partially soluble in EtOAc. The material was transferred to a separatory funnel containing aqueous NH_4Br (saturated) and shaken, whereupon the orange color appeared in the organic layer while a white flock precipitated in the aqueous phase. The aqueous phase was extracted with EtOAc, but the solid remained in the aqueous layer. The combined EtOAc extracts were washed (3×) with brine, filtered through cotton, concentrated, and placed under high vacuum. Column chromatography (750 g silica gel, 1:1 EtOAc–ligroin [60–80 °C]) afforded 1.8 g (2.054 mmol, 27%) of white solid **23**, which was chemically pure by TLC. The IR spectrum (AgCl, CH_3CN) showed an OH stretch (3375 cm^{-1}), a C–O stretch (1205 cm^{-1}), but no lactone carbonyl stretch. ^1H NMR (acetone-d_6): δ 3.34 (bs, 2 H, alcoholic OH), 6.7–7.9 (m, 14 H, aromatic), 8.72 (bs, 2 H, phenolic OH). ^{13}C NMR (acetone-d_6): δ 114.55, 116.74, 126.70, 129.18, 130.94, 131.0, 132.29, 133.0, 133.60, 135.37, 136.24, 147.92, 159.98. The lines at 131.0 and 133.0 were very small. LRMS: M^+ 876 (9), 859 (76), 857 (100). HRMS: *m/e* calculated 876.081 60, *m/e* observed 876.078 87.

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Registry No. **1**, 1095-77-8; **2**, 127002-41-9; **3**, 127002-42-0; **4**, 127002-43-1; **5**, 127002-44-2; **6a**, 127002-45-3; **6b**, 127002-46-4; **6c**, 127002-47-5; **6c** diacid derivative, 127002-48-6; **7a**, 127002-49-7; **7b**, 127002-50-0; **8**, 127002-51-1; **9**, 127002-52-2; **10**, 127002-57-7; (**10**) (**11**) (copolymer), 127002-58-8; (**10**) (**13**) (copolymer), 127032-66-0; **11**, 1478-61-1; **12**, 127002-55-5; **13**, 101-80-4; **14**, 127002-56-6; **22**, 127002-53-3; **23**, 127002-54-4; HFA, 684-16-2; *p*-NO_2PhCH_2Br, 100-11-8; 4-FPhCOCl, 403-43-0; 4-BrPhOH, 106-41-2; 4-cyanobenzyl bromide, 17201-43-3; 1,4-dibromobenzene, 106-37-6.

Base-Induced Disproportionation of Halomethyl Phenyl Sulfones to Methyl and Dihalomethyl Phenyl Sulfones

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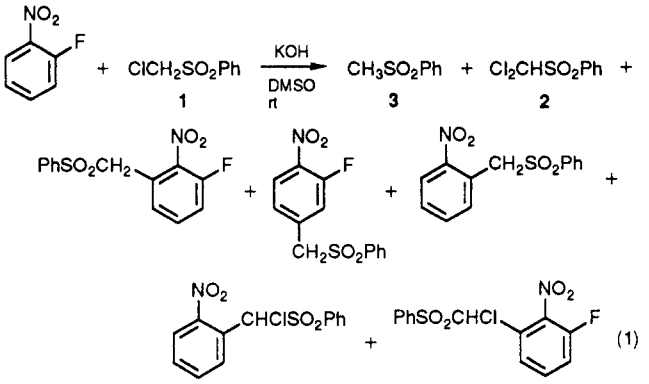
Due to steric hindrance at the tetrahedral carbon, α-halomethyl sulfones are relatively inert toward intermolecular nucleophilic substitution,[1] a feature that renders these compounds especially suited for the alkylation of nitroarenes via the vicarious nucleophilic substitution (VNS) reaction.[2] Thus, chloromethyl phenyl sulfone (**1**) has been used as a model nucleophile in many applications of the VNS reaction since it has no tendency to self-condensation.[2] In an attempt to perform the VNS reaction between 2-fluoronitrobenzene and **1** with KOH in DMSO, we observed a very fast and exothermic reaction; **1** was consumed in only a few minutes and led to a complex product mixture, which included dichloromethyl phenyl sulfone (**2**) and methyl phenyl sulfone (**3**), as well as several nitrobenzene derivatives conceivably resulting from S_NAr and VNS reactions involving the anions of **1**–**3** (eq 1). These observations prompted the present investigation which revealed a so far unreported reactivity of α-halomethyl phenyl sulfones in strongly basic media.

