# Aryllead Triacetates as Synthons for the Synthesis of Biflavonoids. Part 2.† Synthesis of a *Garcinia*-Type Biflavonoid

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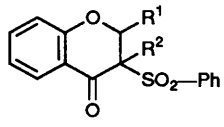
Arylation of 3-(phenylsulfonyl)chroman-4-one **1** with simple aryllead triacetates affords the corresponding 3-aryl-3-(phenylsulfonyl)chroman-4-one in 64–74% yield. However, no reaction took place with the hindered 2,4,6-trimethoxyphenyllead triacetate **9**. Reaction of the 8-triacetoxyplumbylflavane derivative **10** with 4'-methoxy-3-(phenylsulfanyl)flavanone **11** afforded the biflavanone **12** in 64% yield. Nickel boride reduction of compound **12** led to the chalcone **13**, which was recyclised to the Garcinia-type (I-3, II-8) biflavanone **14**. Dimethyldioxirane oxidation of **12** gave the flavone-flavanone **15**.

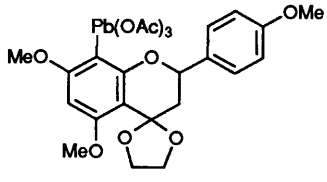
In the preceding paper, we have shown that activation of flavan-4-one as its β-keto ester derivative to allow C-3 arylation cannot be obtained. The sulfone group appears as an attractive alternative for an activating group with electron-withdrawing properties similar to an ester group.[1] Among the known methods for the preparation of β-keto sulfones, a very useful one is the oxidation of sulfides, a group which can be introduced either by nucleophilic or electrophilic reagents. Moreover a variety of methods are available for their selective removal when required. As an example, the phenylation of 3-(phenylsulfonyl)-chroman-4-ones by triphenylbismuth carbonate has recently been described and the mild selective deprotection of the C(3)-phenyl derivatives led to the corresponding flavanones or flavones.[2] We therefore decided to study the arylation of this type of β-keto sulfone by aryllead triacetates, a reaction which had not been previously reported. 3-(Phenylsulfonyl)chroman-4-one **1** was easily prepared by either oxone ($2KHSO_5 \cdot KHSO_4 \cdot K_2SO_4$)[3] or dimethyldioxirane[4] oxidation of 3-(phenylsulfanyl)chroman-4-one.[5] It reacted with aryllead triacetates **2**–**4** under classical arylation conditions (substrate, 1 mol equiv.; aryllead triacetate, 1.3 mol equiv.; pyridine, 3.3 mol equiv.; 60 °C; 8 h) to afford the corresponding 3-aryl-3-(phenylsulfonyl)chroman-4-ones **5**–**7** in good yield.‡ However, 4'-methoxy-3-(phenylsulfonyl)flavanone **8**, prepared in 96% yield from the corresponding 3-phenylsulfanyl derivative by Patonay's procedure,[7] failed to react with 2,4,6-trimethoxyphenyllead triacetate **9** under the usual reaction conditions. The lack of reactivity of this sulfone is attributed to steric crowding. Since the flavanonyllead triacetate derivative **10** required for the biflavanone synthesis is more hindered than compound **9**, it was decided to abandon the sulfone approach to flavanone activation.

In a recent paper,[5] we have reported that 4'-methoxy-3-(phenylsulfanyl)flavanone **11** reacts with various substituted monoaryllead triacetates in high to quantitative yields. Removal of the activating phenylsulfanyl group led, by reduction with a large excess of nickel boride, to the corresponding 3-aryl-4'-methoxyflavanones and, by oxidation



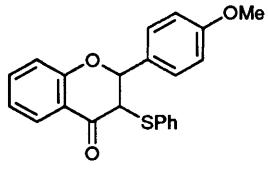

**1** $R^1 = H$, $R^2 = H$
**5** $R^1 = H$, $R^2 = Ph$
**6** $R^1 = H$, $R^2 = 4\text{-}MeC_6H_4$
**7** $R^1 = H$, $R^2 = 2,4\text{-}(MeO)_2C_6H_3$
**8** $R^1 = 4\text{-}MeOC_6H_4$, $R^2 = H$

**2** $PhPb(OAc)_3$
**3** $4\text{-}MeC_6H_4Pb(OAc)_3$
**4** $2,4\text{-}(MeO)_2C_6H_3Pb(OAc)_3$
**9** $2,4,6\text{-}(MeO)_3C_6H_2Pb(OAc)_3$




**10**

with dimethyldioxirane, to the 3-aryl-4'-methoxyflavones. In the preceding paper, we have shown that the 4',5,7-trimethoxy-8-(triacetoxyplumbyl)flavanone ethylene ketal **10** is capable of




**11**

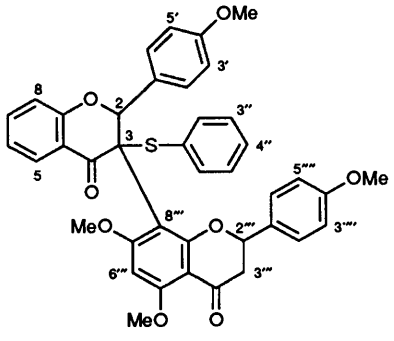
arylating a hindered enolisable substrate in good yield.[8] Therefore, having found two suitable flavanone moieties it was decided to apply this methodology to the synthesis of *Garcinia* biflavonoids.

