), 2.31 (dt, *J* = 7.2, 6.6 Hz, 2H); ^{13}C NMR (101 MHz, $CDCl_3$): δ = 144.4 (C), 135.7 (CH), 131.7 (CH), 129.6 (2CH), 125.1 (2CH), 116.8 (CH_2), 106.2 (C), 78.2 (C), 31.7 (CH_2), 19.7 (CH_2); IR (neat): ν = 3078, 2981, 2913, 2180, 1643, 1581, 1476, 1444, 1188, 1086, 1052, 985, 917, 885, 788, 749, 687; HR-MS (ES-TOF): *m/z*: calcd for $C_{12}H_{12}ONaS$: 227.0507, found 227.0502 $[M + Na]^+$.

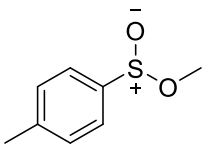
1-(Phenylsulfinyl)bicyclo[3.1.0]hexan-2-one (323 and 323')



323 was isolated from the combination of crude NMR's from 3 (0.1 M) scale screening reactions. Column chromatography (2:1 hexane:EtOAc) afforded firstly one diastereomer (5.0 mg) as an oily solid; R_f 0.22 (2:1 hexane:EtOAc); ^{1}H NMR (300 MHz, $CDCl_3$): δ = 7.82 – 7.74 (m, 2H), 7.50 (dd, *J* = 5.0, 1.9 Hz, 3H), 2.80 – 2.70 (m, 2H), 2.38 – 2.23 (m, 6H), 2.13 – 2.01 (m, 2H), 1.75 (dd, *J* = 8.6, 5.3 Hz, 2H), 1.24 (t, *J* = 5.3 Hz, 3H); ^{13}C NMR (101 MHz, $CDCl_3$): δ = 208.5 (C), 143.2 (C), 131.3 (CH), 129.1 (2CH), 124.8 (2CH), 54.6 (C), 34.4 (CH_2), 30.3 (CH), 21.6 (CH_2), 15.5 (CH_2); IR (neat): ν = 3059, 2946, 2879, 1718, 1582, 1477, 1443, 1276, 1083, 1041, 1022, 749, 689; HR-MS (ES-TOF): *m/z*: calcd for $C_{12}H_{13}O_2S$: 221.0636, found 221.0638 $[M+ H]^+$.

The other diastereomer (5.0 mg) was next eluted (2:1 hexane:EtOAc) as a colorless oil; ^{1}H NMR (300 MHz, $CDCl_3$): δ = 7.68 – 7.58 (m, 2H), 7.52 – 7.46 (m, 3H), 2.44 (dt, *J* = 8.7, 5.0 Hz, 1H), 2.29 – 1.91 (m, 4H), 1.90 – 1.74 (m, 1H), 1.48 (t, *J* = 5.3 Hz, 1H); ^{13}C NMR (101 MHz, $CDCl_3$): δ = 208.5 (C), 143.2 (C), 131.5 (CH), 129.2 (2CH), 124.6 (2CH), 55.4 (C), 33.6 (CH_2), 26.5 (CH), 21.1 (CH_2), 19.0 (CH_2); IR (neat): ν = 3060, 2944, 2880, 1721, 1582, 1476, 1443, 1274, 1084, 1030, 956, 748, 690; HR-MS (ES-TOF): *m/z*: calcd for $C_{12}H_{13}O_2S$: 221.0636, found 221.0631 $[M + H]^+$.

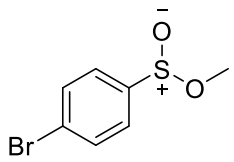
Methyl 4-methylbenzenesulfinate (324)



324 was prepared according to **GP8** with 1,2-di-p-tolyldisulfane (2.09 g, 8.40 mmol), *N*-bromosuccinimide (4.49 g, 25.2 mmol) and MeOH (50 mL). The reaction time was 2 hours. Aqueous workup and purification by column chromatography (1:1 CH_2Cl_2:hexane) afforded the title compound (2.48 g, 87%) as a colourless oil; R_f 0.60 (CH_2Cl_2); ^{1}H NMR (300 MHz, $CDCl_3$): δ = 7.59 (d, *J* = 8.1 Hz, 2H), 7.34 (d, *J* = 8.1 Hz, 2H), 3.46 (s, 3H), 2.43 (s, 3H); ^{13}C NMR (101 MHz, $CDCl_3$): δ = 143.1 (C), 140.8 (C),

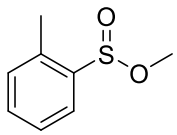
129.9 (2CH), 125.5 (2CH), 49.7 (CH_2), 21.7 (CH_2); IR (neat): ν = 3082, 2994, 2941, 2827, 1572, 1472, 1386, 1128, 1062, 1009, 954, 818, 676. Data matches that reported in the literature.[128]

Methyl 4-bromobenzenesulfinate (325)



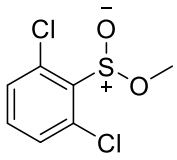
325 was prepared according to **GP8** with 1,2-bis(4-bromophenyl)disulfane (3.17 g, 8.40 mmol), *N*-bromosuccinimide (4.49 g, 25.2 mmol) and MeOH (50 mL). The reaction time was 2 hours. Aqueous workup and purification by column chromatography (CH_2Cl_2) afforded the title compound (3.42 g, 86%) as a colourless oil; R_f 0.60 (CH_2Cl_2); ^{1}H NMR (300 MHz, $CDCl_3$): δ = 7.73 – 7.66 (m, 2H), 7.62 – 7.55 (m, 2H), 3.48 (s, 3H); ^{13}C NMR (101 MHz, $CDCl_3$): δ = 143.1 (C), 132.5 (2CH), 127.2 (2CH), 49.9 (CH_3); IR (neat): ν = 3082, 2994, 2941, 2826, 1572, 1472, 1386, 1128, 1062, 954, 818, 676; HR-MS (ES-TOF): *m/z*: calcd for $C_7H_{18}O_2S^{79}Br$: 234.9428, found 234.9425 $[M + H]^+$.

Methyl 2-methylbenzenesulfinate (326)



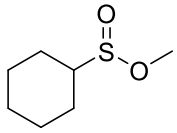
326 was prepared according to **GP8** with 1,2-di-o-tolyldisulfane (2.46 g, 10.0 mmol), *N*-bromosuccinimide (2.49 g, 30.0 mmol) and MeOH (60 mL). The reaction time was 2 hours. Aqueous workup and purification by column chromatography (CH_2Cl_2) afforded the title compound (2.49 g, 73%) as a colourless oil; R_f 0.24 (CH_2Cl_2); ^{1}H NMR (300 MHz, $CDCl_3$): δ = 7.90 (dd, *J* = 7.4, 1.8 Hz, 1H), 7.42 (pd, *J* = 7.3, 1.4 Hz, 2H), 7.25 (d, *J* = 7.3 Hz, 1H), 3.47 (s, 3H), 2.48 (s, 3H); IR (neat): ν = 2931, 2855, 1727, 1450, 1298, 1130, 987, 690. Data matches that reported in the literature.[185]

Methyl 2,6-dichlorobenzenesulfinate (327)



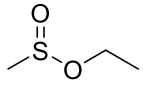
327 was prepared adapting **GP8**. Disulfide (6.1 mmol) was dissolved in CH_2Cl_2 (200 mL) and MeOH (200 mL). *N*-bromosuccinimide (3.26 g, 18.3 mmol) was added in one portion at 0 ^oC. The mixture was allowed to warm to rt and was then heated to reflux for 2 hours, cooled to rt and stirred for a further 12 hours. It was then washed with $NaHCO_3$ (2 × 50 mL) and water (50 mL). The organic layer was dried Na_2SO_4, filtered, concentrated under reduced pressure and purified by column chromatography (1:1 CH_2Cl_2:hexane to CH_2Cl_2) to afford sulfinic ester **327** (1.91 g, 69%) over 2 steps, as a colourless oil. R_f 0.58 (CH_2Cl_2); ^1H NMR (300 MHz, $CDCl_3$): δ = 7.35 (app q, *J* = 3.3 Hz, 3H), 3.89 (s, 1H); ^{13}C NMR (101 MHz, $CDCl_3$): δ = 134.9 (C), 132.9 (CH), 130.4 (2CH), 55.0 (CH_3); IR (neat): *ν* = 3073, 2942, 1559, 1425, 964, 778, 717, 691; HR-MS (ES-TOF): *m/z*: calcd for $C_7H_7O_2SCl_2$: 224.9544, found 224.9543 $[M + H]^+$.

Methyl cyclohexanesulfinate (329)



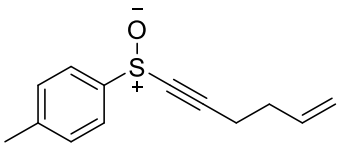
329 was prepared according to **GP8** with disulfide (2.30 g, 10.0 mmol), *N*-bromosuccinimide (5.34 g, 30 mmol) and MeOH (60 mL). The reaction time was 2 hours. Aqueous workup and purification by column chromatography (CH_2Cl_2) afforded the title compound (1.60 g, 49%) as a colourless oil; R_f 0.24 (CH_2Cl_2); ^1H NMR (300 MHz, $CDCl_3$): δ = 3.78 (s, 3H), 2.61 – 2.47 (m, 1H), 2.05 – 1.94 (m, 2H), 1.92 – 1.78 (m, 3H), 1.73 – 1.65 (m, 1H), 1.41 – 1.22 (m, 4H); IR (neat): ν = 3056, 2942, 2547, 1705, 1473, 1458, 1278, 1141, 1087, 1006, 805, 755, 702. Data matches that reported in the literature.[186]

Ethyl methanesulfinate (328)



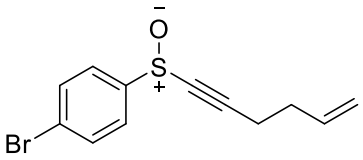
328 Prepared according to **GP8** and used directly with no data collected.

1-(Hex-5-en-1-yn-1-ylsulfinyl)-4-methylbenzene (330)



330 was prepared according to **GP9** with magnesium (437 mg, 18.0 mmol), allyl bromide (1.57 mL, 18.0 mmol), propargyl chloride (829 µl, 7.50 mmol) and sulfinate **324** (15.0 mmol). The reaction time was 16 hours. Aqueous workup and purification by column chromatography (9:1 hexane:EtOAc) afforded **330** as a yellow oil (195 mg, 12%); R_f 0.24 (9:1 hexane:EtOAc); ^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.69 (d, *J* = 8.1 Hz, 2H), 7.34 (d, *J* = 8.1 Hz, 2H), 5.79 (ddt, *J* = 17.0, 10.2, 6.6 Hz, 1H), 5.07 (dd, *J* = 17.0, 1.5 Hz, 1H), 5.04 (dd, *J* = 10.2, 1.5 Hz, 1H), 2.51 (t, *J* = 7.2 Hz, 2H), 2.43 (s, 3H), 2.31 (dt, *J* = 7.2, 6.6 Hz, 2H); ^{13}C NMR (101 MHz, $CDCl_3$): δ = 142.4 (C), 141.4 (C), 135.8 (CH), 130.3 (2CH), 125.3 (2CH), 116.7 (CH_2), 104.9 (C), 78.9 (C), 31.7 (CH_2), 21.6 (CH_3), 19.7 (CH_2); IR (neat): ν = 3079, 2980, 2922, 2180, 1643, 1595, 1492, 1085, 1055, 808; HR-MS (ES-TOF): *m/z*: calcd for $C_{13}H_{15}OS$: 219.0844, found 219.0847 $[M + Na]^+$.

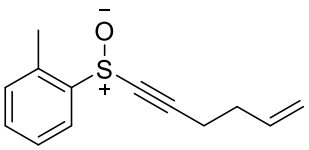
1-Bromo-4-(hex-5-en-1-yn-1-ylsulfinyl)benzene (331)



331 was prepared according to **GP9** above with magnesium (437 mg, 18.0 mmol), allyl bromide (1.57 mL, 18.0 mmol), propargyl chloride (829 µl, 7.50 mmol) and sulfinate **325** (15.0 mmol). The reaction time was 16 hours. Aqueous workup and purification by column chromatography (9:1 hexane:EtOAc) afforded **331** as a yellow oil (215 mg, 10%); R_f 0.16 (9:1 hexane:EtOAc); ^{1}H NMR (300 MHz, $CDCl_3$): δ = 7.71 – 7.63 (m, 4H), 5.78 (ddt, *J* = 17.0, 10.2, 6.5 Hz, 1H), 5.07 (dd, *J* = 17.0, 1.5 Hz, 1H), 5.05 (dd, *J* = 10.2, 1.5 Hz, 1H), 2.52 (t, *J* = 7.2 Hz, 2H), 2.32 (dd, *J* = 7.2, 6.5 Hz, 2H); ^{13}C NMR (101 MHz, $CDCl_3$): δ = 143.5 (C), 135.6 (CH), 132.8 (2CH), 126.6 (2CH), 126.3 (C), 116.8 (CH_2), 105.7 (C), 78.5 (C), 31.6 (CH_2), 19.7 (CH_2); IR (neat): ν

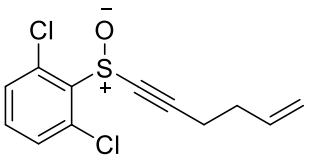
= 3079, 2980, 2916, 2180, 1642, 1569, 1470, 1386, 1085, 1055, 1006, 815, 721; HR-MS (ES-TOF): *m/z*: calcd for $C_{12}H_{12}OS^{79}Br$: 282.9792, found 282.9786 $[M + H]^+$.

1-(Hex-5-en-1-yn-1-ylsulfinyl)-2-methylbenzene (332)



332 was prepared according to **GP9** above using magnesium (437 mg, 18.0 mmol), allyl bromide (1.57 mL, 18.0 mmol), propargyl chloride (829 µl, 7.50 mmol) and sulfinate **326** (15.0 mmol). The reaction time was 16 hours. Subsequent workup and purification by column chromatography (8:2 hexane:EtOAc) afforded **332** (649 mg, 40%) as a yellow oil; R_f 0.10 (8:2 hexane:EtOAc); ^{1}H NMR (300 MHz, $CDCl_3$): δ = 8.01 – 7.93 (m, 1H), 7.46 – 7.38 (m, 2H), 7.26 – 7.22 (m, 1H), 5.76 (ddt, *J* = 17.0, 10.2, 6.6 Hz, 1H), 5.03 (dd, *J* = 17.0, 1.5 Hz, 1H), 5.02 (dd, *J* = 10.2, 1.5 Hz, 1H), 2.49 (t, *J* = 7.2 Hz, 2H), 2.48 (s, 3H), 2.28 (dt, *J* = 7.2, 6.6 Hz, 2H); ^{13}C NMR (101 MHz, $CDCl_3$): δ = 142.1 (C), 135.7 (CH), 135.4 (C), 131.4 (CH), 131.3 (CH), 127.3 (CH), 124.4 (CH), 116.7 (CH_2), 104.5 (C), 77.7 (C), 31.7 (CH_2), 19.7 (CH_2), 18.4 (CH_3); IR (neat): ν = 3067, 2980, 2919, 2180, 1643, 1594, 1471, 1454, 1074, 1036, 916, 755, 708; HR-MS (ES-TOF): *m/z*: calcd for $C_{13}H_{15}OS$: 219.0844, found 219.0848 $[M + H]^+$.

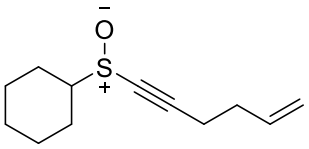
1,3-Dichloro-2-(hex-5-en-1-yn-1-ylsulfinyl)benzene (333)



333 was prepared according to **GP9** with magnesium (243 mg, 10.0 mmol), allyl bromide (869 µl, 10.0 mmol), propargyl chloride (3.45 mL, 4.0 mmol) and **327** (9.37 g, 4.0 mmol). The reaction time was 16 hours. Subsequent workup and purification by column chromatography (9:1 hexane:EtOAc) afforded **333** as a yellow oil (273 mg, 15%); ^{1}H NMR (300 MHz, $CDCl_3$): δ = 7.44 – 7.31 (m, 3H), 5.78 (ddt, *J* = 17.1, 10.2, 1.6 Hz, 1H), 5.07 (dd, *J* = 17.1, 1.6 Hz, 1H), 5.03 (dd, *J* = 10.2, 1.6 Hz, 1H), 2.54 (t, *J* = 6.9 Hz, 2H), 2.39 – 2.28 (m, 2H); ^{13}C NMR (101 MHz, $CDCl_3$): δ = 139.3 (C), 135.7 (2C), 135.7 (2CH), 133.0 (CH), 130.2 (CH), 116.7 (CH_2), 107.0 (C), 76.5 (C),

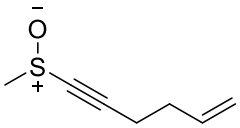
31.6 (CH_2), 19.9 (CH_2); IR (neat): ν = 3066, 2902, 21670, 1758, 1559, 1428, 1374, 1186, 1071, 783, 769, 661; HR-MS (ES-TOF): *m/z*: calcd for $C_{12}H_{11}OSCl_2$: 272.9908, found 272.9908 [M + H]$^+$.

(Hex-5-en-1-yn-1-ylsulfinyl)cyclohexane (335)



335 was prepared according to **GP9** with magnesium (267 mg, 14.0 mmol), allyl bromide (1.21 mL, 14.0 mmol), propargyl chloride (608 µl, 30.0 mmol) and **329** (1.60 g, 11.0 mmol). The reaction time was 16 hours. Subsequent workup and purification by column chromatography (8:2 hexane:EtOAc) afforded **335** (269 mg, 23%) as a yellow oil; R_f 0.21 (8:2 hexane:EtOAc); ^{1}H NMR (300 MHz, $CDCl_3$): δ = 5.82 (ddt, *J* = 16.8, 10.2, 6.5 Hz, 1H), 5.16 – 5.04 (m, 2H), 2.88 (tt, *J* = 11.6, 3.6 Hz, 1H), 2.55 (dd, *J* = 10.8, 3.8 Hz, 2H), 2.39 – 2.28 (m, 2H), 2.23 – 2.06 (m, 2H), 2.01 – 1.85 (m, 2H), 1.80 – 1.66 (m, 1H), 1.59 – 1.16 (m, 5H); ^{13}C NMR (101 MHz, $CDCl_3$): δ = 135.9 (CH), 116.7 (CH_2), 105.1 (C), 76.4 (C), 63.4 (CH), 31.9 (CH_2), 25.7 (CH_2), 25.6 (CH_2), 25.5 (CH_2), 25.4 (CH_2), 19.6 ($2CH_2$); IR (neat): ν = 3079, 2930, 2855, 2182, 1677, 1643, 1449, 1058, 995, 915; HR-MS (ES-TOF): *m/z*: calcd for $C_{12}H_{18}ONaS$: 233.0976, found 233.0981 [M + Na]$^+$.

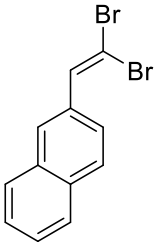
6-(Methylsulfinyl)hex-1-en-5-yne (334)



334 was prepared according to **GP9** with magnesium (437 mg, 18 mmol), allyl bromide (1.57 mL, 18 mmol), propargyl chloride (829 µl, 7.5 mmol) and sulfinate **328** (1.63 g, 15 mmol). The reaction time was 16 hours. Aqueous workup and purification by column chromatography (9:1 hexane:EtOAc) afforded **334** (185 mg, 17%) as a yellow oil; R_f 0.12 (7:3 hexane:EtOAc); ^{1}H NMR (300 MHz, $CDCl_3$): δ = 5.82 (ddt, *J* = 16.8, 10.2, 6.5 Hz, 1H), 5.16 – 5.04 (m, 2H), 2.94 (s, 3H), 2.57-2.49 (m, 2H), 2.33 (dt, *J* = 7.0, 3.8

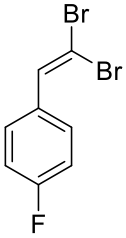
Hz, 2H); ^{13}C NMR (101 MHz, $CDCl_3$): δ = 135.7 (CH), 116.7 (CH_2), 103.9 (C), 79.1 (C), 43.9 (CH_3), 31.7 (CH_2), 19.5 (CH_2); IR (neat): ν = 3079, 3303, 2981, 2917, 2183, 1643, 1417, 1061, 917, 675; HR-MS (ES-TOF): *m/z*: calcd for $C_7H_{10}ONaS$: 165.0350, found 165.0345 $[M + Na]^+$.

2-(2,2-Dibromovinyl)naphthalene (344)



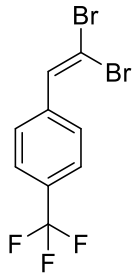
Prepared using **GP1**, with 2-naphthaldehyde (546 µL, 4.00 mmol), CBr_4 (2.63 g, 8.00 mmol) and PPh_3 (4.20 g, 16.0 mmol) in dry CH_2Cl_2 (12 mL). The reaction time was 1 hour. Purification by column chromatography, eluting with *n*-hexane, afforded the dibromoalkene **344** as a white solid (1.05 g, 84%); mp: 93-94 °C; ^{1}H NMR (300 MHz, $CDCl_3$): δ = 8.02 (s, 1H), 7.88 – 7.81 (m, 3H), 7.68 – 7.62 (m, 2H), 7.53 – 7.48 (m, 2H); ^{13}C NMR (101 MHz, $CDCl_3$): δ = 137.1 (CH), 133.1 (2C), 132.9 (C), 128.4 (CH), 128.3 (CH), 128.2 (CH), 127.9 (CH), 126.9 (CH), 126.7 (CH), 125.8 (CH), 90.0 (C); IR (neat): *v* = 3060, 3014, 1588, 1505, 1372, 1081, 1013, 945, 830, 789, 771, 709. Data matches that reported in the literature.[187]

1-(2,2-Dibromovinyl)-4-fluorobenzene (345)



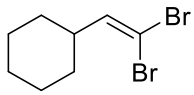
Prepared using **GP1**, with *para*-fluorobenzaldehyde (422 µl, 4.00 mmol), CBr_4 (2.63 g, 8.00 mmol) and PPh_3 (4.63 g, 16.00 mmol) in dry CH_2Cl_2 (12 mL). The reaction time was 1 hour. Aqueous work-up and purification by column chromatography (hexane), provided the dibromoalkene **345** (880 mg, 79%) as a colourless oil; ^{1}H NMR (300 MHz, $CDCl_3$): δ = 7.52 (dd, *J* = 8.7, 5.5 Hz, 2H), 7.44 (s, 1H), 7.12 – 7.00 (m, 2H); ^{13}C NMR ($CDCl_3$): δ = 163.2 (*J* = 248.7 Hz, C) 130.9 (*J* = 7.6 Hz, C), 136.4 (CH), 132.0 (C), 115.1 (*J* = 21.6 Hz, C), 90.0 (C); IR (neat): ν = 2981, 1602, 1506, 1411, 1229, 1160, 1099, 1015, 875, 812. Data matches that reported in the literature.[108]

1-(2,2-Dibromovinyl)-4-(trifluoromethyl)benzene (346)



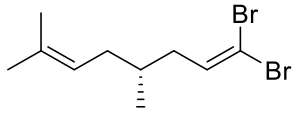
Prepared using **GP1**, with 4-(Trifluoromethyl)benzaldehyde (546 µL, 4.00 mmol), CBr_4 (2.63 g, 8.00 mmol), and PPh_3 (4.20 g, 16.0 mmol) in dry CH_2Cl_2 (12 mL). The reaction time was 1 hour. Aqueous work-up and purification by column chromatography, eluting with *n*-hexane, afforded the dibromoalkene **346** (977 mg, 74%) as a colourless oil; ^{1}H NMR (300 MHz, $CDCl_3$): δ = 7.63 (s, 4H), 7.52 (s, 1H); ^{13}C NMR (101 MHz, $CDCl_3$): δ = 138.9 (C), 135.7 (CH), 130.3 (C), 128.8 (2CH), 125.6 (CH), 125.5 (CH), 123.8 (C), 92.4 (C); IR (neat): ν = 1617, 1409, 1320, 1165, 1122, 1067, 1017, 877, 746. Data matches that reported in the literature.[108]

(2,2-Dibromovinyl)cyclohexane (347)



Prepared using **GP1**, with 2-cyclohexylcarbaldehyde (606 µl, 5.00 mmol), CBr_4 (3.18 g, 10.0 mmol), and PPh_3 (5.79 g, 20.0 mmol) in dry CH_2Cl_2 (15 mL). The reaction time was 10 minutes. The mixture was precipitated with pentane, filtering through celite, repeating (× 4), the residue was dry loaded and filtered through a short silica column affording dibromooalkene **347** (640 mg, 48%) as a colourless oil; R_f 0.90 (hexane); ^{1}H NMR (300 MHz, $CDCl_3$): δ = 6.23 (d, *J* = 9.1 Hz, 1H), 2.35 – 2.20 (m, 1H), 1.80 – 1.59 (m, 5H), 1.38 – 1.04 (m, 5H); ^{13}C NMR (101 MHz, $CDCl_3$): δ = 143.9 (CH), 87.1 (C), 42.6 (CH), 31.4 ($2CH_2$), 25.9 (CH_2), 25.6 ($2CH_2$); IR (neat): *ν* = 2924, 2851, 1610, 1448, 1350, 1311, 1257, 1218, 1140, 965, 893, 833, 813, 764. Data matches that reported in the literature.[188]

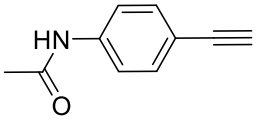
1,1-Dibromo-8-methylnona-1,7-diene (348)



Prepared using **GP1**, with citronellal (722 µl, 4.00 mmol), CBr_4 (2.63 g, 8.00 mmol), and PPh_3 (4.63 g, 16.0 mmol) in dry CH_2Cl_2 (12 mL). The reaction time was 2 hours. Aqueous work-up and purification by column chromatography (hexane), yielded **320** (882 mg, 71%) as a colourless oil; ^{1}H NMR (300 MHz, $CDCl_3$): δ = 6.40

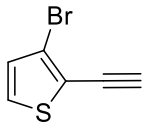
(t, *J* = 7.3 Hz, 1H), 5.08 (dddt, *J* = 8.4, 4.1, 2.7, 1.3 Hz, 1H), 2.10 (ddd, *J* = 14.7, 7.1, 5.9 Hz, 1H), 2.05 – 1.90 (m, 3H), 1.72 – 1.56 (m, 7H), 1.41 – 1.27 (m, 1H), 1.26 – 1.11 (m, 1H), 0.92 (d, *J* = 6.7 Hz, 3H); IR (neat): *ν* = 2959, 1705, 1458, 1381, 1127, 779. Data matches that reported in the literature.[189]

N-(4-Ethynylphenyl)acetamide (350)



350 was prepared according to a literature procedure.[135, 143] 4-iodoaniline (2.00 g, 9.12 mmol, 1.0 eq.), $Pd(PPh_3)_2Cl_2$ (166 mg, 2.7 mol%) and CuI (44 mg, 2.7 mol%) were added to a RBF under argon. Degassed triethylamine (30 mL) was added and the mixture was stirred at rt over 30 minutes. TMS acetylene (1.56 mL 11.4 mmol, 1.25 eq.) was added dropwise and the reaction mixture was stirred at rt for 24 hours, The organic phase was extracted with water/ethyl acetate (3 ×), washed with brine, dried over Na_2SO_4, filtered and the solvent was removed under reduced pressure. The crude product was purified by column chromatography to afford 4-(trimethylsilylethynyl)aniline as a yellow solid. The alkyne was dissolved in MeOH (20 mL) and K_2CO_3 (189 mg, 1.37 mmol, 0.15 eq.) Water (20 mL) was added and the mixture was extracted with CH_2Cl_2 (3 × 20 mL), dried over Na_2SO_4, filtered and concentrated under reduced pressure to afford 4-ethynylaniline (1.01 g, 86%). 4-Ethynylaniline (995 mg, 8.50 mmol, 1.0 eq.) was dissolved in CH_2Cl_2 (20 mL) and acetic anhydride (892 µL, 9.5 mmol, 1.12 eq.) was added. The mixture was stirred at rt for 16 hours, CH_2Cl_2 removed under reduced pressure and the residue was purified by column chromatography (6:4 hexane:EtOAc) yielding the title compound (694 mg, 44%) as a yellow solid); mp: 114-117 ^oC; ^1H NMR (300 MHz, $CDCl_3$): δ = 7.53 – 7.42 (m, 4H), 7.31 (s, 1H), 3.04 (s, 1H), 2.18 (s, 3H); IR (neat): ν = 3317, 3301, 3185, 3115, 3055, 2107, 1666, 1596, 1529, 1508, 1319, 832, 822. Data matches that reported in the literature.[135]

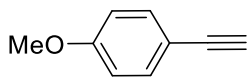
3-Bromo-2-ethynylthiophene (351)



351 was prepared in two steps from 3-bromothiophene according to a literature procedure.[137,138] To a mixture of 3-bromothiophene (1.63 g, 10.0 mmol, 1.0 eq.), $CHCl_3$ (20 mL) and acetic acid (10 mL) in the dark was added *N*-iodosuccinimide (2.70 g, 12.0 mmol, 1.2 eq.) in one portion and the reaction was stirred at rt for 48 hours. The solution was concentrated under reduced pressure, $NaHCO_3$ (sat) (20 mL) was added to neutralise the solution and the mixture was extracted with hexane (2 × 10 mL). The combined organics layers were dried over Na_2SO_4, filtered and concentrated under reduced pressure to afford a pink oil which was directly used in the sonagashira coupling.

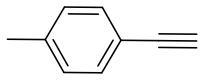
A flame dried 100 mL RBF was charged with 3-bromo-2-iodothiophene (1.80 g, 5.6 mmol), $Pd(PPh_3)_2Cl_2$ (36 mg, 1 mol%) and CuI (90 mg, 5 mol%). Degassed diisopropyl amine (56 mL) and degassed anhydrous toluene (15 mL) were added before the dropwise addition of TMS acetylene (1.01 ml, 7.3 mmol, 1.3 eq.). The reaction mixture was heated to 70 ^oC and stirred at this temperature for 16 hours. On cooling to rt, HCl (50 mL of a 2M solution) was added, the organic layer was separated and washed with brine (20 mL), dried over Na_2SO_4, filtered, concentrated under reduced pressure and purified by column chromatography (hexane) to afford the TMS protected alkyne. The alkyne was dissolved in MeOH (20 mL) and K_2CO_3 (189 mg, 1.37 mmol, 0.15 eq.) and stirred at rt for 1 hour. Water (20 mL) was added and the mixture was extracted with CH_2Cl_2 (3 × 20 mL), dried over Na_2SO_4, filtered and concentrated under reduced pressure to afford the title compound (443 mg, 24%) over 3 steps; ^1H NMR (300 MHz, $CDCl_3$): δ = 7.22 (d, *J* = 5.4 Hz, 1H), 6.97 (d, *J* = 5.4 Hz, 1H), 3.58 (s, 1H); IR (neat): ν = 3290, 3107, 2981, 2104, 1661, 1498, 1416, 1347, 1161, 865, 711. Data is in agreement with literature values.[138]

1-Ethynyl-4-methoxybenzene (352)



352 was prepared according to a literature procedure.[10] To a RBF under argon was added 4-iodoanisole (1.17 g, 5.00 mmol) and Et_3N (10 mL). The vessel was degassed for 10 minutes before the addition of $Pd(PPh_3)_2Cl_2$ (35.0 mg, 1 mol%) and CuI (10.0 mg, 1 mol%), TMS acetylene (1.38 mL, 10.0 mmol) was added dropwise and the reaction mixture was stirred for 1 hour at rt. The mixture was concentrated under reduced pressure, CH_2Cl_2 (20 mL) added, washed with $NaHCO_3$ (sat) (20 mL), water (20 mL), dried over Na_2SO_4, filtered and concentrated under reduced pressure. The residue was purified by column chromatography (hexane) to afford the TMS protected alkyne. The alkyne in a RBF was evacuated and MeOH (5 mL) and CH_2Cl_2 (5 mL) were added followed by K_2CO_3 (1.38 g, 10.0 mmol, 2.0 eq.). The reaction was stirred at rt for 1 hour before the addition of water (10 mL). The organic layer was collected and the aqueous layer was extracted with CH_2Cl_2 (3 × 10 mL), dried over Na_2SO_4, filtered and concentrated under reduced pressure to afford the title compound (562 mg, 85% over 2 steps) as a yellow oil; ^1H NMR (300 MHz, $CDCl_3$): δ = 7.46 – 7.39 (m, 2H), 6.88 – 6.80 (m, 2H), 3.82 (s, 3H), 3.00 (s, 1H). IR (neat): ν = 3286, 2961, 2839, 2106, 1606, 1571, 1505, 1290, 1245, 1169, 1029, 830, 811, 685. Data matches that reported in the literature.[134]

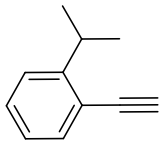
1-Ethynyl-4-methylbenzene (353)



353 was prepared according to a literature procedure.[134] To a RBF under argon was added 4-iodotoluene (1.09 g, 5.00 mmol) and Et_3N (10 mL). The vessel was degassed for 10 minutes before the addition of $Pd(PPh_3)_2Cl_2$ (35.0 mg, 1 mol%) and CuI (10.0 mg, 1 mol%), TMS acetylene (1.38 mL, 10.0 mmol) was added dropwise and the reaction mixture was stirred for 1 hour at rt. The mixture was concentrated under reduced pressure, extracted with CH_2Cl_2 (20 mL), washed with $NaHCO_3$ (sat) (20 mL), water (20 mL),

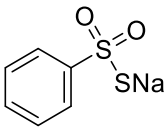
dried over Na_2SO_4, filtered and concentrated under reduced pressure. The residue was purified by column chromatography (hexane) to afford the TMS protected alkyne. The alkyne in a RBF was evacuated and MeOH (5 mL) and CH_2Cl_2 (5 mL) were added followed by K_2CO_3 (1.38 g, 10.0 mmol, 2.0 eq.). The reaction was stirred at rt for 1 hour before the addition of water (10 mL). The organic layer was collected and the aqueous was extracted CH_2Cl_2 (3 × 10 mL), dried Na_2SO_4, filtered and concentrated under reduced pressure to afford the title compound (562 mg, 43% over 2 steps) as a yellow oil; ^{1}H NMR (300 MHz, $CDCl_3$): δ = 7.39 (d, *J* = 8.0 Hz, 2H), 7.13 (d, *J* = 8.0 Hz, 2H), 3.03 (s, 1H), 2.36 (s, 3H); IR (neat): ν = 3312, 2955, 2924, 2855, 1693, 1608, 1508, 1249, 838, 755. Data matches that reported in the literature.[190]

1-Ethynyl-2-isopropylbenzene (354)



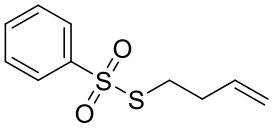
354 was prepared according to a literature procedure.[136] To a mixture of 1-iodo-2-isopropyl benzene (1.23 g, 5.00 mmol), $Pd(PPh_3)_2Cl_2$ (166 mg, 5 mol%) and CuI (88 mg, 10 mol%) under argon was added degassed Et_3N (10 mL). The mixture was cooled to 0 °C and TMS acetylene (0.78 mL, 5.5 mmol, 1.1 eq.) was added dropwise. The mixture was stirred at rt for 20 hours, filtered through celite and concentrated under reduced pressure. The residue was purified by column chromatography (hexane) affording the TMS protected alkyne. The alkyne was dissolved in MeOH (10 mL) and K_2CO_3 (104 mg, 0.15 eq.) was added and the reaction was stirred at rt for 1 hour. Water (10 mL) was added and the mixture was extracted with CH_2Cl_2 (3 × 10 mL), dried over Na_2SO_4, filtered and concentrated under reduced pressure to afford the title compound (655 mg, 91%) as a pale orange oil; ^{1}H NMR (300 MHz, $CDCl_3$): δ = 7.50 – 7.45 (m, 1H), 7.36 – 7.27 (m, 2H), 7.18 – 7.10 (m, 1H), 3.50 (dt, *J* = 13.8, 6.9 Hz, 1H), 3.25 (s, 1H), 1.27 (d, *J* = 6.9 Hz, 6H); IR (neat): ν = 3299, 2965, 1922, 1599, 1444, 1080, 1032, 758, Data is in agreement with literature values.[136]

Sodium benzenesulfonothioate (358)



358 was prepared according to a literature procedure.[141] To a RBF under argon was added pyridine (31 mL) and benzene sulfinate (5.00 g, 30.0 mmol). Sulfur (975 mg, 30.0 mmol) was added and the suspension was stirred at rt for 75 minutes. The mixture was filtered, washing with anhydrous Et_2O (30 mL) and the crude product collected. Recrystallisation from boiling (EtOH) affording the title compound (4.91 g, 83%) as white crystals; mp: 286-288 ^oC; ^1H NMR (300 MHz, DMSO): δ = 7.76 – 7.70 (m, 2H), 7.39 – 7.29 (m, 3H); IR (neat): ν = 3467, 3405, 3063, 1608, 1444, 1222, 1118, 1064, 760, 718, 688. Data is in agreement with literature values.[141]

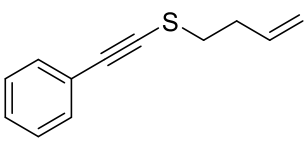
S-(But-3-en-1-yl) benzenesulfonothioate (359)



359 was prepared following a literature procedure.[142] To a RBF was added sodium benzenesulfonothioate **358** (7.60 g, 38.7 mmol, 1.0 eq) and the flask was evacuated and refilled with argon (× 3). Anhydrous DMF (60 mL) was added and the mixture was stirred at rt. 4-bromo-1-butene (4.03 mL, 40 mmol, 1.03 eq.) was added over 5 minutes by syringe and the mixture was stirred for 4 days. The mixture was poured into ice/ water (200 mL) and was extracted with Et_2O (6 × 50 mL). The combined organic fractions were washed with $NaHCO_3$ (sat) solution (50 mL), brine (3 × 50 mL), dried over Na_2SO_4, filtered, concentrated under reduced pressure and purified by column chromatography (9:1 hexane:EtOAc) to afford **359** (8.90 g, 86%) as a pale orange oil; R_f 0.29 (9:1 hexane: EtOAc); ^1H NMR (300 MHz, $CDCl_3$): δ = 8.01 – 7.87 (m, 2H), 7.75 – 7.49 (m, 3H), 5.67 (ddt, J = 17.0, 10.4, 6.7 Hz, 1H), 5.08 – 4.96 (m, 2H), 3.07 (t, J = 7.3 Hz, 2H), 2.41 – 2.28 (m, 2H); ^{13}C NMR (101 MHz, $CDCl_3$): δ = 145.0 (C), 134.8 (CH), 133.8 (CH), 129.4 (2CH), 127.1 (2CH), 117.7 (CH_2), 35.3 (CH_2), 32.9 (CH_2); IR (neat): ν = 3068, 2981, 1641, 1582, 1447, 1322, 1308, 1293,

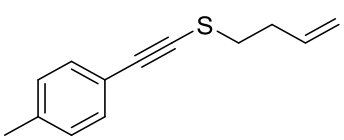
1139, 1076, 714; HR-MS (ES-TOF): *m/z*: calcd for $C_{10}H_{12}O_2S_2Na$: 251.0179, found 251.0176 $[M + Na]^+$.

But-3-en-1-yl(phenylethynyl)sulfane (355)



355 was prepared according to **GP11** using phenylacetylene (563 mg, 5.5 mmol), LiHMDS (1 M, 5.5 mL, 5.5 mmol), **359** (1.14 g, 5.0 mmol) and THF (25 mL). The reaction time was 19 hours. Aqueous workup and purification by column chromatography (hexane) provided **355** (804 mg, 94%) as a colourless oil; R_f 0.26 (hexane); ^{1}H NMR (300 MHz, $CDCl_3$): δ = 7.46 – 7.37 (m, 2H), 7.34 – 7.27 (m, 3H), 5.88 (ddt, *J* = 17.0, 10.2, 6.6 Hz, 1H), 5.16 (dd, *J* = 17.0, 1.6 Hz, 1H), 5.10 (dd, *J* = 10.2, 1.6 Hz, 1H), 2.86 (t, *J* = 7.4 Hz, 2H), 2.57 (dt, *J* = 7.4, 6.6 Hz, 2H); ^{13}C NMR (101 MHz, $CDCl_3$): δ =135.8 (CH), 131.7 (2CH), 128.5 (2CH), 128.3 (C), 117.1 (CH_2), 93.5 (C), 35.1 (CH_2), 33.7 (CH_2); IR (neat): ν = 3079, 2979, 2927, 2166, 1640, 1595, 1487, 1442, 915, 752, 688; HR-MS (ES-TOF): *m/z*: calcd for $C_{12}H_{12}S$: 188.0660, found 188.0663 $[M + H]^+$.

