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REACTIONS OF *N*-SULFINYL-*p*-TOLUENESULFONAMIDE WITH ALCOHOLS

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Abstract— *N*-Sulfinyl-*p*-toluenesulfonamide (**1**) reacted with triaryl- and diarylmethanols to give predominantly *N*-substituted sulfonamides and SO_2 presumably *via* carbonium ion intermediates. When carbonium ion forming alcohols, such as *t*-BuOH and $Ph_2C(Me)OH$, were used, the predominant products were alkenes and *p*-toluenesulfonamide. Allylic alcohols afforded *N*-substituted sulfonamides, along with dienes and *p*-toluenesulfonamide. Alcohols which could not predictably give relatively stable intermediate carbonium ions, gave either dialkyl sulfites or dialkyl ethers, along with *p*-toluenesulfonamide. In one case, namely with 9-phenylfluorenol, the 1:1 adduct with **1** (an amidosulfite) was isolated. A mechanism for the reactions is proposed.

It has been shown that sulfonyl isocyanates ($RSO_2N{=}C{=}O$) react readily with phenols[1,2] and alcohols[2] to give the normal urethan products. Triaryl methanols, however, afford the corresponding N-(triarylmethyl)sulfonamides and carbon dioxide.[3-6] In view of these findings it is of interest to compare the reactions of these sulfonyl isocyanates with that of a related cumulated system, *viz* N-sulfinyl sulfonamide.

Simple alcohols, such as methanol, have been shown to react with N-sulfinyl arylamines[7-11] but aliphatic sulfinylamines showed little or no reaction.[9] Since dimethyl sulfite was obtained from the reaction of N-sulfinylaniline and methanol the following course of reaction was suggested (Scheme 1).

$$ArN{=}S{=}O + ROH \longrightarrow ArNHS(O)OR$$

$$\xrightarrow{ROH} ArNH_2 + (RO)_2SO$$

Scheme 1.

The reaction of N-sulfinyl sulfonamides with alkyl alcohols was briefly mentioned only as giving a quantitative yield of sulfonamide and dialkyl sulfites.[12,13] Primary adducts of these simple alcohols and N-sulfinyl sulfonamides could not be isolated. Only with thiols primary adducts, $RSO_2NHS(O)SR'$, were stable enough to permit isolation.[14] This study deals with the reactions of N-sulfinyl-*p*-toluenesulfonamide **1** and a variety of substituted alcohols.

The products obtained from **1** and alcohols are dependent on the alcohol structure (Table). In addition to *p*-toluenesulfonamide **6** five different types of products were isolated, viz N-substituted sulfonamides (A), 1:1 adducts (amidosulfite B), sulfites (C), ethers (D) and alkenes (E) (Scheme 2). In those cases where triphenylmethanol, diphenylmethanol, or allylic alcohols were used products of type A resulted.

With 9-phenylfluorenol an amidosulfite of type B was isolated when the reaction was performed at 60° for 1 hr. However, employing a higher temperature and a longer reaction time this carbinol yielded N-(9-phenylfluorenyl)-*p*-toluenesulfonamide (**4**) belonging to type A. Heating the 1:1 adduct **11** in toluene resulted in loss of sulfur dioxide and formation of sulfonamide **4** in quantitative yield. When heated in ethanol **11** gave 9-ethoxy-9-phenylfluorene **21** (Scheme 3).

Types of products

A $p\text{-}CH_3C_6H_4SO_2NHR$

B $p\text{-}CH_3C_6H_4SO_2NHS(O)OR$

C $(RO)_2SO$

D R-O-R

E Alkene derived from ROH

Scheme 2

The sulfonamides A derived from allylic alcohols were always accompanied by *p*-toluenesulfonamide **6**. In two cases the other product was cycloadduct **10** of isoprene and **1** (Table 1).

With aliphatic alcohols (and also with propenol) the predominant products were sulfites C (the one exception was t-butyl alcohol, *vide infra*). The other product invariably was **6**.