4',5,7-Trimethoxy-8-(triacetoxyplumbyl)flavanone ethylene ketal **10** was stirred with a 2:1 mixture of *cis*- and *trans*-4'-methoxy-3-(phenylsulfanyl)flavanone **11** and dry pyridine in dry chloroform at 60 °C for 4 h. 4'-Methoxy-3-(phenylsulfanyl)-

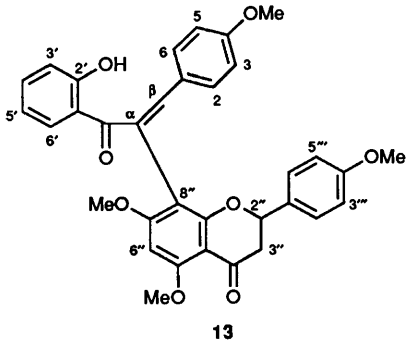
† Part 1 is reference 8.

‡ In parallel to our work, Santhosh and Balasubramanian have extended their investigations on the chemistry of 3-(phenylsulfonyl)-chroman-4-ones[2,6] to the study of their arylation with aryllead triacetates. We thank them for informing us of their results, published in preliminary form at the 14th International Congress of Heterocyclic Chemistry, Antwerp, Belgium, August 1993.

flavanone-(I-3, II-8)-4′,5,7-trimethoxyflavanone **12** was formed in 64% yield, as the dioxolane ring cleaved during the acid work-up, thus saving a step in the synthesis. The biflavanone **12** has three chiral centres and so a possible maximum number of four pairs of diastereoisomers could have formed. In fact, only a mixture of two diastereoisomers was detected (*a*/*b* 1.4:1), which is consistent with our previous findings that the arylation of 4′-methoxy-3-(phenylsulfanyl)flavanone is stereospecific at carbon C-3.[5] No atropisomerism was detected but $^1$H–$^1$H correlation spectra were required to assign the chemical shifts of all the protons of the two diastereoisomers. The $^1$H NMR spectrum of compound **12** presents some unusual features. 6-H and 8-H usually have similar chemical shifts and are found together under the same multiplet. However, in the case of compound **12**, 8-H is found as part of a multiplet between $\delta$ 7.5 and 7.19 together with 7-H, 2‴-H and 6‴-H, whereas 6-H is found as a distorted double double doublet at $\delta$ 6.36. A through-space interaction between 6-H and the methoxyphenyl ring of flavanone II causes a significant shielding of that proton. 2‴*b*-H is also shifted approximately 1 ppm upfield as it appears as a double doublet at $\delta$ 4.16 whereas 2‴*a*-H appears as a double doublet at $\delta$ 5.18. Again a through-space non-bonding interaction can be invoked to explain this phenomenon. One of the methoxy groups of diastereoisomer *a*, presumably the 7‴-methoxy, resonates upfield at $\delta$ 3.23 and is thus shielded considerably compared with the others. This methoxy group is considered to be also involved in a through-space interaction with the carbonyl oxygen. In the $^{13}$C NMR spectrum of compound **12**, only very small differences (< 1 ppm) exist between the chemical shifts of most of the corresponding carbons of the two diastereoisomers *a* and *b*. However, three carbons display a notable difference in chemical shift: for the *b* isomer, C-4, C-9 and C-7‴ resonate 1.34, 1.24 and 1.21 ppm, respectively, upfield from the corresponding signals for the *a* isomer.




**12**

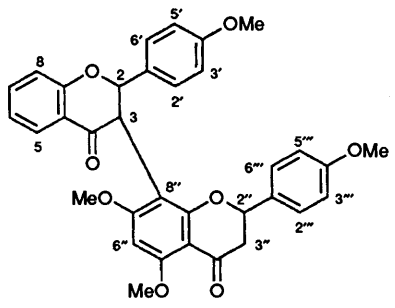



**13**

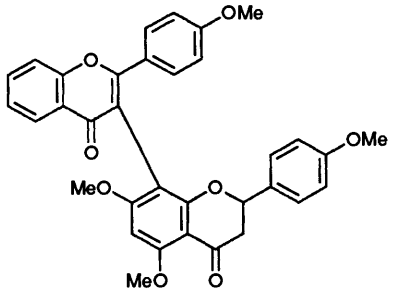
For the electron-rich 3-aryl groups, it was found that desulfurisation of 3-aryl-4′-methoxy-3-(phenylsulfanyl)-flavanones yielded the corresponding α-aryl-2′-hydroxy-4-methoxychalcones. A single isomer formed in each case, presumably the more stable *E*-isomer.[5] Therefore, it was argued that since the introduced flavanone moiety is electron-rich, desulfurisation of the diastereoisomeric mixture should yield a single chalcone isomer. Desulfurisation of compound **12** with a large excess of nickel boride yielded the chalcone **13**, but surprisingly, however, a 1.1:1 mixture of isomers formed. The synthesis of 2′-hydroxychalcones *via* the Claisen–Schmidt condensation of the relevant acetophenones and aldehydes is known to yield *E*-isomers exclusively, the *Z*-isomers being usually prepared by light-induced isomerisation of the *E*-isomers.[9] However, mixtures of *E*- and *Z*-2′-hydroxychalcones have been found in Nature[9] and it has been reported that the condensation of deoxybenzoins and benzaldehyde gives the corresponding chalcones as mixtures of *E* and *Z* isomers.[10] For compound **13** the *E*-configuration is considered to be more stable and so is tentatively assigned to the more abundant isomer. It is believed that a steric or possibly electronic repulsion between the β-methoxyphenyl group and the flavanonyl group may destabilise the *E*-isomer, thus favouring the formation of an almost equal amount of the *Z*-isomer. In the $^1$H NMR spectrum of compound **13**, most of the signals for the *E*- and the *Z*-isomers were separated but close. However, the methine proton, 2″-H, would be expected to resonate at $\delta$ 5.2: the 2″-H$^E$ appears as a double doublet at $\delta$ 5.16 but the 2″-H$^Z$ appears as a double doublet at $\delta$ 4.87. This upfield shift of approximately 0.3 ppm is probably due to a through-space interaction with an electron-rich centre.

