

[CONTRIBUTION FROM THE DEPARTMENT OF CHEMISTRY OF VANDERBILT UNIVERSITY]

Grignard Reagents of Sulfones. II. Reactions with Carbonyl Compounds¹

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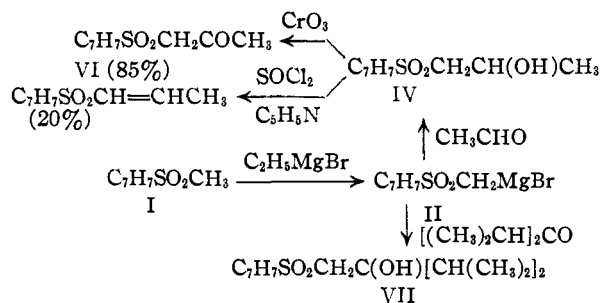
p-Tolylsulfonylmethylmagnesium bromide (II) adds normally to acetaldehyde and diisopropyl ketone. The reactivity of phenylsulfonylmethylmagnesium bromide (III) seems comparable to that of phenylmagnesium bromide in competition for benzaldehyde, but conclusions as to the reactivity of III alone from this result may be unjustified. α -(*p*-Tolylsulfonyl)ethylmagnesium bromide (IX) and α -(*p*-tolylsulfonyl)isopropylmagnesium bromide (XIV) add normally both to benzaldehyde and acetone, but XIV neither adds to nor reduces diisopropyl ketone significantly. The yields of addition products are generally fair to excellent. α -(Phenylsulfonyl)benzohydrylmagnesium bromide (XVII) is apparently unobtainable from benzohydryl phenyl sulfone and ethyl-magnesium bromide; subsequent hydrolysis regenerates only traces of the sulfone. Methyl sulfone forms both a mono- (XIX) and bis-Grignard derivative (XXI) which add to benzaldehyde and acetone, respectively, but in relatively lower yields. Physical and chemical evidence is given for the structure of typical addition products.

The reactions of *p*-tolylsulfonylmethylmagnesium bromide (II) with benzophenone² and of phenylsulfonylmethylmagnesium bromide (III) with benzaldehyde³ give adducts which are typical of those normally encountered in reactions of carbonyl compounds with Grignard reagents. This paper reports a study of the generality of this type of reaction between Grignard reagents of sulfones and carbonyl compounds.

Neither benzophenone nor benzaldehyde contains an enolizable hydrogen atom. Accordingly, the first reaction studied was that of II and acetaldehyde. The product IV, obtained in 100% yield despite the seeming insolubility of II in the ether-benzene solvent, was characterized as the known acetate. In order to provide information as to the synthetic possibilities of compounds of its type, IV was oxidized to the known ketone in a yield similar to that obtained³ with β -phenyl- β -hydroxyethyl phenyl sulfone (V). Dehydration of IV on the other hand to the known 1-(*p*-tolylsulfonyl)-1-propene was effected only in much lower yields than with V.

Recent work by Bordwell and Cooper⁴ indicates that in nucleophilic displacement reactions such as those of α -halosulfones, the sulfone group resembles the neopentyl group, to which it also shows a formal similarity, in exerting a steric blocking effect. In contrast, however, to the reaction of neopentylmagnesium chloride and diisopropyl ketone, in which addition occurs only to the extent of about 4%,⁵ II and diisopropyl ketone give a normal adduct in 55% yield. This result, indicating that hindrance is insignificant in this addition reaction of II, seemingly supports the suggestion⁴ that the hindrance exerted by the sulfonyl group to nucleophilic displacement may be explained by assuming that the partial negative charge on the oxygen atoms of the sulfonyl group greatly extends their effective radii in blocking an incoming nucleophilic reagent.

Comparison of the reactivity of several Grignard



reagents by competition experiments using benzophenone has established that those reagents with more electronegative radicals add more slowly.⁶ Phenylsulfonylmethylmagnesium bromide (III) would accordingly be expected to react rather slowly, owing to its highly electronegative sulfonyl group. Consequently, the order of reactivity of III relative to the typical reagents studied by Kharasch and Weinhouse was determined by bringing into competition for benzaldehyde equimolar amounts of III and phenylmagnesium bromide, one of the least reactive reagents in the earlier study. Separation of the products by a rather involved and tedious procedure showed the formation of β -phenyl- β -hydroxyethyl phenyl sulfone (V)³ in 29% yield (isolated in part as the more easily separable benzoate)³ and of benzohydrol in 33% yield (isolated in part as benzohydryl ether). The conclusion that III and phenylmagnesium bromide react to approximately the same extent is confirmed by the recovery of methyl phenyl sulfone in 23% yield from the competition experiment as well as by isolation of V in 64% yield from a control reaction of benzaldehyde with III alone. It may be important, however, to note that III when mixed with phenylmagnesium bromide changes from a solid suspension to a gum which may be a complex of the two, and that a complex, if formed, might well lead to a different view of relative reactivities than would result if it were possible to study III and phenylmagnesium bromide independently of one another.

