SYNTHESIS OF FIVE-MEMBERED HETEROARYLMETHYL *P*-TOLYLSULFONES FROM HETEROARENEMETHANOLS UNDER ACIDIC CONDITIONS: SCOPE AND LIMITATIONS

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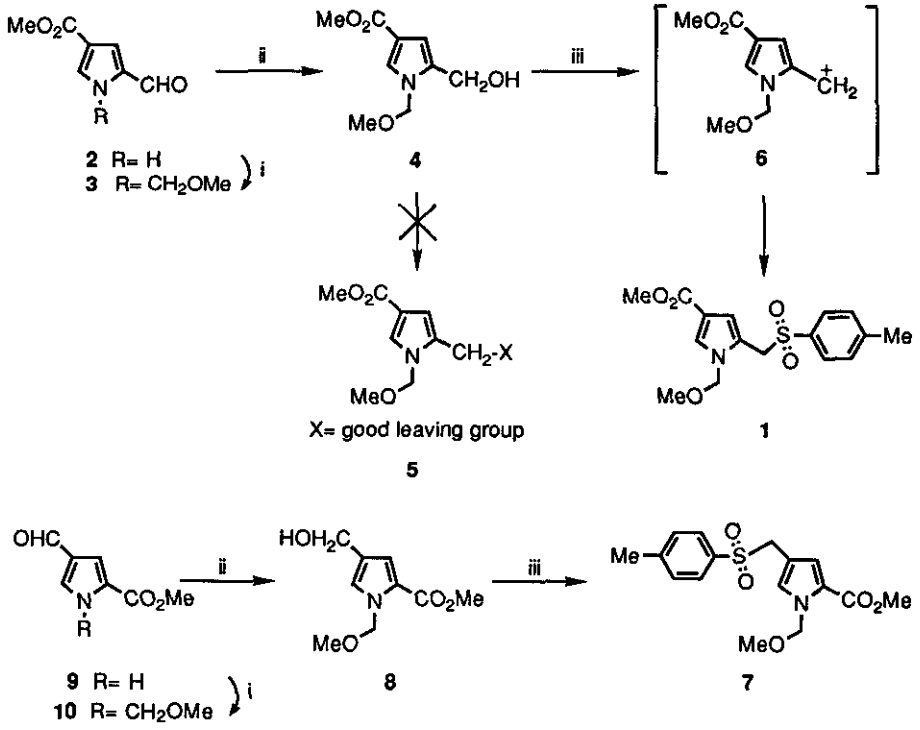
Abstract- It is shown that the successful conversion of five-membered heteroarenemethanols into the corresponding heteroarylmethyl *p*-tolylsulfones by treatment with sodium *p*-toluenesulfinate under acidic conditions depends on the stability of the intermediate heteroarylmethyl carbocations.

In connection with research on the synthesis of the antitumour agent CC-1065[1] we needed sulfone (**1**). As starting compound we employed the readily available methyl 2-formylpyrrole-4-carboxylate (**2**).[2] *N*-Methoxymethylation of pyrrolecarboxylate (**2**) by treatment with chloromethyl methyl ether and potassium *tert*-butoxide in dimethylformamide, followed by reduction of the resulting formyl derivative (**3**) with sodium borohydride in methanol, afforded alcohol (**4**).

Initially, we attempted the transformation of alcohol (**4**) into sulfone (**1**) *via* compound (**5**), where x is a good leaving group, intending to treat **5** with sodium *p*-toluenesulfinate. Regrettably, we were unable to synthesize any compound (**5**) from alcohol (**4**). In all cases, either the starting alcohol or a complex reaction mixture was obtained. We attribute this failure to the ease with which any compound (**5**) undergoes heterolytic bond cleavage to give the side-chain carbocation (**6**), which either leads back to alcohol (**4**) or yields a complex mixture.

