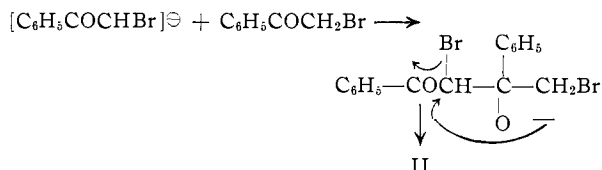II (R = CH₂Br) ⟶ II (R = CH₂OAc)

The formation of the bromodiphenacyls may be represented as a normal Darzens condensation[17,18]


If the reaction is carried out using a ratio of 1 mole of sodium ethoxide to 2 moles of phenacyl bromide (stoichiometric quantities), the product is a mixture of 8 parts of α-bromodiphenacyl to 5 parts of the β-isomer.[7] The rate of formation of the α-isomer must then be at least eight-fifths as fast as that of the β-isomer since the equilibrium in the epimerization process[7] favors β-bromodiphenacyl. If the condensation is run in the presence of excess sodium ethoxide, the β-isomer is the sole product. This situation, in which the kinetically-favored product

(17) (a) Darzens, *Compt. rend.*, **139**, 1214 (1904), and many subsequent papers; (b) *cf.* M. S. Newman and B. J. Magerlein, "Organic Reactions," Vol. V, edited by R. Adams, John Wiley and Sons, Inc., New York, N. Y., 1949, p. 413.

(18) While apparently accepting Widman's structure (I), W. Madelung and M. E. Oberwegner, *Ann.*, **490**, 200 (1931), recognized that II would result from a condensation of this type and that it would accommodate much of the chemistry of the bromodiphenacyls.

is thermodynamically unstable with respect to a more slowly-formed isomer, is apparently not unique in Darzens reactions. In addition to the direct parallel between the self-condensations of phenacyl bromide and phenacyl chloride,[7] the condensation of *o*-nitrobenzaldehyde with phenacyl bromide leads to a product (III, α-form, m.p. 110°) which is readily converted by ethoxide ion to a β-isomer (m.p. 175°).[19]
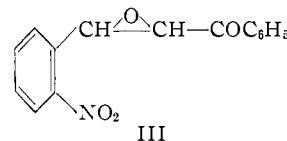
III

Experimental[20]

β-Bromodiphenacyl[7] was obtained as white needles from ethyl acetate, m.p. 158–158.5° (reported[7] m.p. 161°). The ultraviolet spectrum showed λmax 251 mμ, log ε 4.11. A plateau occurred at *ca.* 320–340, log ε 2.06. Calcd. for C₁₆H₁₃O₂Br: mol. wt., 317. Found: (in camphor), mol. wt., 314.

α-Bromodiphenacyl[7] was obtained as rosettes of white needles from ethyl acetate–methanol, m.p. 134–135° (reported m.p. 129°). The ultraviolet spectrum showed λλmax 253 mμ, log ε 4.17 and 340 mμ, log ε 2.35.

Benzalacetophenone oxide,[21] m.p. 88.5–89.2° (reported m.p. 90°), showed λλmax 250 mμ, log ε 4.21 and 330 mμ, log ε 2.31.

(19) S. Bodforss, *Ber.*, **51**, 192 (1918).

(20) Melting points are corrected. The infrared spectra were determined in chloroform by Mr. S. M. Nagy of the Massachusetts Institute of Technology using the Baird Associates spectrophotometer. The ultraviolet spectra were determined in 95% ethanol with the Beckman spectrophotometer, model DU.

(21) E. Weitz and A. Scheffer, *Ber.*, **54**, 2327 (1921).

LOS ANGELES 7, CALIF.


Sulfination of Organolithium Derivatives of Thiophene and Furan

BY WILLIAM E. TRUCE AND ERIC WELLISCH

Lithium 2-thiophenesulfinate and lithium 2-furansulfinate were prepared by the metalation of thiophene and furan with *n*-butyllithium followed by sulfination with sulfur dioxide. Reaction of these lithium sulfinates with methyl vinyl sulfone gave the corresponding γ-disulfones, 1-(2-thiophenesulfonyl)-2-methanesulfonylethane and 1-(2-furansulfonyl)-2-methanesulfonylethane, in good yield. It was also found that excess lithium 2-thiophenesulfinate caused the cleavage of 1-(2-thiophenesulfonyl)-2-methanesulfonylethane.