Bis(9-fluorenyl)ether (**18**, type D) was the principal product, along with **6**, from the reaction of 9-fluorenol and **1**. With diphenylmethanol also an ether was obtained when the reaction was carried out at ambient temperature.

t-Butyl alcohol and 1,1-diphenylethanol led only to isobutene and diphenyl ethene (**19**, type E) respectively, along with **6**.

A plausible mechanism for the reactions described above involves the initial formation of 1:1 addition product B as is illustrated in Scheme 4 (steps *a* and *b*). If the incipient carbonium ion is sufficiently stable the amidosulfite B may dissociate into an ion pair (step *c*). The amidosulfite anion should easily lose sulfur dioxide (step *d*) to give a new ion pair which on collapse leads to N-substituted sulfonamides A (step *e*). Alternatively, the carbonium ion in the ion pair may release a proton to produce alkene E (step *f*). The proposed mechanism following steps *c*, *d* and *e* is consistent with the behaviour of triaryl- and

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Table. Reactions of N-sulfinyl-*p*-toluenesulfonamide with alcohols

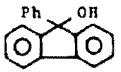
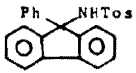
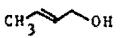
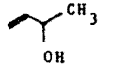
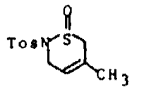
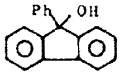
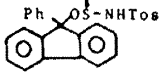
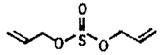
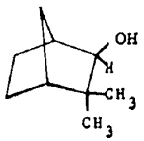
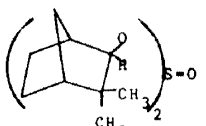
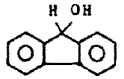
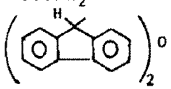
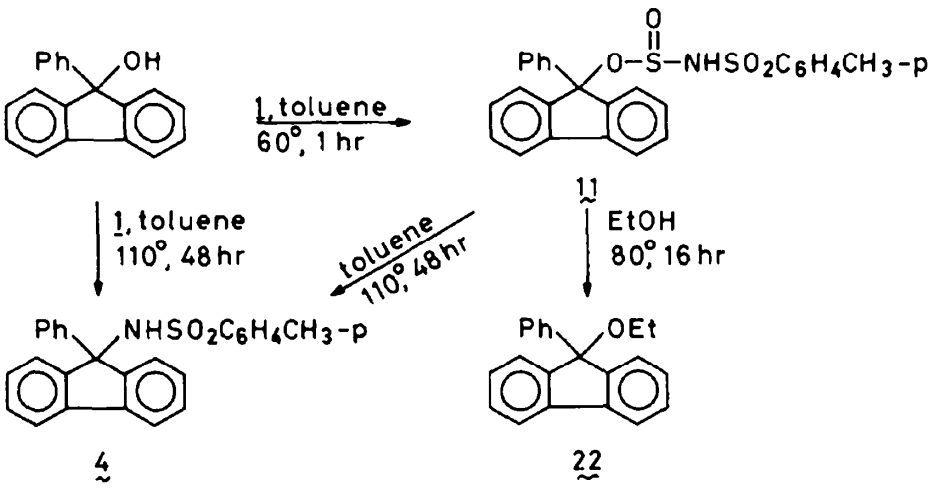
Alcohol	Ratio -N=S=O/Alc.	Solvent	Temp. (°C)	Time (hr)	Product [code #; type; %yield; m.p.(°C)]
Ph_3COH	1:1	benzene	23	2	TosNHCPh$_3$ (2; A; 86; 241-242) [3]
Ph_3COH	1:1	benzene	50-55	3.5	TosNHCPh (2; A; 84; 241-242)
Ph_3COH	1:1	xylene	100-110	0.5	TosNHCPh$_3$ (2; A; 87; 241-242)
Ph_3COH	1:1	toluene	110	6	TosNHCPh$_3$ (2; A; 84; 241-242)
Ph_2CHOH	1:1	toluene	110	12	TosNHCHPh$_2$ (3; A; 70; 155-155.5) [26]
	1:1	toluene	110	48	 (4; A; 70; 201-201.5)
	1:1	toluene	90	3	 (5; A; 59; 106-107) [27]
					TosNH$_2$ (6; -; small amt.;-)*
	1:1	toluene	90	16	 (7; A; 17; 62-63)
					(8; A; 14; -)*
					TosNH$_2$ (6; -; 55; -)*
	1:1	toluene	90	16	 (7; A; 16; 62-63)
					(8; A; 13; -)*
					TosNH$_2$ (6; -; 54; -)*
	1:1	toluene	90	3	(9; A; 37; 50-51)
					(10; -; 13; 145-146) [10]
					TosNH$_2$ (6; -; 43; -)*
	1:1	toluene	90	3	(9; A; 25; 50-51)

