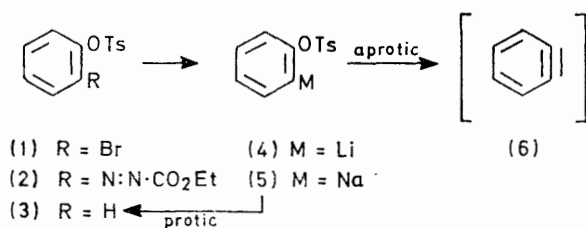


Preparation of Benzyne from Phenyl Benzenesulphonate

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Phenyl benzenesulphonate (7) gives benzyne when treated with lithium tetramethylpiperidide (9). The yields of various benzyne-derived products are not as high as when bromobenzene is used to generate the benzyne. Such benzyne as is produced comes entirely from the aromatic ring derived from the phenol.

ARENESULPHONATE ions are often used as leaving groups in place of halide ions. Yet only once has an arenesulphonate ion been the nucleofugal leaving group for the formation of a benzyne: *o*-bromophenyltoluene-*p*-sulphonate (1) with lithium at -70°C gave benzyne (6), which was identified by trapping with furan.¹ When



o-ethoxycarbonylazophenyl toluene-*p*-sulphonate (2) was treated with sodium ethoxide in ethanol, no benzyne was formed under conditions where the corresponding bromide did give benzyne, and hence phenetole.³ Presumably the metallation to give (5) proceeded in the usual way, but, for a sulphonate leaving group, elimination must have been much slower than protonation by ethanol.² When bromide was the leaving group, elimination was evidently faster than protonation. When phenyl toluene-*p*-sulphonate (3) itself was heated with sodium ethoxide, it did give a nearly quantitative yield of phenetole,⁴ but this was not a benzyne reaction. The ethoxide ion had attacked the sulphonyl group to give phenoxide ion and ethyl toluene-*p*-sulphonate, which recombined to give phenetole and toluene-*p*-sulphonate ion.

In connection with another problem, we wanted to be able to make benzyne from simple phenyl arenesulphonates. We thought that none of the obstacles encountered in the earlier work was insuperable, and that the lithium dialkylamides, which have come into use since that earlier work was done, would be suitable bases. They should be strong enough to carry out the elimination; they would, if a suitably hindered base were used, be unlikely to attack at the sulphonyl group; and they are known not to be especially nucleophilic towards benzyne, a circumstance that permits a number of alternative nucleophiles to be added to benzyne in their presence.

When phenyl benzenesulphonate (7) was treated at room temperature in tetrahydrofuran (THF) with lithium tetramethylpiperidide (9),⁵ *N*-phenyltetramethylpiperi-

¹ G. Wittig and K. Grohmann, personal communication to R. W. Hoffmann, quoted in ref. 2, p. 66.

² R. W. Hoffmann, 'Dehydrobenzene and Cycloalkynes,' Academic Press, New York, 1967.

dine (10) was produced in 10–20% yield. Benzyne was shown to be involved by trapping it with lithium phenylacetylide, with diphenylisobenzofuran, and with the enolate of acetaldehyde (present when THF is warmed with this base⁶): the expected benzyne-derived products, (11), (12), and (13),⁶ respectively, were obtained (Scheme 1). In each case, the yield was clearly lower than we obtained from the corresponding bromide (8). Thus aryl arenesulphonates *can* be used for the preparation of benzyne, but they do not seem to be as useful as the corresponding aryl bromides.