The principal objective of the present work was to develop a convenient synthesis of α-thiophenesulfinic acid[1] and α-furansulfinic acid, an unknown compound. Organolithium compounds have been employed to good advantage recently for the preparation of sulfinic acids.[2] This method was employed in the present work.
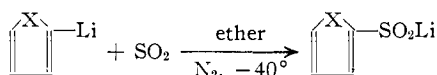
(where X is S or O)

The sulfination of 2-thienyllithium[3] was carried out by adding this compound with vigorous stirring

(1) L. Weitz, *Ber.*, **17**, 800 (1884); A. Biedermann, *ibid.*, **19**, 1615 (1886).

(2) W. E. Truce and J. F. Lyons, THIS JOURNAL, **73**, 126 (1951).

(3) H. Gilman and D. A. Shirley, *ibid.*, **71**, 1870 (1949).

to an ethereal solution of sulfur dioxide at −30°. For optimum yields, lithium 2-furansulfinate was prepared by the reverse addition of an ethereal solution of sulfur dioxide to the 2-furyllithium reagent.[4] Presumably this result is a consequence of the sensitivity of furan compounds to acid-catalyzed ring opening.

The lithium sulfinates were converted to the corresponding γ-disulfones by treatment with methyl vinyl sulfone.[5] The products, 1-(2-thio-
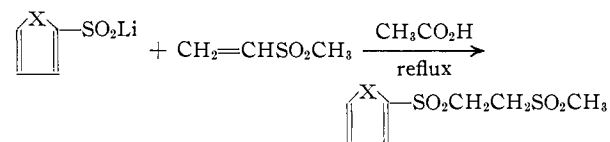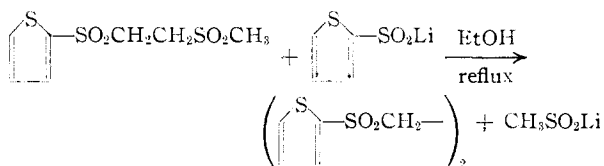

(4) R. A. Benkeser and R. B. Currie, *ibid.*, **70**, 1780 (1948).

(5) H. Ufer, German Patent 663,992 (1938); *C. A.*, **33**, 174 (1939).

phenesulfonyl)-2-methanesulfonylethane and 1-(2-furansulfonyl)-2-methanesulfonylethane, were identical with those prepared by the method
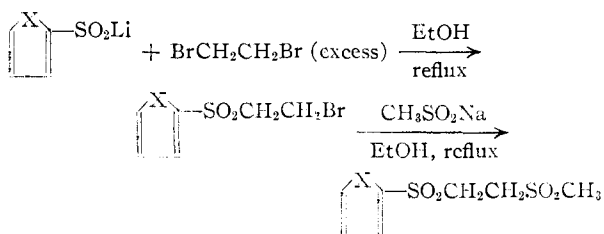
An attempted synthesis of 1-(2-thiophenesulfonyl)-2-methanesulfonylethane by treating lithium 2-thiophenesulfinate with β-chloroethyl methyl sulfone, yielded 1,2-bis-(thiophenesulfonyl)-ethane instead. An authentic sample of the latter compound was prepared by the reaction of lithium 2-thiophenesulfinate with ethylene bromide. Apparently the initially-formed γ-disulfone in the first reaction was cleaved by excess lithium 2-thiophene-

sulfinate. Such cleavage of γ-disulfones by alkaline reagents such as potassium hydroxide or potassium cyanide has been observed frequently.[6]

Experimental

Lithium 2-Thiophenesulfinate.—n-Butyllithium reagent[7] was prepared in 86% yield[8] from 102 g. (0.75 mole) of n-butyl bromide and 10.5 g. (1.5 moles) of lithium wire. This was transferred, by nitrogen pressure, through a filter stick and into a separatory funnel. The butyllithium reagent was added slowly with stirring and under an atmosphere of nitrogen to 66 g. (0.75 mole) of thiophene (b.p. 80–82°) contained in a one-liter, three-neck flask, which was also equipped with a stirrer and a condenser. When the addition was completed, the mixture was refluxed for six hours.

The metalation product was transferred (through a filter stick and under nitrogen) slowly and with rapid stirring into a three-neck, round-bottom flask equipped with a stirrer and Dry Ice condenser and containing 1.0 mole of sulfur dioxide dissolved in 100 ml. of ether. The temperature was kept at about −30°. The heavy, slightly-yellow precipitate, which formed, was separated by centrifuging. Washing with ether, recentrifuging and drying in a vacuum desiccator gave 120 g. of crude material. Crystallization of a 10-g. portion from pyridine gave 5.5 g. of a crystalline product, representing a total of 66 g. (0.43 mole) of lithium 2-thiophenesulfinate; conversion, 57% based on thiophene.

