Synthesis of functionalized 2-(arylthio)benzoates by cyclization of 3-arylthio-1-silyloxy-1,3-butadienes with 3-silyloxy-2-en-1-ones, 3-alkoxy-2-en-1-ones, 1,1-diacylcyclopropanes, and dimethyl acetylenedicarboxylate

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The ink of the scholar is more holy than the blood of the martyr.

Sayings of Prophet Muhammad S. A. W

People from the time of Adam onwards are as equal as the teeth of a comb. Arabs are not superior to non Arabs, nor are Redskinned people better than Blacks. No superiority or virture exists except in terms of Piety.

Sayings of Prophet Muhammad S. A. W

The best of men is he who refrains from that which does not concern him.

Sayings of Prophet Muhammad S. A. W

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Affectionately Dedicated to

"All my family, specially my beloved Parents and my nice teacher Prof. Maqsood Ilahi Naqshbandi"

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*In the name of **GOD**, Who is Ubiquitous, Omniscient, Worthy of all praise and Creator of all of us, Who guides in darkness and helps in difficulties.*

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I dedicate this work to my all family members, spacially my parents and my brother Muhammad Imran

The most important is, to say that I have a great debt on my life due to the enormous sacrifices of my parents for their divine love, prayers, constant care, encouragement and continuous support throughout my studies. Whatever, I am, that is because of the countless prayers of my parents, who instilled in me, a charm for education and the value of being organized.

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List of used abbreviations

Ar	Aromatic
APT	Attached proton test
ATCC	American Type Culture Collection
nBuLi	n-Butylithium
DEPT	Distortionless Enhancement by Polarisation Transfer
EI	Electronic Ionization
ESI	Electrospray Ionization
EtOAc	Ethylacetate
HRMS	High Resolution Mass Spectroscopy
IR	Infrared spectroscopy
LDA	Lithium diisopropylamide
MS	Mass Spectrometry
Ph	Phenyl
NEt_3	Triethylamine
NMR	Nuclear Magnetic Resolution
HMQC	Heteronuclear Multiple Quantum Coherence
HMBC	Heteronuclear Multiple Bond Correlation
COSY	Correlated Spectroscopy
NOESY	Nuclear Overhauser and Exchange Spectroscopy
Me_3SiOTf	Trimethylsilyl-trifluoro methanesulfonate
Me_3SiCl	Trimethylsilylchloride
mp.	Melting point

RCM	Ring Closing Metathesis
TBAI	Tetrabutyl amonium iodie
TFA	Trifluoroacetic acid
Tf_2O	Trifluoromethanesulfonic anhydride
THF	Tetrahydrofurane
TLC	Thin Layer Chromatography
TMS	Trimethylsilane
UV	Ultraviolet Spectroscopy

General Introduction

Because sulfur is directly below oxygen in the periodic table, these elements have similar electron configurations. As a result, sulfur forms many compounds that are analogs of oxygen compounds. There are four principal differences between the chemistry of sulfur and oxygen: O=O double bonds are much stronger than S=S double bonds. S-S single bonds are almost twice as strong as O-O single bonds. Sulfur (EN = 2.58) is much less electronegative than oxygen (EN = 3.44). Sulfur can expand its valence shell to hold more than eight electrons, but oxygen cannot.

The C-S bond is both longer, because S is larger, and weaker than C-C bonds. Selected bond lengths in sulfur compounds are 183 pm for the S-C single bond in methanethiol and 173 pm in thiophene.[1]

Some applications of sulphur can be summarized as follows: Sulfur is mostly used for the production of sulfuric acid, H_2SO_4. Most sulfur is mined using the Frasch process. Sulfur is, for example, used for the synthesis of sulfuric acid which is the most abundantly produced chemical in the United States and manufactured by the Contact process. Most (about 70%) of the sulfuric acid produced in the world is used in the fertilizer industry. Sulfuric acid can act as a strong acid, as a dehydrating agent, and as an oxidizing agent.

Although there is no known dietary requirement for inorganic sulfur, it is an essential element for all animal species as they all require the sulfur-containing amino acid methionine. There are three predominant forms of organic sulfur in animals and

humans: 1) the thiomethyl of methionine residues in proteins; 2) the disulfides present in proteins; and 3) sulfates present in glycosaminoglycans, steroids, and many xenobiotic metabolites. Thus, sulfur is an important constituent of amino acids, proteins, enzymes, vitamins and other biomolecules. Unlike mammalian species, plants can use inorganic sulfur for the biosynthesis of methionine from which are synthesized all the other important bioorganic sulfur compounds. Hence, sulfur deficiency occurs mainly when plants are grown in sulfur-depleted soils and when humans and animals consume low-protein diets. In recent time, the increasing prevalence of refining petroleum and the conversion of sulfur-containing metal salts and minerals into the free metals have a large impact on the balance of sulfur in the environment. Sulfur toxicity is associated mainly with high levels of volatile substances in the environment. Sulfur dioxide (SO_2), a major air pollutant, may adversely affect animal and human health by causing bronchitis, bronchoconstriction, and increased pulmonary resistance. Most organic sulfur compounds in the environment are naturally occurring, as a consequence of the fact that sulfur is essential for life and two amino acids contain this element.

Organosulfur compounds are often associated with foul odours, but ironically many of the sweetest compounds known are organosulfur derivatives. Nature abounds with organosulfur compounds—sulfur is essential for life. Two of the 20 common amino acids are organosulfur compounds. Fossil fuels, coal, petroleum, and natural gas, which are derived from ancient organisms, necessarily contain organosulfur compounds, the removal of which is a major focus of oil refineries.

Not all organosulfur compounds are foul-smelling pollutants. Compounds like allicin (chart 1) and ajoene (chart 2) are responsible for the odor of garlic, and lenthionine contributes to the flavor of shiitake mushrooms. Many of these natural products also

have important medicinal properties such as preventing platelet aggregation or fighting cancer. They are colourless liquids which have a distinctively pungent smell. These compounds exhibit antibacterial and anti-fungal properties.[2] The defence mechanism of garlic against attacks by certain diseases is based on Allicin.[3]

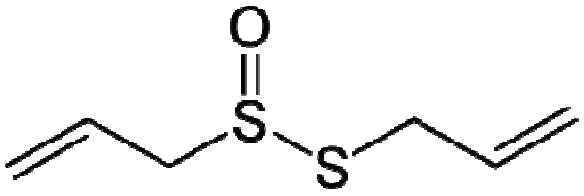


Chart 1. Structure of allicin

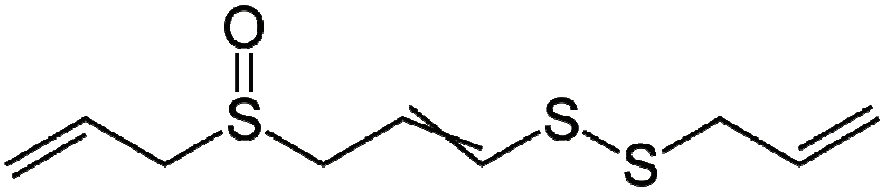


Chart 2. Structure of ajoene

Scientists have found that ajoene has many properties of interest to current medicine. It functions as an antioxidant, by inhibiting the release of superoxide. Ajoene also has antithrombotic (anti-clotting) properties, which helps to prevent platelets in the blood from forming blood clots, potentially reducing the risk of heart disease and stroke in humans. Ajoene is also known to have effective broad-spectrum antimicrobial (antibacterial and antifungal) properties, it is kn own to be helpful in preventing yeast infection (Candida albicans) and in treating athlete's foot (tinea pedis), for example. Ajoene has even been shown effective in inhibiting tumor cell growth by targeting the microtubule cytoskeleton of such cells.

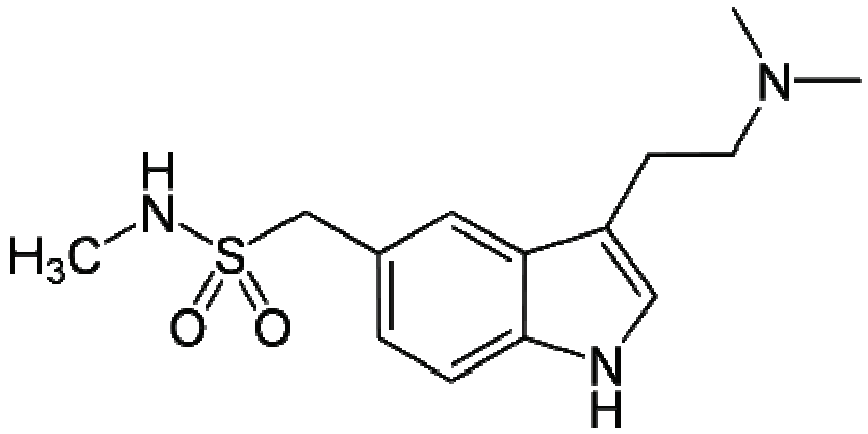


Chart 3. Structure of sumatriptan

Sumatriptan (Chart 3.) represents an sufonamide-substituted indole which is an important modern drug for the treatment of migraine. Some organosulfur compounds in the environment, are generated as minor by-products of industrial processes such as the manufacture of plastics and tires.

Because the role of elemental sulfur in human nutrition has not been studied extensively, it is the purpose of this introduction to emphasize the importance of this element for humans and to discuss the therapeutic applications of sulfur compounds in medicine. Sulfur is the sixth most abundant macromineral in breast milk and the third most abundant mineral based on percentage of total body weight. The sulfur-containing amino acids (SAAs) are methionine, cysteine, cystine, homocysteine, homocystine, and taurine. Dietary SAA analysis and protein supplementation may be indicated for vegan athletes, children, or patients with HIV, because of an increased risk for SAA deficiency in these groups. Methylsulfonylmethane (MSM), a volatile component in the sulfur cycle, is another source of sulfur found in the human diet.

Increases in serum sulfate may explain some of the therapeutic effects of MSM, DMSO, and glucosamine sulfate. Organic sulfur, as SAAs, can be used to increase synthesis of S-adenosylmethionine (SAMe), glutathione (GSH), taurine, and N-acetylcysteine (NAC). MSM may be effective for the treatment of allergy, pain syndromes, athletic injuries, and bladder disorders. Other sulfur compounds such as SAMe, dimethylsulfoxide (DMSO), taurine, glucosamine or chondroitin sulfate, and reduced glutathione may also have clinical applications in the treatment of a number of conditions such as depression, fibromyalgia, arthritis, interstitial cystitis, athletic injuries, congestive heart failure, diabetes, cancer, and AIDS. Dosages, mechanisms of action, and rationales for use are discussed. The low toxicological profiles of these sulfur compounds, combined with promising therapeutic effects, warrant continued human clinical trails.

Garlic has been used for centuries for disease prevention and treatment by several ethnic cultures. Epidemiologic investigations have found that risk of developing stomach, colon, and prostate cancers seems to be inversely related to garlic consumption.[4,5] Experimental animal and laboratory studies provide convincing evidence that garlic and some of its organosulfur components are effective inhibitors of a variety of cancers and cancer cells in culture, including those of breast, colon, skin, uterine, esophagus, and lung.[5,6] However, the specific component(s) of garlic that underlies the specific cellular and molecular events, which govern the anticancer properties, are not known with certainty. Depending on conditions of its cultivation, garlic can contain at least 33 different organosulfur compounds in addition to amino acids, vitamins, and micronutrients. The allyl sulfur compounds formed by enzymatic activity when garlic is minced or crushed, such as allicin, water-soluble S-allylmercaptocysteine (SAMC) and S-allylcysteine (SAC), and oil-soluble diallyl

disulfide (DADS) and diallyl sulfide (DAS), probably account for the majority of these anticancer effects.[7, 8]

Summary

A significant part of the present dissertation has been recently published. The work presented in this dissertation is concerned with the regioselective synthesis of functionalized 2-(arylthio)benzoates by cyclization of 3-arylthio-1-silyloxy-1,3-butadienes with 3-silyloxy-2-en-1-ones, 3-alkoxy-2-en-1-ones, 1,1-diacylcyclopropanes, and dimethyl acetylenedicarboxylate by formal [3+3] and [4+2] cyclization reactions mediated by $TiCl_4$.

1. The first chapter includes the synthesis of functionalized 2-(phenylthio)benzoates, containing halogenated side chain, by domino '[3+3] cyclization / Homo-Michael' reactions of 1-trimethylsilyloxy-3-arylthio-1,3-butadienes with 1,1-diacylcyclopropanes. In addition, 2-(phenylthio)benzoates are prepared by formal [3+3] cyclizations of1-trimethylsilyloxy-3-arylthio-1,3-butadienes with 3-silyloxy-2-en-1-ones. Some of the products were transformed into thioxanthones.

2. In the second chapter, a regioselective synthesis of 2-(arylthio)benzoates by the first [3+3] cyclizations of 3-arylthio-1-silyloxy-1,3-butadienes with 3-alkoxy-2-en-1-ones is reported.

3. In the third chapter, the synthesis of 5-arylthio-3-hydroxyphthalates by the first [4+2] cycloadditions of 3-arylthio-1-silyloxy-1,3-butadienes with dimethyl acetylenedicarboxylate is reported.

All products developed in this thesis allow for the efficient synthesis of highly functionalized organic sulfur compounds which are not readily available by other methods.

1. Synthesis of functionalized 2-(arylthio)benzoates by formal [3+3] cyclizations of 3-arylthio-1-silyloxy-1,3-butadienes with 3-silyloxy-2-en-1-ones and 1,1-diacylcyclopropanes

1.1 Introduction

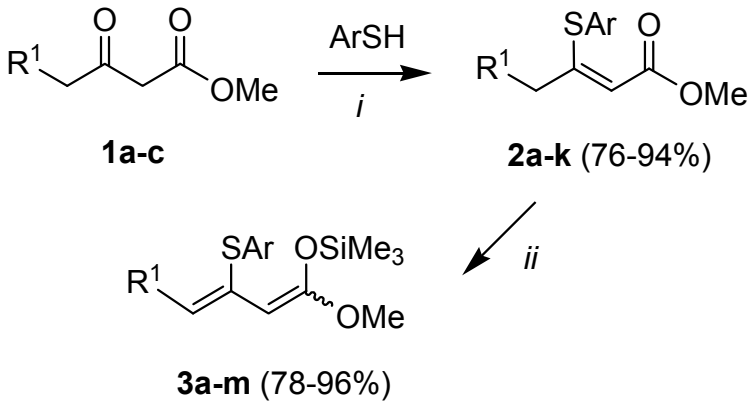
Functionalized diaryl sulfides are pharmacologically important molecules which occur in various natural products. For example, they are present in dibenzothiophenes,[9] varacins (lissoclinotoxins),[10] lissoclibadins,[11] cyclic sulfides,[12] and various other natural products isolated from Streptomyces griseus.[13] Diaryl sulfides are synthetically available by reaction of arenes with sulphur[14] and sulphur dichloride,[15] by condensation of organometallic reagents with chlorophenyl-sulfide[16] and by base-mediated reaction of chloroarenes with thiophenols.[17] These reactions often suffer from their low regioselectivity and from the formation of polysulfides, due to the harsh reaction conditions.

An alternative approach to diaryl sulfides is based on the use of sulfur-containing building blocks in cyclization reactions. Hilt and coworkers reported a convenient approach to diaryl sulfides by cobalt(I)-catalyzed [4+2] cycloaddition of alkynyl sulfides with 1,3-butadienes.[18] Recently, Langer *et al.* studied[19] the synthesis of 3- and 5-(arylthio)salicylates by $TiCl_4$-mediated formal [3+3] cyclizations[20] of 1,3-bis(silyloxy)-1,3-butadienes[21] with 3-silyloxy-2-en-1-ones.[22] Chan *et al.* reported the synthesis of methyl 4,6-dimethyl-2-(phenylthio)benzoate by $TiCl_4$-mediated [3+3] cyclization of 4-trimetyhlsilyloxy-3-penten-2-one with 1-methoxy-3-phenylthio-1-trimethylsilyloxy-1,3-butadiene.[23] I recently prepared 2-(arylthio)benzoates by catalytic cyclizations of 3-arylthio-1-trimethylsilyloxy-1,3-butadienes with 1,1,3,3-tetramethoxypropane.[24] In addition, the synthesis of 6-alkyl- and 6-aryl-2-(arylthio)benzoates by cyclization of 3-arylthio-1-trimethylsilyloxy-1,3-butadienes with

3-alkoxy-2-en-1-ones has been reported.[25] I have also recently studied the synthesis of 5-chloroethyl-2-(arylthio)benzoates by $TiCl_4$-mediated domino ′[3+3] cyclization / homo-Michael′ reaction of 3-arylthio-1-trimethylsilyloxy-1,3-butadienes with 1,1-diacylcyclopropanes.[26] Herein, I provide a full account of this work. In addition, I report a comprehensive study related to the formal [3+3] cyclization of 3-arylthio-1-trimethylsilyloxy-1,3-butadienes with 3-silyloxy-2-en-1-ones. The reactions reported provide a convenient approach to substituted 2-(arylthio)benzoates and thioxanthones which are not readily available by other methods.

1.2 Result and Discussions.

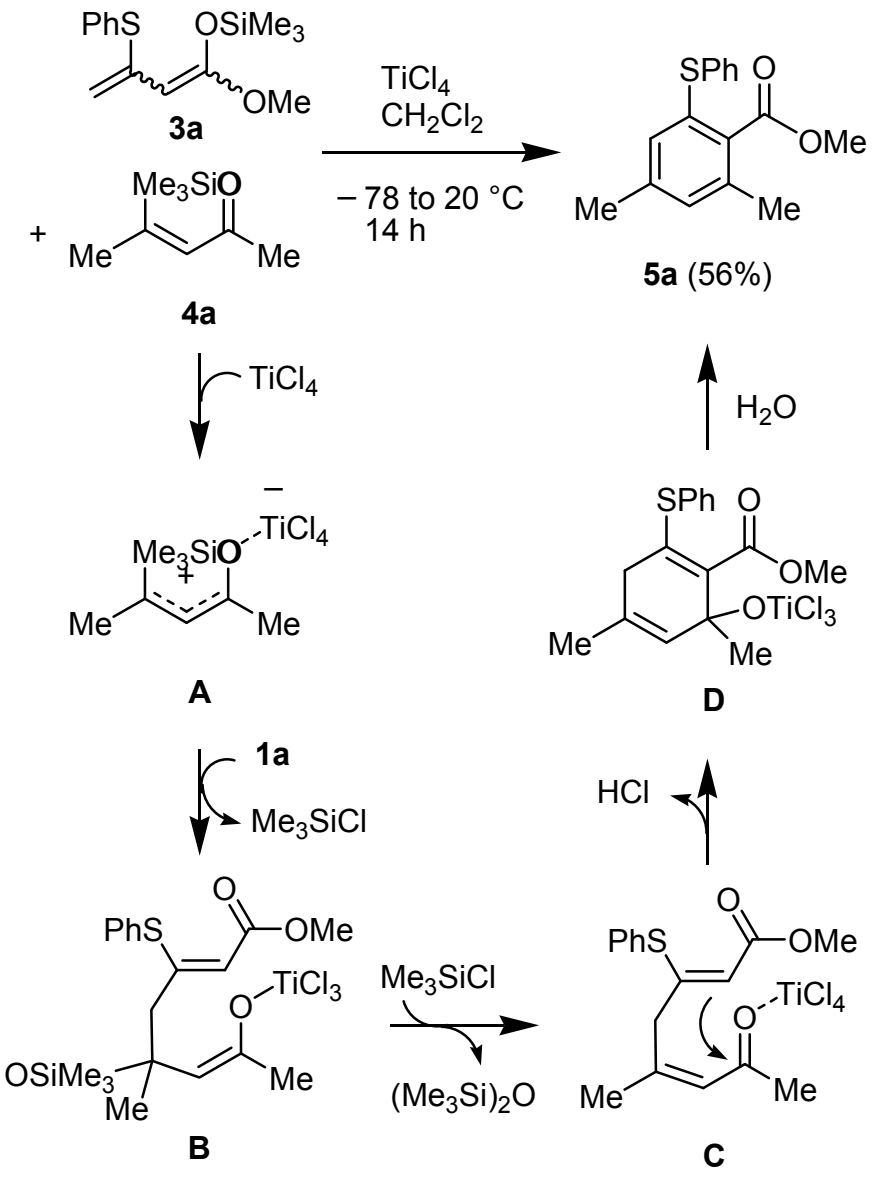
The reaction of β-ketoesters **1a-c** with various thiophenols gave, following the procedure reported by Chan *et al.,*[22,23] the 3-(arylthio)alkanoates **2a-k** (Scheme 1). Deprotonation of **2a-k** (LDA) and subsequent addition of Me_3SiCl afforded, again following the procedure reported by Chan *et al.,* [22,23] the 3-arylthio-1-silyloxy-1,3-butadienes **3a-m**. The synthesis of **2a** and **3a** has been previously reported. Dienes **3a-m** proved to be unstable and had to be used directly after their preparation.



Scheme 1. Synthesis of **3a-m** (for R^1 and Ar, see Table 1); conditions: *i,* P4O10, CH2Cl2, 20 °C, 18 h; *ii*, 1) LDA, THF, –78 °C, 1 h; 2) Me_3SiCl, –78 → 20 °C, 14 h

3-Arylthio-1-trimethylsilyloxy-1,3-butadienes **3a-m** were prepared, as previously reported, by reaction of methyl acetoacetate **(1a)**, methyl 3-oxopentanoate **(1b)**, and methyl 3-oxohexanoate **(1c)** with various thiophenols to give methyl 3-(arylthio)crotonates **2a-m**. The latter were subsequently transformed into **3a-m** by deprotonation (LDA) and subsequent silylation. The $TiCl_4$-mediated cyclization of **3a** with 3-silyloxy-2-en-1-one **4a**, prepared from acetylacetone, afforded the 2-(phenylthio)benzoate **5a** (Scheme 1). The best yields were obtained when the reaction was carried out in a highly concentrated solution (stoichiometric ratio: **3a**/**4a**/ $TiCl_4$ = 1.0/1.5/1.5). The solution was slowly warmed from –78 to 20 °C (20 h). The formation of **5a** can be explained by reaction of **4a** with $TiCl_4$ to give intermediate A. The attack of the terminal carbon atom of **3a** onto A afforded intermediate B. The elimination of TMS-siloxane (intermediate C) and subsequent cyclization gave intermediate D. The elimination of titanium hydroxide (before or during the aqueous work-up) and aromatization resulted in the formation of product **5a**. Due to the symmetrical structure of A, the attack of 1a on either terminal allylic carbon atom would result in the formation of the same product **(5a)**.

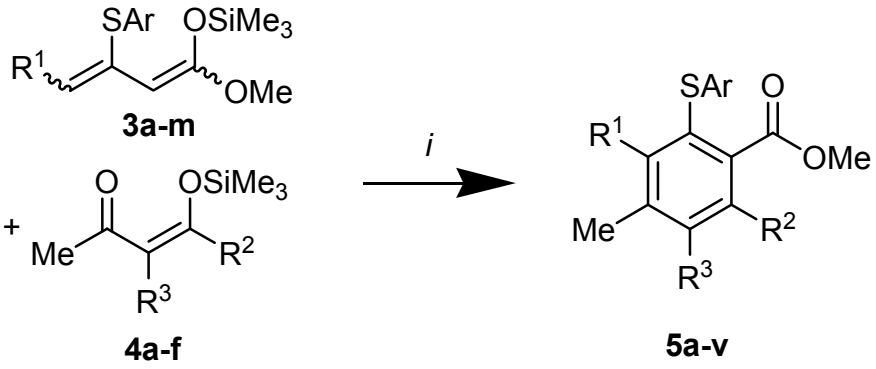
The cyclization of dienes **3a-m** with 3-silyloxy-2-en-1-ones **4a-f** afforded the 2-(thioaryloxy)benzoates **5a-v** (Scheme 3, Table 1). Noteworthy, products **5e**, **5h** and **5k** were formed with very good regioselectivity (vide infra). For **5h** and **5k**, this result is in agreement with the regiochemical result of the reaction of **4f** with 1,3-bis(silyloxy)-1,3-butadienes.[12,15] The reaction of 1,3-bis(silyloxy)-1,3-butadienes with **4e** has not been previously studied. The yields of products **5** depend on the substituents of dienes **3**. This can be seen by comparison of the yields of products derived from the same electrophile and different dienes (or vice versa). The comparison of the yields of **5b**, **5f**, and **5i** (or of **5c**, **5g**, and **5j**) show that higher yields are often obtained for products derived from dienes containing an alkyl group attached to carbon C-4 of the diene. However, this effect is not general. The aryl group of the diene also has some influence. The yields of the products derived from dienes containing an electron-rich aryl group **(5a,l,o)** are higher than the products derived from dienes containing electron-poor aryl groups **(5q,t,u)**. No clear trend is observed for the influence of the 3-silyloxy-2-en-1-one **4**.



Scheme 2. Possible mechanism of the formation of **5a**

The regioselective formation of **5h** and **5k** might be rationalized by comparison of the resonance structures of the cations formed by reaction of $TiCl_4$ with 3-silyloxy-2-en-1-one **4f** (Scheme 4). It can be expected that resonance structure $\mathbf{A_1}$ is more stable than $\mathbf{A_2}$, due to the σ-donating effect of the methyl group. The phenyl group is presumably twisted out of plane, due to steric reasons. The reactions may proceed,

under kinetic reaction control, by attack of the terminal carbon atom of **3b** onto the cationic intermediate which is predominantly present. The selective formation of **5e** might be explained by steric reasons. The attack of **3a** on the allyl cation occurs at its sterically less hindered carbon atom (next to the methyl group) (Scheme 5).



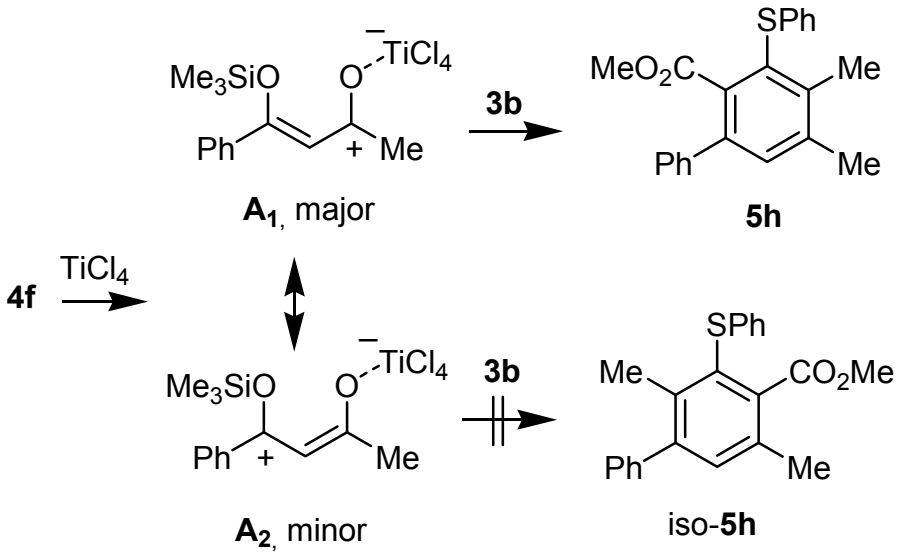
Scheme 3. Synthesis of **5a-v**. *Conditions i* CH_2Cl_2, $TiCl_4$ at –78 to 20 °C, 20 h.