Cyclisation of the 1.1:1 mixture of (*E*/*Z*)-8-[1-(2-hydroxybenzoyl)-2-(4-methoxyphenyl)vinyl]-4′,5,7-trimethoxyflavanone **13** to 2,3-*trans*-4′-methoxyflavanone-(I-3, II-8)-4′,5,7-trimethoxyflavanone **14** was performed by treatment of a stirred ethanolic solution of compound **13** in the presence of a base for 16 h. Only a moderate yield (43%) was obtained when sodium hydroxide was used as catalyst (1.6 mol equiv.) at 25 °C. However, refluxing in the presence of a large excess of anhydrous sodium acetate (38 mol equiv.) provided the required biflavanone in good yield (73%). A mixture of two diastereoisomers in the ratio *a*/*b* 1.4:1 was formed, but only the 2,3-*trans* isomer was obtained. For both isomers the 2-H, 3-H coupling constant was found to be 12.38 Hz. Peak broadening in the $^1$H NMR spectrum indicated that compound **14** also exists as a mixture of atropisomers at room temperature. Many biflavonoids are known to display atropisomerism due to restricted rotation about the interflavonoid link.[11,12] In this case a temperature of 35 °C was sufficient to overcome the rotational barrier. Only a few protons and carbons in the $^1$H and $^{13}$C NMR spectra of compound **14** display separate signals for isomers *a* and *b*. A difference in chemical shift of 0.15 ppm exists between the *a* and *b* isomers for the 3′-H and 5′-H signals, indicating that these two protons exist in different chemical environments for the two isomers. In addition, the signal for 2″*b*-H is shifted approximately 0.45 ppm downfield from its expected position of resonance, suggesting the presence of a non-bonding interaction. The overall yield for the preparation of this synthetic biflavanone was found to be 12% from (*o*-hydroxyphenyl)ethanone (precursor to compound **11**) and ~2% from phloroglucinol trimethyl ether (precursor to compound **10**).

When compound **12** was treated with 2 mol equivalents of dimethyldioxirane[13] in acetone at room temperature 4′-methoxyflavone-(I-3, II-8)-4′,5,7-trimethoxyflavanone **15** was formed in 47% yield after 3 h. No intermediate sulfoxide was detected but some sulfone did form. Compound **15** was synthesized in an overall yield of 11% from (*o*-hydroxyphenyl)-ethanone and ~2% from phloroglucinol trimethyl ether. Flavone-(I-3, II-8)-flavanones are not known to occur naturally.



14



15

Our studies on the synthesis of *Garcinia* biflavonoids have led to the preparation of a series of 3-arylflavanones and 3-arylflavones.[5] By applying the methodology used in these syntheses, two *Garcinia* biflavonoids have now been synthesized in good overall yield with the critical step being the coupling of a 3-(phenylsulfanyl)flavanone with a 8-(triacetoxyplumbyl)flavanone. By varying the substitution pattern in these two flavanone substrates, an efficient and selective route to a number of naturally occurring *Garcinia* biflavonoids is now available.

## Experimental

For the general procedures and abbreviations, see preceding paper. In the following NMR data, A and B refer to non-equivalent protons borne by one atom, whereas a and b superscripts refer to distinct data for each isomer of a pair of diastereoisomers. For compounds **5**–**7**, A′ refers to atom A borne by the aryl group linked to C-3 and A″ to atom A borne by the phenyl group linked to the sulfonyl group.

*Preparation of* 3-(*Phenylsulfonyl*)*chroman*-4-*one* **1**.—(a) *With dimethyldioxirane.* A mixture of 3-(phenylsulfanyl)chroman-4-one (0.105 g, 0.41 mmol) and dimethyldioxirane[13] (2.05 mol equiv.) in acetone (2 $cm^3$) was stirred for 10 min at room temperature and gave, after purification by CC [eluent: ether–hexane (3:1)], 3-(*phenylsulfonyl*)*chroman*-4-*one* **1** (0.11 g, 93%) as needles (from EtOH), m.p. 145–148 °C; $\nu_{max}$(KBr)/$cm^{-1}$ 1686, 1610, 1300 and 1140; $\delta_H$(60 MHz; $CDCl_3$) 7.9–6.83 (9 H, m, ArH), 5.3 (1 H, dd, *J* 13 and 4, 2A- or 2B-H), 4.71 (1 H, dd, *J* 13 and 3, 2B- or 2A-H) and 4.07–4.01 (1 H, m, 3-H) (Found: C, 62.5; H, 4.3; S, 10.8. $C_{15}H_{12}O_4S$ requires C, 62.5; H, 4.15; S, 11.1%).