The electron-richness of pyrrole rings with no electron withdrawing substituents means that side-chain carbenium ions are formed and lead to other derivatives before reaction with the sulfinate salt can occur. Although there are many examples in the literature of chloromethyl- and bromomethylpyrroles with electron-withdrawing substituents, we have found no report of the isolation and characterization of any such compound that was not stabilized by an electron-withdrawing group.[4] It seems that in our case an ester group does not suffice for kinetic stabilization of compounds (**5**).

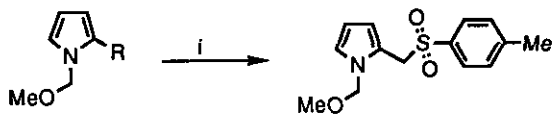
As an alternative route to sulfone (**1**), we reasoned that the cation (**6**) should be easily formed and trapped with sulfinate on treatment of alcohol (**4**) with acid. In the event, treatment of alcohol (**4**) at room temperature with a solution of sodium *p*-toluenesulfinate in formic acid led to clean conversion of **4** into sulfone (**1**) in 98% yield. No formation of alkyl sulfinate was detected.[5]
Similary sulfone (**7**) was successfully obtained in 75% yield from alcohol (**8**), an isomer of compound (**4**), under the same conditions. Alcohol (**8**) was obtained from methyl 4-formylpyrrole-2-carboxylate (**9**)[7] using the same *N*-protection and reduction sequence previously used for the transformation of aldehyde (**2**) into alcohol (**4**).



Reagents: i: $ClCH_2OMe$, t-BuOK, DMF, room temperature; ii: $NaBH_4$, MeOH, room temperature; iii: sodium *p*-toluenesulfinate, 85% formic acid.

Attempts to extend this reaction to an unsubstituted pyrrole ring were less successful. *N*-Methoxymethylpyrrole-2-methanol (**11**), prepared from pyrrole-2-carbaldehyde by *N*-protection and reduction as above, gave only a very low, erratic yield of the corresponding sulfone (**13**) when treated under the above conditions. This was at least partly a result of the instability of alcohol (**11**), which decomposes very quickly during work-up, although it seems to be perfectly stable in the basic reaction medium in which it is obtained. Better results were obtained with a one-pot procedure whereby sodium borohydride was added to a solution of aldehyde (**12**) in isopropyl alcohol. The solvent was evaporated and the residue containing the stable sodium salt of alcohol

(**11**) was treated with a solution of sodium *p*-toluenesulfinate in formic acid. This afforded a moderate overall yield (50%) of the desired sulfone (**13**) from aldehyde (**12**). In this case the lack of electron-withdrawing substituent in alcohol (**11**) makes the corresponding side-chain carbocation very stable. We believe that this stability allows the generation of a high concentration of this carbocation, which leads to its oligomerization and hence prevents efficient trapping with sulfinate.

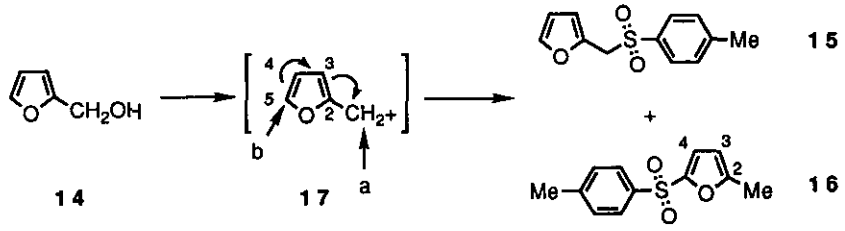


12 R= CHO
11 R= CH_2OH

13

Reagents: i: (one-pot **13** from **12**): a) $NaBH_4$, i-PrOH, room temperature; b) removal of i-PrOH; c) sodium *p*-toluenesulfinate, 85% formic acid.