In further exploration of the generality of the addition reaction the effect of α -substitution in the Grignard reagent was examined. Ethyl *p*-tolyl sulfone (VIII) gave a mildly exothermic reaction with ethylmagnesium bromide, probably because

(1) Presented in part at the Southeastern Regional Meeting of the American Chemical Society at Auburn, Ala., Oct. 23-25, 1952. Abstracted from the Ph.D. dissertation of John W. McFarland, June, 1953.

(2) H. A. Potter, Spring Meeting, Midland Section of the A.C.S. (1951).

(3) Previous paper in this series, L. Field, *THIS JOURNAL*, **74**, 3919 (1952).

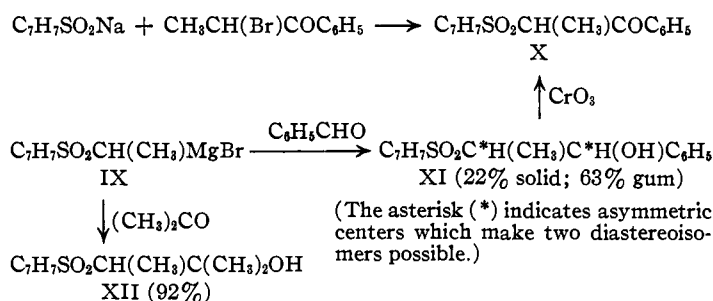
(4) F. G. Bordwell and G. D. Cooper, *ibid.*, **73**, 5184 (1951).

(5) F. C. Whitmore and R. S. George, *ibid.*, **64**, 1239 (1942).

(6) M. S. Kharasch and S. Weinhouse, *J. Org. Chem.*, **1**, 209 (1936).

of complex formation. Since ethane was not evolved until the mixture was heated, however, the conversion of VIII to α -(*p*-tolylsulfonyl)-ethylmagnesium bromide (IX) is evidently less rapid than the conversion of methyl *p*-tolyl sulfone (I) with ethylmagnesium bromide to II in which gas evolution occurs vigorously without external heating.

Addition of IX to benzaldehyde gave an oil XI which was characterized by oxidation to α -(*p*-tolylsulfonyl)-propiophenone (X). X yielded two isomeric 2,4-dinitrophenylhydrazones which are presumably *syn*, *anti* isomers. Independent synthesis of X was effected from sodium *p*-toluenesulfinate and α -bromopropiophenone, thus confirming its structure and indirectly that of XI. The only addition product XI crystallized in part, and a solid and oil were separated which are almost certainly diastereoisomers. The reaction of IX with acetone gave an oil XII which did not crystallize.



The conversion of isopropyl *p*-tolyl sulfone (XIII) to α -(*p*-tolylsulfonyl)-isopropylmagnesium bromide (XIV) proceeded much like that of VIII to IX except that XIV often does not precipitate immediately from solution in the manner characteristic of II, III and IX. XIV reacted typically with benzaldehyde and acetone. The fact that XIV and benzaldehyde give a single product XV in high yield lends further weight to the supposition that the two substances corresponding to XI are indeed diastereoisomers rather than structural isomers.

Whitmore and George⁵ reported that the reaction of diisopropyl ketone with either an isopropyl or *t*-butyl Grignard reagent resulted in reduction to the extent of 65% and that no addition occurred. It is interesting therefore that the reaction of XIV and diisopropyl ketone either at room temperature or with prolonged heating at 74° resulted in no reduction. The original sulfone XIII was recovered in yields of 80–91%. A small amount of unidentified oil isolated did not reduce aqueous potassium permanganate and hence could not be the unsaturated sulfone anticipated from a ketone reduction process. The recovery of XIII may simply be a result of no reaction, but is more probably a consequence of enolization of the ketone accompanied by simultaneous conversion of the Grignard reagent XIV to the sulfone XIII.

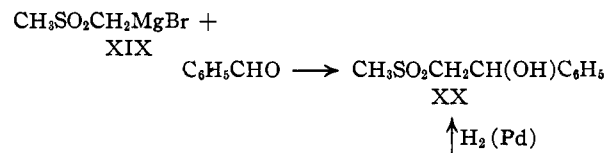
The Grignard reagent (XVII) of benzohydril phenyl sulfone (XVI) is of interest, representing as it does a Grignard reagent rather highly hin-

dered by disubstitution with aryl groups in the α -position. Unfortunately, XVII is seemingly unobtainable in the usual way from the sulfone XVI and ethylmagnesium bromide. Thus when XVI and ethylmagnesium bromide were heated at 70° for five minutes and the product then hydrolyzed only traces of XVI could be recovered.

