Arylation of α-(Phenylthio)ketones with Aryllead(IV) Derivatives: Application to the Synthesis of 2-Arylbenzofuran-3(2*H*)-one Derivatives

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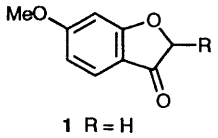
The reaction of aryllead(IV) triacetates with benzofuran-3(2*H*)-one **1** yields the 2,2-diarylated ketone or the monoarylated ketone with the hindered lead reagent **15**. 2-Phenylthiobenzofuran-3(2*H*)-one **2** was easily arylated with a wide range of aryllead reagents to give arylated ketones in 29–92% yields. α-Acetoxylation was observed only as a side reaction with hindered lead reagents, bearing *ortho*-substituents.

Naturally occurring 2-arylbenzofurans are mostly found in two taxonomically different families, the *Leguminosae* and the *Krameriaceae*. The biological activity of some naturally occurring 2-arylbenzofurans, particularly the phytoalexin properties, has prompted interest in their synthesis. Although a number of methods are known,[1] attention has generally focused on two general methods: (i) rearrangements of flavylium or isoflavylium salts[2] or of chalcones[3] and (ii) cyclisation involving copper(I) acetylides.[4] The latter is a relatively general synthesis of 2-arylbenzofurans but suffers from low-yielding steps, especially the key coupling of the copper acetylide with the aryl halide. Although there are few literature reports of the synthesis of 2-arylbenzofuran-3(2*H*)-ones, Katamna described the synthesis of 2-aryl-4,6-dihydroxybenzofuran-3(2*H*)-ones using a Hoesch reaction between phloroglucinol and an aryl(α-halogeno)acetonitrile; the low product yields made this method unsatisfactory.[5] Acidic rearrangement of 2,3-dihydro-2-methoxy-2-phenylbenzofuran-3-ol with boron trifluoride leads to 2-phenylbenzofuran-3(2*H*)-one by a 1,2-hydride shift but although the rearrangement step is achieved with 80% conversion, the synthesis of benzofuranol is low yielding.[6] Recently Hanaya *et al.* obtained 2-phenylbenzofuran-3(2*H*)-one by bromination of 2'-hydroxy-2-phenylacetophenone and subsequent cyclisation of the intermediate 2-bromo-2'-hydroxy-2-phenylacetophenone. Again the yield is low (30%) and, moreover, the application to the synthesis to other 2-arylbenzofuran-3(2*H*)-ones has not been explored.[7]

2-Arylbenzofurans have been synthesized with, as the key synthetic step, direct C-arylation of benzofuran-3(2*H*)-ones. Of the reagents suitable for this reaction, the recently introduced aryllead triacetates[8] are efficient, high-yielding, electrophilic arylating agents for a wide range of enolisable substrates under mild reaction conditions.[9] However, such reactions generally require the presence of a strongly activating electron-withdrawing substituent. For example, nitroalkanes or β-dicarbonyl compounds such as β-keto esters or β-diketones are easily and efficiently arylated on the α-carbon, whereas malonic acid derivatives are not.

In a recent communication,[10] we have reported the relatively easy arylation of an α-aryloxy ketone under mild conditions. Reaction of 6-methoxybenzofuran-3(2*H*)-one **1** with 2.2 equiv. of the unhindered organolead reagent **6** in presence of pyridine led to a good yield (71%) of the diarylated ketone **3**. However, no reaction was observed with the more sterically demanding organolead reagent **15**. In the proposed mechanism for organolead arylation,[11] the formation of a covalent lead enolate is followed by reductive elimination. A stronger base, such as



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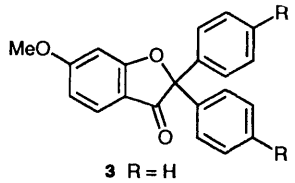
2 R = SPh



3 R = H
4 R = Me

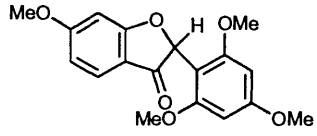


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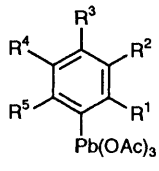
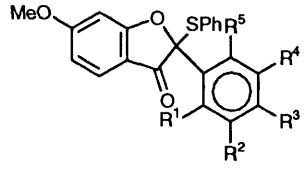
Table 1 Aryllead triacetates and 2-aryl-2-(phenylthio)benzopyran-3-ones prepared[a]





$ArPb(OAc)_3$	R^1	R^2	R^3	R^4	R^5	Furanone
6	H	H	H	H	H	**16**
7	OMe	H	H	H	H	**17**
8	H	OMe	H	H	H	**18**
9	H	H	OMe	H	H	**19**
10	H	H	Me	H	H	**20**
11	OMe	H	OMe	H	H	**21**
12	H	OMe	OMe	H	H	**22**
13	OMe	H	H	OMe	H	**23**
14	H	H	OCH_2O		H	**24**
15	OMe	H	OMe	H	OMe	**25**

[a] For the preparation of the organolead reagents, see ref. 11.

N,N,N',N'-tetramethylguanidine (TMG), should facilitate the interaction of the ketone with the lead reagent. Indeed, reaction of **1** with **6** in presence of TMG led to a high yield of the diarylated ketone (84%), whereas only a poor yield of monoarylated ketone was obtained with 1 equiv. of **6**. The more sterically hindered reagent **15** afforded only the monoarylated product in a relatively modest yield (31%). These results showed that arylation of even unactivated ketones could be obtained, if an organic base stronger than pyridine was used.