Table 1. Synthesis of arenes **5a-v**

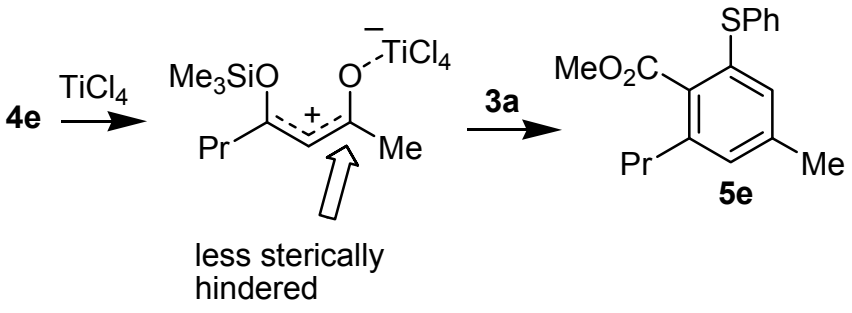
3	**4**	**5**	Ar	R^1	R^2	R^3	% (**5**)[a]
a	**a**	**a**	Ph	H	Me	H	56
a	**b**	**b**	Ph	H	Me	Me	43
a	**c**	**c**	Ph	H	Me	Cl	43
a	**d**	**d**	Ph	H	Me	PhS	63
a	**e**	**e**	Ph	H	nPr	H	42
b	**b**	**f**	Ph	Me	Me	Me	55
b	**c**	**g**	Ph	Me	Me	Cl	49
b	**f**	**h**	Ph	Me	Ph	H	52
c	**b**	**i**	Ph	Et	Me	Me	55
c	**c**	**j**	Ph	Et	Me	Cl	51
c	**f**	**k**	Ph	Et	Ph	H	50
d	**a**	**l**	4-MeC_6H_4	H	Me	H	54
e	**a**	**m**	4-MeC_6H_4	Me	Me	H	39
f	**a**	**n**	3-MeC_6H_4	H	Me	H	57
g	**a**	**o**	4-EtC_6H_4	H	Me	H	49
h	**a**	**p**	4-EtC_6H_4	Me	Me	H	45
i	**a**	**q**	4-ClC_6H_4	H	Me	H	37
i	**c**	**r**	4-ClC_6H_4	H	Me	Cl	35
j	**a**	**s**	4-ClC_6H_4	Me	Me	H	36
k	**a**	**t**	3-ClC_6H_4	H	Me	H	37

l	**a**	**u**	4-FC_6H_4	H	Me	H	40
m	**a**	**v**	4-FC_6H_4	Me	Me	H	33

[a] Yields of isolated products

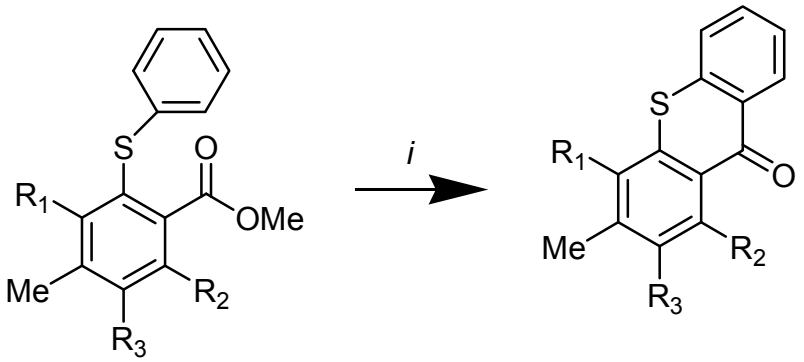


Scheme 4. Possible explanation for the regioselective formation of **5h,k**



Scheme 5. Possible explanation for the regioselective formation of **5e**

Treatment of 2-(arylthio)benzoates **5b,c,e,f,g,i,j** with concentrated sulfuric acid resulted in an intramolecular Friedel-Crafts cyclization to give the thioxanthones **6a-g** in excellent yields (Scheme 6, Table 2). The structures of all products were elucidated by spectroscopic methods. The structure of **6f** was independently confirmed by X-ray crystal structure analysis (Figure 1).



5b,c,e,f,g,i,j **6a-g**

Scheme 6. Synthesis of **6a-g**. *Conditions*: *i*, conc H_2SO_4 20 °C, 2 h

Table 2. Synthesis of thioxanthones **6a-g**

5	**8**	R^1	R^2	R^3	% (**6**) [a]
b	**a**	H	Me	Me	98
c	**b**	H	Me	Cl	97
e	**c**	H	*n*Pr	H	95
f	**d**	Me	Me	Me	97
g	**e**	Me	Me	Cl	97
i	**f**	Et	Me	Me	95
j	**g**	Et	Me	Cl	96

[a] Yields of isolated products

The $TiCl_4$-mediated cyclization of **3a** with 1,1-diacetylcyclopropane (**7a**) afforded the 2-(phenylthio)benzoate **8a** (Scheme 7). During the optimization, the stoichiometry (1.5 equiv. of $TiCl_4$ and of **7a**) played an important role. The yields dropped when only 1.0 equiv. of $TiCl_4$ and of **7a** were employed. The yield also decreased when an excess of **3a** was used. The concentration (30 mL per mmol of **3a**) also proved to be an important parameter. A complex mixture was obtained when the reaction was carried out in a highly concentrated solution (following the procedure given for the reaction of **3a** with 4-(trimethylsilyloxy)pent-3-en-2-one, vide supra). The formation of 8a can be explained by a domino ′[3+3] cyclization / homo-Michael′ reaction. The $TiCl_4$-mediated attack of the terminal carbon atom of **3a** onto **7a** gave intermediate E, cyclization via the central carbon atom gave intermediate F, and $TiCl_4$-assisted cleavage of the spirocyclopropane moiety and aromatization led to the formation of the final product **8a**. Reactions of acceptor-substituted cyclopropanes have been classified by Danishefsky in terms of ′strictly nucleophilic ring openings′,

′electrophilically assisted ring openings′ and ′spiro-activations′.[27] In the present case, a ′spiro-activation′ is combined with the activation by an electrophile.[28]

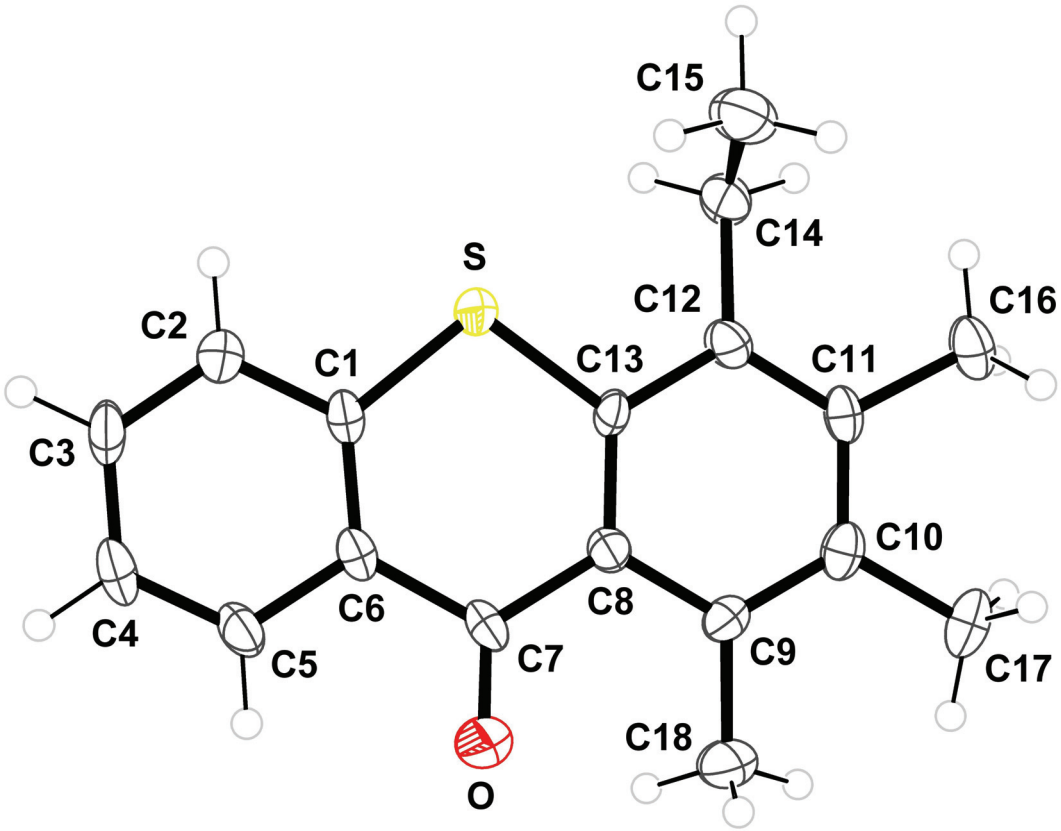
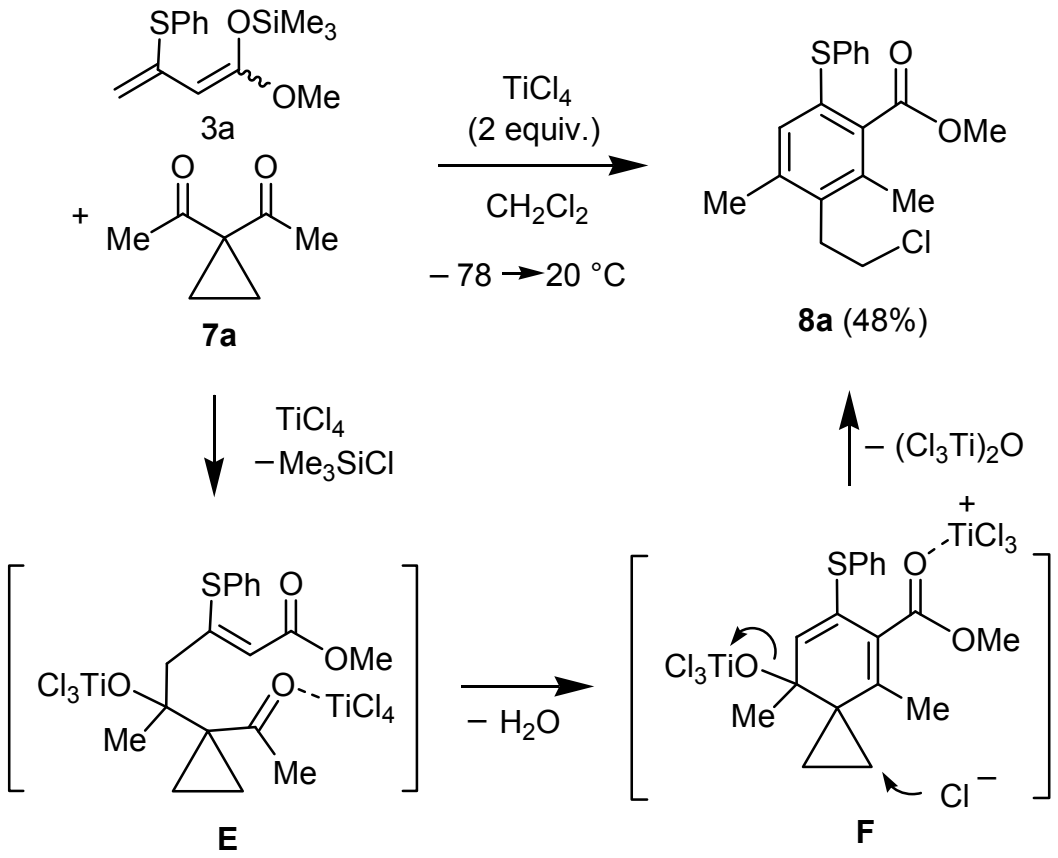
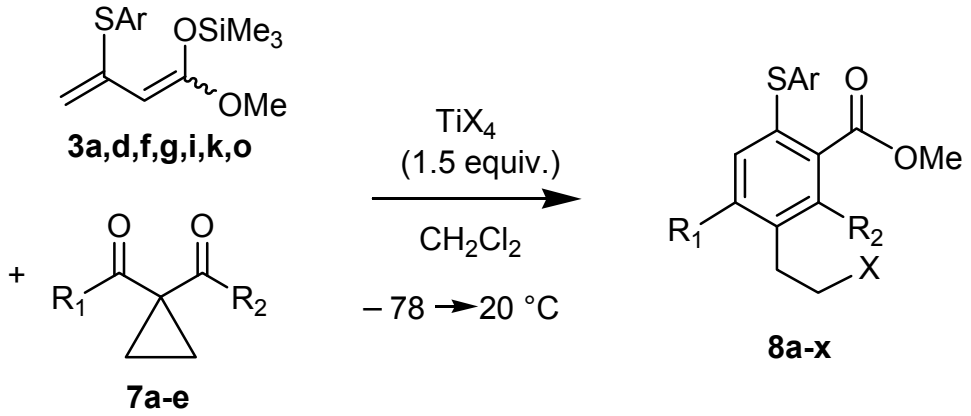


Figure 1. Structure of **6f**



Scheme 7. Possible mechanism of the formation of **8a**

The cyclization of 1-trimethylsilyloxy-3-arylthio-1,3-butadienes **3a,d,f,g,i,k,o** with 1,1-diacylcyclopropanes **7a-e**, in the presence of $TiCl_4$ or $TiBr_4$, afforded the 5-haloethyl-2-(arylthio)benzoates **8a-x** (Scheme 8, Table 3). Products **8b-d,g,i,j,l,o**, derived from the unsymmetrical cyclopropanes **7b-d**, were formed with very good regioselectivity. This can be explained by regioselective attack of the terminal carbon atom of diene **3** onto the acetyl rather than the less reactive aroyl group of **7b-d**.



Scheme 8. Synthesis of **8a-x**: *Reagents and conditions*: *i*: TiX_4, CH_2Cl_2, –78 → 20 °C, 14 h

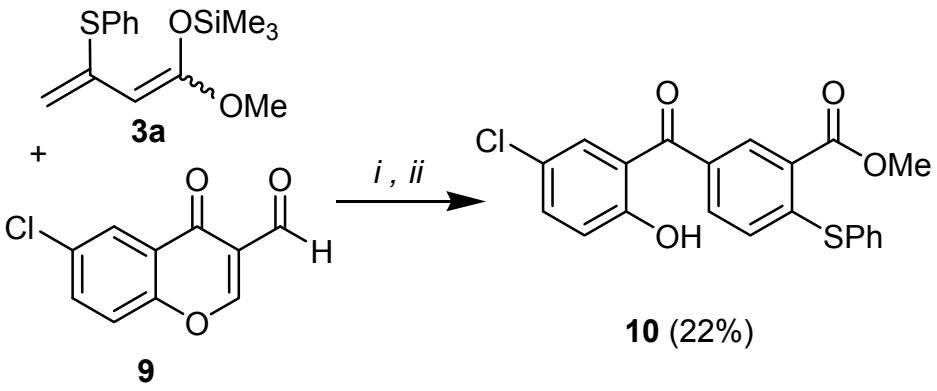
Table 3. Synthesis of **8a-x**

3	**7**	**8**	Ar	R^1	R^2	X	% (**8**) [a]
a	**a**	**a**	Ph	Me	Me	Cl	48
a	**b**	**b**	Ph	Me	Ph	Cl	47
a	**c**	**c**	Ph	Ph	4-ClC_6H_4	Cl	43
a	**d**	**d**	Ph	Ph	4-FC_6H_4	Cl	40
a	**e**	**e**	Ph	Et	Et	Br	28
a	**a**	**f**	Ph	Me	Me	Br	58
a	**b**	**g**	Ph	Me	Ph	Br	40
d	**a**	**h**	4-MeC_6H_4	Me	Me	Cl	40
d	**b**	**i**	4-MeC_6H_4	Me	Ph	Cl	41
d	**b**	**j**	4-MeC_6H_4	Me	Ph	Br	45
i	**a**	**k**	4-ClC_6H_4	Me	Me	Cl	43
i	**b**	**l**	4-ClC_6H_4	Me	Ph	Cl	47
i	**a**	**m**	4-ClC_6H_4	Me	Me	Br	41
o	**a**	**n**	3-$(MeO)C_6H_4$	Me	Me	Cl	35
o	**b**	**o**	3-$(MeO)C_6H_4$	Me	Ph	Cl	33
o	**a**	**p**	3-$(MeO)C_6H_4$	Me	Me	Br	41
k	**a**	**q**	3-ClC_6H_4	Me	Me	Br	40

f	**a**	**r**	3-MeC_6H_4	Me	Me	Br	40
f	**a**	**s**	3-MeC_6H_4	Me	Me	Cl	43
d	**a**	**t**	4-MeC_6H_4	Me	Me	Br	40
g	**b**	**u**	4-EtC_6H_4	Me	Ph	Br	38
g	**a**	**v**	4-EtC_6H_4	Me	Me	Br	42
g	**a**	**w**	4-EtC_6H_4	Me	Me	Cl	44
g	**b**	**x**	4-EtC_6H_4	Me	Ph	Cl	40

[a] Yields of isolated products

The Me_3SiOTf-catalyzed reaction of diene **3a** with 3-formylchromone **9** afforded the highly functionalized diaryl sulfide **10** (Scheme 9). The formation of product **10** can be explained by a domino ′Michael / retro-Michael / Mukaiyama-Aldol′ reaction. This type of reaction has been earlier reported for 1,3-bis(silyloxy)-1,3-butadienes.[29]



Scheme 9. Synthesis of **10**: *Reagents and conditions: i*: Me_3SiOTf (0.3 equiv) 20 °C, 10 min; *ii*: 1) **3a** (1.3 equiv), CH_2Cl_2, 0 → 20 °C, 12 h; 2) HCl (10%).

1.3 Conclusion

In conclusion, I have reported the synthesis of substituted 2-(arylthio)benzoates and thioxanthones based on formal [3+3] cyclizations of 3-arylthio-1-trimethylsilyloxy-1,3-butadienes with 3-silyloxy-2-en-1-ones and 1,1-diacylcyclopropanes.

2 Regioselective synthesis of 2-(arylthio)benzoates by the first [3+3] cyclizations of 3-arylthio-1-silyloxy-1,3-butadienes with 3-alkoxy-2-en-1-ones

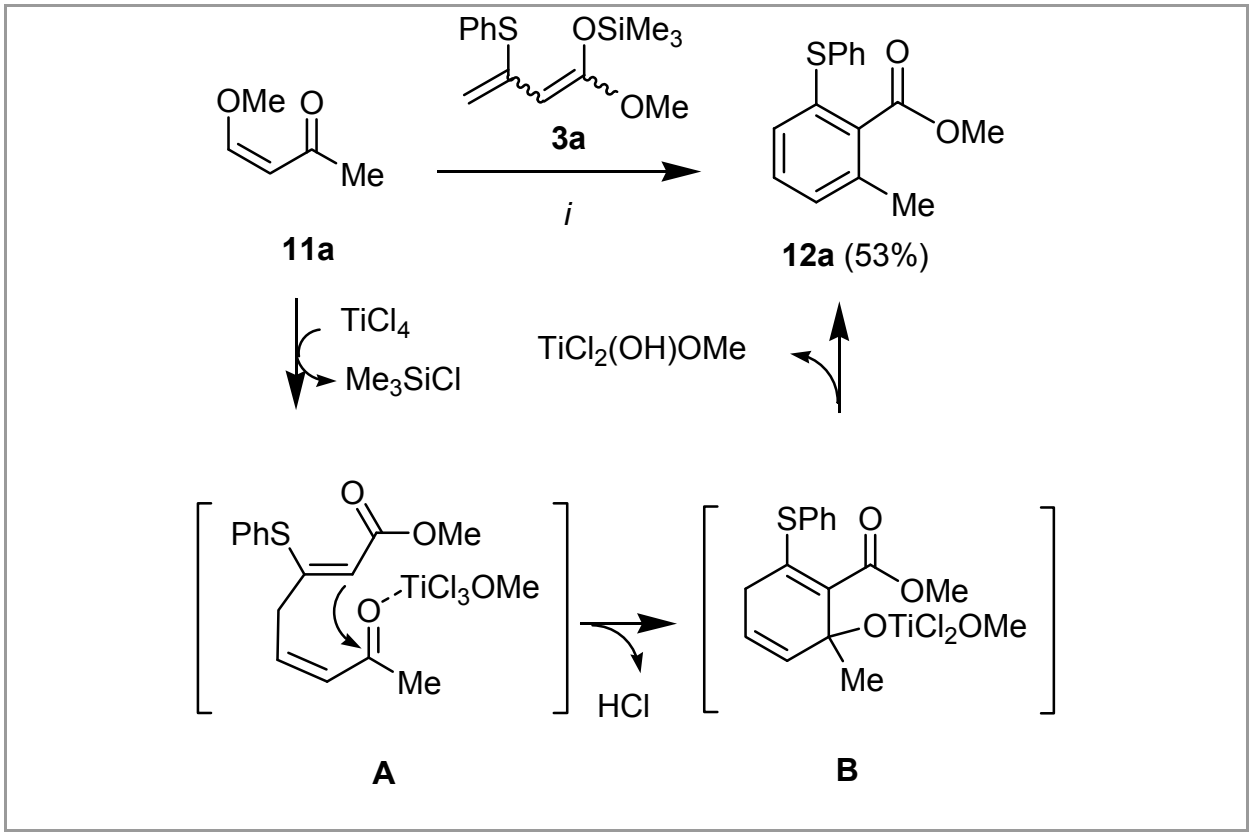
2.1 Introduction

The synthesis of methyl 4,6-dimethyl-2-(phenoxythio)benzoate by cyclization of 1-methoxy-1-trimethylsilyloxy-3-phenoxythio-1,3-butadiene with 4-(trimethylsilyloxy)pent-3-en-2-one has also been reported.[23] Recently, I have studied the synthesis of 2-arylthio-5-(haloethyl)benzoates by cyclization of 3-arylthio-1-silyloxy-1,3-butadienes with 1,1-diacylcyclopropanes.[26] Herein I report what are, to the best of my knowledge, the first [3+3] cyclizations of 3-arylthio-1-silyloxy-1,3-butadienes with 3-alkoxy-2-en-1-ones. These reactions provide a convenient and regioselective approach to sterically encumbered and functionalized 2-(arylthio)benzoates which are not readily available by other methods. In contrast to the coupling reactions outlined above, my method relies on the assembly of one of the two arene moieties.

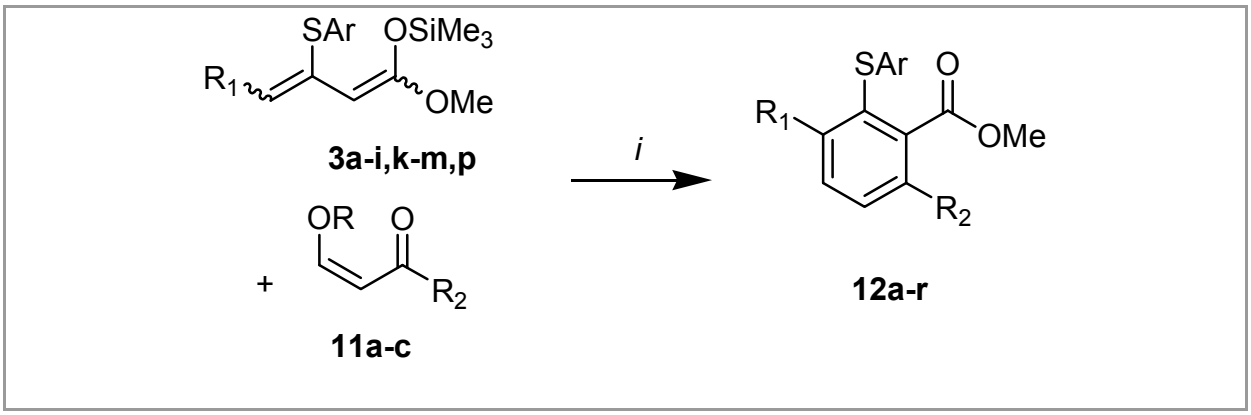
2.2 Result and discussions

The $TiCl_4$-mediated cyclization of 3-phenoxythio-1-silyloxy-1,3-butadiene **3a** with 1-(methoxy)but-1-en-3-one **(11a)** afforded methyl 6-methyl-2-(phenoxythio)benzoate **(12a)** with very good regioselectivity (Scheme 11). Notably, the formation of regioisomeric methyl 4-methyl-2-(phenoxythio)benzoate was not observed. The best yields were obtained when the reaction was carried out in a highly concentrated

solution. The use of an excess (1.5 equiv.) of 4a and of $TiCl_4$ also proved to be important. The formation of **5a** can be explained by $TiCl_4$-mediated conjugate addition of the terminal carbon atom of **3a** onto **11a** to give intermediate A, cyclization via the central carbon atom (intermediate B), (Scheme 10), and subsequent aromatization.



Scheme 10. Possible mechanism of the formation of **12a**; conditions: *i*: 1) $TiCl_4$, CH_2Cl_2, −78 to 20 °C, 20 h; 2) $NaHCO_3$, H_2O



Scheme 11. Synthesis of **12a-r**; conditions: *i*: 1) $TiCl_4$, CH_2Cl_2, –78 to 20 °C, 20 h; 2) $NaHCO_3$, H_2O

The structure of all products was established by spectroscopic methods. The structure of **12i** was independently confirmed by X-ray crystal structure analysis (Figure 1).[30]

Table 4. Synthesis of **12a-r**

3	**11**	**12**	R^1	Ar	R^2	R	% (2)[a]	% (3)[a]	% (12)[a]
a	**a**	**a**	H	Ph	Me	Me	90	90	53
b	**a**	**b**	Me	Ph	Me	Me	84	82	40
c	**a**	**c**	Et	Ph	Me	Me	84	83	35
d	**a**	**d**	H	4-MeC_6H_4	Me	Me	85	88	51
e	**a**	**e**	Me	4-MeC_6H_4	Me	Me	85	83	37
f	**a**	**f**	H	3-MeC_6H_4	Me	Me	82	87	50
i	**b**	**g**	H	4-ClC_6H_4	Ph	Et	87	84	37
k	**a**	**h**	H	3-ClC_6H_4	Me	Me	80	86	48
l	**c**	**i**	H	4-FC_6H_4	4-ClC_6H_4	Et	80	80	35
m	**a**	**j**	Me	4-FC_6H_4	Me	Me	74	78	34
a	**b**	**k**	H	Ph	Ph	Et	90	90	40
p	**a**	**l**	H	2-Naph	Me	Me	75	79	33
a	**c**	**m**	H	Ph	4-ClC_6H_4	Et	90	90	47
i	**c**	**n**	H	4-ClC_6H_4	4-ClC_6H_4	Et	87	84	46
d	**c**	**o**	H	4-MeC_6H_4	4-ClC_6H_4	Et	85	88	47
b	**c**	**p**	Me	Ph	4-ClC_6H_4	Et	81	82	40
b	**c**	**q**	H	4-FC_6H_4	Me	Me	80	80	35
c	**c**	**r**	Et	Ph	4-ClC_6H_4	Et	84	83	36

[a] Yields of isolated products

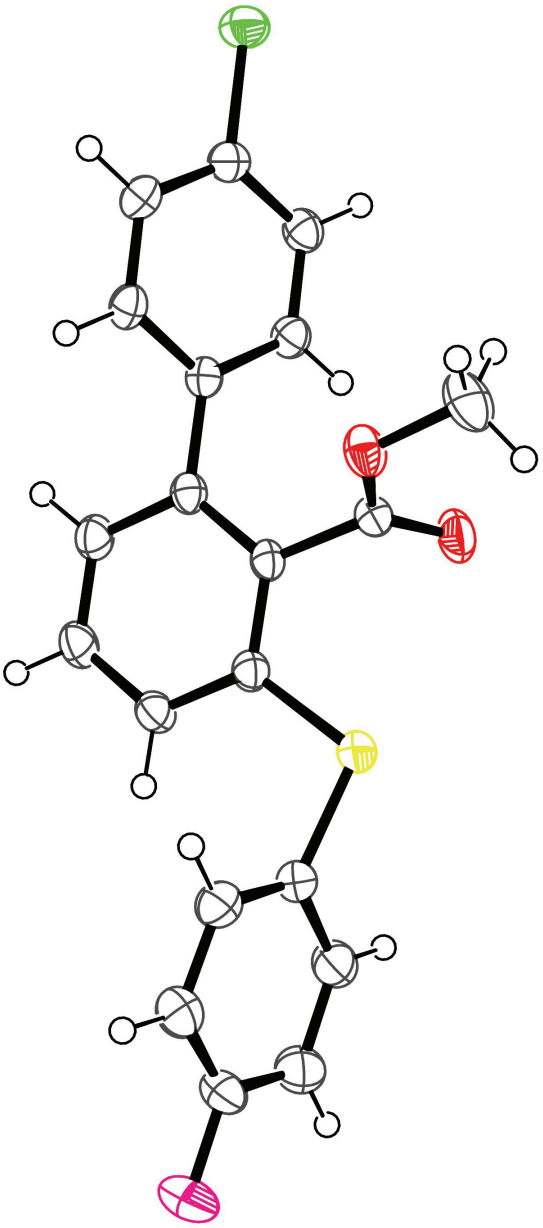


Figure 1. Crystal structure of 4`-chloro-3-(4-fluorophenylsulfanyl)-biphenyl-2-carboxylic acid methyl ester

2.3 Conclusion

In conclusion, I have reported a convenient and regioselective approach to functionalized 2-(arylthio)benzoates by the first [3+3] cyclizations of 3-arylthio-1-trimethylsilyloxy-1,3-butadienes with 3-alkoxy-2-en-1-ones.