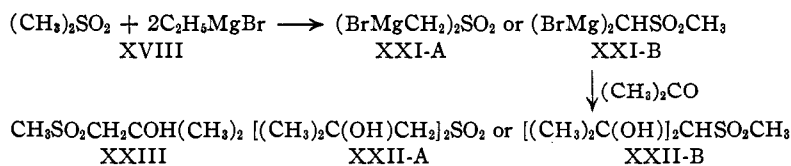
Methyl sulfone (XVIII) was chosen as a representative of sulfones containing only aliphatic groups. Upon addition of approximately one molar equivalent of ethylmagnesium bromide to XVIII a white precipitate formed and a slightly exothermic reaction occurred, both of which observations are consistent with complex formation. Ethane was evolved only upon heating. Addition of benzaldehyde to the Grignard reagent XIX yielded the typical adduct XX but in a maximum yield of only 33%. The structure of XX follows from its identity with XX synthesized by reaction of sodium methanesulfinate and phenacyl chloride and subsequent catalytic reduction. Identity was established by mixture m.p. and infrared spectra.

The low yield of XX is partly accounted for if XIX reacts further with ethylmagnesium bromide giving XXI-A or XXI-B. XXI-A seems the more probable of the two possible structures on the basis of the probable relative acidities of the hydrogen atoms involved and the tendency for maximum dispersal of any charge associated with the -MgBr moieties.

The feasibility of a reaction of this kind was tested by heating XVIII with somewhat more than two molar equivalents of ethylmagnesium bromide. The reaction product was then char-



$\text{CH}_3\text{SO}_2\text{Na} + \text{ClCHOC}_2\text{C}_6\text{H}_5 \longrightarrow \text{CH}_3\text{SO}_2\text{CH}_2\text{COC}_6\text{H}_5$
 characterized by allowing it to react with acetone, rather than with benzaldehyde in order to avoid stereochemical complications. In addition to the bis-adduct XXII, material also was obtained which appeared to be a mixture of XXII with the mono-adduct XXIII. An attempted synthesis of XXII-A through the reaction of diacetyl sulfide and ethylmagnesium bromide and subsequent oxidation gave only intractable tars.



Confirmation of structure for all of the adducts was obtained by infrared absorption spectra which showed strong absorption bands at 3400–3550 cm^{-1} , a typical region of absorption for the hydroxyl group; there were no bands in the carbonyl region. The following compounds were examined in this way: IV, VII, XI, XII, XV, XX, XXII,

XXIV. All of these compounds also gave positive ceric nitrate tests⁷ for an hydroxyl group with the exception of XX and XXII which gave no perceptible color change.

Acknowledgment.—The authors are indebted to the Research Corporation of New York for financial support of this investigation, and to the Office of Ordnance Research, U. S. Army, for support of the latter phases. Dr. Nelson Fuson and associates of Fisk University kindly determined and interpreted the infrared spectra.

Experimental⁸

Reactions of *p*-Tolylsulfonylmethylmagnesium Bromide (II).—Methyl *p*-tolyl sulfone (I) was prepared from methyl iodide and sodium *p*-toluenesulfinate in 79% yield, m.p. 85–86.5°, by a procedure based on one of Otto.⁹ I was converted to II, which formed an insoluble slurry, by using essentially the procedure of Ziegler and Connor¹⁰ and Field.³ Other Grignard reagents of sulfones were prepared in a similar manner unless differences are specifically mentioned.

(a) **With Acetaldehyde.**—A suspension of II prepared in ether–benzene from 30.0 g. of I was cooled to 0° and 12 g. of freshly distilled acetaldehyde in 35 ml. of benzene was added with stirring during 30 minutes at 0–5° using ice–salt cooling. Cooling was then discontinued and the mixture was stirred for three hours. Hydrolysis was effected with cold 1 *N* hydrochloric acid, and a benzene extract was washed until neutral with water and dried. Removal of solvent left 37.7 g. (100%) of white solid β -hydroxy-*n*-propyl *p*-tolyl sulfone (IV), m.p. 69–75°, which after recrystallization from 1:2 benzene–petroleum ether amounted to 32.6 g. (86%) of short white needles, constant m.p. 77–78° (*i.e.*, unchanged by further recrystallization); m.p. reported, 77–78°,¹¹ 77.5–78.5°.¹²

Anal. Calcd. for C₁₀H₁₄O₃S: S, 14.96. Found: S, 15.04.