Treatment of **1** with excess KOH in DMSO at room temperature (typical conditions used for the VNS reaction)[2b] resulted in complete reaction after 1 h and led to the isolation of **2** and **3** in 22% and 26% yields, respectively (eq 2, X = Cl). The bromo-substituted analogue,



(1)

$$\underset{0.5\ M}{PhSO_2CH_2X} \xrightarrow[DMSO,\ rt]{KOH\ (7\ equiv)} PhSO_2CHX_2 + PhSO_2CH_3 \quad (2)$$

bromomethyl phenyl sulfone, when subjected to the same conditions, underwent the same process with greater efficiency: the reaction was complete in 1 min, methyl phenyl sulfone and dibromomethyl phenyl sulfone being recovered in 57% and 31% yields, respectively (eq 2, X = Br).

To further investigate this interesting disproportionation of a monohalo derivative to the corresponding dihalo and hydrogenated derivatives, experiments were conducted under homogeneous conditions, using *t*-BuOK as a base. The results with 0.31 M *t*-BuOK were not significantly different from those obtained with KOH. The progress of a typical reaction, monitored by GLC analysis, is shown in Figure 1. In this as in all other experiments, it was noted that the concentration of the dihalo derivative reached a maximum and then decreased, an effect which was more evident for the bromo-substituted compound. Independent experiments proved that the dihalomethyl phenyl sulfones are reactive in the basic media used to study reaction 2.[3]

The effects of added nitroarenes are also of interest. While, as mentioned earlier, 2-fluoronitrobenzene activates the disproportionation reaction, nitrobenzene and other halonitrobenzenes, like 4-chloronitrobenzene, react more slowly with **1** to give the product of VNS substitution in high yields.[2b]

It was also found that the substrate initial concentration has an effect on the efficiency of reaction 2, which occurs to a significant extent only at high substrate concentration, as indicated by the data of Table I. From the curves of Figure 2, half-life times were roughly 5 and 190 min for initial substrate concentrations of 0.30 and 0.10 M, respectively. It should be also noted that reaction 2 is in competition with at least one other process, prevailing at low substrate concentrations, which consumes **1** and base, as shown, for example, by the drop in base concentration from 0.31 to 0.05 M in the experiment with [**1**] = 0.1 M.

As for the mechanism of reaction 2, which displays a kinetic order greater than 1 for the substrate, an attractive possibility is shown in Scheme I. The key step in this mechanism is an X-philic reaction,[4] which involves nu-

† Erasmus visiting student from University College, Dublin, Ireland.

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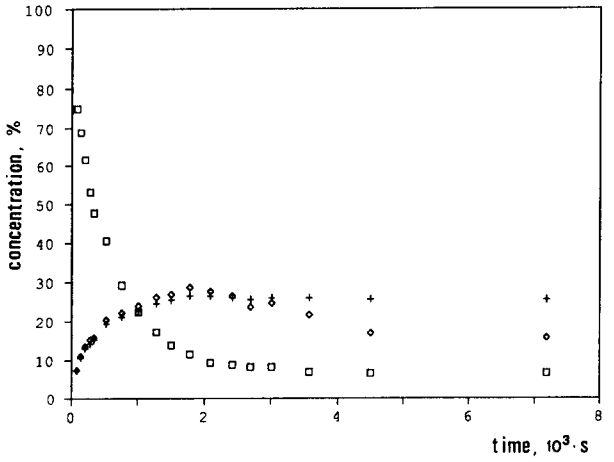

Figure 1. Time dependence of reagent and products concentrations, expressed as percent of the reagent initial concentration, in the reaction of $PhSO_2CH_2Cl$ (1) (0.30 M) with *t*-BuOK (0.31 M) in DMSO at 25 °C. (□) $PhSO_2CH_2Cl$; (+) $PhSO_2CH_3$; (◇) $PhSO_2CHCl_2$.