(b) *With oxone.* A solution of oxone® (4.32 g, 6.9 mmol) in cold (0 °C) water (12 $cm^3$) was slowly added to a solution of 3-(phenylsulfanyl)chroman-4-one (0.6 g, 2.3 mmol) in methanol (2.05 mol equiv.) at 0 °C. The mixture was then stirred for 4 h at room temperature, diluted with water, and extracted with chloroform. Purification by CC (eluent as above), afforded 3-(phenylsulfonyl)chroman-4-one (0.525 g, 78%).

*Arylation of* 3-(*Phenylsulfonyl*)*chroman*-4-*one Derivatives.*—*General procedure.* A mixture of the 3-(phenylsulfonyl)chroman-4-one (1 mol equiv.), pyridine (3.3 mol equiv.) and aryllead(IV) triacetate (1.3 mol equiv.) in chloroform (1 $cm^3$ per 0.6 mmol of substrate) was stirred at 60 °C for 8 h. The reaction mixture was diluted with chloroform (100 $cm^3$) and washed with 6% aq. $H_2SO_4$ (100 $cm^3$). The organic layer was filtered through Celite, dried ($Na_2SO_4$), and concentrated. The residue was purified by PTLC [developer: chloroform–ether (10:1)].

3-Phenyl-3-(phenylsulfonyl)chroman-4-one **5** (74%), needles, m.p. 198–200 °C (from EtOH) (lit.,[2] 205 °C); $\nu_{max}$(KBr)/$cm^{-1}$ 1688, 1620, 1300 and 1150; $\delta_H$(270 MHz; $CDCl_3$) 7.94 (1 H, dd, *J* 7.87 and 1.65, 5-H), 7.61–7.58 (2 H, m, 3″- and 5″-H), 7.56–7.51 (1 H, m, 7-H), 7.45–7.23 (8 H, m, ArH), 7.04–6.98 (1 H, m, 6-H), 6.86 (1 H, d, *J* 8.2, 8-H), 5.55 (1 H, d, *J* 10.8, 2A- or 2B-H) and 5.2 (1 H, d, *J* 10.8, 2B- or 2A-H); $\delta_C$ 186.35 (C-4), 160.38 (C-9), 136.65 (C-7), 134.56 (C-1″), 134.06 (C-3″ and -5″), 131.12 (C-5), 129.87 (C-2″ and -6″), 129.19 (C-3′ and -5′), 128.69 (C-4′), 128.11 (C-4″), 128.03 (C-2′ and -6′), 127.09 (C-1′), 122.19 (C-6), 120.47 (C-10), 117.7 (C-8), 75.69 (C-3) and 68 (C-2); *m*/*z* 364 ($M^+$, 1%), 223 (100), 141 (5), 121 (32), 120 (25), 103 (26), 92 (30) and 77 (95) (Found: C, 69; H, 4.45; S, 8.8. Calc. for $C_{21}H_{16}O_4S$: C, 69.2; H, 4.4; S, 8.8%).

3-*Phenylsulfonyl*-3-(p-*tolyl*)*chroman*-4-*one* **6** (70%), needles (from EtOH), m.p. 138–140 °C; $\nu_{max}$(KBr)/$cm^{-1}$ 1688, 1620, 1310 and 1150; $\delta_H$(270 MHz; $CDCl_3$) 7.93 (1 H, dd, *J* 7.87 and 1.28, 5-H), 7.64–7.24 (8 H, m, ArH), 7.09–6.97 (3 H, m, 3′-, 5′- and 6-H), 6.85 (1 H, d, *J* 8.24, 8-H), 5.51 (1 H, d, *J* 11.9, 2A- or 2B-H), 5.16 (1 H, d, *J* 11.9, 2B- or 2A-H) and 2.3 (3 H, s, Me); $\delta_C$ 186.41 (C-4), 160.35 (C-9), 140.12 (C-4′), 136.68 (C-1″), 136.57 (C-3″ and -5″), 134 (C-7), 131.16 (C-2″ and -6″), 129.45 (C-5), 129.10 (C-4″), 128.11 (C-2′ and -6′), 128.05 (C-3′ and -5′), 123.85 (C-1′), 122.2 (C-6), 120.47 (C-10), 117.7 (C-8), 75.51 (C-3), 68.02 (C-2) and 21.16 (Me); *m*/*z* 378 ($M^+$, 5%), 237 (100), 141 (2), 121 (9) and 77 (26) (Found: C, 69.4; H, 4.85; S, 8.3. $C_{22}H_{18}O_4S$ requires C, 69.8; H, 4.8; S, 8.5%).