One reason why the yields were low was revealed by a more careful study of the products of the simple reaction of phenyl benzenesulphonate (7) with lithium tetramethylpiperidide (9). Two of the neutral products were dibenzothiophene dioxide (15) and tribenzothiepin dioxide (16), and a major acidic product was phenol. (Benzenesulphonic acid must also have been produced, but we did not attempt to isolate it.) These products could have been produced by the route shown in Scheme 2. Since that scheme involves metallation *ortho* to the sulphonyl group (14), it was possible that the benzyne detected in all our reactions had come, not from the benzene ring derived from phenol, but from the benzene ring derived from benzenesulphonyl chloride. This proved not to be true. Using the conditions (hot THF⁶) which lead to anthracene products, and using phenyl toluene-*p*-sulphonate in place of phenyl benzenesulphonate, we obtained only anthracene and no detectable amount of methyl- or dimethyl-anthracene. On the other hand, using *p*-cresyl benzenesulphonate, we obtained a mixture of 2,6- and 2,7-dimethylanthracenes and no detectable amount of anthracene.

One way to improve the yield of benzyne might be to prevent the occurrence of these side reactions by using an arenesulphonate which has no *ortho*-hydrogen atoms. Phenyl mesitylenesulphonate, however, gave a high yield of phenol, perhaps as a result of metallation on the *ortho*-methyl groups

EXPERIMENTAL

Preparation and Reactions of Benzyne.—Typical reaction conditions were as follows: phenyl benzenesulphonate (0.468 g, 2 mmol) in dry tetrahydrofuran (10 ml) was added dropwise over 20 min with continuous stirring under nitrogen at -5°C to a mixture of 2,2,6,6-tetramethylpiperidine (0.84 ml, 5 mmol) and *n*-butyl-lithium (15% solution in

³ R. W. Hoffmann, *Chem. Ber.*, 1965, **98**, 222.

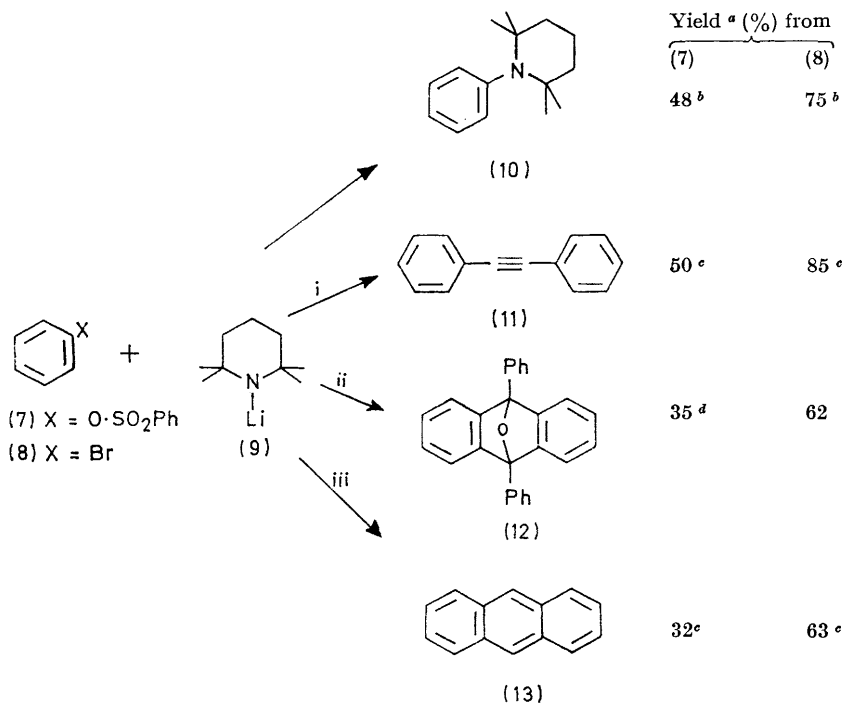
⁴ J. Ferns and A. Lapworth, *J. Chem. Soc.*, 1912, 273.

⁵ R. A. Olofinson and C. M. Dougherty, *J. Amer. Chem. Soc.*, 1973, **95**, 582.

⁶ I. Fleming and T. Mah, *J.C.S. Perkin I*, 1975, 964.