Table I. Effect of Substrate Concentration in the Base-Induced Disproportionation of $PhSO_2CH_2Cl$ (1) to $PhSO_2CHCl_2$ (2) and $PhSO_2CH_3$ (3)[a]

		yield, %	
[1], M	*t*,[b] min	2	3
0.30	120 (5)	16	26
0.25	150 (35)	10	16
0.20	164 (75)	8	13
0.10	280 (190)	1	3

[a] In DMSO with *t*-BuOK (0.31 M) at 25 °C. [b] Time required for substrate concentration to reach a few percent and, in parentheses, half of its original value.

Scheme I

$$PhSO_2CH_2Cl + B^- \rightleftharpoons PhSO_2\bar{C}HCl + BH$$

$$PhSO_2\bar{C}HCl + Cl{-}CH_2SO_2Ph \rightleftharpoons PhSO_2CHCl_2 + PhSO_2CH_2^-$$

$$PhSO_2CH_2^- + PhSO_2CHCl_2 \longrightarrow PhSO_2CH_3 + PhSO_2\bar{C}Cl_2$$

cleophilic attack on halogen, a reaction with precedents in the literature. It has long been known that the reaction of α-halo sulfones with nucleophiles (alkoxide ions,[5,6] thioanions,[5,6] PhMgBr,[5] piperidine,[6] phosphines,[7] and sulfite ion[8]) leads, in the presence of a proton donor, to reductive dehalogenation initiated by nucleophilic attack at halogen. Procedures of synthetic utility have recently been developed based on this reaction.[9] Even for the few instances when substitution at the α-carbon was observed, as in the reaction of $PhCOCHXSO_2CH_3$ (X = Cl, Br) with RS^- in THF, a two-step mechanism has been proposed, involving initial attack on halogen.[10] We note that likely the second step of Scheme I is reversible, the irreversibility of the third step being the driving force for the overall reaction.

Reductive dehalogenation has also been observed with carbon anions.[11] Thus, methyl phenyl sulfone was obtained from the reaction of $PhSO_2CH_2Br$ with 9-substituted fluorenyl anions in DMSO. In these systems, however, all evidence pointed to the operation of a radical mechanism, initiated by one-electron reduction of the sulfone. The resulting radical anion fragments to Br^- and $PhSO_2CH_2^\bullet$, and the latter forms methyl phenyl sulfone via H• abstraction from the solvent or some other hydrogen donor.[11] Thus, a radical mechanism should also be considered for reaction 2. To account for the formation of the dihalomethyl phenyl sulfone product, never observed in the radical processes mentioned above,[11] an additional step should be included, involving X• abstraction from the substrate by $PhSO_2\dot{C}HX$ (Scheme II). The radical mechanism of Scheme II, however, appears rather unlikely for the following reasons: (i) the reaction takes place in solutions containing oxygen, a known oxidant of radical anions; (ii) there is no precedent in the literature, to the best of our knowledge, for closely related X• abstractions; and (iii) the stimulation by 2-fluoronitrobenzene (eq 1) is not readily accounted for. Thus, while it could be argued that the effect of 2-fluoronitrobenzene is due to catalysis in the electron transfer steps, it is not clear why the other halonitrobenzenes, which all have very similar electrochemical reduction potentials,[12] should not behave equally, but rather undergo the VNS reaction quite efficiently.[2b] The peculiar behavior of 2-fluoronitrobenzene is likely related to the far greater S_NAr reactivity of *o*- and *p*-fluoronitrobenzenes relative to all other halonitrobenzenes. The enhanced reactivity of 1 in the presence of 2-fluoronitrobenzene can thus be attributed to a fast S_NAr step