Anal. Calcd. for $C_4H_3O_2S_2Li$: Li, 4.51. Found: Li, 4.64

A portion of the lithium sulfinate was quantitatively converted to the water-insoluble ferric salt by treatment with an acidic aqueous solution of ferric chloride. The ferric salt was treated with aqueous ammonia and the precipitate of ferric hydroxide was filtered off. The filtrate was acidified with cold hydrochloric acid and the somewhat unstable free acid was extracted with ether; m.p. 65–67°, reported[1] m.p. 67°; conversion 57% based on ferric salt.

Lithium 2-Furansulfinate.—2-Furyllithium reagent was prepared from 51 g. (0.75 mole) of furan by essentially the same procedure as was used with thiophene. The resulting

(6) W. E. Truce and A. M. Murphy, *Chem. Revs.*, **48**, 93 (1951).
(7) H. Gilman, *et al.*, THIS JOURNAL, **71**, 1499 (1949).
(8) H. Gilman and A. H. Haubein, *ibid.*, **66**, 1515 (1944).

reagent was cooled in a Dry Ice-bath to −40°, and approx. 1 mole of sulfur dioxide in 150 ml. of anhydrous ether was added with vigorous stirring. The dried, crude, yellow product (94.5 g.) was isolated by the same procedure as that used for the thiophene analog. A 10-g. portion of the product, recrystallized twice from dimethylformamide, gave 6 g. of a white, crystalline material (55% conversion based on furan).

Anal. Calcd. for $C_4H_3O_3SLi$: Li, 5.03. Found: Li, 5.12.

All attempts to convert lithium 2-furansulfinate to the free sulfinic acid failed. Addition of aqueous (neutral to acidic) ferric chloride to the lithium salt did not give a water-insoluble ferric salt but resulted in blood-red coloration of the solution. Careful acidification of an aqueous solution of the lithium salt resulted in decomposed material.

Reactions with Methyl Vinyl Sulfone.—Lithium 2-thiophenesulfinate (8 g., 0.05 mole), contained in a 100-ml., three-neck flask fitted with a stirrer, reflux condenser and separatory funnel, was mixed with 40 g. of glacial acetic acid and heated to reflux to bring the mixture into solution. Methyl vinyl sulfone (5.3 g., 0.05 mole) was added slowly; stirring and refluxing were continued for 8 hours. The precipitate, formed on pouring the solution onto ice water, was filtered off; more precipitate was obtained upon evaporation of the filtrate. Recrystallization from an alcohol–water mixture yielded 4.5 g. (46%) of a white, crystalline solid, 1-(2-thiophenesulfonyl)-2-methanesulfonylethane, m.p. 145–146° (mixed melting point with authentic sample prepared below, 146°).

Anal. Calcd. for $C_7H_{10}O_4S_3$: C, 33.07; H, 3.94; S, 37.79. Found: C, 33.14; H, 3.85; S, 37.84.

Lithium 2-furansulfinate (7 g., 0.05 mole) was treated with methyl vinyl sulfone (5.3 g., 0.05 mole) in a similar manner. The solid compound obtained was recrystallized from hot water, to give 5 g. (42%) of a slightly yellow crystalline material, 1-(2-furansulfonyl)-2-methanesulfonylethane, m.p. 110° (mixed m.p. with authentic sample prepared below, 107–109°).

Anal. Calcd. for $C_7H_{10}O_5S_2$: C, 35.29; H, 4.20; S, 26.89. Found: C, 35.26; H, 4.20; S, 26.92.

Preparation of 1-(2-Thiophenesulfonyl)-2-methanesulfonylethane.—1,2-Dibromoethane (8.8 g., 0.1 mole) was dissolved in 50 ml. of absolute ethanol; lithium 2-thiophenesulfinate (1.5 g., 0.01 mole) was added to this solution. The mixture was refluxed for 3 hours and poured into water. After standing for 12 hours in the cold a solid compound, m.p. 208°, identified as 1,2-bis-(thiophenesulfonyl)-ethane, was isolated. Evaporation of the excess dibromoethane and the water solution yielded 0.25 g. of a solid compound, 1-(2-thiophenesulfonyl)-2-bromoethane, m.p. 83° after recrystallization from absolute ethanol. A portion of this compound (0.20 g., 0.0008 mole) was treated with 0.1 g. (0.001 mole) of sodium methanesulfinate[9] in 20 ml. of absolute ethanol. After refluxing for 2 hours with stirring, the mixture was poured into water. A solid material was obtained which was recrystallized twice from water and a third time from ethanol to give 0.1 g. of a white crystalline compound, m.p. 145–146°.