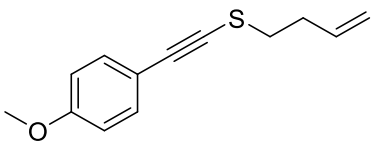
But-3-en-1-yl(p-tolylethynyl)sulfane (356)



356 was prepared according to a literature procedure.[140] To a 50 mL 3 neck RBF was added alkyne **353** (190 mg, 1.64 mmol, 1.0 eq.) and THF (8 mL). The mixture was cooled to -78 ^{o}C in a dry ice/ acetone bath and *n*-BuLi (2.5 M in hexanes) (0.72 mL, 1.80 mmol, 1.0 eq.) was added dropwise. On complete addition the mixture was stirred for 1 hour at -78 ^{o}C before addition of sulfur (52.6 mg, 1.64 mmol, 1.0 eq.). The resulting red solution was stirred for a further hour at -78 ^{o}C before warming to 0 ^{o}C over 1 hour. 4 Bromo-1-butene (167 µL, 1.64 mmol, 1.0 eq.) was added and the mixture was stirred for 2 hours at 0 ^{o}C and left to warm to rt for 16 hours. The mixture was quenched with NH_4Cl (10 mL of a saturated solution), extracted with Et_2O (3 × 10 mL), washed with brine (10 mL), dried over Na_2SO_4, concentrated under reduced pressure and purified by column

chromatography (hexane) to afford **356** (222 mg, 67%) as a colourless oil; R_f 0.43 (hexane); ^{1}H NMR (300 MHz, $CDCl_3$): δ = 7.32 (d, *J* = 8.0 Hz, 2H), 7.11 (d, *J* = 8.0 Hz, 2H), 5.88 (ddt, *J* = 17.0, 10.2, 6.4 Hz, 1H), 5.15 (dd, *J* = 17.0, 1.6 Hz, 1H), 5.20 – 5.07 (dd, 10.2, 1.6 Hz, 2H), 2.85 (t, *J* = 7.5 Hz, 2H), 2.56 (dt, *J* = 7.5, 6.4 Hz, 2H), 2.34 (s, 3H); ^{13}C NMR (101 MHz, $CDCl_3$): δ = 138.4 (C), 135.8 (CH), 131.7 (2CH), 129.2 (2CH), 120.5 (C), 116.9 (CH_2), 93.5 (C), 78.2 (C), 35.1 (CH_2), 33.6 (CH_2), 21.6 (CH_3); IR (neat): ν = 3079, 3028, 2979, 2921, 2166, 1641, 1506, 1434, 1417, 916, 813; HR-MS (ES-TOF): *m/z*: calcd for $C_{13}H_{15}S$: 203.0894, found 203.0893 $[M + H]^+$.

But-3-en-1-yl((4-methoxyphenyl)ethynyl)sulfane (357)



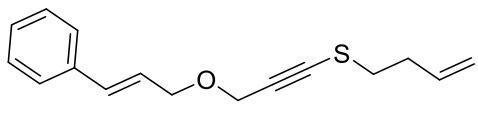
357 was prepared according to a literature procedure.[140] To a 50 mL 3 neck RBF was added alkyne **352** (170 mg, 1.29 mmol, 1.0 eq.) and THF (7 mL). The mixture was cooled to -78 ^{o}C in a dry ice/ acetone bath and *n*-BuLi (2.5 M in hexanes) (0.57 mL, 1.42 mmol, 1.0 eq.) was added dropwise. After complete addition the mixture was stirred for 1 h at -78 ^{o}C before addition of sulfur (41.3 mg, 1.29 mmol, 1.0 eq.) the resulting red solution was stirred for a further 1 h at -78 ^{o}C before warming to 0 ^{o}C slowly. 4 Bromo-1-butene (131 µL, 1.29 mmol, 1.0 eq.) was added and the mixture was stirred for 2 h at 0 ^{o}C and left to warm to rt for 16 h. The mixture was quenched with NH_4Cl (10 ml of a saturated solution), extracted with Et_2O (3 × 10 mL), washed with brine (10 mL), dried over Na_2SO_4, concentrated under reduced pressure and purified by column chromatography (hexane) to afford **356** (222 mg, 67%) as a colourless oil; R_f 0.34 (19:1 hexane:EtOAc); ^{1}H NMR (300 MHz, $CDCl_3$): δ = 7.41 – 7.35 (m, 2H), 6.85 – 6.81 (m, 2H), 5.87 (ddt, *J* = 17.0, 10.2, 6.6 Hz, 1H), 5.15 (dd, *J* = 17.0, 1.6 Hz, 1H), 5.10 (dd, *J* = 10.2, 1.6 Hz, 1H), 3.81 (s, 3H), 2.83 (t, *J* = 7.4 Hz, 2H), 2.55 (dt, *J* = 7.4, 6.6 Hz, 2H); ^{13}C NMR (101 MHz, $CDCl_3$): δ = 159.8 (C), 135.9 (CH), 133.5 (2CH), 116.9 (CH_2), 115.7 (C),

114.1 (2CH), 93.2 (C), 55.4 (CH_3), 35.1 (CH_2), 33.6 (CH_2); IR (neat): ν = 2933, 2837, 1604, 1505, 1289, 1245, 1171, 1030, 917, 829, 810, 777; HR-MS (ES-TOF): *m/z*: calcd for $C_{13}H_{15}OS$: 219.0844, found 219.0836 $[M + H]^+$.

(3-(Allyloxy)prop-1-yn-1-yl)(but-3-en-1-yl)sulfane (360)

To a flame dried (50 mL) 3 neck RBF was added alkyne **152** (60% in Et_2O (760 µl, 4.00 mmol) and THF (20 mL). The mixture was cooled to -78 ^oC in a dry ice/ acetone bath and *n*-BuLi (2.4 M in hexane) (1.82 mL, 1.2 equiv, 4.4 mmol) was added dropwise. On complete addition the mixture was stirred for an hour at -78 ^oC before the dropwise addition of **359** (827 mg, 3.63 mmol). The reaction mixture was allowed to warm to rt over 16 hours. The mixture was quenched NH_4Cl (20 mL), the organic layer was removed and the aqueous layer extracted with Et_2O (3 × 10 mL). The combined organic portions were washed with brine (20 mL), dried over Na_2SO_4, filtered, concentrated under reduced pressure and purified by column chromatography (hexane) providing **360** (376 mg, 57%) as a pale yellow oil; R_f 0.50 (19:1 hexane:EtOAc); ^1H NMR (300 MHz, $CDCl_3$): δ = 5.99 – 5.74 (m, 2H), 5.38 – 5.03 (m, 4H), 4.26 (s, 2H), 4.06 (dt, *J* = 5.8, 1.3 Hz, 2H), 2.81 – 2.72 (m, 2H), 2.55 – 2.43 (m, 2H); ^{13}C NMR (101 MHz, $CDCl_3$): δ = 135.7 (CH), 134.2 (CH), 118.0 (CH_2), 117.0 (CH_2), 90.7 (C), 90.7 (C), 70.5 (CH_2), 58.4 (CH_2), 34.7 (CH_2), 33.5 (CH_2); IR (neat): ν = 3080, 2980, 2847, 2179, 1641, 1420, 1279, 1124, 1074, 991, 917; HR-MS (AP-TOF): m/z: calcd for $C_{10}H_{15}OS$: 183.0844, found 183.0852 $[M + H]^+$.

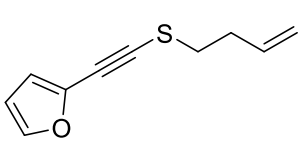
But-3-en-1-yl(3-(cinnamyloxy)prop-1-yn-1-yl)sulfane (361)



To a flame dried (50 mL) 3 neck RBF was added alkyne **153** (692 mg, 1.1 equiv, 4.00 mmol) and THF (20 mL). The mixture was cooled to -78 ^oC in a dry ice/ acetone bath and *n*-BuLi (2.35 M in hexane) (1.87 mL, 1.2 equiv, 4.4 mmol) was added dropwise. On complete addition the mixture was

stirred for an hour at -78 °C before the dropwise addition of **359** (820 mg, 1.0 equiv, 3.6 mmol). The reaction mixture was allowed to warm to rt over 16 hours. The mixture was quenched NH_4Cl (20 mL), the organic layer was removed and the aqueous layer extracted with Et_2O (3 × 10 mL). The combined organics were washed with brine (20 mL), dried over Na_2SO_4, filtered, concentrated under reduced pressure and purified by column chromatography (hexane) providing **361** (683 mg, 66%) as a pale yellow oil; R_f 0.41 (hexane); ^{1}H NMR (300 MHz, $CDCl_3$): δ = 7.29 (m, 5H), 6.67 (d, *J* = 15.9 Hz, 1H), 6.32 (dt, *J* = 15.9, 6.2 Hz, 1H), 5.87 (ddt, *J* = 16.9, 10.2, 6.6 Hz, 1H), 5.23 – 5.07 (m, 2H), 4.34 (s, 2H), 4.27 (d, *J* = 6.2 Hz, 2H), 2.80 (t, *J* = 7.4 Hz, 2H), 2.55 – 2.45 (m, 2H); ^{13}C NMR (101 MHz, $CDCl_3$): δ = 136.7 (C), 135.7 (CH), 133.4 (CH), 128.7 (2CH), 127.9 (CH), 126.7 (2CH), 125.3 (CH), 117.0 (CH_2), 90.7 (C), 70.1 (C), 58.3 (CH_2), 34.7 (CH_2), 33.5 (CH_2); IR (neat): ν = 3027, 2845, 2179, 1640, 1495, 1448, 1350, 1073, 966, 916, 744, 692; HR-MS (ES-TOF): *m/z*: calcd for $C_{16}H_{19}OS$: 259.1157, found 259.1159 $[M + H]^+$.

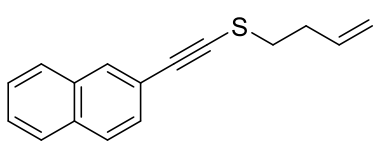
2-((But-3-en-1-ylthio)ethynyl)furan (362)



362 was prepared according to **GP10** using dibromoolefin **229** (670 mg, 2.66 mmol), *n*-BuLi (2.4 M in hexanes) (2.32 mL, 5.57 mmol), **331** (552 mg, 2.42 mmol). The reaction time was 18 hours. Aqueous workup and purification by column chromatography (pentane) provided **362** (191 mg, 44%) as a colourless oil; R_f 0.50 (hexane); ^{1}H NMR (300 MHz, $CDCl_3$): δ = 7.39 (dd, *J* = 1.9, 0.7 Hz, 1H), 6.64 (dd, *J* = 3.4, 0.7 Hz, 1H), 6.39 (dd, *J* = 3.4, 1.9 Hz, 1H), 5.85 (ddt, *J* = 17.0, 10.2, 6.6 Hz, 1H), 5.15 (dd, *J* = 17.0, 1.6 Hz, 1H), 5.09 (dd, *J* = 10.2, 1.6 Hz, 1H), 2.84 (t, *J* = 7.5 Hz, 2H), 2.53 (dt, *J* = 7.5, 6.6 Hz, 2H); ^{13}C NMR (101 MHz, $CDCl_3$): δ = 144.1 (CH), 137.4 (C), 135.6 (CH), 117.1 (CH_2), 117.1 (CH), 111.2 (CH), 85.3 (C), 83.4 (C), 35.3 (CH_2), 33.5 (CH_2); IR (neat): ν = 3079, 2979,

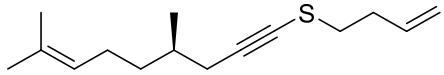
2925, 2154, 1640, 1565, 1461, 1015, 917, 745; HR-MS (EI-TOF): *m/z*: calcd for $C_{10}H_{10}OS$: 178.0452, found 178.0454 $[M + H]^+$.

But-3-en-1-yl(naphthalen-2-ylethynyl)sulfane (365)



365 was prepared according to **GP10** using dibromoolefin **344** (550 mg, 1.76 mmol), *n*-BuLi (1.54 mL, 3.69 mmol) and **359** (365 mg, 1.60 mmol). The reaction time was 18 hours. Aqueous work-up and purification by column chromatography (hexane) provided **365** (248 mg, 65%) as a colourless oil; R_f 0.26 (hexane); ^{1}H NMR (300 MHz, $CDCl_3$): δ = 7.94 (s, 1H), 7.86 – 7.73 (m, 3H), 7.51-7.45 (m, 3H), 5.91 (ddt, *J* = 17.0, 10.2, 6.6 Hz, 1H), 5.19 (dd, *J* = 17.0, 1.6 Hz, 1H), 5.10 (dd, *J* = 10.2, 1.6 Hz, 1H), 2.91 (t, *J* = 7.5 Hz, 2H), 2.61 (dt, *J* = 7.5, 6.6 Hz, 2H); ^{13}C NMR (101 MHz, $CDCl_3$): δ = 135.7 (CH), 133.1 (C), 132.8 (C), 131.3 (CH), 128.4 (CH), 128.1 (CH), 127.9 (CH), 127.8 (CH), 126.7 (2CH), 120.9 (C), 117.0 (CH_2), 93.9 (C), 79.7 (C), 35.1 (CH_2), 33.7 (CH_2); IR (neat): ν = 3057, 2979, 2928, 2156, 1640, 1626, 1596, 1501, 1272, 918, 857, 816, 746; HR-MS (ES-TOF): *m/z*: calcd for $C_{16}H_{15}S$: 239.0894, found 239.0899 $[M + H]^+$.

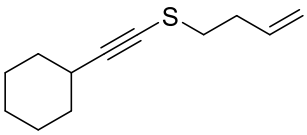
(R)-But-3-en-1-yl(4,8-dimethylnon-7-en-1-yn-1-yl)sulfane (366)



366 was prepared according to **GP10** using dibromoolefin **348** (828 mg, 2.67 mmol), *n*-BuLi (2.4 M in hexanes) (2.21 mL, 5.52 mmol), **359** (547 mg, 2.40 mmol) and THF (20 mL). The reaction time was 16 hours. Aqueous workup and purification by column chromatography (hexane) provided **338** (346 mg, 62%) as a colourless oil; R_f 0.33 (hexane); $[\alpha]_D^{21}$ 11.60 (*c* 0.010 in $CHCl_3$); ^{1}H NMR (300 MHz, $CDCl_3$): δ = 5.84 (ddt, *J* = 16.9, 10.2, 6.6 Hz, 1H), 5.17 – 5.03 (m, 3H), 2.76 – 2.68 (m, 2H), 2.53 – 2.43 (m, 2H), 2.24 (qd, *J* = 16.8, 6.2 Hz, 2H), 1.98 (dd, *J* = 15.1, 7.5 Hz, 2H), 1.75 – 1.58 (m, 7H), 1.52 – 1.37 (m, 1H), 1.32 – 1.16 (m, 1H), 0.98 (d, *J* = 6.7 Hz, 3H); ^{13}C NMR (101 MHz, $CDCl_3$): δ = 136.1 (CH), 131.6 (C), 124.6 (CH), 116.7 (CH_2), 93.7 (C), 68.8

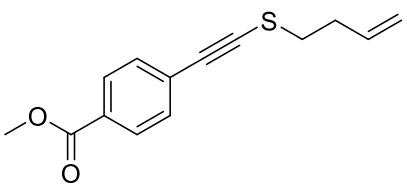
(C), 36.2 (CH_2), 34.8 (CH_2), 33.6 (CH_2), 32.5 (CH), 27.5 (CH_2), 25.9 (CH_3), 25.7 (CH_2), 19.6 (CH_3), 17.8 (CH_3); IR (neat): ν = 2964, 2914, 1641, 1445, 1377, 1277, 1222, 993, 916, 825; HR-MS (EI-TOF): *m/z*: calcd for $C_{15}H_{24}S$: 236.1599, found 236.1604 $[M + H]^+$.

But-3-en-1-yl(cyclohexylethynyl)sulfane (367)



367 was prepared according to **GP10** using dibromoolefin **347** (630 mg, 2.35 mmol), *n*-BuLi (2.5M in hexanes) (1.97 mL, 4.91 mmol), **359** (448 mg, 2.14 mmol) and THF (10 mL). The reaction time was 17 hours. Aqueous work-up and purification by column chromatography (hexane) provided **367** (260 mg, 63%) as a colourless oil; R_f 0.34 (hexane); ^{1}H NMR (300 MHz, $CDCl_3$): δ = 5.85 (ddt, *J* = 17.0, 10.2, 6.6 Hz, 1H), 5.12 (dd, *J* = 17.0. 1.6 Hz, 1H), 5.07 (dd, *J* = 10.2, 1.6 Hz, 1H), 2.71 (t, *J* = 7.2 Hz, 2H), 2.55 – 2.41 (m, 3H), 1.73 (ddt, *J* = 14.7, 12.0, 6.0 Hz, 4H), 1.55 – 1.37 (m, 3H), 1.37 – 1.20 (m, 3H); ^{13}C NMR (101 MHz, $CDCl_3$): δ = 136.1 (CH), 116.7 (CH_2), 99.0 (C), 67.9 (C), 34.8 (CH_2), 33.5 ($2CH_2$), 32.8 (CH_2), 30.5 (CH), 26.0 ($2CH_2$), 25.0 (CH_2); IR (neat): *v* = 2928, 2853, 1641, 1496, 1447, 993, 910, 730; HR-MS (ES-TOF): *m/z*: calcd for $C_{12}H_{18}S$: 194.1129, found 194.1134 $[M + H]^+$.

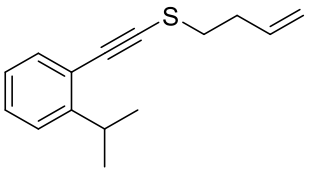
Methyl-4-((but-3-en-1-ylthio)ethynyl)benzoate (368)



368 was prepared according to **GP11** using terminal alkyne (333 mg, 2.08 mmol), LiHMDS 1 M (2.08 mL, 2.08 mmol), **359** (432 mg, 1.89 mmol) and THF (10 mL). The reaction time was 16 hours. Aqueous work-up and purification by column chromatography (hexane) provided **368** (428 mg, 92%) as a colourless oil; R_f 0.15 (hexane); ^{1}H NMR (300 MHz, $CDCl_3$): δ = 7.96 (d, *J* = 8.2 Hz, 2H), 7.43 (d, *J* = 8.2 Hz, 2H), 5.87 (ddt, *J* = 17.0, 10.2, 6.6 Hz, 1H), 5.16 (dd, *J* = 17.0, 1.6 Hz, 1H), 5.11 (d, *J* = 10.2, 1,6 Hz, 1H), 3.91 (s, 3H), 2.88 (t, *J* = 7.3 Hz, 2H), 2.63 – 2.51 (m, 2H); ^{13}C NMR (101 MHz, $CDCl_3$): δ = 166.7 (C), 135.5 (CH), 131.0

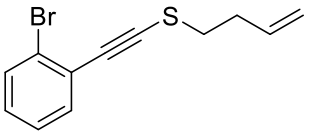
(2CH), 129.6 (2CH), 129.1 (C), 128.3 (C), 117.2 (CH_2), 93.1 (C), 83.5 (C), 52.3 (CH_3), 35.1 (CH_2), 33.6 (CH_2); IR (neat): ν = 2951, 2162, 1717, 1603, 1434, 1270, 1174, 1270, 1174, 1105, 1017, 855, 766; HR-MS (ES-TOF): *m/z*: calcd for $C_{14}H_{15}O_2S$: 247.0793, found 247.0789 [M + H]$^+$.

But-3-en-1-yl((2-isopropylphenyl)ethynyl)sulfane (369)



369 was prepared according to **GP11** using alkyne **354** (300 mg, 2.08 mmol), LiHMDS (1 M, 2.08 mL, 2.08 mmol), **359** (431 mg, 1.89 mmol) and THF (10 mL). The reaction time was 20 hours. Aqueous workup and purification by column chromatography (hexane) provided **369** (350 mg, 80%) as a colourless oil; R_f 0.64 (hexane); ^{1}H NMR (300 MHz, $CDCl_3$): δ = 7.39 (dd, *J* = 4.6, 3.6 Hz, 1H), 7.29 – 7.24 (m, 2H), 7.12 (ddd, *J* = 7.7, 5.2, 3.6 Hz, 1H), 5.89 (ddt, *J* = 17.0, 10.2, 6.6 Hz, 1H), 5.16 (dd, *J* = 17.0, 1.6 Hz, 1H), 5.11 (dd, *J* = 10.2, 1.6 Hz, 1H), 3.51 – 3.35 (m, 1H), 2.87 (t, *J* = 7.4 Hz, 2H), 2.58 (dt, *J* = 7.4, 6.6 Hz, 2H), 1.28 (s, 3H), 1.25 (s, 3H); ^{13}C NMR (101 MHz, $CDCl_3$): δ = 150.5 (C), 135.8 (CH), 132.3 (CH), 128.5 (CH), 125.6 (CH), 125.0 (CH), 122.4 (C), 117.0 (CH_2), 92.3 (C), 82.4 (C), 35.2 (CH_2), 33.8 (CH_2), 31.7 (CH), 23.3 ($2CH_3$); IR (neat): *v* = 3048, 2961, 2927, 2868, 2163, 1641, 916, 754. No success was found in obtaining a HRMS for this compound, however the HRMS for the corresponding sulfoxide was obtained.

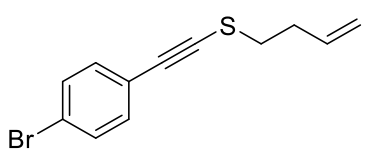
((2-Bromophenyl)ethynyl)(but-3-en-1-yl)sulfane (370)



370 was prepared according to **GP11** using 2-bromophenylacetylene (195 mg, 1.08 mmol), LiHMDS 1 M (1.08 mL, 1.08 mmol), **359** (223 mg, 0.98 mmol) and THF (5 mL). The reaction time was 16 hours. Aqueous work-up and purification by column chromatography (hexane) provided **370** (183 mg, 70%) as a colourless oil; R_f 0.30 (hexane); ^{1}H NMR (300 MHz, $CDCl_3$): δ = 7.56 (dd, *J* = 8.0, 1.1 Hz, 1H), 7.42 (dd, *J* = 7.7, 1.7 Hz, 1H), 7.24 (app dt, *J* = 7.7, 1.4 Hz, 1H), 7.17 – 7.08 (m,

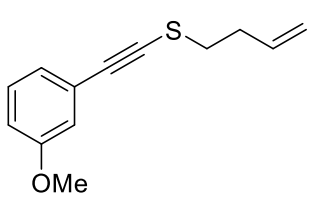
1H), 5.88 (ddt, *J* = 17.0, 10.2, 6.6 Hz, 1H), 5.18 (dd, *J* = 17.0, 1.6 Hz, 1H), 5.11 (dd, *J* = 10.2, 1.6 Hz, 1H), 2.90 (t, *J* = 7.4 Hz, 2H), 2.63 (dt, *J* = 7.4, 6.6 Hz, 2H); ^{13}C NMR (101 MHz, $CDCl_3$): δ = 135.7 (CH), 132.8 (CH), 132.5 (CH), 129.0 (CH), 126.9 (CH), 125.7 (C), 125.0 (C), 117.1 (CH_2), 92.2 (C), 84.9 (C), 35.2 (CH_2), 33.7 (CH_2); IR (neat): *v* = 3075, 2978, 2926, 2170, 1640, 1585, 1465, 1432, 1025, 918, 750; HR-MS (ES-TOF): *m/z*: calcd for $C_{12}H_{12}S^{79}Br$: 266.9843, found 266.9841 $[M + H]^+$.

((4-Bromophenyl)ethynyl)(but-3-en-1-yl)sulfane (371)



371 was prepared according to **GP11** using 4- bromophenylacetylene (240 mg, 1.32 mmol), LiHMDS 1 M (1.32 mL, 1.32 mmol), **359** (275 mg, 1.21 mmol) and THF (7 mL). The reaction time was 16 hours. Aqueous work-up and purification by column chromatography (hexane) provided **371** (190 mg, 59%) as a colourless oil; R_f 0.59 (hexane); ^{1}H NMR (300 MHz, $CDCl_3$): δ = 7.25 (d, *J* = 8.6 Hz, 2H) 7.08 (d, *J* = 8.6 Hz, 2H), 5.68 (ddt, *J* = 17.0, 10.2, 6.6 Hz, 1H), 4.97 (dd, *J* = 17.0, 1.6 Hz, 1H), 4.92 (dd, *J* = 10.2, 1.6 Hz, 1H), 2.68 (t, *J* = 7.4 Hz, 2H), 2.39 (dt, *J* = 7.4, 6.6 Hz, 2H); ^{13}C NMR (101 MHz, $CDCl_3$): δ = 135.6 (CH), 132.9 (2CH), 131.7 (2CH), 122.5 (C), 122.3 (C), 117.1 (CH_2), 92.4 (C), 80.8 (C), 35.0 (CH_2), 33.6 (CH_2); IR (neat): *v* = 3078, 2978, 2925, 2164, 1640, 1583, 1483, 1393, 1069, 1009, 819; HR-MS (ES-TOF): *m/z*: calcd for $C_{12}H_{12}S^{79}Br$: 266.9843, found 266.9837 $[M + H]^+$.

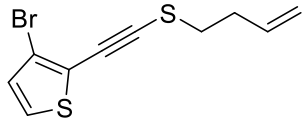
But-3-en-1-yl((3-methoxyphenyl)ethynyl)sulfane (373)



373 was prepared according to **GP11** using 3-methoxyphenylacetylene (265 mg, 2.00 mmol), LiHMDS (1 M, 2.00 mL, 2.00 mmol), **359** (415 mg, 1.82 mmol) and THF (10 mL). The reaction time was 16 hours. Aqueous workup and purification by column chromatography (hexane) provided **373** (346 mg, 91%) as a colourless oil; R_f 0.18 (hexane); ^{1}H NMR (300 MHz,

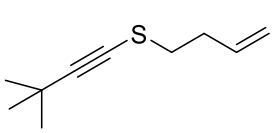
$CDCl_3$): δ = 7.21 (t, *J* = 8.1 Hz, 1H), 7.04 – 6.98 (m, 1H), 6.94 (dd, *J* = 2.6, 1.4 Hz, 1H), 6.85 (ddd, *J* = 8.1, 2.6, 1.0 Hz, 1H), 5.88 (ddt, *J* = 17.1, 10.2, 6.6 Hz, 1H), 5.16 (dd, *J* = 17.1, 1.6 Hz, 1H), 5.10 (dd, *J* = 10.2, 1.6 Hz, 1H), 3.80 (s, 3H), 2.86 (t, *J* = 7.5 Hz, 2H), 2.57 (dt *J* = 7.5, 6.6 Hz, 2H); ^{13}C NMR (101 MHz, $CDCl_3$): δ = 159.4 (C), 135.8 (CH), 129.5 (CH), 124.3 (C), 124.1 (CH), 117.0 (CH_2), 116.3 (CH), 114.8 (CH), 93.4 (C), 79.2 (C), 55.4 (CH_3), 35.0 (CH_2), 33.6 (CH_2); IR (neat): *v* = 3076, 2962, 2935, 2835, 2162, 1640, 1593, 1573, 1283, 1157, 1041, 775, 684; HR-MS (ES-TOF): *m/z*: calcd for $C_{13}H_{15}OS$: 219.0844, found 219.0838 $[M + H]^+$.

3-Bromo-2-((but-3-en-1-ylthio)ethynyl)thiophene (374)



374 was prepared according to **GP1** using **351** (335 mg, 1.78 mmol), LiHMDS (1 M, 1.78 mL, 1.78 mmol), **359** (369 mg, 1.62 mmol) and THF (9 mL). The reaction time was 16 hours. Aqueous work-up and purification by column chromatography (hexane) provided **374** (238 mg, 55%) as a yellow oil; R_f 0.47 (hexane); ^{1}H NMR (300 MHz, $CDCl_3$): δ = 7.19 (d, *J* = 5.4 Hz, 1H), 6.95 (d, *J* = 5.4 Hz, 1H), 5.87 (ddt, *J* = 17.0, 10.2, 6.6 Hz, 1H), 5.18 (dd, *J* = 17.1, 1.6 Hz, 1H), 5.11 (dd, *J* = 10.2, 1.6 Hz, 1H), 2.87 (t, *J* = 7.4 Hz, 2H), 2.60 (dt, *J* = 7.4, 6.6 Hz, 2H); ^{13}C NMR (101 MHz, $CDCl_3$): δ = 135.6 (CH), 130.1 (CH), 127.4 (CH), 121.3 (C), 117.2 (CH_2), 117.1 (C), 88.4 (C), 84.5 (C), 35.4 (CH_2), 33.5 (CH_2); IR (neat): *v* = 3105, 3081, 2978, 2925, 2153, 1640, 1499, 1416, 917, 862, 708; HR-MS (ES-TOF): *m/z*: calcd for $C_{10}H_9S_2{}^{79}Br$: 271.9329, found 271.9335 $[M + H]^+$.

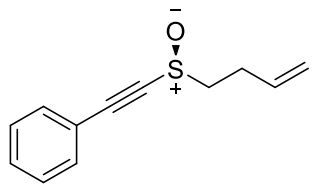
But-3-en-1-yl(3,3-dimethylbut-1-yn-1-yl)sulfane (375)



375 was prepared according to **GP11** using 3,3-dimethyl-1-butyne (400 µL, 3.30 mmol), LiHMDS (1 M, 3.30 mL, 3.30 mmol), **359** (678 mg, 3.00 mmol) and THF (10 mL). The reaction time was 20 hours. Aqueous workup and purification by column chromatography (hexane) provided **374** (336 mg, 67%) as a colourless oil; R_f 0.33 (hexane); ^{1}H NMR (300 MHz $CDCl_3$): δ = 5.85 (ddt, *J* = 17.2, 10.2, 6.6, 1H), 5.12

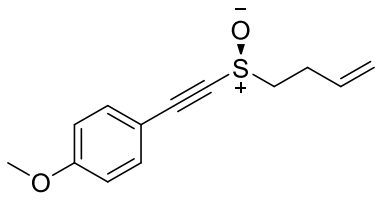
(dd, *J* = 17.2, 1.7, 1H), 5.07 (dd, *J* = 10.2, 1.7, 1H), 2.71 (t, *J* = 7.2, 2H), 2.48 (td, *J* = 7.2, 6.6, 2H), 1.23 (s, 9H); ^{13}C NMR (101 MHz $CDCl_3$): δ = 136.2 (CH), 116.7 (CH_2), 103.0 (C), 66.7 (C), 34.8 (CH_2), 33.5 (CH_2), 31.2 ($3CH_3$), 29.0 (C); IR (neat): *ν* = 2963, 2865, 1706, 1640, 1467, 1393, 1362, 1218, 991, 914, 744. HR-MS (ES-TOF): *m/z* calculated for $C_{10}H_{16}S$ 168.0973, found 168.0976 $[M + H]^+$.

((But-3-en-1-ylsulfinyl)ethynyl)benzene (376)



376 was prepared according to **GP12** using sulfide **355** (266 mg, 1.41 mmol), *m*CPBA (243 mg, 1.41 mmol) and CH_2Cl_2 (14 mL). The reaction time was 2 hours. Aqueous work-up and column chromatography (9:1 hexane: EtOAc) provided **376** (220 mg, 77%) as a colourless oil; R_f 0.67 (1:1 hexane:EtOAc); ^{1}H NMR (300 MHz, $CDCl_3$): δ = 7.58 – 7.50 (m, 2H), 7.50 – 7.34 (m, 3H), 5.90 (ddt, *J* = 17.0, 10.2, 6.6 Hz, 1H), 5.21 (dd, *J* = 17.0, 1.5 Hz, 1H), 5.15 (dd, *J* = 10.2, 1.5 Hz, 1H), 3.23 (ddd, *J* = 8.0, 7.2, 1.0 Hz, 2H), 2.82 – 2.60 (m, 2H); ^{13}C NMR (101 MHz, $CDCl_3$): δ = 134.6 (CH), 132.4 (2CH), 130.8 (CH), 128.8 (2CH), 119.9 (C), 117.7 (CH_2), 102.7 (C), 85.1 (C), 55.4 (CH_2), 26.7 (CH_2); IR (neat): ν = 3068, 2920, 2164, 1719, 1574, 1282, 1244, 1057, 1023, 917, 832, 753, 688; HRMS (ES) *m/z* calculated for $C_{12}H_{12}OSNa$ 227.0507, found 227.0504 $[M + Na]^+$.

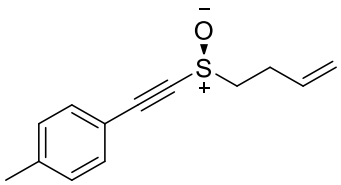
1-((But-3-en-1-ylsulfinyl)ethynyl)-4-methoxybenzene (377)



377 was prepared according to **GP3** using **357** (151 mg, 0.69 mmol), *m*CPBA (120 mg, 0.69 mmol) and CH_2Cl_2 (7 mL). The reaction time was 2 hours. Aqueous work-up followed by column chromatography (4:1 hexane: EtOAc) provided **377** (124 mg, 75%) as a colourless oil; R_f 0.11 (4:1 hexane: EtOAc); ^{1}H NMR (300 MHz, $CDCl_3$): δ = 7.48 (d, *J* = 8.9 Hz, 2H), 6.89 (d, *J* = 8.9 Hz, 2H,), 5.90 (ddt, *J* = 16.9, 10.1, 6.6 Hz, 1H), 5.21 (dd, *J* = 16.9, 1.5 Hz, 1H), 5.15

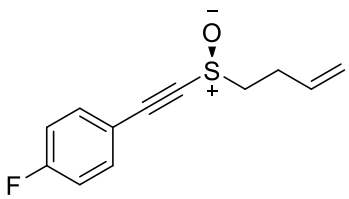
(dd, *J* = 10.1, 1.5 Hz, 1H), 3.84 (s, 3H), 3.21 (t, *J* = 7.2 Hz, 2H), 2.79 – 2.61 (m, 2H); ^{13}C NMR (101 MHz, $CDCl_3$): δ = 161.6 (C), 139.3 (C), 134.7 (CH), 134.3 (2CH), 117.6 (CH_2), 114.5 (2CH), 103.4 (C), 84.1 (C), 55.6 (CH_3), 55.4 (CH_2), 26.8 (CH_2); IR (neat): ν = 3077, 2918, 2840, 2156, 1641, 1602, 1507, 1295, 1251, 1172, 1024, 832, 762; HR-MS (ES-TOF): *m/z*: calcd for $C_{13}H_{15}O_2S$: 235.0793, found 235.0799 $[M + H]^+$.

1-((But-3-en-1-ylsulfinyl)ethynyl)-4-methylbenzene (378)



378 was prepared according to **GP12** using **356** (180 mg, 0.89 mmol), *m*CPBA (154 mg, 0.89 mmol) and CH_2Cl_2 (9 mL). The reaction time was 2 hours. Aqueous work-up and purification by column chromatography (9:1 hexane: EtOAc) provided **378** (143 mg, 74%) as a pale yellow oil; R_f 0.24 (4:1 hexane: EtOAc); ^{1}H NMR (300 MHz, $CDCl_3$): δ = 7.43 (d, *J* = 8.0 Hz, 2H), 7.19 (d, *J* = 8.0 Hz, 2H), 5.89 (ddt, *J* = 17.0, 10.1, 6.6 Hz, 1H), 5.21 (dd, *J* = 17.0, 1.5 Hz, 1H), 5.14 (dd, *J* = 10.2, 1.5 Hz, 1H), 3.29 – 3.14 (m, 2H), 2.84 – 2.57 (m, 2H), 2.39 (s, 3H); ^{13}C NMR (101 MHz, $CDCl_3$): δ = 141.4 (C), 134.6 (CH), 132.4 (2CH), 129.5 (2CH), 117.6 (CH_2), 116.8 (C), 103.2 (C), 84.5 (C), 55.4 (CH_2), 26.7 (CH_2), 21.9 (CH_3); IR (neat): ν = 2923, 2243, 2162, 1605, 1508, 1055, 908, 817, 730; HR-MS (ES-TOF): *m/z*: calcd for $C_{13}H_{14}OSNa$: 241.0663, found 241.0670 $[M + Na]^+$.

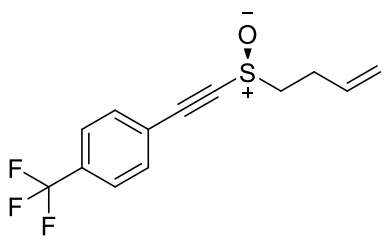
1-((But-3-en-1-ylsulfinyl)ethynyl)-4-fluorobenzene (379)



379 was prepared in 2 steps starting from dibromoolefin **345**. Prepared according to **GP10** using dibromoolefin **345** (840 mg, 3.0 mmol), *n*-BuLi (2.7 mL, 6.2 mmol), THF (15 mL) and **359** (616 mg, 2.7 mmol). The reaction time was 16 hours. Purification by column chromatography (hexane) afforded **363** (90% pure) 65%. **379** was prepared according to **GP3** using **363** (97 mg, 0.47 mmol), *m*CPBA (81 mg, 0.47 mmol) and CH_2Cl_2 (5 mL). The reaction time was 2 hours.

Aqueous workup and purification by column chromatography (9:1 hexane: EtOAc) provided **379** (76 mg, 73%) as a colourless oil; R_f 0.19 (9:1 hexane:EtOAc); ^{1}H NMR (300 MHz, $CDCl_3$): δ = 7.65 – 7.46 (m, 2H), 7.17 – 7.00 (m, 2H), 5.89 (ddt, *J* = 17.0, 10.2, 6.6 Hz, 1H), 5.21 (dd, *J* = 17.0, 1.5 Hz, 1H), 5.15 (dd, *J* = 10.2, 1.5 Hz, 1H), 3.31 – 3.13 (m, 2H), 2.82 – 2.59 (m, 2H); ^{13}C NMR (101 MHz, $CDCl_3$): δ = 164.0 (d, *J* = 253.6 Hz, C), 134.6 (d, *J* = 8.8 Hz, 2CH), 134.4 (CH), 117.7 (CH_2), 116.3 (d, *J* = 22.4 Hz, 2CH), 116.0 (d, *J* = 2.8 Hz, C) 101.6 (C), 85.0 (C), 55.3 (CH_2), 26.7 (CH_2); IR (neat): ν = 3077, 2981, 2919, 2165, 1641, 1598, 1505, 1233, 1216, 1157, 1054, 918, 837, 775; HR-MS (ES-TOF): *m/z*: calcd for $C_{12}H_{12}OSF$: 223.0593, found 223.0601 $[M + H]^+$.

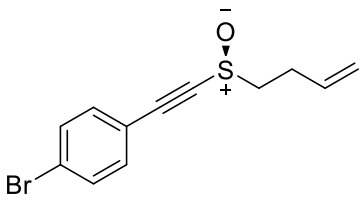
1-((But-3-en-1-ylsulfinyl)ethynyl)-4-(trifluoromethyl)benzene (380)



380 was prepared in 2 steps according to **GP10** and **GP12** starting from dibromoolefin **346** (825 mg, 2.50 mmol), *n*-BuLi (2.18 mL, 5.23 mmol), **359** (517 mg, 2.27 mmol) and THF (12 mL). The reaction time was 16 hours. Aqueous work-up and removal of most impurities by column chromatography (hexane) provided the crude sulfide **364** (537 mg). Sulfide **364** (195 mg) was dissolved in CH_2Cl_2 (7 mL), the mixture was cooled to 0 ^{o}C and *m*CPBA (118 mg, 0.68 mmol) was added in 5 portions over 10 minutes. The reaction time was 2 hours. The mixture was washed with $NaHCO_3$ (10 mL) and the aqueous phase was extracted with CH_2Cl_2 (3 × 10 mL). The combined organic layers were dried over Na_2SO_4, filtered, concentrated and purified by column chromatography (9:1 hexane:EtOAc) to yield **380** (130 mg, 59% over 2 steps); ^{1}H NMR (300 MHz, $CDCl_3$): δ = 7.65 (s, 4H), 5.89 (ddt, *J* = 16.9, 10.1, 6.6 Hz, 1H), 5.26 – 5.13 (m, 2H), 3.31 – 3.18 (m, 2H), 2.84 – 2.60 (m, 2H); ^{13}C NMR (101 MHz, $CDCl_3$): δ = 134.3 (CH), 134.7 (q, *J* = 32.6 Hz, C) 132.6 (2CH), 125.8 (d, *J* = 3.2 Hz, 2CH), 123.6 (q, *J* = 271.4 Hz, C), 123.6 (C), 117.9 (CH_2), 100.6 (C), 87.4 (C), 55.3 (CH_2),

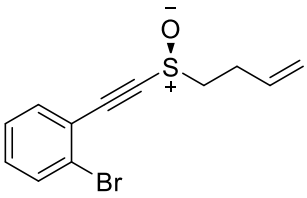
26.7 (CH_2); IR (neat): ν = 2981, 2170, 1643, 1615, 1321, 1241, 1128, 1065, 842, 655; HR-MS (ES-TOF): *m/z*: calcd for $C_{13}H_{11}OF_3NaS$: 295.0380, found 295.0371 $[M + Na]^+$.