3-(2,4-*Dimethoxyphenyl*)-3-(*phenylsulfonyl*)*chroman*-4-*one* **7** (64%), needles, m.p. 118–120 °C (from EtOH); $\nu_{max}$(KBr)/$cm^{-1}$ 1690, 1620, 1335 and 1140; $\delta_H$(270 MHz; $CDCl_3$) 7.79–7.73 (3 H, m, 5-, 7- and 6′-H), 7.57–7.48 (2 H, m, 3″- and 5″-H), 7.39–7.27 (3 H, m, 2″-, 4″- and 6″-H), 6.97–6.91 (1 H, m, 6-H), 6.78–6.75 (1 H, m, 8-H), 6.51 (1 H, d, *J* 9, 5′-H), 6.21 (1 H, s, 3′-H), 5.56 (1 H, d, *J* 11.91, 2A- or 2B-H), 5.03 (1 H, d, *J* 12.09, 2B- or 2A-H), 3.77 (3 H, s, 4′-OMe) and 3.27 (3 H, s, 2′-OMe); $\delta_C$ 187.17 (C-4), 162.01 (C-9), 159.78 (C-4′), 159.63 (C-2′), 137.84 (C-1″), 135.35 (C-3″ and -5″), 133.71 (C-7), 132.57 (C-5), 131.12 (C-6′), 127.87 (C-2″ and -6″), 127.7 (C-4″), 121.69 (C-6), 121.37 (C-10), 117.18 (C-8), 109.06 (C-1′), 105 (C-5′), 99.67 (C-3′), 74.68 (C-3), 69.05 (C-2), 55.39 (2′-OMe) and 55.11 (4′-OMe); *m*/*z* 424 ($M^+$, 21%), 283 (100), 141 (4), 121 (4), 120 (3) and 77 (17) (Found: C, 64.65; H, 4.65; S, 7.9. $C_{23}H_{20}O_6S$ requires C, 65.0; H, 4.75; S, 7.55%).

*Preparation of* 2,3-cis/trans-4′-*Methoxy*-3-(*phenylsulfanyl*)-*flavanone* **11**.—Sodium hydride (0.033 g of an 80% dispersion in oil, 1.25 mmol) was added to a suspension containing benzenethiol (0.12 g, 1.09 mmol) in dry benzene (7 $cm^3$) under nitrogen at 3 °C. After the mixture had been stirred for 30 min, 3-methanesulfonyloxy-4′-methoxyflavanone (0.37 g, 1.06 mmol) was added in three portions. The resultant suspension was stirred at room temperature for 24 h, filtered, and washed with water (3 × 25 $cm^3$). After being dried ($Na_2SO_4$), the solvent was removed under reduced pressure and the residue was purified by CC on silica gel [eluent: hexane–ether (2:1)]. Addition of a 4:1 mixture of light petroleum–ethyl acetate (20 $cm^3$) to the yellow solid gave 4′-methoxy-3-(phenylsulfanyl)-flavanone as cream coloured needles (0.305 g, 79%) as a 2:1 *cis*/*trans* mixture, m.p. 104–107 °C and 117–120 °C (lit.,[7] *cis* isomer 121–123 °C); $\nu_{max}$(KBr)/$cm^{-1}$ 1692, 1687, 1610, 1513, 1465 and 1252; $\delta_H$(60 MHz; $CDCl_3$) 8.04–7.75 (1 H, m, 5-H),

7.56–6.68 (12 H, m, 6-, 7-, 8-, 2'-, 3'-, 5'-, 6'-, 2″-, 3″-, 4″-, 5″- and 6″-H), 5.65–5.52 (1 H, m, 2-H), 4.78 (0.33 H, d, *J* 6.4, *trans* 3-H), 3.94 (0.67 H, d, *J* 2, *cis* 3-H), 3.94 (0.67 H, d, *J* 2, *cis* 3-H), 3.77 (2.01 H, s, *cis* OMe) and 3.67 (0.99 H, s, *trans* OMe); *m/z* 362 ($M^+$, 48%), 253 (100), 242 (55), 197 (33) and 121 (74).