Furfuryl alcohol (**14**) reacted very slowly to give a mixture of products from which a low yield (24%) of the desired sulfone (**15**) together with a 10% yield of the isomeric sulfone (**16**) were isolated. The slowness of this reaction is due to the furan ring being less able than the pyrrole ring to stabilize side-chain carbocations. The isomeric sulfone (**16**) was formed because, due to its lower stability, the intermediate carbocation (**17**) can be attacked either at the side chain (route a) or directly at the aromatic ring (route b). The location of the *p*-tolylsulfonyl substituent in sulfone (**16**) was inferred from the following arguments: a) its introduction at the C-4 position was discarded on straightforward mechanistic grounds; b) the presence, in the ^{1}H-nmr spectrum, of a small coupling constant (0.4 Hz) between the methyl group at the C-2 position and one aromatic proton showed there to be a hydrogen at the C-3 position; and c) it is known that carbocation (**17**) may be trapped by other nucleophiles which enter at the C-5 position, whereas no examples of their attack at the C-3 position are known.[8]

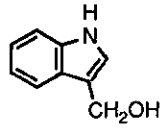


14 **17** **15** + **16**

A good measure of the stability of these arylmethyl cations is the σ^+ constant of the corresponding aryl group originally defined by Brown and co-workers.[9] A low value of σ^+ shows electron-richness and high ability to stabilize carbocations. The values for *N*-methyl-2-pyrrolyl and 2-furyl are -1.90 and -0.95 respectively.[10] Assuming for the *N*-methoxymethyl-2-pyrrolyl group a σ^+ value close to

that of *N*-methyl-2-pyrrolyl, we may predict that attemps to introduce a *p*-toluenesulfonyl group in any arenemethanol for which the σ^+ value of the corresponding aryl group is smaller than -1.90 will fail due to the carbocation intermediate being too stable, which will lead to a complex reaction mixture. We checked this hypothesis with 3-indolemethanol (**18**), assuming that σ^+ for the 3-indolyl group is close to σ^+ for 1-methyl-3-indolyl, -1.93. As expected, treatment of indolemethanol (**18**) with sodium *p*-toluenesulfinate in formic acid led to a complex mixture of compounds.

While a σ^+ value of -1.90 is the limit below which an arylmethanol will not give a good yield of sulfone due to the carbocation intermediate being too stable, the marginal efficiency in the conversion of furfuryl alcohol (**14**) into sulfone (**15**) sets an upper limit of -0.95 for σ^+, above which the reaction should fail due to the carbocation being too unstable or too unselective under the reaction conditions used, for efficient formation of an arylmethyl *p*-tolylsulfone. We decided to check this in the cases of 2-thenyl alcohol (**19**) and 3-thenyl alcohol (**20**), the σ^+ values of whose 2-thienyl and 3-thienyl groups are -0.85 and -0.49 respectively. As expected, both **19** and **20** were recovered unchanged after long reaction times with sodium *p*-toluenesulfinate in formic acid.



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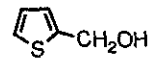

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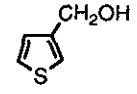

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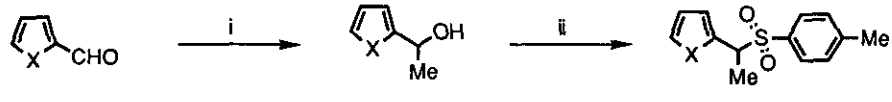
In those cases in which the aromatic ring is insufficiently electron-rich to stabilize an arylmethyl cation, further stabilization can be sought by introducing a methyl group in the α exocyclic position. Treatment of 2-thiophenecarbaldehyde (**21**) and furfural (**22**) with methyllithium allowed the preparation of the 1-arylethanols (**23**) and (**24**), and treatment of these compounds with sodium *p*-toluenesulfinate and formic acid gave sulfones (**25**) and (**26**) in respectively 31% and 63% overall yields from the corresponding aldehydes.



21 X=S **22** X=O **23** X=S **24** X=O **25** X=S **26** X=O

Reagents: i: MeLi, THF; ii: sodium *p*-toluenesulfinate, 85% formic acid.