IV was characterized as the acetate (90% yield), m.p. 93.5–95°; reported¹² 94.5–95°.

Oxidation of IV to *p*-tolylsulfonylacetone (VI) was effected by addition of 0.49 g. of chromium trioxide in 0.5 ml. of water and 2.5 ml. of glacial acetic acid to 1.43 g. of IV in 10 ml. of acetic acid during 1.5 hours at 55°. After 1.5 hours of further heating, 4 ml. of methanol was added and heating was continued for 15 minutes more. Solvent was removed and the residue was washed with ether. Evaporation of the ether gave 1.20 g. (85%) of VI, m.p. 44–50°. After several recrystallizations from 1:1 benzene–petroleum ether the yield of VI was 65% and the white needles obtained had a constant m.p. of 50–51°, reported 50–51°,¹¹ 51.5–52.5°.¹² The product gave a positive 2,4-dinitrophenylhydrazine test. Purification of the crude VI by chromatography¹² gave lower yields; attempted purification *via* the sodium salt was unsuccessful because of the water solubility of VI.

The most effective procedure found for dehydrating IV to 1-(*p*-tolylsulfonyl)-1-propene was based on a method of Fuson and Bannister.¹³ A solution of 11.0 g. of IV in 25 ml. of dry pyridine and 60 ml. of dry benzene was cooled in an ice–salt–bath and 10 ml. of thionyl chloride was added with stirring during ten minutes. The mixture was then heated under gentle reflux for seven hours, cooled and

acidified with 150 ml. of 2 *N* hydrochloric acid. A benzene extract was washed with water, dried and treated with decolorizing carbon. Removal of solvent left 9.19 g. of oily solid which was rubbed with carbon tetrachloride, allowed to stand at 5° overnight, and was then chilled in Dry Ice. The solid was separated, washed with cold benzene–petroleum ether, and recrystallized from 1:2 benzene–petroleum ether; yield 2.06 g. (20%), m.p. 98–100°; reported¹³ 99–100°. The use of 2,4,6-collidine instead of pyridine seemed to give a less pure product.

(b) **With Diisopropyl Ketone.**—To the II prepared from 10.21 g. of I in 100 ml. of benzene using 0.08 mole of 3.25 *N* ethereal ethylmagnesium bromide,¹⁴ 9.12 g. of diisopropyl ketone¹⁵ in 20 ml. of benzene was added during one hour at 30–35°. The mixture was stirred at about 25° for three hours. Hydrolysis and isolation of the product as with IV gave an oil which solidified on seeding. The oily solid was recrystallized from 1:1 ethanol–water and yielded 9.34 g. (55%) of short white needles, m.p. 51–55°, which after another recrystallization gave a first crop of 8.32 g. (49%), m.p. 55–56.5°, and a second crop of 0.53 g. (3%), m.p. 46–52°. Further recrystallization gave γ -methyl- β -isopropyl- β -hydroxy-*n*-butyl *p*-tolyl sulfone (VII) with a constant m.p. of 57–58°.

Anal. Calcd. for C₁₅H₂₄O₃S: C, 63.34; H, 8.51; S, 11.27. Found: C, 63.47; H, 8.74; S, 11.11.

In the first preparation of VII crystalline material was obtained only after two short-path distillations.

Relative Reactivity of Phenylsulfonylmethylmagnesium Bromide (III) and Phenylmagnesium Bromide.—III was prepared³ by adding 14.8 ml. of 3.25 *N* ethereal ethylmagnesium bromide¹⁴ to 6.25 g. of methyl phenyl sulfone in 100 ml. of benzene. The precipitated III was separated by centrifugation and decantation of solvent and was dried at 1 mm. pressure.

The powdery III and 100 ml. of ether were added under nitrogen to the phenylmagnesium bromide prepared from 7.07 g. of bromobenzene in 40 ml. of ether using 0.97 g. of magnesium (all of which was consumed). A gummy material formed, although III added to ether alone gives a suspension of white solid.

A solution of 4.24 g. of purified¹⁶ benzaldehyde in 25 ml. of ether was then added with stirring during 45 minutes. The gum was gradually replaced by a white flocculent precipitate. The mixture was stirred for three hours, hydrolyzed, and the products isolated as with IV. A yellow oil (13.34 g.) was obtained. Short-path distillation and various solvents separated the following substances, all of which were identified by m.p. and mixed m.p.: β -phenyl- β -hydroxyethyl phenyl sulfone³ (V; 3.02 g., 29% yield, obtained in part as the more easily isolable benzoate³); benzohydroly (2.46 g., 33% yield, obtained in part as benzohydroly ether); methyl phenyl sulfone (1.42 g., 23% yield).