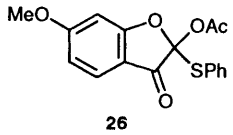
Table 2 Arylation of **1** with the aryllead triacetates **6**, **10** and **15**

$ArPb(OAc)_3$ (equiv.)	Base (equiv.)	*T*/h	Products (%)
6 (2.2)	TMG (2)	1	**3** (84)
6 (1)	TMG (1.1)	6	**3** (21), **1** (71)
6 (2.2)	Pyridine (2)	1	**3** (71)
10 (2.2)	TMG (2)	1	**4** (81)
15 (1.1)	Pyridine (3.3)	0.5	**1** (91)
15 (1.1)	TMG (3.3)	0.5	**5** (31)

Table 3 Reaction of aryllead triacetates with 6-methoxy-2-(phenylthio)benzofuran-3(2*H*)-one **2**

$ArPb(OAc)_3$	*T*/h	Products (%)
6	5	**16** (92)
7	8	**17** (68), **26** (7)
8	10	**18** (82)
9	8	**19** (86)
10	8	**20** (86)
11	10	**21** (31), **26** (45)
12	10	**22** (29)
13	8	**23** (49)
14	8	**24** (66)
15	15	**25** (14), **26** (55)

In view of the synthetic versatility of the homologous α-(arylthio)ketones, we decided to study their reactivity towards aryllead triacetates, since the phenylthio group increases the acidity of an α-CH_2 of a ketone, even if it is only by 3 pK_a units[12] as opposed to the much stronger effect of a β-carbonyl substituent.[13] The benzofuranone **2** was synthesised in three steps from 2-chloro-2′-hydroxy-4′-methoxyacetophenone:[14] thus reaction of the latter with sodium thiophenolate at 0 °C gave 2′-hydroxy-4′-methoxy-2-(phenylthio)acetophenone (73% yield), chlorination of which with *N*-chlorosuccinimide in CCl_4 afforded 2-chloro-2′-hydroxy-4′-methoxy-2-(phenylthio)acetophenone (83%). This, upon cyclisation under basic conditions afforded **2** in nearly quantitative yield (96%). Although aryl sulfides are easily oxidised by lead tetraacetate,[15] the reaction of the β-keto sulfide **2** with variously substituted electron-rich aryllead(IV) triacetate derivatives under the classical arylation reaction conditions [aryllead triacetate (1 equiv.), pyridine (3 equiv.) in anhydrous chloroform at 60 °C][11] gave good results with most arylating agents (Table 3). However, three aryllead(IV) triacetates containing *ortho*-substituents also gave the α-acetoxy product, 2-acetoxy-6-methoxy-2-(phenylthio)benzofuran-3(2*H*)-one **26** as a side-



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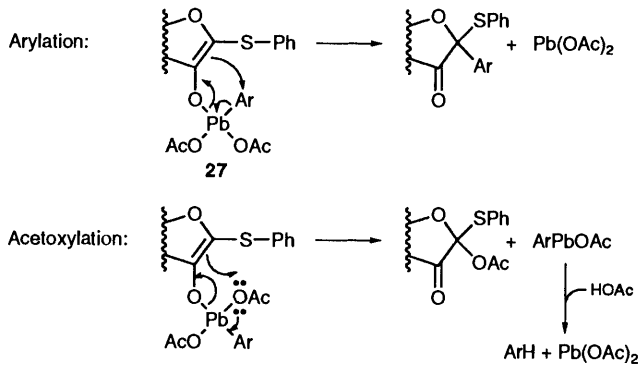
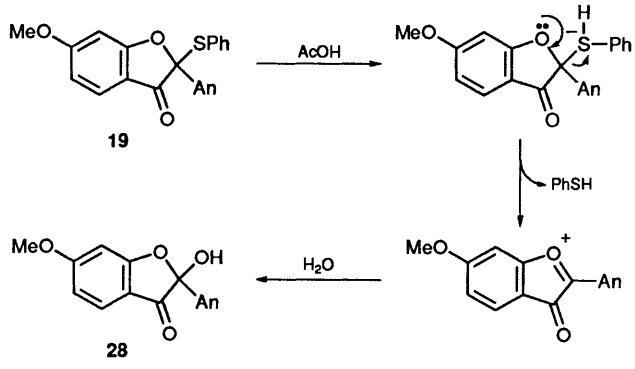
product. With the 2,4,6-trimethoxyphenyl derivative, this α-acetoxy product predominanted (55%). When arylation at the α-position is sterically hindered (due to *ortho*-substituents on the aryl group and the phenylthio moiety) the supposed intermediate **27** must reductively break down by a Wessely-type rearrangement resulting in α-acetoxylation[16] instead of arylation (Scheme 1).

The next step in the synthetic pathway towards 2-arylbenzofurans was removal of the sulfur-containing moiety. Applying the method of desulfurisation used by McKervey *et al.* in the synthesis of aromatic γ-lactones,[17] a mixture of activated zinc and 6-methoxy-2-(4-methoxyphenyl)-2-(phenylthio)ben-



Scheme 1

zofuran-3(2*H*)one **19** in refluxing acetic acid gave a complex crude product which could not be resolved by PLC. However, mass spectral analysis showed the heaviest ion at *m*/*z* 286, indicating the possible formation of 2-hydroxy-6-methoxy-2-(4-methoxyphenyl)benzofuran-3(2*H*)-one **28**. The formation of this compound probably results from acid-catalysed elimination of thiophenol followed by addition of water (present as traces in the medium) on the intermediate oxonium (Scheme 2).*



Scheme 2

As an alternative, W-2[18] and W-5[19] Raney nickel were used. Both these catalysts were used with 6-methoxy-2-(4-methoxyphenyl)-2-(phenylthio)benzofuran-3(2*H*)-one **19** under different reaction conditions, but without any reaction. Nickel boride, recently used as an alternative to Raney nickel, was formed by the reaction of nickel(II) chloride and sodium borohydride in ethanol, after the method of Truce and Roberts;[20] with 6-methoxy-2-(4-methoxyphenyl)-2-(phenylthio)benzofuranone **19** it failed to produce a reaction whether at reflux or at room temperature. Having the sulfur compound present as the nickel boride formed, used by Boar *et al.*,[21] also failed to initiate a reaction.