In conclusion, we have shown that the formation of heteroarylmethyl *p*-tolylsulfones by treatment of heteroarylmethanols with sodium *p*-toluenesulfinate in formic acid succeeds with aromatics whose aryl rings have σ^+ values between approximately -1.90 and -0.95. In keeping with the above results, in the non-heterocyclic arenemethanol series, only benzyl alcohols, whose ring is electron-

rich, have successfully been converted into sulfones under acidic conditions.[12] In this series it is very difficult to find cases of σ^+ values below -1.90, so that failure due to extreme electron-richness of the aryl group is unlikely.

EXPERIMENTAL

Tetrahydrofuran (THF) was distilled under Ar from sodium. Methanol and isopropanol were distilled from magnesium prior to use. Dimethylformamide (DMF) was dried over 4-Å molecular sieves. Melting points are uncorrected. Ir spectra were taken in KBr pellets on Perkin-Elmer 1420 and 180 instruments. Nmr spectra were recorded in chloroform-*d* solutions on a Bruker WM-250 (250 MHz) instrument using tetramethylsilane as an internal standard. Ms were recorded using electron impact at 70 eV on Kratos MS-50 or Hewlett-Packard 5988A spectrometers; HRms data were determined on the Kratos MS-50 using perfluorokerosene as standard. Tlc was carried out on Merck GF-254 silica gel, and flash chromatography on Merck 60 (230-400 mesh) silica gel. Alcohols (**14**, **19** and **20**) were synthesized by reduction (with $NaBH_4$) of the commercially available furfural, 2-thiophenecarbaldehyde and 3-thiophenecarbaldehyde.

Methyl 2-formyl-*N*-methoxymethylpyrrole-4-carboxylate (3). To a solution of pyrrole (**2**)[2] (6.00 g, 39.17 mmol) in 60 ml of dry DMF, cooled in an ice/water bath, was added 9.18 g (81.86 mmol) of potassium *tert*-butoxide. The reaction mixture was allowed to warm up to room temperature and was then stirred for 1 h, cooled again to 0°C and treated with chloromethyl methyl ether (7.5 ml, 98.80 mmol). After 30 h, water was added and the reaction mixture was extracted with dichloromethane. The organic layer was dried with sodium sulfate and the solvent was evaporated. After purification by flash chromatography on silica gel (19:1 CH_2Cl_2/EtOAc), 6.82 g (88%) of **3** were obtained as a solid, mp 65-66°C (hexane/Et_2O). Ir (KBr, ν_{max}): 1670, 1705, 2950, 3115 cm^{-1}. ^1H Nmr ($CDCl_3$) δ: 9.62 (1H, d, J= 0.8 Hz, ArC*H*O), 7.69 (1H, br s, Ar*H*), 7.39 (1H, d, J= 1.6 Hz, Ar*H*), 5.67 (2H, s, $ArCH_2OCH_3$), 3.85 (3H, s, $ArCO_2CH_3$), 3.34 (3H, s, $ArCH_2OCH_3$). ^{13}C Nmr ($CDCl_3$) δ: 180.1, 163.6, 133.7, 132.2, 125.1, 117.5, 79.1, 56.5, 51.4. Ms: m/z (%) 197 ($M^{+\cdot}$,29), 182 ($M^{+\cdot}$-CH_3, 100), 166 ($M^{+\cdot}$-OCH_3, 28), 154 ($M^{+\cdot}$-CH_3CO, 23). HRms calcd for $C_9H_{11}NO_4$: 197.0688, found: 197.0661. Anal. Calcd for $C_9H_{11}NO_4$, C 54.77, H 5.62, N 7.10: Found, C 55.04, H 5.65, N 6.95.