In a control experiment the reaction of III alone with benzaldehyde under the same conditions gave V in 64% yield, m.p. 82–95° (comparable in purity to the V isolated in the competition experiment).

Reactions of α -(*p*-Tolylsulfonyl)-ethylmagnesium Bromide (IX).—Ethyl *p*-tolyl sulfone (VIII) was prepared by a method based on one of Otto¹⁷ in 67% yield, m.p. 54–55°; reported¹⁷ 55–56°. The conversion of VIII to IX was effected in much the same way as the conversion of I to II, except that after dilution with benzene the mixture was heated slowly to the reflux temperature (65°) during 20 minutes and was maintained at this temperature for 45 minutes until gas evolution seemed complete. When the solution of VIII was added to the ethylmagnesium bromide solution the temperature rose to 41° and a gum precipitated. Gas evolution, however, began only at a temperature of about 50°. At the end of the heating period the gum initially formed had been replaced by a considerable amount of suspended white solid.

(a) **With Benzaldehyde.**—The resulting suspension of IX from 11.05 g. of VIII was cooled and 8.48 g. of purified¹⁶ benzaldehyde in 20 ml. of benzene was added at 30–35°

(7) R. L. Shriner and R. C. Fuson, "Identification of Organic Compounds," 3rd ed., John Wiley and Sons, Inc., New York, N. Y., 1948, p. 96.

(8) Melting points are corrected and boiling points are uncorrected. All solvents used directly in the Grignard reaction were dried over sodium. Moist extracts were dried using anhydrous magnesium or sodium sulfate; solvent removal was then effected under reduced pressure. Analyses except for sulfur were by Clark Microanalytical Laboratory, Urbana, Ill., or Micro-Tech Laboratories, Skokie, Ill.

(9) R. Otto, *Ber.*, **18**, 161 (1885).

(10) W. M. Ziegler and R. Connor, *THIS JOURNAL*, **62**, 2596 (1940).

(11) C. C. J. Culvenor, W. Davies and W. E. Savidge, *J. Chem. Soc.*, 2198 (1949).

(12) H. J. Backer, J. Strating and J. Drenth, *Rec. trav. chim.*, **70**, 365 (1951).

(13) R. C. Fuson and R. G. Bannister, *THIS JOURNAL*, **74**, 1629 (1952).

(14) Arapahoe Chemicals, Inc., Boulder, Colorado. A clear solution obtained by centrifugation was stored under dry nitrogen and was titrated from time to time.

(15) Redistilled and subsequently stored over calcium chloride.

(16) L. F. Fieser, "Experiments in Organic Chemistry," 2nd ed., D. C. Heath and Co., New York, N. Y., 1941, p. 224.

(17) R. Otto, *Ber.*, **18**, 1276 (1880).

during 45 minutes. A nearly clear solution which had no odor of sulfide or thiol resulted after stirring at about 25° for 2.5 hours.

Hydrolysis and isolation as described for IV resulted in material which was washed with cold petroleum ether and then amounted to 18.47 g. of yellow oil.

For characterization of this yellow oil, 5.00 g. was oxidized using chromium trioxide to α -(*p*-tolylsulfonyl)-propio-phenone (X) by a procedure based on one of Field³ except that heating of the mixture at 55° was continued for 6.5 hours after an oxidant addition period of one hour. The white solid obtained by pouring the chilled reaction mixture into water amounted to 3.59 g. (72%) of X, m.p. 97–99°. Recrystallization from ethanol–water (2:1) and carbon tetrachloride gave X with a constant m.p. of 99.5–100.5°.

Anal. Calcd. for C₁₄H₁₆O₃S: C, 66.64; H, 5.59; S, 11.12. Found: C, 66.61; H, 5.52; S, 11.22.

The ketosulfone X gave a crude 2,4-dinitrophenylhydrazone in 94% yield, m.p. 195–216°, which was separated into two orange isomers by recrystallization using absolute ethanol. The more soluble isomer had a constant m.p. of 210–211°.

Anal. Calcd. for C₂₂H₂₀N₄O₆S: N, 11.96. Found: N, 12.24.

The less soluble isomer was crystallized from ethyl acetate to a constant m.p. of 241–242°.

Anal. Calcd. for C₂₂H₂₀N₄O₆S: N, 11.96. Found: N, 11.97.