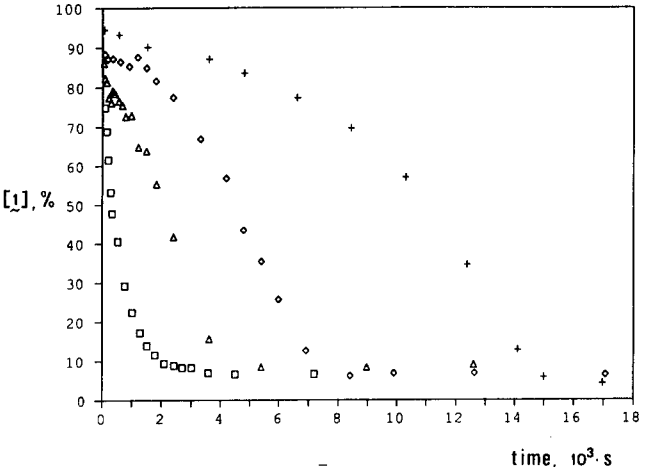

Figure 2. Time dependence of reagent concentration, expressed as percent of the reagent initial concentration, in reactions of $PhSO_2CH_2Cl$ (1) with *t*-BuOK (0.31 M) in DMSO at 25 °C. Initial concentrations of 1 were: 0.30 M (□), 0.25 M (△), 0.20 M (◇), and 0.10 M (+).

Scheme II

$$PhSO_2CH_2X + B^- \rightleftharpoons PhSO_2\bar{C}HX + BH$$

$$PhSO_2\bar{C}HX + PhSO_2CH_2X \longrightarrow PhSO_2\dot{C}HX + [PhSO_2CH_2X]^{\bullet-}$$

$$[PhSO_2CH_2X]^{\bullet-} \longrightarrow PhSO_2CH_2^\bullet + X^-$$

$$PhSO_2CH_2^\bullet \xrightarrow{+H^\bullet} PhSO_2CH_3$$

$$PhSO_2\dot{C}HX + PhSO_2CH_2X \longrightarrow PhSO_2CHX_2 + PhSO_2CH_2^\bullet$$

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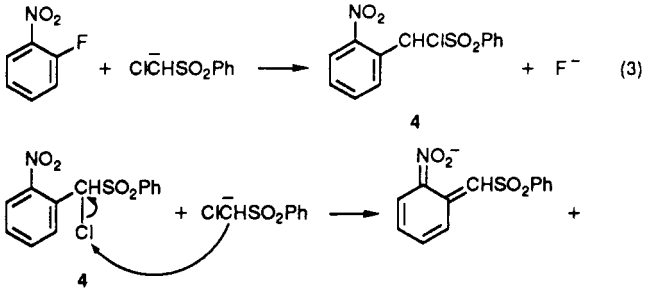
to give 4 (eq 3), which in turn undergoes halogen abstraction by the anion of 1 (eq 4). This latter step should



(3)

(4)

compete favorably with the analogous attack on 1 of Scheme I (forming methyl phenyl sulfone), since the resonance-stabilized nitrophenyl-substituted carbanion should be a better leaving group than $PhSO_2CH_2^-$. We thus favor Scheme I for the disproportionation of eq 2 and suggest that, in the presence of 2-fluoronitrobenzene, chloromethyl phenyl sulfone reacts according to a mechanism which comprises Scheme I and eqs 3–4.

In the case of bromomethyl phenyl sulfone, which gave the reduced product 3 in slight excess of the stoichiometric 50% yield required by the mechanism of Scheme I, there is probably a minor radical reaction component. $PhSO_2CH_2Br$ is a better one-electron acceptor than $PhSO_2CH_2Cl$,[11a] and the ease of fragmentation of the carbon–halogen bond in radical anions of haloderivatives follows the order Br > Cl. Thus, in this case (eq 2, X = Br), steps 1–4 of Scheme II probably provide a competing route for reductive dehalogenation of $PhSO_2CH_2Br$ to 3.

In conclusion, we believe that reaction 2 is an example of nucleophilic attack on halogen by an sp^3 hybridized carbanion. Precedents of carbon anions as nucleophiles in X-philic reactions commonly involve aryl anions as in the "halogen dance" of polyhalobenzenes.[13]

Experimental Section

GC analyses were performed on a Varian 3700 gas chromatograph interfaced to a Varian 401 Vista Series integrator and equipped with a 1.8 m × 2 mm i.d. glass column packed with 10% Carbowax 20 M on Chromosorb Z-DMCS. A Hewlett-Packard 5890 GC-5970 MSD system was used for GC–MS analysis, with a 15-m fused silica capillary column of polymethylsiloxane bonded phase. ^1H NMR spectra were recorded on a 200-MHz Bruker spectrometer.