Compounds (**10**) and (**12**) were obtained by an analogous *N*-protection procedure, as follows:
Methyl 4-formyl-*N*-methoxymethylpyrrole-2-carboxylate (10). Obtained from **9** in 77% yield as a yellow solid, mp 37-40°C (EtOAc/hexane). Ir (KBr, ν_{max}): 1680, 1710 cm^{-1}(C=O). ^1H Nmr ($CDCl_3$) δ: 9.82 (1H, s, C*H*O), 7.60 (1H, dd, J= 1.6, 10.6 Hz, Ar*H*), 7.30 (1H, m, Ar*H*), 5.70 (2H, s, CH_2OCH_3), 3.87 (3H, s, CO_2CH_3), 3.35 (3H, s, OCH_3). ^{13}C Nmr ($CDCl_3$) δ: 185.2, 160.9, 132.9, 125.3, 124.3, 117.8, 79.6, 56.5, 51.6. Ms: m/z (%) 197 ($M^{+\cdot}$, 65); 182 ($M^{+\cdot}$-CH_3, 80); 166 ($M^{+\cdot}$-OCH_3, 51); 150 (100). HRms calcd for $C_9H_{11}NO_4$: 197.0688, found: 197.0687.

N-Methoxymethylpyrrole-2-carbaldehyde (12). Obtained from pyrrole-2-carbaldehyde in 90% yield as a colourless oil, bp 201-202°C. Ir ν_{max}: 1660 cm^{-1} (C=O). ^1H Nmr ($CDCl_3$) δ: 9.60 (1H, s, C*H*O), 7.10 (1H, d, J= 1.1 Hz, Ar*H*), 6.90 (1H, dd, J= 3.9, 1.6 Hz, Ar*H*), 6.30 (1H, dd, J= 3.8, 2.6 Hz, Ar*H*), 5.66 (2H, s, CH_2OCH_3), 3.30 (3H, s, OCH_3). Ms: m/z (%) 139 ($M^{+\cdot}$, 54), 124 ($M^{+\cdot}$-CH_3, 100), 108 ($M^{+\cdot}$-OCH_3, 47), 94 ($M^{+\cdot}$-CH_2OCH_3, 14), 80 ($M^{+\cdot}$-CH_2OCH_3, CO, 23). HRms calcd for $C_7H_9NO_2$: 139.0633, found: 139.0637.

Methyl 2-hydroxymethyl-*N*-methoxymethylpyrrole-4-carboxylate (4). To a solution of aldehyde (3) (515 mg, 2.61 mmol) in 8 ml of dry methanol cooled in an ice/water bath, was added 165 mg (4.36 mmol) of sodium borohydride. The reaction mixture was warmed to room temperature and stirred for 1.5 h. A brine solution was added and the resulting mixture was extracted with ethyl acetate. The organic layer was dried (Na_2SO_4) and the solvent was evaporated. After purification by flash chromatography on silica gel (19:3 CH_2Cl_2/EtOAc) 507 mg (98%) of **4** was obtained as a solid, mp 56-57°C (EtOAc/hexane). Ir (KBr, ν_{max}): 1710, 2950, 3120, 3400 (broad) cm^{-1}. ^1H Nmr ($CDCl_3$) δ: 7.40 (1H, d, J= 1.6 Hz, Ar*H*), 6.60 (1H, d, J= 1.6 Hz, Ar*H*), 5.28 (2H, s, $ArCH_2OCH_3$), 4.61 (2H, s, $ArCH_2OH$), 3.80 (3H, s, $ArCO_2CH_3$), 3.29 (3H, s, $ArCH_2OCH_3$). ^{13}C Nmr ($CDCl_3$) δ: 165.1, 133.4, 128.1, 114.8, 111.0, 78.4, 55.8, 55.7, 50.9. Ms: m/z (%) 199 ($M^{+\cdot}$, 28), 182 ($M^{+\cdot}$-OH, 3), 168 ($M^{+\cdot}$-OCH_3, 13), 45 ($CH_3OCH_2^{+\cdot}$, 100). HRms calcd for $C_9H_{13}NO_4$: 199.0844, found: 199.0854. Anal. Calcd for $C_9H_{13}NO_4$, C 54.26, H 6.57, N 7.03: Found, C 53.91, H 6.82, N 6.95.