The ketosulfone X was synthesized independently by heating 35.6 g. of anhydrous¹⁸ sodium *p*-toluenesulfinate with 42.6 g. of α -bromopropiophenone¹⁹ in 225 ml. of ethanol at the reflux temperature for 17 hours. The cooled mixture was poured into 800 ml. of water containing 6 g. of sodium bisulfite. The resulting solid amounted to 54.2 g. (94%), m.p. 95–98.5°. Several recrystallizations from carbon tetrachloride gave X with a constant m.p. of 99.5–100.5°, unchanged by mixture with the X prepared by oxidation. X dissolves very slowly in aqueous sodium hydroxide but, unlike phenylsulfonylacetophenone, does not give appreciable precipitate on acidification.

Anal. Calcd. for C₁₆H₁₈O₃S: S, 11.12. Found: S, 10.82.

The yellow oil mentioned above, presumably a mixture of diastereoisomers of α -methyl- β -phenyl- β -hydroxyethyl *p*-tolyl sulfone (XI) from the above evidence, slowly crystallized. When crystallization appeared to have ceased (several days), 12.69 g. of the semisolid material was rubbed with 10 ml. of carbon tetrachloride and allowed to stand at –5° for several days. The solid then separated by filtration amounted to 2.63 g. (22%), m.p. 88–102°. Recrystallization from carbon tetrachloride gave 2.20 g. (18%) of XI, m.p. 95–100°, and further recrystallization from 1:1 ethanol–water gave a white solid having a constant m.p. of 99–100.5°.

Anal. Calcd. for C₁₆H₁₈O₃S: C, 66.18; H, 6.24. Found: C, 66.30; H, 6.31.

Removal of solvent from the original carbon tetrachloride extract gave 9.17 g. (77%) of viscous yellow oil. Short-path distillation at 290–450° (0.4–0.7 mm.) gave 7.55 g. (63%) of nearly colorless glass. Redistillation of a portion of this material at 250° (0.3 mm.) gave a colorless glassy diastereoisomer of the solid XI.

Anal. Calcd. for C₁₆H₁₈O₃S: C, 66.18; H, 6.24. Found: C, 66.01; H, 6.23.

(b) **With Acetone.**—A suspension of IX was prepared from 11.05 g. of VIII as already described and a solution of 5.23 g. of purified²⁰ acetone in 20 ml. of benzene was added during one hour at 30–35° with stirring. Further stirring for 2.5 hours at about 25° resulted in replacement of the white suspension by a dark gum. Hydrolysis and isolation in the manner described for IV yielded 14.55 g. of yellow oil which was washed with 10 ml. of petroleum ether and

then amounted to 14.18 g. (98%). Short-path distillation of this material (12.02 g.) at 205–215° (0.3–0.4 mm.) gave 11.29 g. (92%) of nearly colorless oil, n_D^{20} 1.5320–1.5335. Further distillation of a middle fraction gave α , β -dimethyl- β -hydroxy-*n*-propyl *p*-tolyl sulfone (XII), n_D^{20} 1.5307.

Anal. Calcd. for C₁₂H₁₈O₃S: C, 59.48; H, 7.48. Found: C, 59.22; H, 7.46.

Reactions of α -(*p*-Tolylsulfonyl)-isopropylmagnesium Bromide (XIV).—Isopropyl *p*-tolyl sulfone (XIII) was prepared by a procedure based on that used by Otto and Otto²¹ for isopropyl phenyl sulfone; yield 34%, m.p. 81–82°. The conversion of XIII to XIV was effected like that of I to II except that after dilution with benzene the clear solution was heated at the reflux temperature for 1.5 hours. Gas evolution began at about 55° but a suspension of white solid appeared only after cooling to room temperature and occasionally not even then.

(a) **With Benzaldehyde.**—The XIV from 11.89 g. of XIII was treated with 8.48 g. of benzaldehyde in benzene using the same conditions and isolation procedure described for the conversion of IX to XI. Removal of solvent left 18.23 g. (100%) of α , α -dimethyl- β -phenyl- β -hydroxyethyl *p*-tolyl sulfone (XV) as a slightly greasy white solid, m.p. 143–158.5°. Recrystallization from carbon tetrachloride gave 13.5 g. (74%) of XV as white tablets with a constant m.p. of 164.5–165.5° and an additional 2% as a second crop, m.p. 162–164°.

Anal. Calcd. for C₁₇H₂₀O₃S: C, 67.08; H, 6.62; S, 10.53. Found: C, 67.11; H, 6.62; S, 10.54.

(b) **With Acetone.**—Reaction of the XIV from 11.89 g. of XIII with 5.23 g. of acetone in the manner described for the conversion of IX to XII, followed by isolation as before gave after removal of solvent a yellow oil which upon trituration with cold petroleum ether yielded 12.8 g. (83%) of greasy solid, m.p. 46–61°. Four recrystallizations from petroleum ether gave 7.2 g. (47%) of α , α , β -trimethyl- β -hydroxy-*n*-propyl *p*-tolyl sulfone (XXIV) with a constant m.p. of 65.5–67°.