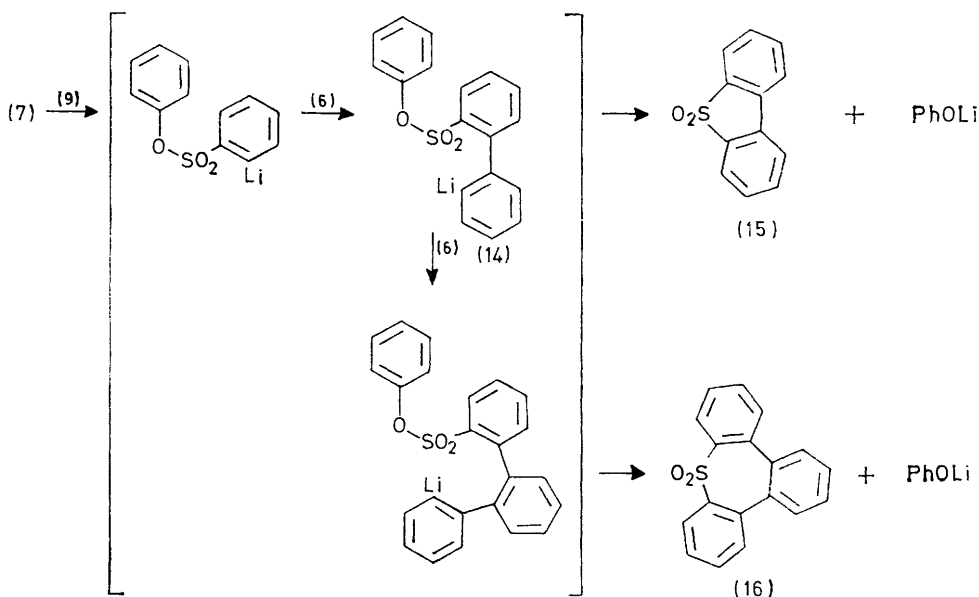
hexane; 2.1 ml, 5 mmol) prepared at -5°C in dry tetrahydrofuran (30 ml). The mixture immediately turned dark brown. When the addition was complete, the mixture was allowed to warm to room temperature and stirred for

identical (m.p. and mixed m.p.) with an authentic sample. The ether layer was washed with dilute hydrochloric acid and water and dried (Na_2SO_4). Evaporation left an oil (0.114 g), which was a mixture of the neutral products.



SCHEME 1 Reagents: i, $\text{PhC}\equiv\text{CLi}$; ii, diphenylisobenzofuran; iii, $\text{CH}_2=\text{CH-OLi}$ ⁶

^a Not optimised, but the same reaction conditions were used for (7) and (8). ^b Estimated by n.m.r. ^c Yield of isolated product. ^d Yield estimated by reduction ⁹ to diphenylanthracene and isolation.



SCHEME 2

another 30 min. The tetrahydrofuran was evaporated off and the residue taken up in ether and washed with water. The aqueous layer contained the acidic product, phenol (0.038 g, 20%), identified as its toluene-*p*-sulphonate,

T.l.c. (silica gel; ether-hexane, 2 : 1) showed several bands. One fluorescent spot (R_F 0.7) ran at the same rate as biphenylene; eluting this product gave an oil (0.021 g), the mass spectrum of which showed only a weak peak at m/e

152; biphenylene was evidently a very minor product, if present at all. The major spot on the t.l.c. plate (R_F 0.2) yielded crystalline material (0.040 g; m.p. 175–195°); the mass spectrum before recrystallization, showed prominent peaks at m/e 292 and 216. After several recrystallizations from chloroform–ethanol, tribenzothiepin dioxide (16) (0.025 g) was obtained; m.p. 211–212° (lit.,⁷ 200–201°; lit.,⁸ 192–194°); m/e 292 (100%), ν_{\max} (KBr) 3 085w, 3 010w, 1 595m, 1 580m, 1 495w, 1 295s (SO₂), 1 155s (SO₂), 760s, and 705s cm⁻¹, τ (CDCl₃) 2.1–2.6 (m); λ_{\max} (EtOH) 323 (ϵ 564), 289.5 (6 800), 277 (8 900), 241 (47 000), 233.5 (47 000), 227 (36 000), and 222 nm (31 000). [With inverse addition the yield of pure tribenzothiepin dioxide (16) was raised to 25%.] We were not able to separate the dibenzothienophen dioxide (15), but the t.l.c. behaviour of an authentic sample showed that it would be found in this fraction and the mass spectrum showed that it was present as a minor contaminant before the recrystallization.