Using a similar procedure alcohol (8) was obtained:

Methyl 4-hydroxymethyl-*N*-methoxymethylpyrrole-2-carboxylate (8). Obtained in 50% yield from **10** as an oil, bp 197-200°C. Ir (film, ν_{max}): 1700 (CO), 3400 (br, OH) cm^{-1}. ^1H Nmr ($CDCl_3$) δ: 7.01 (1H, s, Ar*H*), 7.00 (1H, s, Ar*H*), 5.62 (2H, s, $ArCH_2OCH_3$), 4.55 (2H, s, $ArCH_2OH$), 3.82 (3H, s, $ArCO_2CH_3$), 3.30 (3H, s, $ArCH_2OCH_3$). Ms: m/z (%) 199 ($M^{+\cdot}$, 71), 184 ($M^{+\cdot}$-CH_3, 33), 169 (44), 152 (100), 45 ($CH_3OCH_2^{+\cdot}$, 20). HRms calcd for $C_9H_{13}NO_4$: 199.0844 , found: 199.0841.

Methyl *N*-methoxymethyl-2-tosylmethylpyrrole-4-carboxylate (1). To a mixture of alcohol (4) (438 mg, 2.20 mmol) and sodium *p*-toluenesulfinate (1.88 g, 8.78 mmol), was added 85% formic acid (5 ml). The reaction mixture was stirred for one day at room temperature. Water was added, and the resulting mixture was extracted with dichloromethane. The organic layer was dried (Na_2SO_4) and the solvent was evaporated. After purification by flash chromatography on silica gel (19:1 CH_2Cl_2/EtOAc), 702 mg (95%) of **1** were isolated, mp 104-105°C (EtOAc/hexane). Ir (KBr, ν_{max}): 1320, 1705, 2940, 3120 cm^{-1}. ^1H Nmr ($CDCl_3$) δ: 7.57 (2H, d, J= 8.2, Ar*H*), 7.38 (1H, d, J= 1.5 Hz, Ar*H*), 7.30 (2H, d, J= 8.2 Hz, Ar*H*), 6.30 (1H, d, J= 1.5 Hz, Ar*H*), 5.27 (2H, s, $ArCH_2OCH_3$), 4.42 (2H, s, $ArCH_2Ts$), 3.77 (3H, s, $ArCO_2CH_3$), 3.17 (3H, s, $ArCH_2OCH_3$), 2.44 (3H, s, $ArCH_3$). ^{13}C Nmr ($CDCl_3$) δ: 164.5, 145.1, 134.8, 129.7, 129.1, 128.5, 120.6, 115.5, 115.3, 79.2, 55.8, 53.9, 51.0, 21.5. Ms: m/z (%) 337 ($M^{+\cdot}$, 0.3), 306 ($M^{+\cdot}$-OCH_3, 3), 182 ($M^{+\cdot}$-Ts, 100). HRms calcd for $C_{16}H_{19}NO_5S$: 337.0984, found: 337.0981. Anal. Calcd for $C_{16}H_{19}NO_5S$, C 56.96, H 5.67, N 4.15: Found: C 56.83, H 5.80, N 3.86.

Sulfones (**7**, **15** and **16**) were obtained as follows by a similar reaction.

Methyl *N*-methoxymethyl-4-tosylmethylpyrrole-2-carboxylate (7). Obtained from **8** in 75% yield, mp 67-70°C (EtOAc/hexane). Ir (KBr, ν_{max}): 1300, 1590, 1700, 2950 cm^{-1}. ^1H Nmr ($CDCl_3$) δ: 7.60 (2H, d, J= 8.2, Ar*H*), 7.28 (2H, d, J= 8.3 Hz, Ar*H*), 6.83 (2H, d, J= 2.9 Hz, Ar*H*), 5.54 (2H, s, $ArCH_2OCH_3$), 4.17 (2H, s, $ArCH_2Ts$), 3.80 (3H, s, $ArCO_2CH_3$), 3.22 (3H, s, $ArCH_2OCH_3$), 2.42 (3H, s, $ArCH_3$). Ms: m/z (%) 337 ($M^{+\cdot}$, 3.3), 182 ($M^{+\cdot}$-Ts, 100). Anal. Calcd for $C_{16}H_{19}NO_5S$, C 56.96, H 5.68, N 4.15: Found, C 57.21, H 5.39, N 4.33.