Anal. Calcd. for C₁₃H₂₀O₃S: C, 60.91; H, 7.86; S, 12.51. Found: C, 60.98; H, 7.99; S, 12.53.

(c) **With Diisopropyl Ketone.**—The XIV from 11.89 g. of XIII was allowed to react with 7.98 g. of diisopropyl ketone with the conditions and isolation procedure essentially the same as for the conversion of II to VII. Apart from a mildly exothermic reaction, there was no apparent change in the reaction mixture during or after the addition of the ketone. Trituration with petroleum ether of the greasy solid obtained by removal of solvent after hydrolysis gave 9.55 g. (80% recovery) of XIII, m.p. and mixture m.p. with XIII 78–82°. The petroleum ether washings contained 3.25 g. of oil which could not be crystallized and decomposed on attempted distillation. This oil did not reduce 2% aqueous potassium permanganate but gave a positive test for sulfur and a positive ceric nitrate test.⁷

More vigorous conditions were used in a similar experiment to minimize the possibility that reaction failed to occur. After a two-hour stirring period at about 25° the mixture was heated at 74° for eight hours without apparent change. The XIII recovered amounted to 91%, m.p. 77–82°; recrystallization gave XIII with m.p. and mixed m.p. 81–83°. An oil (2.02 g.) also obtained had properties similar to those of the oil previously isolated.

α -(Phenylsulfonyl)-benzohydrylmagnesium Bromide (XVII).—A solution of 2.00 g. of benzohydryl phenyl sulfone²² (XVI, 56% yield, m.p. 188–189°) in 40 ml. of benzene was treated at 60° with 0.00975 mole of ethereal ethylmagnesium bromide.¹⁴ The solution, which became green and then orange, was heated at 70° for five minutes during which time it became red and gummy solid separated. Hydrolysis gave 1.67 g. of red oil from which only 6% of XVI could be separated; m.p. after several recrystallizations 180–185°, undepressed by authentic XVI.

Chromatography of the residue from a similar experiment using alumina and several solvents gave only 0.15 g. of a solid which after two recrystallizations from ethanol had m.p. 166–189° (depressed to 158–179° by XVI); it contained no sulfur.

Reactions of Methylsulfonylmethylmagnesium Bromide (XIX).—Methyl sulfone (XVIII) was prepared by a proce-

(21) R. Otto and W. Otto, *Ber.*, **21**, 998 (1888).

(22) O. Hinsberg, *ibid.*, **50**, 473 (1917).

(18) L. Panizzi and R. A. Nicolaus, *Gazz. chim. ital.*, **80**, 431 (1950); *C. A.*, **45**, 3812 (1951).

(19) Prepared in 89% yield by essentially the method of C. Schmidt, *Ber.*, **22**, 3251 (1889); b.p. 84–87° (2.5–4.0 mm.), n_D^{20} 1.5692–1.5701; n_D^{20} reported, 1.5716 (K. v. Auwers, *Ber.*, **50**, 1177 (1917)).

(20) Dried over and distilled from phosphorus pentoxide and stored over calcium chloride.

dures similar to a general one of Suter, *et al.*²³ Methyl sulfide (100 g.) in 300 ml. of glacial acetic acid was cooled in an ice-salt bath and 360 ml. of aqueous hydrogen peroxide (0.32 g. of peroxide/ml. of solution by potassium permanganate titration) was added during 1.75 hours with stirring. The mixture after standing at about 25° for 25 hours was heated at 70° for several hours. Acetaldehyde (10 ml.) was added and the solution heated until starch-iodide paper showed absence of peroxide. Solvent was removed and the XVIII was recrystallized from ethanol; yield 141.7 g. (94%), m.p. 108–109.5°.

(a) **With Benzaldehyde.**—For conversion of XVIII to XIX, a solution of 5.65 g. in 100 ml. of hot benzene was cooled to about 25° and ethereal ethylmagnesium bromide¹⁴ (0.07 mole) was added rapidly with stirring to the resulting slurry. A heavy white precipitate formed and the temperature rose to 38° but only a small amount of gas was evolved. The mixture was heated rapidly to the reflux temperature (70°) and there maintained for 1.5 hours after which gas evolution had nearly ceased; considerable solid was then present.

The mixture was cooled to about 25° and 7.42 g. of purified¹⁸ benzaldehyde in 10 ml. of benzene was added during 30 minutes. The mixture was stirred at about 25° for 17 hours and then at the reflux temperature for six hours.