1-Bromo-4-((but-3-en-1-ylsulfinyl)ethynyl)benzene (381)



381 was prepared according to **GP12** using **371** (180 mg, 0.67 mmol), *m*CPBA (117 mg, 0.67 mmol) and CH_2Cl_2 (7 mL). The reaction time was 2 hours. Aqueous work-up and purification by column chromatography (9:1 hexane: EtOAc) provided **381** (153 mg, 80%) as a yellow oil; R_f 0.15 (9:1 hexane: EtOAc); ^{1}H NMR (300 MHz, $CDCl_3$): δ = 7.53 (d, *J* = 8.4 Hz, 2H), 7.39 (d, *J* = 8.4 Hz, 2H), 5.89 (ddt, *J* = 17.0, 10.2, 6.6 Hz, 1H), 5.21 (dd, *J* = 17.0, 1.4 Hz, 1H), 5.15 (dd, *J* = 10.2, 1.4 Hz, 1H), 3.34 – 3.12 (m, 2H), 2.85 – 2.55 (m, 2H); ^{13}C NMR (101 MHz, $CDCl_3$): δ = 134.4 (CH), 133.7 (2CH), 132.2 (2CH), 125.6 (C), 118.7 (C), 117.8 (CH_2), 101.5 (C), 86.2 (C), 55.3 (CH_2), 26.7 (CH_2); IR (neat): ν = 3080, 2978, 2914, 2163, 1640, 1583, 1483, 1394, 1056, 762; HR-MS (ES-TOF): *m/z*: calcd for $C_{12}H_{11}ONaS^{79}Br$: 304.9612, found 304.9620 $[M + Na]^+$

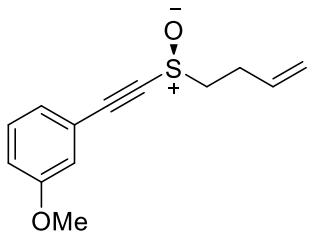
1-Bromo-2-((but-3-en-1-ylsulfinyl)ethynyl)benzene (382)



382 was prepared according to **GP12** using **370** (175 mg, 0.65 mmol), *m*CPBA (114 mg, 0.65 mmol) and CH_2Cl_2 (7 mL). The reaction time was 2 hours. Aqueous work-up and purification by column chromatography (9:1 hexane: EtOAc) provided **382** (157 mg, 85%) as a yellow oil; R_f 0.15 (9:1 hexane: EtOAc); ^{1}H NMR (300 MHz, $CDCl_3$): δ = 7.68 – 7.54 (m, 2H), 7.40 – 7.26 (m, 2H), 5.90 (ddt, *J* = 17.0, 10.1, 6.6 Hz, 1H), 5.22 (dd, *J* = 17.0, 1.5 Hz, 1H), 5.15 (dd, *J* = 10.1, 1.5 Hz, 1H), 3.35 – 3.20 (m, 2H), 2.87 – 2.63 (m, 2H); ^{13}C NMR (101 MHz, $CDCl_3$): δ = 134.5 (CH), 134.4 (CH), 132.9 (CH), 131.8 (CH), 127.5 (CH), 126.1 (C), 122.3 (C), 117.7 (CH_2), 100.0 (C), 89.2 (C), 55.4 (CH_2), 26.7 (CH_2); IR (neat): ν = 3077, 2979, 2917, 2167,

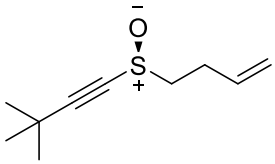
1675, 1640, 1584, 1057, 1045, 754; HR-MS (ES-TOF): *m/z*: calcd for $C_{12}H_{12}OS^{79}Br$: 282.9808, found 282.9792 $[M + H]^+$.

1-((But-3-en-1-ylsulfinyl)ethynyl)-3-methoxybenzene (383)



383 was prepared according to **GP12** using **373** (218 mg, 1.00 mmol), *m*CPBA (173 mg, 1.00 mmol) and CH_2Cl_2 (10 ml). The reaction time was 2 hours. Aqueous work-up and purification by column chromatography (8:2 hexane: EtOAc) afforded **383** (170 mg 72%) as a yellow oil; ^{1}H NMR (300 MHz, $CDCl_3$): δ = 7.32 – 7.25 (m, 1H), 7.16 – 7.09 (m, 1H), 7.08 – 6.96 (m, 2H), 5.89 (ddt, *J* = 16.8, 10.2, 6.6 Hz, 1H), 5.26 – 5.11 (m, 2H), 3.81 (s, 3H), 3.23 (ddd, *J* = 8.1, 7.1, 1.2 Hz, 2H), 2.85 – 2.58 (m, 2H); ^{13}C NMR (101 MHz, $CDCl_3$): δ = 159.5 (C), 134.5 (CH), 129.9 (CH), 124.8 (CH), 120.7 (C), 117.7 (CH_2), 117.3 (CH), 117.0 (CH), 102.6 (C), 84.8 (C), 55.5 (CH_3), 55.3 (CH_2), 26.7 (CH_2); IR (neat): *ν* = 3076, 2939, 2837, 2159, 1641, 1594, 1574, 1487, 1287, 1156, 1042, 683; HR-MS (ES-TOF): *m/z*: calcd for $C_{13}H_{15}O_2S$: 235.0793, found 235.0796 $[M + H]^+$.

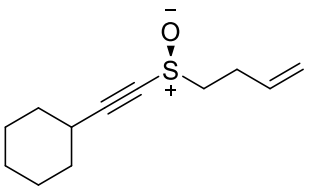
4-((3,3-Dimethylbut-1-yn-1-yl)sulfinyl)but-1-ene (384)



384 was prepared according to **GP12** using **375** (336 mg, 2.00 mmol), *m*CPBA (345 mg, 2.00 mmol) and CH_2Cl_2 (20 mL). The reaction time was 16 hours. Aqueous workup and purification by column chromatography (hexane to 4:1 hexane: EtOAc) provided **384** (190 mg, 52%) as a colourless oil; R_f 0.21 (4:1 hexane: EtOAc); ^{1}H NMR (300 MHz $CDCl_3$): δ = 5.81 (ddt, *J* = 17.1, 10.2, 6.6 Hz, 1H), 5.14 (dd, *J* = 17.1, 1.4 Hz, 1H), 5.08 (dd, *J* = 10.2, 1.4 Hz, 1H), 3.08 (td, *J* = 7.7, 2.1 Hz, 2H), 2.67 – 2.51 (m, 2H), 1.25 (s, 9H); ^{13}C NMR (101 MHz $CDCl_3$): δ = 134.7 (CH), 117.5 (CH_2), 112.9 (C), 73.2 (C), 55.5 (CH_2), 30.2 ($3CH_3$), 29.9 (C), 26.7 (CH_2); IR (neat): ν = 2973, 2928, 2870, 2162, 1720,

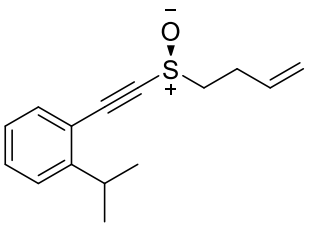
1642, 1575, 1456, 1365, 1252, 1141, 1060, 918, 838, 768, 752, 701; HRMS (ES-TOF) *m/z* calculated for $C_{10}H_{17}OS$ $[M+H]^+$ 185.1000 found 185.1001.

((But-3-en-1-ylsulfinyl)ethynyl)cyclohexane (385)



385 was prepared according to **GP12** using **367** (225 mg, 1.16 mmol), *m*CPBA (200 mg, 1.16 mmol) and CH_2Cl_2 (12 mL). The reaction time was 2 hours. Aqueous workup and purification by column chromatography (hexane to 4:1 hexane:EtOAc) provided **385** (140 mg, 57%) as a colourless oil; R_f 0.25 (4:1 hexane:EtOAc); ^{1}H NMR (300 MHz, $CDCl_3$): δ = 5.86 (ddt, *J* = 16.8, 10.1, 6.6 Hz, 1H), 5.17 (dd, *J* = 17.1, 1.5 Hz, 1H), 5.12 (dd, *J* = 10.2, 1.5 Hz, 1H), 3.09 (t, *J* = 7.7 Hz, 2H), 2.74 – 2.50 (m, 3H), 1.91 – 1.77 (m, 2H), 1.76 – 1.66 (m, 2H), 1.60 – 1.45 (m, 3H), 1.43 – 1.23 (m, 3H); ^{13}C NMR (101 MHz, $CDCl_3$): δ = 134.7 (CH), 117.4 (CH_2), 109.4 (C), 76.8 (C), 55.5 (CH_2), 31.6 (CH_2), 29.9 (CH), 26.7 ($2CH_2$), 25.7 ($2CH_2$), 24.7 (CH_2); IR (neat): *v* = 2930, 2855, 2177, 1641, 1448, 1057, 915, 650; HR-MS (ES-TOF): *m/z*: calcd for $C_{12}H_{18}ONaS$: 233.0973, found 233.0976 $[M + Na]^+$.

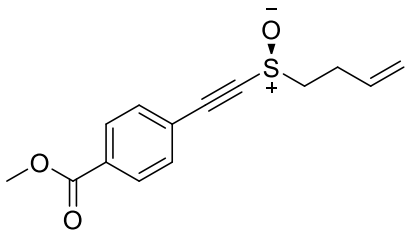
1-((But-3-en-1-ylsulfinyl)ethynyl)-2-isopropylbenzene (386)



386 was prepared according to **GP12** using **369** (230 mg, 1.00 mmol), *m*CPBA (173 mg, 1.00 mmol) and CH_2Cl_2 (10 mL). The reaction time was 2 hours. Aqueous work-up and purification by column chromatography (17:3 hexane: EtOAc) provided **386** (218 mg, 89%) as a yellow oil; R_f 0.16 (17:3 hexane: EtOAc); ^{1}H NMR (300 MHz, $CDCl_3$): δ = 7.50 (dd, *J* = 7.7, 1.1 Hz, 1H), 7.41 (td, *J* = 7.7, 1.4 Hz, 1H), 7.32 (d, *J* = 6.7 Hz, 1H), 7.19 (td, *J* = 7.7, 1.4 Hz, 1H), 5.90 (ddt, *J* = 17.0, 10.2, 6.6 Hz, 1H), 5.21 (dd, *J* = 17.0, 1.5 Hz, 1H), 5.15 (dd, *J* = 10.2, 1.5 Hz, 1H), 3.39 (dt, *J* = 13.8, 6.9 Hz, 1H), 3.24 (t, *J* = 7.7 Hz, 2H), 2.87 – 2.58 (m, 2H), 1.27 (d, *J* = 6.9 Hz, 6H); ^{13}C NMR (101 MHz, $CDCl_3$): δ = 152.0 (C), 134.6 (CH),

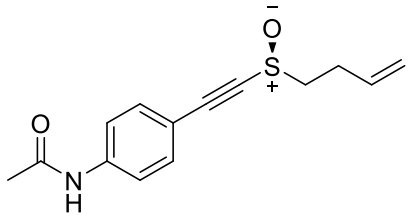
133.4 (CH), 131.2 (CH), 126.0 (CH), 125.5 (CH), 118.6 (C), 117.6 (CH_2), 101.7 (C), 88.4 (C), 55.4 (CH_2), 32.0 (CH), 26.8 (CH_2), 23.3 (CH_3), 23.3 (CH_3); IR (neat): ν = 3067, 2963, 2870, 2157, 1641, 1482, 1444, 1056, 758; HR-MS (ES-TOF): *m/z*: calcd for $C_{15}H_{19}OS$: 247.1157, found 247.1155 $[M + H]^+$.

Methyl 4-((but-3-en-1-ylsulfinyl)ethynyl)benzoate (387)



387 was prepared according to **GP12** using **368** (246 mg, 1.00 mmol), *m*CPBA (173 mg, 1.00 mmol) and CH_2Cl_2 (10 mL). The reaction time was 2 hours. Aqueous work-up and purification by column chromatography (17:3 hexane: EtOAc) provided **387** (206 mg, 77%) as a pale orange oil; R_f 0.19 (17:3 hexane: EtOAc); ^{1}H NMR (300 MHz, $CDCl_3$): δ = 8.05 (d, *J* = 8.6 Hz, 2H), 7.60 (d, *J* = 8.6 Hz, 2H), 5.89 (ddt, *J* = 17.0, 10.2, 6.6 Hz, 1H), 5.22 (dd, *J* = 17.0, 1.5 Hz, 1H), 5.16 (dd, *J* = 10.2, 1.5 Hz, 1H), 3.93 (s, 3H), 3.30 – 3.19 (m, 2H), 2.83 – 2.59 (m, 2H); ^{13}C NMR (101 MHz, $CDCl_3$): δ = 166.1 (C), 134.4 (CH), 132.3 (2CH), 131.8 (C), 129.8 (2CH), 124.2 (C), 117.8 (CH_2), 101.3 (C), 87.6 (C), 55.3 (CH_2), 52.6 (CH_3), 26.7 (CH_2); IR (neat): ν = 2952, 2166, 1436, 1275, 1107, 1060, 769; HR-MS (ES-TOF): *m/z*: calcd for $C_{14}H_{14}O_3NaS$: 285.0561, found 285.0567 $[M + Na]^+$.

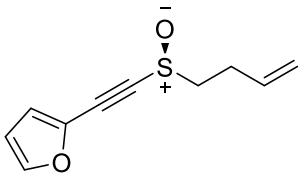
N-(4-((but-3-en-1-ylsulfinyl)ethynyl)phenyl)acetamide (388)



To a flame dried 2 neck RBF under argon was added **350** (320 mg, 1.01 mmol, 1.1 eq.) and anhydrous THF (10 mL). The flask was cooled to -78 ^{o}C using a dry ice/ acetone bath. LiHMDS (1 M in ethylbenzene) (4.02 mL, 4.02 mmol, 2.2 eq.) was added dropwise and on complete addition the mixture was stirred at -78 ^{o}C for an hour before **359** (417 mg, 1.83 mmol, 1.0 eq.) was added dropwise. The reaction was allowed to warm to rt for 16 hours. The reaction was quenched with NH_4Cl (10 mL of a saturated solution) and the mixture was extracted with

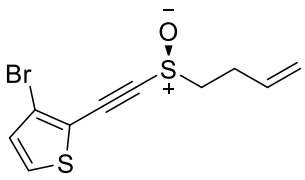
Et_2O (3 × 10 mL), the organics were washed with brine (10 mL), dried over Na_2SO_4, filtered, concentrated under reduced pressure and most impurities were removed by column chromatography (7:3 hexane: EtOAc) to provide (370 mg) of a 1.8:1 ratio of sulfide **372** to alkyne. (**372** was used as a 1.8:1 mixture of alkynyl sulfide to alkyne) **388** was prepared according to **GP12** using **372** (225 mg, 0.92 mmol), *m*CPBA (158 mg, 0.92 mmol) and CH_2Cl_2 (9 mL). The reaction time was 2 hours. Aqueous workup and purification by column chromatography (1:1 hexane: EtOAc) to (EtOAc) provided **388** (176 mg, 74%) as a yellow solid; R_f 0.20 (1:1 hexane: EtOAc); mp: 73-74 ^oC; ^1H NMR (300 MHz, $CDCl_3$): δ = 8.17 (s, 1H), 7.57 (d, *J* = 8.6 Hz, 2H), 7.37 (d, *J* = 7.0 Hz, 2H), 5.89 (ddt, *J* = 16.8, 10.1, 6.6 Hz, 1H), 5.27 – 5.10 (m, 2H), 3.32 – 3.15 (m, 2H), 2.81 – 2.56 (m, 2H), 2.19 (s, 3H); ^{13}C NMR (101 MHz, $CDCl_3$): δ = 169.0 (C), 140.7 (C), 134.4 (CH), 133.5 (2CH), 119.6 (2CH), 117.8 (CH_2), 114.4 (C), 103.7 (C), 84.3 (C), 55.3 (CH_2), 26.8 (CH_2), 24.8 (CH_3); IR (neat): ν = 3307, 3257, 3096, 2980, 2163, 1688, 1592, 1525, 1509, 1313, 1022, 839; HR-MS (ES-TOF): *m/z*: calcd for $C_{14}H_{16}NO_2S$: 262.0902, found 262.0900 $[M + H]^+$.

2-((But-3-en-1-ylsulfinyl)ethynyl)furan (389)



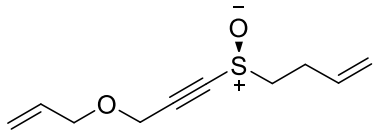
389 was prepared according to **GP12** from **362** (54.3 mg, 0.30 mmol), *m*CPBA (52.0 mg, 0.30 mmol) and CH_2Cl_2 (3 mL). The reaction time was 16 hours. Aqueous workup and purification by column chromatography (4:1 hexane: EtOAc) provided **389** (41.4 mg, 70%) as a colourless oil; R_f 0.83 (1:1 hexane:EtOAc). On solvent removal the product was unstable and was used directly in the catalysis reaction.

3-Bromo-2-((but-3-en-1-ylsulfinyl)ethynyl)thiophene (390)



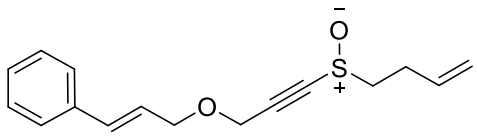
390 was prepared according to **GP12** from **374** (82.0 mg, 0.30 mmol), *m*CPBA (52.0 mg, 0.30 mmol) and CH_2Cl_2 (3 mL). The reaction time was 16 hours. Aqueous workup and purification by column chromatography (4:1 hexane: EtOAc) provided **390** (60.7 mg, 70%) as a colourless oil; R_f 0.81 (1:1 hexane: EtOAc). On solvent removal the product was unstable and was used directly in the catalysis reaction.

4-((3-(Allyloxy)prop-1-yn-1-yl)sulfinyl)but-1-ene (391)



391 was prepared according to **GP12** using **360** (249 mg, 1.36 mmol), *m*CPBA (233 mg, 1.36 mmol) and CH_2Cl_2 (13 mL). The reaction time was 2 hours. Aqueous workup and purification by column chromatography (4:1 hexane: EtOAc) provided **363** (217 mg, 80%) as a colourless oil; R_f 0.25 (7:3 hexane: EtOAc); ^{1}H NMR (300 MHz, $CDCl_3$): δ = 5.95 – 5.76 (m, 2H), 5.36 – 5.08 (m, 4H), 4.34 (s, 2H), 4.06 (dt, *J* = 5.8, 1.3 Hz, 2H), 3.14 (dd, *J* = 11.6, 4.1 Hz, 2H), 2.76 – 2.51 (m, 2H); ^{13}C NMR (101 MHz, $CDCl_3$): δ = 134.3 (CH), 133.3 (CH), 118.7 (CH_2), 117.7 (CH_2), 99.7 (C), 82.9 (C), 71.3 (CH_2), 57.3 (CH_2), 55.1 (CH_2), 26.5 (CH_2); IR (neat): ν = 3081, 2850, 2181, 1641, 1435, 1351, 1058, 990, 919; HR-MS (ES-TOF): *m/z*: calcd for $C_{10}H_{15}O_2S$: 199.0793, found 199.0799 [M + H]$^+$.

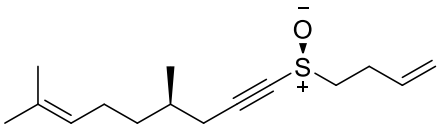
(E)-(3-((3-(But-3-en-1-ylsulfinyl)prop-2-yn-1-yl)oxy)prop-1-en-1-yl)benzene (392)



392 was prepared according to **GP12** using **361** (500 mg, 1.93 mmol), *m*CPBA (333 mg, 1.93 mmol) and CH_2Cl_2 (19 mL). The reaction time was 16 hours. Aqueous workup and purification by column chromatography (4:1 hexane: EtOAc) provided **392** (353 mg, 66%) as a colourless oil; R_f 0.20 (4:1 hexane: EtOAc); ^{1}H NMR (300 MHz, $CDCl_3$): δ = 7.44 – 7.21 (m, 5H), 6.65 (d, *J* = 15.9

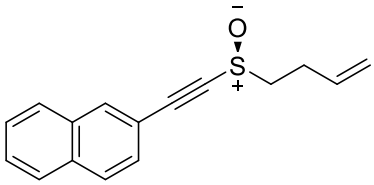
Hz, 1H), 6.25 (dt, *J* = 15.9, 6.3 Hz, 1H), 5.85 (ddt, *J* = 16.9, 10.1, 6.6 Hz, 1H), 5.25 – 5.09 (m, 2H), 4.41 (s, 2H), 4.25 (dd, *J* = 6.3, 1.3 Hz, 2H), 3.28 – 3.06 (m, 2H), 2.79 – 2.52 (m, 2H); IR (neat): ν = 2850, 2180, 1641, 1599, 1495, 1448, 1352, 1057, 990, 968, 918, 744, 692; HR-MS (ES-TOF): *m/z*: calcd for $C_{16}H_{19}O_2S$: 275.1106, found 275.1113 $[M + H]^+$. ^{13}C NMR was not successfully obtained.

R)-1-((R)-but-3-en-1-ylsulfinyl)-4,8-dimethylnon-7-en-1-yne (393)



393 was prepared according to **GP12** using **366** (156 mg, 0.66 mmol), *m*CPBA (113 mg, 0.66 mmol) and CH_2Cl_2 (7 mL). The reaction time was 19 hours. Aqueous workup and purification by column chromatography (9:1 hexane: EtOAc) afforded **393** (118 mg, 71%) as a colourless oil; R_f 0.57 (7:3 hexane: EtOAc); $[\alpha]_D^{21}$ 16.80 (*c* 0.010 in $CHCl_3$); ^1H NMR (300 MHz, $CDCl_3$): δ = 5.86 (ddt, *J* = 16.9, 10.1, 6.6 Hz, 1H), 5.23 – 4.99 (m, 3H), 3.09 (t, *J* = 7.7 Hz, 2H), 2.75 – 2.51 (m, 2H), 2.38 (qd, *J* = 17.2, 6.3 Hz, 2H), 2.07 – 1.90 (m, 2H), 1.76 (td, *J* = 13.3, 6.6 Hz, 1H), 1.68 (s, 3H), 1.60 (s, 3H), 1.43 (ddt, *J* = 13.3, 8.5, 6.5 Hz, 1H), 1.35 – 1.19 (m, 1H), 1.01 (d, *J* = 6.7 Hz, 3H); ^{13}C NMR (101 MHz, $CDCl_3$): δ = 134.7 (CH), 132.0 (C), 124.1 (CH), 117.4 (CH_2), 104.9 (C), 78.0 (C), 55.5 (CH_2), 36.2 (CH_2), 31.8 (CH), 27.0 (CH_2), 26.6 (CH_2), 25.8 (CH_3), 25.5 (CH_2), 19.6 (CH_3), 17.8 (CH_3); IR (neat): ν = 2964, 2916, 2180, 1641, 1444, 1379, 1060, 993, 915, 617; HR-MS (ES-TOF): *m/z*: calcd for $C_{15}H_{25}OS$: 253.1626, found 253.1631 $[M + H]^+$.

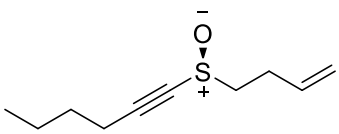
2-((But-3-en-1-ylsulfinyl)ethynyl)naphthalene (394)



394 was prepared according to **GP12** using sulfide **365** (90 mg, 0.38 mmol), *m*CPBA (65 mg, 0.38 mmol) and CH_2Cl_2 (4 mL). The reaction time was 2 hours. Aqueous work-up and purification by column chromatography (9:1 hexane: EtOAc) provided **394** as a clear oil (73

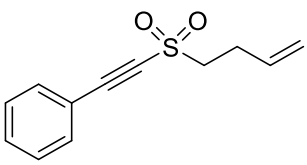
mg, 79%); R_f 0.24 (4:1 hexane: EtOAc); ^{1}H NMR (300 MHz, $CDCl_3$): δ = 8.10 (d, *J* = 0.9 Hz, 1H), 7.85 (dd, *J* = 7.2, 3.7 Hz, 3H), 7.56 (app tdd, *J* = 8.7, 6.9, 1.8 Hz, 3H), 5.92 (ddt, *J* = 17.0, 10.2, 6.6 Hz, 1H), 5.24 (dd, *J* = 17.0, 1.5 Hz, 1H), 5.17 (dd, *J* = 10.2, 1.5 Hz, 1H), 3.35 – 3.20 (m, 2H), 2.89 – 2.62 (m, 2H); ^{13}C NMR (101 MHz, $CDCl_3$): δ = 134.6 (CH), 133.9 (C), 133.5 (CH), 132.7 (C), 128.6 (CH), 128.3 (CH), 128.1 (CH), 128.1 (CH), 127.8 (CH), 127.2 (CH), 117.7 (CH_2), 117.0 (C), 103.2 (C), 85.3 (C), 55.4 (CH_2), 26.8 (CH_2); IR (neat): ν = 3057, 2924, 2154, 1720, 1641, 1277, 1056, 916, 818, 749; HR-MS (ES-TOF): *m/z*: calcd for $C_{16}H_{15}OS$: 255.0844, found 255.0841 $[M + H]^+$.

1-(But-3-en-1-ylsulfinyl)hex-1-yne (342)



Following GP1 using **sulfide** (371 mg, 2.21 mmol) *m*CPBA (381.4 mg, 2.21 mmol) and CH_2Cl_2 (22 mL). The reaction time was 16 hours. Aqueous workup and purification by column chromatography (4:1 hexane: EtOAc) provided **342** as a pale yellow oil (308 mg, 76%); ^{1}H NMR (300 MHz $CDCl_3$): δ = 5.66 (ddt, *J* = 17.2, 10.3, 6.6, 1H), 5.17 (dd, *J* = 17.2, 1.4, 1H), 5.12 (dd, *J* = 10.3, 1.4, 1H), 3.09 (t, *J* = 7.7, 2H), 2.63 (m, 2H), 2.44 (t, *J* = 7.0, 2H), 1.60 – 1.37 (m, 4H), 0.93 (t, *J* = 7.3, 3H); ^{13}C NMR (101 MHz $CDCl_3$): δ = 134.7 (CH), 117.4 (CH_2), 106.1 (C), 56.4 (C), 55.5 (CH_2), 29.8 (CH_2), 26.6 (CH_2), 22.1 (CH_2), 19.5 (CH_2), 13.6 (CH_3); IR (neat): ν = 2959, 2933, 2873, 2181, 1641, 1466, 1056, 916; HR-MS (ES-TOF): *m/z*: calcd for $C_{10}H_{16}OSNa$ 207.0820, found 207.0825. $[M + Na]^+$.

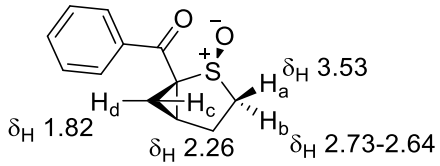
((But-3-en-1-ylsulfonyl)ethynyl)benzene (396)



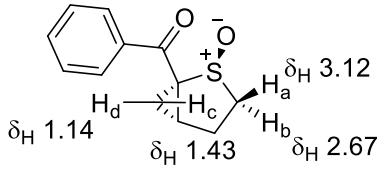
To a RBF under argon was added **376** (130 mg, 0.69 mmol), and CH_2Cl_2 (10 mL). The mixture was cooled to 0 °C and *m*CPBA (238 mg, 1.38 mmol, 2.0 eq.) was added in 5 portions over 10 mins. The mixture was stirred for 3 hours allowinging to warm to rt. The mixture was cooled to 0 °C and

*m*CPBA (59 mg, 0.35 mmol, 0.5 eq.) was added in one portion. The reaction was stirred for a further hour. The mixture was washed with $NaHCO_3$ (3 × 10 mL) and the aqueous phase was extracted with CH_2Cl_2 (3 × 10 mL). The combined organic layers were dried over Na_2SO_4, filtered, concentrated and purified by column chromatography (9:1 hexane: EtOAc) providing **396** (129 mg, 85%) as a viscous colourless oil; R_f 0.80 (7:3 hexane: EtOAc); ^{1}H NMR (300 MHz, $CDCl_3$): δ = 7.69 – 7.60 (m, 2H), 7.59 – 7.51 (m, 1H), 7.50 – 7.40 (m, 2H), 5.89 (ddt, *J* = 16.8, 10.2, 6.5 Hz, 1H), 5.30 – 5.14 (m, 2H), 3.44 – 3.34 (m, 2H), 2.83 – 2.70 (m, 2H); ^{13}C NMR (101 MHz, $CDCl_3$): δ = 133.4 (CH), 133.0 (2CH), 131.9 (CH), 129.0 (2CH), 117.8 (CH_2), 117.7 (C), 92.8 (C), 83.3 (C), 57.5 (CH_2), 27.3 (CH_2); IR (neat): ν = 3082, 2922, 2181, 1643, 1490, 1444, 1319, 1232, 1136, 847, 756, 687; HR-MS (AP-TOF): *m/z*: calcd for $C_{12}H_{13}O_2S$: 221.0636, found 221.0630 $[M + H]^+$.

Major diastereomer

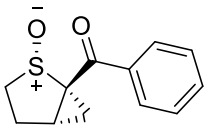


Minor diastereomer



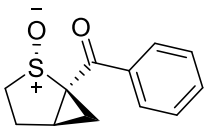
(2-Oxido-2-thiabicyclo[3.1.0]hexan-1-yl)(phenyl)methanone (397)

397 was prepared according to **GP13** using **376** (61.2 mg, 0.30 mmol), 3,5-dichloropyridine-*N*-oxide (59.1 mg, 0.36 mmol), $SPhosAuNTf_2$ (6.6 mg, 2.5 mol%) and 1,4-dioxane (6 mL). The reaction time was 28 hours. ^{1}H NMR analysis using 1,2,4,5 tetramethyl benzene as internal standard showed a d.r. ratio of 8:1. Purification by column chromatography (3:7 hexane:EtOAc)



afforded **397** (48.2 mg, 73%) as an off white solid as a single diastereomer; **397** prepared using an alternative method. To a Radleys tube under argon was added 3,5-dichloropyridine-*N*-oxide (59.1 mg, 0.3 mmol, 1.2 eq.) and alkynyl sulfoxide **348** (61.2 mg, 0.30 mmol,1 eq.) as a 0.2 M solution in 1,4-dioxane. The flask was placed in an oil bath at 65 ^{o}C and SPhosAuNTf$_2$ (5 mol%) was added followed by 1,4-dioxane (0.067 M) and the reaction was stirred for 45 minutes. The mixture was filtered through a pad of silica, washing with EtOAc, concentrated and purified by column chromatography providing **397** (52.8 mg, 80%) as a single diastereomer; R_f 0.06 (1:1 hexane:EtOAc); mp: 77-78 ^{o}C (Et_2O); ^{1}H NMR (300 MHz, $CDCl_3$): δ = 8.06 – 7.92 (m, 2H), 7.65 – 7.56 (m, 1H), 7.50 (t, *J* = 7.4 Hz, 2H), 3.53 (ddd, *J* = 12.9, 7.7, 4.3 Hz, 1H), 2.79 – 2.64 (m, 2H), 2.56 – 2.34 (m, 2H), 2.26 (t, *J* = 5.9 Hz, 1H), 1.82 (dd, *J* = 8.7, 5.9 Hz, 1H); ^{13}C NMR (101 MHz, $CDCl_3$): δ = 196.5 (C), 136.9 (C), 133.5 (CH), 129.5 (2CH), 128.8 (2CH), 59.7 (C), 54.4 (CH_2), 34.0 (CH), 26.5 (CH_2), 19.5 (CH_2); IR (neat): ν = 3078, 3006, 2989, 2934, 2860, 1661, 1600, 1449, 1442, 1060, 754, 692, 662; HR-MS (ES-TOF): *m/z*: calcd for $C_{12}H_{12}O_2NaS$: 243.0456, found 243.0458 [M + Na]$^{+}$.

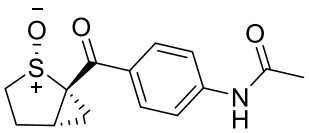
(2-Oxido-2-thiabicyclo[3.1.0]hexan-1-yl)(phenyl)methanone (397')



The minor diastereomer **397'** was isolated from a separate reaction run; R_f 0.07 (3:7 hexane:EtOAc); mp: 129-130 ^{o}C; ^{1}H NMR (400 MHz, $CDCl_3$): δ = 8.10 – 8.02 (m, 2H), 7.60 (t, *J* = 7.4 Hz, 1H), 7.49 (t, *J* = 7.6 Hz, 2H), 3.12 (dd, *J* = 14.4, 7.1 Hz, 1H), 3.02 – 2.85 (m, 2H), 2.67 (ddd, *J* = 14.4, 12.4, 7.1 Hz, 1H), 2.40 (dd, *J* = 13.2, 7.0 Hz, 1H), 1.43 (dd, *J* = 8.2, 6.6 Hz, 1H), 1.14 (app t, *J* = 6.2 Hz, 1H); ^{13}C NMR (101 MHz, $CDCl_3$): δ = 194.0 (C), 137.3 (C), 133.6 (CH), 129.0 (2CH), 128.8 (2CH), 58.7 (C), 50.4 (CH_2), 27.5 (CH), 25.5 (CH_2), 18.4 (CH_2); IR (neat): ν = 3082, 3009, 2990, 2934, 2865, 1667, 1597, 1286,

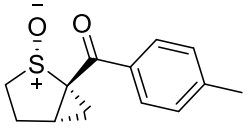
1022, 989, 775; HR-MS (EI-TOF): *m/z*: calcd for $C_{12}H_{12}O_2S$: 220.0558 found 220.0556 [M + H]$^+$.

N-(4-(2-Oxido-2-thiabicyclo[3.1.0]hexane-1-carbonyl)phenyl)acetamide (398)



398 was prepared according to **GP13** using **388** (78.3 mg, 0.30 mmol), 3,5-dichloropyridine-*N*-oxide (59.1 mg, 0.36 mmol), SPhosAuNTf$_2$ (6.6 mg, 2.5 mol%) and 1,4-dioxane (6 mL). The reaction time was 28 hours. ^{1}H NMR analysis using 1,2,4,5 tetramethyl benzene as internal standard showed a d.r. of 8:1. Purification by column chromatography (3:7 hexane:EtOAc) afforded **398** (66.0 mg, 79%) as a white solid as a single diastereomer; **398** was also prepared according to **GP14** using **388** (52.2 mg, 0.20 mmol), 3,5-dichloropyridine-*N*-oxide (39.4 mg, 0.24 mmol), SPhosAuNTf$_2$ (8.8 mg, 5 mol%) and 1,4-dioxane (4 mL). The reaction time was 4 hours. Purification by column chromatography (EtOAc) afforded **398** (44.0 mg, 79%) as a white solid; R_f 0.14 (EtOAc); mp: 170-172 ^{o}C; ^{1}H NMR (300 MHz, $CDCl_3$): δ = 8.48 (s, 1H), 7.99 (d, *J* = 8.6 Hz, 2H), 7.71 (d, *J* = 8.6 Hz, 2H), 3.58 (ddd, *J* = 12.9, 7.8, 4.0 Hz, 1H), 2.81 – 2.64 (m, 2H), 2.59 – 2.34 (m, 2H), 2.22 (t, *J* = 6.0 Hz, 1H), 2.18 (s, 3H), 1.77 (dd, *J* = 8.6, 6.0 Hz, 1H); ^{13}C NMR (101 MHz, $CDCl_3$): δ = 194.3 (C), 169.1 (C), 143.6 (C), 131.8 (C), 131.1 (2CH), 119.0 (2CH), 59.1 (C), 54.4 (CH_2), 33.0 (CH_3), 26.4 (CH_2), 24.8 (CH), 18.9 (CH_2); IR (neat): ν = 3086, 3039, 2958, 1678, 1662, 1597, 1579, 1286, 1117, 885; HR-MS (ES-TOF): *m/z*: calcd for $C_{14}H_{15}NO_3NaS$: 300.0670, found 300.0658 [M + Na]$^+$.

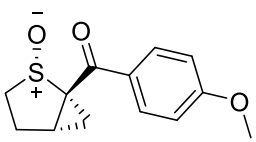
(2-Oxido-2-thiabicyclo[3.1.0]hexan-1-yl)(p-tolyl)methanone (399)



399 was prepared according to **GP13** using **378** (65.4 mg, 0.30 mmol), 3,5-dichloropyridine-*N*-oxide (59.1 mg, 0.36 mmol), SPhosAuNTf$_2$ (6.6 mg, 2.5 mol%) and 1,4-dioxane (6 mL). The reaction time was 28 hours. ^{1}H NMR analysis using 1,2,4,5 tetramethyl benzene as internal standard showed a d.r. of 8:1. Purification by

column chromatography (3:7 hexane: EtOAc) afforded **399** (53.0 mg, 75%) as a colourless oil as a single diastereomer; R_f 0.29 (EtOAc); ^{1}H NMR (300 MHz, $CDCl_3$): δ = 7.87 (d, *J* = 8.1 Hz, 2H), 7.27 (d, *J* = 8.1 Hz, 2H), 3.49 (ddd, *J* = 13.1, 7.7, 4.3 Hz, 1H), 2.73 – 2.62 (m, 2H), 2.52 – 2.29 (m, 2H), 2.39 (s, 3H), 2.24 – 2.17 (t, *J* = 5.9 Hz, 1H), 1.75 (dd, *J* = 8.7, 5.9 Hz, 1H); ^{13}C NMR (101 MHz, $CDCl_3$): δ = 195.8 (C), 144.4 (C), 134.2 (C), 129.6 (2CH), 129.4 (2CH), 59.4 (C), 54.5 (CH_2), 33.3 (CH), 26.4 (CH_2), 21.8 (CH_3), 19.1 (CH_2); IR (neat): ν = 3463, 2926, 1760, 1660, 1605, 1571, 1281, 1180, 1055, 1029, 734; HR-MS (ES-TOF): *m/z*: calcd for $C_{13}H_{14}O_2NaS$: 257.0612, found 257.0605 $[M + Na]^+$.

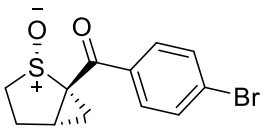
(4-Methoxyphenyl)(2-oxido-2-thiabicyclo[3.1.0]hexan-1-yl)methanone (400)



400 was prepared according to **GP13** using **377** (70.2 mg, 0.30 mmol), 3,5-dichloropyridine-*N*-oxide (59.1 mg, 0.36 mmol), $SPhosAuNTf_2$ (6.6 mg, 2.5 mol%) and 1,4-dioxane (6 mL). The reaction time was 19 hours. ^{1}H NMR analysis using 1,2,4,5 tetramethyl benzene as internal standard showed a d.r. ratio of 8:1. Purification by column chromatography (1:1 hexane:EtOAc to EtOAc) afforded **400** (53.0 mg, 74%) as a colourless oil as a single diastereomer; **400** prepared using an alternative method. To a Radleys tube under argon was added 3,5-dichloropyridine-*N*-oxide (59.1 mg, 0.3 mmol, 1.2 eq.) and alkynyl sulfoxide **377** (70.2 mg, 0.30 mmol, 1 eq.) as a 0.2 M solution in 1,4-dioxane. The flask was placed in an oil bath at 40 ^{o}C and $SPhosAuNTf_2$ (5 mol%) was added followed by 1,4-dioxane (0.067 M) and the reaction was stirred for 1 hour. The mixture was filtered through a pad of silica, washing with EtOAc, concentrated and purified by column chromatography providing **400** (58.5 mg, 78%) as a single diastereomer; R_f 0.25 (EtOAc); ^{1}H NMR (300 MHz, $CDCl_3$): δ = 8.08 – 7.99 (m, 2H), 7.04 – 6.95 (m, 2H), 3.53 (ddd, *J* = 13.1, 7.8, 4.3 Hz, 1H), 2.77 – 2.64 (m, 2H), 2.55 – 2.31 (m, 2H), 2.22 (t, *J* = 5.9 Hz, 1H), 1.71 (dd, *J* = 8.7, 5.9 Hz, 1H); ^{13}C NMR (101 MHz, $CDCl_3$): δ = 194.2 (C), 164.1 (C), 132.3 (2CH), 129.6

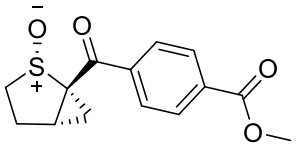
(C), 114.1 (2CH), 59.1 (C), 55.7 (CH_3) 54.7 (CH_2), 32.4 (CH) 26.4 (CH_2), 18.8 (CH_2); IR (neat): ν = 3452, 2934, 1731, 1655, 1597, 1573, 1510, 1285, 1258, 1170, 1024, 841; HR-MS (ES-TOF): *m/z*: calcd for $C_{13}H_{14}O_3NaS$: 273.0561, found 273.0570 $[M + Na]^+$.

4-Bromophenyl)(2-oxido-2-thiabicyclo[3.1.0]hexan-1-yl)methanone (401)



401 was prepared according to **GP13** using **381** (85.0 mg, 0.30 mmol), 3,5-dichloropyridine-*N*-oxide (59.1 mg, 0.36 mmol), SPhosAuNTf$_2$ (6.6 mg, 2.5 mol%) and 1,4-dioxane (6 mL). The reaction time was 28 hours. ^{1}H NMR analysis using 1,2,4,5 tetramethyl benzene as internal standard showed a d.r. of 8:1. Purification by column chromatography (3:7 hexane:EtOAc) afforded **401** (49.3 mg, 54%) as a white solid as a single diastereomer; R_f 0.19 (1:1 hexane:EtOAc); **401** was also prepared according to **GP14** using **381** (56.6 mg, 0.20 mmol), 3,5-dichloropyridine-*N*-oxide (39.4 mg, 0.24 mmol), SPhosAuNTf$_2$ (8.8 mg, 5 mol%) and 1,4-dioxane (4 mL). The reaction time was 3 hours. Purification by column chromatography (3:7 hexane:EtOAc) afforded **401** (42.0 mg, 74%) as a white solid; mp: 78-80 ^{o}C; ^{1}H NMR (300 MHz, $CDCl_3$): δ = 7.89 – 7.82 (m, 2H), 7.67 – 7.59 (m, 2H), 3.54 (ddd, *J* = 13.2, 7.5, 4.1 Hz, 1H), 2.78 – 2.61 (m, 2H), 2.53 – 2.32 (m, 2H), 2.25 (t, *J* = 6.0 Hz, 1H), 1.76 (dd, *J* = 8.7, 6.0 Hz, 1H); ^{13}C NMR (101 MHz, $CDCl_3$): δ = 195.5 (C), 135.5 (C), 132.1 (2CH), 131.1 (2CH), 128.8 (C), 59.2 (C), 54.0 (CH_2), 33.6 (CH), 26.2 (CH_2), 19.3 (CH_2); IR (neat): ν = 3082, 3068, 2991, 1647, 1410, 1275, 1013, 874, 756; HR-MS (ES-TOF): *m/z*: calcd for $C_{12}H_{11}O_2SNa^{79}Br$: 320.9561, found 320.9550 $[M + Na]^+$.