3 Synthesis of 5-arylthio-3-hydroxyphthalates by the first [4+2] cycloadditions of 3-arylthio-1-silyloxy-1,3-butadienes with dimethyl acetylenedicarboxylate

3.1 Introduction

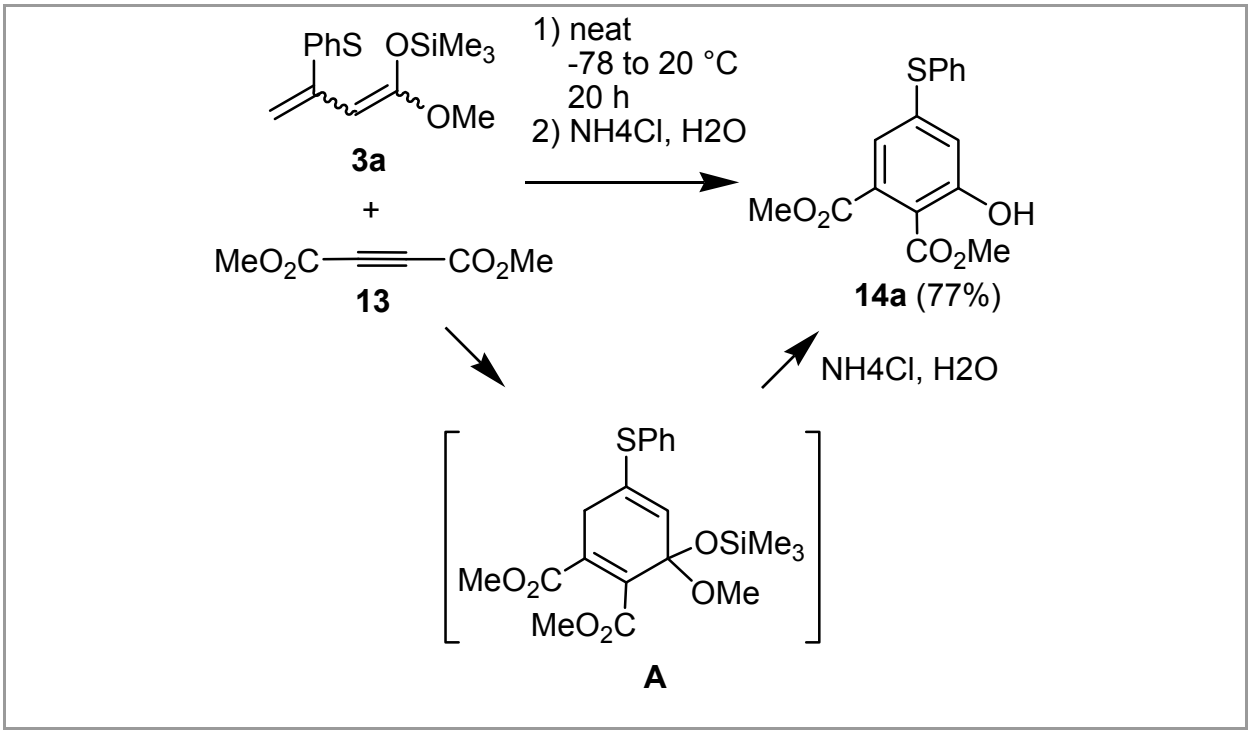
Herein, I report [4+2] cycloaddition reactions of 3-arylthio-1-trimethylsilyloxy-1,3-butadienes with dimethyl acetylenedicarboxylate (DMAD). This method provides a convenient and general approach to a wide range of novel 5-arylthio-3-hydroxyphthalates which are not readily available by other methods. In contrast to the C-S coupling reactions outlined above, the method reported herein relies on the assembly of one of the two arene moieties.

3.2 Result and Discussions

The known 3-arylthio-1-trimethylsilyloxy-1,3-butadienes **3a-p** were prepared from methyl acetoacetate or methyl 3-oxopentanoate and from the corresponding thiophenols in two steps.[23,25,31]

The [4+2] cycloaddition of DMAD (**13**) with 3-phenylthio-1-trimethylsilyloxy-1,3-butadiene (**3a**) resulted in formation of the 5-phenylthio-3-hydroxyphthalate **14a** in up to 77% yield (Scheme 1). The best yields were obtained when a ratio of **3a**/**p** ≅ 1:2 was used, when the reaction was carried out without solvent (neat), when the temperature was allowed to slowly rise from −78 to 20 °C, and when an aqueous solution of ammonium chloride was used for the work-up (to induce the

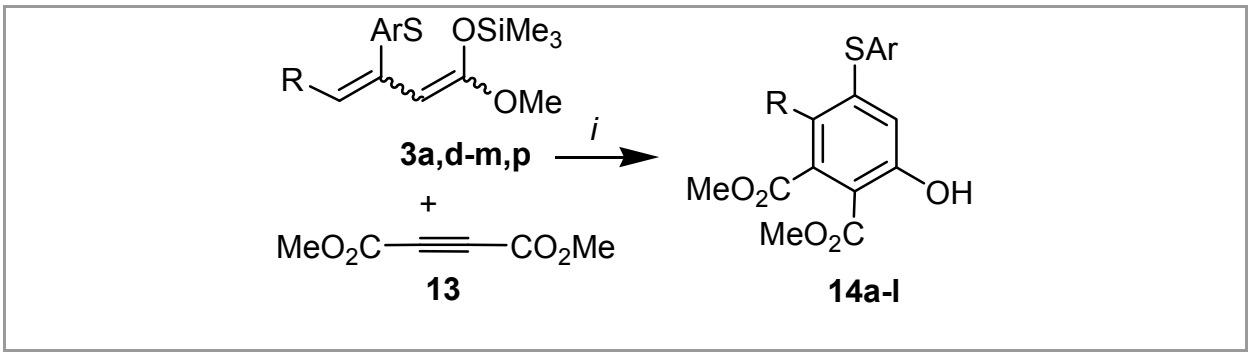
aromatization). An unseparable 1:2 mixture of **14a** and of 5-phenylthio-3-methoxyphthalate was obtained when a benzene solution of the starting materials was stirred at −10 °C for 16 h and when the reaction was quenched by addition of THF and hydrochloric acid (5%). The reaction presumably proceeds by cycloaddition to give intermediate **A**. Subsequently, cleavage of the silyl ether under the acidic work-up conditions and subsequent elimination of methanol from the intermediary hemiacetal afforded product **14a**.



Scheme 12. Possible mechanism of the formation of arene **14a**

The cyclization of DMAD with 3-arylthio-1-trimethylsilyloxy-1,3-butadienes **3a,d-m,p** afforded the novel 5-arylthio-3-hydroxyphthalates **14a-l** in moderate to good yields (Scheme 13, Table 5). A wide range of products could be successfully prepared. The best yields were obtained for products derived from dienes containing an electron-

rich aryl group. The yield of product **3h**, containing a bulky naphthyl group, was lower than the yield of **14a** containing a phenyl group. The yields slightly dropped for dienes containing a methyl group located at carbon atom C-4 of the diene.

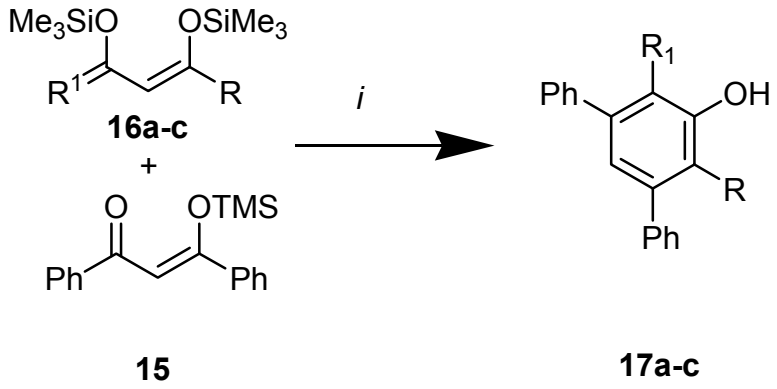


Scheme 13. Synthesis of arenes **14a-l**; *i*: 1) neat, –78 → 20 °C, 20 h; 2) NH_4Cl, H_2O

Table 5. Synthesis of arenes **14a-l**

3	**14**	R	Ar	% (**14**) [a]
a	**a**	H	Ph	77
d	**b**	H	4-MeC_6H_4	69
e	**c**	Me	4-MeC_6H_4	59
f	**d**	H	3-MeC_6H_4	67
g	**e**	H	4-EtC_6H_4	69
h	**f**	Me	4-EtC_6H_4	64
i	**g**	H	4-ClC_6H_4	64
j	**h**	Me	4-ClC_6H_4	55
k	**i**	H	3-ClC_6H_4	60
l	**j**	H	4-FC_6H_4	51
m	**k**	Me	4-FC_6H_4	53
p	**l**	H	2-Naphthyl	54

[a] Yields of isolated products



Scheme 14. Synthesis of **17a-l**; *i*: 1) CH_2Cl_2, –78 → 20 °C, 20 h; 2) 10% HCl, H_2O

Table 6. Synthesis of **17a-c**

16,17	R	R^1	% (**17**) [a]
a	MeO	H	40
b	Me	H	41
c	MeO	Me	37

[a] Yields of isolated products

3.3 Conclusion

In conclusion, I have reported a convenient synthesis of a variety of 5-arylthio-3-hydroxyphthalates by the first [4+2] cycloadditions of 3-arylthio-1-trimethylsilyloxy-1,3-butadienes with dimethyl acetylenedicarboxylate. The scope and applications of this methodology are currently studied in my laboratory.

4 Experimental section

4.1 General: Equipments, chemicals and work techniques

^{1}H NMR Spectroscopy: Bruker: AM 250, Avance 250, AC 250 (250 MHz); ARX 300, Avance 300 (300 MHz); Varian VXR 500 S, Avance 500 (500 MHz); δ = 0.00 ppm for Tetramethylsilane; δ = 2.04 ppm for Acetone d-6; δ = 7.26 ppm for Deuterochloroform

(CDCl3); characterization of the signal fragmentations: s = singlet, d = doublet, dd = double of doublet, ddd = doublet of a double doublet, t = triplet, q = quartet, quint = quintet; sext = Sextet, sept = Septet, m = multiplet, br = broadly. Spectra were evaluated

according to first order rule. All coupling constants are indicated as (*J*).

^{13}C NMR Spectroscopy: Bruker: AM 250, Avance 250, AC 250 (62.9 MHz); ARX 300,

Avance 300 (75 MHz); Varian VXR 500 S, Avance 500 (125 MHz); δ = 128.00 ppm for

Acetone d-6; δ = 77.00ppm for CDCl3. The multiplicity of the carbon atoms was determined by the DEPT 135 and APT technique (APT = Attached Proton Test) and quoted as CH3, CH2, CH and C for primary, secondary, tertiary and quaternary carbon

atoms. characterization of the signal fragmentations: quart = quartet the multiplicity of the signals was determined by the DEPT recording technology and/or the APT recording

technology.

Mass Spectroscopy: AMD MS40, AMD 402 (AMD Intectra), Varian MAT CH 7, MAT 731.

High Resolution mass spectroscopy: Finnigan MAT 95 or Varian MAT 311; Bruker FT CIR, AMD 402 (AMD Intectra).

Infrared spectroscopy (IR): Bruker IFS 66 (FT IR), Nicolet 205 FT IR; Nicolet Protégé 460, Nicolet 360 Smart Orbit (ATR); KBr, KAP, Nujol, and ATR; Abbreviations for signal allocations: w = weak, m = medium, s = strong, br = broad.

X-ray crystal structure analysis: Bruker X8Apex Diffractometer with CCD-Kamera (Mo-Ka und Graphit Monochromator, λ = 0.71073 Å).56

Column chromatography: Chromatography was performed over Merck silica gel 60 (0,063 -0,200 mm, 70 - 230 mesh) as normal and/or over mesh silica gel 60 (0,040 - 0,063 mm, 200 -400 mesh) as Flash Chromatography. All solvent were distilled beforeuse.

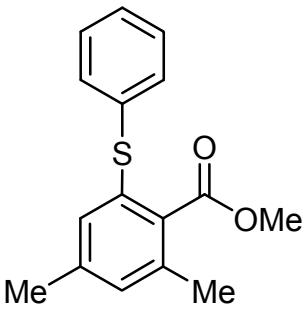
TLC: Merck DC finished foils silica gel 60 F254 on aluminum foil and Macherey finished foils Alugram® Sil G/UV254. Detection under UV light with 254 nm and/or 366 nm without dipping reagent, as well as with anisaldehyde sulfuric acid reagent (1 mL)anisaldehyde consisting in 100 mL stock solution of 85% methanol, 14% acetic acid and 1% sulfuric acid).

Chemicals and work technique: All solvents used, were distilled by standard methods.

All reactions were carried out under an inert atmosphere, oxygen and humidity exclusion.

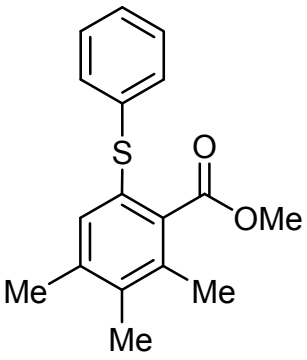
All of the chemicals are standard, commercially available from Merck®, Aldrich®, Acros® and others. The order of the characterized connections effected numerically, but does not correspond to the order in the main part of dissertation.

General procedure for the synthesis of 2-(thiophenoxy)benzoates 5a-v: To a dichloromethane solution (5 mL / mmol of **3**) of **3** (1.0 mmol) and of **4** (1.5 mmol) was added $TiCl_4$ (1.5 mmol) at –78 °C. The solution was allowed to warm to 20 °C within 20 h. To the solution was added a saturated aqueous solution of $NaHCO_3$ (15 mL). The organic and the aqueous layer were separated and the latter was extracted with diethyl ether (3 x 20 mL). The combined organic layers were dried (Na_2SO_4), filtered, and the filtrate was concentrated in vacuo. The residue was purified by chromatography (silica gel, EtOAc / *n*-heptane = 1:4).

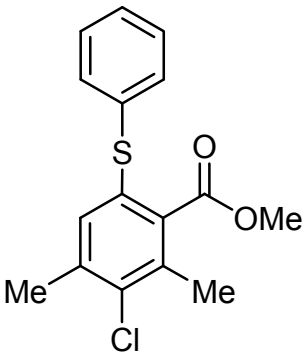


2,4-Dimethyl-6-phenylsulfanyl-benzoic acid methyl ester (5a): Starting with **4a** (387 mg, 2.3 mmol), **3a** (420 mg, 1.5 mmol), $TiCl_4$ (0.25 mL, 2.3 mmol) and CH_2Cl_2 (9 mL), **5a** was isolated as a highly viscous oil (229 mg, 56%). ^{1}H NMR (250 MHz, $CDCl_3$): δ = 2.05 (s, 3H, CH_3), 2.13 (s, 3H, CH_3), 3.67 (s, 3H, OCH_3), 6.75-7.12 (m, 7H, ArH). ^{13}C NMR (63 MHz, $CDCl_3$): δ = 19.6, 21.1 (CH_3), 52.0 (OCH_3), 126.9 (ArCH), 129.0 (2C ArCH), 130.4 (ArCH), 130.8 (2C ArCH),

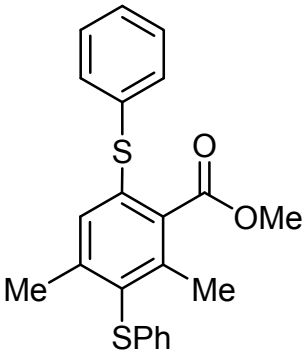
131.0 (ArCH), 132.7, 134.0, 135.9, 136.1, 140.7 (ArC), 169.1 (C). IR (neat): $\tilde{\nu}$ = 3056 (w), 2990 (w), 2947 (w), 2920 (w), 1726 (s), 1599 (m), 1581 (w), 1516 (w), 1476 (m), 1438 (s), 1378 (w), 1267 (s), 1257 (s), 1217 (m), 1188 (m), 1151 (s), 1078 (s), 1023 (m), 999 (w), 956 (w) 852 (m), 810 (m), 738 (s), 689(s) 579 (m), 555 (w) cm^{-1}. GC-MS (EI, 70 eV): *m/z* (%): 272 (60), 241 (41), 240 (21), 239 (M^+, 100), 198 (15), 197 (26), 165 (6), 91 (4). HRMS (EI): calcd for $C_{16}H_{16}O_2S$ [M^+]: 272.08655, found 272.086221.



Methyl 2,3,4-trimethyl-6-(phenylsulfanyl)benzoate (5b): Starting with **4b** (558 mg, 3.0 mmol), **3a** (562 g, 2.0 mmol), $TiCl_4$ (0.32 mL, 3.0 mmol) and CH_2Cl_2 (10 mL), **5b** was isolated as a yellow highly viscous oil (250 mg, 43%). ^1H NMR (250 MHz, $CDCl_3$): δ = 2.00 (s, 3 H, CH_3), 2.04 (s, 3 H, CH_3), 2.05 (s, 3 H, CH_3), 3.65 (s, 3 H, OCH_3), 6.76 (s, 1 H, ArH), 7.0 (m, 2 H, ArH), 7.06 (m, 2 H, ArH). ^{13}C NMR (62 MHz, $CDCl_3$): δ = 15.7, 17.5, 20.6 (CH_3), 52.6 (OCH_3), 126.2 (ArCH), 127.2 (C), 128.8 (2C ArCH), 129.5 (2C ArCH), 133.3 (ArCH), 133.7 136.0, 136.07, 137.2, 138.7, 169.7 (C). IR (neat): $\tilde{\nu}$ = 3382 (w), 2940 (s), 1712 (m), 1609 (m), 1530 (m), 1481 (m), 1311 (m), 1213 (m), 1162 (m), 1010 (m), 758 (w) 730 (m) cm^{-1}. GC-MS (EI, 70 eV): *m/z* (%): 286 (M^+, 58), 253 (100), 240 (8), 211 (15), 178 (6). HRMS (EI): calcd for $C_{17}H_{18}O_2S$ [M^+] 286.10220, found 286.10225.

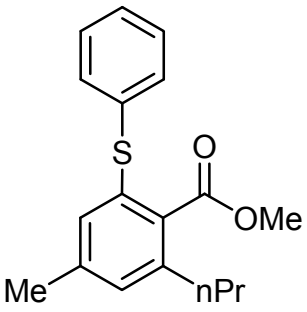


Methyl 3-chloro-2,4-dimethyl-6-(phenylsulfanyl)benzoate (5c): Starting with **4c** (621 mg, 3.0 mmol), **3a** (562 mg, 2.0 mmol), $TiCl_4$ (0.32 mL, 3.0 mmol) and CH_2Cl_2 (11 mL), **5c** was isolated as a highly viscous oil (350 mg, 57%). ^{1}H NMR (250 MHz, $CDCl_3$): δ = 2.23 (s, 3 H, CH_3), 2.28 (s, 3 H, CH_3), 3.79 (s, 3 H, OCH_3), 7.01 (s, 1 H, ArH), 7.16 (m, 2 H, ArH), 7.33 (m, 2 H, ArH). ^{13}C NMR (75 MHz, $CDCl_3$): δ = 18.1, 20.8 (CH_3), 52.3 (OCH_3), 127.0 (ArCH), 129.1 (2C ArCH), 130.0 (C), 130.5 (2C ArCH), 133.0 (ArCH), 135.0 135.7, 135.8, 136.6, 138.4, 168.3 (C). IR (neat): $\tilde{\nu}$ = 3382 (w), 2898 (s), 1722 (m), 1663 (s), 1534 (m), 1434 (m), 1321 (s), 1223 (s), 1123 (m), 1024 (m), 768 (w), 713 (m) cm^{-1}. GC-MS (EI, 70 eV): *m/z* (%): 308 (M^+, ^{37}Cl, 37), 306 (M^+, ^{35}Cl, 41), 267 (100), 105 (89), 77 (34). HRMS (EI): calcd for $C_{15}H_{17}O_2ClS$ [M^+, ^{35}Cl]: 306.06127, found 306.06139.

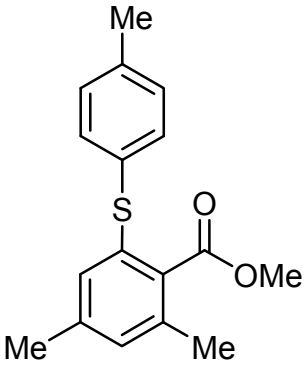


Methyl 2,4-dimethyl-3,6-bis(phenylsulfanyl)benzoate (5d): Starting with **4d** (840 mg, 3.0 mmol), **3a** (562 mg, 2.0 mmol), $TiCl_4$ (0.32 mL, 3.0 mmol), and CH_2Cl_2 (11 mL), **5d** was isolated as a highly viscous oil (485 mg, 63%). ^{1}H NMR (250 MHz, $CDCl_3$): δ = 2.23 (s, 3 H, CH_3), 2.35 (s, 3 H, CH_3), 3.81 (s, 3 H, OCH_3), 6.87 (s, 1 H, ArH), 7.03 (m, 3 H, ArH), 7.11 (m, 2 H, ArH), 7.23 (m, 3 H, ArH), 7.34 (m, 2 H, ArH). ^{13}C NMR (62 MHz, $CDCl_3$): δ = 19.1, 22.1 (CH_3), 52.1 (OCH_3), 125.1 (ArCH), 125.9 (2C, ArCH), 127.7 (ArCH), 129.0 (2C, ArCH), 129.3 (2C, ArCH), 130.0 (C), 131.2 (ArCH), 132.0 (2C, ArCH), 134.5, 134.9, 135.1, 136.9, 141.1, 145.8, 168.8 (C). IR (neat): $\tilde{\nu}$ = 3056 (w), 2938 (w), 1721 (s), 1685 (m), 1512 (m), 1423 (m), 1236 (s), 1149 (s), 1056 (s), 728 (s), 681 (s), 538 (m) cm^{-1}. GC-MS

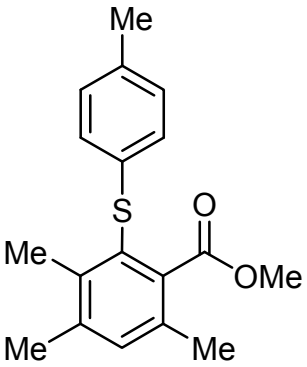
(EI, 70 eV): *m/z* (%): 380 (100), 213 (26), 182 (25), 153 (16), 139 (20), 108 (8). HRMS (EI): calcd for $C_{22}H_{20}O_2S_2$ ([M^+]: 380.06225, found 380.06228.



Methyl 4-methyl-6-(phenylsulfanyl)-6-propylbenzoate (5e): Starting with **4e** (600 mg, 3.0 mmol), **3a** (562 g, 2.0 mmol), $TiCl_4$ (0.32 mL, 3.0 mmol), and CH_2Cl_2 (11 mL), **5e** was isolated as a highly viscous oil (255 mg, 42%). ^{1}H NMR (250 MHz, $CDCl_3$): δ = 0.85 (t, 3 H, *J* = 7.1 Hz, CH_3), 1.47 (m, 2 H, CH_2), 2.11 (q, 2 H, *J* = 6.4 Hz, CH_3), 2.24 (s, 3 H, CH3), 3.80 (s, 3 H, OCH3), 6.91 (s, 1 H, ArH), 7.16 (m, 2 H, ArH), 7.33 (m, 2 H, ArH). ^{13}C NMR (62 MHz, $CDCl_3$): δ = 13.5, 19.7 (CH_3), 24.3, 36.7 (CH_2), 52.0 (OCH_3), 126.8 (ArCH), 129.0 (2C ArCH), 129.5 (C), 130.0 (ArCH), 131.3 (2C ArCH), 135.5 (ArCH), 136.1 139.9, 144.8, 160.2, 165.8 (C). IR (neat): $\tilde{\nu}$ = 3045 (w), 2978 (w), 1714 (s), 1675 (m), 1590 (s), 1460 (m), 1369 (s), 1269 (m), 1171 (m), 1024 (m), 751 (s) 690 (m) cm^{-1}. GC-MS (EI, 70 eV): *m/z* (%): 300 (40), 287 (46), 211 (23), 139 (23), 105 (23). HRMS (EI): calcd for $C_{18}H_{20}O_2S$ [M^+]: 300.03177, found 300.03156.

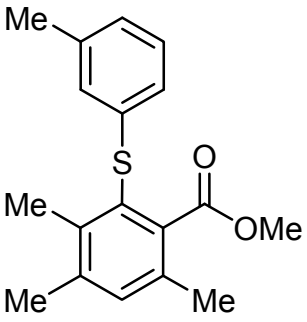


2,4-Dimethyl-6-(4-tolylsulfanyl)benzoic acid methyl ester (5l): Starting with **4a** (387mg, 2.3 mmol), **3d** (441 g, 1.5 mmol), $TiCl_4$ (0.25 mL, 2.3 mmol) and CH_2Cl_2 (9 mL), **5l** was isolated as a highly viscous oil (232mg, 54%). ^{1}H NMR (250 MHz, $CDCl_3$): δ = 2.12 (s, 3H, CH3), 2.22 (s, 3H, CH3), 2.25 (s, 3H, CH3), 3.79 (s, 3H, OCH3), 6.80-7.19 (m, 6H, ArH); ^{13}C NMR (63 MHz, $CDCl_3$): δ = 19.6, 21.1, 21.3 (CH_3), 52.0 (OCH_3), 129.8 (ArCH), 129.9, 131.8 (2C, ArCH), 131.9 (ArCH), 133.1, 134.1, 135.9, 137.4, 137.9, 139.9 (ArC), 169.1 (C). IR (neat): $\tilde{\nu}$ = 3018 (w), 2947 (w), 2919 (w), 2863 (w), 2733 (w), 1726 (s), 1598 (m), 1560 (m), 1490 (m), 1435 (m), 1378 (w), 1267 (s), 1257 (s), 1217 (m), 1188 (m), 1151 (s), 1078 (s), 1023 (m), 999 (w), 956 (w) 852 (m), 810 (m), 738 (s), 689(s) 579 (m), 553 (w) cm^{-1}. GC-MS (EI, 70 eV): *m/z* (%): 286 (100), 255 (55), 255 (55), 254 (20), 253 (76), 240 (15), 239 (56), 212 (17), 211 (23), 197 (11), 165 (5), 91 (4). HRMS (EI): calcd for [M$^+$]: $C_{17}H_{18}O_2S$: 286.10220, found 286.101944.

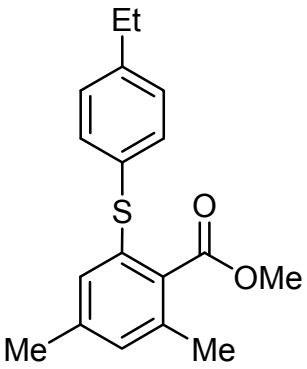


3,4,6-Trimethyl-2-(4-tolylsulfanyl)benzoic acid methyl ester (5m): Starting with **4a** (387 mg, 2.3 mmol), **3e** (462 mg, 1.5 mmol), $TiCl_4$ (0.25 mL, 2.3 mmol) and CH_2Cl_2 (9 mL), **5m** was isolated as a highly viscous oil (176 mg, 39%). ^{1}H NMR (250 MHz, $CDCl_3$): δ = 2.16 (s, 3H, CH_3), 2.18 (s, 3H, CH_3), 2.18 (s, 3H, CH_3), 2.19 (s, 3H, CH_3), 3.79 (s, 3H, OCH_3), 6.87-7.16 (m, 5H, ArH). ^{13}C NMR (63 MHz, $CDCl_3$): δ = 16.9, 18.9, 20.9, 21.0 (CH_3), 52.0 (OCH_3), 127.5 (2C, ArCH), 128.4 (ArCH), 129.6. (2C ArCH), 131.8, 132.7, 133.9, 135.3, 138.8, 139.0, 139.3 (ArC), 169.6 (C). IR (neat): $\tilde{\nu}$ = 2946 (w), 2919 (w), 2863 (w), 1728 (s), 1596

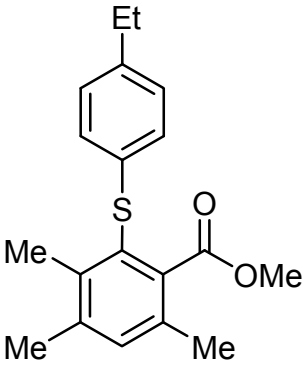
(m), 1490 (m), 1434 (m), 1383 (w), 1285 (s), 1223 (m), 1189 (m), 1140 (s), 1085 (m), 1015 (m), 965 (w), 948 (w) 853 (m), 803 (m), 751 (m), 626(m) 557 (m) cm^{-1}. GC-MS (EI, 70 eV): *m/z* (%):300 (96), 269 (33), 268 (12), 267 (43), 253 (M^+, 100), 226 (14), 225 (20), 211 (13), 192 (4), 91 (9), 65 (4). HRMS (EI): calcd for $C_{18}H_{20}O_2S$ [M^+]: 300.11767, found 300.117653.