In conclusion, attempts to arylate the non-activated benzofuran-3(2*H*)-one nucleus met with limited success. In the successful reactions, monoarylation could not be controlled. But the presence of an SPh substitutent as activating/protecting group in the α-position of the benzofuranone allowed facile and high-yielding introduction of the aryl group in the α-position. Although arylation of 6-methoxy-2-(phenylthio)benzofuran-3(2*H*)-one was sensitive to steric effects with α-acetoxylation being a competing reaction, this new reaction of aryllead triacetates should prove useful with other less sterically hindered substrates, in which the removal of the sulfur group could be easier to effect.

* We thank a referee for his comments on the mechanism of formation of this compound.

Experimental

M.p.s were determined with a Reichert-Jung Thermovar apparatus and are uncorrected. ^{1}H NMR spectra were recorded on a JEOL JNM-GX 270FT (^{1}H NMR: 270 MHz, ^{13}C-NMR: 67.80 MHz) spectrometer for solutions in $CDCl_3$ with TMS as internal standard. All *J* values are given in Hz. IR spectra were recorded on a Perkin–Elmer 1710 Infrared FT spectrometer. Mass spectra were recorded with a VG Analytical 770 mass spectrometer with attached INCOS 2400 data system in the EI mode. All solvents and reagents were purified and dried by standard techniques. Chromatographic separations were performed using Merck Kieselgel PF-254 (Preparative TLC) and Merck Kieselgel 60 (Art. 7734 for column chromatography). Ether refers to diethyl ether and ethanol to 95% ethanol. Phenyllead triacetate is commercially available (Alfa) and the other aryllead reagents were prepared as previously described.[11]

2'-Hydroxy-4'-methoxy-2-(phenylthio)acetophenone.—A solution of 2-chloro-2'-hydroxy-4'-methoxyacetophenone[14] (2 g, 0.01 mol) in dry THF (20 cm^3) was added dropwise, over 30 min, to a stirred solution of sodium thiophenolate, prepared from thiophenol (1.21 g, 0.011 mol) and sodium hydride (80% suspension in oil; 0.33 g, 0.011 mol) in dry THF (20 cm^3) under argon. The reaction mixture was stirred at room temperature for 10 min, filtered through Celite and the solid washed with ether. The filtrate was washed with water (2 × 50 cm^3), dried (Na_2SO_4) and concentrated to yield a pale yellow viscous oil which crystallised from pentane to give a yellow solid (2 g, 73%), m.p. 42–44 °C; δ_H 3.82 (3 H, s, OCH_3), 4.17 (2 H, s, 2-H), 6.41 (1 H, dd, *J* 6.96 and 2.56, 5'-H), 6.42 (1 H, d, *J* 2.56, 3'-H), 7.23–7.32 (3 H, m, 2''-H, 4''-H, 6''-H), 7.39–7.42 (2 H, m, 3''-H, 5''-H), 7.57 (1 H, d, *J* 6.96, 6'-H) and 12 (1 H, s, ex. D_2O, OH); δ_C 40.76 (C-2), 55.62 (OCH_3), 101.08 (C-3'), 107.94 (C-5'), 112.24 (C-1'), 127.38 (C-4''), 129.06 (C-2'', 6''), 130.88 (C-3'', 5''), 131.9 (C-6'), 134.53 (C-1''), 165.98 (C-4'), 166.47 (C-2') and 198.26 (C-1).

2-Chloro-2'-hydroxy-4'-methoxy-2-(phenylthio)acetophenone.—*N*-Chlorosuccinimide (1.024 g, 7.67 mmol) was added to a solution of 2'-hydroxy-4'-methoxy-2-(phenylthio)acetophenone (2 g, 7.3 mmol) in dry carbon tetrachloride (20 cm^3) under argon in one portion. The mixture was stirred at room temperature for 2 h and then filtered and washed thoroughly with carbon tetrachloride. The filtrate was concentrated to leave a yellow oil which crystallised from pentane to give a yellow solid (1.88 g, 83%), m.p. 49–50.5 °C; ν_{max}(KBr)/cm^{-1} 1713 and 1694; δ_H 3.86 (3 H, s, OCH_3), 6.33 (1 H, s, 2-H), 6.46–6.50 (2 H, m, 3'-H, 5'-H), 7.35–7.43 (3 H, m, 2''-H, 4''-H, 6''-H), 7.56–7.60 (2 H, m, 3''-H, 5''-H) and 7.75 (1 H, dd, *J* 8.06 and 1.1, 6'-H); δ_C 55.74 (OCH_3), 68.71 (C-2), 101.25 (C-3'), 108.48 (C-5'), 109.54 (C-1'), 129.44 (C-2'', 6''), 129.69 (C-4''), 130.66 (C-1''), 131.73 (C-6'), 134.06 (C-3'', 5''), 166.90 (C-4')*, 167.10 (C-2')* and 191.65 (C-1) [* signals may be reversed]; *m/z* 308 (M^+, 4%), 272 (22), 245 (7) and 151 (100).