2-Furfuryl *p*-tolylsulfone (15) and 2-methyl-5-furyl *p*-tolylsulfone (16). Obtained from **14** in 26% and 10% yields respectively as solid compounds. **15** mp 102-104°C (EtOAc/hexane) (lit.,[13] mp 100°C). **16** mp 98-100°C (EtOAc/hexane). Ir (KBr, ν_{max}): 1320, 1490, 1590, 2925 cm^{-1}. ^1H Nmr ($CDCl_3$) δ: 7.86 (2H, d, J= 8.4 Hz, Ar*H*), 7.32 (2H, d, J= 8.4 Hz, Ar*H*), 7.07 (1H, d, J= 3.3 Hz, Ar*H*), 6.10 (1H, m, Ar*H*), 2.43 (3H, s, $TsCH_3$), 2.31 (3H, d, J= 0.4 Hz, $ArCH_3$). Ms: m/z (%) 236 ($M^{+\cdot}$, 38), 139 (CH_3PhSO, 64), 97 ($M^{+\cdot}$-CH_3PhSO, 100). Anal. Calcd for $C_{12}H_{12}O_3S$, C 61.00, H 5.12: Found, C 61.26, H 5.20.

N-Methoxymethyl-2-pyrrolylmethyl *p*-tolylsulfone (13). To a solution of pyrrole (**12**) (127 mg, 0.912 mmol) in dry isopropanol (8ml), cooled in an ice/water bath, was added 17 mg (0.45 mmol) of sodium borohydride. The reaction mixture was warmed to room temperature and stirred for 1.5 h. After removal of the solvent, sodium *p*-toluensulfinate (602 mg, 2.810 mmol) and 85% formic acid (2ml) were added and the reaction mixture was stirred for 1.5 h. Water was added and the resulting mixture was extracted with dichloromethane. The organic phase was dried (Na_2SO_4) and the solvent was evaporated, leaving a crude which was purified by flash chromatography on silica gel (9:1 hexane/EtOAc) to afford 127 mg (50%) of **13**, mp 104-105°C (EtOAc/hexane). Ir (KBr, ν_{max}): 1270, 1325, 1620, 2975, 3175 cm^{-1}. ^1H Nmr ($CDCl_3$) δ: 7.55 (2H, d, J= 8.6 Hz, Ar*H*), 7.28 (2H, d, J= 8.6 Hz, Ar*H*), 6.75 (1H, dd, J= 3.5, 1.5 Hz, Ar*H*), 6.03 (1H, d, J= 3.2 Hz, Ar*H*), 5.88 (1H, dd, J= 2.8, 1.7 Hz, Ar*H*), 5.21 (2H, s, $ArCH_2OCH_3$), 4.45 (2H, s, $ArCH_2Ts$), 3.15 (3H, s, $ArCH_2OCH_3$), 2.44 (3H, s, $ArCH_3$). ^{13}C Nmr ($CDCl_3$) δ: 144.7, 135.4, 129.5, 128.7, 124.6, 119, 114.6, 108.1, 78.6, 55.5, 54.3, 21.5. Ms: m/z (%) 279 ($M^{+\cdot}$, 31), 248 ($M^{+\cdot}$-OCH_3, 12), 124 ($M^{+\cdot}$-Ts, 100), 94 ($M^{+\cdot}$-Ts, OCH_3, 18). HRms: calcd for $C_{14}H_{17}NO_3S$: 279.0929; found: 279.0931. Anal. Calcd for $C_{14}H_{17}NO_3S$, C 60.19, H 6.13, N 5.01: Found, C 60.55, H 5.74, N 5.28.