The aqueous layer was made alkaline with sodium hydroxide solution and extracted with ether; the extract washed with water, dried (Na₂SO₄), and evaporated to leave a mixture of *N*-phenyl-2,2,6,6-tetramethylpiperidine (10) and 2,2,6,6-tetramethylpiperidine (0.5 g). The yield (0.204 g, 47%) of *N*-phenyl-2,2,6,6-tetramethylpiperidine (10) was estimated by integration of the n.m.r. spectrum of the mixture. It was not isolated, but the mass spectrum of the mixture showed the expected peaks at m/e 217 (M^+), 202 ($M - \text{CH}_3$, 100%), 146 (202 - C₄H₈) (m^* 105.5 for 202 → 146), and 118 (146 - C₂H₄, *i.e.* PhN⁺=CMe), together with smaller peaks at m/e 141 (M^+), 126, 70, and 42 for 2,2,6,6-tetramethylpiperidine. The reactions with bromobenzene in place of phenyl benzenesulphonate were done under the same conditions; the yields are quoted in Scheme 1.

Trapping of Benzynes with Various Reagents.—The typical conditions described above were used, with the following variations.

⁷ A. J. Neale, T. J. Rawlings, and E. B. McCall, *Tetrahedron*, 1965, **21**, 1299.

⁸ W. Tochtermann, K. Oppenländer, and M. N.-D. Hoang, *Annalen*, 1967, **701**, 117.

(i) *Diphenylacetylene* (11). Two mmol of phenylacetylene and 2 mmol extra of *n*-butyl-lithium were used. The neutral products (0.302 g) after t.l.c. (silica gel; ether–hexane, 2:1) gave diphenylacetylene (0.178 g, 50%), identical with an authentic sample (m.p., n.m.r. and i.r. spectra, t.l.c. and g.l.c.).

(ii) 9,10-*Diphenylanthracene oxide* (12). The oxide was prepared by adding the solution of the base in cold tetrahydrofuran to a mixture of 1,3-diphenylisobenzofuran (2 mmol) and the benzyne precursor. The crude neutral products were reduced with zinc⁹ and the 9,10-diphenylanthracene was isolated by simple crystallization. Recrystallization from acetic acid gave needles (0.170 g), m.p. 247.5–248.5° (lit.,⁹ 245–247°). The yield of 9,10-diphenylanthracene oxide (12) (0.176 g, 35%) was estimated on the assumption of a 100% yield for the reduction.

2,6- and 2,7-*Dimethylanthracene*.—*p*-Cresyl benzenesulphonate (0.496 g) was used in place of phenyl benzenesulphonate in the general reaction. The neutral product was purified by t.l.c. (silica gel; ether–hexane, 2:1) to separate the anthracene products (0.11 g, 29%). The mass spectrum of the mixture showed a strong peak at m/e 206 (M^+ for dimethylanthracene) and only a very weak peak at m/e 178. Furthermore, the n.m.r. spectrum of the mixture integrated well for dimethylanthracene: τ (CDCl₃) 7.45 (6 H, s) and 1.7–2.85 (8 H, m), and the signal of the 9- and 10-protons of anthracene at τ 1.58, was absent. The mixture crystallised, and had m.p. 210–212° (lit.,¹⁰ for a comparable mixture, 219–220°). By contrast, when phenyl toluene-*p*-sulphonate was used, anthracene (13) was produced, identical (m.p. and n.m.r. spectrum) with authentic material.

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⁹ G. Wittig, E. Knauss, and K. Niethammer, *Annalen*, 1960, **630**, 10.

¹⁰ D. H. Hey, *J. Chem. Soc.*, 1935, 72.