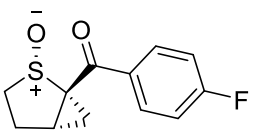
Methyl 4-(2-oxido-2-thiabicyclo[3.1.0]hexane-1-carbonyl)benzoate (402)



402 was prepared according to **GP13** using **387** (78.6 mg, 0.30 mmol), 3,5-dichloropyridine-*N*-oxide (59.1 mg, 0.36 mmol), SPhosAuNTf$_2$ (6.6 mg, 2.5 mol%) and 1,4-dioxane (6 mL). The reaction time was 28 hours. ^{1}H NMR analysis

using 1,2,4,5 tetramethyl benzene as internal standard showed a d.r. of 8:1. Purification by column chromatography (3:7 hexane:EtOAc) afforded **402** (38.5 mg, 54%) as an off white solid as a single diastereomer; **402** was also prepared according to **GP14** using **387** (52.5 mg, 0.20 mmol), 3,5-dichloropyridine-*N*-oxide (39.4 mg, 0.24 mmol), SPhosAuNTf$_2$ (8.8 mg, 5 mol%) and 1,4-dioxane (4 mL). The reaction time was 20 hours. Purification by column chromatography (3:7 hexane:EtOAc) afforded **402** (35.6 mg, 64%) as an off white solid; R_f 0.35 (EtOAc); mp: 63-64 ^oC; ^1H NMR (300 MHz, $CDCl_3$): δ = 8.18 – 8.12 (m, 2H), 8.04 – 7.98 (m, 2H), 3.94 (s, 3H), 3.55 (ddd, *J* = 13.2, 7.5, 4.2 Hz, 1H), 2.80 – 2.62 (m, 2H), 2.54 – 2.38 (m, 2H), 2.33 – 2.26 (t, *J* = 5.9 Hz, 1H), 1.86 (dd, *J* = 8.7, 5.9 Hz, 1H); ^{13}C NMR (101 MHz, $CDCl_3$): δ = 196.6 (C) 166.2 (C), 140.3 (C), 134.1 (C), 129.9 (2CH), 129.3 (2CH), 59.7 (C), 54.0 (CH_2), 52.6 (CH_3), 34.7 (CH), 26.3 (CH_2), 19.7 (CH_2); IR (neat): ν = 3493, 3094, 3022, 2960, 2936, 1716, 1665, 1436, 1273, 1031, 763; HR-MS (ES-TOF): *m/z*: calcd for $C_{14}H_{14}O_4NaS$: 301.0510, found 301.0500 $[M + Na]^+$.

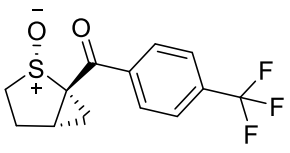
(4-Fluorophenyl)(2-oxido-2-thiabicyclo[3.1.0]hexan-1-yl)methanone (403)



403 was prepared according to **GP13** using **379** (66.6 mg, 0.30 mmol), 3,5-dichloropyridine-*N*-oxide (59.1 mg, 0.36 mmol), SPhosAuNTf$_2$ (6.6 mg, 2.5 mol%) and 1,4-dioxane (6 mL). The reaction time was 28 hours. ^1H NMR analysis using 1,2,4,5 tetramethyl benzene as internal standard showed a d.r. ratio of 8:1. Purification by column chromatography (3:7 hexane:EtOAc) afforded **403** (38.5 mg, 54%) as a viscous oil; **403** was also prepared according to **GP14** using **379** (66.6 mg, 0.30 mmol), 3,5-dichloropyridine-*N*-oxide (59.1 mg, 0.36 mmol), SPhosAuNTf$_2$ (13.2 mg, 5 mol%) and 1,4-dioxane (6 mL). The reaction time was 17 hours. Purification by column chromatography (3:7 hexane:EtOAc) afforded **375** (53.6 mg, 68%) as a colourless viscous oil, as a single diastereomer; R_f 0.39 (EtOAc); ^1H NMR (300 MHz, $CDCl_3$): δ = 8.15 – 7.99 (m, 2H), 7.23 –

7.10 (m, 2H), 3.56 (ddd, *J* = 13.2, 7.6, 4.1 Hz, 1H), 2.78 – 2.64 (m, 2H), 2.54 – 2.33 (m, 2H), 2.25 (t, *J* = 5.9 Hz, 1H), 1.76 (dd, *J* = 8.7, 5.9 Hz, 1H); ^{13}C NMR (101 MHz, $CDCl_3$): δ = 194.8 (C), 166.1 (d, *J* = 255.8 Hz, C), 133.1 (C), 132.5 (d, *J* = 9.4 Hz, 2CH), 116.0 (d, *J* = 22.1 Hz, 2CH), 59.1 (C), 54.2 (CH_2), 33.2 (CH), 26.3 (CH_2), 19.2 (CH_2); IR (neat): ν = 3070, 2937, 1663, 1596, 1506, 1280, 1230, 1027, 844, 609; HR-MS (ES-TOF): *m/z*: calcd for $C_{12}H_{12}O_2FS$: 239.0542, found 239.0547 $[M + H]^+$.

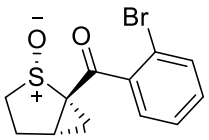
(2-Oxido-2-thiabicyclo[3.1.0]hexan-1-yl)(4-(trifluoromethyl)phenyl)methanone (404)



404 was prepared according to **GP13** using **380** (81.6 mg, 0.30 mmol), 3,5-dichloropyridine-*N*-oxide (59.1 mg, 0.36 mmol), $SPhosAuNTf_2$ (6.6 mg, 2.5 mol%) and 1,4-dioxane (6 mL). The reaction time was 28 hours. ^{1}H NMR analysis using 1,2,4,5 tetramethyl benzene as internal standard showed a d.r. of 8:1; Purification by column chromatography (1:1 hexane:EtOAc to EtOAc) afforded **404** (26.0 mg, 30%) as a colourless oil, as a single diastereomer; ^{1}H NMR analysis using 1,2,4,5 tetramethyl benzene as internal standard showed a d.r. of 8:1; **404** was also prepared according to **GP14** using **380** (54.4 mg, 0.20 mmol), 3,5-dichloropyridine-*N*-oxide (39.4 mg, 0.24 mmol), $SPhosAuNTf_2$ (8.8 mg, 5 mol%) and 1,4-dioxane (4 mL). The reaction time was 17 hours. Purification by column chromatography (1:1 hexane:EtOAc to EtOAc) afforded **404** (35.6 mg, 63%) as a colourless oil, as a single diastereomer; R_f 0.26 (1:1 hexane:EtOAc); ^{1}H NMR (300 MHz, $CDCl_3$): δ = 8.09 (d, *J* = 8.2 Hz, 2H), 7.77 (d, *J* = 8.2 Hz, 2H), 3.57 (ddd, *J* = 13.2, 7.3, 4.2 Hz, 1H), 2.82 – 2.64 (m, 2H), 2.55 – 2.36 (m, 2H), 2.31 (t, *J* = 5.9 Hz, 1H), 1.85 (dd, *J* = 8.7, 5.9 Hz, 1H); ^{13}C NMR (101 MHz, $CDCl_3$): δ = 196.2 (C), 139.8 (C), 134.7 (q, *J* = 32.7 Hz, C), 129.8 (2CH), 125.8 (d, *J* = 3.2 Hz, 2CH), 123.4 (q, *J* = 272.4 Hz, C), 59.4 (C), 53.8 (CH_2), 34.4 (CH), 26.2 (CH_2), 19.8 (CH_2); IR (neat): *ν* = 2937, 1673, 1409, 1323, 1279, 1167, 1112,

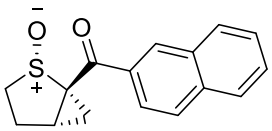
1063, 855; HR-MS (ES-TOF): *m/z*: calcd for $C_{13}H_{11}O_2NaSF_3$: 311.0330, found 311.0327 [M + Na]$^+$.

(2-Bromophenyl)(2-oxido-2-thiabicyclo[3.1.0]hexan-1-yl)methanone (405)



405 was prepared according to **GP13** using **383** (85.0 mg, 0.30 mmol), 3,5-dichloropyridine-*N*-oxide (59.1 mg, 0.36 mmol), SPhosAuNTf$_2$ (6.6 mg, 2.5 mol%) and 1,4-dioxane (5 mL). The reaction time was 28 hours. ^{1}H NMR analysis using 1,2,4,5 tetramethyl benzene as internal standard showed a d.r. of 8:1; Purification by column chromatography (3:7 hexane:EtOAc) afforded **405** (44.3 mg, 50%) as a white solid as a single diastereomer; R_f 0.29 (EtOAc); mp: 120-122 ^{o}C; ^{1}H NMR (300 MHz, $CDCl_3$): δ = 7.65 – 7.59 (m, 1H), 7.49 – 7.41 (m, 1H), 7.41 – 7.32 (m, 2H), 3.60 – 3.48 (m, 1H), 2.73 – 2.63 (m, 1H), 2.59 – 2.39 (m, 3H), 2.31 – 2.16 (m, 2H); ^{13}C NMR (101 MHz, $CDCl_3$): δ = 199.2 (C), 140.2 (C), 133.0 (CH), 131.9 (CH), 128.4 (CH), 128.0 (CH), 118.4 (C), 60.4 (C), 52.4 (CH_2), 40.2 (CH), 26.6 (CH_2), 19.1 (CH_2); IR (neat): ν = 3049, 3006, 2924, 1662, 1589, 1426, 1326, 1054, 1026, 754; HR-MS (ES-TOF): *m/z*: calcd for $C_{12}H_{11}O_2SNa^{79}Br$: 320.9561, found 320.9551 [M + Na]$^+$.

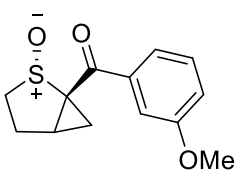
Naphthalen-2-yl(2-oxido-2-thiabicyclo[3.1.0]hexan-1-yl)methanone (406)



406 was prepared according to **GP13** using **394** (48.9 mg, 0.20 mmol), 3,5-dichloropyridine-*N*-oxide (39.4 mg, 0.24 mmol), SPhosAuNTf$_2$ (4.4 mg, 2.5 mol%) and 1,4-dioxane (4 mL). The reaction time was 28 hours. ^{1}H NMR analysis using 1,2,4,5 tetramethyl benzene as internal standard showed a d.r. ratio of 8:1. Purification by column chromatography (3:7 hexane:EtOAc) afforded **406** (35.1 mg, 65%) as an off white solid as a single diastereomer; **406** was also prepared according to **GP14** using **394** (50.9 mg, 0.20 mmol), 3,5-dichloropyridine-*N*-oxide (39.4 mg, 0.24 mmol), SPhosAuNTf$_2$ (8.8 mg, 0.01 mmol) and 1,4-dioxane (4 mL). The reaction time was 28 hours. Purification by column

chromatography (3:7 hexane: EtOAc) afforded **406** (37.7 mg, 70%) as a white solid; R_f 0.41 (EtOAc); mp: 108-109 °C; ^{1}H NMR (300 MHz, $CDCl_3$): δ = 8.65 (s, 1H), 8.09 – 7.83 (m, 4H), 7.67 – 7.52 (m, 2H), 3.56 (ddd, *J* = 13.0, 7.7, 4.2 Hz, 1H), 2.85 – 2.61 (m, 2H), 2.62 – 2.38 (m, 2H), 2.33 (t, *J* = 5.9 Hz, 1H), 1.86 (dd, *J* = 8.6, 5.9 Hz, 1H); ^{13}C NMR (101 MHz, $CDCl_3$): δ = 196.3 (C), 135.8 (C), 134.1 (C), 132.4 (C), 132.1 (CH), 130.1 (CH), 128.9 (CH), 128.7 (CH), 127.9 (CH), 127.1 (CH), 124.7 (CH), 59.6 (C), 54.4 (CH_2), 33.6 (CH), 26.4 (CH_2), 19.5 (CH_2); IR (neat): ν = 3065, 3021, 2930, 1651, 1628, 1365, 1292, 1181, 1125, 1051, 1001, 813; HR-MS (ES-TOF): *m/z*: calcd for $C_{16}H_{15}O_2S$: 271.0793, found 271.0798 $[M + H]^+$.

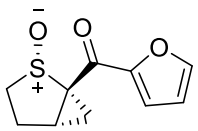
(3-Methoxyphenyl)(2-oxido-2-thiabicyclo[3.1.0]hexan-1-yl)methanone (407)



407 was prepared according to **GP13** using **383** (70.3 mg, 0.30 mmol), 3,5-dichloropyridine-*N*-oxide (59.1 mg, 0.36 mmol), $SPhosAuNTf_2$ (6.6 mg, 2.5 mol%) and 1,4-dioxane (6 mL). The reaction time was 28 hours. ^{1}H NMR analysis using 1,2,4,5 tetramethyl benzene as internal standard showed a d.r. ratio of 8:1; Purification by column chromatography (3:7 hexane: EtOAc) afforded **407** (40.0 mg, 54%) as colourless oil as a single diastereomer; R_f 0.33 (EtOAc); **407** was also prepared according to **GP14** using **383** (46.9 mg, 0.20 mmol), 3,5-dichloropyridine-*N*-oxide (39.4 mg, 0.24 mmol), $SPhosAuNTf_2$ (4.4 mg, 2.5 mol%) and 1,4-dioxane (4 mL). The reaction time was 18 hours. Purification by column chromatography (3:7 hexane:EtOAc) afforded **407** (35.0 mg, 70%); ^{1}H NMR (300 MHz, $CDCl_3$): δ = 7.61 – 7.54 (m, 1H), 7.49 (dd, *J* = 2.4, 1.7 Hz, 1H), 7.40 (t, *J* = 7.9 Hz, 1H), 7.13 (ddd, *J* = 8.2, 2.6, 0.9 Hz, 1H), 3.85 (s, 3H), 3.53 (ddd, *J* = 13.2, 7.6, 4.1 Hz, 1H), 2.76 – 2.61 (m, 2H), 2.52 – 2.32 (m, 2H), 2.25 (t, *J* = 5.9 Hz, 1H), 1.80 (dd, *J* = 8.7, 5.9 Hz, 1H); ^{13}C NMR (101 MHz, $CDCl_3$): δ = 196.4 (C), 159.8 (C), 138.1 (C), 129.8 (CH), 122.0 (CH), 120.4 (CH), 113.4 (CH), 59.5 (C), 55.6 (CH_3), 54.2 (CH_2), 34.0 (CH), 26.3 (CH_2), 19.4

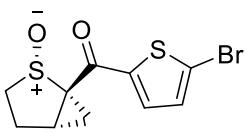
(CH_2); IR (neat): ν = 2939, 1722, 1663, 1596, 1580, 1279, 1030, 787; HR-MS (ES-TOF): *m/z*: calcd for $C_{13}H_{14}O_3SNa$: 273.0561, found 273.0563 $[M + Na]^+$.

Furan-2-yl(2-oxido-2-thiabicyclo[3.1.0]hexan-1-yl)methanone (408)



A Radleys tube under argon was charged with 3,5-dichloropyridine-*N*-oxide (39.4 mg, 0.24 mmol, 1.2 eq.) and **389** (38.8 mg, 0.20 mmol, 1.0 eq.) as a 0.2 M solution in 1,4-dioxane. SPhosAuNTf$_2$ (8.8 mg, 5 mol%) was added followed by 1,4-dioxane (3 mL) and the reaction mixture was stirred for 22 hours. Purification by column chromatography (1:4 hexane:EtOAc) afforded **408** (20.0 mg, 46%) as a colourless oil, as a single diastereomer; **408** was also prepared according to **GP14** using **389** (41.4 mg, 0.21 mmol), 3,5-dichloropyridine-*N*-oxide (41.0 mg, 0.25 mmol), SPhosAuNTf$_2$ (9.0 mg, 5 mol%) and 1,4-dioxane (4.2 mL). The reaction time was 28 hours. Purification by column chromatography (1:4 hexane:EtOAc) afforded **408** (33.3 mg, 74%) as a colourless oil; R_f 0.08 (1:1 hexane: EtOAc); ^{1}H NMR (300 MHz, $CDCl_3$): δ = 7.67 – 7.58 (m, 2H), 6.58 (dd, *J* = 3.7, 1.7 Hz, 1H), 3.57 (dt, *J* = 13.1, 5.0 Hz, 1H), 2.88 – 2.77 (m, 1H), 2.68 – 2.53 (m, 1H), 2.44 – 2.33 (m, 2H), 2.18 (t, *J* = 6.1 Hz, 1H), 1.91 (dd, *J* = 8.6, 6.1 Hz, 1H); ^{13}C NMR (101 MHz, $CDCl_3$): δ = 182.5 (C), 151.5 (C), 147.4 (CH), 120.9 (CH), 112.8 (CH), 58.1 (C), 52.0 (CH_2), 33.8 (CH), 25.5 (CH_2), 18.3 (CH_2); IR (neat): ν = 3425, 3127, 2935, 1635, 1563, 1461, 1390, 1297, 1138, 1055, 1017, 991, 884, 768; HR-MS (AP-TOF): *m/z*: calcd for $C_{10}H_{11}O_3S$: 211.0429, found 211.0425 $[M + H]^+$.

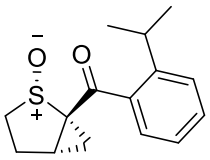
(5-Bromothiophen-2-yl)(2-oxido-2-thiabicyclo[3.1.0]hexan-1-yl)methanone (409)



409 was prepared according to **GP14** using **390** (60.7 mg, 0.21 mmol), 3,5-dichloropyridine-*N*-oxide (41.0 mg, 0.25 mmol), SPhosAuNTf$_2$ (9.0 mg, 5 mol%) and 1,4-dioxane (4.2 mL). The reaction time was 28 hours. Purification by column chromatography (1:4 hexane:EtOAc) afforded **409** (44.4 mg, 73%) as a white solid, as a single diastereomer; R_f 0.12 (1:1 hexane:EtOAc); mp: 116-118 ^{o}C; ^{1}H NMR (300 MHz, $CDCl_3$): δ =

7.58 (d, *J* = 5.1 Hz, 1H), 7.13 (d, *J* = 5.1 Hz, 1H), 3.68 – 3.52 (m, 1H), 2.72 – 2.39 (m, 4H), 2.13 (t, *J* = 6.2 Hz, 1H), 2.07 (dd, *J* = 8.3, 6.2 Hz, 1H); ^{13}C NMR (101 MHz, $CDCl_3$): δ = 187.2 (C), 135.1 (C), 132.9 (CH), 132.1 (CH), 115.2 (C), 60.8 (C), 54.5 (CH_2), 36.6 (CH), 27.8 (CH_2), 16.8 (CH_2); IR (neat): ν = 3082, 3068, 2989, 1650, 1411, 1277, 1011, 755; HR-MS (ES-TOF): *m/z*: calcd for $C_{10}H_9O_2NaS_2{}^{79}Br$: 326.9125, found 326.9131 $[M + Na]^+$.

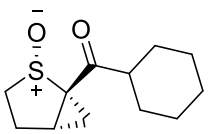
2-Isopropylphenyl)(2-oxido-2-thiabicyclo[3.1.0]hexan-1-yl)methanone (410)



410 was prepared according to **GP13** using **386** (74.0 mg, 0.30 mmol), 3,5-dichloropyridine-*N*-oxide (59.1 mg, 0.36 mmol), $SPhosAuNTf_2$ (6.6 mg, 2.5 mol%) and 1,4-dioxane (6 mL). The reaction time was 28 hours. Purification by column chromatography (3:7 hexane:EtOAc) afforded **410** (39.4 mg, 50%) as a colourless oil; R_f 0.35 (EtOAc); **410** was also prepared according to **GP14** using **386** (49.3 mg, 0.20 mmol), 3,5-dichloropyridine-*N*-oxide (39.4 mg, 0.24 mmol), $SPhosAuNTf_2$ (8.8 mg, 5 mol%) and 1,4-dioxane (4 mL). The reaction time was 28

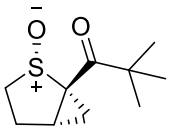
hours. Purification by column chromatography (3:7 hexane:EtOAc) afforded **410** (27.5 mg, 52%) as a colourless oil, as a 7:1 mixture of diastereomers; ^{1}H NMR (300 MHz, $CDCl_3$): δ = 7.41 – 7.32 (m, 2H), 7.29 – 7.24 (m, 1H), 7.21 (dd, *J* = 6.0, 2.2 Hz, 1H), 3.45 – 3.35 (m, 1H), 3.03 – 2.87 (m, 1H), 2.64 – 2.45 (m, 2H), 2.36 – 2.28 (m, 2H), 2.25 – 2.15 (m, 1H), 1.96 (dd, *J* = 8.7, 5.7 Hz, 1H), 1.19 (d, *J* =, 6.8 Hz, 3H), 1.14 (d, *J* =, 6.8 Hz, 3H); ^{13}C NMR (101 MHz, $CDCl_3$): δ = 201.7 (C), 146.4 (C), 137.2 (C), 130.9 (CH), 126.6 (CH), 126.3 (CH), 125.7 (CH), 61.1 (C), 52.4 (CH_2), 37.2 (CH), 30.5 (CH), 26.1 (CH_2), 24.2 (CH_3), 24.0 (CH_3), 19.1 (CH_2); IR (neat): *v* = 3039, 3084, 2959, 1677, 1663, 1597, 1579, 1286, 1263, 1056, 762; HR-MS (ES-TOF): *m/z*: calcd for $C_{15}H_{18}O_2NaS$: 285.0925, found 285.0932 $[M + Na]^+$.

Cyclohexyl(2-oxido-2-thiabicyclo[3.1.0]hexan-1-yl)methanone (413)



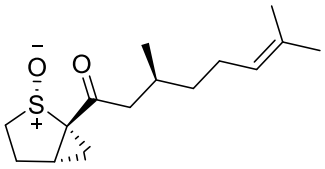
413 was prepared according to **GP14** using **385** (42.7 mg, 0.20 mmol), 3,5-dichloropyridine-*N*-oxide (39.4 mg, 0.24 mmol), $SPhosAuNTf_2$ (8.8 mg, 5 mol%) and 1,4-dioxane (4 mL). The reaction time was 24 hours. Purification by column chromatography (1:1 hexane:EtOAc to EtOAc) afforded **413** (20.6 mg, 45%) as a white solid as a 7:1 mixture of diastereomers; R_f 0.20 (EtOAc); mp: 86-87 °C; ^{1}H NMR (300 MHz, $CDCl_3$): δ = 3.60 – 3.48 (ddd, *J* = 10.2, 6.2, 4.8, 1H), 3.17 – 3.01 (m, 1H), 2.59 – 2.47 (m, 1H), 2.45 – 2.36 (m, 1H), 2.34 – 2.27 (m, 2H), 2.08 – 2.02 (m, 1H), 2.02 – 1.95 (m, 1H), 1.85 (dd, *J* = 8.5, 5.6 Hz, 1H), 1.80 (dd, *J* = 9.1, 3.2 Hz, 2H), 1.75 – 1.63 (m, 2H), 1.56 – 1.11 (m, 5H); ^{13}C NMR (101 MHz, $CDCl_3$): δ = 207.1 (C), 58.3 (C), 51.8 (CH_2), 48.7 (CH), 36.2 (CH), 28.8 (CH_2), 28.5 (CH_2), 25.8 (CH_2), 25.7 (CH_2), 25.5 ($2CH_2$), 18.0 (CH_2); IR (neat): *v* = 2980, 2925, 2853, 1667, 1442, 1382, 1332, 1267, 1259, 1057, 1041, 980, 874; HR-MS (ES-TOF): *m/z*: calcd for $C_{12}H_{18}O_2NaS$: 249.0925, found 249.0920 $[M + Na]^+$.

2,2-Dimethyl-1-((1S,2R)-2-oxido-2-thiabicyclo[3.1.0]hexan-1-yl)propan-1-one (414)



414 was prepared according to **GP14** using **384** (36.9 mg, 0.20 mmol), 3,5-dichloropyridine-*N*-oxide (39.4 mg, 0.24 mmol), $SPhosAuNTf_2$ (8.8 mg, 5 mol%) and 1,4-dioxane (4 mL). The reaction time was 25 hours. ^1H NMR analysis using 1,2,4,5 tetramethyl benzene as internal standard showed a d.r. ratio of 12:1. Purification by column chromatography (EtOAc) afforded **414** (28.0 mg, 70%) as a colourless oil as a 12:1 mixture of diastereomers; ^1H NMR (300 MHz $CDCl_3$): δ = 3.51 (ddd, *J* = 13.2, 6.8, 4.9, 1H), 2.65 (ddd, *J* = 13.2, 6.8, 4.9, 1H), 2.48 – 2.39 (m, 1H), 2.38 – 2.29 (m, 2H), 2.03 (app t, *J* = 5.7, 1H), 1.78 (dd, *J* = 8.6, 5.7, 1H), 1.36 (s, 9H); ^{13}C NMR (101 MHz $CDCl_3$): δ = 207.0 (C), 58.3 (C), 53.7 (CH_2), 45.4 (C), 36.6 (CH), 26.7 ($3CH_3$), 25.9 (CH_2), 18.5 (CH_2); IR (neat): *ν* = 3470, 2971, 2871, 1678, 1478, 1367, 1225, 1169, 1091, 1057, 994. HR-MS (ES-TOF): *m/z* calculated for $C_{10}H_{16}O_2S$ 200.0871, found 200.0879 $[M + H]^+$.

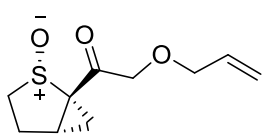
3S)-3,7-Dimethyl-1-(2-oxido-2-thiabicyclo[3.1.0]hexan-1-yl)oct-6-en-1-one (415)



415 was prepared according to **GP14** using **393** (50.4 mg, 0.20 mmol), 3,5-dichloropyridine-*N*-oxide (39.4 mg, 0.24 mmol), $SPhosAuNTf_2$ (8.8 mg, 0.010 mmol) and 1,4-dioxane (4 mL). The reaction time was 21 hours. Purification by column chromatography (1:1 hexane:EtOAc to EtOAc) afforded **415** (37.8 mg, 70%) as a colourless oil (d.r. ratio 10:10:1:1, assignment of the two major diastereomers is observed in the ^{13}C NMR); R_f 0.17 (1:1 hexane:EtOAc); $[\alpha]_D^{21}$ 3.60 (*c* 0.010 in $CHCl_3$); ^1H NMR (300 MHz, $CDCl_3$): δ = 5.08 (dtd, *J* = 7.0, 2.7, 1.3 Hz, 1H), 3.58 – 3.45 (m, 1H), 2.93 – 2.62 (m, 2H), 2.59 – 2.38 (m, 2H), 2.37 – 2.25 (m, 2H), 2.19-2.05 (m, 1H), 2.10 – 2.04 (m, 1H), 1.97 (td, *J* = 14.0, 7.1 Hz, 2H), 1.85 (dd, *J* = 7.9, 5.8 Hz, 1H), 1.67 (s, 3H), 1.59 (s, 4H), 1.43 – 1.15 (m, 3H), 0.93 (dd, *J* = 6.6, 2.0 Hz, 3H); Major diastereomer 1;^{13}C NMR (101 MHz, $CDCl_3$): 203.5 (C), 131.7 (C), 124.3 (CH), 59.3 (C), 51.3 (CH_2), 50.1

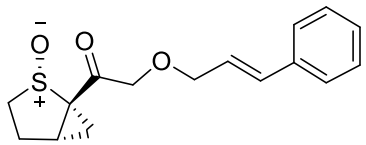
(CH_2), 48.6 (CH_2), 37.0 (CH_2), 35.5 (CH), 28.8 (CH), 25.8 (CH_3), 25.6 (CH_2), 19.9 (CH_3), 18.1 (CH_2), 17.8 (CH_3); Major diastereomer 2: δ = 203.5 (C), 131.7 (C), 124.3 (CH), 59.2 (C), 51.1 (CH_2), 50.1 (CH_2), 48.6 (CH_2), 36.9 (CH_2), 35.4 (CH), 28.8 (CH), 25.8 (CH_3), 25.6 (CH_2), 19.8 (CH_3), 18.0 (CH_2), 17.8 (CH_3); IR (neat): *v* = 3458, 2961, 2924, 1688, 1446, 1375, 1287, 1241, 1100, 1057, 1031, 989; HR-MS (ES-TOF): *m/z*: calcd for $C_{15}H_{24}O_2NaS$: 291.1395, found 291.1393 $[M + Na]^+$.

2-(Allyloxy)-1-(2-oxido-2-thiabicyclo[3.1.0]hexan-1-yl)ethan-1-one (416)



416 was prepared according to **GP14** using **391** (39.7 mg, 0.20 mmol), 3,5-dichloropyridine-*N*-oxide (39.4 mg, 0.24 mmol), $SPhosAuNTf_2$ (8.8 mg, 5 mol%) and 1,4-dioxane (4 mL). The reaction time was 21 hours. Purification by column chromatography (EtOAc to 1:9 MeOH:EtOAc) afforded **416** (27.0 mg, 63%) as a colourless oil as a 10:1 mixture of diastereomers; R_f 0.35 (1:9 MeOH:EtOAc); ^1H NMR (300 MHz, $CDCl_3$): δ = 5.92 (ddt, *J* = 17.0, 10.4, 5.8 Hz, 1H), 5.37 – 5.17 (m, 2H), 4.64 (d, *J* = 17.0 Hz, 1H), 4.52 (d, *J* = 17.0 Hz, 1H), 4.11 – 4.05 (m, 2H), 3.52 (dt, *J* = 13.1, 5.2 Hz, 1H), 2.63 – 2.48 (m, 2H), 2.32 (ddd, *J* = 5.9, 4.4, 2.0 Hz, 2H), 2.14 – 2.06 (m, 1H), 1.94 (dd, *J* = 8.6, 5.7 Hz, 1H); ^{13}C NMR (101 MHz, $CDCl_3$): δ = 200.4 (C), 133.5 (CH), 118.8 (CH_2), 74.4 (CH_2), 72.7 (CH_2), 58.1 (C), 52.3 (CH_2), 36.9 (CH), 25.9 (CH_2), 18.6 (CH_2); IR (neat): *v* = 3451, 2935, 1703, 1423, 1250, 1140, 1092, 992, 926, 730; HR-MS (AP-TOF): *m/z*: calcd for $C_{10}H_{15}O_3S$: 215.0742, found 215.0746 $[M + H]^+$.

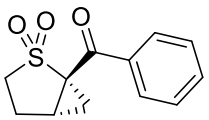
2-(Cinnamyloxy)-1-(2-oxido-2-thiabicyclo[3.1.0]hexan-1-yl)ethan-1-one (417)



417 was prepared according to **GP14** using **392** (54.8 mg, 0.20 mmol), 3,5-dichloropyridine-*N*-oxide (39.4 mg, 0.24 mmol), $SPhosAuNTf_2$ (8.8 mg, 5 mol%) and 1,4-dioxane (4 mL). The reaction time was 21 hours. Purification by column chromatography (EtOAc to 1:19

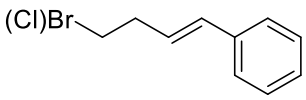
MeOH:EtOAc) afforded **417** (38.0 mg, 65%) as a viscous white semi solid, as a 10:1 mixture of diastereomers; R_f 0.40 (1:9 MeOH:EtOAc); ^{1}H NMR (300 MHz, $CDCl_3$): δ = 7.46 – 7.22 (m, 5H), 6.64 (d, *J* = 16.0 Hz, 1H), 6.30 (dt, *J* = 16.0, 6.3 Hz, 1H), 4.71 (d, *J* = 17.0 Hz, 1H), 4.60 (d, *J* = 17.0 Hz, 1H), 4.36 – 4.19 (m, 2H), 3.59 – 3.48 (m, 1H), 2.65 – 2.50 (m, 2H), 2.38 – 2.26 (m, 2H), 2.16 – 2.07 (m, 1H), 1.95 (dd, *J* = 8.6, 5.7 Hz, 1H); ^{13}C NMR (101 MHz, $CDCl_3$): δ = 200.5 (C), 136.3 (C), 134.1 (CH), 128.7 (2CH), 128.1 (CH), 126.7 (2CH), 124.7 (CH), 74.4 (CH_2), 72.4 (CH_2), 58.1 (C), 52.2 (CH_2), 37.0 (CH), 25.9 (CH_2) 18.8 (CH_2); IR (neat): *v* = 2934, 1704, 1495, 1449, 1248, 1137, 1093, 1058, 1031, 968, 872, 735, 693; HR-MS (AP-TOF): *m/z*: calcd for $C_{16}H_{19}O_3S$: 291.1055, found 291.1059 $[M + H]^+$.

(2,2-Dioxido-2-thiabicyclo[3.1.0]hexan-1-yl)(phenyl)methanone (419)



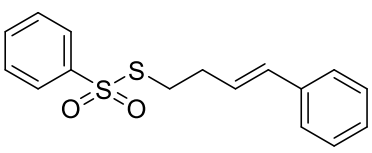
419 was prepared according to **GP13** using **396** (66.0 mg, 0.30 mmol), 3,5-dichloropyridine-*N*-oxide (59.1 mg, 0.36 mmol), $SPhosAuNTf_2$ (6.6 mg, 2.5 mol%) and 1,4-dioxane (6 mL). The reaction time was 28 hours. Purification by column chromatography (7:3 hexane:EtOAc), followed by recrystallisation from hot EtOH afforded **419** (56.0 mg, 79%) as a white solid; R_f 0.28 (7:3 hexane: EtOAc); mp: 118-119 °C (EtOH); ^{1}H NMR (300 MHz, $CDCl_3$): δ = 8.18 – 8.09 (m, 2H), 7.68 – 7.58 (m, 1H), 7.56 – 7.46 (m, 2H), 3.34 – 3.03 (m, 2H), 2.79 (dt, *J* = 8.6, 5.7 Hz, 1H), 2.63 – 2.46 (m, 1H), 2.32 (dd, *J* = 13.7, 7.7 Hz, 1H), 1.85 (t, *J* = 6.6 Hz, 1H), 1.77 – 1.68 (m, 1H); ^{13}C NMR (101 MHz, $CDCl_3$): δ = 190.7 (C), 136.5 (C), 134.3 (CH), 129.7 (2CH), 128.8 (2CH), 50.6 (C), 48.6 (CH_2), 25.4 (CH), 19.7 (CH_2), 18.4 (CH_2); IR (neat): *v* = 3039, 3086, 2958, 1678, 1662, 1597, 1452, 1302, 1286, 1117, 885; HR-MS (ES-TOF): *m/z*: calcd for $C_{12}H_{12}O_3NaS$: 259.0405, found 259.0416 $[M + Na]^+$.

Phenylhalide (428)



428 was prepared according to a literature procedure.[147] A 3 neck RBF was fitted with a reflux condenser. Mg turnings (550 mg, 22.5 mmol, 1.0 eq.), and THF (22 mL) was added. Cyclopropylbromide (2.00 mL, 25 mmol, 1.1 eq.) was added dropwise to the stirred mixture with gentle warming. Upon reflux starting, heating was stopped until complete halide addition. Once reflux had stopped the reaction was heated to reflux for 1 hour and cooled to rt. The Grignard was added to a separate flask and cooled to 0 ^{o}C. Benzaldehyde (2.03 mL, 22.0 mmol) was added and the solution stirred for 15 minutes followed by the addition of acetyl chloride (1.92 mL, 22.0 mmol, 1.0 eq.). The reaction was heated to 50 ^{o}C for 1 hour and then concentrated under reduced pressure. The residue was dissolved in a H_2O/Et_2O mixture and the organic layer was separated. The aqueous layer was extracted with Et_2O (2 × 25 ml). The organic layers were combined, dried over $NaSO_4$, filtered, concentrated under reduced pressure and purified by column chromatography (hexane) to afford the title compound (1.08 g, 39%) as a yellow oil; R_f 0.33 (hexane); ^1H NMR (300 MHz, $CDCl_3$): δ = 7.42 – 7.20 (m, 5H), 6.49 (d, *J* = 15.8 Hz, 1H), 6.32 – 6.13 (m, 1H), 3.63 (t, *J* = 7.0 Hz, 0.5H, C*H*$_2$CH$_2$Cl), 3.48 (t, *J* = 7.0 Hz, 1.5H, C*H*$_2$CH$_2$Br), 2.78 (dt, *J* = 7.0, 1.3 Hz, 3H CH$_2$*Br*), 2.69 (dt, *J* = 7.0, 1.3 Hz, 0.5H CH$_2$*Cl*); ^{13}C NMR (101 MHz, $CDCl_3$): δ = 137.2 (C), 132.8 (CH), 128.7 (2CH), 127.6 (C), 126.8 (C), 126.3 (CH), 36.4 (CH_2), 32.4 (CH_2); IR (neat): ν = 3028, 2966, 1701, 1598, 1495, 1311, 1262, 966, 744, 695. The data matches the literature data.[147]

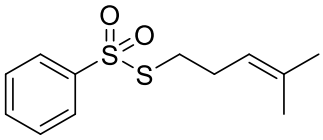
(E)-S-(4-Phenylbut-3-en-1-yl) benzenesulfonothioate (429)



429 was prepared following a literature procedure.[142] To a RBF was added sodium benzenesulfonothioate **358** (981 mg, 5.0 mmol, 1.2 eq.) and the flask was evacuated and refilled with

argon (× 3). Anhydrous DMF (7 mL) was added and the mixture was stirred at rt for 10 minutes. Halide **428** (1.00 g, 4.0 mmol, 1.0 eq.) was added over 5 minutes by syringe and the mixture was stirred at rt for 2.5 days. The mixture was poured into ice/ water (20 mL) and was extracted with Et_2O (6 × 15 mL). The combined organics were washed with $NaHCO_3$ (sat) solution (15 mL), brine (3 × 15 mL), dried over Na_2SO_4, filtered, concentrated under reduced pressure and purified by column chromatography (95:5 hexane:EtOAc) to (9:1 hexane:EtOAc) to afford **429** (930 mg, 76%) as a viscous orange oil; R_f 0.30 (9:1 hexane:EtOAc); ^{1}H NMR (300 MHz, $CDCl_3$): δ = 8.01 – 7.91 (m, 2H), 7.71 – 7.51 (m, 3H), 7.33 – 7.28 (m, 4H), 7.25 – 7.19 (m, 1H), 6.34 (dt, *J* = 15.8, 1.3 Hz, 1H), 6.04 (dt, *J* = 15.8, 7.2 Hz, 1H), 3.15 (t, *J* = 7.2 Hz, 2H), 2.53 (qd, *J* = 7.2, 1.3 Hz, 2H); ^{13}C NMR (101 MHz, $CDCl_3$): δ = 145.0 (C), 136.9 (C), 133.8 (CH), 132.9 (CH), 129.5 (2CH), 128.7 (2CH), 127.7 (2CH), 127.1 (2CH), 126.3 (2CH), 35.8 (CH_2), 32.3 (CH_2); IR (neat): *ν* = 3060, 3026, 2933, 1597, 1581, 1446, 1307, 1320, 1138, 1076, 966, 744, 714, 684, 594; HR-MS (ES-TOF): *m/z*: calcd for $C_{16}H_{16}O_2NaS_2$: 327.0489, found 327.0484 $[M + Na]^+$.