*4'-Methoxy-3-(phenylsulfanyl)flavanone*-(I-3, II-8)-*4',5,7-trimethoxyflavanone* **12**.—Dry pyridine (0.48 $cm^3$, 5.056 mmol) followed by 4',5,7-trimethoxy-8-(triacetoxyplumbyl)flavanone ethylene ketal **10** (1.25 g, 1.685 mmol) was added to a stirred solution of 2:1 *cis/trans*-4'-methoxy-3-(phenylsulfanyl)flavanone **11** (0.555 g, 1.532 mmol) in dry chloroform (5 $cm^3$) and the resultant mixture was stirred at 60 °C for 4 h. After this time, the reaction mixture was diluted with chloroform (200 $cm^3$) and washed with 3 mol $dm^{-3}$ sulfuric acid (100 $cm^3$). The aqueous layer was extracted with chloroform (3 × 100 $cm^3$). The combined organic layers were washed with 3 mol $dm^{-3}$ sulfuric acid (100 $cm^3$) and the aqueous layer was again extracted with chloroform (3 × 100 $cm^3$). All the chloroform layers were combined, filtered through Celite, dried ($MgSO_4$), and the solvent was removed under reduced pressure. The residue was purified by CC on silica gel [eluent: ethyl acetate–hexane (3:1)] to give the *title compound* as a mixture of two diastereoisomers *a*:*b* 1.4:1 (0.659 g, 64%). This mixture was crystallised from ethanol in pale yellow plates, m.p. 143–146 °C; $\nu_{max}$(KBr)/$cm^{-1}$ 1678, 1605, 1591 and 1252; $\lambda_{max}$(MeOH)/nm 224.5, 283 and 318.2; $\delta_H$(400 MHz; $CDCl_3$) 7.81 (0.58 H, dd, *J* 8.1 and 1.5, $5^a$-H), 7.78 (0.42 H, dd, *J* 7.9 and 1.7, $5^b$-H), 7.5–7.19 (4 H, m, 7-, 8-, 2‴- and 6‴-H), 7.12–6.51 (11 H, m, 2'-, 3'-, 5'-, 6'-, 2″-, 3″-, 4″-, 5″-, 6″-, 3‴- and 5‴-H), 6.36 (1 H, distorted dd, *J* 7.5 and 1, 6-H), 6.2 (0.42 H, s, $6'''^b$-H), 5.91 (0.58 H, s, $6'''^a$-H), 5.73 (0.58 H, s, $2^a$-H), 5.64 (0.42 H, s, $2^b$-H), 5.18 (0.58 H, dd, *J* 13.6 and *J* 3, $2'''^a$-H), 4.16 (0.42 H, dd, *J* 14 and 2.5, $2'''^b$-H), 3.95 (1.26 H, s, *b*-OMe), 3.91 (1.26 H, s, *b*-OMe), 3.8 (1.74 H, s, *a*-OMe), 3.77 (1.74 H, s, *a*-OMe), 3.72 (1.26 H, s, *b*-OMe), 3.7 (1.26 H, s, *b*-OMe), 3.67 (1.74 H, s, *a*-OMe), 3.23 (1.74 H, s, *a*-OMe), 2.92 (0.58 H, dd, *J* 17.4 and 13.6, $3'''^a$-H axial), 2.7 (0.58 H, dd, *J* 17.4 and 3.1, $3'''^a$-H equatorial), 2.6 (0.42 H, dd, *J* 16.9 and 14, $3'''^b$-H axial) and 2.41 (0.42 H, dd, *J* 16.9 and 2.7, $3'''^b$-H equatorial); $\delta_C$(100.62 MHz; $CDCl_3$) *Isomer a*: 189.92 (C-4‴), 186.21 (C-4), 165.71 (C-7‴), 162.78 (C-5‴), 162.65 (C-9‴), 161.06 (C-9), 159.67 (C-4'), 159.31 (C-4‴), 136.45 (C-3″ and -5″), 133.76 (C-5), 132.68 (C-1″), 130.27 (C-1‴), 129.91 (C-2' and -6'), 128.67 (C-1'), 128.34 (C-7), 127.91 (C-2″ and -6″), 127.68 (C-4″), 127.42 (C-2‴ and -6‴), 121.54 (C-10), 121.06 (C-6), 116.83 (C-8), 113.59 (C-3‴ and -5‴), 112.43 (C-3' and -5'), 107.17 (C-10‴), 106.81 (C-8‴), 90.49 (C-6‴), 83.97 (C-2), 80.03 (C-2‴), 67.19 (C-3), 56.19 (OMe), 55.4 (OMe), 55.31 (OMe), 55.28 (OMe) and 47.01 (C-3‴), *Isomer b*: 190.42 (C-4‴), 184.87 (C-4), 164.5 (C-7‴), 162.93 (C-5‴), 162.56 (C-9‴), 159.82 (C-9), 159.54 (C-4'), 159.26 (C-4‴), 135.73 (C-3″ and -5″), 134.48 (C-5), 132.31 (C-1″), 130.9 (C-1‴), 129.62 (C-2' and -6'), 129.12 (C-1'), 128.3 (C-7), 128.15 (C-2″ and -6″), 127.98 (C-4″), 127.74 (C-2‴ and -6‴), 121.74 (C-6), 121.52 (C-10), 117.61 (C-8), 113.33 (C-3‴ and -5‴), 112.71 (C-3' and -5'), 106.97 (C-10‴), 106.72 (C-8‴), 90.41 (C-6‴), 83.74 (C-2), 79.64 (C-2‴), 66.61 (C-3), 56.0 (OMe), 55.43 (OMe), 55.16 (OMe), 54.91 (OMe) and 46.95 (C-3‴); *m/z* 674 ($M^+$, 10%), 565 (14), 549 (10), 445 (5), 431 (100), 311 (14) and 121 (28) (Found: $M^+$, 674.1975. $C_{40}H_{34}O_8S$ requires M, 674.1965).