TABLE (continued)

Alcohol	Ratio -N=S=O/Alc.	Solvent	Temp.(°C)	Time(hr)	Product [code #; type; %yield; m.p.(°C)]
					 (10; -; 21; 145-146)[10]
					$TosNH_2$ (6; -; 28; -)*
	1:1	toluene	65	1	 (11; B; 78; 150)
	1:2	benzene	80	16	 (12; C; 71; oil)[22]**
	1:2	toluene	90	16	 (16; C; 87; -)**[24]
					$TosNH_2$ (6; -; 80; -)*
Ph_2CHOH	1:1	ether	25	20	$Ph_2CHOCHPh_2$ (17; D; 94; -)*
					$TosNH_2$ (6; -; 97; -)*
	1:1	toluene	110	5	 (18; D; -; -)*[25]
					$TosNH_2$ (6; -; 88; -)*
$Ph_2\overset{CH_3}{\underset{}{C}}-OH$	1:1	toluene	110	20	$Ph_2C=CH_2$ (19; E; 94; oil)*
					$TosNH_2$ (6; -; 97; -)*
$(CH_3)_3COH$	1:2	toluene	90	6	$(CH_3)_2C=CH_2$ (20; E; not isolated)
					$TosNH_2$ (6; -; 70; -)*

* Product identified by NMR and IR.