6-Methoxy-2-phenylthiobenzofuran-3(2H)-one **2**.—A solution of 2-chloro-2'-hydroxy-4'-methoxy-2-(phenylthio)acetophenone (1.61 g, 5.22 mmol) and *N,N,N',N'*-tetramethylguanidine (2.9 g, 16.8 mmol) in dry chloroform (125 cm^3) was stirred at room temperature for 30 min. The reaction mixture was washed with dilute HCl (100 cm^3) and then water (2 × 100 cm^3). The organic layer was dried (Na_2SO_4) and evaporated to yield a viscous oil which solidified with time to give a pale yellow solid (1.36 g, 96%) which was recrystallised from alcohol (95%), m.p. 85.5–88 °C; ν_{max}(KBr)/cm^{-1} 1731, 1276 and 1014; δ_H 3.86 (3 H, s, OCH_3), 5.83 (1 H, s, 2-H), 6.51 (1 H, d, *J* 2.2, 7-H), 6.58 (1 H, dd, *J* 8.43 and 2.2, 5-H), 7.23–7.28 (3 H, m, 2'-H, 4'-H, 6'-H), 7.45 (1 H, d, *J* 8.43, 4-H) and 7.55–7.59 (2 H, m, 3'-H, 5'-H); δ_C 55.96 (OCH_3), 89.86 (C-2), 96.24 (C-7), 112.05 (C-5), 113.45 (C-9), 125.64 (C-4'), 128.79 (C-4), 128.99 (C-2', 6'), 130.28 (C-1'), 133.68 (C-3', 5'), 168.74 (C-8), 174.28 (C-6) and 193.20 (C-3); *m/z* 272 (M^+, 92%), 163 (100) and 135 (69).

Arylation of 6-methoxybenzofuran-3(2H)-one

With Phenyllead Triacetate.—(a) *With* 2.2 *equiv. of* **6**. A mixture of 6-methoxybenzofuran-3(2*H*)-one **1**[14] (0.098 g, 0.6 mmol), TMG (0.138 g, 1.2 mmol) and phenyllead triacetate (0.608 g, 1.32 mmol) in dry chloroform (1 cm^3) was stirred at 60 °C for 1 h. Dichloromethane (70 cm^3) was added to the mixture which was then washed with 3 mol dm^{-3} sulfuric acid (50 cm^3). The aqueous layer was extracted with dichloromethane (3 × 50 cm^3) and the combined extracts were dried ($MgSO_4$) and evaporated to give 6-methoxy-2,2-diphenylbenzofuran-3(2*H*)-one **3** (0.159 g, 84%) as fine needles, after recrystallisation from methanol–acetone, m.p. 137–139 °C (Found: C, 79.4; H, 5.1. $C_{21}H_{16}O_3$ requires C, 79.75; H, 5.05%); ν_{max}(KBr)/cm^{-1} 1713, 1691 and 1610; δ_H 3.86 (3 H, s, OCH_3), 6.59–6.69 (2 H, m, 5-H, 7-H) and 7.28–7.65 (11 H, m, 4-H and Ph); *m/z* 316 (M^+, 100%), 287 (76), 239 (18), 211 (25), 165 (34), 134 (48) and 106 (15).

(b) *With* 1.1 *equiv. of* **6**. A similar reaction was performed with TMG (0.069 g, 0.6 mmol) and phenyllead triacetate (0.304 g, 0.66 mol) with a 6 h reaction time. Distillation of the solvent gave a yellow oil which was purified by column chromatography on silica (eluent: ether–hexane, 1 : 1) to give **3** (0.04 g, 21%) and **1** (0.07 g, 71%).

(c) *With* 2.2 *equiv. of* **6** *and pyridine*. The reaction was identical with experiment (a) except that pyridine (0.095 g, 1.2 mmol) was used instead of TMG and afforded **3** (0.135 g, 71%).

With 4-Methylphenyllead Triacetate **10**.—A mixture of **1** (0.098 g, 0.6 mmol), TMG (0.138 g, 1.2 mmol) and **10** (0.628 g, 1.32 mmol) in dry chloroform (1 cm^3) was treated as in experiment (a) above, to give 2,2-bis(4'-methylphenyl)-6-methoxybenzofuran-3(2*H*)-one **4** (0.167 g, 81%), as a solid, after crystallisation from methanol–acetone, m.p. 111–114 °C (Found: C, 80.2; H, 5.95. $C_{23}H_{20}O_3$ requires C, 80.25; H, 5.8%; ν_{max}(KBr)/cm^{-1} 1712 and 1494; δ_H 2.31 (6 H, s, 2 × Ar-CH_3), 3.87 (3 H, s, OCH_3), 6.62–6.66 (2 H, m, 5-H, 7-H), 7.13 (4 H, d, *J* 8.06, 3'-H, 5'-H). 7.38 (4 H, d, *J* 8.24, 2'-H, 6'-H) and 7.58 (1 H, d, *J* 9.14, 4-H); δ_C 21.10 (Ar-CH_3), 55.87 (OCH_3), 96.06 (C-7), 111.93 (C-5), 113.29 (C-9), 118.81 (C-2), 126.27 (C-4), 126.75 (C-3', 5'), 129.09 (C-2', 6'), 135.73 (C-1'), 138.17 (C-4'), 168.70 (C-8), 173.84 (C-6) and 197.60 (C-3); *m/z* 344 (M^+, 100%), 315 (43), 301 (98), 253 (29), 225 (38), 179 (45), 134 (37), 119 (28), 10 (26), 91 (24) and 63 (22).