2,4-Dimethyl-6-(m-tolylsulfanyl)benzoic acid methyl ester (5n): Starting with **4a** (387 mg, 2.3 mmol), **3f** (441 mg, 1.5 mmol), $TiCl_4$ (0.25 mL, 2.3 mmol) and CH_2Cl_2 (9 mL), **5n** was isolated as a highly viscous oil (232 mg, 54%). ^1H NMR (250 MHz, $CDCl_3$): δ = 2.12 (s, 3H, CH_3), 2.22 (s, 3H, CH_3), 2.25 (s, 3H, CH_3), 3.79 (s, 3H, OCH_3), 6.80-7.19 (m, 6H, ArH). ^{13}C NMR (63 MHz, $CDCl_3$): δ = 19.6, 21.1, 21.3 (CH_3), 52.0 (OCH_3), 129.8 (ArCH), 129.9, 131.8 (2C ArCH), 131.9 (ArCH), 133.1, 134.1, 135.9, 137.4, 137.9, 139.9 (ArC), 169.1 (C). IR (neat): $\tilde{\nu}$ = 3018 (w), 2947 (w), 2919 (w), 2863 (w), 2733 (w), 1726 (s), 1598 (m), 1560 (m), 1490 (m), 1435 (m), 1378 (w), 1267 (s), 1257 (s), 1217 (m), 1188 (m), 1151 (s), 1078 (s), 1023 (m), 999 (w), 956 (w) 852 (m), 810 (m), 738 (s), 689(s) 579 (m), 553 (w) cm^{-1}. GC-MS (EI, 70 eV): *m/z* (%): 286 (100), 255 (55), 255 (55), 254 (20), 253 (76), 240 (15), 239 (56), 212 (17), 211 (23), 197 (11), 165 (5), 91 (4). HRMS (EI): calcd for $C_{17}H_{18}O_2S$ [M^+]: 286.10220, found 286.101944.

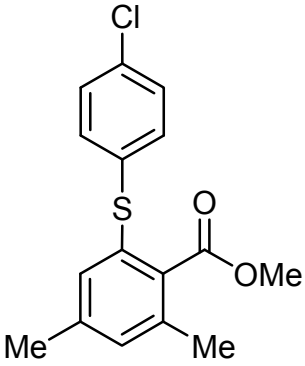


2-(4-Ethylphenylsulfanyl)-4,6-dimethyl-benzoic acid methyl ester (5o): Starting with **4a** (387 mg, 2.3 mmol), **3g** (462 mg, 1.5 mmol), $TiCl_4$ (0.25 mL, 2.3 mmol) and CH_2Cl_2 (9 mL), **5o** was isolated as a highly viscous oil (221 mg, 49%). ^{1}H NMR (250 MHz, $CDCl_3$): δ = 1.14 (t, 3H, J = 7.2 Hz, CH3), 2.12 (s, 3H, CH_3), 2.22 (s, 3H, CH_3), 2.56 (q, 2H, *J* = 7.2 Hz, CH_2), 3.79 (s, 3H, OCH_3), 6.82-7.21 (m, 6H, ArH). ^{13}C NMR (75 MHz, $CDCl_3$): δ = 15.4, 19.6, 21.6 (CH_3), 28.4 (CH_2), 52.0 (OCH_3), 128.7 (2C, ArCH), 129.4, 129.9 (ArCH), 131.8 (2C ArCH), 132.1, 133.2, 133.9, 135.9, 139.9, 143.6 (ArC), 169.2 (C). IR (neat): $\tilde{\nu}$ = 3018 (w), 2963 (w), 2928 (w), 2871 (w),1727 (s), 1599 (m), 1491 (m), 1435 (m), 1404 (w), 1377 (w), 1266 (s), 1257 (s), 1217 (m), 1187 (m), 1152 (s), 1078 (s), 1016 (m), 965 (w), 947 (w) 849 (m), 810 (m), 778 (w), 738(m) 579 (m), 555 (w) cm^{-1}. GC-MS (EI, 70 eV): *m/z* (%): 300 (M^+, 100), 284 (5), 283 (26), 282 (10), 281 (27), 267 (7), 254 (20), 253 (97), 239 (7), 225 (15), 178 (5), 134 (4), 121 (19). HRMS (EI): calcd for $C_{18}H_{20}O_2S$ [M^+]: 300.11785, found 300.117168.

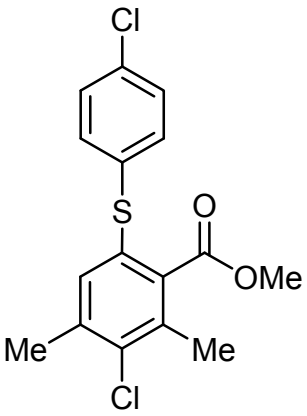


2-(4-Ethylphenylsulfanyl)-3,4,6-trimethyl-benzoic acid methyl ester (5p): Starting with **4a** (387 mg, 2.3 mmol), **3h** (483 mg, 1.5 mmol), $TiCl_4$ (0.25 mL, 2.25 mmol) and CH_2Cl_2 (9 mL), **5p** was isolated as a highly viscous oil (212 mg, 45%). ^{1}H NMR (250 MHz, $CDCl_3$): δ = 1.09 (t, 3H, *J* = 7.2 Hz, CH_3), 2.16 (s, 3H, CH_3), 2.18 (s, 3H, CH_3), 2.19 (s, 3H, CH_3), 2.47 (q, 2H, *J* = 7.2 Hz, CH_2), 3.74 (s, 3H, OCH_3), 6.93-7.17 (m, 5H, ArH). ^{13}C NMR (75 MHz, $CDCl_3$): δ =

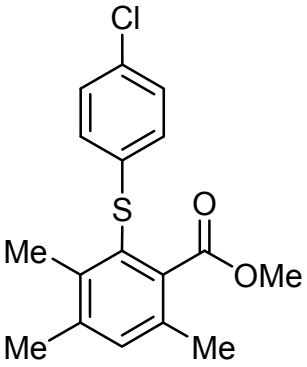
15.4, 16.9, 18.9 (CH_3), 28.3 (CH_2), 52.0 (OCH_3), 127.6 (2C, ArCH), 128.4 (2C, ArCH), 128.5, 131.9 (ArC), 132.8 (ArCH), 134.1, 138.7, 139.0, 141.6 (ArC), 169.7 (C). IR (neat): $\tilde{\nu}$ = 3016 (w), 2963 (w), 2948 (w), 2928 (w), 2871 (w),1729 (s), 1596 (m), 1491 (m), 1433 (m), 1404 (w), 1383 (w), 1285 (s), 1242 (m), 1223 (m), 1187 (m), 1142 (s), 1119 (m), 1087 (m),1052 (m), 1014 (m), 1004 (m), 821 (s), 789 (m), 751 (w), 721(m) cm^{-1}. GC-MS (EI, 70 eV): *m/z* (%): 314 (M^+, 100), 284 (5), 283 (26), 182 (10), 281 (27), 267 (7), 254 (20), 253 (97), 239 (7), 225 (15), 178 (5), 134 (4), 121 (19). HRMS (EI): calcd for $C_{19}H_{22}O_2S$ [M^+]: 314.13350, found 314.133456.



2-(4-Chlorophenylsulfanyl)-4,6-dimethyl-benzoic acid methyl ester (5q): Starting with **4a** (387 mg, 2.3 mmol), **3i** (470 mg, 1.5 mmol), $TiCl_4$ (0.25 mL, 2.3 mmol) and CH_2Cl_2 (9 mL), **5q** was isolated as a highly viscous oil (170 mg, 37%). ^1H NMR (250 MHz, $CDCl_3$): δ = 2.17 (s, 3H, CH_3), 2.37 (s, 3H, CH_3), 3.77 (s, 3H, OCH_3), 6.90-7.34 (m, 6H, ArH). ^{13}C NMR (63 MHz, $CDCl_3$): δ = 18.1, 20.1 (CH_3), 49.9 (OCH_3), 127.0 128.1 (ArCH), 129.0 (2C ArCH), 130.3 (ArC), 135.7 (2C ArCH), 137.1, 137.3, 139.2, 164.5 (ArC), 167.9 (C). IR (neat): $\tilde{\nu}$ = 2945 (w), 2918 (w), 2853 (w), 1728 (s), 1596 (m), 1491 (m), 1435 (m), 1383 (w), 1285 (s), 1223 (m), 1189 (m), 1140 (s), 1085 (m), 1015 (m), 965 (w), 948 (w) 853 (m), 803 (m), 751 (m), 626 (m) 554 (m) cm^{-1}. GC-MS (EI, 70 eV): *m/z* (%): 308 (M^+, 25), 306 (M^+, 100), 266 (12), 262 (43), 253 (100), 226 (14), 225 (20), 211 (13), 192 (4), 91 (9), 63 (4). HRMS (EI): calcd for $C_{16}H_{15}O_2ClS$: [M^+] 306.58923, found 306.587603.

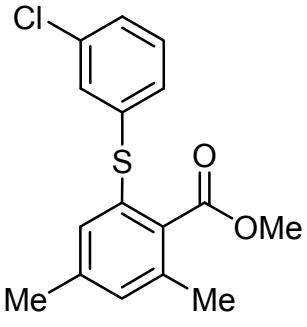


3-Chloro-6-(4-chlorophenylsulfanyl)-2,4-dimethyl-benzoic acid methyl ester (5r): Starting with **4c** (460 mg, 2.3 mmol), **3i** (470 mg, 1.5 mmol), $TiCl_4$ (0.25 mL, 2.25 mmol) and CH_2Cl_2 (9 mL), **5r** was isolated as a highly viscous oil (179 mg, 35%). ^1H NMR (250 MHz, $CDCl_3$): δ = 2.31 (s, 3H, CH_3), 2.42 (s, 3H, CH_3), 3.75 (s, 3H, OCH_3), 6.90-7.19 (m, 5H, ArH). ^{13}C NMR (63 MHz, $CDCl_3$): δ = 18.1, 20.9 (CH3), 52.4 (OCH3), 129.1 (2C ArCH), 129.2 (ArCH), 131.5 (2C ArCH), 133.0, 133.8, 134.1, 135.5, 137.0, 138.7 (ArC), 168.2 (C). IR (neat): $\tilde{\nu}$ = 2946 (w), 2919 (w), 2863 (w), 1728 (s), 1596 (m), 1490 (m), 1434 (m), 1383 (w), 1285 (s), 1223 (m), 1189 (m), 1140 (s), 1085 (m), 1015 (m), 965 (w), 948 (w) 853 (m), 803 (m), 751 (m), 626(m) 557 (m) cm^{-1}. GC-MS (EI, 70 eV): *m/z* (%): 344 (25, M^+), 342 (50, M^+), 340 (100, M^+), 268 (12), 267 (43), 253 (100), 226 (14), 225 (20), 211 (13), 192 (4), 91 (9), 65 (4). HRMS (EI): calcd for $C_{16}H_{14}O_2Cl_2S$ [M^+]: 341.01787, found 341.017653.

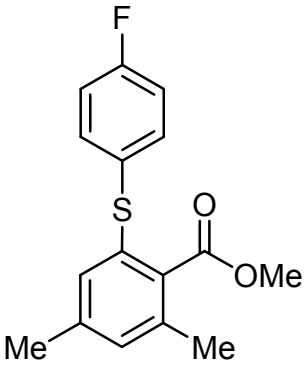


2-(4-Chlorophenylsulfanyl)-3,4,6-trimethyl-benzoic acid methyl ester (5s): Starting with **4a** (387 mg, 2.3 mmol), **3j** (490 mg, 1.5 mmol), $TiCl_4$ (0.25 mL, 2.25 mmol) and CH_2Cl_2 (9 mL), **5s** was isolated as a highly viscous oil (188 mg, 36%). ^1H NMR (250 MHz, $CDCl_3$): δ = 2.18 (s, 3H, CH_3), 2.20 (s, 3H, CH_3), 2.38 (s, 3H, CH_3), 3.77 (s, 3H, OCH_3), 6.90-7.34 (m, 5H, ArH). ^{13}C NMR (63 MHz, $CDCl_3$): δ = 18.1, 18.3, 20.1 (CH_3), 50.6 (OCH_3), 127.0 128.1 (ArCH), 129.0 (2C ArCH), 130.3. (ArC), 135.7 (2C, ArCH), 137.1, 137.3, 139.2, 164.5 (ArC), 167.9

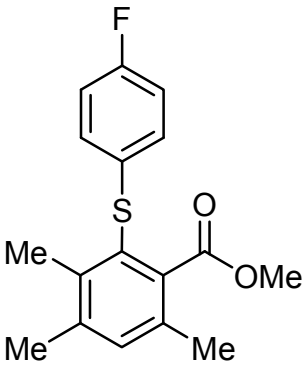
(C). IR (neat): $\tilde{\nu}$ = 2945 (w), 2918 (w), 2853 (w), 1728 (s), 1596 (m), 1491 (m), 1435 (m), 1383 (w), 1285 (s), 1223 (m), 1189 (m), 1140 (s), 1085 (m), 1015 (m), 965 (w), 948 (w) 853 (m), 803 (m), 751 (m), 626(m) 554 (m) cm^{-1}. GC-MS (EI, 70 eV): *m/z* (%): 322 (M^+, 25), 320 (M^+, 100), 266 (12), 262 (43), 253 (10), 226 (14), 225 (20), 211 (13), 192 (4), 91 (9), 63 (4). HRMS (EI): calcd for $C_{17}H_{17}O_2ClS$ [M^+]: 320.58923, found 320.587603.



2-(3-Chlorophenylsulfanyl)-4,6-dimethyl-benzoic acid methyl ester (5t): Starting with **4a** (387 mg, 2.3 mmol), **3k** (470 mg, 1.5 mmol), $TiCl_4$ (0.25 mL, 2.25 mmol) and CH_2Cl_2 (9 mL), **5t** was isolated as a highly viscous oil (171 mg, 37%). ^{1}H NMR (250 MHz, $CDCl_3$): δ = 2.18 (s, 3H, CH_3), 2.38 (s, 3H, CH_3), 3.77 (s, 3H, OCH_3), 6.90-7.34 (m, 6H, ArH). ^{13}C NMR (63 MHz, $CDCl_3$): δ = 18.1, 20.1 (CH_3), 50.6 (OCH_3), 127.0 128.1 (ArCH), 129.0 (2C ArCH), 130.3 (ArC), 135.7 (2C ArCH),137.1, 137.3, 139.2, 164.5 (ArC), 167.9 (C). IR (neat): $\tilde{\nu}$ = 2945 (w), 2918 (w), 2853 (w), 1728 (s), 1596 (m), 1491 (m), 1435 (m), 1383 (w), 1285 (s), 1223 (m), 1189 (m), 1140 (s), 1085 (m), 1015 (m), 965 (w), 948 (w) 853 (m), 803 (m), 751 (m), 626(m) 554 (m) cm^{-1}. GC-MS (EI, 70 eV): *m/z* (%): 308 (M^+, 25), 306 (M^+, 100), 266 (12), 262 (43), 253 (100), 226 (14), 225 (20), 211 (13), 192 (4), 91 (9), 63 (4). HRMS (EI): calcd for $C_{16}H_{15}O_2ClS$ [M^+]: 306.58923, found 306.587603.



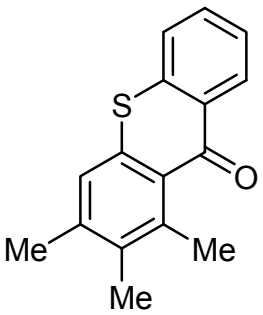
2(4-Fluorophenylsulfanyl)-4,6-dimethyl-benzoic acid methyl ester (5u): Starting with **4a** (387 mg, 2.3 mmol), **3l** (447 mg, 1.5 mmol), $TiCl_4$ (0.25 mL, 2.25 mmol) and CH_2Cl_2 (9 mL), **5u** was isolated as a highly viscous oil (174 mg, 40%). ^{1}H NMR (250 MHz, $CDCl_3$): δ = 2.14 (s, 3H, CH_3), 2.23 (s, 3H, CH_3), 3.80 (s, 3H, OCH_3), 6.79-7.29 (m, 6H, ArH). ^{13}C NMR (63 MHz, $CDCl_3$): δ = 19.6, 21.1 (CH_3), 52.0 (OCH_3), 130.2 (2C ArCH), 130.8, 133.3 (ArCH), 133.7 (2C ArCH), 136.1, 137.2, 137.9, 140.2 (ArCH), 169.1 (C). IR (neat): $\tilde{\nu}$ = 2949 (w), 2921 (w), 2737 (w), 1726 (s), 1599 (m), 1588 (m), 1561 (w), 1487 (s), 1436 (m), 1396 (w), 1378 (w), 1267 (s), 1219 (s), 1189 (m), 1152 (s), 1078 (s), 1012 (m), 965 (w), 947 (w) 827 (m), 810 (m), 738 (s), 689(s) 579 (m), 554 (w) cm^{-1}. GC-MS (EI, 70 eV): *m/z* (%): 290 (66, M^+), 259 (46), 258 (22), 257 (100), 216 (17), 215 (28), 91 (4), 75 (2). HRMS (EI): calcd for $C_{16}H_{15}O_2FS$ [M^+]: 290.07713, found 290.077041.



2-(4-Fluorophenylsulfanyl)-3,4,6-trimethylbenzoic acid methyl ester (5v): Starting with **4a** (387 mg, 2.3 mmol), **3m** (468 mg, 1.5 mmol), $TiCl_4$ (0.25 mL, 2.25 mmol) and CH_2Cl_2 (9 mL), **5v** was isolated as a highly viscous oil (161 mg, 33%). ^{1}H NMR (250 MHz, $CDCl_3$): δ = 2.19 (s, 3H, CH_3), 2.22 (s, 3H, CH_3), 2.41 (s, 3H, CH_3), 3.88 (s, 3H, OCH_3), 6.90-7.34 (m, 5H, ArH). ^{13}C NMR (63 MHz, $CDCl_3$): δ = 18.3, 18.6, 20.9 (CH_3), 51.5 (OCH_3), 127.0 128.1 (ArCH), 129.0 (2C ArCH), 130.3 (ArC), 135.7 (2C ArCH), 137.1, 137.3, 139.2, 164.5 (ArC), 167.9 (C). IR (neat): $\tilde{\nu}$ = 2945 (w), 2918 (w), 2853 (w), 1728 (s), 1596 (m), 1491 (m), 1435 (m), 1383 (w), 1285 (s), 1223 (m), 1189 (m), 1140 (s), 1085 (m), 1015 (m), 965 (w),

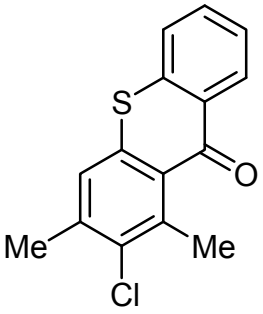
948 (w) 853 (m), 803 (m), 751 (m), 626(m) 554 (m) cm^{-1}. GC-MS (EI, 70 eV): *m/z* (%): 304 (M^+, 100), 266 (12), 262 (43), 226 (14), 225 (20), 211 (13), 192 (4), 91 (9), 63 (4). HRMS (EI): calcd for $C_{16}H_{15}O_2ClS$ [M^+]:304.04523, found 304.045603.

General procedure for the synthesis of thioxanthones 6a-g: To **5** (1.0 mmol) was added concentrated sulfuric acid (98%, 12 mL / mmol of **5**) at 20 °C and the solution was stirred for 2 h. To the solution was added ice water (50 mL). The organic and the aqueous layer were separated and the latter was extracted with dichloromethane (3 x 15 mL). The combined organic layers were dried (Na_2SO_4), filtered, and the filtrate was concentrated in vacuo. The residue was purified by chromatography (silica gel, heptanes / EtOAc).

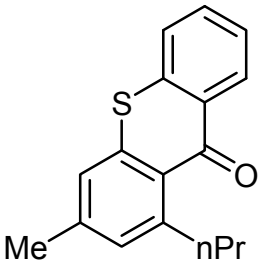


1,2,3-Trimethylthioxanthone (6a): Starting with **5b** (114 mg, 1.0 mmol) and conc. sulfuric acid, **6a** was isolated as a highly viscous oil (270 mg, 98%). ^{1}H NMR (250 MHz, $CDCl_3$): δ = 2.21 (s, 3 H, CH_3), 2.30 (s, 3 H, CH_3), 2.68 (s, 3 H, CH_3), 7.31 (m, 1 H, ArH), 7.40 (m, 3 H, ArH), 8.30 (dd, 1 H, ^3J = 7.4, ^4J = 2.1 Hz, ArH). ^{13}C NMR (62 MHz, $CDCl_3$): δ = 15.9, 19.1, 21.4 (CH_3), 124.2, 125.0, 125.7 (ArCH), 127.0 (C), 129.4, 131.0 (ArCH), 132.4, 134.9, 135.4, 135.7, 141.0, 141.1, 183.3 (C). IR (neat): $\tilde{\nu}$ = 3023 (w), 2918 (w), 1712 (m), 1671 (s), 1530 (m), 1493 (s), 1329 (m), 1216 (s), 1166 (m), 1019 (m), 7546 (w) 645 (m) cm^{-1}. GC-MS (EI, 70 eV):

m/z (%): 254 (100), 239 (46), 225 (34), 211 (12), 178 (13), 165 (15), 91 (8). HRMS (EI): calcd for $C_{16}H_{14}OS$ [M^+]: 254.07799, found 254.07586.



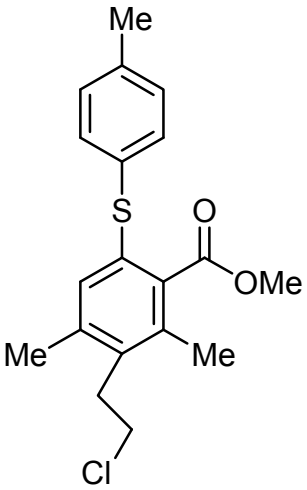
2-Chloro-1,3-dimethylthioxanthone (6b): Starting with **5c** (114 mg, 0.4 mmol) and conc. sulfuric acid, **6b** was isolated as a highly viscous oil (114 mg, 97%). ^{1}H NMR (250 MHz, $CDCl_3$): δ = 2.38 (s, 3 H, CH_3), 2.83 (s, 3 H, CH_3), 7.16 (s, 1 H, ArH), 7.45 (m, 3 H, ArH), 8.31 (dd, 1 H, ^3J = 7.9, ^4J = 2.0 Hz, ArH). ^{13}C NMR (62 MHz, $CDCl_3$): δ = 19.8, 21.4 (CH_3), 125.1 (2C, ArCH), 126.2 (ArCH), 127.3 (C), 129.6, 131.7 (ArCH), 131.8, 135.0, 135.3, 136.7, 141.7, 141.9, 182.4 (C). IR (neat): $\tilde{\nu}$ = 3375 (w), 2978 (s), 1734 (m), 1675 (m), 1590 (m), 1490 (m), 1319 (m), 1219 (m), 1176 (m), 1029 (m), 751 (w) 690 (m) cm^{-1}. GC-MS (EI, 70 eV): *m/z* (%): 276 (M^+, ^{37}Cl, 37), 274 (M^+, ^{35}Cl, 41), 267 (100), 105 (89), 77 (34). HRMS (EI): calcd for $C_{15}H_{11}OClS$ [M^+, ^{35}Cl]: 274.06127, found 274.06139.



1-Propyl-3-methylthioxanthone (6c): Starting with **5e** (50 mg, 0.16 mmol) and conc. sulfuric acid, **6c** was isolated as a highly viscous oil (42 mg, 95%). ^{1}H NMR (250 MHz, $CDCl_3$): δ = 0.90 (t, 3 H, *J* = 7.4, CH_3), 1.60 (m, 2 H, CH_2), 2.55 (t, H, *J* = 7.4, CH_2), 2.81 (m, 3 H, CH_3), 7.10 (S, 1 H, ArH), 7.38 (m, 3 H, ArH), 8.25 (dd, 1 H, ^3J = 7.2, ^4J =1.87 Hz, ArH). ^{13}C NMR (62 MHz, $CDCl_3$): δ = 13.8, 23.4 (CH_3), 24.8, 37.6 (CH_2), 123.6, 125.1, 125.9 (ArCH), 127.2 (C), 129.6, 131.0, 131.5 (ArCH), 132.1,

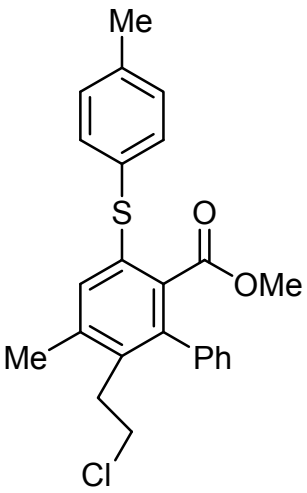
135.4, 139.2, 143.8, 146.5, 182.2 (C). IR (neat): $\tilde{\nu}$ = 3056 (w), 2973 (w), 1732 (m), 1625 (s), 1560 (m), 1460 (s), 1329 (s), 1249 (2), 1186 (s), 1029 (m), 723 (w) 690 (m) cm^{-1}. GC-MS (EI, 70 eV): *m/z* (%): 268 (100), 253 (7), 239 (34), 211 (36), 178 (10), 120 (7), 77 (8). HRMS (EI): calcd for $C_{17}H_{16}OS$ [M^+]: 268.09164, found 268.09153.

General procedure for the synthesis of diaryl sulfides 8a-x: To a dichloromethane solution (30 mL/mmol) of 3-arylthio-1-trimethylsilyloxy-1,3-butadienes **3** (1.0 mmol) and 1,1-diacyclopropane **7** (1.5 mmol) was added TiX_4 (1.5 mmol, X = Cl, Br) at –78 °C. The solution was allowed to warm to ambient temperature within 14 h. To the solution was added a diluted aqueous solution of HCL (25 mL). The organic and the aqueous layer were separated and the latter was extracted with dichloromethane (3 x 20 mL). The filtrate was concentrated in vacuo and the residue was purified by chromatography (silica gel, EtOAc / *n*-heptane).

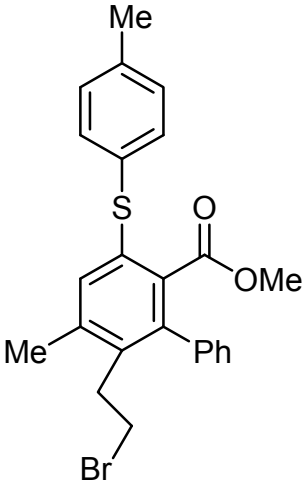


Methyl 4,6-dimethyl-5-(2-chloroethyl)-2-(4-methylphenyl-sulfanyl)benzoate (8h): Starting with **7a** (283 mg, 2.25 mmol) **3d** (441 mg, 1.5 mmol), $TiCl_4$ (0.25 mL, 2.25 mmol) and CH_2Cl_2 (45 mL), **8h** was isolated as a highly viscous oil (208 mg, 40%). ^{1}H NMR (250 MHz, $CDCl_3$): δ = 2.18 (s, 3 H, CH_3), 2.21 (s, 3 H, CH_3), 2.22 (s, 3 H, CH_3), 3.03 (t, *J*=8.3 Hz, 2 H, CH_2), 3.44 (t, *J*=8.3 Hz, 2 H, CH_2), 3.78 (s, 3 H, OC*H*$_3$), 6.93-7.07 (m, 5 H, ArH). ^{13}C NMR (62 MHz, $CDCl_3$): δ = 16.8, (CH_3), 20.1 (CH_3), 21.3 (CH_3), 33.1 (CH_2), 41.6

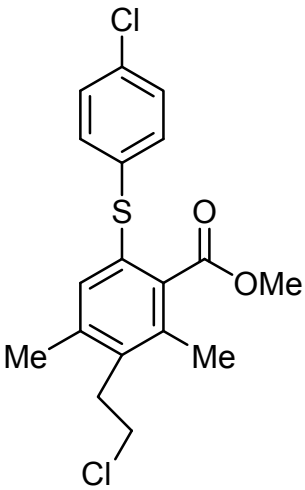
(CH_2), 52.1 (OCH_3), 111.3 (C), 127.9 (2CH), 128.9 (CH), 130.7 (C), 131.1, 132.8 (CH),133.0, 134.0, 134.8, 135.5, 138.9, 169.3 (C). IR (ATR): $\tilde{\nu}$ = 2948 (w), 2921 (w), 2734 (w)., 2249 (w), 1728 (s), 1588 (m), 1573 (m), 1473 (m), 1435 (m), 1392 (m), 1377 (m), 1325 (m), 1270 (sd), 1190 (s), 1140 (s), 1040 (s), 907 (s), 777 (s), 728 (s), 691 (s), 646 (m) cm^{-1}. GC-MS (EI, 70 eV): *m/z* (%): 350 (M^+, ^{37}Cl, 38), 348 (M^+, ^{35}Cl, 100), 317 (29), 315 (37), 303 (10) 301 (10), 281 (24), 268 (13), 267 (63), 225 (12), 224 (10). HRMS (EI): calcd for $C_{19}H_{21}O_2ClS$ [M^+]: 348.09453, found 348.094465.