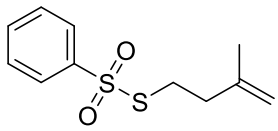
S-(4-Methylpent-3-en-1-yl) benzenesulfonothioate (431)



The homo prenyl bromide **430** was prepared first, following a literature procedure.[148] To a flame dried RBF under argon was added THF (7 mL) and MeMgBr (3M in Et_2O) (6.66 mL, 20 mmol, 1.2 eq.). A condenser was fitted and cyclopropylmethylketone (1.65 mL, 16.7 mmol, 1.0 eq.) in THF (3 mL) was added dropwise. On complete addition, the mixture was heated to reflux and stirred for 20 minutes. On cooling to rt, the solution was added slowly to an ice cooled conical flask containing 15 mL of a 1:2 H_2SO_4: H_2O mixture keeping the temperature below 10 ^oC. On complete addition the mixture was stirred for 30 minutes and the organic layer separated. The aqueous layer was extracted with Et_2O (3 × 10 mL), and the combined organic layers were

washed with $NaHCO_3$, brine, dried over Na_2SO_4, filtered and concentrated. The crude oil **430** was taken forward in the next step (yield taken as quant). **431** was prepared following a literature procedure.[142] To a RBF was added sodium benzenesulfonothioate **358** (3.93 g, 20.0 mmol, 1.2 eq.) and the flask was evacuated and refilled with argon (× 3). Anhydrous DMF (30 mL) was added and the mixture was stirred at rt for 10 minutes. Crude bromide **430** (2.71 g, 16.7 mmol, 1.0 eq.) was added over 5 minutes by syringe and the mixture was stirred for 2.5 days at rt. The mixture was poured into ice/ water (100 mL) and was extracted Et_2O (6 × 30 mL). The combined organic layers were washed with $NaHCO_3$ (sat) solution (30 mL), brine (3 × 30 mL), dried over Na_2SO_4, filtered, concentrated under reduced pressure and purified by column chromatography eluting (97:3 hexane:EtOAc) to afford **431** (1.67 g, 39%) as a colourless oil; R_f 0.45 (9:1 hexane:EtOAc); ^{1}H NMR (300 MHz, $CDCl_3$): δ = 7.97 – 7.91 (m, 2H), 7.68 – 7.59 (m, 1H), 7.59 – 7.51 (m, 2H), 5.02 – 4.93 (m, 1H), 2.99 (t, *J* = 7.4 Hz, 2H), 2.28 (q, *J* = 7.3 Hz, 2H), 1.65 (s, 3H), 1.53 (s, 3H); ^{13}C NMR (101 MHz, $CDCl_3$): δ = 145.1 (C), 135.4 (C), 133.7 (CH), 129.4 (2CH), 127.1 (2CH), 120.7 (CH), 36.3 (CH_2), 27.6 (CH_2), 25.8 (CH_3), 18.0 (CH_3); IR (neat): ν = 3063, 2970, 2933, 2870, 1446, 1303, 1291, 1143, 1084, 723, 688, 583; HR-MS (ES-TOF): *m/z*: calcd for $C_{12}H_{16}O_2S_2$: 256.0592, found 256.0595 [M + H]$^+$

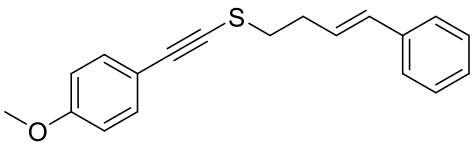
S-(3-Methylbut-3-en-1-yl) benzenesulfonothioate (433)



433 was prepared according to a literature procedure.[149] To a 25 mL RBF under argon was added 3-methyl-3-butene-1-ol (2.53 mL, 25 mmol, 1.0 eq.), CH_2Cl_2 (5 mL) and triphenylphosphine (7.20 g, 27.5 mmol, 1.1 eq.). The mixture was cooled to 0 °C and *N*-bromosuccinimide (4.90 g, 27.5 mmol) was added in 5 portions with vigorous stirring over 15 mins. On complete addition the reaction was stirred for a further 90 minutes. Hexane (20 mL) was added and the mixture was filtered through a pad of

silica, washing with hexane (20 mL). The solvent was removed under reduced pressure providing **432** as a colourless oil (1.76 g, 45%) which was used directly. **433** was prepared following a literature procedure.[142] To a RBF was added sodium benzenesulfonothioate **358** (2.67 g, 13.6 mmol, 1.2 eq) and the flask was evacuated and refilled with argon (× 3). Anhydrous DMF (12 mL) was added and the mixture was stirred at rt. Halide **432** (1.76 g, 11.2 mmol, 1.0 eq.) was added over 5 minutes by syringe and the mixture was stirred for 24 hours. The mixture was poured into ice/ water (50 mL) and was extracted with Et_2O (6 × 25 mL). The combined organic layers were washed with $NaHCO_3$ (sat) solution (25 mL), brine (3 × 25 mL), dried Na_2SO_4, filtered, concentrated under reduced pressure and purified by column chromatography (95:5 hexane:EtOAc) to afford **433** (1.04 g, 39%) as a viscous colourless oil; R_f 0.50 (4:1 hexane:EtOAc); ^{1}H NMR (300 MHz, $CDCl_3$): δ = 8.02 – 7.86 (m, 2H), 7.68 – 7.53 (m, 3H), 4.77 (s, 1H) 4.62 (s, 1H), 3.11 (t, *J* = 7.5 Hz, 2H), 2.30 (t, *J* = 7.5 Hz, 2H), 1.66 (s, 3H); ^{13}C NMR (101 MHz, $CDCl_3$): δ = 144.9 (C), 142.3 (C), 133.8 (CH), 129.4 (CH), 127.1 (2CH), 112.7 (CH_2), 36.6 (CH_2), 34.2 (CH_2), 22.1 (CH_3); IR (neat): ν = 3074, 2972, 2936, 1650, 1447, 1321, 1307, 1138, 1077, 894, 754, 714, 685, 593, 535; HR-MS (ES-TOF): *m/z*: calcd for $C_{11}H_{15}O_2S_2$: 243.0513, found 243.0506 $[M + H]^+$.

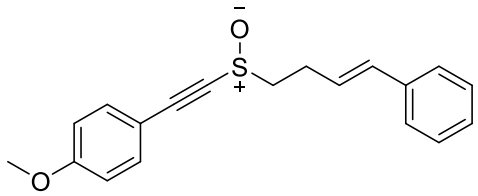
(E)-((4-Methoxyphenyl)ethynyl)(4-phenylbut-3-en-1-yl)sulfane (434)



434 was prepared according to **GP11** using **352** (132 mg, 1.00 mmol), LiHMDS (1 M, 1.00 mL, 1.00 mmol), **429** (277 mg, 0.91 mmol) and THF (5 mL). The reaction time was 20 hours. Aqueous workup and purification by column chromatography (hexane) provided **434** (216 mg, 75%) as a colourless oil; R_f 0.19 (hexane); ^{1}H NMR (300 MHz, $CDCl_3$): δ = 7.32 – 7.08 (m, 8H), 6.77 – 6.70 (m, 2H), 6.41 (d, *J* = 15.8 Hz, 1H), 6.18 (dt, *J* = 15.8, 7.1 Hz, 1H), 3.71 (s, 3H), 2.81 (t, *J* = 7.1 Hz, 2H), 2.67 – 2.56 (m, 2H); ^{13}C NMR (101 MHz,

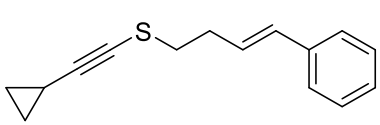
$CDCl_3$): δ = 159.8 (C), 137.4 (C), 133.6 (2CH), 132.1 (CH), 128.7 (2CH), 127.6 (CH), 127.4 (CH), 126.3 (2CH), 115.7 (C), 114.1 (2CH), 93.4 (C), 77.3 (C), 55.5 (CH_3), 35.6 (CH_2), 33.1 (CH_2); IR (neat): *v* = 3025, 2959, 2836, 2156, 1603, 1505, 1246, 1171, 1030, 963, 829, 741, 691; HR-MS (ES-TOF): *m/z*: calcd for $C_{19}H_{19}OS$: 295.1157, found 295.1161 $[M + H]^+$.

(E)-1-Methoxy-4-(((4-phenylbut-3-en-1-yl)sulfinyl)ethynyl)benzene (435)



435 was prepared according to **GP12** using using **434** (200 mg, 0.68 mmol), *m*CPBA (117 mg, 0.68 mmol) and CH_2Cl_2 (7 mL). The reaction time was 2 hours. Aqueous workup and purification by column chromatography (4:1 hexane:EtOAc) provided **435** (157 mg, 74%) as a white solid; R_f 0.37 (2:1 hexane:EtOAc); mp: 50-51 °C ; ^{1}H NMR (300 MHz, $CDCl_3$): δ = 7.47 (d, *J* = 8.9 Hz, 2H), 7.40 – 7.19 (m, 5H), 6.89 (d, *J* = 8.9 Hz, 2H), 6.56 (d, *J* = 15.8 Hz, 1H), 6.26 (dt, *J* = 15.8, 7.0 Hz, 1H), 3.84 (s, 3H), 3.28 (t, J = 7.7 Hz, 2H), 2.99 – 2.76 (m, 2H); ^{13}C NMR (101 MHz, $CDCl_3$): δ = 161.6 (C), 137.0 (C), 134.3 (CH), 132.9 (2CH), 128.7 (2CH), 127.7 (CH), 126.3 (2CH), 126.1 (CH), 114.5 (2CH), 111.7 (C), 103.7 (C), 84.1 (C), 55.7 (CH_3), 55.6 (CH_2), 26.1 (CH_2); IR (neat): *v* = 3052, 2966, 2840, 2159, 1604, 1508, 1264, 1250, 1028, 731, 700; HR-MS (ES-TOF): *m/z*: calcd for $C_{19}H_{18}O_2NaS$: 333.0925, found 333.0929 $[M + Na]^+$.

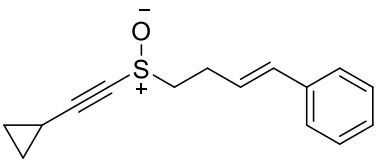
(E)-(Cyclopropylethynyl)(4-phenylbut-3-en-1-yl)sulfone (436)



436 was prepared according to **GP11** using cyclopropylacetylene (168 µl, 2.00 mmol), LiHMDS (1 M, 2.00 mL, 2.00 mmol), **429** (554 mg, 1.82 mmol) and THF (10 mL). The reaction time was 16 hours. Aqueous workup and purification by column chromatography (hexane) provided **436** (308 mg, 74%) as a pale yellow oil; R_f 0.21 (hexane); ^{1}H NMR (300 MHz, $CDCl_3$): δ = 7.42 – 7.27 (m, 4H), 7.25 – 7.18 (m, 1H), 6.48 (d, *J* = 15.8 Hz, 1H), 6.25 (dt, *J* = 15.8, 6.8 Hz, 1H),

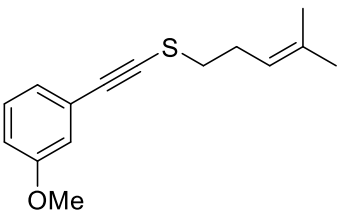
2.78 (dd, *J* = 10.7, 4.1 Hz, 2H), 2.69 – 2.58 (m, 2H), 1.37 (tt, *J* = 8.3, 5.0 Hz, 1H), 0.85 – 0.70 (m, 4H); ^{13}C NMR (101 MHz, $CDCl_3$): δ = 137.4 (C), 131.9 (CH), 128.7 (2CH), 127.7 (CH), 127.4 (CH), 126.2 (2CH), 98.8 (C), 64.0 (C), 35.2 (CH_2), 32.9 (CH_2), 9.1 ($2CH_2$), 0.9 (CH); IR (neat): *v* = 3025, 2924, 2167, 1598, 1493, 1448, 1350, 1268, 1192, 1053, 1028, 987, 963, 839, 810, 740, 691; HR-MS (EI-TOF): *m/z*: calcd for $C_{15}H_{16}S$: 228.0977, found 228.0973 $[M + H]^+$.

(E)-(4-((Cyclopropylethynyl)sulfinyl)but-1-en-1-yl)benzene (437)



437 was prepared according to **GP12** using **436** (280 mg, 1.23 mmol), *m*CPBA (212 mg, 1.23 mmol) and CH_2Cl_2 (12 mL). The reaction time was 2 hours. Aqueous workup and purification by column chromatography (4:1 hexane:EtOAc) provided **437** (208 mg, 69%) as a colourless oil; R_f 0.37 (2:1 hexane:EtOAc); ^{1}H NMR (300 MHz, $CDCl_3$): δ = 7.39 – 7.18 (m, 5H), 6.52 (d, *J* = 15.8 Hz, 1H), 6.21 (dt, *J* = 15.8, 7.0 Hz, 1H), 3.14 (t, *J* = 7.6 Hz, 2H), 2.89 – 2.66 (m, 2H), 1.51 – 1.41 (m, 1H), 1.03 – 0.85 (m, 4H); ^{13}C NMR (101 MHz, $CDCl_3$): δ = 137.0 (C), 132.7 (CH), 128.7 (2CH), 127.6 (CH), 126.2 (2CH), 126.1 (CH), 109.8 (C), 72.0 (C), 55.8 (CH_2), 26.0 (CH_2), 9.7 (CH), 0.3 ($2CH_2$); IR (neat): *v* = 3025, 2179, 1598, 1493, 1444, 1059, 967, 829, 745, 694; HR-MS (ES-TOF): *m/z*: calcd for $C_{15}H_{17}OS$: 245.1000, found 245.1004 $[M + H]^+$.

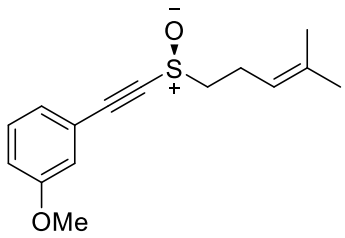
((3-Methoxyphenyl)ethynyl)(4-methylpent-3-en-1-yl)sulfane (438)



438 was prepared according to **GP11** using 3-methoxybenzene (330 mg, 2.50 mmol), LiHMDS (1 M 2.50 mL, 2.50 mmol), **431** (581 mg, 2.27 mmol) and THF (13 mL). The reaction time was 16 hours. Aqueous workup and purification by column chromatography (hexane) provided **438** (388 mg, 60%) as a colourless oil; R_f 0.23 (hexane); ^{1}H NMR (300 MHz, $CDCl_3$): δ = 7.20 (t, *J* = 7.9 Hz, 1H), 7.03 – 6.98 (m, 1H), 6.93 (dd, *J* =

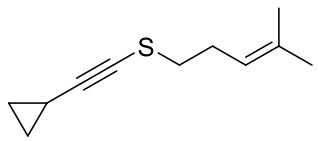
2.5, 1.4 Hz, 1H), 6.85 (ddd, *J* = 8.3, 2.6, 1.0 Hz, 1H), 5.23 – 5.14 (m, 1H), 3.79 (s, 3H), 2.79 (t, *J* = 7.4 Hz, 2H), 2.49 (q, *J* = 7.3 Hz, 2H), 1.73 (s, 3H), 1.67 (s, 3H); IR (neat): ν = 2925, 2854, 2162, 1594, 1574, 1479, 1284, 1157, 1040, 776, 685; HR-MS (ES-TOF): *m/z*: calcd for $C_{15}H_{18}OS$: 246.1078, found 246.1075 $[M + H]^+$. (No 13C NMR obtained!)

1-Methoxy-3-(((4-methylpent-3-en-1-yl)sulfinyl)ethynyl)benzene (439)



439 was prepared according to **GP12** using **438** (246 mg, 1.00 mmol), *m*CPBA (173 mg, 1.00 mmol) and CH_2Cl_2 (10 mL). The reaction time was 2 hours. Aqueous workup and purification by column chromatography (4:1 hexane:EtOAc) provided **439** (139 mg, 53%) as a pale yellow oil; R_f 0.15 (4:1 hexane:EtOAc); ^{1}H NMR (300 MHz, $CDCl_3$): δ = 7.25 – 7.19 (m, 1H), 7.07 (d, *J* = 7.6 Hz, 1H), 7.00 – 6.97 (m, 1H), 6.97 – 6.91 (m, 1H), 5.20 – 5.09 (m, 1H), 3.76 (s, 3H), 3.19 – 3.03 (m, 2H), 2.70 – 2.46 (m, 2H), 1.68 (s, 3H), 1.63 (s, 3H); ^{13}C NMR (101 MHz, $CDCl_3$): δ = 159.6 (C), 135.5 (C), 129.9 (CH), 124.8 (CH), 120.9 (C), 120.1 (CH), 117.4 (CH), 116.9 (CH), 102.3 (C), 85.1 (C), 56.4 (CH_2), 55.5 (CH_3), 25.9 (CH_3), 21.5 (CH_2), 18.0 (CH_3); IR (neat): ν = 2966, 2928, 2836, 2162, 1670, 1595, 1580, 1464, 1286, 1268, 1037, 786; HR-MS $(EI)^+$: *m/z*: calcd for $C_{15}H_{18}O_2S$: 262.1022, found 262.1028 $[M + H]^+$.

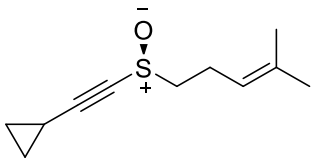
Cyclopropylethynyl)(4-methylpent-3-en-1-yl)sulfane (440)



440 was prepared according to **GP11** using cyclopropylacetylene (126 µl, 1.50 mmol), LiHMDS (1 M, 1.50 mL, 1.50 mmol), **431** (349 mg, 1.36 mmol) and THF (8 mL). The reaction time was 4 hours. Aqueous workup and purification by column chromatography (hexane) provided **440** (166 mg, 68%) as a colourless oil; R_f 0.82 (4:1 hexane:EtOAc); ^{1}H NMR (400 MHz, $CDCl_3$): δ = 5.17 – 5.11 (m, 1H), 2.62 (t, *J* = 7.4 Hz, 2H), 2.39 (q, *J* = 7.3 Hz, 2H), 1.71 (s, 3H), 1.64 (s, 3H), 1.34 (tt, *J* = 8.1, 5.0 Hz, 1H), 0.82 – 0.68 (m, 4H); ^{13}C NMR (101 MHz, $CDCl_3$): δ = 134.2 (C), 121.8 (CH), 98.4 (C),

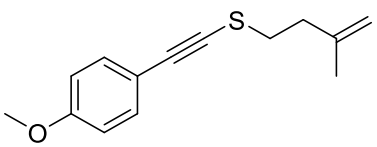
64.3 (C), 35.7 (CH_2), 28.1 (CH_2), 25.9 (CH_3), 18.0 (CH_3), 9.0 (CH_2), 0.9 (CH); IR (neat): ν = 3094, 3012, 2967, 2917, 2857, 1449, 1377, 1027, 988, 839, 811; HR-MS (EI-TOF): *m/z*: calcd for $C_{11}H_{16}S$: 180.0973 found 180.0966 $[M + H]^+$.

(((4-Methylpent-3-en-1-yl)sulfinyl)ethynyl)cyclopropane (441)



441 was prepared according to **GP12** using **440** (140 mg, 0.78 mmol), *m*CPBA (134 mg, 0.78 mmol) and CH_2Cl_2 (8 mL). The reaction time was 2 hours. Aqueous workup and purification by column chromatography (4:1 hexane:EtOAc) provided **441** (107 mg, 70%) as a colourless oil; R_f 0.14 (4:1 hexane:EtOAc); ^{1}H NMR (300 MHz, $CDCl_3$): δ = 5.14 (tdt, *J* = 7.2, 2.7, 1.3 Hz, 1H), 3.09 – 2.91 (m, 2H), 2.66 – 2.38 (m, 2H), 1.71 (s, 3H), 1.65 (s, 3H), 1.53 – 1.37 (m, 1H), 1.03 – 0.84 (m, 4H); ^{13}C NMR (101 MHz, $CDCl_3$): δ = 135.2 (C), 120.2 (CH), 109.2 (C), 72.3 (C), 56.5 (CH_2), 25.8 (CH_3), 21.4 (CH_2), 17.9 (CH_3), 9.6 (CH_2), 0.31 (CH); IR (neat): ν = 2969, 2915, 2179, 2161, 1450, 1056, 829, 781, 579; HR-MS (ES-TOF): *m/z*: calcd for $C_{19}H_{18}O_2NaS$: 333.0920, found 333.0925 $[M + Na]^+$.

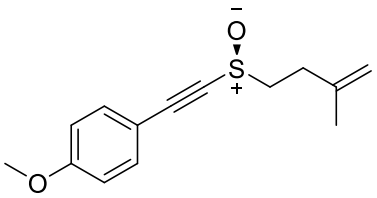
((4-Methoxyphenyl)ethynyl)(3-methylbut-3-en-1-yl)sulfane (442)



442 was prepared according to **GP11** using **353** (145 mg, 1.10 mmol), LiHMDS 1M (1.10 mL, 1.10 mmol), **433** (238 mg, 1.00 mmol) and THF (6 mL). The reaction time was 20 hours. Aqueous workup and purification by column chromatography (98:2 hexane:EtOAc) provided **442** (187 mg, 81%) as a colourless oil; R_f 0.40 (hexane); ^{1}H NMR (300 MHz, $CDCl_3$): δ = 7.41 – 7.34 (m, 2H), 6.87 – 6.79 (m, 2H), 4.86 – 4.77 (m, 2H), 3.81 (s, 3H), 2.94 – 2.86 (m, 2H), 2.50 (t, *J* = 7.6 Hz, 2H), 1.77 (s, 3H); ^{13}C NMR (101 MHz, $CDCl_3$): δ = 159.7 (C), 143.3 (C), 133.5 (2CH), 115.7 (2CH), 114.0 (C), 112.1 (CH_2), 93.2 (C), 55.4 (CH_3), 37.5 (CH_2), 34.0 (CH_2), 22.4 (CH_3); IR (neat): ν = 3075, 2966, 2933, 2836, 2167, 1650, 1604, 1569, 1505, 1441,

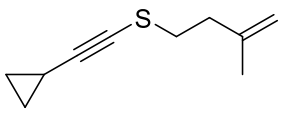
1289, 1246, 1171, 1031, 891, 829, 777; HR-MS (EI-TOF): *m/z*: calcd for $C_{14}H_{16}OS$: 232.0922 found 232.0909 $[M + H]^+$.

1-Methoxy-4-(((3-methylbut-3-en-1-yl)sulfinyl)ethynyl)benzene (443)



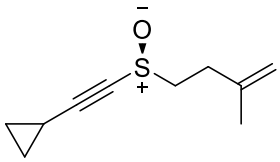
443 was prepared according to **GP12** using **442** (166 mg, 0.71 mmol), *m*CPBA (123 mg, 0.71 mmol) and CH_2Cl_2 (7 mL). The reaction time was 2 hours. Aqueous workup and purification by column chromatography (4:1 hexane:EtOAc) provided **443** (134 mg, 75%) as a colourless oil; R_f 0.33 (7:3 hexane:EtOAc); ^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.52 – 7.44 (m, 2H), 6.92 – 6.86 (m, 2H), 4.85 (d, *J* = 13.9 Hz, 2H), 3.83 (s, 3H), 3.25 (t, *J* = 7.9 Hz, 2H), 2.76 – 2.50 (m, 2H), 1.81 (s, 3H); ^{13}C NMR (101 MHz, $CDCl_3$): δ = 161.6 (C), 142.2 (C), 134.3 (2CH), 114.4 (2CH), 112.4 (CH_2), 111.7 (C), 103.4 (C), 84.1 (C), 55.5 (CH_3), 54.6 (CH_2), 30.3 (CH_2), 22.6 (CH_3).

(Cyclopropylethynyl)(3-methylbut-3-en-1-yl)sulfone (417)



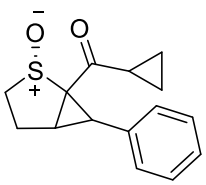
417 was prepared according to **GP11** using cyclopropylacetylene (176 µl, 2.00 mmol), LiHMDS 1M (2.00 mL, 2.00 mmol), **406** (433 mg, 2.00 mmol) and THF (10 mL). The reaction time was 17 hours. Aqueous workup and purification by column chromatography (hexane) provided **417** (253 mg, 84%) as a colourless oil; R_f 0.32 (hexane); ^{1}H NMR (300 MHz, $CDCl_3$): δ = 4.78 (d, *J* = 16.2 Hz, 2H), 2.85 – 2.71 (m, 2H), 2.41 (t, *J* = 7.6 Hz, 2H), 1.75 (s, 3H), 1.40 – 1.29 (m, 1H), 0.87 – 0.65 (m, 4H); ^{13}C NMR (101 MHz, $CDCl_3$): δ = 142.3 (C), 112.3 (CH_2), 109.4 (C), 72.1 (C), 54.6 (CH_2), 30.2 (CH_2), 22.6 (CH_3), 9.7 (CH), 0.32 ($2CH_2$); IR (neat): *v* = 3078, 3013, 2969, 2935, 1650, 1445, 1375, 1350, 1028, 989, 890, 839, 811; HR-MS (ES-TOF): *m/z*: calcd for $C_{10}H_{14}S$: 166.0816, found 166.0817 $[M + H]^+$.

(((3-Methylbut-3-en-1-yl)sulfinyl)ethynyl)cyclopropane (445)



445 was prepared according to **GP12** using **444** (151 mg, 0.91 mmol), *m*CPBA (157 mg, 0.91 mmol) and CH_2Cl_2 (9 mL). The reaction time was 2 hours. Aqueous workup and purification by column chromatography (4:1 hexane:EtOAc) provided **445** (125 mg, 76%) as a colourless oil; R_f 0.17 (4:1 hexane:EtOAc); ^{1}H NMR (400 MHz, $CDCl_3$): δ = 4.82 (d, *J* = 20.4 Hz, 2H), 3.16 – 3.06 (m, 2H), 2.66 – 2.44 (m, 2H), 1.78 (s, 3H), 1.51 - 1.42 (m, 1H), 1.04 – 0.86 (m, 4H); ^{13}C NMR (101 MHz, $CDCl_3$): δ = 142.3 (C), 112.2 (CH_2), 109.4 (C), 72.1 (C), 54.6 (CH_2), 30.2 (CH_2), 22.6 (CH_3), 9.7 (CH), 0.3 ($2CH_2$); IR (neat): *ν* = 3080, 2971, 2919, 2179, 1650, 1446, 1057, 890, 828, 781; IR (neat): ν = 3029, 2914, 1753, 1640, 1603, 1389, 1211, 1132, 1044, 999, 915, 701; HR-MS (ES-TOF): *m/z*: calcd for $C_{10}H_{15}OS$: 183.0839, found 183.0844 $[M + H]^+$.

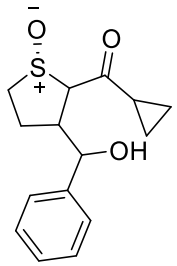
Cyclopropyl(2-oxido-6-phenyl-2-thiabicyclo[3.1.0]hexan-1-yl)methanone (446)



Prepared according to **GP14** using sulfoxide **437** (97.7 mg, 0.40 mmol), 3,5 dichloropyridine-*N*-oxide (78.6 mg, 0.48 mmol), $SPhosAuNTf_2$ (17.6 mg, 5 mol%) and dioxane (8 mL). The reaction time was 3 hours. Purification by column chromatography (1:1 hexane:EtOAc) to (2:1 hexane:EtOAc) afforded **446** (41.6 mg, 40%) as a white solid, stereochemistry is undefined; R_f 0.38 (EtOAc); mp: 107-108 ^{o}C; ^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.35 – 7.22 (m, 5H), 3.77 (d, *J* = 6.8 Hz, 1H), 3.58 (dt, *J* = 13.1, 5.8 Hz, 1H), 3.17 (dt, *J* = 6.8, 3.3 Hz, 1H), 2.83 – 2.70 (m, 1H), 2.61 – 2.50 (m, 2H), 2.39 – 2.28 (m, 1H), 1.07 – 0.94 (m, 1H), 0.92 – 0.83 (m, 1H), 0.82 – 0.71 (m, 1H), 0.67 – 0.58 (m, 1H); ^{13}C NMR (101 MHz, $CDCl_3$): δ = 201.1 (C), 133.3 (C), 129.2 (2CH), 128.4 (CH), 127.7 (2CH), 68.3 (C), 53.6 (CH_2), 35.4 (CH), 33.9 (CH), 27.1 (CH_2), 21.3 (CH), 12.6 (CH_2), 12.2 (CH_2); IR (neat): *ν* = 2983, 2941, 2871, 1659, 1601, 1497, 1447, 1396, 1249, 1218, 1058, 1032, 968, 896,

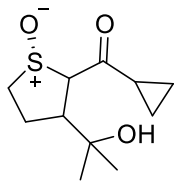
747, 702; HR-MS (ES-TOF): *m/z*: calcd for $C_{15}H_{16}O_2NaS$: 283.0769, found 283.0775 [M + Na]$^+$.

Cyclopropyl(3-(hydroxy(phenyl)methyl)-1-oxidotetrahydrothiophen-2-yl)methanone (447)



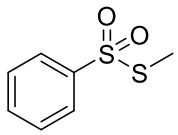
Prepared from the same reaction eluting with (EtOAc) yielding **422** (24.5 mg, 22%); mp: 94-95 ^{o}C; ^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.37 (dt, *J* = 15.1, 7.4 Hz, 4H), 7.27 (t, *J* = 6.3 Hz, 1H), 4.86 (t, *J* = 5.1 Hz, 1H), 4.24 (dd, *J* = 4.7, 1.5 Hz, 1H), 3.74 (d, *J* = 4.7 Hz, 1H), 3.22 – 3.05 (m, 2H), 2.78 – 2.60 (m, 2H), 2.44 – 2.29 (m, 1H), 1.69 (ddd, *J* = 12.4, 7.8, 4.6 Hz, 1H), 1.00 – 0.80 (m, 4H); ^{13}C NMR (101 MHz, $CDCl_3$): δ = 205.4 (C), 143.7 (C), 128.8 (2CH), 127.9 (CH), 126.0 (2CH), 80.0 (CH), 74.8 (CH), 53.1 (CH_2), 52.2 (CH), 29.6 (CH_2), 21.3 (CH), 12.4 (CH_2), 12.3 (CH_2); IR (neat): *v* = 3314, 3063, 3011, 2935, 1677, 1604, 1380, 1063, 1028, 1041, 998, 760, 703; HR-MS (ES-TOF): *m/z*: calcd for $C_{15}H_{18}O_3SNa$: 301.0874, found 301.0878 [M + Na]$^+$.

Cyclopropyl(3-(2-hydroxypropan-2-yl)-1-oxidotetrahydrothiophen-2-yl)methanone (453)



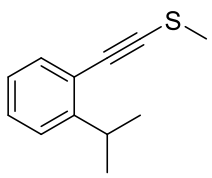
Prepared according to **GP14** using sulfoxide **441** (78.5 mg, 0.40 mmol), 3,5 dichloropyridine-*N*-oxide (78.6 mg, 0.48 mmol), $SPhosAuNTf_2$ (17.6 mg, 5 mol%) and dioxane (8 mL). The reaction time was 24 hours. Purification by column chromatography (EtOAc) afforded **453** (35.0 mg, 38%) as a white solid; R_f 0.17 (EtOAc); mp: 96-98 ^{o}C; ^{1}H NMR (400 MHz, $CDCl_3$): δ = 4.34 (dd, *J* = 6.1, 1.6 Hz, 1H), 3.17 – 3.09 (m, 1H), 2.87 (dt, *J* = 10.4, 6.4 Hz, 1H), 2.72 – 2.60 (m, 1H), 2.57 (t, *J* = 6.2 Hz, 2H), 2.47 – 2.39 (m, 1H), 2.30 (tt, *J* = 7.7, 4.6 Hz, 1H), 1.30 (s, 3H), 1.25 (s, 3H), 1.18 – 1.06 (m, 4H); ^{13}C NMR (101 MHz, $CDCl_3$): δ = 205.2 (C), 81.4 (CH), 70.3 (C), 53.8 (CH), 53.0 (CH_2), 30.5 (CH_3), 28.3 (CH_2), 27.6 (CH_3), 22.2 (CH), 12.8 (CH_2), 12.6 (CH_2); IR (neat): *v* = 3372, 2968, 2926, 1678, 1452, 1380, 1040, 1001, 955, 909; HR-MS (ES-TOF): *m/z*: calcd for $C_{11}H_{19}O_3S$: 231.1055, found 231.1047 [M + H]$^+$.

S-methyl benzenesulfonothioate (457)



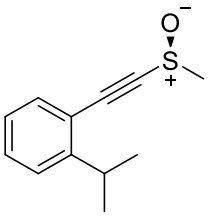
457 was prepared according to a literature procedure.[191] To RBF was added benzenethiosulfonate **358** (4.00 g, 20.0 mmol, 1.2 eq.) and anhydrous DMF (20 mL). After stirring at rt for 10 minutes methyl iodide (1.04 mL, 16.7 mmol, 1.0 eq.) was added dropwise and the reaction mixture was stirred at rt for 3 days. The mixture was then poured in to H_2O (100 mL) and extracted with Et_2O (6 × 30 mL). The combined organics were washed with $NaHCO_3$ (30 mL of a saturated solution), brine (3 × 30 mL), dried over Na_2SO_4, filtered, concentrated under reduced pressure and purified by column chromatography (19:1 hexane:EtOAc) to (9:1 hexane:EtOAc) yielding the title compound (2.62 g, 85%) as a colourless oil; R_f 0.25 (9:1 hexane:EtOAc); ^{1}H NMR (300 MHz, $CDCl_3$): δ = 7.97 – 7.90 (m, 2H), 7.70 – 7.62 (m, 1H), 7.61 – 7.52 (m, 2H), 2.51 (s, 3H); IR (neat): *v* = 3065, 1582, 1447, 1328, 1305, 1138, 1076, 754, 714, 684. Data is in agreement with literature values.[191]

((2-Isopropylphenyl)ethynyl)(methyl)sulfane (458)



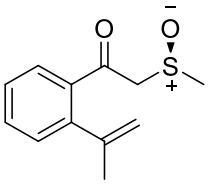
458 was prepared according to **GP11** using sulfinate (144 mg, 1.00 mmol), LiHMDS (1 M, 1.00 mL, 1.00 mmol), **457** (167 mg, 0.91 mmol) and THF (5 mL). The reaction time was 16 hours. Aqueous workup and purification by column chromatography (hexane) provided **458** (82 mg, 50%) as a colourless oil; R_f 0.47 (hexane); ^{1}H NMR (300 MHz, $CDCl_3$): δ = 7.30 – 7.25 (m, 1H), 7.15 (dd, *J* = 2.6, 1.1 Hz, 1H), 7.14 (d, *J* = 1.0 Hz, 1H), 7.00 (ddd, *J* = 7.7, 5.3, 3.4 Hz, 1H), 3.30 (dt, *J* = 13.8, 6.9 Hz, 1H), 2.38 (s, 3H), 1.15 (d, *J* = 6.9 Hz, 6H); ^{13}C NMR (101 MHz, $CDCl_3$): δ = 150.4 (C), 132.2 (CH), 128.4 (CH), 125.5 (CH), 124.9 (CH), 122.2 (C), 90.7 (C), 84.1 (C), 31.6 (CH), 23.1 ($2CH_3$), 19.6 (CH_3); IR (neat): *v* = 3062, 2961, 2927, 2868, 2164, 1596, 1481, 1444, 1312, 1082, 976, 754; HR-MS (EI-TOF): *m/z*: calcd for $C_{12}H_{14}S$: 245.1000, found 245.1004 $[M + H]^+$.

1-Isopropyl-2-((methylsulfinyl)ethynyl)benzene (459)



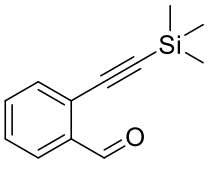
459 was prepared according to **GP12** from **458** (74.1 mg, 0.39 mmol), *m*CPBA (67.3 mg, 0.39 mmol) and CH_2Cl_2 (4 mL). The reaction time was 2 hours. Aqueous workup and purification by column chromatography (4:1 hexane: EtOAc) provided **459** (60.3 mg, 75%) as a colourless oil; The product was used directly in the catalysis.

2-(Methylsulfinyl)-1-(2-(prop-1-en-2-yl)phenyl)ethan-1-one (462)



462 was prepared according to **GP13** using **459** (41.2 mg, 0.20 mmol), 3,5-dichloropyridine-*N*-oxide (39.4 mg, 0.24 mmol), $SPhosAuNTf_2$ (4.4 mg, 2.5 mol%) and 1,4-dioxane (4 mL). The reaction time was 24 hours. Purification by column chromatography (7:3 hexane:EtOAc) afforded **462** (9.0 mg, 22%) as an off white solid; R_f 0.11 (1:1 hexane:EtOAc); mp: 104-106 ^oC; ^1H NMR (300 MHz, $CDCl_3$): δ = 7.51 (ddd, *J* = 15.2, 7.6, 1.3 Hz, 2H), 7.42 – 7.30 (m, 2H), 5.29 – 5.26 (m, 1H), 4.90 (d, *J* = 0.5 Hz, 1H), 4.33 (d, *J* = 14.3 Hz, 1H), 4.14 (d, *J* = 14.4 Hz, 1H), 2.76 (s, 3H), 2.18 (dd, *J* = 1.3, 0.9 Hz, 3H); ^{13}C NMR (101 MHz, $CDCl_3$); δ = 197.2 (C), 144.8 (C), 143.2 (C), 137.9 (C), 132.2 (CH), 128.8 (CH), 128.7 (CH), 127.9 (CH), 118.2 (CH_2), 65.4 (CH_2), 40.0 (CH_3), 24.0 (CH_2); IR (neat): ν = 2916, 1679, 1594, 1288, 1039, 770; HR-MS (ES-TOF): *m/z*: calcd for $C_{12}H_{14}O_2S$: 222.0715, found 222.0713 $[M + H]^+$.

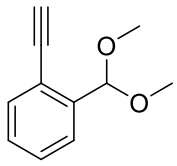
2-((Trimethylsilyl)ethynyl)benzaldehyde (464)



464 was prepared according to a modified literature procedure.[152] To an argon dried flask was added Et_3N (17 mL) and 2-bromobenzaldehyde (1.67 g, 9.0 mmol, 1.0 eq.). The flask was degassed for 10 minutes before the addition of $Pd(PPh_3)_2Cl_2$ (121 mg, 0.18 mmol, 2 mol%) and CuI (55 mg, 0.36 mmol, 4 mol%). TMS acetylene (1.49 mL, 10.8 mmol, 1.2 eq.) was added dropwise over 40 minutes and the

reaction was stirred at rt for 22 hours. Additional $Pd(PPh_3)_2Cl_2$ (30 mg, 0.045 mmol, 0.5 mol%) and CuI (14 mg, 0.09 mmol, 1 mol%) was added and the reaction was stirred for a further 2 hours. The reaction mixture was filtered through celite, and the filtrate concentrated under reduced pressure. Column chromatography (hexane) to (96:4 hexane:EtOAc) afforded the title compound as a yellow solid (1.55 g, 85%); R_f 0.87 (9:1 hexane:EtOAc); mp: 46-48 ^oC; ^1H NMR (300 MHz, $CDCl_3$): δ = 10.56 (d, *J* = 0.8 Hz, 1H), 7.93 – 7.89 (m, 1H), 7.60 – 7.51 (m, 2H), 7.47 – 7.40 (m, 1H), 0.28 (s, 9H), IR (neat): *ν* = 2958, 2900, 2763, 2152, 1694, 1593, 1474, 1246, 1217, 863, 842, 757, 653. Data matches that reported in the literature.[152]

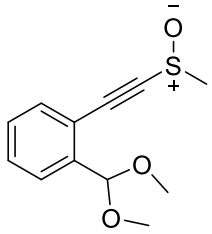
1-(Dimethoxymethyl)-2-ethynylbenzene (465)



465 was prepared according to a literature procedure.[153] To a methanol (16.4 mL) solution of **464** (1.66 g, 8.2 mmol) and $HC(OMe)_3$ (8.30 g, 82 mmol) was added *p*-TSA (0.14 g, 0.82 mmol). The reaction was stirred for 1 h before it was quenched with $NaHCO_3$ solution (10 mL), and extracted with EtOAc (3 × 10 mL). The combined organic layers were washed with brine, dried over Na_2SO_4 and concentrated under reduced pressure. The crude residue was dissolved in dichloromethane (10 mL)/methanol (20 mL), and added with potassium carbonate (1.13 g, 8.2 mmol). Upon completion, the reaction was quenched by water and extracted with dichloromethane. The combined organic layers were dried over Na_2SO_4 and concentrated under reduced pressure. The crude residue was then purified by column chromatography to afford **465** (1.20 g, 83%) as a colourless oil; ^1H NMR (300 MHz, $CDCl_3$): δ = 7.60 (dd, *J* = 7.6, 1.4 Hz, 1H), 7.52 (dd, *J* = 7.6, 1.4 Hz, 1H), 7.38 (td, *J* = 7.6, 1.4 Hz, 1H), 7.30 (td, *J* = 7.6, 1.4 Hz, 1H), 5.72 (s, 1H), 3.39 (s, 6H), 3.33 (s, 1H); ^{13}C NMR (101 MHz, $CDCl_3$): δ =140.3 (C), 133.1 (CH), 128.9 (CH), 128.5 (CH), 126.4 (CH), 121.1 (C), 102.1 (CH), 81.9 (CH), 81.3 (C), 53.97 ($2CH_3$); IR (neat): ν = 2992, 2906, 2830,

1464, 1448, 1367, 1211, 1114, 1084, 1070, 1050, 978, 909, 760, 649. Data is in agreement with literature values.[153]

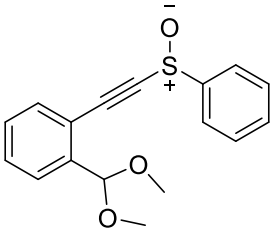
1-(Dimethoxymethyl)-2-((methylsulfinyl)ethynyl)benzene (467)



467 was prepared according to a literature procedure over 2 steps.[27] Alkyne **465** (468 mg, 2.66 mmol 1.1 eq.) was added to a flame dried 2 neck RBF under argon. THF (14 mL) was added and the reaction mixture was cooled to -78 °C. LiHMDS (1M) (2.66 mL, 2.66 mmol, 1.1 eq.) was added dropwise and the mixture was stirred for a further hour at -78 °C. Methyl thionosulfonate **457** was added (443 mg, 2.41 mmol, 1.0 eq.) and the reaction allowed to warm to rt and stirred for 4 hours. NH_4Cl (10 mL) was added and the mixture was extracted with Et_2O (3 × 10 mL), the organics washed with brine (10 mL), dried over Na_2SO_4, filtered, concentrated under reduced pressure and purified by column chromatography (hexane) affording the crude sulfide **466** 476 mg (~80% pure). The sulfide (278 mg, 1.00 mmol) was dissolved in CH_2Cl_2 (10 mL), the mixture was cooled to 0 °C and *m*CPBA (173 mg, 1.00 mmol) was added in 5 portions over 10 minutes. The mixture was allowed to warm to rt and was stirred for 2 hours. The reaction mixture was washed $NaHCO_3$ (sat.) (3 × 10 mL) and the aqueous layers were extracted with CH_2Cl_2 (3 × 5 mL). The organic layers were dried Na_2SO_4, filtered, concentrated under reduced pressure and purified by column chromatography (EtOAc) providing the title compound (195 mg, 53% over 2 steps) as a yellow oil; R_f 0.68 (EtOAc); ^{1}H NMR (300 MHz, $CDCl_3$): δ = 7.64 (dd, *J* = 7.8, 0.5 Hz, 1H), 7.55 (d, *J* = 6.5 Hz, 1H), 7.47 (dd, *J* = 11.0, 4.2 Hz, 1H), 7.35 (td, *J* = 7.5, 1.0 Hz, 1H), 5.59 (s, 1H), 3.38 (s, 6H), 3.08 (s, 3H); ^{13}C NMR (101 MHz, $CDCl_3$): δ = 141.0 (C), 133.3 (CH), 130.7 (CH), 128.7 (CH), 126.7 (CH), 118.5 (C), 101.9 (CH), 99.1 (C), 90.7 (C), 54.2 (CH_3), 43.6 ($2CH_3$); IR (neat): *v* = 2935, 2830, 2163, 1671, 1447, 1351, 1198, 1116, 1048, 979,

959, 763; HR-MS (ES-TOF): *m/z*: calcd for $C_{12}H_{14}O_3NaS$: 261.0561, found 261.0552 [M + Na]$^+$.