With 2,4,6-Trimethoxyphenyllead Triacetate.—A mixture of **1** (0.098 g, 0.6 mmol), 2,4,6-trimethoxyphenyllead triacetate (0.363 g, 0.66 mmol) and TMG (0.228 g, 1.98 mmol) in dry chloroform (1 cm^3) was heated at 60 °C for 30 min. The reaction mixture was diluted with dichloromethane (70 cm^3) and washed with 3 mol dm^{-3} sulfuric acid (50 cm^3). The aqueous layer was extracted with dichloromethane (3 × 50 cm^3) and the combined extracts were washed with 3 mol dm^{-3} sulfuric acid (50 cm^3), dried ($MgSO_4$) and evaporated. PLC of the residue [eluant: ether–hexane, 4 : 1] gave 6-methoxy-2-(2,4,6-trimethoxyphenyl)benzofuran-3(2*H*)-one **5** (0.06 g, 31%) as a solid, m.p. 133–135 °C; ν_{max}(KBr)/cm^{-1} 1724 and 1608; δ_H 3.46 (3 H, br s, 2'-OCH_3), 3.79 (3 H, s, 4'-OCH_3), 3.86 (3 H, br s, 6'-OCH_3), 3.86 (3 H, s, 6-OCH_3), 5.96 (1 H, s, 2-H), 6.06–6.17 (2 H, br m, 3'-H, 5'-H), 6.51 (1 H, d, *J* 2.02, 7-H), 6.62 (1 H, dd, *J* 2.2 and 8.61, 5-H) and 7.61 (1 H, d, *J* 8.61, 4-H); δ_C 55.41 (4'-OCH_3), 55.57 (2'-OCH_3), 55.71 (6'-OCH_3), 56.09 (6-OCH_3), 79.8 (C-2), 90.9, 91.13, 91.36, 91.43 (C-3', 5'), 96.01 (C-7),

103.89 (C-9), 110.44 (C-5), 115.23 (C-1'), 124.77 (C-4), 160.77 (C-2', 6'), 162.85 (C-4'), 167.53 (C-8), 174.2 (C-6) and 199.76 (C-3); *m/z* 330 (M^+, 78%), 315 (21), 272 (17), 271 (100), 256 (16), 195 (45), 179 (15), 165 (27), 151 (21), 121 (18), 106 (23), 79 (18), 77 (17), 69 (22), 63 (39) and 51 (17).

Arylation of 6-*Methoxy*-2-(*phenylthio*)*benzofuran*-3(2H)-*one*

General Procedure.—The aryllead(IV) triacetate (1.1 equiv.) was added to a stirred solution of 6-methoxy-2-(phenylthio)-benzofuran-3(2*H*)-one (1 equiv.) and dry pyridine (3.3 equiv.) in dry chloroform (1 cm^3 per 0.6 mmol of substrate) and the mixture stirred at 60 °C for the time indicated in Table 2. After this, the reaction mixture was diluted with chloroform (100 cm^3) and washed with 3 mol dm^{-3} sulfuric acid (50 cm^3). The aqueous layer was extracted with chloroform (3 × 50 cm^3) and the combined extracts were washed with 3 mol dm^{-3} sulfuric acid. The remaining aqueous layer was extracted with chloroform (2 × 50 cm^3). All the chloroform layers were combined, filtered through Celite, dried ($MgSO_4$) and evaporated and the residue was purified as indicated.

6-*Methoxy*-2-*phenyl*-2-(*phenylthio*)*benzofuran*-3(2H)-*one* **16**. (TLC; ether–hexane, 3:1), plates from ethanol, m.p. 87–89.5 °C (Found: C, 71.2; H, 4.85; S, 9.35. $C_{20}H_{16}O_3S$ requires C, 71.45; H, 4.75; S, 9.5%); ν_{max}(KBr)/cm^{-1} 1714 and 1275; δ_H 3.84 (3 H, s, OCH_3), 6.47–6.55 (2 H, m, 5-H, 7-H), 7.09–7.38 (8 H, m, 2″-H, 4″-H, 6″-H, Ph), 7.48–7.52 (2 H, dt, 3″-H, 5″-H) and 7.8 (1 H, dd, *J* 1.1 and 8.05, 4-H); δ_C 55.92 (OCH_3), 95.70 (C-7), 97.82 (C-2), 111.85 (C-5), 112.70 (C-9), 125.89 (C-2″, 6″), 126 (C-4″), 128.36 (C-3', 5'), 128.62 (C-2', 6'), 128.79 (C-4'), 129.52 (C-4), 130.89 (C-1'), 134.96 (C-1″), 136.52 (C-3″, 5″), 168.55 (C-8), 172.64 (C-6) and 193.74 (C-3); *m/z* 348 (M^+, 1%), 239 (100), 149 (36) and 77 (29).

6-*Methoxy*-2-(2-*methoxyphenyl*)-2-(*phenylthio*)*benzofuran*-3(2H)-*one* **17**. (TLC; ether–hexane 7:2), plates from ethanol, m.p. 161.5–164 °C (Found: C, 69.55; H, 4.6; S, 8.35. $C_{22}H_{18}O_4S$ requires C, 69.85; H, 4.75; S, 8.45%); ν_{max}(KBr)/cm^{-1} 1712 and 1272; δ_H 3.47 (3 H, s, 2'-OCH_3), 3.79 (3 H, s, 6-OCH_3), 6.30 (1 H, d, *J* 2.2, 7-H), 6.41 (1 H, dd, *J* 2.2, 8.43, 5-H), 6.86 (1 H, d, *J* 8.06, 3'-H), 7.02–7.19 (4 H, m, 5'-H, 2″-H, 4″-H, 6″-H), 7.26–7.41 (2 H, m, 3″-H, 5″-H), 7.49–7.52 (2 H, m, 4-H, 4'-H) and 7.99 (1 H, dd, *J* 1.47, 7.7, 6'-H); δ_C 55.65 (2'-OCH_3), 55.69 (6-OCH_3), 95.30 (C-7), 96.24 (C-2), 110.34 (C-5), 112.18 (C-3'), 114.85 (C-9), 120.85 (C-5'), 123.76 (C-1'), 124.85 (C-4″), 128.27 (C-2″, 6″), 129.34 (C-4), 129.67 (C-4'), 131.29 (C-6'), 136.9 (C-3″, 5″), 157.16 (C-2'), 167.46 (C-8), 172.02 (C-6) and 195.81 (C-3); *m/z* 378 (M^+, < 1%), 270 (17), 269 (100), 239 (18), 213 (24), 211 (41), 151 (28), 133 (26), 109 (22), 77 (42) and 63 (38).