Methyl 4-methyl-5-(2-chloroethyl)-2-(4-methylphenyl-sulfanyl)-6-phenylbenzoate (8i): Starting with **7b** (283 mg, 2.25 mmol) **3d** (441 mg, 1.5 mmol), $TiCl_4$ (0.25 mL, 2.25 mmol) and CH_2Cl_2 (45 mL), **8i** was isolated as a highly viscous oil (252 mg, 41%). ^1H NMR (250 MHz, $CDCl_3$): δ = 2.18 (s, 3 H, CH_3), 2.21 (s, 3 H, CH_3), 3.03 (t, *J*=8.3 Hz, 2 H, CH_2), 3.44 (t, *J*=8.3 Hz, 2 H, CH_2), 3.77 (s, 3 H, OCH_3), 6.96-7.28 (m, 10H, ArH). ^{13}C NMR (62 MHz, $CDCl_3$): δ = 18.6 (CH_3), 21.3 (CH_3), 33.1 (CH_2), 40.2 (CH_2), 52.1 (OCH_3), 127.8 (CH), 128.0, 128.8, 129.2 (2CH), 131.2, 132.3 (C), 132.4 (2CH), 132.5 (CH), 133.6, 134.7, 138.0, 139.1, 140.7, 144.1, 168.3 (C). IR (ATR): $\tilde{\nu}$ = 2948 (w), 2921 (w), 2734 (w), 2249 (w), 1728 (s), 1588 (m), 1573 (m), 1473 (m), 1435 (m), 1392 (m), 1377 (m), 1325 (m), 1270 (sd), 1190 (s), 1140 (s), 1040 (s), 907 (s), 777 (s), 728 (s), 691 (s), 646 (m) cm^{-1}. GC-MS (EI, 70 eV): *m/z* (%): 350 (M^+, ^{37}Cl, 38), 348 (M^+, ^{35}Cl, 100), 317 (29), 315 (37), 303 (10), 301 (10), 281 (24), 268 (13), 267 (63), 225 (12), 224 (10). HRMS (EI): calcd for $C_{19}H_{21}O_2ClS$ [M^+]: 348.09453, found 348.094465.

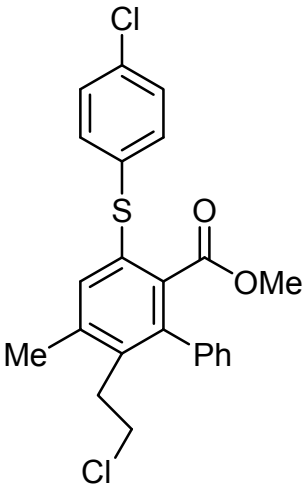


Methyl 4-methyl-5-(2-bromoethyl)-2-(4-methylphenyl-sulfanyl)-6-phenylbenzoate (8j): Starting with **7b** (283 mg, 2.25 mmol) **3d** (441 mg, 1.5 mmol), $TiBr_4$ (0.826 g, 2.25 mmol) and CH_2Cl_2 (45 mL), **8j** was isolated as a highly viscous oil (306 mg, 45%). ^{1}H NMR (250 MHz, $CDCl_3$): δ = 2.18 (s, 3 H, CH_3), 2.21 (s, 3 H, CH_3), 3.03 (t, *J*=8.3 Hz, 2 H, CH_2), 3.39 (t, *J*=8.3 Hz, 2 H, CH_2), 3.77 (s, 3 H, OC*H*$_3$), 6.96-7.66 (m, 10H, ArH). ^{13}C NMR (62 MHz, $CDCl_3$): δ = 20.1 (CH_3), 21.3 (CH_3), 33.1 (CH_2), 40.2 (CH_2), 52.1 (OCH_3), 127.8 (CH), 128.0, 128.8, 129.2 (2CH), 131.2, 132.3 (C), 132.4 (2CH), 132.5 (CH), 133.6, 134.7, 138.0, 139.1, 140.7, 144.1, 168.3 (C). IR (ATR): $\tilde{\nu}$ = 2948 (w), 2921 (w), 2734 (w), 2249 (w), 1728 (s), 1588 (m), 1573 (m), 1473 (m), 1435 (m), 1392 (m), 1377 (m), 1325 (m), 1270 (sd), 1190 (s), 1140 (s), 1040 (s), 907 (s), 777 (s), 728 (s), 691 (s), 646 (m) cm^{-1}. GC-MS (EI, 70 eV): *m/z* (%): 350 (M^+, ^{81}Br, 100), 348 (M^+, ^{79}Br, 75), 317 (87), 315 (37), 303 (10) 301 (10), 281 (24), 268 (13), 267 (63), 225 (12), 224 (10). HRMS (EI): calcd for $C_{24}H_{23}O_2BrS$ [M^+]: 454.05966, found 454.059387.



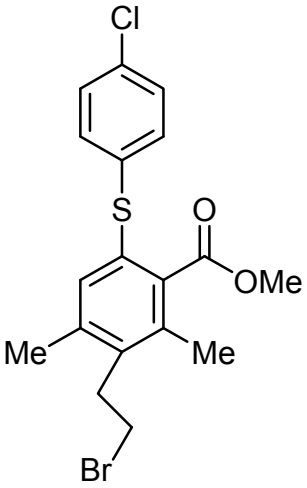
Methyl 4,6-dimethyl-5-(2-chloroethyl)-2-(4-chlorophenyl-sulfanyl)benzoate (8k): Starting with **7a** (283 mg, 2.25 mmol), **3i** (472 mg, 1.5 mmol), $TiCl_4$ (0.25ml, 2.25 mmol) and CH_2Cl_2 (45 mL), **8k** was isolated as a highly viscous oil (237 mg, 43%). ^{1}H NMR (250 MHz, $CDCl_3$): δ = 2.18 (s, 3 H, CH_3), 2.24 (s, 3 H, CH_3), 3.03 (t, *J*=8.3 Hz, 2 H, CH_2), 3.46 (t,

J=8.3 Hz, 2 H, CH_2), 3.78 (s, 3 H, OC*H*$_3$), 6.93-7.29 (m, 5 H, ArH). ^{13}C NMR (62 MHz, $CDCl_3$): δ = 21.1 (CH_3), 21.3 (CH_3), 33.1 (CH_2), 41.6 (CH_2), 52.1 (OCH_3), 111.3 (C), 127.9 (2CH), 128.9 (CH), 130.7 (C), 131.1, 132.8 (CH),133.0, 134.0, 134.8, 135.5, 138.9, 169.3 (C). IR (ATR): $\tilde{\nu}$ = 2947 (w), 2926 (w), 2736 (w), 2249 (w), 1728 (s), 1588 (m), 1573 (m), 1473 (m), 1435 (m), 1392 (m), 1377 (m), 1327 (m), 1270 (sd), 1190 (s), 1140 (s), 1040 (s), 907 (s), 777 (s), 728 (s), 691 (s), 645 (m) cm^{-1}. GC-MS (EI, 70 eV): *m/z* (%): 372 (M^+, ^{37}Cl, ^{37}Cl, 14), 371 (M^+, ^{35}Cl, ^{37}Cl, 70), 370 (M^+, ^{35}Cl, ^{35}Cl, 100), 317 (29), 315 (37), 303 (10) 301 (10), 281 (24), 268 (13), 267 (63), 225 (12), 224 (10). HRMS (EI): calcd for $C_{18}H_{18}O_2Cl_2S$ [M^+]: 368.03991, found 368.040296.

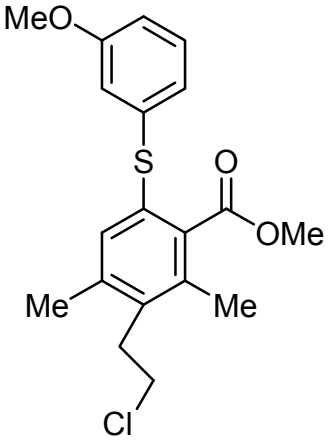


Methyl 4-methyl-5-(2-chloroethyl)-2-(4-chlorophenyl-sulfanyl)-6-phenylbenzoate (8l): Starting with **7b** (283 mg, 2.25 mmol), **3i** (472 mg, 1.5 mmol), $TiCl_4$ (0.25 mL, 2.25 mmol) and CH_2Cl_2 (45 mL), **8l** was isolated as a highly viscous oil (303 mg, 47%). ^{1}H NMR (250 MHz, $CDCl_3$): δ = 2.18 (s, 3 H, CH_3), 3.03 (t, *J*=8.3 Hz, 2 H, CH_2), 3.44 (t, *J*=8.3 Hz, 2 H, CH_2), 3.77 (s, 3 H, OC*H*$_3$), 6.93-7.26 (m, 5 H, ArH). ^{13}C NMR (62 MHz, $CDCl_3$): δ = 20.1 (CH_3), 33.1 (CH_2), 41.6 (CH_2), 52.1 (OCH_3), 127.8 (CH), 128.0, 128.8, 129.2 (2CH), 131.2, 132.3 (C), 132.4 (2CH), 132.5 (CH), 133.6, 134.7, 138.0, 139.1, 140.7, 144.1, 168.3 (C). IR (ATR): $\tilde{\nu}$ = 2947 (w), 2921 (w), 2734 (w), 2249 (w), 1728 (s), 1588 (m), 1577 (m), 1473 (m), 1435 (m), 1392 (m), 1377 (m), 1325 (m), 1270 (sd), 1190 (s), 1140 (s), 1040 (s), 907 (s), 777 (s), 728 (s), 691 (s), 646 (m) cm^{-1}. GC-MS (EI, 70 eV): *m/z* (%): 434 (M^+, ^{37}Cl, ^{37}Cl, 12), 432 (M^+,

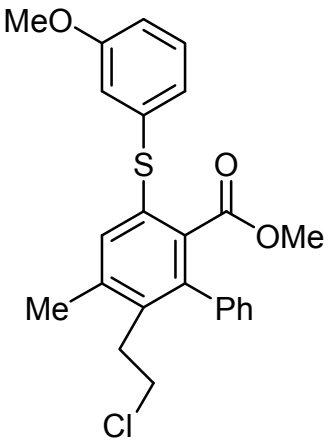
^{35}Cl, ^{37}Cl, 61), 430 (M^+, ^{35}Cl, ^{35}Cl, 85), 349 (100), 315 (37), 303 (10), 301 (10), 281 (24), 268 (13), 267 (63), 225 (12), 224 (10). HRMS (EI): calcd for $C_{23}H_{20}O_2Cl_2S$ [M^+]: 430.09453, found 430.094465.



Methyl 4,6-dimethyl-5-(2-bromooethyl)-2-(4-chlorophenyl-sulfanyl)benzoate (8m): Starting with **7a** (283 mg, 2.25 mmol) **3i** (472 mg, 1.5 mmol), $TiBr_4$ (0.826 g, 2.25 mmol) and CH_2Cl_2 (45 mL), **8m** was isolated as a highly viscous oil (252 mg, 41%). ^1H NMR (250 MHz, $CDCl_3$): δ = 2.18 (s, 3 H, CH_3), 2.24 (s, 3 H, CH_3), 3.03 (t, *J*=8.3 Hz, 2 H, CH_2), 3.46 (t, *J*=8.3 Hz, 2 H, CH_2), 3.78 (s, 3 H, OC*H*$_3$), 6.93-7.29 (m, 5 H, ArH). ^{13}C NMR (62 MHz, $CDCl_3$): δ = 21.1, (CH_3), 21.3 (CH_3), 33.1 (CH_2), 41.6 (CH_2), 52.1 (OCH_3), 111.3 (C), 127.9 (2CH), 128.9 (CH), 130.7 (C), 131.1, 132.8 (CH),133.0, 134.0, 134.8, 135.5, 138.9, 169.3 (C). IR (ATR): $\tilde{\nu}$ = 2947 (w), 2926 (w), 2736 (w), 2249 (w). MS (EI, 70 eV): *m/z* (%): 416 (29), 415 (20), 414 (100), 413 (16), 412 (M^+, 74), 315 (37), 303 (10), 301 (10), 281 (24), 268 (13), 267 (63), 225 (12), 224 (10). HRMS (EI): calcd for $C_{18}H_{18}O_2BrClS$ [M^+]: 411.98939, found 411.989037.

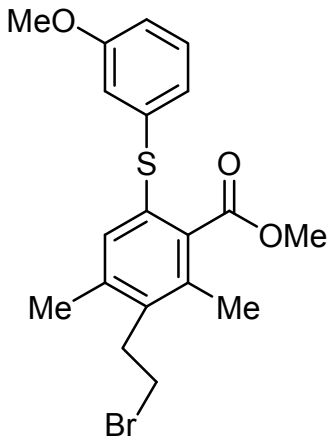


Methyl 4,6-dimethyl-5-(2-chloroethyl)-2-(3-methoxyphenyl-sulfanyl)benzoate (8n): Starting with **7a** (283 mg, 2.25 mmol), **3o** (466 mg, 1.5 mmol), $TiCl_4$ (0.25 mL, 2.25 mmol) and CH_2Cl_2 (45 mL), **8n** was isolated as a highly viscous oil (191 mg, 35%). ^{1}H NMR (250 MHz, $CDCl_3$): δ = 2.18 (s, 3 H, CH_3), 2.22 (s, 3 H, CH_3), 3.03 (t, *J*=8.3 Hz, 2 H, CH_2), 3.44 (t, *J*=8.3 Hz, 2 H, CH_2), 3.66 (s, 3H, O*CH*$_3$), 3.78 (s, 3 H, O*CH*$_3$), 6.93-7.07 (m, 5 H, ArH). ^{13}C NMR (62 MHz, $CDCl_3$): δ = 20.1 (CH_3), 21.3 (CH_3), 33.1 (CH_2), 41.6 (CH_2), 51.2 (OCH_3), 52.1 (OCH_3), 111.3 (C), 127.9 (2CH), 128.9 (CH), 130.7 (C), 131.1, 132.8 (CH), 133.0, 134.0, 134.8, 135.5, 138.9, 169.3 (C). IR (ATR): $\tilde{\nu}$ = 2948 (w), 2921 (w), 2734 (w), 2249 (w), 1728 (s), 1588 (m), 1573 (m), 1473 (m), 1435 (m), 1392 (m), 1377 (m), 1325 (m), 1270 (sd), 1190 (s), 1140 (s), 1040 (s), 907 (s), 777 (s), 728 (s), 691 (s), 646 (m) cm^{-1}. GC-MS (EI, 70 eV): *m/z* (%): 366 (M^+, ^{37}Cl, 39), 364 (M^+, ^{35}Cl, 100), 317 (29), 315 (37), 303 (10) 301 (10), 281 (24), 268 (13), 267 (63), 225 (12), 224 (10). HRMS (EI): calcd for $C_{19}H_{21}O_3ClS$ [M^+]: 364.09453, found 364.094465.



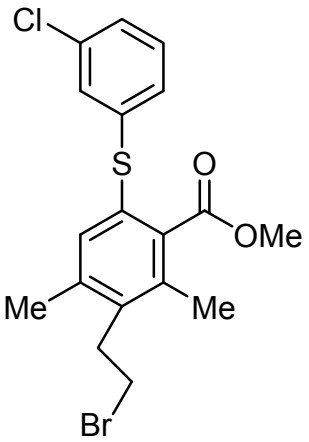
Methyl 4-methyl-5-(2-chloroethyl)-2-(3-methoxyphenyl-sulfanyl)-6-phenylbenzoate (8o): Starting with **7b** (283 mg, 2.25 mmol), **3o** (466 mg, 1.5 mmol), $TiCl_4$ (0.25 mL, 2.25 mmol) and CH_2Cl_2 (45 mL), **8o** was isolated as a highly viscous oil (211 mg, 33%). ^{1}H NMR (250 MHz, $CDCl_3$): δ = 2.18 (s, 3 H, CH_3), 3.03 (t, *J*=8.3 Hz, 2 H, CH_2), 3.44 (t, *J*=8.3 Hz, 2 H, CH_2), 3.42 (s, 3 H, O*CH*$_3$), 3.77 (s, 3 H, O*CH*$_3$), 6.96-7.28 (m, 10H,

ArH). ^{13}C NMR (62 MHz, $CDCl_3$): δ = 20.1 (CH_3), 21.3 (CH_3), 33.1 (CH_2), 41.6 (CH_2), 52.1 (OCH_3), 127.8 (CH), 128.0, 128.8, 129.2 (2CH), 131.2, 132.3 (C), 132.4 (2CH), 132.5 (CH), 133.6, 134.7, 138.0, 139.1, 140.7, 144.1, 168.3 (C). IR (ATR): $\tilde{\nu}$ = 2948 (w), 2921 (w), 2734 (w)., 2249 (w), 1728 (s), 1588 (m), 1573 (m), 1473 (m), 1435 (m), 1392 (m), 1377 (m), 1324 (m), 1270 (sd), 1190 (s), 1140 (s), 1040 (s), 907 (s), 777 (s), 728 (s), 691 (s), 646 (m) cm^{-1}. GC-MS (EI, 70 eV): *m/z* (%): 428 (M^+, ^{37}Cl, 38), 426 (M^+, ^{35}Cl, 100), 318 (29), 315 (37), 303 (10) 301 (10), 281 (24), 268 (13), 267 (63), 225 (12), 224 (10). HRMS (EI): calcd for $C_{24}H_{23}O_3ClS$ [M^+]: 426.09453, found 426.094465.

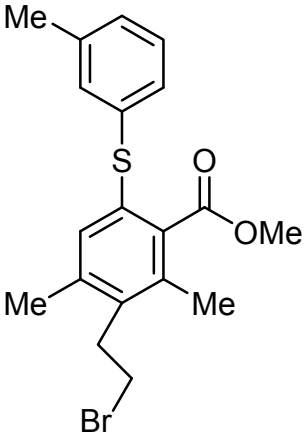


Methyl 4,6-dimethyl-5-(2-chloroethyl)-2-(3-methoxyphenyl-sulfanyl)benzoate (8p): Starting with **7a** (283 mg, 2.25 mmol), **3o** (466 mg, 1.5 mmol), $TiBr_4$ (0.826 g, 2.25 mmol) and CH_2Cl_2 (45 mL), **8p** was isolated as a highly viscous oil (251 mg, 41%). ^{1}H NMR (250 MHz, $CDCl_3$): δ = 2.18 (s, 3 H, CH_3), 2.22 (s, 3 H, CH_3), 3.03 (t, *J*=8.3 Hz, 2 H, CH_2), 3.44 (t, *J*=8.3 Hz, 2 H, CH_2), 3.66 (s, 3H, O*CH*$_3$), 3.78 (s, 3 H, O*CH*$_3$), 6.93-7.07 (m, 5 H, ArH). ^{13}C NMR (62 MHz, $CDCl_3$): δ = 20.1 (CH_3), 21.3 (CH_3), 33.1 (CH_2), 41.6 (CH_2), 51.2 (OCH_3), 52.1 (OCH_3), 111.3 (C), 127.9 (2CH), 128.9 (CH), 130.7 (C), 131.1, 132.8 (CH),133.0, 134.0, 134.8, 135.5, 138.9, 169.3 (C). IR (ATR): $\tilde{\nu}$ = 2948 (w), 2921 (w), 2734 (w), 2249 (w), 1728 (s), 1588 (m), 1573 (m), 1473 (m), 1435 (m), 1392 (m), 1377 (m), 1325 (m), 1270 (sd), 1190 (s), 1140 (s), 1040 (s), 907 (s), 777 (s), 728 (s), 691 (s), 646 (m) cm^{-1}. GC-MS (EI, 70 eV): *m/z* (%): 410 (M^+, ^{81}Br, 79), 408 (M^+, ^{79}Br, 100), 317 (29), 315 (37), 303 (10) 301 (10),

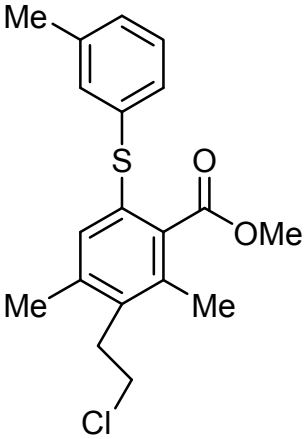
281 (24), 268 (13), 267 (63), 225 (12), 224 (10). HRMS (EI): calcd for $C_{19}H_{21}O_3ClS$ [M^+]: 408.09853, found 408.094465.



Methyl 4,6-dimethyl-5-(2-bromooethyl)-2-(3-chlorophenyl-sulfanyl)benzoate (8q): Starting with **7a** (283 mg, 2.25 mmol), **3k** (472 mg, 1.5 mmol), $TiBr_4$ (0.826 g, 2.25 mmol) and CH_2Cl_2 (45 mL), **8q** was isolated as highly viscous oil (221 mg, 40%). ^{1}H NMR (250 MHz, $CDCl_3$): δ = 2.18 (s, 3 H, CH_3), 2.24 (s, 3 H, CH_3), 3.03 (t, *J*=8.3 Hz, 2 H, CH_2), 3.46 (t, *J*=8.3 Hz, 2 H, CH_2), 3.78 (s, 3 H, OC*H*$_3$), 6.93-7.29 (m, 5 H, ArH). ^{13}C NMR (62 MHz, $CDCl_3$): δ = 21.1, (CH_3), 21.3 (CH_3), 33.1 (CH_2), 41.6 (CH_2), 52.1 (OCH_3), 111.3 (C), 127.9 (2CH), 128.9 (CH), 130.7 (C), 131.1, 132.8 (CH),133.0, 134.0, 134.8, 135.5, 138.9, 169.3 (C). IR (ATR): $\tilde{\nu}$ = 2947 (w), 2926 (w), 2736 (w), 2249 (w). MS (EI, 70 eV): *m/z* (%): 416 (M^+, 29), 415 (M^+, 20), 414 (M^+, 100), 413 (M^+, 16), 412 (M^+, 74), 315 (37), 303 (10) 301 (10), 281 (24), 268 (13), 267 (63), 225 (12), 224 (10). HRMS (EI): calcd for $C_{18}H_{18}O_2BrClS$ [M^+]: 411.98939, found 411.989037.

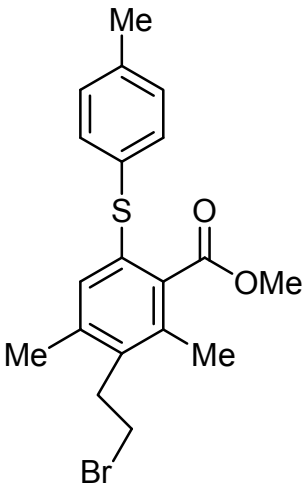


Methyl 4,6-dimethyl-5-(2-bromooethyl)-2-(3-methylphenyl-sulfanyl)benzoate (8r): Starting with **7a** (283 mg, 2.25 mmol), **3f** (441 mg, 1.5 mmol), $TiBr_4$ (0.826 g, 2.25 mmol) and CH_2Cl_2 (45 mL), **8r** was isolated as a highly viscous oil (235 mg, 40%). ^{1}H NMR (250 MHz, $CDCl_3$): δ = 2.18 (s, 3 H, CH_3), 2.14 (s, 3 H, CH_3), 2.24 (s, 3 H, CH_3), 3.03 (t, *J*=8.3 Hz, 2 H, CH_2), 3.46 (t, *J*=8.3 Hz, 2 H, CH_2), 3.78 (s, 3 H, OC*H*$_3$), 6.93-7.29 (m, 5 H, ArH). ^{13}C NMR (62 MHz, $CDCl_3$): δ = 18.6 (CH_3), 21.1, (CH_3), 21.3 (CH_3), 33.1 (CH_2), 41.6 (CH_2), 52.1 (OCH_3), 111.3 (C), 127.9 (2CH), 128.9 (CH), 130.7 (C), 131.1, 132.8 (CH), 133.0, 134.0, 134.8, 135.5, 138.9, 169.3 (C). IR (ATR): $\tilde{\nu}$ = 2947 (w), 2926 (w), 2736 (w), 2249 (w). MS (EI, 70 eV): *m/z* (%): 394 (100), 392 (M^+, 74), 315 (37), 303 (10) 301 (10), 281 (24), 268 (13), 267 (63), 225 (12), 224 (10). HRMS (EI): calcd for $C_{19}H_{21}O_2BrS$ [M^+]: 391.98939, found 391.989037.

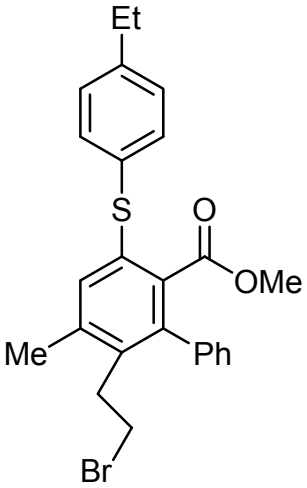


Methyl 4,6-dimethyl-5-(2-chloroethyl)-2-(3-methylphenyl-sulfanyl)benzoate (8s): Starting with **7a** (283 mg, 2.25 mmol), **3f** (441 mg, 1.5 mmol), $TiCl_4$ (0.25 mL, 2.25 mmol) and CH_2Cl_2 (45 mL), **8s** was isolated as a highly viscous oil (224 mg, 43%). ^{1}H NMR (250 MHz, $CDCl_3$): δ = 2.18 (s, 3 H, CH_3), 2.21 (s, 3 H, CH_3), 2.22 (s, 3 H, CH_3), 3.03 (t, *J=8.3* 2 H, CH_2), 3.44 (t, *J=8.3* 2 H, CH_2), 3.78 (s, 3 H, OC*H*$_3$), 6.93-7.07 (m, 5 H, ArH). ^{13}C NMR (62 MHz, $CDCl_3$): δ = 16.8, (CH_3), 20.1 (CH_3), 21.3 (CH_3), 33.1 (CH_2), 41.6 (CH_2), 52.1 (OCH_3), 111.3 (C), 127.9 (2CH), 128.9 (CH), 130.7 (C), 131.1, 132.8 (CH),133.0, 134.0, 134.8, 135.5, 138.9, 169.3 (C). IR (ATR): $\tilde{\nu}$ = 2948 (w), 2921 (w),

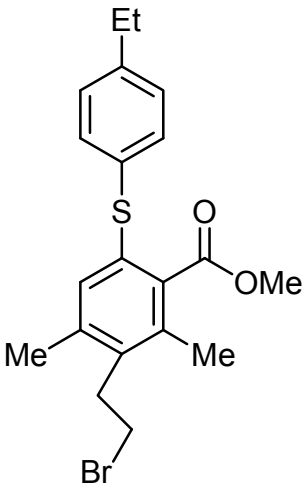
2734 (w), 2249 (w), 1728 (s), 1588 (m), 1573 (m), 1473 (m), 1435 (m), 1392 (m), 1377 (m), 1325 (m), 1270 (sd), 1190 (s), 1140 (s), 1040 (s), 907 (s), 777 (s), 728 (s), 691 (s), 646 (m) cm^{-1}. GC-MS (EI, 70 eV): *m/z* (%): 350 (M^+, ^{37}Cl, 38), 348 (M^+, ^{35}Cl, 100), 317 (29), 315 (37), 303 (10) 301 (10), 281 (24), 268 (13), 267 (63), 225 (12), 224 (10). HRMS (EI): calcd for $C_{19}H_{21}O_2ClS$ [M^+]: 348.09453, found 348.094465.



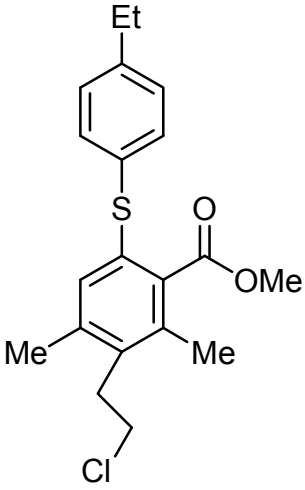
Methyl 4,6-dimethyl-5-(2-bromooethyl)-2-(4-methylphenyl-sulfanyl)benzoate (8t): Starting with **7a** (283 mg, 2.25 mmol), **3d** (441 mg, 1.5 mmol), $TiBr_4$ (0.826 g, 2.25 mmol) and CH_2Cl_2 (45 mL), **8t** was isolated as a highly viscous oil (235 mg, 40%). ^1H NMR (250 MHz, $CDCl_3$): δ = 2.18 (s, 3 H, CH_3), 2.14 (s, 3 H, CH_3), 2.24 (s, 3 H, CH_3), 3.03 (t, *J=8.3* 2 H, CH_2), 3.46 (t, *J=8.3* 2 H, CH_2), 3.78 (s, 3 H, OCH_3), 6.93-7.29 (m, 5 H, ArH). ^{13}C NMR (62 MHz, $CDCl_3$): δ = 18.6 (CH_3), 21.1, (CH_3), 21.3 (CH_3), 33.1 (CH_2), 41.6 (CH_2), 52.1 (OCH_3), 111.3 (C), 127.9 (2CH), 128.9 (CH), 130.7 (C), 131.1, 132.8 (CH),133.0, 134.0, 134.8, 135.5, 138.9, 169.3 (C). IR (ATR): $\tilde{\nu}$ = 2947 (w), 2926 (w), 2736 (w)., 2249 (w). MS (EI, 70 eV): *m/z* (%): 394 (100), 392 (M^+, 74), 315 (37), 303 (10) 301 (10), 281 (24), 268 (13), 267 (63), 225 (12), 224 (10). HRMS (EI): calcd for $C_{19}H_{21}O_2BrS$ [M^+]: 391.98939, found 391.989037.