8-[1-(2-*Hydroxybenzoyl*)-2-(4-*methoxyphenyl*)*vinyl*]-4',5,7-*trimethoxyflavanone* **13**.—A solution of sodium boranuide ($NaBH_4$) (0.21 g, 5.55 mmol) in water (2.2 $cm^3$) was added dropwise to a solution of nickel(II) chloride hexahydrate (1.587 g, 6.66 mmol) in ethanol (19 $cm^3$). To the stirred, black, nickel boride suspension was added 4'-methoxy-3-(phenylsulfanyl)flavanone-(I-3, II-8)-4',5,7-trimethoxyflavanone **12** (0.15 g, 0.222 mmol) and the resulting mixture was heated at 90 °C for 2 h. After cooling, the mixture was diluted with chloroform, then was filtered, and the filtrate was washed with water (3 × 100 $cm^3$). After being dried ($Na_2SO_4$), the solvent was removed under reduced pressure and the residue was purified by CC on silica gel [eluent: ethyl acetate–hexane (3:1)] to give the *title compound* as a 1.1:1 *E*/*Z* mixture (0.093 g, 74%). This mixture was crystallised from ethanol in yellow needles, m.p. 172–176 °C; $\nu_{max}$(KBr)/$cm^{-1}$ 3480, 1681, 1618 and 1253; $\delta_H$(270 MHz; $CDCl_3$) *E isomer*: 11.58 (1 H, s, OH), 7.66 (1 H, dd, *J* 8.13 and 1.33, 6'-H), 7.2 (2 H, d, *J* 8.72, 2‴- and 6‴-H), 7.12 (1 H, s, β-H), 5.16 (1 H, dd, *J* 12.92 and 2.81, 2″-H), 3.81 (3 H, s, OMe), 3.75 (3 H, s, OMe) and 3.74 (3 H, s, OMe); *Z isomer*: 11.69 (1 H, s, OH), 7.74 (1 H, dd, *J* 8.13 and 1.33, 6'-H), 7.11 (1 H, s, β-H), 7.07 (2 H, d, *J* 8.72, 2‴- and 6‴-H), 4.87 (1 H, dd, *J* 13.02 and 2.43, 2″-H), 3.79 (3 H, s, OMe), 3.67 (3 H, s, OMe) and 3.63 (3 H, s, OMe); *mixed signals*: 7.44–7.32 (m, 4'-H), 7.02–6.86 (m, 2-, 6- and 3'-H), 6.82–6.59 (m, 3-, 5-, 5'-, 3‴- and 5‴-H), 6.15 (s, 6″-H), 3.99 (s, OMe) and 2.99–2.61 (m, 3″-$H_2$); $\delta_C$(67.80 MHz; $CDCl_3$) *E isomer*: 202.66 (CO), 189.88 (C-4″), 163.19 (C-7″), 162.99 (C-5″), 162.2 (C-9″), 161.06 (C-4), 160.39 (C-2'), 159.54 (C-4‴), 141.74 (C-β), 135.2 (C-6'), 130.89 (C-2 and -6), 130.45 (C-1‴), 128.58 (C-1), 127.57 (C-2‴ and -6‴), 118.22 (C-5'), 117.89 (C-3'), 89.21 (C-6″) and 45.49 (C-3″); *Z isomer*: 202.58 (CO), 189.96 (C-4″), 163.29 (C-7″), 163.02 (C-5″), 162.34 (C-9″), 160.73 (C-4), 160.25 (C-2'), 159.49 (C-4‴), 141.35 (C-β), 135.31 (C-6'), 130.67 (C-2 and -6), 130.13 (C-1‴), 129.09 (C-1), 127.35 (C-2‴ and -6‴), 118.14 (C-5'), 117.78 (C-3'), 89.1 (C-6″) and 45.25 (C-3″); *mixed signals*: 132.63 (C-4'), 128.73 (C-α), 119.82 (C-1'), 113.65 (C-3‴ and -5‴), 113.6 (C-3 and -5), 107.42 (C-10″), 106.29 (C-8″), 78.85 (C-2″), 56.18 (MeO), 55.87 (*Z*-MeO), 55.79 (*E*-MeO), 55.31 (MeO) and 55.24 (MeO); *m/z* 566 ($M^+$, 47%), 548 (25), 445 (76), 403 (100), 312 (64), 253 (36) and 121 (60) (Found: $M^+$, 566.1980. $C_{34}H_{30}O_8$ requires M, 566.1932).

2,3-trans-4'-*Methoxyflavanone*-(I-3, II-8)-*4',5,7-trimethoxyflavanone* **14**.—Compound **13** (0.13 g, 0.229 mmol) and anhydrous sodium acetate (0.72 g, 38 mol equiv.) were refluxed in ethanol (24 $cm^3$) for 16 h. After cooling, the reaction mixture was diluted with ether (20 $cm^3$) and washed successively with 10% aq. HCl (2 × 15 $cm^3$) and water (2 × 15 $cm^3$). The organic layer was dried ($MgSO_4$), the solvent was removed under reduced pressure, and the residue was purified by CC on silica gel [eluent: ethyl acetate–hexane (3:1)]. 2,3-trans-4'-*Methoxyflavanone*-(I-3, II-8)-4',5,7-*trimethoxyflavanone* **14** was isolated as a 1.4:1 mixture of two diastereoisomers *a* and *b* (0.095 g, 73%), and was crystallised from ethanol in plates, m.p. 130–134 °C and 184–186 °C; $\nu_{max}$(KBr)/$cm^{-1}$ 1692, 1606, 1582, 1519, 1467 and 1256; $\delta_H$(270 MHz; $CDCl_3$; *T* 35 °C) 7.97 (1 H, dd, *J* 7.88 and 1.41, 5-H), 7.44 (1 H, distorted ddd, *J* 7.88 and 1.68, 7-H), 7.22 (2 H, d, *J* 8.44, 2‴- and 6‴-H), 7.18 (1.17 H, d, *J* 8.44, $2'^a$- and $6'^a$-H), 7.16 (0.83 H, d, *J* 8.72, $2'^b$- and $6'^b$-H), 7.13–6.95 (2 H, m, 6- and 8-H), 6.83 (0.83 H, d, *J* 8.4, $3'^b$- and $5'^b$-H), 6.76 (2 H, d, *J* 8.72, 3‴- and 5‴-H), 6.68 (1.17 H, d, *J* 8.16, $3'^a$- and $5'^a$-H), 6.03 (1 H, br s, 6″-H), 5.7 (0.42 H, d, *J* 13.5, $2''^b$-H), 5.65 (1 H, d, *J* 12.38, 2-H), 5.25 (0.58 H, d, *J* 13.5, $2''^a$-H), 4.7 (0.42 H, d, *J* 12.38, $3^b$-H), 4.67 (0.58 H, d, *J* 12.38, $3^a$-H), 3.89 (s, OMe), 3.78 (s, OMe), 3.77 (s, OMe), 3.75 (s, OMe) and 2.98–2.54 (2 H, m, 3″-$H_2$); $\delta_C$(67.80 MHz; $CDCl_3$) 192.38 (C-4″), 190.08 (C-$4^a$), 189.74 (C-$4^b$), 163.3 (C-$7''^b$), 162.18 (C-$7''^a$), 161.44 (C-5″ and -9″), 159.65 (C-9), 159.62 (C-4'), 159.51 (C-4‴), 135.59 (C-5), 130.85 (C-1‴), 130.43 (C-1'), 128.49 (C-$2'^a$ and -$6'^a$), 128.31 (C-$2'^b$ and -$6'^b$), 127.59 (C-7), 127.41 (C-2‴ and - 6‴), 121.42 (C-6), 120.99 (C-10), 117.97 (C-8), 113.92 (C-3‴ and -5‴), 113.29 (C-$3'^a$ and -$5'^a$), 113.22 (C-$3'^b$ and - $5'^b$), 105.79 (C-10″), 104.07 (C-8″),