6-*Methoxy*-2-(3-*methoxyphenyl*)-2-(*phenylthio*)*benzofuran*-3(2H)-*one* **18**. (TLC; ether–hexane 3:1), plates from ethanol, m.p. 102–104 °C (Found: C, 69.55; H, 4.7; S, 8.6. $C_{22}H_{18}O_4S$ requires C, 69.85; H, 4.75; S, 8.45%); ν_{max}(KBr)/cm^{-1} 1714 and 1272; δ_H 3.81 (3 H, s, 3'-OCH_3), 3.85 (3 H, s, 6-OCH_3), 6.49 (1 H, dd, *J* 2.2, 8.4, 5-H), 6.54 (1 H, d, *J* 2.2, 7-H), 6.83–6.87 (1 H, m, 4'-H), 7.10–7.41 (7 H, m, 4-H, 2'-H, 5'-H, 6'-H, 2″-H, 4″-H, 6″-H) and 7.5 (2 H, dd, *J* 1.47, 8.06, 3″-H, 5″-H); δ_C 55.35 (3'-OCH_3), 55.92 (6-OCH_3), 95.68 (C-7), 97.61 (C-2), 111.33 (C-5), 111.85 (C-4'), 112.67 (C-9), 114.66 (C-2'), 118.19 (C-6'), 126 (C-4″), 127.13 (C-1″), 127.41 (C-1'), 128.49 (C-2″, 6″), 129.38 (C-4)*, 129.53 (C-5')*, 136.35 (C-3″, 5″), 159.46 (C-3'), 168.54 (C-8), 172.6 (C-6), 193.61 (C-3); * Signals may be reversed; *m/z* 378 (M^+, 2%), 271 (8), 270 (40), 269 (100), 211 (9), 135 (10) and 110 (9).

6-*Methoxy*-2-(4-*methoxyphenyl*)-2-(*phenylthio*)*benzofuran*-3(2H)-*one* **19**. (TLC; ether–hexane 3:1), plates from ethanol, m.p. 132.5–134 °C (Found: C, 70.15; H, 4.85; S, 8.5. $C_{22}H_{18}O_4S$ requires C, 69.85; H, 4.75; S, 8.45%); ν_{max}(KBr)/cm^{-1} 1716 and 1276; δ_H 3.78 (3 H, s, 4'-OCH_3), 3.84 (3 H, s, 6-OCH_3), 6.48 (1 H, dd, *J* 2.2, *J* 8.61, 5-H), 6.53 (1 H, d, *J* 1.83, 7-H), 6.87 (2 H, d, *J* 8.98, 3'-H, 5'-H), 7.09–7.19 (3 H, m, 2″-H, 4″-H, 6″-H), 7.33 (1 H, d, *J* 8.61, 4-H), 7.49 (2 H, dd, *J* 1.61, 7.97, 3″-H, 5″-H) and 7.72 (2 H, d, *J* 9.16, 2'-H, 6'-H); δ_C 55.28 (4'-OCH_3), 55.9 (6-OCH_3), 95.73 (C-7), 97.86 (C-2), 111.71 (C-5), 112.88 (C-9), 113.78 (C-3', 5'), 126 (C-4″), 126.99 (C-1'), 127.37 (C-2″, 6″), 128.47 (C-2', 6'), 129.38 (C-1″), 129.44 (C-4), 136.32 (C-3″, 5″), 160 (C-4'), 168.54 (C-8), 172.57 (C-6) and 193.99 (C-3); *m/z* 378 (M^+, 1%), 270 (27), 269 (100), 135 (20) and 28 (22).

6-*Methoxy*-2-(4-*methylphenyl*)-2-(*phenylthio*)*benzofuran*-3(2H)-*one* **20**. (TLC; ether–hexane, 3:1), plates from ethanol, m.p. 112–115 °C (Found: C, 72.6; H, 5.0; S, 8.8. $C_{22}H_{18}O_3S$ requires C, 72.95; H, 4.95; S, 8.85%); ν_{max}(KBr)/cm^{-1} 1716 and 1275; δ_H 2.32 (3 H, s, Ar-CH_3), 3.84 (3 H, s, OCH_3), 6.48 (1 H, dd, *J* 2.02, 8.61, 5-H), 6.53 (1 H, d, *J* 2.01, 7-H), 7.09–7.34 (5 H, m, 3'-H, 5'-H, 2″-H, 4″-H, 6″-H), 7.33 (1 H, d, *J* 8.61, 4-H), 7.48–7.52 (2 H, m, 3″-H, 5″-H) and 7.68 (2 H, d, *J* 8.34, 2'-H, 6'-H); δ_C 21.15 (Ar-CH_3), 55.9 (OCH_3), 95.71 (C-7), 98.16 (C-2), 111.75 (C-5), 112.83 (C-9), 125.83 (C-3', 5'), 126.04 (C-4″), 127.52 (C-1'), 128.47 (C-2', 6'), 129.11 (C-2″, 6″), 129.45 (C-4), 131.98 (C-1″), 136.33 (C-3″, 5″), 138.79 (C-4'), 168.59 (C-8), 172.70 (C-6) and 194.34 (C-3); *m/z* 362 (M^+, 1%), 271 (6), 255 (6), 254 (41), 253 (100), 239 (8), 225 (10), 211 (12), 134 (12), 119 (16), 110 (15), 91 (17) and 28 (43).