Methyl 4-methyl-5-(2-bromoethyl)-2-(4-ethylphenyl-sulfanyl)-6-phenylbenzoate (8u): Starting with **7b** (283 mg, 2.25 mmol), **3g** (460 mg, 1.5 mmol), $TiBr_4$ (0.826 g, 2.25 mmol) and CH_2Cl_2 (45 mL), **8u** was isolated as a highly viscous oil (266 mg, 38%). ^{1}H NMR (250 MHz, $CDCl_3$): δ = 1.15 (t, *J*=7.5 Hz, 3 H, $CH_2\mathit{CH_3}$), 2.13 (s, 3 H, CH_3), 2.54 (q, *J*=7.5 Hz, 2H, $\mathit{CH_2}CH_3$), 3.03 (t, *J*=8.3 Hz, 2 H, CH_2), 3.39 (t, *J*=8.3 Hz, 2 H, CH_2), 3.77 (s, 3 H, $OC\mathit{H_3}$), 6.96-7.66 (m, 10H, ArH). ^{13}C NMR (62 MHz, $CDCl_3$): δ = 20.1 (CH_3), 21.3 (CH_3), 28.5 ($\mathit{CH_2}CH_3$), 33.1 (CH_2), 40.2 (CH_2), 52.1 (OCH_3), 127.8 (CH), 128.0, 128.8, 129.2 (2CH), 131.2, 132.3 (C), 132.4 (2CH), 132.5 (CH), 133.6, 134.7, 138.0, 139.1, 140.7, 144.1, 168.3 (C). IR (ATR): $\tilde{\nu}$ = 2948 (w), 2921 (w), 2734 (w), 2249 (w), 1728 (s), 1588 (m), 1573 (m), 1473 (m), 1435 (m), 1392 (m), 1377 (m), 1325 (m), 1270 (sd), 1190 (s), 1140 (s), 1040 (s), 907 (s), 777 (s), 728 (s), 691 (s), 646 (m) cm^{-1}. GC-MS (EI, 70 eV): *m/z* (%): 470 (M^+, ^{81}Br, 100), 468 (M^+, ^{79}Br, 75), 317 (87), 315 (37), 303 (10) 301 (10), 281 (24), 268 (13), 267 (63), 225 (12), 224 (10). HRMS (EI): calcd for $C_{25}H_{25}O_2BrS$ [M^+]: 468.98939, found 468.989037.

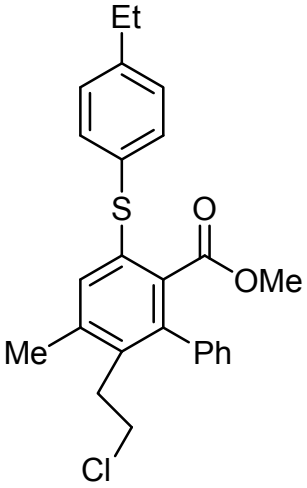


Methyl 4,6-dimethyl-5-(2-bromoethyl)-2-(4-ethylphenyl-sulfanyl)benzoate (8v): Starting with **7a** (283 mg, 2.25 mmol), **3g** (441 mg, 1.5 mmol), $TiBr_4$ (0.826, 2.25 mmol) and CH_2Cl_2 (45 mL), **8v** was isolated as a highly viscous oil (170 mg, 42%). ^{1}H NMR (250 MHz, $CDCl_3$): δ = 1.15 (t, *J*=7.5 Hz, 3 H, CH_2CH_3), 2.13 (s, 3 H, CH_3), 2.21 (s, 3 H, CH_3), 2.23 (s, 3 H, CH_3), 2.54 (q, *J*=7.5 Hz, 2H, CH_2CH_3), 3.03 (t, *J*=8.3 Hz, 2 H, CH_2), 3.39 (t, *J*=8.3 Hz, 2 H, CH_2), 3.77 (s, 3 H, OCH_3), 6.93-7.29 (m, 5 H, ArH). ^{13}C NMR (62 MHz, $CDCl_3$): δ = 18.7 (CH_3), 20.1 (CH_3), 21.3 (CH_3), 28.5 (CH_2CH_3), 33.1 (CH_2), 40.2 (CH_2), 52.1 (OCH_3), 111.3 (C), 127.9 (2CH), 128.9 (CH), 130.7 (C), 131.1, 132.8 (CH),133.0, 134.0, 134.8, 135.5, 138.9, 169.3 (C). IR (ATR): $\tilde{\nu}$ = 2947 (w), 2926 (w), 2736 (w), 2249 (w). MS (EI, 70 eV): *m/z* (%): 408 (100), 406 (M^+, 74), 315 (37), 303 (10) 301 (10), 281 (24), 268 (13), 267 (63), 225 (12), 224 (10). HRMS (EI): calcd for $C_{20}H_{23}O_2BrS$ [M^+]: 405.98939, found 405.989037.



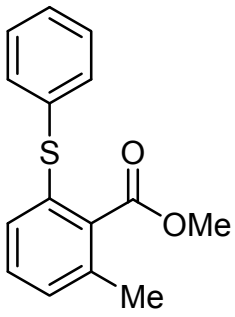
Methyl 4,6-dimethyl-5-(2-chloroethyl)-2-(4-ethylphenyl-sulfanyl)benzoate (8w): Starting with **7a** (283 mg, 2.25 mmol), **3g** (441 mg, 1.5 mmol), $TiCl_4$ (0.25 mL, 2.25 mmol) and CH_2Cl_2 (45 mL), **8w** was isolated as highly viscous oil (239 mg, 44%). ^{1}H NMR (250 MHz, $CDCl_3$): δ = 1.15 (t, *J*=7.5 Hz, 3 H, CH_2CH_3), 2.13 (s, 3 H, CH_3), 2.21 (s, 3 H, CH_3), 2.24 (s, 3 H, CH_3), 2.54 (q, *J*=7.5 Hz, 2H, CH_2CH_3), 3.03 (t, *J*=8.3 Hz, 2 H, CH_2), 3.39 (t, *J*=8.3 Hz, 2 H, CH_2), 3.77 (s, 3 H, OCH_3), 6.93-7.29 (m, 5 H, ArH). ^{13}C NMR (62 MHz, $CDCl_3$): δ = 18.7 (CH_3), 20.1 (CH_3), 21.3 (CH_3), 28.5

(CH_2CH_3), 33.3 (CH_2), 40.1 (CH_2), 52.1 (OCH_3), 111.3 (C), 127.9 (2CH), 128.9 (CH), 130.7 (C), 131.1, 132.8 (CH),133.0, 134.0, 134.8, 135.5, 138.9, 169.3 (C). IR (ATR): $\tilde{\nu}$ = 2947 (w), 2926 (w), 2736 (w)., 2249 (w), cm^{-1}. MS (EI, 70 eV): *m/z* (%): 364 (M^+, ^{37}Cl, 38), 362 (M^+, ^{35}Cl, 100), 317 (29), 315 (37), 303 (10) 301 (10), 281 (24), 268 (13), 267 (63), 225 (12), 224 (10). HRMS (EI): calcd for $C_{20}H_{23}O_2ClS$ [M^+]: 362.09453, found 362.094465.

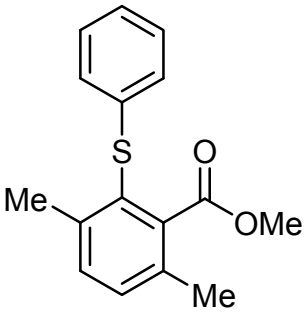


Methyl 4-methyl-5-(2-chloroethyl)-2-(4-ethylphenyl-sulfanyl)-6-phenylbenzoate (8x): Starting with **7b** (283 mg, 2.25 mmol), **3g** (460 mg, 1.5 mmol), $TiCl_4$ (0.25 mL, 2.25 mmol) and CH_2Cl_2 (45 mL), **8x** was isolated as a highly viscous oil (248 mg, 40%). ^1H NMR (250 MHz, $CDCl_3$): δ = 1.15 (t, *J*=7.5 Hz, 3 H, CH_2CH_3), 2.13 (s, 3 H, CH_3), 2.23 (s, 3 H, CH_3), 2.54 (q, *J*=7.5 Hz, 2H, CH_2CH_3) 3.03 (t, *J*=8.3 Hz, 2 H, CH_2), 3.39 (t, *J*=8.3 Hz, 2 H, CH_2), 3.77 (s, 3 H, OCH_3), 6.96-7.66 (m, 10H, ArH). ^{13}C NMR (62 MHz, $CDCl_3$): δ = 20.1 (CH_3), 21.3 (CH_3), 28.5 (CH_2CH_3), 33.1 (CH_2), 40.2 (CH_2), 52.1 (OCH_3), 127.8 (CH), 128.0, 128.8, 129.2 (2CH), 131.2, 132.3 (C), 132.4 (2CH), 132.5 (CH), 133.6, 134.7, 138.0, 139.1, 140.7, 144.1, 168.3 (C). IR (ATR): $\tilde{\nu}$ = 2948 (w), 2921 (w), 2734 (w)., 2249 (w), 1728 (s), 1588 (m), 1573 (m), 1473 (m), 1435 (m), 1392 (m), 1377 (m), 1325 (m), 1270 (sd), 1190 (s), 1140 (s), 1040 (s), 907 (s), 777 (s), 728 (s), 691 (s), 646 (m) cm^{-1}. MS (EI, 70 eV): *m/z* (%): 426 (M^+, ^{37}Cl, 38), 424 (M^+, ^{35}Cl, 100), 317 (29), 315 (37), 303 (10) 301 (10), 281 (24), 268 (13), 267 (63), 225 (12), 224 (10). HRMS (EI): calcd for $C_{20}H_{23}O_2Cl_1S$ [M^+]: 424.09453, found 424.094465.

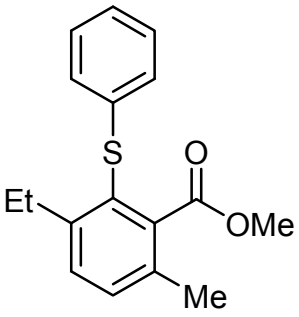
General procedure for the synthesis of 2-(arylthio)benzoates 12a-r: To a dichloromethane solution (5 mL / mmol of **3**) of **3** (1.0 mmol) and of **11** (1.5 mmol) was added $TiCl_4$ (1.5 mmol) at –78 °C. The solution was allowed to warm to 20 °C within 20 h. To the solution was added a saturated aqueous solution of $NaHCO_3$ (15 mL). The organic and the aqueous layer were separated and the latter was extracted with diethyl ether (3 x 20 mL). The combined organic layers were dried (Na_2SO_4), filtered, and the filtrate was concentrated in vacuo. The residue was purified by chromatography (silica gel, EtOAc / *n*-heptane = 1:4).



4-Methyl-2-phenylsulfanyl-benzoic acid methyl ester (12a): Starting with **3a** (420 mg, 1.5 mmol), **11a** (0.23 mL, 2.25 mmol), $TiCl_4$ (0.25 mL, 2.25 mmol) and CH_2Cl_2 (9 mL), **12a** was isolated as a highly viscous oil (205 mg, 53%). ^{1}H NMR (250 MHz, $CDCl_3$): δ = 2.27 (s, 3H, CH_3), 3.80 (s, 3H, OCH_3), 7.05-7.24 (m, 8H, Ar); ^{13}C NMR (63 MHz, $CDCl_3$): δ = 18.6 (CH_3), 51.1 (OCH_3), 126.1, 128.1, 128.3, 128.9, 129.3, 130.1 (ArCH), 132.1, 134.7, 134.9, 135.6, 167.9 (C); IR (KBr, cm^{-1}): $\tilde{\nu}$ = 3056 (w), 2994 (w), 2948 (w), 2927 (w), 2857 (w), 1727 (s), 1606 (m), 1581 (m), 1476 (m), 1449 (s), 1437 (s), 1380 (w), 1266 (s), 1240 (s), 1188 (m), 1152 (m), 1105 (s), 1066 (s), 1023 (m), 954 (m), 738 (s), 688 (s); MS (EI, 70 eV): *m/z* (%) = 258 (M^+, 69), 227 (46), 226 (22), 225 (100), 197 (15), 184 (33), 165 (8), 152 (6), 63 (3); HRMS (EI): calcd for $C_{15}H_{14}O_2S$ [M^+]: 258.07090, found: 258.070766.

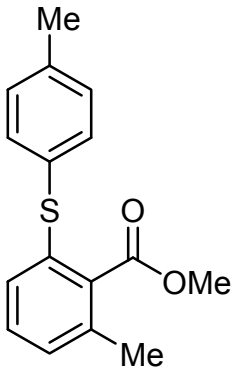


3,4-Dimethyl-2-phenylsulfanyl-benzoic acid methyl ester (12b): Starting with **3b** (440 mg, 1.5 mmol), **11a** (0.23 mL, 2.25 mmol), $TiCl_4$ (0.25 mL, 2.25 mmol) and CH_2Cl_2 (9 mL), **12b** was isolated as a highly viscous oil (163 mg, 40%). ^{1}H NMR (250 MHz, $CDCl_3$): δ = 2.19 (s, 3H, CH_3), 2.23 (s, 3H, CH_3), 3.75 (s, 3H, OCH_3), 7.09-7.13 (m, 7H, Ar); ^{13}C NMR (63 MHz, $CDCl_3$): δ = 19.1 (CH_3), 20.5 (CH_3), 52.1 (OCH_3), 125.5, 127.3 (ArCH), 127.8 (C), 128.8, 131.2, 131.4 (ArCH), 132.8, 137.0, 140.7, 141.4 (C); IR (KBr, cm^{-1}): $\tilde{\nu}$ = 2949 (w), 2922 (w), 2855 (w), 1729 (s), 1588 (m), 1487 (s), 1432 (m), 1386 (m), 1281 (s), 1203 (s), 156 (s), 1111 (s); MS (EI, 70 eV): *m/z* (%) = 272 (M^+, 85), 241 (41), 240 (29), 239 (100), 211 (26), 197 (35), 179 (10), 135 (5); HRMS (EI): calcd for $C_{16}H_{16}O_2S$ [M^+]: 272.08655, found: 272.086221.

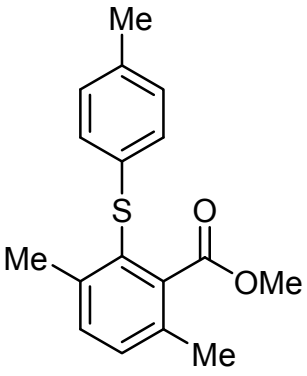


3-Ethyl-4-methyl-2-phenylsulfanyl-benzoic acid methyl ester (12c): Starting with **3c** (460 mg, 1.5 mmol), **11a** (0.23 mL, 2.25 mmol), $TiCl_4$ (0.25 mL, 2.25 mmol) and CH_2Cl_2 (9 mL), **12c** was isolated as a highly viscous oil (150 mg, 35%). ^{1}H NMR (250 MHz, $CDCl_3$): δ = 1.00 (t, ^2J = 7.5 Hz, 3H, CH_2CH_3), 2.23 (s, 3H, CH_3), 2.63 (q, ^2J = 7.5 Hz, 2H, CH_2), 3.71 (s, 3H, OCH_3), 7.08-7.17 (m, 7H, Ar); ^{13}C NMR (75 MHz, $CDCl_3$): δ = 14.8, 19.1 (CH_3), 26.7 (CH_3CH_2), 52.0 (OCH_3), 125.3, 127.0, 128.7, 129.8, 131.6 (ArCH), 132.8, 137.9, 141.7, 146.5, 169.3 (C); IR (KBr, cm^{-1}): $\tilde{\nu}$ = 3055 (w), 2965 (w), 2948 (w), 2928 (w), 2870 (w), 2738 (w), 1729 (s), 1580 (m), 1477 (m), 1432 (m), 1393 (w), 1323 (w), 1271 (s), 1200 (s), 1157 (m), 1111 (s), 1080 (m), 1058 (m), 1023 (m), 1013 (m), 959 (m), 893 (w), 826

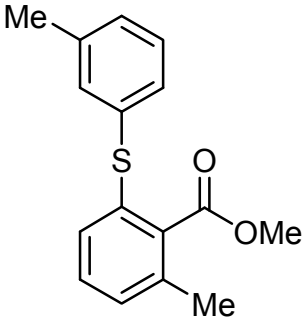
(m), 790 (m),736 (s), 688 (s), 636 (m); MS (EI, 70 eV): *m/z* (%) = 286 (M^+, 100), 255 (22), 254 (23), 253 (59), 239 (47), 227 (12), 225 (16), 211 (26), 197 (19), 184 (14), 178 (14), 105 (30), 77 (10); HRMS (EI): calcd for $C_{17}H_{18}O_2S$ [M^+]: 286.10220, found 286.102040.



4-Methyl-2-(*p*-tolylsulfanyl)-benzoic acid methyl ester (12d): Starting with **3d** (350 mg, 1.2 mmol), **11a** (0.15 mL, 1.44 mmol), $TiCl_4$ (0.20 mL, 1.8 mmol) and CH_2Cl_2 (7 mL), **12d** was isolated as a highly viscous oil (166 mg, 51%). ^{1}H NMR (250 MHz, $CDCl_3$): δ = 2.25 (s, 3H, CH_3), 2.26 (s, 3H, CH_3), 3.83 (s, 3H, OCH_3), 6.97-7.22 (m, 7H, Ar); ^{13}C NMR (75 MHz, $CDCl_3$): δ = 19.6 (CH_3), 21.1 (CH_3), 52.1 (OCH_3) 128.7, 129.1 (ArCH), 129.8 (C), 129.9, 132.0 (ArCH), 132.3, 134.6, 135.5, 135.9, 137.7 (C); IR (KBr, cm^{-1}): $\tilde{\nu}$ = 3091 (w), 3063 (w), 2950 (w), 2924 (w), 2853 (w), 1728 (s), 1712 (s), 1661 (m), 1588 (s), 1485 (s), 1434 (m), 1272 (s), 1220 (s), 1154 (s), 1106 (s); MS (EI, 70 eV): *m/z* (%) = 3272 (M^+, 100), 241 (50), 239 (64), 225 (56), 211 (11), 198 8209, 197 (30), 165 (10), 152 (4), 121 (10), 105 (85), 77 (6), 63 (4); HRMS (EI): calcd for $C_{16}H_{16}O_2S$ [M^+]: 272.08655, found: 272.086425.

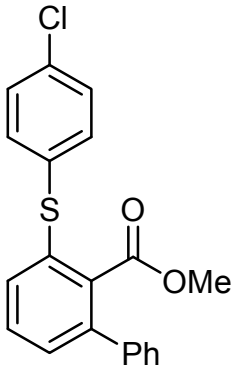


3,4-Dimethyl-2-(*p*-tolylsulfanyl)-3,4-dimethyl-benzoic acid methyl ester (12e). Starting with **3e** (616 mg, 2.0 mmol), **11a** (0.3 mL, 3.0 mmol), $TiCl_4$ (0.33 mL, 3.0 mmol) and CH_2Cl_2 (12 mL), **12e** was isolated as a highly viscous oil (212 mg, 37%). ^{1}H NMR (250 MHz, $CDCl_3$): δ = 2.14 (s, 3H, CH_3), 2.18 (s, 3H, CH_3), 2.22 (s, 3H, CH_3), 3.76 (s, 3H, OCH_3), 7.17 (m, 6H, Ar); ^{13}C NMR (75 MHz, $CDCl_3$): δ = 19.1 (CH_3), 20.5 (CH_3), 20.9 (CH_3), 52.1 (OCH_3), 127.7 ArCH), 128.5 (C), 129.6, 131.0, 131.4 (ArCH), 132.7, 133.4, 135.4, 140.7, 141.3 (C); IR (KBr, cm^{-1}): $\tilde{\nu}$ = 3017 (w), 2948 (w), 2921 (w), 2734 (w), 1731 (s), 1656 (w), 1490 (m), 1431 (m), 1280 (s), 1203 (s), 1111 (s), 1085 (m), 802 (s), 754 (w), 718 (m); MS (EI, 70 eV): *m/z* (%) = 286 (M^+, 100), 255 (38), 254 (15), 253 (42), 240 (19), 239 (82), 225 (12), 212 (16), 211 (35), 193 (7), 178 (8), 91 (10); HRMS (EI): calcd for $C_{17}H_{18}O_2S$ [M^+]: 286.10220, found: 286.101482.

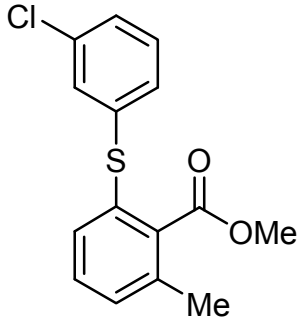


4-Methyl-2-(*m*-tolylsulfanyl)benzoic acid methyl ester (12f). Starting with **3f** (441 mg, 1.5 mmol), **11a** (0.23 mL, 2.25 mmol), $TiCl_4$ (0.25 mL, 2.25 mmol) and CH_2Cl_2 (9 mL), **12f** was isolated as a highly viscous oil (204 mg, 50%). ^{1}H NMR (250 MHz, $CDCl_3$): δ = 2.22 (s, 3H, CH_3), 2.27 (s, 3H, CH_3), 3.82 (s, 3H, OCH_3), 7.03-7.18 (m, 7H, Ar); ^{13}C NMR (63 MHz, $CDCl_3$): δ = 19.6 (CH_3), 21.27 (CH_3), 52.1 (OCH_3), 128.1, 128.5, 128.9, 129.0, 129.8, 129.9, 132.0 (ArCH), 135.1, 135.9, 136.2, 138.9, 168.9 (C); IR (KBr, cm^{-1}): $\tilde{\nu}$ = 3091 (w), 3063 (w), 2950 (w), 2924 (w), 2853 (w), 1728 (s), 1712 (s), 1661 (m), 1588 (s), 1487 (s), 1434 (m), 1273 (s), 1220 (s), 1154 (s), 1107 (s); MS (EI, 70 eV): *m/z* (%) = 272 (M^+, 100),

241 (54), 240 (16), 239 (72), 226 (16), 225 (73), 198 (22), 197 (35), 165 (11), 121 (9), 105 (5), 77 (6); HRMS (EI): calcd for $C_{16}H_{16}O_2S$ [M^+]: 272.08655, found 272.086256.

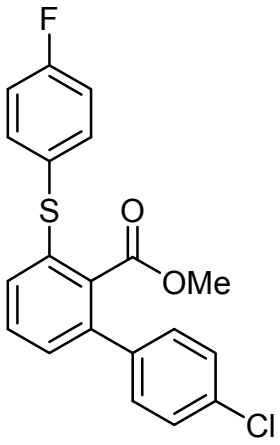


3-(4-Chlorophenylsulfanyl)-biphenyl-4-benzoic acid methyl ester (12g). Starting with **3i** (370 mg, 1.2 mmol), **11b** (0.22 mL, 1.3 mmol), $TiCl_4$ (0.2 mL, 1.7mmol) and CH_2Cl_2 (7 mL), **12g** was isolated as a highly viscous oil (157 mg, 37%). ^{1}H NMR (250 MHz, $CDCl_3$): δ = 3.53 (s, 3H, OCH_3), 7.18-7.32 (m, 12H, Ar); ^{13}C NMR (63 MHz, $CDCl_3$): δ = 52.1 (OCH_3), 127.8, 128.2, 128.4, 129.0, 129.4, 130.1, 131.2, 132.8 (ArCH), 133.6, 133.6, 133.9, 135.7, 139.81, 141.1, 168.6 (C); IR (KBr, cm^{-1}): $\tilde{\nu}$ = 3058 (w), 2996 (w), 2949 (w), 2927 (w), 2856 (w), 1729 (s), 1662 (w), 1574 (m), 1563 (m), 1459 (m), 1451 (m), 1435 (m), 1337 (w), 1267 (s), 1242 (s), 1189 (m), 1106 (s), 1067 (s), 955 (w), 773 (s), 678 (m), 663 (w); MS (EI, 70 eV): *m/z* (%) = 356 (M^+, ^{37}Cl, 39), 354 (M^+, ^{35}Cl, 100), 323 (36), 244 (15), 91 (7), 77 (5); HRMS (EI): calcd for $C_{20}H_{15}O_2ClS$ [M^+]: 354.06323, found: 354.063118.

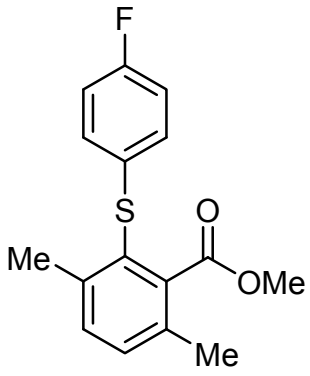


2-(3-Chlorophenylsulfanyl)-4-methyl-benzoic acid methyl ester (12h): Starting with **3k** (470 mg, 1.5 mmol), **11a** (0.23 mL, 2.25 mmol), $TiCl_4$ (0.25 mL, 2.25 mmol) and CH_2Cl_2 (9 mL), **12h** was isolated as a highly viscous oil (210 mg, 48%). ^{1}H NMR (250 MHz, $CDCl_3$): δ = 2.28 (s, 3H, CH_3), 3.79 (s, 3H,

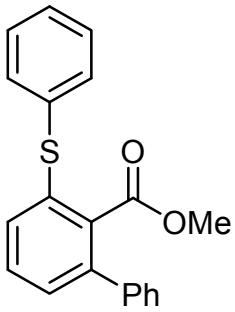
OCH_3), 7.08-7.17 (m, 7H, Ar); ^{13}C NMR (63 MHz, $CDCl_3$): δ = 19.6 (CH_3), 52.1 (OCH_3), 126.9, 128.3, 129.6, 130.0, 130.1, 130.2, 131.2 (ArCH), 131.4, 134.7, 136.3, 137.7, 138.5 (C); IR (KBr, cm^{-1}): $\tilde{\nu}$ = 3058 (w), 2996 (w), 2949 (w), 2927 (w), 2856 (w), 1729 (s), 1662 (w), 1574 (m), 1563 (m), 1459 (m), 1451 (m), 1435 (m), 1337 (w), 1267 (s), 1242 (s), 1189 (m), 1106 (s), 1067 (s), 955 (w), 773 (s), 678 (m), 663 (w); MS (EI, 70 eV): *m/z* (%) = 294 (M^+, ^{37}Cl, 16), 292 (M^+, ^{35}Cl, 71), 261 (71), 260 (18), 259 (100), 226 (15), 225 (37), 198 (16), 197 (29), 165 (8), 152 (6), 121 (9), 63 (5); HRMS (EI): calcd for $C_{15}H_{13}O_2SCl$ [M^+,^{35}Cl]: 292.03193, found 292.032372.



4`-Chloro-3-(4-fluorophenylsulfanyl)-biphenyl-2-ArCboxylic acid methyl ester (12i). Starting with **3l** (440 mg, 1.5 mmol), **11c** (0.37 mL, 1.8 mmol), $TiCl_4$ (0.25 mL, 2.25 mmol) and CH_2Cl_2 (9 mL), **12i** was isolated as a colourless solid (195 mg, 35%). ^1H NMR (250 MHz, $CDCl_3$): δ = 3.57 (s, 3H, OCH_3), 6.99-7.27 (m, 11H, Ar); ^{13}C NMR (75 MHz, $CDCl_3$): δ = 51.2 (OCH_3), 115.4, 115.7, 127.2 (ArCH), 127.6, 128.5,129.1, 129.2, 132.7, 133.7, 133.9 (ArCH), 134.4, 134.5, 136.6, 136.7, 137.3, 138.7, 167.4 (C); IR (KBr, cm^{-1}): $\tilde{\nu}$ = 3091 (w), 3065 (w), 2992 (w), 2948 (w), 2851 (w), 1892 (w), 1711 (m), 1678 (m), 1587 (s), 1488 (s), 1445 (m), 1435 (m), 1397 (m), 1337 (m), 1272 (m), 1221 (s), 1193 (s), 1153 (s), 1105 (m), 1088 (s), 1012 (m), 898 (m), 829 (s), 813 (s), 790 (m), 733 (m), 637 (m); MS (EI, 70 eV): *m/z* (%) = 374 (M^+, ^{37}Cl, 40), 372 (M^+, ^{35}Cl, 100), 343 (16), 341 (42), 305 (14), 278 (16), 276 (20), 168 (8), 152 (6), 138 (9); HRMS (EI): calcd for $C_{20}H_{14}O_2ClFS$ [M^+]: 372.063816, found: 372.038069.