Materials. DMSO (reagent grade product from Merck) was fractionally distilled and stored over molecular sieves (4 Å). *t*-BuOK (Aldrich) was sublimed before use. $PhSO_2CH_2Cl$ (1),[2b] $PhSO_2CH_2Br$,[2b] $PhSO_2CHCl_2$,[14] and $PhSO_2CHBr_2$[14] were prepared and purified according to published procedures.

$PhSO_2CHCl_2$: mp 59–60 °C (lit. mp 59 °C.[15] *NOTE*: higher melting point values have also been reported; 81.5–83 °C,[14] 79–81 °C[16]); ^1H NMR ($CDCl_3$) δ 6.25 (s, 1 H), 7.59–7.70 (m, 2 H), 7.74–7.84 (m, 1 H), 8.00–8.07 (m, 2 H); MS *m/z* (relative intensity) 225 (<1, M^+), 141 (16), 125 (3), 77 (100), 51 (70).

$PhSO_2CHBr_2$: mp 78–79 °C (lit. mp 78 °C.[17] *NOTE*: higher melting point values have also been reported; 114.5–115 °C[14]); ^1H NMR ($CDCl_3$) δ 6.24 (s, 1 H), 7.57–7.68 (m, 2 H), 7.72–7.83 (m, 1 H), 8.02–8.10 (m, 2 H); MS *m/z* (relative intensity) 314 (<1, M^+), 141 (10), 125 (47), 77 (100), 51 (90).

Product Studies. Finely powdered KOH (3.7 g, 70 mmol) was added to a solution of 1 (1.8 g, 9.5 mmol) in 19 mL of DMSO. After being stirred for 1 h, the mixture was poured in dilute aqueous HCl and extracted with $CHCl_3$. The crude product (1.7 g) was subjected to low-pressure column chromatography (eluent: petroleum ether/chloroform mixtures) and yielded 0.39 g (2.5 mmol, 26% yield) of methyl phenyl sulfone (2) and 0.46 g (2.0 mmol, 22% yield) of dichloromethyl phenyl sulfone (3). The same procedure was used when *t*-BuOK was used as the base, and also in the reactions of bromomethyl phenyl sulfone, except that with this substrate the reaction was quenched after one min. The recovered products had melting points (cf. values above) and spectral properties equal to those of authentic samples.

The products of the reaction between 2-fluoronitrobenzene and chloromethyl phenyl sulfone were characterized by HRGC–MS analysis, and, when possible, by the coincidence of retention times and mass spectra with those of authentic samples. Notably, eq 1 describes the product distribution at very short reaction times; most of these products rapidly undergo further reactions.

Kinetic Experiments. To a solution of 1 (1.14 g, 6 mmol in 2 mL of DMSO) contained in a vessel thermostatted at 25 °C was added 18 mL of a previously thermostatted 0.31 M *t*-BuOK DMSO solution in DMSO. Next, 1.0-mL aliquots were withdrawn with graduated pipettes at desired times and quenched with ca. 1 mL of dilute aqueous HCl (2%). After addition of 5.0 mL of a CH_2Cl_2 solution containing dibenzyl ether, used as GC internal standard, the layers were separated, and the organic layer was subjected to GC analysis.

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Registry No. 1, 7205-98-3; 2, 31540-74-6; 3, 3112-85-4; 4, 127354-27-2; $PhSO_2CH_2Br$, 19169-90-5; $PhSO_2CHBr_2$, 16003-66-0; *o*-$FC_6H_4NO_2$, 1493-27-2; *o*-$C_2NC_6H_4CH_2SO_2Ph$, 69709-34-8; 2-fluoro-6-[(phenylsulfonyl)methyl]nirobenzene, 127354-25-0; 2-fluoro-4-[(phenylsulfonyl)methyl]nitrobenzene, 127354-26-1.

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Reaction of Aryl and Alkyl Nitro Compounds with 2-Butenylmagnesium Chloride: Synthesis of a New Class of Nitrones

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Nitrones have received great attention during recent years because they have been revealed as important intermediates in organic synthesis. Indeed nitrones are versatile 1,3-dipoles useful for the construction of nitrogen heterocycles, which are largely present in natural products like alkaloids and β-lactams.[1] Some of them, e.g. phenyl-*tert*-butylnitrone have also been used as spin-trapping reagents and utilized in studies concerning radical pro-

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