Preparation of 1-(2-Furansulfonyl)-2-methanesulfonylethane.—Lithium 2-furansulfinate (0.7 g., 0.005 mole) was treated with excess 1,2-dibromoethane (20 g.) in 30 ml. of absolute ethanol as above. A small amount of 1,2-bis-(furansulfonyl)-ethane, m.p. 202–203°, was obtained; 1-(2-furansulfonyl)-2-bromoethane, m.p. 78°, was isolated in 12.4% yield. The latter compound (0.15 g.) was dissolved in 12 ml. of absolute ethanol and 0.2 g. of sodium methanesulfinate was added with stirring. After the solution was refluxed for 3 hours, it was poured into a small amount of water and was allowed to stand in the cold for 12 hours. The precipitated solid (0.1 g.), melted at 108–109°, after two recrystallizations from a water–alcohol solution.

Cleavage of 1-(2-Thiophenesulfonyl)-2-methanesulfonylethane by Excess Lithium 2-Thiophenesulfinate.—β-Chloroethyl methyl sulfide (7 g., 0.05 mole) was dissolved in 20 ml. of glacial acetic acid and was oxidized with 15 g. of hydrogen peroxide (30%). The solvent was removed under vacuum. The resulting sulfone was then added to lithium 2-thiophenesulfinate (8 g., 0.05 mole), dissolved in 40 ml. of absolute ethanol and the mixture was refluxed

(9) Courtesy of Mr. J. P. Milionis, this Laboratory.

gently for 2 hours. A precipitate (NaCl) was formed during this period. The mixture was poured onto ice-water and left standing in the cold for 12 hours. The precipitate, 1,2-bis-(thiophenesulfonyl)-ethane, melted at 207–208° after recrystallization from an ethanol–water solution.

Anal. Calcd. for $C_{10}H_{10}O_4S_4$: C, 37.27; H, 3.12; S, 39.75. Found: C, 37.35; H, 3.17; S, 39.69.

This compound was also obtained by treating 1-(2-thiophenesulfonyl)-2-methanesulfonylethane (1.0 g., 0.004 mole) with excess lithium 2-thiophenesulfinate (1.2 g., 0.008 mole). Both compounds were dissolved in 80 ml. of absolute alcohol and refluxed for 12 hours, with stirring. The solution was poured into water and the precipitate formed was filtered off and recrystallized from ethanol. This compound, m.p. 207–208°, was found to be 1,2-bis-(thiophene-

sulfonyl)-ethane by comparison with an authentic sample. It weighed 0.7 g. (yield, 54%).

Independent Synthesis of 1,2-Bis-(thiophenesulfonyl)-ethane.—1,2-Dibromoethane (1.9 g., 0.01 mole) was dissolved in 30 ml. of absolute ethanol and 3 g. of lithium 2-thiophenesulfinate (0.02 mole) was added with stirring. The mixture was refluxed and stirred for 3 hours. A precipitate (NaBr) was formed during this time. After pouring the mixture into water and allowing it to stand for 10 hours in the cold, a solid compound was isolated. The crude material, weighing 3 g., was recrystallized from an ethanol–water mixture to give 2.4 g. (75%) of a slightly yellow flaky solid, m.p. 207–208°. A mixed melting point with the cleavage products obtained above, was 206–208°.

LAFAYETTE, INDIANA

# Nucleophilic Displacement *via* Frontal Attack. The Stereochemistry of the Stevens Rearrangement

BY JAMES H. BREWSTER AND MILTON W. KLINE[1]

The relation of the Stevens rearrangement to the amine replacement and alkylide-forming reactions of quaternary ammonium salts is discussed. *d*-α-Dimethylamino-β-phenylbutyrophenone, prepared by the Stevens rearrangement of the phenacyl bromide derivative of *l*-N,N-dimethyl-α-phenylethylamine, has been degraded to *l*-β-methylhydrocinnamic acid *via* Beckmann rearrangement of the oxime of the ketone formed by reductive deamination of the rearrangement product. The previously established configurational relation of *l*-N,N-dimethyl-α-phenylethylamine to *l*-β-methylhydrocinnamic acid shows that the α-phenylethyl group retains its original configuration during its intramolecular migration from nitrogen to carbon. The rearrangement occurs with little racemization; racemic forms of several of the degradation products are, however, concentrated by recrystallization. These findings lend strong support to the concept that nucleophilic displacement can occur by frontal as well as by lateral and rearward attack.