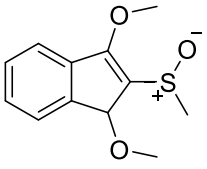
1-(Dimethoxymethyl)-2-((phenylsulfinyl)ethynyl)benzene (469)



469 was prepared over 2 steps. Alkyne **466** (468 mg, 2.66 mmol 1.1 eq.) was added to a flame dried 2 neck RBF under argon. THF (14 mL) was added and the reaction mixture was cooled to -78 ^{o}C. LiHMDS (1M) (2.66 mL, 2.66 mmol) was added dropwise and the mixture was stirred for a further hour at -78 ^{o}C. Phenyl thionosulfonate (607 mg, 2.41 mmol, 1.0 eq.) was added and the reaction allowed to warm to rt and stirred for 4 hours. NH_4Cl (10 mL) was added and the mixture was extracted with Et_2O (3 × 10 mL), the organics were washed with brine (10 mL), dried Na_2SO_4, filtered, concentrated under reduced pressure and purified by column chromatography (hexane) affording the crude sulfide **468** 446 mg (~75% pure). The sulfide (284 mg, 1.00 mmol) was dissolved in CH_2Cl_2 (12 mL), the mixture was cooled to 0 ^{o}C and *m*CPBA (173 mg, 1.00 mmol) was added in 5 portions over 10 minutes. The mixture was allowed to warm to rt and was stirred for 2 hours. The reaction mixture was washed with $NaHCO_3$ (sat.) (3 × 10 mL) and the aqueous layers were extracted with CH_2Cl_2 (3 × 5 mL). The organic layers were dried over Na_2SO_4, filtered, concentrated under reduced pressure and purified by column chromatography (4:1 hexane:EtOAc) providing the title compound (246 mg, 36% over 2 steps) as a viscous yellow oil; R_f 0.30 (4:1 hexane:EtOAc); ^{1}H NMR (300 MHz, $CDCl_3$): δ = 7.98 – 7.86 (m, 2H), 7.65 – 7.51 (m, 5H), 7.45 (td, *J* = 7.7, 1.3 Hz, 1H), 7.33 (td, *J* = 7.6, 1.3 Hz, 1H), 5.46 (s, 1H), 3.33 (s, 3H), 3.29 (s, 3H); ^{13}C NMR (101 MHz, $CDCl_3$): δ = 144.1 (C), 141.3 (C), 133.3 (CH), 131.9 (CH), 130.8 (CH), 129.7 (2CH), 128.7 (CH), 126.6 (CH), 125.2 (2CH), 118.6 (C), 102.2 (CH), 99.9 (C), 90.6 (C), 54.4 (CH_3), 54.3 (CH_3); IR (neat): *ν* = 3061, 2934, 2829, 2162, 1724, 1678, 1578, 1476, 1444, 1196, 1084, 1070, 1049,

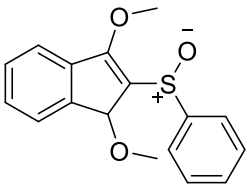
747, 686; HR-MS (ES-TOF): *m/z*: calcd for $C_{17}H_{16}O_3NaS$: 323.0718, found 323.0706 $[M + Na]^+$.

1,3-Dimethoxy-2-(methylsulfinyl)-1H-indene (471)



A Radleys tube under argon was charged with 3,5-dichloropyridine-*N*-oxide (39.4 mg, 0.24 mmol, 1.2 eq.) and alkynyl sulfoxide **467** (47.6 mg, 0.20 mmol, 1.0 eq.) as a 0.2 M solution in 1,4-dioxane. The mixture was transferred to an oil bath at 50 °C and SPhosAuNTf$_2$ (8.8 mg, 5 mol%) was added followed by 1,4-dioxane (3 mL). The reaction was stirred for 16 hours, allowed to cool and the mixture was filtered through a pad of silica, washing with EtOAc, concentrated and purified by column chromatography (1:1 hexane:EtOAc to EtOAc) yielding the title compound (45.2 mg, 95%) as a colourless oil as a 2.7:1 inseparable mixture of diastereomers; R_f 0.16 (EtOAc) Major diastereomer; ^{1}H NMR (300 MHz, $CDCl_3$): δ = 7.52 – 7.33 (m, 4H), 5.70 (s, 1H), 4.42 (s, 3H), 3.16 (s, 3H), 3.05 (s, 3H); ^{13}C NMR (101 MHz, $CDCl_3$): δ = 163.4 (C), 141.4 (C), 137.6 (C), 129.8 (CH), 129.1 (CH), 123.9 (CH), 120.9 (CH), 112.2 (C), 80.8 (CH), 61.4 (CH_3), 51.3 (CH_3), 37.1 (CH_3); Minor diastereomer; ^{1}H NMR (300 MHz, $CDCl_3$): δ = 7.53 – 7.32 (m, 4H), 5.92 (s, 1H), 4.25 (s, 3H), 3.24 (s, 3H), 3.02 (s, 3H); ^{13}C NMR (101 MHz, $CDCl_3$): δ = 162.3 (C), 142.1 (C), 137.5 (C), 129.6 (CH), 129.0 (CH), 124.1 (CH), 120.8 (CH), 112.6 (C), 78.6 (CH), 61.5 (CH_3), 53.0 (CH_3), 37.9 (CH_3); IR (neat): *ν* = 3260, 3017, 2989, 2827, 1613, 1600, 1563, 1434, 1066, 977, 943, 739; HR-MS (ES-TOF): *m/z*: calcd for $C_{12}H_{14}O_3NaS$: 261.0561, found 261.0556 $[M + Na]^+$.

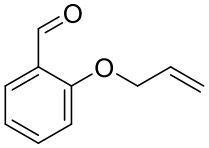
1,3-Dimethoxy-2-(phenylsulfinyl)-1H-indene (472)



A Radleys tube under argon was charged with 3,5 dichloropyridine-*N*-oxide (39.4 mg, 0.24 mmol, 1.2 equiv) and alkynyl sulfoxide **469** (60.8 mg, 0.20 mmol, 1.0 eq.) as a 0.2 M solution in 1,4-dioxane. The mixture

was transferred to an oil bath at 50 ºC and SPhosAuNTf$_2$ (8.8 mg, 5 mol%) was added followed by 1,4-dioxane (3 mL). The reaction was stirred at 50 ºC for 16 hours, allowed to cool and the mixture was filtered through a pad of silica, washing with EtOAc, concentrated and purified by column chromatography (1:9 hexane:EtOAc) to (2:8 hexane:EtOAc) yielding the title compound (48.5 mg, 80%) as a pale yellow oil as a 3.2:1 inseparable mixture of diastereomers; R_f 0.75 (EtOAc); mp: 104-106 ºC; Major diastereomer; ^{1}H NMR (300 MHz, $CDCl_3$): δ = 7.75 – 7.69 (m, 2H), 7.57 – 7.42 (m, 4H), 7.39 – 7.34 (m, 3H), 4.89 (s, 1H), 4.55 (s, 3H), 3.14 (s, 3H); ^{13}C NMR (101 MHz, $CDCl_3$): δ = 164.3 (C), 143.4 (C), 142.0 (C), 137.4 (C), 130.4 (CH), 130.0 (CH), 129.1 (2CH), 129.0 (CH), 124.9 (2CH), 123.8 (CH), 120.8 (CH), 113.5 (C), 80.9 (CH), 62.2 (CH_3), 51.8 (CH_3); Minor diastereomer; ^{1}H NMR (300 MHz, $CDCl_3$): δ = 7.81 – 7.75 (m, 2H), 7.57 – 7.42 (m, 4H), 7.33 – 7.29 (m, 3H), 5.80 (s, 1H), 4.45 (s, 3H), 2.37 (s, 3H); ^{13}C NMR (101 MHz, $CDCl_3$): δ = 163.2 (C), 143.4 (C), 142.8 (C), 137.3 (C), 130.1 (CH), 129.7 (CH), 129.1 (2CH), 128.9 (CH), 128.7 (CH), 124.9 (2CH), 124.2 (CH), 120.8 (CH), 113.7 (C), 77.9 (CH), 62.2 (CH_3), 51.9 (CH_3); IR (neat): *ν* = 3064, 2987, 2931, 2830, 1611, 1598, 1560, 1430, 1361, 1307, 1198, 1081, 1065, 1034, 927, 770, 753, 739, 688, 659; HR-MS (ES-TOF): *m/z*: calcd for $C_{17}H_{16}O_3NaS$: 323.0718, found 323.0702 $[M + Na]^+$.

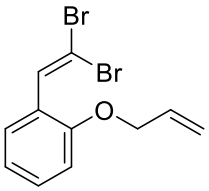
2-(Allyloxy)benzaldehyde (476)



Prepared according to a literature procedure.[154] A RBF was charged with salicaldehyde (1.75 g, 14.3 mmol, 1.0 eq.) and DMF (20 mL). Allyl bromide (1.83 mL, 17.2 mmol, 1.2 eq.) and K_2CO_3 (3.95 g, 28.6 mmol) were added and the mixture was heated to 50 ºC and stirred at this temperature for 16 hours. The mixture was cooled to rt, diluted with EtOAc (20 mL), washed with NH_4Cl (20 mL), water (20 mL), brine (20 mL), dried over Na_2SO_4, filtered and concentrated under reduced pressure. The residue was purified by column chromatography (95:5 hexane:EtOAc) affording the title compound (2.31 g, 99%) as a

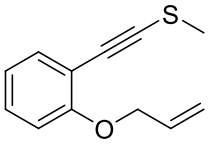
colourless oil. ^{1}H NMR (300 MHz, $CDCl_3$): δ = 10.54 (d, *J* = 0.7 Hz, 2H), 7.84 (dd, *J* = 7.6, 1.8 Hz, 2H), 7.53 (ddd, *J* = 8.5, 7.6, 1.8 Hz, 2H), 7.03 (app t, *J* = 7.6 Hz, 2H), 6.98 (d, *J* = 8.4 Hz, 2H), 6.08 (ddt, *J* = 17.2, 10.5, 5.1 Hz, 2H), 5.46 (dd, *J* = 17.2, 1.5 Hz, 1H), 5.34 (dd, *J* = 10.5, 1.4 Hz, 1H), 4.66 (dt, *J* = 5.1, 1.5 Hz, 4H); IR (neat): ν = 3078, 2988, 2868, 1683, 1597, 1481, 1455, 1396, 1285, 1238, 1161, 992, 843, 755. Data matches that reported in the literature.[154]

1-(Allyloxy)-2-(2,2-dibromovinyl)benzene (349)



Prepared using **GP1**, with 2-(allyloxy)benzaldehyde (2.00 g, 12.3 mmol), CBr_4 (8.18 g, 24.7 mmol), and PPh_3 (12.9 g, 49.0 mmol) in dry CH_2Cl_2 (40 mL). The reaction time was 2 hours. Aqueous work-up and purification by column chromatography, eluting with *n*-hexane, afforded the dibromoalkene **349** (3.76 g, 95%) as a pale yellow oil; ^{1}H NMR (300 MHz, $CDCl_3$): δ = 7.71 (dd, *J* = 7.7, 1.3 Hz, 1H), 7.64 (s, 1H), 7.38 – 7.26 (m, 4H), 6.97 (td, *J* = 7.6, 0.7 Hz, 1H), 6.87 (d, *J* = 8.3 Hz, 1H), 6.06 (ddt, *J* = 17.2, 10.4, 5.1 Hz, 1H), 5.42 (dd, *J* = 17.3, 1.6 Hz, 1H), 5.31 (dd, *J* = 10.5, 1.4 Hz, 1H), 4.57 (dt, *J* = 5.1, 1.5 Hz, 2H); IR (neat): ν = 3071, 2866, 1597, 1481, 1449, 1290, 1242, 1108, 995, 875, 744, 695. Data matches that reported in the literature.[154]

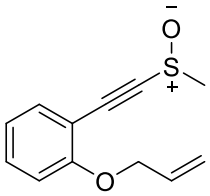
((2-(Allyloxy)phenyl)ethynyl)(methyl)sulfone (477)



477 was prepared according to **GP10** using dibromoolefin **349** (1.27 g, 4.00 mmol), *n*-BuLi (2.5 M in hexanes) (3.37 mL, 8.60 mmol) and **458** (670 mg, 3.64 mmol). The reaction time was 18 hours. Aqueous workup and purification by column chromatography (pentane) provided **477** (510 mg, 69%) as a colourless oil; R_f 0.22 (hexane); ^{1}H NMR (300 MHz, $CDCl_3$): δ = 7.38 (dd, *J* = 7.6, 1.7 Hz, 1H), 7.23 (ddd, *J* = 8.3, 7.6, 1.7 Hz, 1H), 6.92 – 6.80 (m, 2H), 6.07 (ddt, *J* = 17.3, 10.5, 4.9 Hz, 1H), 5.49 (dd, *J* = 17.3, 1.7 Hz, 1H), 5.30 (dd, *J* = 10.5, 1.7 Hz, 1H), 4.60 (dt, *J* = 4.9, 1.7 Hz, 2H), 2.49 (s, 3H); ^{13}C NMR (101 MHz, $CDCl_3$): δ = 159.2 (C), 133.4 (CH), 133.2 (CH), 129.4 (CH), 120.8 (CH), 117.4 (CH_2),

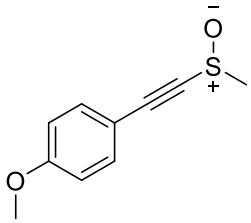
112.1 (CH), 88.2 (C), 84.9 (C), 69.3 (CH_2), 19.8 (CH_3); IR (neat): ν = 3073, 2162, 1721, 1595, 1488, 1287, 1255, 1067, 752; HR-MS (EI-TOF): *m/z*: calcd for $C_{12}H_{12}OS$: 204.0612, found 204.0609 $[M + H]^+$.

1-(Allyloxy)-2-((methylsulfinyl)ethynyl)benzene (478)



478 was prepared according to **GP12** using **4771** (180 mg, 0.88 mmol), *m*CPBA (152 mg, 0.88 mmol) and CH_2Cl_2 (10 mL). The reaction time was 2 hours. Aqueous work-up and purification by column chromatography (7:3 hexane: EtOAc) provided **478** (164 mg, 85%) as a yellow oil; R_f 0.38 (1:1 hexane: EtOAc); ^{1}H NMR (300 MHz, $CDCl_3$): δ = 7.47 (dd, *J* = 7.6, 1.7 Hz, 1H), 7.37 (ddd, *J* = 8.4, 7.5, 1.8 Hz, 1H), 6.94 (td, *J* = 7.6, 0.9 Hz, 1H), 6.88 (d, *J* = 8.5 Hz, 1H), 6.13 – 5.94 (m, 1H), 5.46 (ddd, *J* = 17.3, 3.2, 1.7 Hz, 1H), 5.35 – 5.26 (m, 1H), 4.60 (dt, *J* = 4.8, 1.6 Hz, 2H), 3.06 (s, 3H); ^{13}C NMR (101 MHz, $CDCl_3$): δ = 160.1 (C), 134.3 (CH), 132.6 (CH), 132.3 (CH), 120.9 (CH), 117.8 (CH_2), 112.4 (CH), 109.5 (C), 98.6 (C), 90.2 (C), 69.3 (CH_2), 43.7 (CH_3); IR (neat): ν = 2935, 2162, 1721, 1595, 1488, 1287, 1255, 1067, 752. HR-MS (EI-TOF): *m/z*: calcd for $C_{12}H_{12}O_2S$: 220.0562, found 220.0558 $[M + H]^+$.

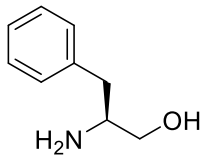
1-Methoxy-4-((methylsulfinyl)ethynyl)benzene (481)



481 was prepared over 2 steps. 4-methoxyphenylacetylene **352** (223 mg, 1.69 mmol) was added to a flame dried 2 neck RBF under argon. THF (8 mL) was added and the reaction mixture was cooled to -78 ^{o}C. LiHMDS (1M) (1.69 mL, 1.69 mmol) was added dropwise and the mixture was stirred for a further hour at -78 ^{o}C. Methyl thionosulfonate **457** was added (1.54 mmol, 1.0 eq.) and the reaction allowed to warm to rt and stirred for 4 hours. NH_4Cl (10 mL) was added and was extracted Et_2O (3 ×10 mL), organics washed with brine (10 mL), dried Na_2SO_4, filtered, concentrated under reduced pressure and purified by column chromatography (hexane) affording the crude sulfide (~85%

pure). The sulfide (240 mg, 1.15 mmol) was dissolved in CH_2Cl_2 (12 mL), the mixture was cooled to 0 °C and *m*CPBA (200 mg, 1.15 mmol) was added in 5 portions over 10 minutes. The mixture was allowed to warm to rt and was stirred for 2 hours. The reaction mixture was washed with $NaHCO_3$ (sat.) (3 × 10 mL) and the aqueous layers were extracted with CH_2Cl_2 (3 × 5 mL). The organic layers were dried over Na_2SO_4, filtered, concentrated under reduced pressure and purified by column chromatography (2:1 hexane:EtOAc) providing the title compound (170 mg, 57% over 2 steps) as a viscous yellow oil; R_f 0.25 (2:1 hexane:EtOAc); ^{1}H NMR (300 MHz, $CDCl_3$): δ = 7.44 (d, *J* = 8.9 Hz, 2H), 6.86 (d, *J* = 8.9 Hz, 2H), 3.80 (s, 3H), 3.01 (s, 3H); ^{13}C NMR (101 MHz, $CDCl_3$): δ = 161.6 (C), 134.1 (2CH), 114.3 (2CH), 111.4 (CH), 102.3 (C), 85.3 (C), 55.4 (CH_3), 43.5 (CH_3); IR (neat): *v* = 3053, 2852, 1724, 1543, 1331, 1145, 1077, 1544, 1331, 1077, 923, 817, 752; HR-MS (EI-TOF): *m/z*: calcd for $C_{10}H_{10}O_2S$: 194.0403 found 194.0402 $[M + Na]^+$.

(S)-2-amino-3-phenylpropan-1-ol (483)

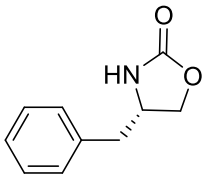


483 was prepared according to a literature procedure.[154] A 500 mL RBF was equipped with a condenser and sodium borohydride (5.49 g, 145 mmol) was added, followed by THF (200 mL). Phenylalanine **482** (10.0 g, 60.50 mmol, 1.0 eq.) was added and the mixture was cooled to 0 °C. Iodine (15.4 g, 60.50 mmol, 1.0 eq.) in THF (50 mL) was added by dropping funnel over 1 hour. The mixture was heated to reflux and stirred at this temperature for 18 hours, cooled to rt and MeOH was added dropwise. The mixture was concentrated under reduced pressure and dissolved in a 20% KOH solution (150 mL), stirred at rt for 4 hours and extracted with $CHCl_3$ (100 mL × 4). The organic layers were dried over Na_2SO_4, filtered and concentrated under reduced pressure affording a white solid which was purified by recrystallisation from hot EtOH affording the title compound (5.90 g, 64%) as a white solid; mp: 85-87 °C (EtOH). ^{1}H NMR (300 MHz, $CDCl_3$): δ = 7.35 – 7.15 (m,

5H), 3.63 (dd, *J* = 10.5, 4.0 Hz, 1H), 3.37 (dd, *J* = 10.5, 7.2 Hz, 1H), 3.18 – 3.06 (m, 1H), 2.79 (dd, *J* = 13.5, 5.2 Hz, 1H), 2.51 (dd, *J* = 13.5, 8.6 Hz, 1H), 1.81 – 1.48 (bs, 3H).

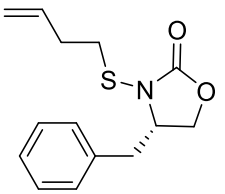
IR (neat): ν = 3357, 3299, 2876, 2820, 1576, 1493, 1065, 753, 698. Data mataches that reported in the literature.[154]

(S)-4-benzyloxazolidin-2-one (484)



484 was prepared according to a literature procedure.[155] A RBF was equipped with an oven dried downward distillation kit. (S)-2-amino-2-phenylethan-1-ol **483** (5.90 g, 39 mmol, 1.0 eq.), diethyl carbonate (13.0 mL, 107 mmol, 2.74 eq.) and K_2CO_3 (684 mg, 5.96 mmol, 0.127 eq.) were combined in the RBF and the mixture was carefully heated to 130 ^oC. After 3 hours no more ethanol was being collected and the mixture was allowed to cool, diluted with CH_2CH_2 (150 mL), filtered through a sintered funnel, concentrated and purified by column chromatography (2:8 EtOAc:hexane) to (1:1 EtOAc:hexane) affording the title compound (5.41 g, 78%) as a white solid. mp: 87-89 ^oC; ^1H NMR (300 MHz, $CDCl_3$): δ = 7.39 – 7.27 (m, 3H), 7.22 – 7.16 (m, 2H), 5.41 (bs, 1H), 4.46 (t, *J* = 8.0 Hz, 1H), 4.20 – 4.02 (m, 2H), 2.87 (d, *J* = 6.8 Hz, 2H); IR (neat): ν = 3257, 2922, 1752, 1700, 1406, 1247, 1019, 703.Data matches that reported in the literature.[155]

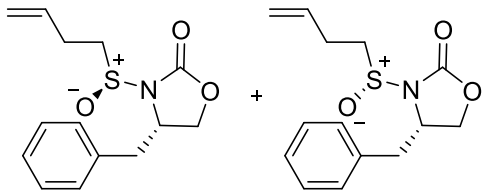
(S)-4-Benzyl-3-(but-3-en-1-ylthio)oxazolidin-2-one (485)



485 was prepared according to a literature procedure[128] A 2 neck flame dried 25 mL RBF was charged with THF (5 mL) and Oxazolidin-2-one **484** (177 mg, 1.00 mmol, 1.0 eq.) and the mixture was cooled to 0 ^oC. *n*-BuLi (2.5 M in hexanes) (0.44 mL, 1.00 mmol, 1.0 eq.) was added dropwise and the mixture was stirred for 30 minutes at this temperature. Sulfonothioate **359** (228 mg, 1.0 mmol, 1.0 eq.) was then added as a solution in THF (2 mL) over 2 mins. The mixture was stirred for 10 mins at 0 ^oC and then

at rt for 2 hours. The reaction mixture was quenched with NH_4Cl (10 mL), extracted with Et_2O (2 × 10 mL) and the combined organics were washed with brine (10 mL), dried over Na_2SO_4, filtered, concentrated under reduced pressure and purified by column chromatography (9:1 hexane:EtOAc to 4:1 hexane:EtOAc) to afford the title compound (190 mg, 75%) as a clear viscous oil; ^{1}H NMR (300 MHz, $CDCl_3$): δ = 7.39 – 7.26 (m, 3H), 7.21 – 7.13 (m, 2H), 5.87 (ddt, *J* = 16.8, 10.2, 6.6 Hz, 1H), 5.20 – 5.05 (m, 2H), 4.26 – 3.90 (m, 3H), 3.37 (dd, *J* = 13.5, 3.4 Hz, 1H), 3.07 – 2.82 (m, 2H), 2.70 (dd, *J* = 13.5, 9.4 Hz, 1H), 2.51 – 2.38 (m, 2H); ^{13}C NMR (101 MHz, $CDCl_3$): δ = 158.3 (C), 135.8 (CH), 135.2 (C), 129.3 (2CH), 129.1 (2CH), 127.4 (CH) , 116.7 (CH_2), 67.2 (CH_2), 60.4 (CH), 39.0 (CH_2), 37.5 (CH_2), 32.4 (CH_2); IR (neat): ν = 3029, 2914, 1753, 1640, 1603,1389, 1211, 1132, 1044, 999, 915, 701; HR-MS (ES-TOF): *m/z*: calcd for $C_{14}H_{18}NO_2S$: 264.1058, found 264.1058 $[M + H]^+$.

(4S)-4-Benzyl-3-(but-3-en-1-ylsulfinyl)oxazolidin-2-one (486a and 486b)



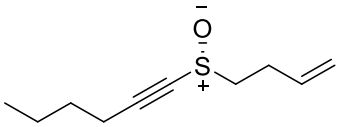
486a and **486b** were prepared according to a literature procedure.[128] A flame dried RBF under argon was charged with **485** (2.40 g, 9.0 mmol) and CH_2Cl_2 (90 mL). The reaction mixture was cooled to -20 °C and *m*CPBA (1.55 mg, 9.0 mmol, 1.0 eq) was added in 5 portions over 10 minutes. The reaction was stirred at -20 °C for 2 hours before being quenched with $NaHCO_3$ (20 mL), washed with $NaHCO_3$ (3 × 20 mL) and extracted with CH_2Cl_2 (3 × 20 mL). The combined organics were then dried over Na_2SO_4, filtered and concentrated under reduced pressure. The residue was purified by column chromatography (3:1 hexanes:EtOAc) to give **486a** (1.17 g, 38%) and then **486b** (795 mg, 31%);

486a ^{1}H NMR (300 MHz, $CDCl_3$): δ = 7.44 – 7.13 (m, 5H), 4.51 (ddt, *J* = 9.8, 7.6, 4.7 Hz, 1H), 4.29 – 4.12 (m, 2H), 3.34 (dd, *J* = 13.4, 4.67 Hz, 1H), 3.20 (ddd, *J* = 12.7, 8.5, 5.1 Hz, 2H), 2.90 (dd, *J* = 13.4, 10.1 Hz, 1H), 2.63 – 2.42 (m, 2H); ^{13}C NMR (101 MHz, $CDCl_3$): δ =156.4

(C), 134.9 (C), 134.0 (CH), 129.3 (2CH), 127.7 (2CH), 117.8 (CH_2), 69.0 (CH_2), 54.8 (CH_2), 53.1 (CH_3), 41.1 (CH_2), 27.2 (CH_2); IR (neat): ν = 2919, 1755, 1386, 1175, 1092, 1038, 919, 729, 701; HR-MS (ES-TOF): *m/z*: calcd for $C_{14}H_{17}NO_3NaS$: 302.0827, found 302.0833 [M + Na]$^+$.

486b ^{1}H NMR (300 MHz, $CDCl_3$): δ = 7.54 – 7.12 (m, 5H), 5.85 (ddt, *J* = 16.9, 10.1, 6.6 Hz, 1H), 5.21 (dd, *J* = 14.3, 1.3 Hz, 1H), 5.17 (dd, *J* = 7.4, 1.4 Hz, 1H), 4.56 (ddt, *J* = 9.5, 7.9, 4.8 Hz, 1H), 4.29 (t, *J* = 8.4 Hz, 1H), 4.18 (dd, *J* = 8.9, 4.9 Hz, 1H), 3.59 (ddd, *J* = 13.1, 8.4, 6.3 Hz, 1H), 3.36 (ddd, *J* = 6.9, 6.5, 3.6 Hz, 2H), 3.02 – 2.83 (m, 1H), 2.64 – 2.38 (m, 2H); ^{13}C NMR (101 MHz, $CDCl_3$): δ = 154.8 (C), 134.8 (C), 134.0 (CH), 129.3 (2CH), 129.2 (2CH), 127.7 (CH), 117.8 (CH_2), 68.0 (CH_2), 57.0 (CH), 52.3 (CH_2), 40.6 (CH_2), 27.4 (CH_2); IR (neat): ν = 2921, 1753, 1641, 1603, 1388, 1186, 1090, 921, 702; HR-MS (ES-TOF): *m/z*: calcd for $C_{14}H_{17}NO_3NaS$: 302.0827, found 302.0833 [M + Na]$^+$.

1-(But-3-en-1-ylsulfinyl)hex-1-yne (487a)



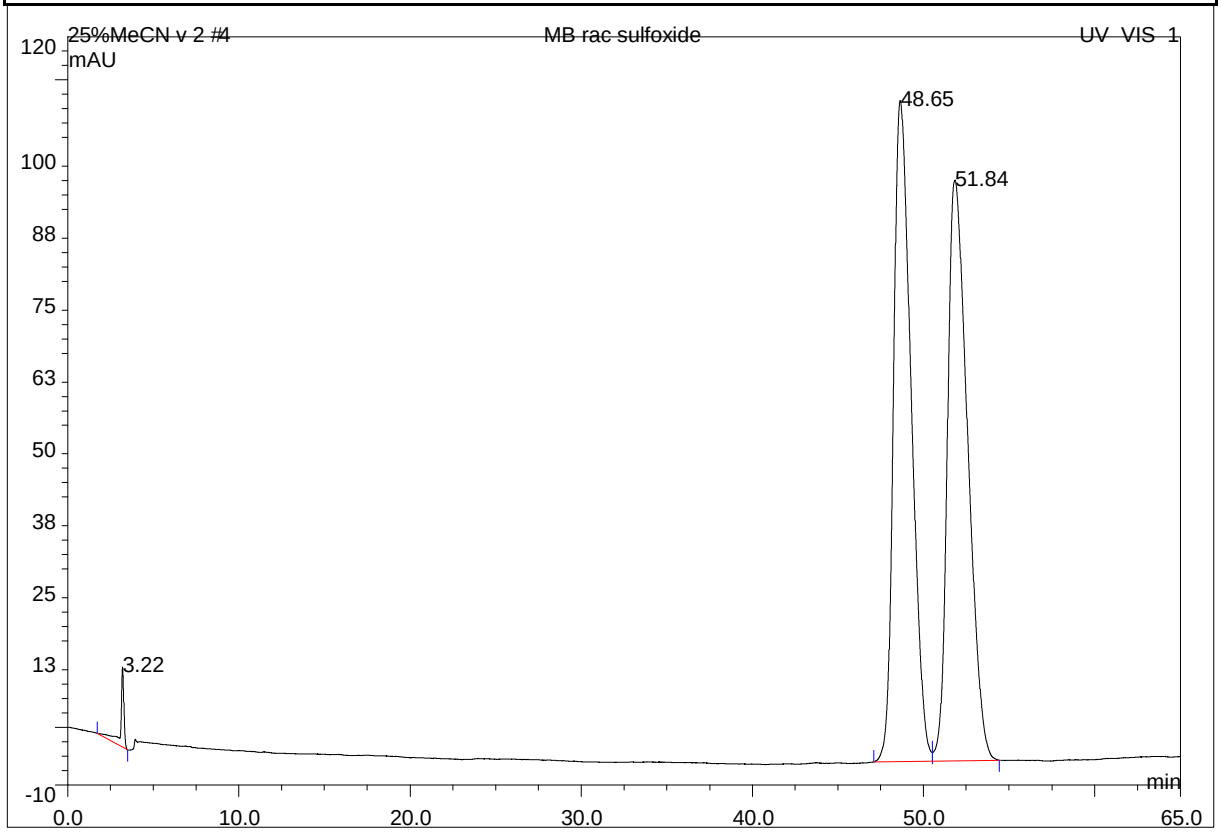
A 2 neck RBF was fitted with a reflux condenser and was flame dried. MeMgBr (3 M in Et_2O) (0.40 mL, 1.18 mmol, 1.0 eq.) was added followed by the addition of 1-hexyne (204 µl, 1.78 mmol, 1.5 eq.). The mixture was heated to reflux for 2 hours before being cooled to -20 ^{o}C. Sulfinamide **486b** (333 mg, 1.18 mmol, 1.0 eq.) in toluene (5 mL) was added dropwise and the reaction was stirred at 0 ^{o}C for 5 hours. The mixture was quenched NH_4Cl, extracted Et_2O (3 × 5 mL), washed brine (5 mL), dried Na_2SO_4, filtered and concentrated undr reduced pressure. The residue was purified by column chromatography (8:2 hexane:EtOAc) to afford the title compound **487a** (145 mg, 67 %) as a colourless oil.

Appendix

4 MB rac sulfoxide

Amylose 2, 25% MeCN, 1 ml/min, 25 degrees

Sample Name:	MB rac sulfoxide	Injection Volume:	10.0
Vial Number:	1_2	Channel:	UV_VIS_1
Sample Type:	unknown	Wavelength:	n.a.
Control Program:	25% MeCN v 2	Bandwidth:	n.a.
Quantif. Method:	25% MeCN v 2	Dilution Factor:	1.0000
Recording Time:	29/11/2014 10:48	Sample Weight:	1.0000
Run Time (min):	65.01	Sample Amount:	1.0000



No.	Ret.Time	Peak Name	Height	Area	Rel.Area	Amount	Type

	min		mAU	mAU*min	%		
1	3.22	n.a.	13.925	3.154	1.13	n.a.	BMB
2	48.65	n.a.	114.871	137.907	49.37	n.a.	BM
3	51.84	n.a.	100.922	138.273	49.50	n.a.	MB
Total:			229.718	279.333	100.00	0.000	

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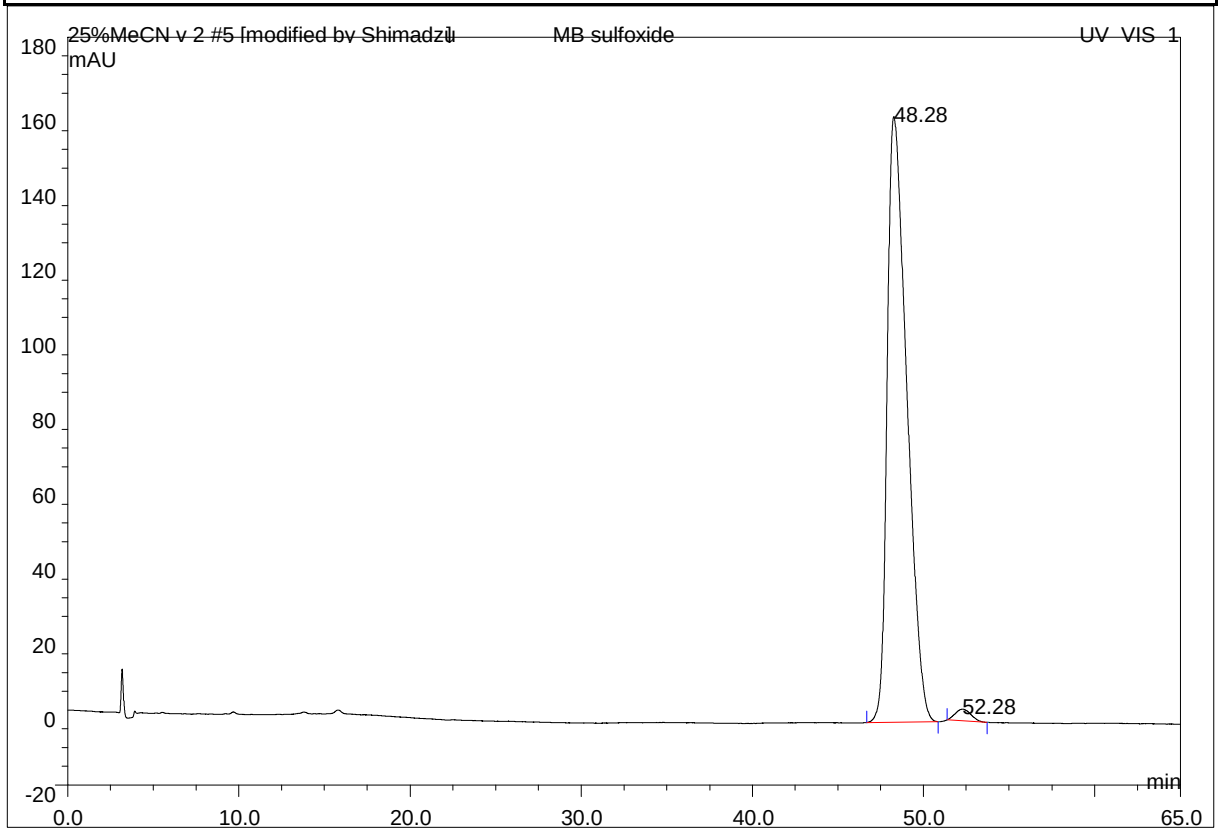
5 MB sulfoxide 461b

Amylose 2, 25% MeCN, 1 ml/min, 25 degrees

Sample Name:	MB sulfoxide a	Injection Volume:	10.0
Vial Number:	1_3	Channel:	UV_VIS_1
Sample Type:	unknown	Wavelength:	n.a.
Control Program:	25% MeCN v 2	Bandwidth:	n.a.
Quantif. Method:	25% MeCN v 2	Dilution Factor:	1.0000
Recording Time:	29/11/2014 11:54	Sample Weight:	1.0000
Run Time (min):	65.01	Sample Amount:	1.0000



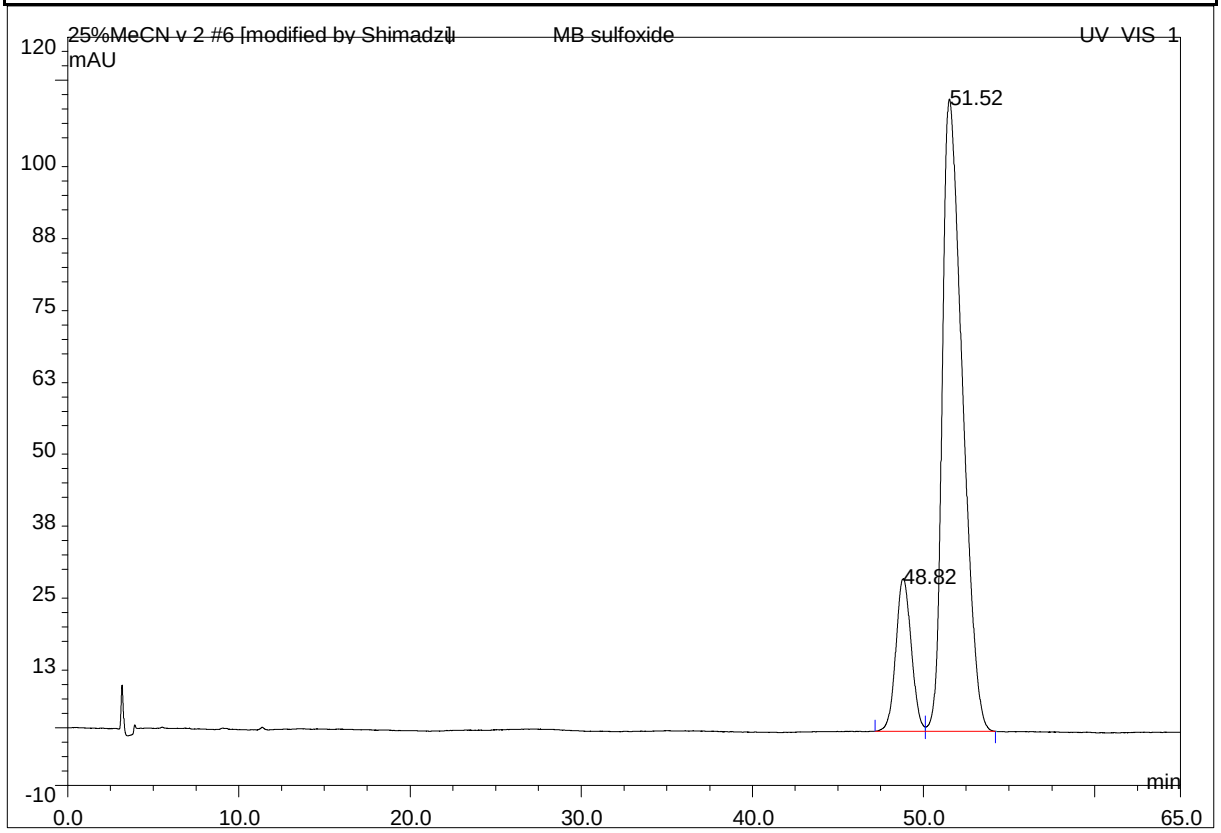
No.	Ret.Time min	Peak Name	Height mAU	Area mAU*min	Rel.Area %	Amount	Type
1	48.28	n.a.	162.033	215.210	98.49	n.a.	BMB
2	52.28	n.a.	3.127	3.297	1.51	n.a.	BMB*

Total:		165.160	218.507	100.00	0.000

6 MB sulfoxide 461a

Amylose 2, 25% MeCN, 1 ml/min, 25 degrees

Sample Name:	MB sulfoxide b	Injection Volume:	10.0
Vial Number:	1_4	Channel:	UV_VIS_1
Sample Type:	unknown	Wavelength:	n.a.
Control Program:	25% MeCN v 2	Bandwidth:	n.a.
Quantif. Method:	25% MeCN v 2	Dilution Factor:	1.0000
Recording Time:	29/11/2014 12:59	Sample Weight:	1.0000
Run Time (min):	65.01	Sample Amount:	1.0000