2-(2,4-*Dimethoxyphenyl*)-6-*methoxy*-2-(*phenylthio*)*benzofuran*-3(2H)-*one* **21**. (TLC; ether–hexane, 4:1), plates from ethanol, m.p. 100–102 °C (Found: C, 67.35; H, 5.1; S, 7.75. $C_{23}H_{20}O_5S$ requires C, 67.65; H, 4.9; S, 7.85%); ν_{max}(KBr)/cm^{-1} 1708 and 1271; δ_H 3.46 (3 H, s, 2'-OCH_3), 3.78 (3 H, s, 4'-OCH_3), 3.80 (3 H, s, 6-OCH_3), 6.28 (1 H, d, *J* 2.02, 3'-H), 6.39–6.42 (2 H, m, 5-H, 7-H), 6.55 (1-H, dd, *J* 2.47, 8.70, 5'-H), 7.06–7.16 (3 H, m, 2″-H, 4″-H, 6″-H), 7.31 (1 H, d, *J* 8.61, 4-H), 7.47–7.5 (2 H, m, 3″-H, 5″-H) and 7.89 (1 H, d, *J* 8.61, 6'-H); δ_C 55.47 (4'-OCH_3), 55.65 (2'-OCH_3), 55.73 (6-OCH_3), 95.41 (C-7), 96.36 (C-2), 99.79 (C-3'), 104.89 (C-5'), 110.33 (C-5), 114.95 (C-9), 116.36 (C-1'), 124.95 (C-4″), 127.79 (C-1″), 128.28 (C-2″, 6″), 129.29 (C-4), 130.69 (C-6'), 136.87 (C-3″, 5″), 158.48 (C-2'), 162.31 (C-4'), 167.53 (C-8), 172.02 (C-6) and 195.97 (C-3); *m/z* 408 (M^+, < 1%), 300 (24), 299 (100), 285 (10), 269 (13), 241 (28), 163 (11), 151 (25), 109 (18) and 28 (19).

2-(3,4-*Dimethoxyphenyl*)-6-*methoxy*-2-(*phenylthio*)*benzofuran*-3(2H)-*one* **22**. (TLC; ether–hexane 4:1), plates from ethanol, m.p. 113.5–115 °C (Found: C, 67.45; H, 5.0; S, 7.75. $C_{23}H_{20}O_5S$ requires C, 67.65; H, 4.9; S, 7.85%); ν_{max}(KBr)/cm^{-1} 1716 and 1274; δ_H 3.92 (3 H, s, 4'-OCH_3), 3.95 (3 H, s, 3'-OCH_3), 3.96 (3 H, s, 6-OCH_3), 6.5 (1 H, d, *J* 2.38, 7-H), 6.53 (1 H, dd, *J* 2.11, 8.52, 5-H), 6.81 (1 H, d, *J* 8.42, 5'-H), 7.13–7.37 (6 H, m, 4-H, 2'-H, 6'-H, 2″-H, 4″-H, 6″-H) and 7.47–7.51 (2 H, m, 3″-H, 5″-H); δ_C 55.79 (4'-OCH_3), 55.87 (3'-OCH_3), 55.93 (6-OCH_3), 95.60 (C-7), 97.88 (C-2), 101.14 (C-5'), 108.76 (C-2'), 111.79 (C-5), 112.83 (C-9), 118.49 (C-6'), 126.61 (C-4″), 127.24 (C-1″), 128.39 (C-2″, 6″), 128.98 (C-1'), 129.52 (C-4), 136.35 (C-3″, 5″), 166.47 (C-4'), 167.51 (C-3'), 168.59 (C-8), 172.53 (C-6) and 194.24 (C-3); *m/z* 408 (M^+, < 1%), 344 (4), 300 (22), 299 (100), 269 (9), 165 (23), 109 (11), 77 (8), 63 (9) and 28 (17).

2-(2,5-*Dimethoxyphenyl*)-6-*methoxy*-2-(*phenylthio*)*benzofuran*-3(2H)-*one* **23**. (TLC; ether–hexane, 4:1), plates from ethanol, m.p. 150–152 °C (Found: C, 67.6; H, 5.0; S, 7.75. $C_{23}H_{20}O_5S$ requires C, 67.65; H, 4.9; S, 7.85%); ν_{max}(KBr)/cm^{-1} 1712 and 1272; δ_H 3.43 (3 H, s, 2'-OCH_3), 3.79 (3 H, s, 5'-OCH_3), 3.81 (3 H, s, 6-OCH_3), 6.30 (1 H, d, *J* 2.01, 7-H), 6.42 (1 H, dd, *J* 2.01, 8.52, 5-H), 6.81 (1 H, d, *J* 8.98, 3'-H), 6.90 (1 H, dd, *J* 2.93, 8.97, 4'-H), 7.07–7.2 (3 H, m, 2″-H, 4″-H, 6″-H), 7.32 (1 H, d, *J* 8.61, 4-H), 7.49–7.53 (2 H, m, 3″-H, 5″-H) and 7.59 (1 H, d, *J* 2.93, 6'-H); δ_C 55.76 (2'-OCH_3), 55.92 (6-OCH_3), 56.9 (5'-OCH_3), 95.48 (C-7), 96.06 (C-2), 110.49 (C-5), 114.13 (C-3'), 114.9 (C-9), 115.58 (C-4'), 116.32 (C-6'), 124.95 (C-4″), 125.05 (C-1'), 127.6 (C-1″), 128.36 (C-2″, 6″), 129.42 (C-4), 136.92 (C-3″, 5″),

151.55 (C-2'), 153.77 (C-5'), 167.57 (C-8), 172 (C-6) and 195.6 (C-3); *m/z* 408 (M^+, 3%), 301 (20), 300 (100), 299 (96), 285 (97), 269 (34), 241 (40), 198 (15), 163 (26), 149 (30), 110 (42), 57 (28) and 43 (30).