1-(2-Thienyl)ethyl *p*-tolylsulfone (25). To a cooled solution (-80°C) of freshly distilled aldehyde (**21**) (300 mg, 2.67 mmol) in dry THF (3 ml), 1.93 ml (3.55 mmol) of a solution of methyllithium in hexanes (1.5 M) was added under argon. After 2 h stirring, methanol (2 ml) was added to destroy excess methyllithium and most methanol was removed. 85% formic acid (2 ml) and sodium *p*-toluenesulfinate (2.00 g, 9.34 mmol) were added to the resulting residue and the mixture was kept stirring at room temperature for 2 h. The resulting solution was washed with water and the aqueous phases were extracted with dichloromethane. The organic solution was dried (Na_2SO_4) and concentrated. After purification by flash chromatography on silica gel (9:1 CH_2Cl_2/hexane), 216 mg of **25** (31%) were obtained, mp 91-93°C (EtOAc/hexane). Ir (KBr, ν_{max}): 1140, 1300, 1590 cm^{-1}. ^1H Nmr ($CDCl_3$) δ: 7.41 (2H, d, J= 8.1 Hz, Ar*H*), 7.19-7.13 (3H, m, Ar*H*), 6.85-6.78 (2H, m, Ar*H*), 4.47 (1H, q, J= 7.0 Hz, CH_3CHTs), 2.31 (3H, s, $ArCH_3$), 1.69 (3H, d, J= 7.0 Hz, CH_3CHTs). ^{13}C Nmr ($CDCl_3$) δ: 144.6, 135.9, 133.2, 129.2, 129.1, 128.3, 126.6, 126.4, 61.5, 21.3, 15.3. Ms: m/z (%) 266 ($M^{+\cdot}$, 0.5), 111 ($M^{+\cdot}$-Ts, 100), 77 (10). Anal. Calcd for $C_{13}H_{14}O_2S_2$, C 58.62, H 5.30: Found, C 58.48, H 5.03.

1-(2-Furyl)ethyl *p*-tolylsulfone (26). Obtained in 63% yield from freshly distilled furfural (**22**) by a similar procedure, mp 88-90°C (EtOAc/hexane). Ir (KBr, ν_{max}): 1140, 1300, 1500, 1590 cm^{-1}. ^1H Nmr ($CDCl_3$) δ: 7.49 (2H, d, J= 8.2 Hz, Ar*H*), 7.29 (1H, d, J= 1.6 Hz, Ar*H*), 7.25 (2H, d, J= 7.9 Hz, Ar*H*), 6.32 (1H, dd, J= 3.3, 1.6 Hz, Ar*H*), 6.24 (1H, d, J= 3.3 Hz, Ar*H*), 4.37 (1H, q, J= 7.2 Hz, CH_3CHTs), 2.42 (3H, s, $ArCH_3$), 1.69 (3H, d, J= 7.2 Hz, CH_3CHTs). ^{13}C Nmr ($CDCl_3$) δ: 147.5, 144.7, 143.0, 133.9, 129.4, 129.1, 110.8, 110.6, 60.2, 21.4, 12.4. Ms: m/z (%) 250 ($M^{+\cdot}$, 0.5), 95 ($M^{+\cdot}$-Ts, 100), 67 ($M^{+\cdot}$-CH_3CHTs, 14). Anal. Calcd for $C_{13}H_{14}O_3S$, C 62.38, H 5.64: Found, C 63.20, H 5.68.

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5. For all sulfones prepared in this work the alternative alkyl sulfinate structure was ruled out on the following grounds:

   a) All the sulfones prepared in this work exhibited a very strong S=O stretching band around 1370-1290 cm^{-1} which is characteristic of sulfones and absent from alkyl sulfinates.
   b) Sulfinate salts have a great tendency to undergo *S*-alkylation as opposed to *O*-alkylation, which, as predicted by the HSAB theory, is only observed under very "hard" alkylation conditions.[6]

   c) Our physical data for compound (**15**) agree with previously published data for this compound, which is described as a sulfone.
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