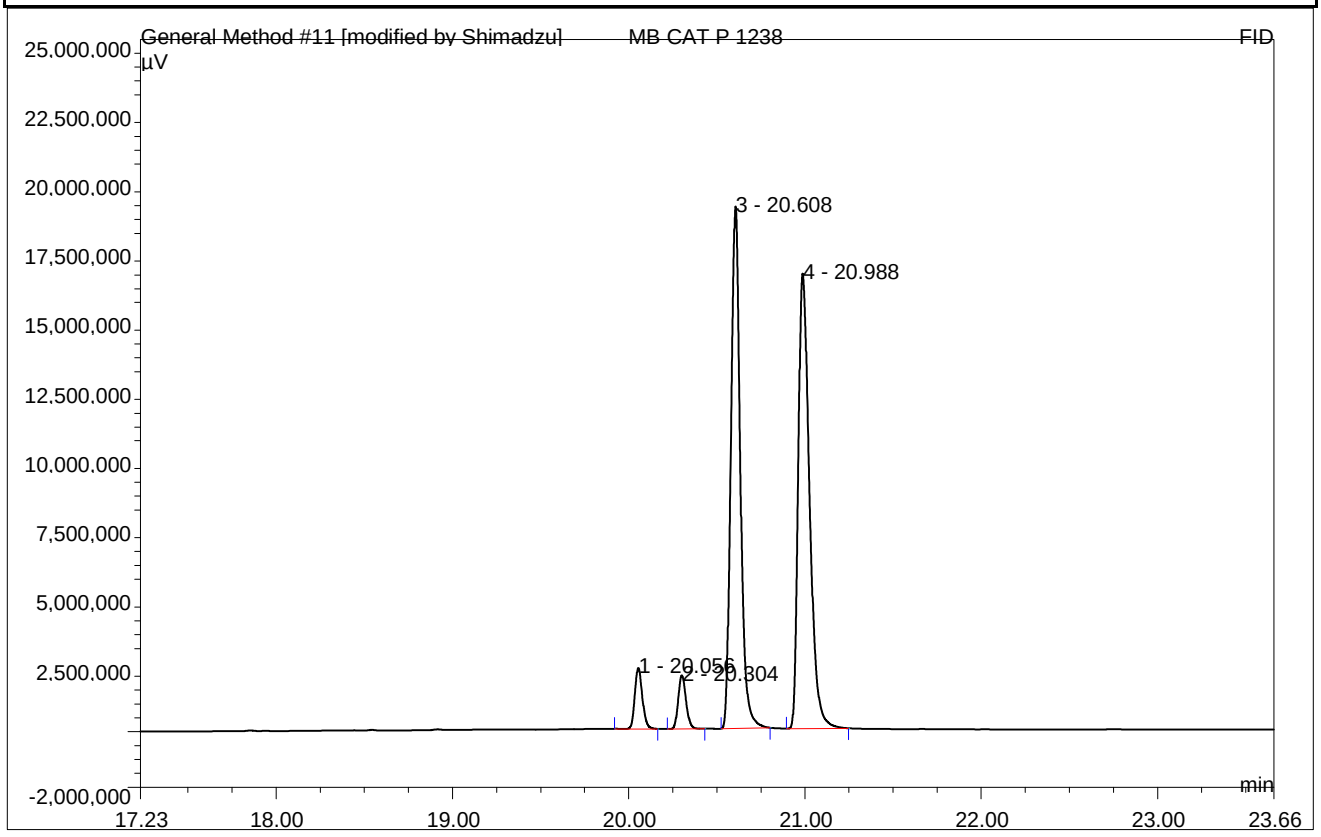
No.	Ret.Time min	Peak Name	Height mAU	Area mAU*min	Rel.Area %	Amount	Type

1	48.82	n.a.	26.527	27.782	15.60	n.a.	BM
2	51.52	n.a.	109.894	150.295	84.40	n.a.	MB
Total:			136.421	178.077	100.00	0.000	

11 462a

Chirasil-Dex CB column

Sampl e Name:	MB CAT P 1238	Injection Vol ıme:	2.0
Vial Number:	4	Channel:	FID
Sample Type:	unknown	Wavelength:	n.a.
Control Program:	Chiral Method	Bandwidth:	n.a.
Quantif. Method:	General Method	Dilution Factor:	1.0000
Recording Time:	18/2/2015 9:23	Sample Weight:	1.0000
Run Time (min):	25.00	Sample Amount:	1.0000



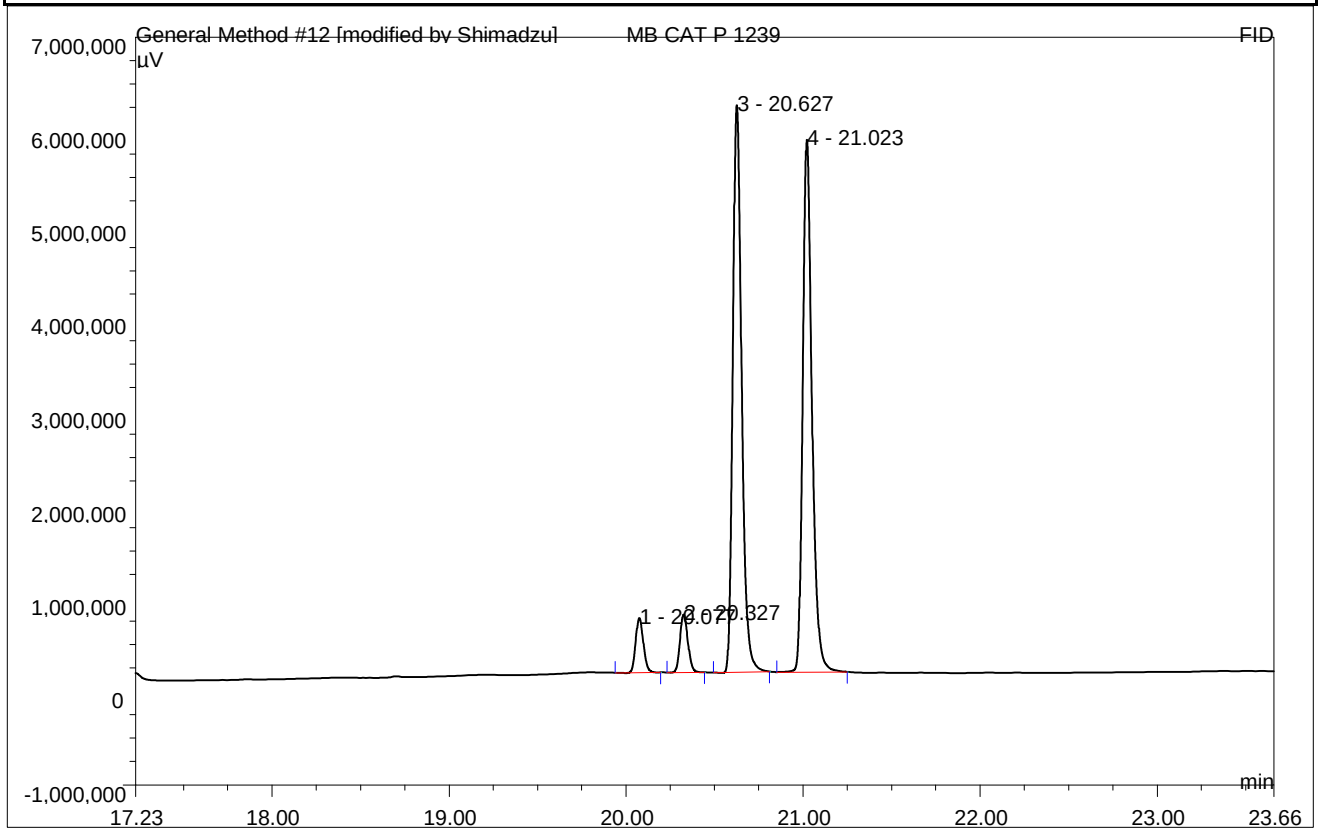
No.	Ret.Time min	Peak Name	Height µV	Area µV*min	Rel.Area %	Amount	Type
1	20.06	n.a.	2195453.00	107832.94	4.16	n.a.	BMB*
2	20.30	n.a.	1925581.00	98037.92	3.78	n.a.	BMB*
3	20.61	n.a.	##########	1166803.44	45.00	n.a.	BMB*
4	20.99	n.a.	##########	1219994.83	47.06	n.a.	BMB*
Total:			##########	2592669.14	100.00	0.000	

Chromeleon (c) Dionex 1996-2006 Default Test/Integration Version 6.80 SR8 Build 2623 (156243)

12 MB 462b

Chirasil-Dex CB column

Sample Name:	MB CAT P 1239	Injection Volume:	2.0
Vial Number:	5	Channel:	FID
Sample Type:	unknown	Wavelength:	n.a.
Control Program:	Chiral Method	Bandwidth:	n.a.
Quantif. Method:	General Method	Dilution Factor:	1.0000
Recording Time:	18/2/2015 9:55	Sample Weight:	1.0000
Run Time (min):	25.00	Sample Amount:	1.0000



No.	Ret.Time min	Peak Name	Height µV	Area µV*min	Rel.Area %	Amount	Type
1	20.08	n.a.	581770.00	29117.14	3.85	n.a.	BMB*
2	20.33	n.a.	618634.00	31872.42	4.22	n.a.	BMB*

3	20.63	n.a.	6067093.00 351427.82	46.49	n.a.	BMB*
4	21.02	n.a.	5695222.00 343541.94	45.44	n.a.	BMB*
Total:			########## 755959.32	100.00	0.000	

Chromeleon (c) Dionex 1996-2006 Default Test/Integration Version 6.80 SR8 Build 2623 (156243)

X-ray Crystallography

The datasets for **160**, **216**, **230** and **369** were measured on an Agilent SuperNova diffractometer u sing an Atlas detector. The data collections were driven and processed and absorption corrections were applied using CrysAlisPro.[1] The structures were solved using ShelXS[2] and refined by a full-matrix least-squares procedure on F^2 in ShelXL.[2] All non-hydrogen atoms were refined with anisotropic displacement parameters. All hydrogen atoms were added at calculated positions and refined by use of a riding model with isotropic displacement parameters based on the equivalent isotropic displacement parameter (U_{eq}) of the parent atom. Figures were produced using OLEX2.[3] The structure of **216** contains two crystallographically-independent molecules.

Crystal structure determination of 160

Crystal Data for $C_{22}H_{20}O_4S$ (M =380.44 g/mol): triclinic, space group P-1 (no. 2), a = 9.0122(4) Å, b = 10.2942(6) Å, c = 10.6266(5) Å, α = 75.079(5)°, β = 73.655(4)°, γ = 75.040(5)°, V = 895.61(8) Å^3, Z = 2, T = 100.00(10) K, μ(Cu Kα) = 1.826 mm^{-1}, *Dcalc* = 1.411 g/cm^3, 4974 reflections measured (15.16° ≤ 2Θ ≤ 136.48°), 3189 unique (R_{int} = 0.0141, R_{sigma} = 0.0202) which were used in all calculations. The final R_1 was 0.0290 (>2σ(I)) and wR_2 was 0.0741 (all data).

Crystal structure determination of 216

Crystal Data for $C_{18}H_{12}OS_2$ (*M* =308.40 g/mol): monoclinic, space group $P2_1/c$ (no. 14), *a* = 15.8775(4) Å, *b* = 14.1420(2) Å, *c* = 13.9094(3) Å, *β* = 115.825(3)°, *V* = 2811.29(12) Å^3, *Z* = 8, *T* = 100.01(10) K, μ(Cu Kα) = 3.378 mm^{-1}, *Dcalc* = 1.457 g/cm^3, 13662 reflections measured (12.728° ≤ 2Θ ≤ 148.922°), 5420 unique (R_{int} = 0.0254, R_{sigma} = 0.0280) which were used in all calculations. The final R_1 was 0.0309 (I > 2σ(I)) and wR_2 was 0.0813 (all data).

Crystal structure determination of 369

Crystal Data for $C_{12}H_{12}O_2S$ (*M* =220.28): triclinic, space group P-1 (no. 2), *a* = 6.2782(3) Å, *b* = 7.1917(3) Å, *c* = 12.4920(6) Å, *α* = 86.275(4)°, *β* = 75.966(4)°, *γ* = 66.086(4)°, *V* = 499.87(4) Å^3, *Z* = 2, *T* = 100.01(11) K, μ(CuKα) = 2.667 mm^{-1}, *Dcalc* = 1.463 g/mm^3, 7549 reflections measured (13.478 ≤ 2Θ ≤ 140.082), 1883 unique (R_{int} = 0.0222, R_{sigma} = 0.0169) which were used in all calculations. The final R_1 was 0.0394 (I > 2σ(I)) and wR_2 was 0.0986 (all data).

1 *CrysAlisPro*, Version 1.171.37.33c, Agilent Technologies, **2014**.

2 Sheldrick, G. M. *Acta Cryst.*, **2008**, *A64*, 112-122.

3 Dolomanov, O. V.; Bourhis, L. J.; Gildea, R. J.; Howard, J. A. K.; Puschmann, H. *J. Appl. Crystallogr.*, **2009**, *42*, 339.

Crystal data and structure refinement for **160**

Identification code	MB-4-464	
Empirical formula	$C_{22}H_{20}O_4S$	
Formula weight	380.44	
Temperature	100.00(10) K	
Wavelength	1.5418 Å	
Crystal system	Triclinic	
Space group	P-1 (no. 2)	
Unit cell dimensions	a = 9.0122(4) Å	□= 75.079(5)°.
	b =10.2942(6) Å	□= 73.655(3)°.
	c = 10.6266(5) Å	□ = 75.040(5)°.
Volume	895.61(8) $Å^3$	
Z	2	
Density (calculated)	1.411 g/cm^3	
Absorption coefficient	1.826 mm^{-1}	
F(000)	4974	

C1 C 0.20594(15) 0.35298(13) -0.11429(13) 0.0125(3) Uani 1 1 d . . .

C2 C 0.25730(15) 0.35624(13) -0.25180(13) 0.0134(3) Uani 1 1 d . . .

C3 C 0.35897(16) 0.44437(14) -0.32511(14) 0.0161(3) Uani 1 1 d . . .

H3 H 0.3958 0.4491 -0.4189 0.019 Uiso 1 1 calc R . .

C4 C 0.40864(16) 0.52625(14) -0.26477(14) 0.0169(3) Uani 1 1 d . . .

H4 H 0.4783 0.5853 -0.3177 0.020 Uiso 1 1 calc R . .

C5 C 0.35682(16) 0.52162(13) -0.12836(14) 0.0149(3) Uani 1 1 d . . .

H5 H 0.3910 0.5769 -0.0874 0.018 Uiso 1 1 calc R . .

C6 C 0.25361(15) 0.43472(13) -0.05146(13) 0.0128(3) Uani 1 1 d . . .

C7 C 0.18282(15) 0.41536(13) 0.09116(13) 0.0134(3) Uani 1 1 d . . .

C8 C 0.20304(16) 0.47629(13) 0.18668(14) 0.0153(3) Uani 1 1 d . . .

H8 H 0.2702 0.5407 0.1612 0.018 Uiso 1 1 calc R . .

C9 C 0.12419(17) 0.44187(14) 0.31878(14) 0.0172(3) Uani 1 1 d . . .

H9 H 0.1380 0.4827 0.3842 0.021 Uiso 1 1 calc R . .

C10 C 0.02451(16) 0.34766(14) 0.35710(13) 0.0165(3) Uani 1 1 d . . .

H10 H -0.0289 0.3261 0.4483 0.020 Uiso 1 1 calc R . .

C11 C 0.00181(15) 0.28492(13) 0.26480(13) 0.0138(3) Uani 1 1 d . . .

C12 C 0.08228(15) 0.32063(13) 0.13140(13) 0.0130(3) Uani 1 1 d . . .

C13 C -0.09785(16) 0.17685(14) 0.30836(13) 0.0152(3) Uani 1 1 d . . .

H13A H -0.1497 0.1831 0.2357 0.018 Uiso 1 1 calc R . .

H13B H -0.1820 0.1977 0.3876 0.018 Uiso 1 1 calc R . .

C14 C -0.00857(16) 0.02980(13) 0.34319(12) 0.0134(3) Uani 1 1 d . . .

C15 C 0.17015(16) 0.00563(13) 0.30819(13) 0.0148(3) Uani 1 1 d . . .

H15A H 0.2073 0.0334 0.2101 0.018 Uiso 1 1 calc R . .

H15B H 0.2036 0.0647 0.3509 0.018 Uiso 1 1 calc R . .

C16 C 0.25410(16) -0.21848(13) 0.25850(13) 0.0165(3) Uani 1 1 d . . .

H16A H 0.1475 -0.2122 0.2461 0.020 Uiso 1 1 calc R . .

H16B H 0.2940 -0.3150 0.2984 0.020 Uiso 1 1 calc R . .

C17 C 0.36125(16) -0.17951(13) 0.12464(14) 0.0166(3) Uani 1 1 d . . .

H17 H 0.4679 -0.1802 0.1212 0.020 Uiso 1 1 calc R . .

C18 C 0.31414(16) -0.14421(14) 0.01100(14) 0.0175(3) Uani 1 1 d . . .

H18 H 0.2064 -0.1413 0.0162 0.021 Uiso 1 1 calc R . .

C19 C 0.41738(17) -0.10867(14) -0.12471(14) 0.0183(3) Uani 1 1 d . . .

H19A H 0.5204 -0.0984 -0.1168 0.022 Uiso 1 1 calc R . .

H19B H 0.4363 -0.1823 -0.1750 0.022 Uiso 1 1 calc R . .

C20 C 0.41523(16) 0.04633(14) -0.33045(13) 0.0163(3) Uani 1 1 d . . .

H20A H 0.4097 -0.0256 -0.3745 0.020 Uiso 1 1 calc R . .

H20B H 0.5279 0.0447 -0.3390 0.020 Uiso 1 1 calc R . .

C21 C 0.33955(16) 0.18476(14) -0.39973(13) 0.0151(3) Uani 1 1 d . . .

C22 C 0.20090(16) 0.27128(14) -0.31927(13) 0.0145(3) Uani 1 1 d . . .

H22A H 0.1342 0.3328 -0.3793 0.017 Uiso 1 1 calc R . .

H22B H 0.1357 0.2107 -0.2506 0.017 Uiso 1 1 calc R . .

O1 O -0.07860(11) -0.06302(10) 0.39713(10) 0.0178(2) Uani 1 1 d . . .

O2 O 0.24287(11) -0.13229(9) 0.34913(9) 0.0161(2) Uani 1 1 d . . .

O3 O 0.33893(12) 0.01735(10) -0.19292(9) 0.0201(2) Uani 1 1 d . . .

O4 O 0.39480(12) 0.22571(10) -0.51703(10) 0.0222(2) Uani 1 1 d . . .

S1 S 0.07645(4) 0.25214(3) -0.00139(3) 0.01308(10) Uani 1 1 d . . .

C1 0.0104(6) 0.0103(6) 0.0153(6) -0.0013(5) -0.0024(5) -0.0015(5)

C2 0.0126(6) 0.0118(6) 0.0149(6) -0.0026(5) -0.0039(5) 0.0001(5)

C3 0.0153(7) 0.0163(6) 0.0141(6) -0.0017(5) -0.0011(5) -0.0026(5)

C4 0.0149(7) 0.0140(6) 0.0199(7) -0.0011(5) -0.0010(5) -0.0050(5)

C5 0.0140(6) 0.0118(6) 0.0196(7) -0.0035(5) -0.0042(5) -0.0031(5)

C6 0.0110(6) 0.0104(6) 0.0159(6) -0.0024(5) -0.0039(5) 0.0003(5)

C7 0.0125(6) 0.0101(6) 0.0161(7) -0.0018(5) -0.0041(5) 0.0005(5)

C8 0.0154(7) 0.0122(6) 0.0190(7) -0.0031(5) -0.0053(5) -0.0024(5)

C9 0.0222(7) 0.0148(6) 0.0163(7) -0.0051(5) -0.0073(6) -0.0015(5)

C10 0.0183(7) 0.0149(6) 0.0133(6) -0.0028(5) -0.0024(5) 0.0003(5)

C11 0.0124(6) 0.0109(6) 0.0154(6) -0.0019(5) -0.0025(5) 0.0007(5)

C12 0.0129(6) 0.0110(6) 0.0150(6) -0.0032(5) -0.0042(5) -0.0003(5)

C13 0.0136(6) 0.0163(7) 0.0141(6) -0.0021(5) -0.0015(5) -0.0032(5)

C14 0.0164(7) 0.0154(6) 0.0098(6) -0.0039(5) -0.0027(5) -0.0047(5)

C15 0.0143(7) 0.0128(6) 0.0163(6) -0.0026(5) -0.0020(5) -0.0032(5)

C16 0.0189(7) 0.0126(6) 0.0182(7) -0.0035(5) -0.0049(6) -0.0024(5)

C17 0.0152(7) 0.0132(6) 0.0205(7) -0.0043(5) -0.0037(5) -0.0010(5)

C18 0.0166(7) 0.0145(6) 0.0210(7) -0.0028(5) -0.0038(6) -0.0037(5)

C19 0.0196(7) 0.0147(6) 0.0187(7) -0.0021(5) -0.0043(6) -0.0014(5)

C20 0.0153(7) 0.0177(7) 0.0145(6) -0.0041(5) -0.0005(5) -0.0031(5)

C21 0.0162(7) 0.0162(6) 0.0151(7) -0.0049(5) -0.0031(5) -0.0061(5)

C22 0.0141(6) 0.0154(6) 0.0137(6) -0.0027(5) -0.0037(5) -0.0024(5)

O1 0.0188(5) 0.0165(5) 0.0191(5) -0.0029(4) -0.0027(4) -0.0079(4)

O2 0.0184(5) 0.0129(5) 0.0165(5) -0.0027(4) -0.0055(4) -0.0007(4)

O3 0.0236(5) 0.0177(5) 0.0133(5) -0.0013(4) -0.0015(4) 0.0009(4)

O4 0.0276(6) 0.0204(5) 0.0146(5) -0.0029(4) 0.0014(4) -0.0055(4)

S1 0.01424(17) 0.01339(17) 0.01233(17) -0.00275(12) -0.00141(12) -0.00565(12)

Table. Bond lengths [Å] and angles [°] for **160**.

C1 C2 1.3974(18) . ?

C1 C6 1.4057(18) . ?

C1 S1 1.7535(13) . ?

C2 C3 1.3903(19) . ?

C2 C22 1.5149(18) . ?

C3 C4 1.3987(19) . ?

C3 H3 0.9500 . ?

C4 C5 1.3843(19) . ?

C4 H4 0.9500 . ?

C5 C6 1.3994(18) . ?

C5 H5 0.9500 . ?

C6 C7 1.4524(18) . ?

C7 C8 1.3957(19) . ?

C7 C12 1.4065(18) . ?

C8 C9 1.3834(19) . ?

C8 H8 0.9500 . ?

C9 C10 1.398(2) . ?

C9 H9 0.9500 . ?

C10 C11 1.3886(19) . ?

C10 H10 0.9500 . ?

C11 C12 1.4005(18) . ?

C11 C13 1.5084(18) . ?

C12 S1 1.7505(13) . ?

C13 C14 1.5252(18) . ?

C13 H13A 0.9900 . ?

C13 H13B 0.9900 . ?

C14 O1 1.2106(16) . ?

C14 C15 1.5159(18) . ?

C15 O2 1.4130(16) . ?

C15 H15A 0.9900 . ?

C15 H15B 0.9900 . ?

C16 O2 1.4366(16) . ?

C16 C17 1.4999(19) . ?

C16 H16A 0.9900 . ?

C16 H16B 0.9900 . ?

C17 C18 1.324(2) . ?

C17 H17 0.9500 . ?

C18 C19 1.4927(19) . ?

C18 H18 0.9500 . ?

C19 O3 1.4279(16) . ?

C19 H19A 0.9900 . ?

C19 H19B 0.9900 . ?

C20 O3 1.4189(16) . ?

C20 C21 1.5096(19) . ?

C20 H20A 0.9900 . ?

C20 H20B 0.9900 . ?

C21 O4 1.2115(17) . ?

C21 C22 1.5172(18) . ?

C22 H22A 0.9900 . ?

C22 H22B 0.9900 . ?

C2 C1 C6 122.13(12) . . ?

C2 C1 S1 125.57(10) . . ?

C6 C1 S1 112.30(10) . . ?

C3 C2 C1 117.03(12) . . ?

C3 C2 C22 121.23(12) . . ?

C1 C2 C22 121.71(12) . . ?

C2 C3 C4 121.89(13) . . ?

C2 C3 H3 119.1 . . ?

C4 C3 H3 119.1 . . ?

C5 C4 C3 120.34(12) . . ?

C5 C4 H4 119.8 . . ?

C3 C4 H4 119.8 . . ?

C4 C5 C6 119.37(12) . . ?

C4 C5 H5 120.3 . . ?

C6 C5 H5 120.3 . . ?

C5 C6 C1 119.24(12) . . ?

C5 C6 C7 128.70(12) . . ?

C1 C6 C7 112.06(11) . . ?

C8 C7 C12 119.21(12) . . ?

C8 C7 C6 128.89(12) . . ?

C12 C7 C6 111.90(12) . . ?

C9 C8 C7 119.29(12) . . ?

C9 C8 H8 120.4 . . ?

C7 C8 H8 120.4 . . ?

C8 C9 C10 120.78(13) . . ?

C8 C9 H9 119.6 . . ?

C10 C9 H9 119.6 . . ?

C11 C10 C9 121.48(12) . . ?

C11 C10 H10 119.3 . . ?

C9 C10 H10 119.3 . . ?

C10 C11 C12 117.19(12) . . ?

C10 C11 C13 121.10(12) . . ?

C12 C11 C13 121.61(12) . . ?

C11 C12 C7 122.05(12) . . ?

C11 C12 S1 125.48(10) . . ?

C7 C12 S1 112.45(10) . . ?

C11 C13 C14 115.14(11) . . ?

C11 C13 H13A 108.5 . . ?

C14 C13 H13A 108.5 . . ?

C11 C13 H13B 108.5 . . ?

C14 C13 H13B 108.5 . . ?

H13A C13 H13B 107.5 . . ?

O1 C14 C15 121.84(12) . . ?

O1 C14 C13 120.91(12) . . ?

C15 C14 C13 117.25(11) . . ?

O2 C15 C14 113.42(11) . . ?

O2 C15 H15A 108.9 . . ?

C14 C15 H15A 108.9 . . ?

O2 C15 H15B 108.9 . . ?

C14 C15 H15B 108.9 . . ?

H15A C15 H15B 107.7 . . ?

O2 C16 C17 112.49(11) . . ?

O2 C16 H16A 109.1 . . ?

C17 C16 H16A 109.1 . . ?

O2 C16 H16B 109.1 . . ?

C17 C16 H16B 109.1 . . ?

H16A C16 H16B 107.8 . . ?

C18 C17 C16 123.08(13) . . ?

C18 C17 H17 118.5 . . ?

C16 C17 H17 118.5 . . ?

C17 C18 C19 125.01(13) . . ?

C17 C18 H18 117.5 . . ?

C19 C18 H18 117.5 . . ?

O3 C19 C18 107.87(11) . . ?

O3 C19 H19A 110.1 . . ?

C18 C19 H19A 110.1 . . ?

O3 C19 H19B 110.1 . . ?

C18 C19 H19B 110.1 . . ?

H19A C19 H19B 108.4 . . ?

O3 C20 C21 111.29(11) . . ?

O3 C20 H20A 109.4 . . ?

C21 C20 H20A 109.4 . . ?

O3 C20 H20B 109.4 . . ?

C21 C20 H20B 109.4 . . ?

H20A C20 H20B 108.0 . . ?

O4 C21 C20 119.00(12) . . ?

O4 C21 C22 121.81(12) . . ?

C20 C21 C22 119.14(11) . . ?

C2 C22 C21 110.87(11) . . ?

C2 C22 H22A 109.5 . . ?

C21 C22 H22A 109.5 . . ?

C2 C22 H22B 109.5 . . ?

C21 C22 H22B 109.5 . . ?

H22A C22 H22B 108.1 . . ?

C15 O2 C16 113.44(10) . . ?

C20 O3 C19 111.50(10) . . ?

C12 S1 C1 91.27(6) . . ?

C6 C1 C2 C3 0.13(19) . . . . ?

Table 6. Torsion angles [°] for MB-4-464.

S1 C1 C2 C3 179.28(10) . . . . ?

C6 C1 C2 C22 -177.91(12) . . . . ?

S1 C1 C2 C22 1.24(18) . . . . ?

C1 C2 C3 C4 0.17(19) . . . . ?

C22 C2 C3 C4 178.21(12) . . . . ?

C2 C3 C4 C5 -0.1(2) . . . . ?

C3 C4 C5 C6 -0.3(2) . . . . ?

C4 C5 C6 C1 0.59(19) . . . . ?

C4 C5 C6 C7 -178.81(13) . . . . ?

C2 C1 C6 C5 -0.51(19) . . . . ?

S1 C1 C6 C5 -179.76(10) . . . . ?

C2 C1 C6 C7 178.99(12) . . . . ?

S1 C1 C6 C7 -0.27(14) . . . . ?

C5 C6 C7 C8 -1.6(2) . . . . ?

C1 C6 C7 C8 179.01(13) . . . . ?

C5 C6 C7 C12 178.75(13) . . . . ?

C1 C6 C7 C12 -0.69(16) . . . . ?

C12 C7 C8 C9 0.20(19) . . . . ?

C6 C7 C8 C9 -179.49(13) . . . . ?

C7 C8 C9 C10 -0.3(2) . . . . ?

C8 C9 C10 C11 0.4(2) . . . . ?

C9 C10 C11 C12 -0.39(19) . . . . ?

C9 C10 C11 C13 176.13(12) . . . . ?

C10 C11 C12 C7 0.30(19) . . . . ?

C13 C11 C12 C7 -176.20(12) . . . . ?

C10 C11 C12 S1 178.23(10) . . . . ?

C13 C11 C12 S1 1.73(18) . . . . ?

C8 C7 C12 C11 -0.21(19) . . . . ?

C6 C7 C12 C11 179.52(12) . . . . ?

C8 C7 C12 S1 -178.38(10) . . . . ?

C6 C7 C12 S1 1.35(14) . . . . ?

C10 C11 C13 C14 -90.30(15) . . . . ?

C12 C11 C13 C14 86.06(15) . . . . ?

C11 C13 C14 O1 169.44(12) . . . . ?

C11 C13 C14 C15 -10.23(17) . . . . ?

O1 C14 C15 O2 -2.24(18) . . . . ?

C13 C14 C15 O2 177.42(11) . . . . ?

O2 C16 C17 C18 -121.69(14) . . . . ?

C16 C17 C18 C19 -178.11(12) . . . . ?

C17 C18 C19 O3 -130.70(14) . . . . ?

O3 C20 C21 O4 177.88(12) . . . . ?

O3 C20 C21 C22 0.44(17) . . . . ?

C3 C2 C22 C21 55.32(16) . . . . ?

C1 C2 C22 C21 -126.73(13) . . . . ?

O4 C21 C22 C2 -91.59(15) . . . . ?

C20 C21 C22 C2 85.77(14) . . . . ?

C14 C15 O2 C16 81.28(13) . . . . ?

C17 C16 O2 C15 65.56(14) . . . . ?

C21 C20 O3 C19 -175.57(11) . . . . ?

C18 C19 O3 C20 -169.59(11) . . . . ?

C11 C12 S1 C1 -179.38(12) . . . . ?

C7 C12 S1 C1 -1.28(10) . . . . ?

C2 C1 S1 C12 -178.35(12) . . . . ?

C6 C1 S1 C12 0.87(10) . . . . ?

Table 1. Crystal data and structure refinement for **216**.

Identification code	MB-4-560	
Empirical formula	$C_{18}H_{12}OS_2$	
Formula weight	308.40	
Temperature	100.01(10) K	
Wavelength	1.5418 Å	
Crystal system	Monoclinic	
Space group	P $2_1/c$	
Unit cell dimensions	a = 15.8775(4) Å	□= 90°.
	b = 14.1420(2) Å	□= 115.825(3)°.
	c = 13.9094(3) Å	□ = 90°.
Volume	2811.29(12) $Å^3$	
Z	8	
Density (calculated)	1.457 Mg/m^3	
Absorption coefficient	3.378 mm^{-1}	
F(000)	1280	
Crystal size	0.340 × 0.200 × 0.100 mm^3	
Theta range for data collection	6.364 to 74.461°.	
Index ranges	-19<=h<=17, -17<=k<=12, -16<=l<=17	
Reflections collected	13662	
Independent reflections	5420 [R(int) = 0.0254]	
Completeness to theta = 67.684°	96.9 %	
Absorption correction	Semi-empirical from equivalents	
Max. and min. transmission	1.00000 and 0.66201	
Refinement method	Full-matrix least-squares on F^2	
Data / restraints / parameters	5420 / 0 / 379	
Goodness-of-fit on F^2	1.030	
Final R indices [I>2sigma(I)]	R1 = 0.0309, wR2 = 0.0776	
R indices (all data)	R1 = 0.0351, wR2 = 0.0813	
Extinction coefficient	n/a	
Largest diff. peak and hole	0.306 and -0.276 e.$Å^{-3}$	

Table 2. Atomic coordinates (x 10^4) and equivalent isotropic displacement parameters ($Å^2$x 10^3) for MB-4-560. U(eq) is defined as one third of the trace of the orthogonalized U^{ij} tensor.

	x	y	z	U(eq)

C(1)	4293(1)	3192(1)	3420(1)	17(1)
C(2)	3455(1)	3270(1)	3483(1)	20(1)
C(3)	3417(1)	3600(1)	4417(1)	22(1)
C(4)	4221(1)	3844(1)	5284(1)	21(1)
C(5)	5937(1)	3976(1)	6191(1)	23(1)
C(6)	6790(1)	3879(1)	6188(1)	25(1)
C(7)	6852(1)	3584(1)	5255(1)	23(1)
C(8)	6063(1)	3378(1)	4334(1)	19(1)
C(9)	5155(1)	3434(1)	4311(1)	17(1)
C(10)	5104(1)	3757(1)	5263(1)	19(1)
C(11)	5193(1)	3247(1)	2108(1)	18(1)
C(12)	4983(1)	4302(1)	1877(1)	18(1)
C(13)	4345(1)	4608(1)	765(1)	18(1)
C(14)	4117(1)	5566(1)	597(1)	22(1)
C(15)	3546(1)	5896(1)	-419(1)	26(1)
C(16)	3196(1)	5275(1)	-1278(1)	26(1)
C(17)	3423(1)	4321(1)	-1120(1)	26(1)
C(18)	3998(1)	3986(1)	-103(1)	21(1)
O(1)	5311(1)	4870(1)	2599(1)	27(1)
S(1)	4216(1)	2683(1)	2224(1)	19(1)
S(2)	6278(1)	3003(1)	3251(1)	22(1)
C(101)	-742(1)	3112(1)	8781(1)	21(1)
C(102)	-1520(1)	3204(1)	8973(1)	27(1)
C(103)	-1462(1)	3631(1)	9911(2)	32(1)
C(104)	-633(1)	3992(1)	10642(1)	29(1)
C(105)	1053(1)	4270(1)	11262(1)	27(1)
C(106)	1846(1)	4190(1)	11122(1)	28(1)
C(107)	1824(1)	3727(1)	10216(1)	24(1)
C(108)	1008(1)	3348(1)	9461(1)	20(1)
C(109)	148(1)	3445(1)	9548(1)	19(1)
C(110)	190(1)	3910(1)	10488(1)	22(1)
C(111)	27(1)	2885(1)	7333(1)	21(1)
C(112)	4(1)	3911(1)	6962(1)	21(1)
C(113)	676(1)	4183(1)	6526(1)	20(1)
C(114)	734(1)	5139(1)	6308(1)	23(1)

C(115)	1362(1)	5435(1)	5921(1)	26(1)
C(116)	1931(1)	4784(1)	5743(1)	27(1)
C(117)	1865(1)	3829(1)	5934(1)	25(1)
C(118)	1240(1)	3529(1)	6322(1)	21(1)
O(101)	-540(1)	4473(1)	7038(1)	29(1)
S(101)	-955(1)	2544(1)	7565(1)	25(1)
S(102)	1126(1)	2644(1)	8483(1)	23(1)

Table 3. Bond lengths [Å] and angles [°] for MB-4-560.