Quaternary ammonium salts have been used in the benzylation of many inorganic and organic anions.[2] It has been suggested that such "amine replacement" reactions are typical S_N2 reactions on the basis of kinetic[3] and stereochemical[4,5] studies of the formation of alcohols[3,4] and an ester[5] (II, X = OAc) from quaternary ammonium compounds. An attempt to demonstrate inversion of configuration in the alkylation of sodiomalonic ester by means of *d*-I was, however, frustrated by racemization of the quaternary salt.[5] It seems likely that this racemization resulted from anionic attack on the α-hydrogen atom, which is activated by both the quaternary nitrogen atom and the phenyl group, to give the internal salt (III). Salts of this nature, termed "alkylides" by Wittig, have been postulated as intermediates in some of the reactions of 'onium salts with strong bases.[6] Thus,

quaternary ammonium salts (*e.g.*, I) appear to be able to react with Lewis bases by either a displacement mechanism (to form II) or an alkylide-forming mechanism (to form III).
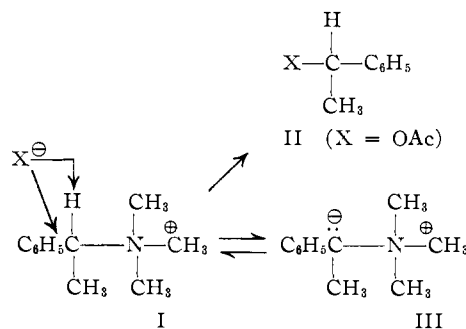
The Stevens rearrangement[7] of phenacylbenzyldialkylammonium bromides (*e.g.*, IV) to α-dialkylaminoketones (*e.g.*, VI) under the influence of alkali seems to be simply an amine replacement reaction which proceeds *via* an alkylide (*e.g.*, V).[7d,6c,8] Evidence suggesting that this rearrangement is

(1) Purdue Research Foundation Fellow, 1951–1952.

(2) (a) W. Michler and A. Gradmann, *Ber.*, 10, 2078 (1877); (b) E. von Meyer, *Abhandl. math.-phys. Klasse sachs. Gesellschaft Wiss.*, 31, 179 (1908) *Chem. Zentr.*, 80, II, 1800 (1909); (c) J. von Braun, *Ann.*, 382, 1 (1911); (d) Hla Baw, *Quart. J. Indian Chem. Soc.*, 3, 101 (1926) (*C. A.*, 20, 3695 (1926)); (e) H. R. Snyder and J. C. Speck, THIS JOURNAL, 61, 668, 2895 (1939); (f) H. R. Snyder, C. W. Smith and J. M. Stewart, *ibid.*, 66, 200 (1944).

(3) (a) E. D. Hughes and C. K. Ingold, *J. Chem. Soc.*, 69 (1933); (b) E. D. Hughes, C. K. Ingold and C. S. Patel, *ibid.*, 526 (1933).

(4) J. Read and J. Walker, *ibid.*, 308 (1934).

(5) H. R. Snyder and J. H. Brewster, THIS JOURNAL, 71, 291 (1949).

(6) (a) C. K. Ingold and J. A. Jessop, *J. Chem. Soc.*, 2357 (1929); 713 (1930); (b) F. Krollpfeiffer and K. Schneider, *Ann.*, 530, 38 (1937); (c) G. Wittig and co-workers, *ibid.*, 555, 133 (1944); 557, 193 (1947); 560, 116 (1948); *Angew. Chem.*, 63, 15 (1951); (d) L. A. Pinck and G. E. Hilbert, THIS JOURNAL, 68, 2011 (1946); 69, 723 (1947); (e) A. Novelli and A. de Varela, *Ciencia e invest.*, 4, 82 (1948); (*C. A.*, 42, 5912 (1948)).

(7) (a) T. S. Stevens, E. M. Creighton, A. B. Gordon and M. MacNicol, *J. Chem. Soc.*, 3193 (1928); (b) T. S. Stevens, W. W. Snedden, E. T. Stiller and T. Thomson, *ibid.*, 2119 (1930); (c) J. Dunn and T. S. Stevens, *ibid.*, 1926 (1932); 279 (1934); (d) T. Thomson and T. S. Stevens, *ibid.*, 69, 1932 (1932).

(8) (a) H. B. Watson, "Modern Theories of Organic Chemistry," Oxford University Press, London, England, 1941, p. 205; (b) C. R. Hauser and S. W. Kantor, THIS JOURNAL, 73, 1437 (1951), have discussed possible mechanisms for the Stevens rearrangement and a number of other reactions apparently occurring by 1,2-rearrangement of a carbanion. This important paper should be consulted for a more detailed discussion of possible alternate mechanisms for this type of rearrangement.