**Product identified by NMR, IR and independent synthesis.

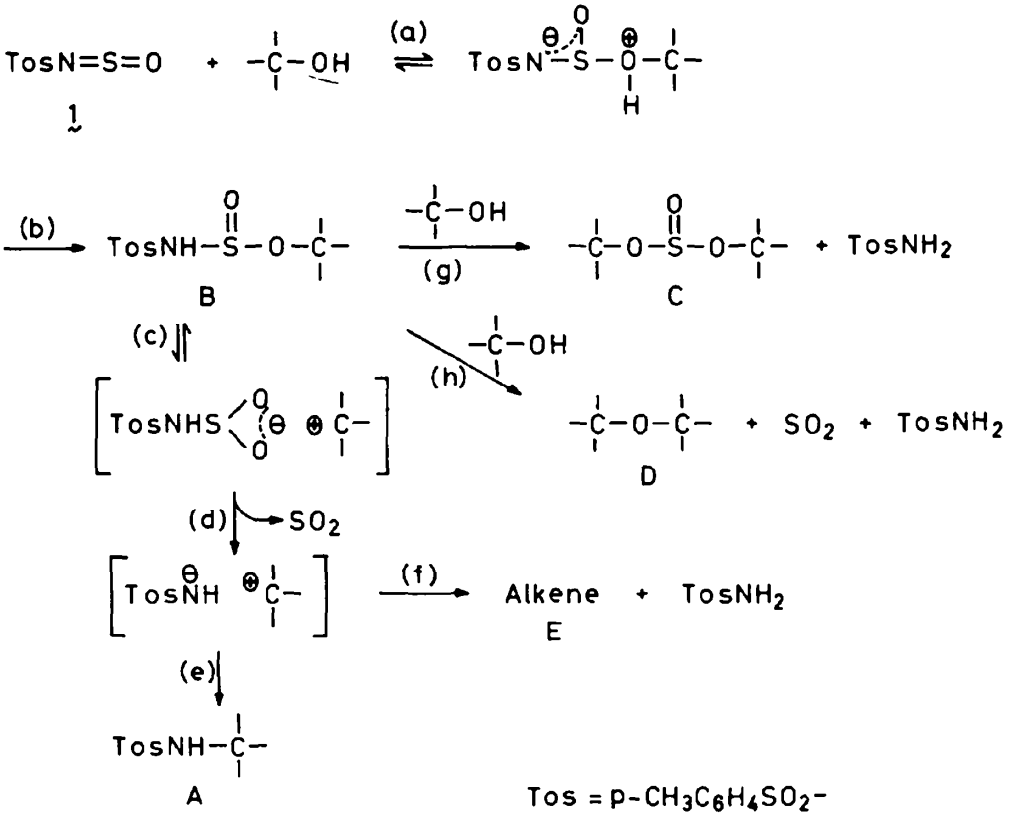


Scheme 3

diarylmethanols, and allylic alcohols. t-Butyl alcohol and 1,1-diphenylethanol follow steps *c*, *d* and *f*. Further evidence for the rationale given is provided by the results pictured in Scheme 3. The carbonium ion formed by heating of amidosulfite **11** either produces sulfonamide **4** (in toluene) or is captured by ethanol to give ether **21**.

In those cases where relatively stable carbonium ions are virtually impossible, a second molecule of alcohol apparently attacks key intermediate B. The product is either sulfite C (alcoholysis of the sulfinamide bond, step *g*) or ether D (alkylation of alcohol by a sulfinic ester, step *h*) along with *p*-toluenesulfonamide.

In summary, N-sulfinyl-*p*-toluenesulfonamide (**1**) is analogous to sulfonyl isocyanates in its reactions with alcohols which can give carbonium ions. The two cumulated systems are different, however, in reactions with alcohols that do not have this tendency to give carbonium ion intermediates. In the latter cases, sulfonyl isocyanates produce 1:1 adducts (urethans), whereas **1** gives sulfites.



Scheme 4

EXPERIMENTAL

IR spectra were taken on a Perkin–Elmer 257 grating spectrometer. NMR spectra were recorded on a Varian A60 or T60 spectrometer using $CDCl_3$ as solvent and TMS as internal standard. Elemental analyses were carried out in the microanalytical department of our laboratory by Mr J. Diersmann. All m.ps are uncorrected and were determined on a Koffler hot stage. Solvents were distilled and dried over Na. Alcohols were distilled or recrystallized before use. N-Sulfinyl-*p*-toluenesulfonamide (**1**) was prepared by a literature method.[10]

N-(Triphenylmethyl)-p-toluenesulfonamide (**2**). The general procedure for the reactions of **1** with alcohols to give N-substituted *p*-toluenesulfonamides is illustrated by this and the next reaction. To a dry, 3-necked r.b. flask fitted with N_2 inlet, stirrer and reflux condenser, were added **1** (651 mg, 3 mmol), triphenylmethanol (780 mg, 3 mmol) and toluene (15 ml). The soln was heated and stirred at 110° under N_2 for 6 hr and then cooled in ice. The white crystals of **2** were collected by filtration, weight 1.040 g (84%), m.p. 225–235°. Recrystallization from toluene afforded pure **2**, m.p. 241–242°; lit.[3] 241–242°; m.m.p. and IR spectra identical.

N-(2-Butenyl)-p-toluenesulfonamide (**7**) *and N-(1-methyl-2-propenyl)-p-toluenesulfonamide* (**8**). A soln of **1** (1302 mg, 6 mmol), 2-buten-1-ol (432 mg, 6 mmol) in toluene (30 ml) was heated and stirred under N_2 at 90° for 16 hr. Upon cooling at 0° **6** (425 mg, 41%) precipitated, identified by m.p., IR and NMR. The residue was chromatographed on a silica gel column using ether–petroleum ether (3:1) as eluent. A fraction amounting to 415 mg (31%) was shown by NMR to be a 55:45 mixture of **7** and **8**. Recrystallization from ether–pentane at −20° gave pure **7**, m.p. 62–63°. (Found: C, 58.54; H, 6.69; N, 6.25; S, 14.24. Calc. for $C_{11}H_{15}NO_2S$: C, 58.64; H, 6.71; N, 6.22; S, 14.23%).