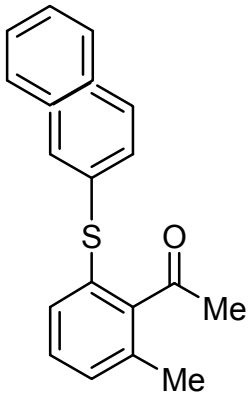


2-(4-Fluorophenylsulfanyl)-3,4-dimenthyl-benzoic acid methyl ester (12j). Starting with **3m** (620 mg, 2.0 mmol), **11a** (0.3 mL, 3.0 mmol), $TiCl_4$ (0.33 mL, 3.0 mmol) and CH_2Cl_2 (12 mL), **12j** was isolated as a highly viscous oil (197 mg, 34%). ^{1}H NMR (250 MHz, $CDCl_3$): δ = 2.18 (s, 3H, CH_3), 2.22 (s, 3H, CH_3), 3.77 (s, 3H, OCH_3), 6.98-7.11 (m, 6H, Ar); ^{13}C NMR (75 MHz, $CDCl_3$): δ = 18.0 (CH_3), 19.4 (CH_3), 51.1 (OCH_3), 114.7, 115.1, (ArCH), 127.2 (C), 128.5, 128.6, 130.3, 130.5 (ArCH), 131.8, 139.5, 140.3, 158.3, 162.2, 168.4 (C); IR (KBr, cm^{-1}): $\tilde{\nu}$ = 2949 (w), 2922 (w), 2855 (w), 1729 (s), 1588 (m), 1487 (s), 1432 (m), 1386 (m), 1281 (s) 1203 (s), 156 (s), 1111 (s), 1084 (m), 1010 (m), 813 (s), 790 (m), 626 (s); MS (EI, 70 eV): *m/z* (%) = 290 (M^+ 90), 259 (45), 258 (25), 257 (100), 229 (34), 216 (19), 215 (38), 197 (8), 77 (6), 51 (3); HRMS (EI): calcd for $C_{16}H_{15}O_2FS$ [M^+]: 290.07713, found: 290.077573.

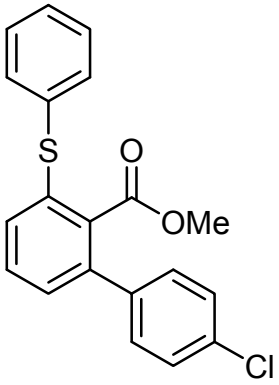


3-Phenylsulfanyl-biphenyl-4-carboxylic acid methyl ester (12k). Starting with **3a** (420 mg, 1.5 mmol), **11b** (0.18 mL, 1.8 mmol), $TiCl_4$ (0.25 mL, 2.25 mmol) and CH_2Cl_2 (9 mL), **12k** was isolated as a highly viscous oil (192 mg, 40%). ^{1}H NMR (250 MHz, $CDCl_3$): δ = 3.53 (s, 3H, OCH_3), 7.16-7.32 (m, 13H, Ar); ^{13}C NMR (MHz, $CDCl_3$): δ = 52.1 (OCH_3), 127.5, 127.7, 128.2, 128.4, 128.5, 129.2, 129.9, 130.7, 131.9 (ArCH), 132.6, 134.5, 135.0, 139.9, 140.9 (C); IR (KBr, cm^{-1}): $\tilde{\nu}$ = 3056 (w), 3029 (w), 2992 (w), 2946 (w), 2838 (w), 1730 (s), 1711 (s), 1638 (w), 1597 (m), 1577 (m), 1556 (w), 1526 (m), 1475 (m), 1438 (s), 1415 (w), 1373 (w), 136 (w), 1258 (s), 1191 (s), 111 (s), 1060 (s), 1034 (m), 1017 (m), 999 (m), 955 (m), 888 (m), 846

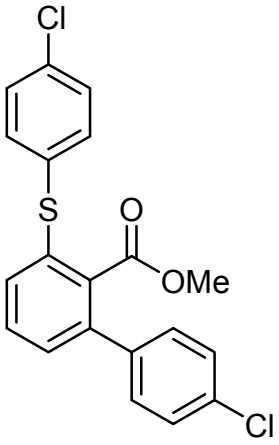
(w), 750 (s), 732 (s), 688 (s), 650 (m), 632 (m); MS (EI, 70 eV): *m/z* (%) = 320 (M^+, 100), 290 (19), 289 (87), 271 (15), 261 810), 260 (14), 240 (25), 163 (18), 152 (11), 131 (15), 110 (13), 105 (17), 77 (17), 69 (5); HRMS (EI): calcd for $C_{20}H_{16}O_2S$ [M^+]: 320.08655, found: 320.086676.



4-Methyl-2-[(naphth-2-yl)sulfanyl]benzoic acid ester (12l): Starting with **3p** (660 mg, 2.0 mmol), **11a** (0.3 mL, 3.0 mmol), $TiCl_4$ (0.33 mL, 3.0 mmol) and CH_2Cl_2 (12mL), **12l** was isolated as a highly viscous oil (203 mg, 33%). ^{1}H NMR (250 MHz, $CDCl_3$): δ = 2.29 (s, 3H, CH_3), 3.80 (s, 3H, OCH_3), 7.06-7.77 (m, 10H, Ar); ^{13}C NMR (63 MHz, $CDCl_3$): δ = 18.7 (CH_3), 51.1 (OCH_3), 125.2, 125.5, 126.7, 126.8, 127.8, 128.2, 128.9, 129.1, 129.2 (ArCH), 131.3, 131.9, 132.4, 132.6, 135.1, 135.3, 167.9 (C); IR (KBr, cm^{-1}): $\tilde{\nu}$ = 3052 (w), 2991 (w), 2947 (w), 2952 (w), 2853 (w), 1727 (s), 1623 (w), 1584 (m), 1568 (m), 1499 (m), 1433 (m), 1379 (w), 1339 (w), 1264 (s), 1241 (s), 1189 (m), 1105 (s), 1066 (s), 1016 (m), 942 (m), 849 (m), 811 (s), 777 (s), 742 (s), 708 (m); MS (EI, 70 eV): *m/z* (%) = 308 (M^+, 100), 277 (32), 276 (16), 275 (81), 248 (10), 234 (22), 117 (6), 115 (5), 69 (3); HRMS (EI): calcd for $C_{17}H_{18}O_3S$ [M^+]: 308.39414, found: 308.38943.

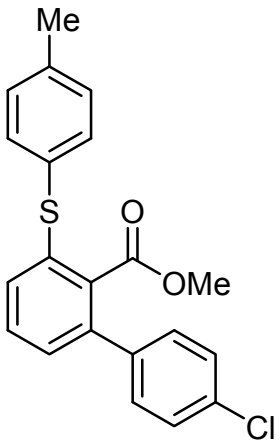


4`-Chloro-3-phenylsulfanyl-biphenyl-2-carboxylic acid methyl ester (12m). Starting with **3a** (400 mg, 1.5 mmol), **11c** (0.37 mL, 1.8 mmol), $TiCl_4$ (0.25 mL, 2.25 mmol) and CH_2Cl_2 (9 mL), **12m** was isolated as a highly viscous oil (250 mg, 47%). ^{1}H NMR (250 MHz, $CDCl_3$): δ = 3.56 (s, 3H, OCH_3), 7.21-7.32 (m, 12H, Ar). ^{13}C NMR (63 MHz, $CDCl_3$): δ = 52.2 (OCH_3), 127.7, 128.3, 128.6, 129.3, 129.6, 130.0, 131.1, (ArCH), 133.9, 134.7, 134.9, 135.0, 138.4, 139.6, 168.4 (C); IR (KBr, cm^{-1}): $\tilde{\nu}$ = 3057 (w), 2997 (w), 2947 (w), 2852 (w), 1728 (s), 1676 (w), 1596 (w), 1580 (m), 1573 (m), 1493 (m), 1438 (s), 1260 (s), 1192 (m), 1152 (w), 1115 (s), 1090 (s), 1061 (m), 1023 (m), 1012 (m), 900 (m), 836 (m), 741 (s), 688 (s); MS (EI, 70 eV): *m/z* (%) = 356 (M^+, ^{37}Cl, 39), 354 (M^+, ^{35}Cl, 100), 323 (46), 287 (13), 260 (18), 259 (12), 258 (23); HRMS (EI): calcd for $C_{20}H_{15}O_2ClS$ [M^+]: 354.06323, found: 354.063118.

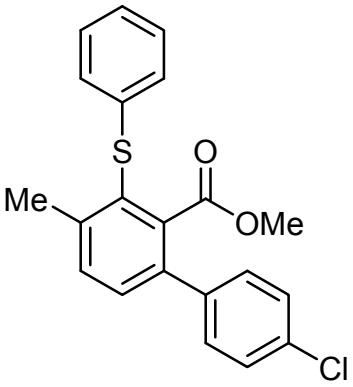


4`-Chloro-3-(4-chlorophenylsulfanyl)-biphenyl-2-carboxylic acid methyl ester (12n): Starting with **3i** (470 mg, 1.5 mmol), **11c** (0.37 mL, 1.8 mmol), $TiCl_4$ (0.25 mL, 2.25 mmol) and CH_2Cl_2 (9 mL), **12n** was isolated as a highly viscous oil (268 mg, 46%). ^{1}H NMR (250 MHZ, $CDCl_3$): δ = 3.56 (s, 3H, OCH_3), 7.15-7.32 (m, 11H, Ar); ^{13}C NMR (63 MHz, $CDCl_3$): δ = IR (KBr, cm^{-1}): $\tilde{\nu}$ = 3445 (w), 3056 (w), 2947 (w), 2385 (w), 2075 (w), 1900 (w), 1728 (s), 1679 (m), 1572 (m), 1493 (m), 1474 (s), 1446 (m), 1388 (m), 1260 (s), 1190 (m), 1116 (m), 1090 (s), 1011 (s), 818 (s), 790 (s), 743 (m), 715 (m); MS (EI, 70 eV): *m/z* (%) = 392 (M^+, ^{37}Cl^{37}Cl, 8), 390 (M^+, ^{35}Cl^{37}Cl, 23), 388 (M^+,

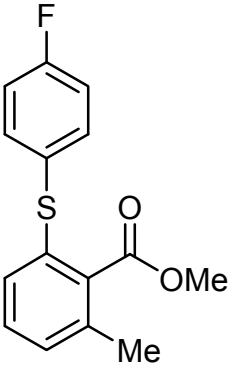
$^{35}Cl^{35}Cl$, 100), 359 (26), 357 (38), 321 (14), 294 (15), 258 (26), 151 (5), 159 (5), 129 (10), 75 (4); HRMS (EI): calcd for $C_{20}H_{14}O_2Cl_2S$ [$M^{+,}$ $^{35}Cl^{35}Cl$)]: 388.00861, found: 388.008235.



4`-Chloro-3-(*p*-tolylsulfanyl)biphenyl-2-carboxylic acid methyl ester (12o). Starting with **3d** (400 mg, 1.5 mmol), **11c** (0.37 mL, 1.8 mmol), $TiCl_4$ (0.25 mL, 2.25 mmol) and CH_2Cl_2 (9 mL), **12o** was isolated as a highly viscous oil (260 mg, 47%). ^1H NMR (250 MHz, $CDCl_3$): δ = 2.27 (s, 3H, CH_3), 3.58 (s, 3H, OCH_3), 7.06-7.29 (m, 11H, Ar); ^{13}C NMR (63 MHz, $CDCl_3$): δ = 18.2 (CH_3), 52.1 (OCH_3), 128.5, 128.8, 129.4, 129.8, 130.5, 131.4, 133.0 (ArCH), 133.7, 134.0, 135.5, 136.2, 138.2, 139.7, 168.3 (C); IR (KBr, cm^{-1}): $\tilde{\nu}$ = 3021 (w), 2947 (w), 2920 (w), 2853(w), 1903 (w), 1728 (s), 1650 (m), 1587 (m), 1546 (m), 1490 (s), 1445 (s), 1390 (m), 1256 (s), 1191 (m), 1115 (s), 1089 (s), 1061 (s), 1012 (s), 806 (s), 789 (s), 742 (m), 684 (m), 533 (m); MS (EI, 70 eV): *m/z* (%) = 370 (M^+, ^{37}Cl, 39), 368 (M^+, ^{35}Cl, 100), 339 (14), 337 (36), 301 (8), 274 (10), 258 (12), 150 (6), 129 (4); HRMS (EI): calcd for $C_{21}H_{17}O_2ClS$ [M^+]: 368.06323, found: 368.063118.

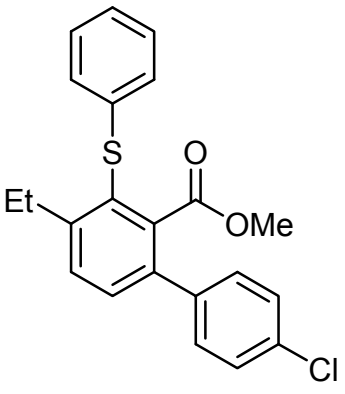


4`-Chloro-4-methyl-3-(phenylsulfanyl)biphenyl-2-ArCboxylic acid methyl ester (12p): Starting with **3b** (400 mg, 1.5 mmol), **11c** (0.37 mL, 1.8 mmol), $TiCl_4$ (0.25 mL, 2.25 mmol) and CH_2Cl_2 (9 mL), **12p** was isolated as a highly viscous oil (220 mg, 40%). ^{1}H NMR (250 MHz, $CDCl_3$): δ = 2.27 (s, 3H, CH_3), 3.54 (s, 3H, OCH_3), 7.04-7.29 (m, 11H, Ar); ^{13}C NMR (75 MHz, $CDCl_3$): δ = 19.8 (CH_3), 51.1 (OCH_3), 124.7, 126.6, 127.5, 127.9, 128.8, 129.7, 130.7 (ArCH), 132.8, 135.6, 135.8, 137.0, 139.5, 142.0, 167.8 (C); IR (KBr, cm^{-1}): $\tilde{\nu}$ = 3055 (w), 2947 (w), 2920 (w), 2851 (w), 2735 (w), 2660 (w), 2112 (w), 1907 (w), 1730 (s), 1673 (m), 1581 (m), 1476 (m), 1459 (m), 1431 (m), 1400 (m), 1277 (s), 1221 (s), 1189 (m), 1118 (s), 1092 (s), 1011 (s), 971 (m), 890 (m), 842 (m), 816 (s), 734 (s), 715 (m), 688 (s), 627 (m); MS (EI, 70 eV): *m/z* (%) = 370 (M^+, ^{37}Cl, 39), 368 (M^+, ^{35}Cl, 100), 337 (52), 336 (23), 335 (60), 309 (13), 307 (27), 301 (23), 271 (13), 258 (18), 165 (13), 152 (10), 51 (4); HRMS (EI): calcd for $C_{21}H_{17}O_2ClS$ [M^+]: 368.06323, found 368.062687.



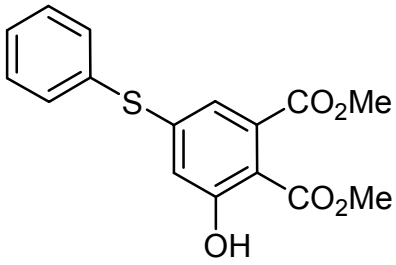
2-(4-Fluorophenylsulfanyl)-4-methyl-benzoic acid methyl ester (12q). Starting with **3l** (440 mg, 1.5 mmol), **11a** (0.23 mL, 2.25 mmol), $TiCl_4$ (0.25 mL, 2.25 mmol) and CH_2Cl_2 (9 mL), **12q** was isolated as a highly viscous oil (153 mg, 37%). ^{1}H NMR (250 MHz, $CDCl_3$): δ = 2.26 (s, 3H, CH_3), 3.83 (s, 3H, OCH_3), 6.92-7.26 (m, 7H, Ar); ^{13}C NMR (75 MHz, $CDCl_3$): δ = 19.6 (CH_3), 52.1 (OCH_3), 116.1, 116.5, 129.1, 1295, 129.9 (ArCH),130.4, 130.5 (C), 133.8, 133.9, 136.1 (ArCH), 160.4, 164.3, 168.8 (C); IR (KBr, cm^{-1}): *v* = 3091 (w), 3063 (w), 2950 (w),

2924 (w), 2853 (w), 1728 (s), 1712 (s), 1661 (m), 1588 (s), 1487 (s), 1434 (m), 1273 (s), 1220 (s), 1154 (s), 1107 (s), 1068 (s), 826 (s), 771 (s), 628 (m); MS (EI, 70 eV): *m/z* (%) = 276 (M^+, 74), 245 (49), 244 (22), 243 (100), 215 (15), 202 (38), 170 (5), 121 (5), 63 (3); HRMS (EI): calcd for $C_{15}H_{13}O_2FS$ [M^+]: 276.06148, found: 276.061483.

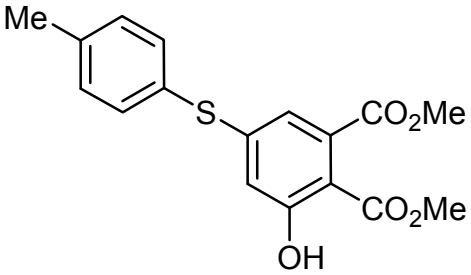


4`-Chloro-4-ethyl-3-(phenylsulfanyl)biphenyl-2-carboxylic acid methyl ester (12r): Starting with **3c** (440 mg, 1.5 mmol), **11c** (0.37 mL, 1.8 mmol), $TiCl_4$ (0.25 mL, 2.25 mmol) and CH_2Cl_2 (9 mL), **12r** was isolated as a highly viscous oil (206 mg, 36%). ^{1}H NMR (250 MHz, $CDCl_3$): δ = 1.05 (t, ^2J = 0.03 Hz, 3H, CH_3), 2.71 (q, ^2J = 0.03 Hz, 2H, CH_2), 3.49 (s, 3H, OCH_3), 7.02-7.17 (m, 11H, Ar); ^{13}C NMR (75 MHz, $CDCl_3$): δ = 14.7 (CH_3), 27.0 (CH_3CH_2), 52.1 (OCH_3), 125.6, 127.39 (ArCH), 128.2 (C), 128.6, 128.8, 129.8, 130.1, 131.1 (ArCH), 133.1, 136.7 137.4, 138.0, 140.9, 148.6, 168.8 (C); IR (KBr, cm^{-1}): $\tilde{\nu}$ = 3055 (w), 2965 (w), 2947 (w), 2931 (w), 2870 (w), 1730 (s), 1673 (w), 1581 (m), 1496 (w), 1477 (m), 1459 (m), 1431 (m), 1403 (w), 1385 (w), 1271 (s), 1229 (m), 1214 (s), 1118 (s), 1092 (s), 1067 (m), 1023 (m), 1012 (s), 959 (m), 900 (m), 823 (s), 737 (s), 688 (s), 539 (m); MS (EI, 70 eV): *m/z* (%) = 384 (M^+, ^{37}Cl, 39), 382 (M^+, ^{35}Cl, 100), 350 (27), 349 (35), 335 (18), 315 (12), 307 (13), 297(31), 271 (26), 258 (18), 245 (27), 237 (22), 178 (16), 165 (12), 105 (24); HRMS (EI): calcd for $C_{22}H_{19}O_2ClS$ [M^+]: 382.07888, found 382.079023.

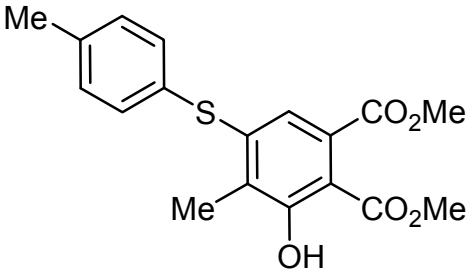
General experimental procedure: To neat **3a,d-m,p** (1.5 mmol) was added **13** (2.25 mmol) at –78 °C. The solution was allowed to warm to 20 °C during 20 h with stirring. To the solution was added ammonium chloride (10%, 25 mL) and dichloromethane. The organic and the aqueous layer were separated and the latter was extracted with dichloromethane (3 x 20 mL). The combined organic layers were dried (Na_2SO_4), filtered, and the filtrate was concentrated in vacuo and the residue was purified by chromatography (silica gel, EtOAc / heptanes = 1:9).



3-Hydroxy-5-phenylsulfanyl-phthalic acid dimethyl ester (14a): Starting with **3a** (420 mg, 1.5 mmol) and **13** (319 mg, 2.25 mmol), **14a** was isolated as a highly viscous oil (367 mg, 77%); ^{1}H NMR (250 MHz, $CDCl_3$): δ = 3.65 (s, 3 H, OCH_3), 3.69 (s, 3 H, OCH_3), 6.48-7.32 (m, 7H, ArH), 10.57 (s, 1H, OH); ^{13}C NMR (63 MHz, $CDCl_3$): δ = 52.6 (OCH_3), 52.8 (OCH_3), 106.6 (C), 116.2, 117.1, 129.5 (ArCH), 129.9 (2ArCH), 130.0 (C), 134.8 (2ArCH), 135.7, 148.3, 161.7, 168.9, 169.0 (C); IR (KBr, cm^{-1}): $\tilde{\nu}$ = 3057 (w), 3000 (w), 2950 (w), 2845 (w), 1732 (s), 1668 (s), 1596 (s), 1556 (m), 1474 (m), 1437 (s), 1329 (s), 1265 (s), 1197 (s), 1167 (s), 1120 (s), 1068 (m), 1016 (s), 933 (m), 852 (m), 802 (m), 774 (m), 744 (s), 689 (s), 562 (m); MS (EI, 70 eV): *m/z* (%) = 319 (18), 318 (M^+, 100), 287 (34), 285 (55), 270 (11), 269 (65), 253 (16), 228 (20), 226 (10), 200 (27), 198 (11), 171 (25); HRMS (EI): calcd for $C_{16}H_{14}O_5S$ [M^+]: 318.05565, found: 318.055736.

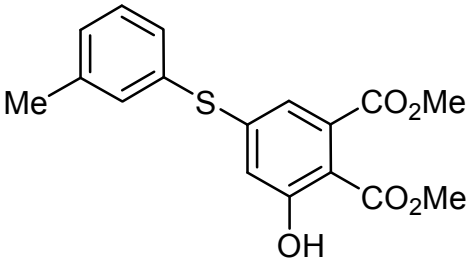


3-Hydroxy-5-(4-methylphenylsulfanyl)phthalic acid dimethyl ester (14b): Starting with **3d** (441 mg, 1.5 mmol) and **13** (319 mg, 2.25 mmol), **14b** was isolated as a highly viscous oil (344 mg, 69%); ^{1}H NMR (250 MHz, $CDCl_3$): δ = 2.32 (s, 3H, CH_3), 3.77 (s, 3 H, OCH_3), 3.80 (s, 3 H, OCH_3), 6.54-6.60 (dd, *J*=1.8 Hz, 2H, ArH), 7.17 (d, *J*=8.2 Hz, 2H, ArH), 7.35 (d, *J*=8.2 Hz, 2H, ArH), 10.69 (s, 1H, OH); ^{13}C NMR (63 MHz, $CDCl_3$): δ = 21.3 (CH_3), 52.6 (OCH_3), 52.7 (OCH_3), 106.3 (C), 115.6, 116.7 (ArCH), 126.0, 130.6 (C), 130.7 (2ArCH), 135.1 (2ArCH), 140.0, 149.1, 161.5, 169.0, 169.1 (C); IR (KBr, cm^{-1}): $\tilde{\nu}$ = 3022 (w), 2998 (w), 2950 (w), 2921 (w), 2847 (w), 1733 (s), 1668 (s), 1595 (s), 1555 (m), 1491 (m), 1433 (s), 1331 (s), 1266 (s), 1196 (s), 1164 (s), 1120 (s), 1016 (s), 934 (m), 852 (m), 802 (s), 773 (m), 744 (m), 703 (m), 636 (m), 586 (m), 567 (m); MS (EI, 70 eV): *m/z* (%) = 333 (17), 332 (M^+, 100), 301 (22), 299 (34), 285 (15), 283 (47) ,267 (12), 242 (11), 214 (15); HRMS (EI): calcd for $C_{17}H_{16}O_5S$ [M^+]: 332.07130, found: 332.071408.

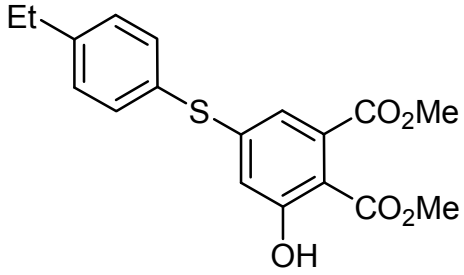


3-Hydroxy-6-(4-methylphenylsulfanyl)-4-methyl-phthalic acid dimethyl ester (14c): Starting with **3e** (462 mg, 1.5 mmol) and **13** (319 mg, 2.25 mmol), **14c** was isolated as a highly viscous oil (306 mg, 59%); ^{1}H NMR (250 MHz, $CDCl_3$): δ = 2.14 (s, 3H, CH_3), 2.33 (s, 3H, CH_3), 3.81 (s, 3 H, OCH_3), 3.84 (s, 3 H, OCH_3), 6.27 (s, 1H, ArH), 7.18 (d, *J*=8.2 Hz, 2H, ArH), 7.36 (d, *J*=8.2 Hz, 2H, ArH), 10.78 (s, 1H, OH); ^{13}C NMR (63 MHz, $CDCl_3$): δ = 14.8 (CH_3), 20.3 (CH_3), 51.4 (OCH_3), 51.8 (OCH_3), 104.6 (C), 113.9 (ArCH), 121.3, 125.1 (C), 129.6, 129.8, 134.4, 134.5 (ArCH), 139.1, 149.2, 158.8,

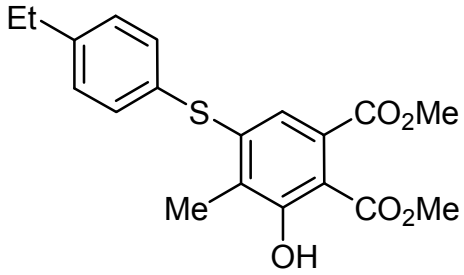
168.1, 168,3 (C); IR (KBr, cm^{-1}): $\tilde{\nu}$ = 3071 (w), 3021 (w), 2951 (w), 2873 (w), 1735 (s), 1667 (s), 1590 (s), 1562 (s), 1492 (m), 1430 (s), 1331 (s), 1278 (m), 1217 (s), 1125 (s), 1042 (s), 1004 (m), 939 (s), 827 (s), 802 (s), 743 (s); MS (EI, 70 eV): *m/z* (%) = 347 (22), 346 (M^+, 100), 329 (27), 326 (26), 313 (17), 312 (12), 311 (56), 299 (29), 296 (39), 270 (10), 268 (10), 267 (26), 240 (12); HRMS (EI): calcd for $C_{18}H_{18}O_5S$ [M^+]: 346.08695, found: 346.086893.



3-Hydroxy-5-(4-methylphenylsulfanyl)-phthalic acid dimethyl ester (14d): Starting with **3f** (441 mg, 1.5 mmol) and **13** (319 mg, 2.25 mmol), **14d** was isolated as a highly viscous oil (333mg, 67%); ^{1}H NMR (300 MHz, $CDCl_3$): δ = 2.28 (s, 3H, CH_3), 3.77 (s, 3 H, OCH_3), 3.80 (s, 3 H, OCH_3), 6.58-7.24 (m, 6H, ArH), 10.68 (s, 1H, OH); ^{13}C NMR (63 MHz, $CDCl_3$): δ = 21.2 (CH_3), 52.6 (OCH_3), 52.7 (OCH_3), 106.5 (C), 116.1, 117.0 (ArCH), 129.5 (C), 129.7, 130.4, 131.9, 135.4 (ArCH), 135.7, 139.8, 148.6, 161.5, 169.0, 169 (C); IR (KBr, cm^{-1}): $\tilde{\nu}$ = 3022 (w), 2998 (w), 2950 (w), 2921 (w), 2847 (w), 1733 (s), 1668 (s), 1595 (s), 1555 (m), 1491 (m), 1433 (s), 1331 (s), 1266 (s), 1196 (s), 1164 (s), 1120 (s), 1016 (s), 934 (m), 852 (m), 802 (s), 773 (m), 744 (m), 703 (m), 636 (m), 586 (m), 567 (m); MS (EI, 70 eV): *m/z* (%) = 333 (17), 332 (M^+, 100), 301 (22), 299 (34), 285 (15), 283 (47) ,267 (12), 242 (11), 214 (15); HRMS (EI): calcd for $C_{17}H_{16}O_5S$ [M^+]: 332.07130, found: 332.071173.