6-*Methoxy*-2-(3,4-*methylenedioxyphenyl*)-2-(*phenylthio*)-*benzofuran*-3(2H)-*one* **24**. (TLC; ether–hexane, 4:1), plates from ethanol, m.p. 108–110 °C (Found: C, 67.15; H, 4.1; S, 8.15. $C_{22}H_{16}O_5S$ requires C, 67.35; H, 4.1; S, 8.15%); ν_{max}(KBr)/cm^{-1} 1717 and 1275; δ_H 3.86 (3 H, s, OCH_3), 5.95 (3 H, s, OCH_2O), 6.48 (1 H, d, *J* 2.2, 7-H); 6.52 (1 H, dd, *J* 1.92, 4.12, 5-H), 6.76 (1 H, d, *J* 8.21, 5'-H), 7.1–7.36 (6 H, m, 4-H, 2'-H, 6'-H, 2″-H, 4″-H, 6″-H) and 7.48–7.51 (2 H, m, 3″-H, 5″-H); δ_C 55.95 (OCH_3), 95.73 (C-7), 97.77 (C-2), 101.33 (OCH_2O), 106.9 (C-5'), 108.04 (C-2'), 111.88 (C-5), 112.75 (C-9), 119.87 (C-6'), 125.8 (C-1″), 126.1 (C-4″), 127.56 (C-1'), 128.25 (C-2″, 6″), 129.53 (C-4), 136.35 (C-3″, 5″), 147.77 (C-4'), 148.1 (C-3'), 168.65 (C-8), 172.56 (C-6), 193.83 (C-3); *m/z* 392 (M^+, 1%), 284 (10), 283 (100), 271 (9), 253 (9), 238 (7), 225 (8), 149 (18), 119 (20), 109 (19) and 63 (31).

6-*Methoxy*-2-(*phenylthio*)-2-(2,4,6-*trimethoxyphenyl*)*benzofuran*-3(2H)-*one* **25**. (TLC; ether–hexane, 3:1), plates from ethanol, m.p. 193.5–195.5 °C (Found: C, 65.7; H, 5.1; S, 7.25. $C_{24}H_{22}O_6S$ requires C, 65.75; H, 5.0; S, 7.3%); ν_{max}(KBr)/cm^{-1} 1716 and 1274; δ_H 3.66 (6 H, s, 2', 6'-OCH_3), 3.79 (6 H, s, 6, 4'-OCH_3), 6.13 (2 H, m, 3'-H, 5'-H), 6.26 (1 H, dd, *J* 2.2, 8.43, 5-H), 6.33 (1 H, d, *J* 2.02, 7-H), 6.96–7.08 (5 H, m, Ph) and 7.44 (1 H, dd, *J* 1.37, 8.15, 4-H); δ_C 55.47 (4'-OCH_3), 55.68 (2', 6'-OCH_3), 55.87 (6-OCH_3), 92.69 (C-3', 5'), 95.18 (C-7), 109.54 (C-5), 116.36 (C-9), 124.33 (C-4″), 127.87 (C-2″, 6″), 129.11 (C-4), 129.77 (C-1″), 137.55 (C-3″, 5″), 160.57 (C-2', 6'), 162.39 (C-4'), 167.27 (C-8), 171.82 (C-6) and 196.06 (C-3); *m/z* 438 (M^+, < 1%), 329 (100), 271 (43), 256 (14), 193 (14), 151 (10) and 109 (14).

2-*Acetoxy*-6-*methoxy*-2-(*phenylthio*)*benzofuran*-3(2H)-*one* **26**. Plates from ethanol, m.p. 108–109 °C (Found: C, 61.85; H, 4.35; S, 9.65. $C_{17}H_{14}O_5S$ requires C, 61.8; H, 4.25; S, 9.7%); ν_{max}(KBr)/cm^{-1} 1748 and 1729; δ_H 2.12 (3 H, s, 2″-CH_3), 3.83 (3 H, s, OCH_3), 6.40 (1 H, d, *J* 2.2, 7-H), 6.01 (1 H, dd, *J* 2.2, 8.6, 5-H), 7.25–7.39 (3 H, m, 2'-H, 4'-H, 6'-H), 7.52 (1 H, d, *J* 8.61, 4-H) and 7.59–7.62 (2 H, m, 3'-H, 5'-H); δ_C 20.42 (C-2″), 55.95 (OCH_3), 91.63 (C-2), 96.24 (C-7), 111.74 (C-5), 112.94 (C-9), 125.99 (C-1'), 126.15 (C-4'), 128.74 (C-2', 6'), 130.12 (C-4), 137.06 (C-3', 5'), 167.43 (C-8), 168.32 (C-6), 169.58 (C-1″) and 188.96 (C-3); *m/z* 330 (M^+, < 1%), 271 (3), 221 (22), 180 (11), 179 (100), 151 (46), 110 (36), 108 (29) and 43 (99).

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