C(1)-C(2)	1.376(2)
C(1)-C(9)	1.432(2)
C(1)-S(1)	1.7669(15)
C(2)-C(3)	1.406(2)
C(2)-H(2)	0.9500
C(3)-C(4)	1.366(2)
C(3)-H(3)	0.9500
C(4)-C(10)	1.420(2)
C(4)-H(4)	0.9500
C(5)-C(6)	1.364(2)
C(5)-C(10)	1.422(2)
C(5)-H(5)	0.9500
C(6)-C(7)	1.406(2)
C(6)-H(6)	0.9500
C(7)-C(8)	1.377(2)
C(7)-H(7)	0.9500
C(8)-C(9)	1.429(2)
C(8)-S(2)	1.7664(16)
C(9)-C(10)	1.437(2)
C(11)-C(12)	1.532(2)
C(11)-S(2)	1.7966(15)
C(11)-S(1)	1.8141(15)
C(11)-H(11)	1.0000
C(12)-O(1)	1.2122(19)
C(12)-C(13)	1.496(2)
C(13)-C(14)	1.395(2)
C(13)-C(18)	1.399(2)
C(14)-C(15)	1.386(2)
C(14)-H(14)	0.9500
C(15)-C(16)	1.389(2)
C(15)-H(15)	0.9500
C(16)-C(17)	1.388(3)
C(16)-H(16)	0.9500
C(17)-C(18)	1.390(2)
C(17)-H(17)	0.9500

C(18)-H(18)	0.9500
C(101)-C(102)	1.378(2)
C(101)-C(109)	1.429(2)
C(101)-S(101)	1.7682(17)
C(102)-C(103)	1.405(3)
C(102)-H(102)	0.9500
C(103)-C(104)	1.364(3)
C(103)-H(103)	0.9500
C(104)-C(110)	1.418(2)
C(104)-H(104)	0.9500
C(105)-C(106)	1.361(3)
C(105)-C(110)	1.418(2)
C(105)-H(105)	0.9500
C(106)-C(107)	1.407(2)
C(106)-H(106)	0.9500
C(107)-C(108)	1.372(2)
C(107)-H(107)	0.9500
C(108)-C(109)	1.429(2)
C(108)-S(102)	1.7611(16)
C(109)-C(110)	1.438(2)
C(111)-C(112)	1.535(2)
C(111)-S(101)	1.7906(16)
C(111)-S(102)	1.8127(16)
C(111)-H(111)	1.0000
C(112)-O(101)	1.2127(19)
C(112)-C(113)	1.489(2)
C(113)-C(114)	1.397(2)
C(113)-C(118)	1.399(2)
C(114)-C(115)	1.388(2)
C(114)-H(114)	0.9500
C(115)-C(116)	1.387(2)
C(115)-H(115)	0.9500
C(116)-C(117)	1.389(2)
C(116)-H(116)	0.9500
C(117)-C(118)	1.386(2)
C(117)-H(117)	0.9500
C(118)-H(118)	0.9500C(2)-C(1)-

C(9)	120.79(13)
C(2)-C(1)-S(1)	114.84(11)
C(9)-C(1)-S(1)	124.14(11)
C(1)-C(2)-C(3)	121.21(14)
C(1)-C(2)-H(2)	119.4
C(3)-C(2)-H(2)	119.4
C(4)-C(3)-C(2)	119.99(14)
C(4)-C(3)-H(3)	120.0
C(2)-C(3)-H(3)	120.0
C(3)-C(4)-C(10)	120.78(14)
C(3)-C(4)-H(4)	119.6
C(10)-C(4)-H(4)	119.6
C(6)-C(5)-C(10)	120.51(15)
C(6)-C(5)-H(5)	119.7
C(10)-C(5)-H(5)	119.7
C(5)-C(6)-C(7)	120.04(15)
C(5)-C(6)-H(6)	120.0
C(7)-C(6)-H(6)	120.0
C(8)-C(7)-C(6)	121.39(15)
C(8)-C(7)-H(7)	119.3
C(6)-C(7)-H(7)	119.3
C(7)-C(8)-C(9)	120.58(14)
C(7)-C(8)-S(2)	114.93(12)
C(9)-C(8)-S(2)	124.44(12)
C(8)-C(9)-C(1)	125.49(13)
C(8)-C(9)-C(10)	117.28(13)
C(1)-C(9)-C(10)	117.23(13)
C(4)-C(10)-C(5)	119.88(14)
C(4)-C(10)-C(9)	119.98(14)
C(5)-C(10)-C(9)	120.13(14)
C(12)-C(11)-S(2)	114.19(10)
C(12)-C(11)-S(1)	109.26(10)
S(2)-C(11)-S(1)	111.39(8)
C(12)-C(11)-H(11)	107.2
S(2)-C(11)-H(11)	107.2
S(1)-C(11)-H(11)	107.2
O(1)-C(12)-C(13)	121.14(14)

O(1)-C(12)-C(11)	119.75(14)
C(13)-C(12)-C(11)	119.08(13)
C(14)-C(13)-C(18)	119.35(14)
C(14)-C(13)-C(12)	117.60(14)
C(18)-C(13)-C(12)	123.02(14)
C(15)-C(14)-C(13)	120.31(15)
C(15)-C(14)-H(14)	119.8
C(13)-C(14)-H(14)	119.8
C(14)-C(15)-C(16)	120.18(15)
C(14)-C(15)-H(15)	119.9
C(16)-C(15)-H(15)	119.9
C(17)-C(16)-C(15)	119.94(15)
C(17)-C(16)-H(16)	120.0
C(15)-C(16)-H(16)	120.0
C(16)-C(17)-C(18)	120.21(15)
C(16)-C(17)-H(17)	119.9
C(18)-C(17)-H(17)	119.9
C(17)-C(18)-C(13)	120.02(15)
C(17)-C(18)-H(18)	120.0
C(13)-C(18)-H(18)	120.0
C(1)-S(1)-C(11)	101.11(7)
C(8)-S(2)-C(11)	103.30(7)
C(102)-C(101)-C(109)	120.14(15)
C(102)-C(101)-S(101)	114.46(13)
C(109)-C(101)-S(101)	125.38(12)
C(101)-C(102)-C(103)	121.30(16)
C(101)-C(102)-H(102)	119.4
C(103)-C(102)-H(102)	119.4
C(104)-C(103)-C(102)	120.26(15)
C(104)-C(103)-H(103)	119.9
C(102)-C(103)-H(103)	119.9
C(103)-C(104)-C(110)	120.69(16)
C(103)-C(104)-H(104)	119.7
C(110)-C(104)-H(104)	119.7
C(106)-C(105)-C(110)	120.66(15)
C(106)-C(105)-H(105)	119.7
C(110)-C(105)-H(105)	119.7

C(105)-C(106)-C(107)	120.19(16)
C(105)-C(106)-H(106)	119.9
C(107)-C(106)-H(106)	119.9
C(108)-C(107)-C(106)	120.95(15)
C(108)-C(107)-H(107)	119.5
C(106)-C(107)-H(107)	119.5
C(107)-C(108)-C(109)	121.08(14)
C(107)-C(108)-S(102)	115.41(12)
C(109)-C(108)-S(102)	123.18(12)
C(108)-C(109)-C(101)	125.13(14)
C(108)-C(109)-C(110)	116.93(14)
C(101)-C(109)-C(110)	117.94(14)
C(104)-C(110)-C(105)	120.31(15)
C(104)-C(110)-C(109)	119.58(15)
C(105)-C(110)-C(109)	120.10(15)
C(112)-C(111)-S(101)	114.88(11)
C(112)-C(111)-S(102)	110.33(11)
S(101)-C(111)-S(102)	111.70(8)
C(112)-C(111)-H(111)	106.5
S(101)-C(111)-H(111)	106.5
S(102)-C(111)-H(111)	106.5
O(101)-C(112)-C(113)	122.12(14)
O(101)-C(112)-C(111)	120.18(14)
C(113)-C(112)-C(111)	117.69(13)
C(114)-C(113)-C(118)	119.13(15)
C(114)-C(113)-C(112)	117.67(14)
C(118)-C(113)-C(112)	123.20(14)
C(115)-C(114)-C(113)	120.18(15)
C(115)-C(114)-H(114)	119.9
C(113)-C(114)-H(114)	119.9
C(114)-C(115)-C(116)	120.20(15)
C(114)-C(115)-H(115)	119.9
C(116)-C(115)-H(115)	119.9
C(115)-C(116)-C(117)	120.10(16)
C(115)-C(116)-H(116)	119.9
C(117)-C(116)-H(116)	119.9
C(118)-C(117)-C(116)	119.93(16)

C(118)-C(117)-H(117)	120.0
C(116)-C(117)-H(117)	120.0
C(117)-C(118)-C(113)	120.43(15)
C(117)-C(118)-H(118)	119.8
C(113)-C(118)-H(118)	119.8
C(101)-S(101)-C(111)	103.34(7)
C(108)-S(102)-C(111)	100.92(7)

Symmetry transformations used to generate equivalent atoms:

Table 4. Anisotropic displacement parameters ($Å^2$x 10^3)for MB-4-560. The anisotropic displacement factor exponent takes the form: $-2\pi^2[h^2a^{*2}U^{11} + ... + 2 h k a^* b^* U^{12}]$

	U^{11}	U^{22}	U^{33}	U^{23}	U^{13}	U^{12}
C(1)	22(1)	14(1)	17(1)	2(1)	10(1)	0(1)
C(2)	21(1)	19(1)	19(1)	1(1)	9(1)	-2(1)
C(3)	25(1)	21(1)	26(1)	3(1)	17(1)	0(1)
C(4)	31(1)	17(1)	21(1)	1(1)	16(1)	-1(1)
C(5)	33(1)	19(1)	17(1)	1(1)	9(1)	-3(1)
C(6)	27(1)	21(1)	19(1)	3(1)	3(1)	-4(1)
C(7)	20(1)	21(1)	26(1)	5(1)	7(1)	0(1)
C(8)	22(1)	15(1)	20(1)	3(1)	9(1)	1(1)
C(9)	21(1)	14(1)	17(1)	3(1)	8(1)	0(1)
C(10)	27(1)	14(1)	17(1)	3(1)	10(1)	-2(1)
C(11)	19(1)	21(1)	17(1)	0(1)	9(1)	0(1)
C(12)	20(1)	20(1)	19(1)	-1(1)	12(1)	-2(1)
C(13)	16(1)	22(1)	19(1)	0(1)	11(1)	-1(1)
C(14)	22(1)	23(1)	23(1)	-1(1)	13(1)	1(1)
C(15)	24(1)	26(1)	31(1)	6(1)	15(1)	6(1)
C(16)	17(1)	37(1)	22(1)	6(1)	8(1)	2(1)
C(17)	22(1)	32(1)	21(1)	-3(1)	7(1)	-5(1)
C(18)	21(1)	23(1)	22(1)	-2(1)	11(1)	-4(1)
O(1)	40(1)	21(1)	19(1)	-3(1)	12(1)	-2(1)
S(1)	21(1)	20(1)	17(1)	-3(1)	10(1)	-4(1)
S(2)	19(1)	27(1)	23(1)	2(1)	11(1)	5(1)
C(101)	22(1)	17(1)	26(1)	6(1)	13(1)	2(1)
C(102)	21(1)	28(1)	36(1)	13(1)	16(1)	3(1)
C(103)	33(1)	33(1)	44(1)	20(1)	30(1)	14(1)
C(104)	42(1)	24(1)	32(1)	13(1)	27(1)	14(1)
C(105)	42(1)	18(1)	20(1)	4(1)	12(1)	5(1)
C(106)	30(1)	24(1)	23(1)	5(1)	5(1)	-2(1)
C(107)	21(1)	26(1)	25(1)	9(1)	9(1)	3(1)
C(108)	22(1)	19(1)	20(1)	6(1)	12(1)	4(1)
C(109)	22(1)	16(1)	21(1)	6(1)	13(1)	3(1)

C(110)	32(1)	17(1)	23(1)	8(1)	16(1)	7(1)
C(111)	25(1)	22(1)	19(1)	0(1)	11(1)	1(1)
C(112)	24(1)	20(1)	16(1)	-1(1)	7(1)	0(1)
C(113)	23(1)	20(1)	14(1)	-2(1)	6(1)	-2(1)
C(114)	26(1)	20(1)	20(1)	-1(1)	7(1)	-1(1)
C(115)	31(1)	20(1)	27(1)	1(1)	11(1)	-5(1)
C(116)	30(1)	28(1)	26(1)	-2(1)	15(1)	-7(1)
C(117)	30(1)	25(1)	23(1)	-2(1)	14(1)	-1(1)
C(118)	27(1)	19(1)	18(1)	-1(1)	10(1)	-2(1)
O(101)	38(1)	25(1)	34(1)	5(1)	24(1)	8(1)
S(101)	24(1)	24(1)	27(1)	-1(1)	10(1)	-6(1)
S(102)	24(1)	27(1)	23(1)	5(1)	14(1)	9(1)

Table 5. Hydrogen coordinates (x 10^4) and isotropic displacement parameters ($Å^2$x 10^3) for MB-4-560.

	x	y	z	U(eq)
H(2)	2892	3097	2886	23
H(3)	2831	3653	4444	26
H(4)	4190	4075	5909	26
H(5)	5898	4192	6817	28
H(6)	7344	4012	6817	30
H(7)	7450	3524	5261	28
H(11)	5238	2965	1472	22
H(14)	4354	5993	1182	26
H(15)	3393	6549	-528	31
H(16)	2803	5502	-1973	31
H(17)	3185	3897	-1708	31
H(18)	4155	3333	1	26
H(102)	-2106	2974	8461	32
H(103)	-2003	3668	10038	38
H(104)	-607	4303	11260	34
H(105)	1077	4570	11884	33
H(106)	2417	4447	11638	34
H(107)	2381	3676	10125	29
H(111)	14	2474	6742	26
H(114)	342	5587	6424	27
H(115)	1401	6086	5778	32
H(116)	2368	4991	5490	33
H(117)	2247	3383	5799	30
H(118)	1195	2876	6450	26

Table 6. Torsion angles [°] for **216**

C(9)-C(1)-C(2)-C(3)	0.9(2)
S(1)-C(1)-C(2)-C(3)	175.48(12)
C(1)-C(2)-C(3)-C(4)	-0.4(2)
C(2)-C(3)-C(4)-C(10)	-0.9(2)
C(10)-C(5)-C(6)-C(7)	1.6(2)
C(5)-C(6)-C(7)-C(8)	-0.6(2)
C(6)-C(7)-C(8)-C(9)	-1.8(2)
C(6)-C(7)-C(8)-S(2)	-179.21(12)
C(7)-C(8)-C(9)-C(1)	-176.66(14)
S(2)-C(8)-C(9)-C(1)	0.5(2)
C(7)-C(8)-C(9)-C(10)	3.0(2)
S(2)-C(8)-C(9)-C(10)	-179.80(11)
C(2)-C(1)-C(9)-C(8)	179.75(15)
S(1)-C(1)-C(9)-C(8)	5.7(2)
C(2)-C(1)-C(9)-C(10)	0.1(2)
S(1)-C(1)-C(9)-C(10)	-174.04(11)
C(3)-C(4)-C(10)-C(5)	-177.24(14)
C(3)-C(4)-C(10)-C(9)	1.8(2)
C(6)-C(5)-C(10)-C(4)	178.79(15)
C(6)-C(5)-C(10)-C(9)	-0.3(2)
C(8)-C(9)-C(10)-C(4)	178.92(14)
C(1)-C(9)-C(10)-C(4)	-1.4(2)
C(8)-C(9)-C(10)-C(5)	-2.0(2)
C(1)-C(9)-C(10)-C(5)	177.69(13)
S(2)-C(11)-C(12)-O(1)	-26.38(18)
S(1)-C(11)-C(12)-O(1)	99.11(15)
S(2)-C(11)-C(12)-C(13)	155.76(10)
S(1)-C(11)-C(12)-C(13)	-78.75(14)
O(1)-C(12)-C(13)-C(14)	-2.1(2)
C(11)-C(12)-C(13)-C(14)	175.71(13)
O(1)-C(12)-C(13)-C(18)	175.88(14)
C(11)-C(12)-C(13)-C(18)	-6.3(2)
C(18)-C(13)-C(14)-C(15)	0.5(2)
C(12)-C(13)-C(14)-C(15)	178.59(13)
C(13)-C(14)-C(15)-C(16)	0.0(2)

C(14)-C(15)-C(16)-C(17)	-0.3(2)
C(15)-C(16)-C(17)-C(18)	0.2(2)
C(16)-C(17)-C(18)-C(13)	0.4(2)
C(14)-C(13)-C(18)-C(17)	-0.7(2)
C(12)-C(13)-C(18)-C(17)	-178.66(14)
C(2)-C(1)-S(1)-C(11)	151.00(12)
C(9)-C(1)-S(1)-C(11)	-34.59(14)
C(12)-C(11)-S(1)-C(1)	-68.18(11)
S(2)-C(11)-S(1)-C(1)	58.91(9)
C(7)-C(8)-S(2)-C(11)	-158.07(12)
C(9)-C(8)-S(2)-C(11)	24.62(15)
C(12)-C(11)-S(2)-C(8)	69.33(12)
S(1)-C(11)-S(2)-C(8)	-55.03(10)
C(109)-C(101)-C(102)-C(103)	0.7(2)
S(101)-C(101)-C(102)-C(103)	179.30(13)
C(101)-C(102)-C(103)-C(104)	2.1(3)
C(102)-C(103)-C(104)-C(110)	-2.5(2)
C(110)-C(105)-C(106)-C(107)	-1.5(2)
C(105)-C(106)-C(107)-C(108)	-0.2(2)
C(106)-C(107)-C(108)-C(109)	2.7(2)
C(106)-C(107)-C(108)-S(102)	-170.99(12)
C(107)-C(108)-C(109)-C(101)	177.10(15)
S(102)-C(108)-C(109)-C(101)	-9.7(2)
C(107)-C(108)-C(109)-C(110)	-3.3(2)
S(102)-C(108)-C(109)-C(110)	169.82(11)
C(102)-C(101)-C(109)-C(108)	176.79(15)
S(101)-C(101)-C(109)-C(108)	-1.7(2)
C(102)-C(101)-C(109)-C(110)	-2.8(2)
S(101)-C(101)-C(109)-C(110)	178.76(11)
C(103)-C(104)-C(110)-C(105)	-178.64(15)
C(103)-C(104)-C(110)-C(109)	0.3(2)
C(106)-C(105)-C(110)-C(104)	179.67(15)
C(106)-C(105)-C(110)-C(109)	0.7(2)
C(108)-C(109)-C(110)-C(104)	-177.32(14)
C(101)-C(109)-C(110)-C(104)	2.3(2)
C(108)-C(109)-C(110)-C(105)	1.7(2)
C(101)-C(109)-C(110)-C(105)	-178.73(14)

S(101)-C(111)-C(112)-O(101)	14.04(19)
S(102)-C(111)-C(112)-O(101)	-113.30(15)
S(101)-C(111)-C(112)-C(113)	-166.76(11)
S(102)-C(111)-C(112)-C(113)	65.90(15)
O(101)-C(112)-C(113)-C(114)	6.7(2)
C(111)-C(112)-C(113)-C(114)	-172.52(13)
O(101)-C(112)-C(113)-C(118)	-172.87(15)
C(111)-C(112)-C(113)-C(118)	8.0(2)
C(118)-C(113)-C(114)-C(115)	-1.8(2)
C(112)-C(113)-C(114)-C(115)	178.69(14)
C(113)-C(114)-C(115)-C(116)	0.4(2)
C(114)-C(115)-C(116)-C(117)	1.1(3)
C(115)-C(116)-C(117)-C(118)	-1.2(3)
C(116)-C(117)-C(118)-C(113)	-0.2(2)
C(114)-C(113)-C(118)-C(117)	1.7(2)
C(112)-C(113)-C(118)-C(117)	-178.82(14)
C(102)-C(101)-S(101)-C(111)	161.05(12)
C(109)-C(101)-S(101)-C(111)	-20.40(15)
C(112)-C(111)-S(101)-C(101)	-74.35(12)
S(102)-C(111)-S(101)-C(101)	52.29(10)
C(107)-C(108)-S(102)-C(111)	-147.12(12)
C(109)-C(108)-S(102)-C(111)	39.37(14)
C(112)-C(111)-S(102)-C(108)	68.68(12)
S(101)-C(111)-S(102)-C(108)	-60.39(10)

Symmetry transformations used to generate equivalent atoms:

Table 1 Crystal data and structure refinement for **230**.

Identification code	MB-7-1424P
Empirical formula	$C_{29}H_{30}OS_2$
Formula weight	458.65
Temperature/K	99.97(13)
Crystal system	monoclinic
Space group	C2/c
a/Å	18.6964(3)
b/Å	11.3269(2)
c/Å	22.8717(4)
α/°	90
β/°	93.2236(18)
γ/°	90
Volume/Å^3	4835.93(14)
Z	8
ρ_{calc}g/cm^3	1.260
μ/mm^{-1}	2.129
F(000)	1952.0
Crystal size/mm^3	0.183 × 0.0399 × 0.0379
Radiation	CuKα (λ = 1.54184)
2Θ range for data collection/°	7.744 to 136.454
Index ranges	$-22 \leq h \leq 22$, $-9 \leq k \leq 13$, $-18 \leq l \leq 27$
Reflections collected	9586
Independent reflections	4425 [R_{int} = 0.0328, R_{sigma} = 0.0395]
Data/restraints/parameters	4425/0/291
Goodness-of-fit on F^2	1.075
Final R indexes [I>=2σ (I)]	R_1 = 0.0353, wR_2 = 0.0823
Final R indexes [all data]	R_1 = 0.0446, wR_2 = 0.0867
Largest diff. peak/hole / e Å^{-3}	0.35/-0.23

Table 2 Fractional Atomic Coordinates (×10^4) and Equivalent Isotropic Displacement Parameters (Å^2×10^3) for MB-7-1424P. U_{eq} is defined as 1/3 of of the trace of the orthogonalised U_{IJ} tensor.

Atom	***x***	***y***	***z***	**U(eq)**
C1	1317.6(9)	10008.2(15)	2880.8(7)	18.4(3)
C2	1029.4(9)	10687.9(16)	2411.1(8)	21.8(4)
C3	1406.3(10)	11593.4(17)	2166.8(8)	23.2(4)

C4	2095.4(9)	11857.2(16)	2391.4(7)	21.4(4)
C5	2388.9(9)	11188.4(15)	2850.4(7)	18.3(3)
C6	3129.9(9)	11355.4(15)	3134.5(7)	18.4(3)
C7	3164.9(9)	10372.2(15)	3578.9(7)	17.9(3)
C8	3758.2(9)	10074.1(16)	3939.9(7)	20.7(4)
C9	3723.5(9)	9088.0(16)	4298.9(8)	22.5(4)
C10	3097.8(9)	8430.6(16)	4296.6(8)	21.4(4)
C11	2497.7(9)	8722.2(15)	3933.2(7)	18.1(3)
C12	2523.6(9)	9706.1(15)	3561.5(7)	17.2(3)
C13	2022.6(9)	10239.3(15)	3103.0(7)	17.1(3)
C14	1009.1(9)	8659.8(16)	3856.0(8)	19.6(3)
C15	392.4(9)	8006.7(16)	4130.0(8)	21.6(4)
C16	222.7(9)	8259.6(15)	4745.7(8)	20.3(4)
C17	-437.9(10)	7854.6(16)	4926.8(8)	23.9(4)
C18	-635.1(10)	8069.6(17)	5490.9(8)	26.5(4)
C19	-169.7(11)	8666.3(17)	5884.1(8)	26.3(4)
C20	483.6(10)	9068.1(16)	5706.8(8)	25.1(4)
C21	677.6(9)	8878.5(16)	5139.6(8)	22.1(4)
C22	3707.4(9)	11202.8(16)	2679.6(8)	20.4(4)
C23	3761.2(9)	9974.0(16)	2413.1(8)	23.5(4)
C24	4250(1)	9973.1(18)	1903.3(8)	27.9(4)
C25	4444.6(11)	8742.0(19)	1701.4(9)	33.4(5)
C26	3216.2(9)	12595.6(16)	3411.6(8)	20.5(4)
C27	2678.9(10)	12897.6(16)	3864.9(8)	24.1(4)
C28	2776.2(11)	14138.5(18)	4106.3(9)	30.3(4)
C29	2245.9(13)	14460(2)	4561(1)	39.0(5)
O1	56.1(7)	7283.6(12)	3835.3(6)	28.4(3)
S1	718.6(2)	8904.4(4)	3099.0(2)	19.40(11)
S2	1785.8(2)	7702.9(4)	3962.8(2)	20.46(11)

Table 3 Anisotropic Displacement Parameters ($Å^2×10^3$) for MB-7-1424P. The Anisotropic displacement factor exponent takes the form: $-2\pi^2[h^2a^{*2}U_{11}+2hka^*b^*U_{12}+\ldots]$.

Atom	**U_{11}**	**U_{22}**	**U_{33}**	**U_{23}**	**U_{13}**	**U_{12}**
C1	19.0(8)	19.5(8)	16.9(8)	-2.5(7)	3.1(6)	0.3(6)
C2	18.7(8)	26.4(9)	20.0(8)	-1.4(7)	-1.6(7)	0.4(7)
C3	25.3(9)	25.6(9)	18.6(8)	2.5(7)	-1.0(7)	4.0(7)
C4	24.7(9)	21.8(9)	17.8(8)	1.9(7)	2.5(7)	-1.0(7)
C5	19.4(8)	20.5(8)	15.4(8)	-3.0(7)	4.0(6)	0.6(7)

C6	17.6(8)	19.1(8)	18.5(8)	-0.4(7)	1.5(6)	-0.9(6)
C7	18.4(8)	18.3(8)	17.1(8)	-2.9(7)	2.3(6)	-0.5(6)
C8	17.0(8)	23.1(9)	22.0(9)	-1.9(7)	-0.1(6)	-0.8(7)
C9	19.1(8)	25.9(9)	22.0(9)	-1.5(7)	-2.4(7)	2.8(7)
C10	22.8(8)	20.1(9)	21.2(8)	1.9(7)	0.8(7)	2.2(7)
C11	16.5(8)	20.1(8)	18.1(8)	-2.4(7)	3.2(6)	-0.2(6)
C12	16.8(8)	18.0(8)	16.9(8)	-3.1(6)	1.9(6)	0.8(6)
C13	18.7(8)	18.1(8)	14.8(8)	-2.4(6)	2.4(6)	1.0(6)
C14	18.2(8)	19.8(8)	20.9(8)	-0.4(7)	0.8(6)	-0.7(7)
C15	18.2(8)	21.4(9)	25.1(9)	1.0(7)	-0.8(7)	-0.7(7)
C16	20.6(8)	17.4(8)	22.9(9)	3.8(7)	0.3(7)	2.1(7)
C17	22.8(9)	23.2(9)	25.5(9)	1.9(7)	-0.7(7)	-1.9(7)
C18	27.1(9)	26.3(10)	26.8(10)	6.1(8)	6.5(7)	-0.4(8)
C19	37.4(10)	22.6(9)	19.5(9)	2.9(7)	6.5(8)	4.0(8)
C20	32.1(10)	19.8(9)	22.7(9)	3.1(7)	-3.0(7)	-0.4(7)
C21	21.7(8)	19.0(9)	25.4(9)	2.4(7)	0.0(7)	0.4(7)
C22	18.6(8)	21.3(9)	21.7(9)	1.1(7)	3.5(7)	-2.3(7)
C23	21.3(8)	23.0(9)	26.4(9)	-1.1(7)	2.8(7)	-1.6(7)
C24	28.7(9)	30.1(10)	25.4(9)	-2.9(8)	6.6(8)	-3.3(8)
C25	29.7(10)	36.1(11)	35.1(11)	-12.7(9)	8.0(8)	-3.5(8)
C26	19.7(8)	19.5(8)	22.1(8)	0.8(7)	0.0(7)	-2.7(7)
C27	25.0(9)	21.4(9)	25.8(9)	-1.5(7)	1.2(7)	-0.9(7)
C28	34.3(10)	25(1)	31.6(10)	-4.1(8)	1.2(8)	-0.7(8)
C29	53.4(13)	30.5(11)	33.6(11)	-9.1(9)	7.7(10)	5(1)
O1	25.3(6)	31.6(7)	28.4(7)	-5.8(6)	4.1(5)	-10.5(6)
S1	17.4(2)	21.7(2)	18.9(2)	-0.43(16)	-1.09(15)	-2.57(15)
S2	18.1(2)	18.2(2)	25.0(2)	3.25(16)	0.75(15)	-1.14(15)

Table 4 Bond Lengths for MB-7-1424P.

Atom	**Atom**	**Length/Å**	**Atom**	**Atom**	**Length/Å**
C1	C2	1.404(2)	C12	C13	1.494(2)
C1	C13	1.410(2)	C14	C15	1.533(2)
C1	S1	1.7690(17)	C14	S1	1.8066(18)
C2	C3	1.380(3)	C14	S2	1.8175(17)
C3	C4	1.392(3)	C15	C16	1.489(3)
C4	C5	1.383(3)	C15	O1	1.214(2)
C5	C6	1.509(2)	C16	C17	1.402(2)
C5	C13	1.415(2)	C16	C21	1.393(3)

C6	C7	1.507(2)	C17	C18	1.383(3)
C6	C22	1.550(2)	C18	C19	1.391(3)
C6	C26	1.546(2)	C19	C20	1.385(3)
C7	C8	1.387(2)	C20	C21	1.383(3)
C7	C12	1.415(2)	C22	C23	1.525(3)
C8	C9	1.390(3)	C23	C24	1.521(2)
C9	C10	1.386(3)	C24	C25	1.519(3)
C10	C11	1.398(2)	C26	C27	1.523(2)
C11	C12	1.404(2)	C27	C28	1.517(3)
C11	S2	1.7662(17)	C28	C29	1.521(3)

Table 5 Bond Angles for MB-7-1424P.

Atom	**Atom**	**Atom**	**Angle/°**	**Atom**	**Atom**	**Atom**	**Angle/°**
C2	C1	C13	118.98(16)	C11	C12	C13	134.77(15)
C2	C1	S1	112.43(13)	C1	C13	C5	117.24(15)
C13	C1	S1	128.55(14)	C1	C13	C12	135.60(16)
C3	C2	C1	122.31(16)	C5	C13	C12	107.16(14)
C2	C3	C4	119.53(16)	C15	C14	S1	105.85(12)
C5	C4	C3	118.82(16)	C15	C14	S2	105.72(12)
C4	C5	C6	125.01(16)	S1	C14	S2	114.52(9)
C4	C5	C13	123.07(16)	C16	C15	C14	119.93(15)
C13	C5	C6	111.91(15)	O1	C15	C14	118.47(16)
C5	C6	C22	110.76(14)	O1	C15	C16	121.59(16)
C5	C6	C26	111.26(14)	C17	C16	C15	117.05(16)
C7	C6	C5	101.64(14)	C21	C16	C15	123.63(16)
C7	C6	C22	111.39(14)	C21	C16	C17	119.32(17)
C7	C6	C26	113.30(14)	C18	C17	C16	120.23(18)
C26	C6	C22	108.42(14)	C17	C18	C19	119.91(17)
C8	C7	C6	125.77(15)	C20	C19	C18	120.02(17)
C8	C7	C12	122.34(16)	C21	C20	C19	120.36(18)
C12	C7	C6	111.75(15)	C20	C21	C16	120.13(17)
C7	C8	C9	119.01(16)	C23	C22	C6	115.72(14)
C10	C9	C8	119.79(16)	C24	C23	C22	111.28(15)
C9	C10	C11	121.62(17)	C25	C24	C23	113.45(16)
C10	C11	C12	119.58(16)	C27	C26	C6	115.20(14)
C10	C11	S2	113.84(13)	C28	C27	C26	112.69(16)
C12	C11	S2	126.43(13)	C27	C28	C29	113.65(17)
C7	C12	C13	107.52(15)	C1	S1	C14	102.58(8)

C11	C12	C7	117.66(15)	C11	S2	C14	101.72(8)		

Table 6 Torsion Angles for MB-7-1424P.

A	B	C	D	Angle/°	A	B	C	D	Angle/°
C1	C2	C3	C4	-0.4(3)	C12	C11	S2	C14	-38.01(16)
C2	C1	C13	C5	2.6(2)	C13	C1	C2	C3	-1.5(3)
C2	C1	C13	C12	-176.60(17)	C13	C1	S1	C14	27.48(17)
C2	C1	S1	C14	-154.74(13)	C13	C5	C6	C7	1.12(18)
C2	C3	C4	C5	1.0(3)	C13	C5	C6	C22	119.56(15)
C3	C4	C5	C6	179.15(16)	C13	C5	C6	C26	-119.78(16)
C3	C4	C5	C13	0.3(3)	C14	C15	C16	C17	165.47(16)
C4	C5	C6	C7	-177.82(16)	C14	C15	C16	C21	-13.8(3)
C4	C5	C6	C22	-59.4(2)	C15	C14	S1	C1	163.33(11)
C4	C5	C6	C26	61.3(2)	C15	C14	S2	C11	-156.11(12)
C4	C5	C13	C1	-2.1(2)	C15	C16	C17	C18	-179.25(17)
C4	C5	C13	C12	177.30(15)	C15	C16	C21	C20	-179.40(17)
C5	C6	C7	C8	175.59(16)	C16	C17	C18	C19	-1.5(3)
C5	C6	C7	C12	-0.11(18)	C17	C16	C21	C20	1.3(3)
C5	C6	C22	C23	-64.6(2)	C17	C18	C19	C20	1.5(3)
C5	C6	C26	C27	57.10(19)	C18	C19	C20	C21	-0.1(3)
C6	C5	C13	C1	178.90(14)	C19	C20	C21	C16	-1.3(3)
C6	C5	C13	C12	-1.66(18)	C21	C16	C17	C18	0.1(3)
C6	C7	C8	C9	-175.41(16)	C22	C6	C7	C8	57.6(2)
C6	C7	C12	C11	176.77(14)	C22	C6	C7	C12	-118.10(16)
C6	C7	C12	C13	-0.86(19)	C22	C6	C26	C27	179.13(15)
C6	C22	C23	C24	170.40(15)	C22	C23	C24	C25	168.23(16)
C6	C26	C27	C28	-178.18(15)	C26	C6	C7	C8	-65.0(2)
C7	C6	C22	C23	47.7(2)	C26	C6	C7	C12	119.35(16)
C7	C6	C26	C27	-56.7(2)	C26	C6	C22	C23	173.02(14)
C7	C8	C9	C10	-0.8(3)	C26	C27	C28	C29	-179.91(17)
C7	C12	C13	C1	-179.19(18)	O1	C15	C16	C17	-15.0(3)
C7	C12	C13	C5	1.53(18)	O1	C15	C16	C21	165.67(18)
C8	C7	C12	C11	0.9(2)	S1	C1	C2	C3	-179.48(14)
C8	C7	C12	C13	-176.73(15)	S1	C1	C13	C5	-179.72(13)
C8	C9	C10	C11	1.0(3)	S1	C1	C13	C12	1.1(3)
C9	C10	C11	C12	-0.2(3)	S1	C14	C15	C16	-143.74(14)
C9	C10	C11	S2	175.55(14)	S1	C14	C15	O1	36.8(2)
C10	C11	C12	C7	-0.7(2)	S1	C14	S2	C11	87.77(10)

C10	C11	C12	C13	176.11(17)	S2	C11 C12 C7	-175.91(12)
C10	C11	S2	C14	146.54(13)	S2	C11 C12 C13	0.9(3)
C11	C12	C13	C1	3.8(3)	S2	C14 C15 C16	94.38(16)
C11	C12	C13	C5	-175.51(18)	S2	C14 C15 O1	-85.12(18)
C12	C7	C8	C9	-0.1(3)	S2	C14 S1 C1	-80.62(11)

Table 7 Hydrogen Atom Coordinates (Å×10^4) and Isotropic Displacement Parameters (Å^2×10^3) for MB-7-1424P.

Atom	***x***	***y***	***z***	**U(eq)**
H2	568	10522	2259	26
H3	1201	12024	1854	28
H4	2354	12472	2236	26
H8	4173	10527	3942	25
H9	4119	8870	4540	27
H10	3077	7780	4543	26
H14	1099	9416	4055	24
H17	-745	7440	4667	29
H18	-1078	7815	5607	32
H19	-297	8796	6266	32
H20	793	9468	5971	30
H21	1113	9165	5021	27
H22A	3609	11763	2365	24
H22B	4170	11405	2867	24
H23A	3946	9427	2711	28
H23B	3287	9708	2277	28
H24A	4015	10394	1577	33
H24B	4687	10396	2019	33
H25A	4736	8800	1370	50
H25B	4015	8312	1592	50
H25C	4706	8336	2014	50
H26A	3695	12659	3595	25
H26B	3175	13179	3101	25
H27A	2198	12819	3687	29
H27B	2730	12337	4185	29
H28A	2725	14696	3785	36
H28B	3259	14215	4282	36
H29A	1767	14406	4389	58
H29B	2336	15252	4695	58

H29C	2300	13924	4886	58

Table 1 Crystal data and structure refinement for **369**.

Identification code	MB-6-985 Rx
Empirical formula	$C_{12}H_{12}O_2S$
Formula weight	220.28
Temperature/K	100.01(11)
Crystal system	triclinic
Space group	P-1
a/Å	6.2782(3)
b/Å	7.1917(3)
c/Å	12.4920(6)
α/°	86.275(4)
β/°	75.966(4)
γ/°	66.086(4)
Volume/Å^3	499.87(4)
Z	2
ρ_{calc}mg/mm^3	1.463
m/mm^{-1}	2.667
F(000)	232.0
Crystal size/mm^3	0.2526 × 0.171 × 0.0864
Radiation	CuKα (λ = 1.54184)
2Θ range for data collection	13.478 to 140.082°
Index ranges	$-7 \leq h \leq 7$, $-8 \leq k \leq 8$, $-14 \leq l \leq 15$
Reflections collected	7549
Independent reflections	1883 [R_{int} = 0.0222, R_{sigma} = 0.0169]
Data/restraints/parameters	1883/0/136
Goodness-of-fit on F^2	1.195
Final R indexes [I>=2σ (I)]	R_1 = 0.0394, wR_2 = 0.0983
Final R indexes [all data]	R_1 = 0.0403, wR_2 = 0.0986
Largest diff. peak/hole / e Å^{-3}	0.77/-0.32

Table 2 Fractional Atomic Coordinates (×10^4) and Equivalent Isotropic Displacement Parameters (Å^2×10^3) for MB-6-985 Rx. U_{eq} is defined as 1/3 of of the trace of the orthogonalised U_{IJ} tensor.

Atom	***x***	***y***	***z***	**U(eq)**
C1	4368(4)	7867(3)	3086.4(19)	13.9(5)
C2	1605(4)	8738(4)	3429(2)	18.3(5)
C3	719(4)	7042(4)	3511(2)	19.3(5)

C4	2712(4)	5098(4)	3766.6(19)	16.8(5)
C5	2999(5)	8817(4)	4227(2)	19.3(5)
C6	5672(4)	8914(3)	2295.7(19)	14.4(5)
C7	6621(4)	8150(3)	1118.3(19)	13.9(5)
C8	8768(4)	8236(4)	527(2)	15.9(5)
C9	9662(4)	7607(4)	-574(2)	17.9(5)
C10	8381(4)	6944(4)	-1110(2)	16.9(5)
C11	6226(4)	6874(4)	-529(2)	16.1(5)
C12	5361(4)	7450(3)	585.4(19)	14.7(5)
O1	7411(3)	4201(3)	3597.1(14)	18.5(4)
O2	5966(3)	10345(3)	2602.0(14)	20.0(4)
S1	5525.1(10)	5124.9(8)	2949.5(4)	13.30(16)

Table 3 Anisotropic Displacement Parameters ($Å^2×10^3$) for MB-6-985 Rx. The Anisotropic displacement factor exponent takes the form: $-2\pi^2[h^2a^{*2}U_{11}+2hka^*b^*U_{12}+\ldots]$.

Atom	**U_{11}**	**U_{22}**	**U_{33}**	**U_{23}**	**U_{13}**	**U_{12}**
C1	16.0(12)	11.1(11)	12.6(11)	0.0(8)	-3.0(9)	-3.7(9)
C2	14.9(12)	16.5(12)	16.8(12)	0.8(9)	1.5(9)	-2.6(10)
C3	15.1(12)	21.5(13)	19.2(12)	2.5(10)	-1.2(9)	-7(1)
C4	18.4(12)	18.2(12)	13.8(11)	1.9(9)	-1.0(9)	-9.1(10)
C5	23.6(13)	16.2(12)	15.0(12)	-2.7(9)	0.9(10)	-7.6(10)
C6	11.5(11)	12.3(11)	17.4(12)	2.3(9)	-4.4(9)	-2.5(9)
C7	13.5(11)	10.1(11)	16.5(12)	3.6(9)	-3.8(9)	-3.5(9)
C8	13.6(11)	13.5(11)	21.2(12)	3.7(9)	-5.9(9)	-5.5(9)
C9	12.6(11)	14.5(12)	21.8(13)	3.1(9)	1.3(9)	-4.0(9)
C10	18.5(12)	13.0(11)	13.9(12)	1.8(9)	-1.0(9)	-3.1(9)
C11	17.2(12)	14.9(12)	16.0(12)	2.4(9)	-6.1(9)	-5.3(10)
C12	11.5(11)	14.4(11)	17.2(12)	4.2(9)	-3.5(9)	-4.7(9)
O1	16.4(8)	19.2(9)	17.1(9)	4.3(7)	-5.0(7)	-4.4(7)
O2	22.8(9)	17.6(9)	20.3(9)	-0.1(7)	-3.5(7)	-9.7(7)
S1	14.5(3)	12.3(3)	11.1(3)	1.0(2)	-1.4(2)	-4.3(2)

Table 4 Bond Lengths for MB-6-985 Rx.

Atom	**Atom**	**Length/Å**	**Atom**	**Atom**	**Length/Å**
C1	C2	1.542(3)	C6	O2	1.217(3)
C1	C5	1.514(3)	C7	C8	1.395(3)
C1	C6	1.491(3)	C7	C12	1.394(3)

C1	S1	1.808(2)	C8	C9	1.382(3)
C2	C3	1.521(3)	C9	C10	1.391(4)
C2	C5	1.494(4)	C10	C11	1.391(3)
C3	C4	1.529(3)	C11	C12	1.389(3)
C4	S1	1.820(2)	O1	S1	1.5015(17)
C6	C7	1.495(3)			

Table 5 Bond Angles for MB-6-985 Rx.

Atom	**Atom**	**Atom**	**Angle/°**	**Atom**	**Atom**	**Atom**	**Angle/°**
C2	C1	S1	109.08(16)	O2	C6	C1	120.9(2)
C5	C1	C2	58.53(16)	O2	C6	C7	120.9(2)
C5	C1	S1	116.72(17)	C8	C7	C6	118.7(2)
C6	C1	C2	121.8(2)	C12	C7	C6	121.8(2)
C6	C1	C5	119.7(2)	C12	C7	C8	119.4(2)
C6	C1	S1	117.46(17)	C9	C8	C7	120.4(2)
C3	C2	C1	110.74(19)	C8	C9	C10	120.1(2)
C5	C2	C1	59.77(16)	C9	C10	C11	119.8(2)
C5	C2	C3	118.7(2)	C12	C11	C10	120.1(2)
C2	C3	C4	107.3(2)	C11	C12	C7	120.1(2)
C3	C4	S1	106.40(16)	C1	S1	C4	91.91(11)
C2	C5	C1	61.69(16)	O1	S1	C1	109.08(10)
C1	C6	C7	118.3(2)	O1	S1	C4	108.88(10)

Table 6 Torsion Angles for MB-6-985 Rx.

A	**B**	**C**	**D**	**Angle/°**	**A**	**B**	**C**	**D**	**Angle/°**
C1	C2	C3	C4	26.3(3)	C6	C1	C5	C2	111.2(2)
C1	C6	C7	C8	-145.8(2)	C6	C1	S1	C4	-162.54(19)
C1	C6	C7	C12	37.3(3)	C6	C1	S1	O1	86.73(19)
C2	C1	C6	C7	-99.6(3)	C6	C7	C8	C9	-177.8(2)
C2	C1	C6	O2	80.7(3)	C6	C7	C12	C11	175.9(2)
C2	C1	S1	C4	-18.61(17)	C7	C8	C9	C10	2.1(4)
C2	C1	S1	O1	-129.35(16)	C8	C7	C12	C11	-1.0(3)
C2	C3	C4	S1	-39.4(2)	C8	C9	C10	C11	-1.4(3)
C3	C2	C5	C1	98.5(2)	C9	C10	C11	C12	-0.5(3)
C3	C4	S1	C1	33.73(18)	C10	C11	C12	C7	1.7(3)
C3	C4	S1	O1	144.66(16)	C12	C7	C8	C9	-0.9(3)

C5	C1	C2	C3	-111.9(2)	O2	C6	C7	C8	33.9(3)
C5	C1	C6	C7	-168.9(2)	O2	C6	C7	C12	-143.0(2)
C5	C1	C6	O2	11.4(3)	S1	C1	C2	C3	-1.6(2)
C5	C1	S1	C4	45.0(2)	S1	C1	C2	C5	110.25(18)
C5	C1	S1	O1	-65.7(2)	S1	C1	C5	C2	-96.95(19)
C5	C2	C3	C4	-39.7(3)	S1	C1	C6	C7	39.5(3)
C6	C1	C2	C3	140.4(2)	S1	C1	C6	O2	-140.2(2)
C6	C1	C2	C5	-107.7(2)					

Table 7 Hydrogen Atom Coordinates (Å×10^4) and Isotropic Displacement Parameters (Å^2×10^3) for MB-6-985 Rx.

Atom	***x***	***y***	***z***	**U(eq)**
H2	692	10040	3103	22
H3A	359	6857	2807	23
H3B	-761	7379	4106	23
H4A	2509	3882	3563	20
H4B	2681	5074	4563	20
H5A	3070	7897	4854	23
H5B	2946	10162	4400	23
H8	9623	8729	884	19
H9	11152	7628	-964	21
H10	8978	6541	-1870	20
H11	5343	6432	-895	19
H12	3911	7366	985	18

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