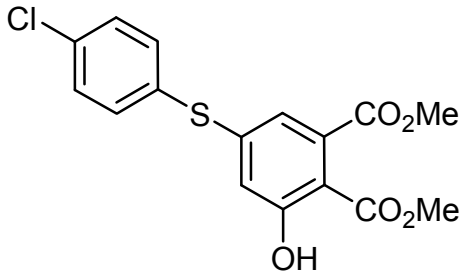


3-Hydroxy-5-(4-ethylphenylsulfanyl)-phthalic acid dimethyl ester (14e): Starting with **3g** (462 mg, 1.5 mmol) and **13** (319 mg, 2.25 mmol), in neat condition **14e** was isolated as a highly viscous oil (358 mg, 69%); ^{1}H NMR (300 MHz, $CDCl_3$): δ = 1.19 (t, *J* = 7.6 Hz, 3H, CH_3), 2.61 (q, *J* = 7.6 Hz, 2H, CH_2), 3.76 (s, 3 H, OCH_3), 3.79 (s, 3 H, OCH_3), 6.17-6.21 (dd, *J*=8.2, 1.8 Hz, 2H, ArH), 7.06 (d, *J*=8.2 Hz, 2H, ArH), 7.23 (d, *J*=8.2 Hz, 2H, ArH), 10.69 (s, 1H, OH); ^{13}C NMR (75.4 MHz, $CDCl_3$): δ = 15.2 (CH_3), 28.6 (CH_2), 52.6 (OCH_3), 52.7 (OCH_3), 106.4 (C), 115.7, 116.8 (ArCH), 126.3 (C), 129.5, 135.1 (2ArCH), 135.7, 146.2, 149.1, 161.5, 169.0, 169.1 (C); IR (KBr, cm^{-1}): $\tilde{\nu}$ = 3094 (w), 3067 (w), 2999 (w), 2951 (w), 2847 (w), 1732 (s), 1669 (s), 1588 (s), 1555 (m), 1488 (s), 1435 (m), 14397 (m), 1332 (s), 1268 (s), 1218 (s), 1198 8s), 1169 8s), 1155 (s), 1121(s), 1089 8m), 1014 (s), 934 (m), 832 (s), 802 (s), 702 (m), 638 (m), 566 (m); MS (EI, 70 eV): *m/z* (%) = 347 (21), 346 (M^+, 100), 315 (24), 313 (35), 299 (12), 298 (11), 297 (53), 285 (33), 281 (14), 228 (10), 227 (10), 226 (10); HRMS (EI): calcd for $C_{18}H_{18}O_5S$ [M^+]: 346.08695, found: 346.086443.



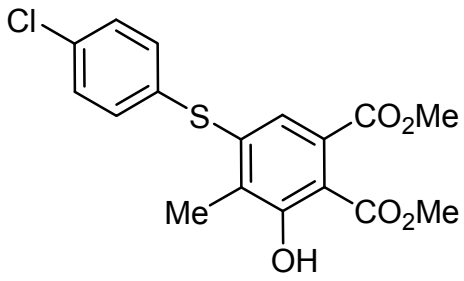
3-hydroxy-6-(4-ethylphenylsulfanyl)-4-methyl-phthalic acid dimethyl ester (14f): Starting with **3h** (483 mg, 1.5 mmol) and **13** (319 mg, 2.25 mmol), **14f** was isolated as a highly viscous oil (345mg, 64%); ^{1}H NMR (300 MHz, $CDCl_3$): δ =1.09 (t, *J* = 7.6 Hz, 3H, CH_3), 2.03 (s, 3H, CH_3), 2.51 (q, *J* = 7.6 Hz, 2H, CH_2), 3.70 (s, 3 H, OCH_3), 3.73 (s, 3 H, OCH_3),

6.19 (s, 1H, ArH), 7.08 (d, *J*=8.2 Hz, 2H, ArH), 7.23 (d, *J*=8.2 Hz, 2H, ArH), 10.68 (s, 1H, OH); ^{13}C NMR (63 MHz, $CDCl_3$): δ = 15.2 ($CH_2\mathit{CH_3}$), 15.8 (CH_3), 28.6 (CH_2), 52.4 (OCH_3), 52.8 (OCH_3), 105.0 (C), 114.8 (ArCH), 122.3, 126.2 (C), 129.6 (2ArCH), 134.7 (C), 135.5 (2ArCH), 146.3, 150.2, 159.8, 169.2, 169.4 (C); IR (KBr, cm^{-1}): $\tilde{\nu}$ = 3071 (w), 3021 (w), 2951 (w), 2873 (w), 1735 (s), 1667 (s), 1590 (s), 1562 (s), 1492 (m), 1430 (s), 1331 (s), 1278 (m), 1217 (s), 1125 (s), 1042 (s), 1004 (m), 939 (s), 827 (s), 802 (s), 743 (s); MS (EI, 70 eV): *m/z* (%) = 361 (22), 360 (M^+, 100), 329 (27), 326 (26), 313 (17), 312 (12), 311 (56), 299 (29), 296 (39), 270 (10), 268 (10), 267 (26), 240 (12); HRMS (EI): calcd for $C_{19}H_{20}O_5S$ [M^+]: 360.10260, found: 360.101772.

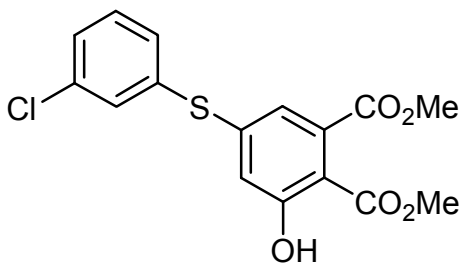


3-Hydroxy-5-(4-chlorophenylsulfanyl)-phthalic acid dimethyl ester (14g): Starting with **3i** (471mg, 1.5 mmol) and **13** (319 mg, 2.25 mmol), **14g** was isolated as a highly viscous oil (338 mg, 64%); ^{1}H NMR (250 MHz, $CDCl_3$): δ = 3.70 (s, 3 H, OCH_3), 3.74 (s, 3 H, OCH_3), 6.52-7.31 (m, 6H, ArH), 10.62 (s, 1H, OH); ^{13}C NMR (63 MHz, $CDCl_3$): δ = 52.7 (OCH_3), 52.8 (OCH_3), 107.0 (C), 116.4, 117.2 (ArCH), 126.9, 128.7, (C), 130.1 (2ArCH), 135.9 (2ArCH), 147.3, 149.1, 161.5, 168.8, 168.9 (C); IR (KBr, cm^{-1}): *v* = 3079 (w), 3044 (w), 3006 (w), 2955 (w), 2853 (w), 1727 (s), 1673 (s), 1594 (s), 1557 (s), 1475 (m), 1440 (s), 1434 (s), 1406 (m), 1388 (m), 1328 (s), 1265 (s), 1199 (s), 1164 (s), 1120 (s), 1016 (s), 934 (m), 852 (m), 802 (s), 773 (m), 744 (m), 703 (m), 636 (m), 586 (m), 567 (m); MS (EI, 70 eV): *m/z* (%) = 354 (M^+, 35), 353 (16), 352 (M^+, 100), 323 (12), 322 (12), 321 (48), 320 (20), 319 (42), 305 (19), 303 (44), 287

(13), 264 (13), 262 (36) ,260 (12), 234 (24), 171 (11); HRMS (EI): calcd for $C_{16}H_{13}O_5SCl$ [M^+]: 352.01667, found: 352.016164.

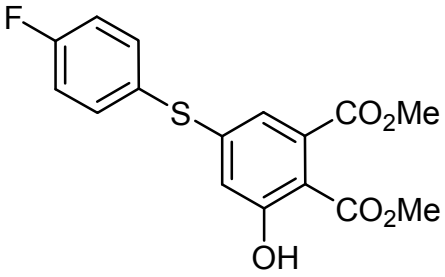


3-Hydroxy-6-(4-chlorophenylsulfanyl)-4-methyl-phthalic acid dimethyl ester; (14h): Starting with **3j** (492 mg, 1.5 mmol) and **13** (319 mg, 2.25 mmol), **14h** was isolated as a highly viscous oil (302 mg, 55%); ^{1}H NMR (300 MHz, $CDCl_3$): δ = 2.16 (s, 3H, CH_3), 3.85 (s, 3 H, OCH_3), 3.87 (s, 3 H, OCH_3), 6.36-7.42 (m, 5H, ArH), 10.81 (s, 1H, OH); ^{13}C NMR (63 MHz, $CDCl_3$): δ = 17.2 (CH_3), 53.8 (OCH_3), 54.0 (OCH_3), 106.6 (C), 117.0 (ArCH), 124.1, 130.3, 130.5, 131.2 (C), 131.4, 137.3 (2ArCH), 149.5, 161.0, 170.2, 170.4 (C); IR (KBr, cm^{-1}): $\tilde{\nu}$ = 3073 (w), 3025 (w), 2951 (w), 2873 (w), 1735 (s), 1667 (s), 1590 (s), 1562 (s), 1492 (m), 1430 (s), 1331 (s), 1278 (m), 1217 (s), 1128 (s), 1046 (s), 1004 (m), 945 (s), 827 (s), 802 (s), 747 (s); MS (EI, 70 eV): *m/z* (%) = 368 (M^+, 39), 367 (19), 366 (M^+, 100), 328 (17), 326 (26), 313 (17), 312 (12), 311 (56), 299 (29), 296 (39), 270 (10), 268 (10), 267 (26), 240 (13); HRMS (EI): calcd for $C_{17}H_{15}O_5SCl$ [M^+]: 366.03232, found: 366.031813.



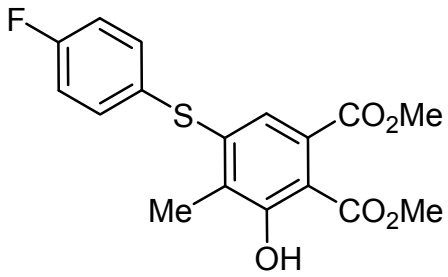
3-Hydroxy-5-(3-chlorophenylsulfanyl)-phthalic acid dimethyl ester (14i): Starting with **3k** (471 mg, 1.5 mmol) and **13** (319 mg, 2.25 mmol), **14i**

was isolated as a highly viscous oil (317 mg, 60%); ^{1}H NMR (250 MHz, $CDCl_3$): δ = 3.78 (s, 3 H, OCH_3), 3.82 (s, 3 H, OCH_3), 6.64-7.30 (m, 6H, ArH), 10.69 (s, 1H, OH); ^{13}C NMR (63 MHz, $CDCl_3$): δ = 52.7 (OCH_3), 52.8 (OCH_3), 107.0 (C), 117.1, 117.8, 129.5, 130.8, 132.3 (ArCH), 132.5 (C), 133.9 (ArCH), 135.4, 136.0, 146.5, 161.5, 168.7, 168.9 (C); IR (KBr, cm^{-1}): $\tilde{\nu}$ = 3079 (w), 3044 (w), 3006 (w), 2955 (w), 2853 (w), 1727 (s), 1673 (s), 1594 (s), 1557 (s), 1475 (m), 1440 (s), 1434 (s), 1406 (m), 1388 (m), 1328 (s), 1265 (s), 1199 (s), 1164 (s), 1120 (s), 1016 (s), 934 (m), 852 (m), 802 (s), 773 (m), 744 (m), 703 (m), 636 (m), 586 (m), 567 (m); MS (EI, 70 eV): *m/z* (%) = 354 (M^+, 35), 353 (16), 352 (M^+, 100), 323 (12), 322 (12), 321 (48), 320 (20), 319 (42), 305 (19), 303 (44), 287 (13), 264 (13), 262 (36) ,260 (12), 234 (24), 171 (11); HRMS (EI): calcd for $C_{16}H_{13}O_5SCl$ [M^+]: 352.01667, found:352.016166.

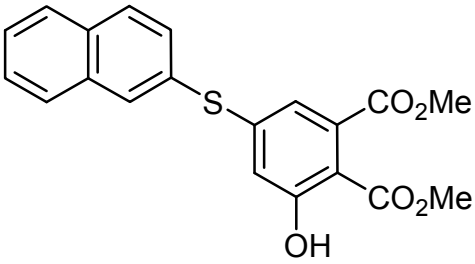


3-Hydroxy-5-(4-fluorophenylsulfanyl)-phthalic acid dimethyl ester (14j): Starting with **3l** (447 mg, 1.5 mmol) and **13** (319 mg, 2.25 mmol), **14j** was isolated as a highly viscous oil (257 mg, 51%); ^{1}H NMR (250 MHz, $CDCl_3$): δ = 3.69 (s, 3 H, OCH_3), 3.73 (s, 3 H, OCH_3), 6.45-7.33 (m, 6H, ArH), 10.62 (s, 1H, OH); ^{13}C NMR (75.4 MHz, $CDCl_3$): δ = 52.7 (OCH_3), 52.8 (OCH_3), 106.0 (C), 115.8, 116.7, 117.0, 117.3 (ArCH), 135.8, (C), 137.2, 137.3 (ArCH), 148.3, 161.5, 161.9, 165.3, 168.9, 169.0 (C); IR (KBr, cm^{-1}): $\tilde{\nu}$ = 3094 (w), 3067 (w), 2999 (w), 2951 (w), 2847 (w), 1732 (s), 1669 (s), 1588 (s), 1555 (m), 1488 (s), 1435 (m), 14397 8m), 1332 8s), 1268 (s), 1218 (s), 1198 (s), 1169 (s), 1155 (s), 1121 (s), 1089 8m), 1014 (s), 934 (m), 832 (s), 802 (s), 702 (m), 638 (m), 567 (m);

MS (EI, 70 eV): *m/z* (%) = 337 (16), 336 (M^+, 100), 305 (36), 304 (24), 303 (39), 287 (38), 271 (12), 246 (42), 244 (11), 218 (25), 216 (10), 189 (16); HRMS (EI): calcd for $C_{16}H_{13}O_5SF$ [M^+]: 336.04622, found: 336.045809.

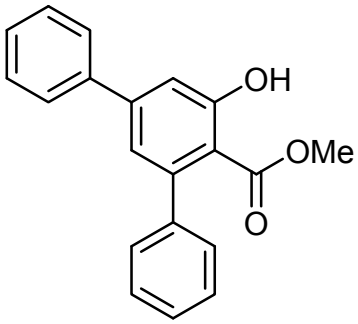


3-Hydroxy-6-(4-fluorophenylsulfanyl)-4-methyl-phthalic acid dimethyl ester (14k): Starting with **3m** (468 mg, 1.5 mmol) and **13** (319 mg, 2.25 mmol), in neat condition **14k** was isolated as a highly viscous oil (378 mg, 53%); ^{1}H NMR (300 MHz, $CDCl_3$): δ = 2.06 (s, 3H, CH_3), 3.73 (s, 3 H, OCH_3), 3.76 (s, 3 H, OCH_3), 6.16-7.33 (m, 5H, ArH), 10.71 (s, 1H, OH); ^{13}C NMR (63 MHz, $CDCl_3$): δ = 15.7 (CH_3), 52.4 (OCH_3), 52.8 (OCH_3), 105.9 (C), 115.0, 117.1, 117.5 (ArCH), 122.4, 125.1 (C), 137.4, 137.6 (ArCH), 137.8, 137.9, 149.3, 159.8, 169.0, 169.2 (C); IR (neat): $\tilde{\nu}$ = 3075 (w), 3025 (w), 2951 (w), 2871 (w), 1736 (s), 1667 (s), 1591 (s), 1562 (s), 1492 (m), 1432 (s), 1331 (s), 1278 (m), 1217 (s), 1128 (s), 1046 (s), 1004 (m), 945 (s), 827 (s), 802 (s), 747 (s); MS (EI, 70 eV): *m/z* (%) = 351 (19), 350 (M^+, 100), 327 (17), 326 (26), 313 (17), 312 (12), 311 (56), 299 (29), 296 (39), 270 (10), 268 (10), 267 (26), 240 (13); HRMS (EI): calcd for $C_{18}H_{18}O_5S$ [M^+]: 350. 04622, found: 350.04731.

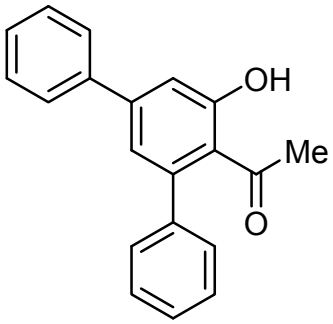


3-Hydroxy-5-(2-naphthyl)sulfanyl-phthalic acid dimethyl ester (14l): Starting with **3p** (496 mg, 1.5 mmol) and **13** (319 mg, 2.25 mmol), **14l** was isolated as a highly viscous oil (298 mg, 54%); ^{1}H NMR (250 MHz, $CDCl_3$): δ = 3.68 (s, 3 H, OCH_3), 3.72 (s, 3 H, OCH_3), 6.56-7.92 (m, 8H, ArH), 10.60 (s, 1H, OH); ^{13}C NMR (63 MHz, $CDCl_3$): δ = 52.6 (OCH_3), 52.8 (OCH_3), 106.6 (C), 116.4, 117.2 (ArCH), 127.2 (C), 127.3, 127.8, 127.9, 129.7, 130.9 (ArCH), 133.3, 133.8 (C), 134.7, 134.9 (ArCH), 135.8, 148.1, 161.5, 168.9, 169.0 (C); IR (neat): $\tilde{\nu}$ = 3052 (w), 2999 (w), 2949 (w), 2840 (w), 1731 (s), 1666 (s), 1595 (s), 1555 (s), 1497 (m), 1434 (s), 1400 (m), 1330 (s), 1264 (s), 1196 (s), 1167 (s), 1119 (s), 1016 (s), 934 (s), 850 (s), 802 (s), 742 (s), 646 (m); MS (EI, 70 eV): *m/z* (%) = 369 (19), 368 (M^+, 100), 337 (11), 335 (17), 319 (24), 303 (18), 250 (19), 248 (10), 221 (12); HRMS (EI): calcd for $C_{20}H_{16}O_5S$ [M^+]: 368.07130, found: 368.071809.

General procedure for the synthesis of 17a-c: To a dichloromethane solution (10 mL / mmol of **15**) of **15** (1.65 mmol) and of **16** (1.5 mmol) was added $TiCl_4$ (1.5 mmol) at –78 °C. The solution was allowed to warm to 20 °C within 20 h. To the solution was added a saturated aqueous solution of 10% HCl (15 mL). The organic and the aqueous layer were separated and the latter was extracted with CH_2Cl_2 (3 x 20 mL). The combined organic layers were dried (Na_2SO_4), filtered, and the filtrate was concentrated in vacuo. The residue was purified by chromatography (silica gel, EtOAc / *n*-heptane = 1:4).

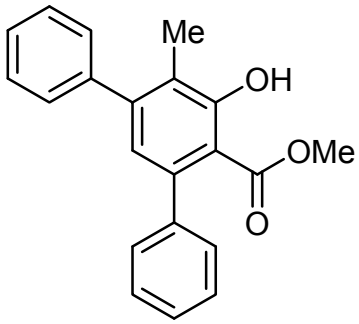


5'-Hydroxy-[1,1';3',1'']terphenyl-4'-carboxylic acid methyl ester (17a): Starting with **15** (430mg, 1.65 mmol), **16a** (444mg, 1.5 mmol), $TiCl_4$ (0.2ml, 1.65 mmol) and CH_2Cl_2 (9ml), **17a** was isolated as a gummy compound (201 mg, 40%); ^{1}H NMR (300 MHz, $CDCl_3$): δ = 3.40 (s, 3H, OCH3), 6.96-7.54 (m, 12H, ArH), 10.75 (s, 1H, OH); ^{13}C NMR (75 MHz, CDCl3): δ = 52.1 (OCH3), 111.1, 115.1, 122.0, 127.3 (ArCH), 127.6, 128.0, 128.5 (2C ArCH), 128.9 (ArCH), 129.3 (2C ArCH), 139.7, 143.2, 145.8, 146.8, 162.3 (ArCH), 171.7 (C); IR (neat): $\tilde{\nu}$ = 3426 (m), 3083 (w), 3054 (m), 3025 (m), 2947 (m), 1664 (s), 1597 (m), 1553 (m), 1491 (w), 1437 (s), 1386 (s), 1354 (m), 1319 (s), 1256 (s), 1230 (s), 1198 (m),. 1142 (s), 1014 (m), 776 (m), 767 (m), 702 (s); cm−1; GC-MS (EI, 70 eV): m/z (%): 304 (40), 273 (23), 272 (M^+, 100), 245 (9), 244 (38), 216 (11), 215 (54), 213 (8), 202 (3), 189 (3), 152 (5), 139 (3), 122 (6), 113 (4), 107 (16), 94 (7). HRMS (EI): calcd for C20H16O3 [M^+]: 304.10940, found 304.109762.



1-(5'-Hydroxy-[1,1';3',1'']terphenyl-4'-yl)-ethanone) (17b): Starting with **15** (403mg, 1.65 mmol), **16b** (444mg, 1.5 mmol), $TiCl_4$ (0.2ml, 1.65 mmol) and CH_2Cl_2 (9ml), **17b** was isolated as a gummy compound (194mg, 41%); ^{1}H NMR (300 MHz, CDCl3): δ = 1.80 (s, 3H, CH3), 6.79-7.93 (m, 12H, ArH), 11.87 (s, 1H, OH); ^{13}C NMR (75 MHz, CDCl3): δ = 28.6 (CH3), 114.1, 116.3, 118.8, 120.3, 122.4(ArCH), 126.2 (2C ArCH), 127.7 (ArCH), 127.9 (2C ArCH), 131.4, 134.5, 138.2, 142.2, 144.3 145.6, 160.8, 184.7 (ArCH), 205.6 (C); IR (neat): $\tilde{\nu}$ = 3425 (m), 3086 (w), 3054 (m), 3025 (m), 2946 (m), 1665 (s), 1596 (m), 1554 (m),

1492 (w), 1437 (s), 1386 (s), 1354 (m), 1319 (s),1230 (s), 1198 (m),. 1142 (s), 1014 (m), 776 (m), 767 (m), 702 (s); cm−1; GC-MS (EI, 70 eV): m/z (%): 288 (M^+, 100), 245 (9), 244 (38), 216 (11), 215 (54), 213 (8), 202 (3), 189 (3), 152 (5), 139 (3), 122 (6), 113 (4), 107 (16), 94 (7). HRMS (EI): calcd for C20H16O2 [M^+]: 288.10632, found 288.105768.



5'-Hydroxy-6'-methyl-[1,1';3',1'']terphenyl-4'-carboxylic acid methyl ester (17c); Starting with **15** (453mg, 1.65 mmol), **16c** (444mg, 1.5 mmol), TiCl4 (0.2ml, 1.65 mmol) and CH_2Cl_2 (9ml), **17c** was isolated as a gummy compound (222.9mg, 37%); ^{1}H NMR (300 MHz, CDCl3): δ = 2.12 (s, 3H, CH3), 3.39 (s, 3H, OCH3), 6.66-7.29 (m, 11H, ArH), 11.05 (s, 1H, OH); ^{13}C NMR (75 MHz, CDCl3): δ = 13.7 (CH3), 52.1 (OCH3), 110.4, 123.7, 124.2, 127.1, 127.6 (ArCH), 127.9, 128.0, 128.5 (2C ArCH), 141.2, 141.9, 143.3, 145.3, 144.5, 147.5, 160.6 (ArCH), 172.3 (C); IR (neat): $\tilde{\nu}$ = 3426 (m), 3087 (w), 3052 (m), 3028 (m), 2947 (m), 1664 (s), 1597 (m), 1556 (m), 1493 (w), 1437 (s), 1386 (s), 1359 (m), 1320 (s), 1256 (s), 1230 (s), 1198 (m),. 1143 (s), 1014 (m), 776 (m), 767 (m), 702 (s); cm−1; GC-MS (EI, 70 eV): m/z (%):318 (M+, 100), 300 (20), 288 (4), 276 (3), 245 (9), 244 (38), 216 (11), 215 (54), 213 (8), 202 (9), 189 (7), 152 (3), 139 (9), 122 (8), 113 (6), 107 (16), 94 (7). HRMS (EI): calcd for C21H18O3 [M^+]: 318.10654, found 318.109762.

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2005-2006 **German Language** Courses *A1and A2* by Goethe Institute Karachi, Pakistan

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Publications

1. **Inam Iqbal**, Muhammad Imran, Nasir Rasool, Muhammad A. Rashid, Munawar Hussain, Alexander Villinger, Christine Fischer, Peter Langer*, submitted to *Tetrahedron*. ‘’Synthesis of Functionalized 2-(Arylthio)benzoates by formal [3+3] Cyclizations of 3-Arylthio-1-trimethylsilyloxy-1,3-butadienes with 3-Silyloxy-2-en-1-ones and 1,1-Diacylcyclopropanes.’’

2. **Inam Iqbal,** Muhammad Imran, Peter Langer*, *Synthesis* **2009,** in print. “Synthesis of 5-Arylthio-3-hydroxyphthalates by the First [4+2] Cycloadditions of 3-Arylthio-1-silyloxy-1,3-butadienes with Dimethyl Acetylenedicarboxylate”.

3. **Inam Iqbal**, Muhammad Imran, Alexander Villinger, Peter Langer*, *Synthesis* **2009**, 297-305. “Regioselective Synthesis of Functionalized 2-(Arylthio)-benzoates by the First [3+3] Cyclizations of 3-Arylthio-1-silyloxy-1,3-butadienes with 3-Alkoxy-2-en-1-ones”.

4. **Inam Iqbal**, Muhammad Imran and Peter Langer*, submitted to *Tetrahedron* .“Regioselective Synthesis of 2-Arylthio-4-methoxybenzoates and 2-Arylthio-6-(methylthio)benzoates based on Formal [3+3] Cyclocondensations of 3-Arylthio-1-trimethylsilyloxy-1,3-butadienes”

5. Muhammad Imran, **Inam Iqbal,** Peter Langer*, *Synlett* **2009**, in print. ‘’Regioselective Synthesis of 2-Arylthio-4-(methoxy)benzoates by the First [3+3]

Cyclocondensations of 3-Arylthio-1-silyloxy -1,3-butadienes with 3-Oxo-orthoesters".

6. Muhammad Imran, **Inam Iqbal,** and Peter Langer*, submitted to *Tetrahedron Lett.* ''Regioselective Synthesis of 4-Arylthio-2-hydroxy-homophthalates by [4+2] Cycloaddition of 3-Arylthio-1-trimethylsiloxy-1,3-butadienes with Dimethyl allene-1,3-dicarboxylate''.

7. Muhammad Imran, **Inam Iqbal**, Nasir Rasool, Muhammad A. Rashid, Peter Langer*, *Synlett* **2008**, 2708-2710 ''Regioselective Synthesis of 2-Thiophenoxybenzoates by the First Catalytic [3+3] Cyclocondensations of 1-Trimethylsilyloxy-3-thiophenoxy-1,3-butadienes with 1,1,3,3-Tetramethoxypropane".

8. Muhammad A. Rashid, Nasir Rasool, **Inam Iqbal**, Imran Iqbal, Peter Langer*, *Tetrahedron Lett.* **2008**, *49,* 2466-2468. "Regioselective Synthesis of Functionalized 2-(Phenylthio)benzoates by ′[3+3] Cyclization / Homo-Michael′ Reactions of 1-Methoxy-1-trimethylsilyloxy-3-phenylthio-1,3-butadienes with 1,1-Diacylcyclopropanes".

9. Mirza A. Yawer, Ibrar Hussain, **Inam Iqbal**, Anke Spannenberg, Peter Langer*, *Tetrahedron Lett.* **2008**, *49*, 4467-4469. "Synthesis of Functionalized Dibenzo[b,d]pyrid-6-ones based on a [3+3]-Cyclocondensation / Lactamization Strategy".

10. Mirza Arfan Yawer, Ibrar Hussain, Stefanie Reim, Zafar Ahmed, Ehsan Ullah, **Inam Iqbal,** Christine Fischer, Helmut Reinke, Helmar Görls, and Peter Langer*,

Tetrahedron **2007**, *63*, 12562-12575. “Regioselective Synthesis of 4-Chlorophenols, 10-Chloro-7-hydroxy-6H-benzo[c]chromen-6-ones and 4-Chloro-1-hydroxy-9H-fluoren-9-ones based on [3+3] Cyclizations of 1,3-Bis(silyloxy)-1,3-dienes with 2-Chloro-3-silyloxy-2-en-1-ones”.

Declaration/Erklärung

Here by I declare that this work has so for neither submitted to the Faculty of Mathematics and Natural Sciences at the University of Rostock nor to any other scientific Institution for the purpose of doctorate. Further more, I declare that I have written this work by myself and that I have not used any other sources, other than mentioned earlier in this work.

Hiermit erkläre ich, daß diese Arbeit bisher von mir weder an der Mathematisch-Naturwissenschaftlichen Fakultät der Universität Rostock noch einer anderen wissenschaftlichen Einrichtung zum Zwecke der Promotion

Eingereicht wurde.

Ferner erkläre ich, dass ich diese Arbeit selbständig verfasst und keine anderen als die darin angegebenen Hilfsmittel benutzt habe

I hereby apply irrevocably to take oral examination in the form of a private viva voce and a public presentation.

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Inam Iqbal