Hydrolysis and isolation as with IV followed by removal of solvent gave 10.44 g. of oily solid which was shaken and allowed to stand with 10 ml. of carbon tetrachloride at 5° overnight. Filtration separated 3.98 g. (33%) of methyl β -phenyl- β -hydroxyethyl sulfone (XX), m.p. 96.5–103°. Similarly prepared material after recrystallization from chloroform-carbon tetrachloride had a constant m.p. of 102–104°.

Anal. Calcd. for $C_8H_{12}O_2S$: C, 53.97; H, 6.04; S, 16.01. Found: C, 53.82; H, 6.07; S, 15.72.

The effect of variation in conditions was explored in several experiments. Replacement of benzene by toluene and heating for one hour at 90° in the XIX preparation had little effect. Moderate variation in the reflux period during the XIX preparation seemed less important than variation in the reflux period after aldehyde addition where reduction to two hours gave 22% of XX (30% of XVIII was recovered and unidentified oils isolated) and elimination altogether gave only 2% of XX. The time of stirring at room temperature after aldehyde addition seemed of little importance.

XX was synthesized by an independent route for comparison with the presumed XX described above. Sodium methanesulfinate was prepared by adding 57.3 g. of methanesulfonyl chloride and 84 g. of sodium bicarbonate concurrently to 126 g. of anhydrous sodium sulfite in 300 ml. of water with stirring during one hour at 75–80°. The mixture was heated and stirred for one hour more after which water was removed under reduced pressure. Extraction of the resulting solid with hot absolute ethanol and subse-

quent evaporation of the ethanol gave 48.4 g. (95%) of white solid. The crude sulfinate (24.5 g.) was heated under reflux with 18.6 g. of phenacyl chloride in 150 ml. of ethanol for 15 hours. Solvent was removed and the solid extracted with chloroform. The solid obtained by evaporation of the chloroform was shaken with 6 g. of sodium hydroxide in 60 ml. of water. The basic solution was washed with ether and acidified; yield of ω -methylsulfonylacetophenone, 21.0 g. (88%), m.p. 105.5–107°. Recrystallization from chloroform-carbon tetrachloride, aqueous methanol and methanol gave material with a constant m.p. of 109–110°; reported²⁵ 110°. This ketone (4.00 g.) was catalytically reduced in the manner described³ for ω -phenylsulfonylacetophenone during 19 hours; it was necessary to replace the catalyst during the reduction owing to poisoning (a faint sulfide-like odor was evident after reduction). Solid obtained after catalyst separation and removal of solvent was dissolved in chloroform. Extraction with cold 10% aqueous sodium hydroxide and acidification of the extract gave 0.97 g. (24%) of the original ketone, m.p. and mixture m.p. 107–110°. Evaporation of the water-washed chloroform layer gave 2.37 g. (59%) of authentic XX, m.p. 103.5–106°. Recrystallization gave XX with a constant m.p. of 105.5–106.5° which when mixed with XX from the Grignard reaction had m.p. 104–106°; the infrared spectra of the two samples were identical.

(b) **With Acetone.**—For conversion of XVIII to the bis-bromomagnesium compound XXI, 46.1 ml. of 3.25 *N* ethereal ethylmagnesium bromide¹⁴ and 5.65 g. of XVIII were heated in 150 ml. of benzene under reflux (68°) for 1.5 hours.

The white precipitate was cooled to 30° and 8.70 g. of purified²⁰ acetone in 20 ml. of benzene was added during 15 minutes with stirring at 30–35°. The mixture was stirred for 16 hours at 25° and for 30 minutes at the reflux temperature. Hydrolysis and isolation as with IV gave 3.27 g. of yellow oil; this was combined with 6.75 g. obtained by chloroform extraction of the solid resulting from evaporation of the aqueous layer.

The oil was dried at 1 mm. pressure and partly solidified. It was then allowed to stand with 10 ml. of carbon tetrachloride at 5° for 12 hours. Filtration separated 2.38 g. (19%) of white bis-acetone adduct (XXII), m.p. 94–101°. Recrystallization from chloroform-carbon tetrachloride (1:2) gave 2.11 g. (17%) of white platelets which after further recrystallization had a constant m.p. of 107.5–109°.

Anal. Calcd. for $C_8H_{12}O_4S$: C, 45.69; H, 8.63; S, 15.24. Found: C, 45.48; H, 8.66; S, 14.93.

Evaporation of the carbon tetrachloride filtrate from the crude XXII gave 7.8 g. of dark oil which after two short-path distillations at 120° (3 mm.) had n_D^{25} 1.4670 and appeared to be a monoacetone adduct (XXIII) contaminated by XXII.

Anal. Calcd. for $C_8H_{12}O_3S$ (XXIII): C, 39.45; H, 7.95; S, 21.06. Found: C, 40.49; H, 8.33; S, 18.68.

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