Another fraction from the column amounted to 136 mg of **6** (a total of 561 mg, 55%).

N-(p-Toluenesulfonylamido)-9-phenylfluorenylsulfite (**11**). A soln of **1** (1.302 g, 6 mmol), 9-phenylfluorenol (1.548 g, 6 mmol) and toluene (30 ml) was stirred under N_2 and heated at 65° for 1 hr. After cooling in ice 2.21 g (78%) of **11** was collected by filtration, m.p. 145–150°. Recrystallization from methylenechloride–ether–pentane afforded pure product, m.p. 150°. (Found: C, 65.72; H, 4.46; N, 2.91; S, 13.30. Calc. for $C_{26}H_{21}NO_4S_2$: C, 65.66; H, 4.45; N, 2.95; S, 13.47%).

Conversion of **11** *to* **4**. A soln of **11** (238 mg, 0.5 mmol) in toluene (10 ml) was heated (110°) and stirred for 48 hr. Removal of solvent under reduced pressure gave 203 mg (99%) of **4**, identical with **4** prepared at high temperature (Table 1) from **1** and 9-phenylfluorenol.

Ethyl 9-phenylfluorenyl ether (**21**). A soln of **11** (476 mg, 1 mmol) in EtOH (5 ml) and toluene (5 ml) was stirred for 16 hr at 80°. Upon cooling 80 mg of **6** was filtered off. Removal of solvent from the filtrate gave a residue which upon chromatography over silica gel with 3:1 ether/petroleum ether as eluent afforded another 60 mg (total 140 mg, 82%) of **6** and 190 mg of **21**. Recrystallization from ether/pentane gave 160 mg (56%) of pure **21**, m.p. 112–114°. (Found: C, 87.87; H, 6.27. Calc. for $C_{21}H_{18}O$: C, 88.11; H, 6.29%).

Dineopentyl sulfite (**14**). This represents a general procedure for those alcohols which gave sulfites. A soln of **1** (651 mg, 3 mmol) and neopentylalcohol (528 mg, 6 mmol) in toluene (15 ml) was stirred under N_2 for 16 hr at 90°. Cooling to 0° caused the precipitation of 482 mg (94%) of **6**. Concentration of the filtrate afforded 490 mg (74%) of oil **14**, which was identified by NMR, IR, and independent synthesis (see below). IR (neat): ν_{max} 1270 (S = O) cm^{-1}; ^{1}H-NMR: δ 0.98 (s, 18H), 3.67 (s, 4H).

An independent synthesis[21–24] of **14** was effected by dissolving neopentyl alcohol (2.2 g, 0.025 mmol) and pyridine (2.05 g, 0.025 mol) in dry ether (5 ml) and adding a soln of $SOCl_2$ (1.5 g, 0.0725 mol) in dry ether (5 ml) at −10°. After 1 hr of stirring the pyridine. HCl was filtered off and the filtrate concentrated. The residual oil was identical by NMR and IR to **14** prepared above.

Reaction of **1** *with fluorenol*. After heating and stirring a soln of **1** (651 mg, 3 mmol) and fluorenol (546 mg, 3 mmol) in toluene (20 ml) at 110° for 5 hr and then cooling at 0°, 450 mg (88%) of **6** was filtered off. Concentration of the filtrate under reduced pressure gave a residue which was identified as **18**[25] by its NMR: δ 5.92 (s, 2H), 7.1–7.8 (m, 16H).

1,1-Diphenylethene (**19**). A soln of **1** (651 mg, 3 mmol) and diphenylmethylmethanol (594 mg, 3 mmol) in toluene (15 ml) was heated and stirred for 20 hr at 110°. Upon cooling at 0° 500 mg (97%) of **6** precipitated and was collected by filtration. Concentration of the filtrate afforded 507 mg of a yellow oil which was identified by NMR as **19** [δ 5.42 (s, 2H), 7.28 (s, 10H)][26].

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