89.18 (C-6″[a]), 88.82 (C-6″[b]), 82.3 (C-2[b]), 82.11 (C-2[a]), 78.88 (C-2″), 56.04 (2 × OMe[a], OMe[b]), 55.79 (OMe[b]), 55.28 (2 × OMe), 49.95 (C-3) and 46.2 (C-3″); *m/z* 566 ($M^+$, 74%), 535 (12), 445 (54), 432 (16), 403 (100), 375 (21), 312 (81), 180 (39), 134 (19) and 121 (26) (Found: $M^+$, 566.1973. $C_{34}H_{30}O_8$ requires M, 566.1932).

*4′-Methoxyflavone-*(I-3, II-8)*-4′,5,7-trimethoxyflavanone* **15**. —Dimethyldioxirane (3.7 $cm^3$ of a 0.084 mol $dm^{-3}$ solution in acetone) was added dropwise to a mixture containing 4′-methoxy-3-(phenylsulfanyl)flavanone-(I-3, II-8)-4′,5,7-trimethoxyflavanone **12** (0.015 g, 0.155 mmol) in dry acetone (1.7 $cm^3$) at 0 °C. The resulting yellow solution was stirred at room temperature for 3 h. The acetone was removed under reduced pressure and the residue was purified by preparative TLC [eluent: ether–hexane–methanol (5:1:1)]. 4′-Methoxyflavone-(I-3, II-8)-4′,5,7-trimethoxyflavanone **15** was isolated as a cream solid (0.041 g, 47%) and was crystallised from methanol in plates, m.p. 159–162 °C (decomp.); $\nu_{max}$(KBr)/$cm^{-1}$ 1674, 1609, 1592, 1516 and 1522; $\delta_H$(270 MHz; $CDCl_3$) 7.93 (1 H, dd, *J* 8.08 and 1.84, 5-H), 7.58 (1 H, distorted ddd, *J* 8.1 and 2.02, 7-H), 7.27 (2 H, d, *J* 8.61, 2‴- and 6‴-H), 7.06 (2 H, d, *J* 8.25, 2′- and 6′-H), 7.0 (2 H, d, *J* 8.61, 3‴- and 5‴-H), 6.82 (2 H, d, *J* 8.79, 3′- and 5′-H), 6.73–6.52 (2 H, m, 6- and 8-H), 6.12 (1 H, s, 6″-H), 5.11 (1 H, d, *J* 11.48, 2″-H), 3.98 (3 H, s, 5″-OMe), 3.83 (6 H, s, 4′- and 4‴-OMe), 3.71 (3 H, s, 7″-OMe) and 2.87–2.63 (2 H, m, 3″-$H_2$); $\delta_C$(67.80 MHz; $CDCl_3$) 189.7 (C-4″), 177.81 (C-4), 165.94 (C-7″), 163.51 (C-5″), 159.96 (C-9″), 159.65 (C-9), 159.41 (C-4′ and -4‴), 134.29 (C-5), 132.99 (C-1‴), 129.86 (C-2′ and -6′), 128.0 (C-7), 127.47 (C-2‴ and -6‴), 126.79 (C-1′), 126.7 (C-3), 121.82 (C-10), 121.24 (C-6), 116.75 (C-8), 113.57 (C-3‴ and -5‴), 112.18 (C-3′ and -5′), 107.39 (C-8″ and -10″), 90.9 (C-6″), 80.24 (C-2″), 56.31 (OMe), 55.28 (OMe), 55.23 (OMe), 55.11 (OMe) and 47.03 (C-3″); *m/z* 564 ($M^+$, 19%), 549 (9), 444 (3), 141 (29), 121 (48), 109 (33) and 77 (100) (Found: $M^+$, 564.1783. $C_{34}H_{28}O_8$ requires M, 564.1776).

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