[CONTRIBUTION FROM THE MCPHERSON CHEMISTRY LABORATORY OF THE OHIO STATE UNIVERSITY]

A New Rearrangement Reaction[1]

MELVIN S. NEWMAN AND ISRAEL UNGAR

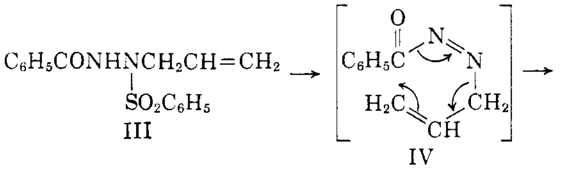
Received October 16, 1961

On heating a solution of 2-allyl-1-benzoyl-2-benzenesulfonyl-hydrazide, III, and sodium carbonate in ethylene glycol at 130° for two minutes, rearrangement to 3-benzenesulfonylpropanal benzhydrazone, V, occurs in about 50% yield (78% in dimethylformamide). A mechanism for this new rearrangement is suggested.

The McFadyen-Stevens aldehyde synthesis[2] involves a base-induced elimination of benzenesulfinic acid from 1-benzoyl-2-benzenesulfonylhydrazide, I, followed by elimination of nitrogen from the hypothetical intermediate, II, and ultimate formation of benzaldehyde.

$$\underset{\text{I}}{C_6H_5CONHNHSO_2C_6H_5} \longrightarrow \underset{\text{II}}{[C_6H_5CON{=}NH]} \longrightarrow C_6H_5CHO + N_2 + C_6H_5SO_2H$$

We thought it likely that if an allyl group were placed on the nitrogen containing the benzenesulfonyl group (as in III) the resulting intermediate, IV, would decompose to yield nitrogen and allyl phenyl ketone by a cyclic path (as shown).



III

IV

$$C_6H_5COCH_2CH{=}CH_2 + N_2 + C_6H_5SO_2H$$

Accordingly, 2-allyl-1-benzoyl-2-benzenesulfonylhydrazide, III, was prepared by allylation[3] of 1-benzoyl-2-benzenesulfonylhydrazide, I. When III was heated at 130° with sodium carbonate in ethylene glycol for two minutes, almost no gas was formed. By suitable work-up of the mixture a new compound, V, m.p. 147–148°, having the same elemental composition as III, m.p. 107–108°, was obtained in about 50% yield. This compound was shown to be 3-benzenesulfonylpropanal benzhydrazone, V, by the following means.

Treatment of an alcoholic solution of V with 2,4-dinitrophenylhydrazine reagent[4] yielded the yellow 2,4-dinitrophenylhydrazone of 3-benzenesulfonylpropanal, VI, which on chromatography over alumina yielded orange acrolein 2,4-dinitrophenylhydrazone, VII. This change could be reversed by adding sodium benzenesulfinate to VII to form VI.[5] When the mother liquors of the reaction of V with 2,4-dinitrophenylhydrazine reagent were made alkaline with sodium carbonate and benzaldehyde was added, benzal benzhydrazide was obtained. This reaction established the presence of benzhydrazide in the mother liquors.

The above evidence indicated that the new compound, V, was 3-benzenesulfonylpropanal benzhydrazone. This structure was confirmed by: synthesis of V by adding sodium benzenesulfinate to acrolein benzhydrazone VIII and acidification; and the NMR spectral analysis.[6] The reactions are summarized below.

In order to throw more light on the mechanism of the change, III → V, two experiments were done. When III was heated as before but in the presence of an excess of sodium *p*-toluenesulfinate, the *p*-toluenesulfonyl derivative, X, comparable to V was obtained. This suggests that the benzenesulfonyl moiety becomes separated from the rest of the molecule during the rearrangement, but does not prove it since the heating of V in the presence of

---

(1) The work herein described is taken largely from the M.S. thesis presented by I. Ungar, Ohio State University, 1957. Additional experiments were done by Mr. Ungar while at the Battelle Memorial Institute, Columbus, Ohio.

(2) (a) See E. Mosettig, *Org. Reactions*, **VIII**, 232 (1954). See also M. S. Newman and E. G. Caflisch, Jr., *J. Am. Chem. Soc.*, **80**, 862 (1958), and ref. 4 therein.

(3) That allylation occurred on the nitrogen adjacent to the benzenesulfonyl group was established by NMR studies in conjunction with NMR studies on the isomeric *N*-methyl analogs (see ref. 2b). We are indebted to Thomas Page, Battelle Memorial Institute, for the NMR analyses and interpretation. His statement follows.

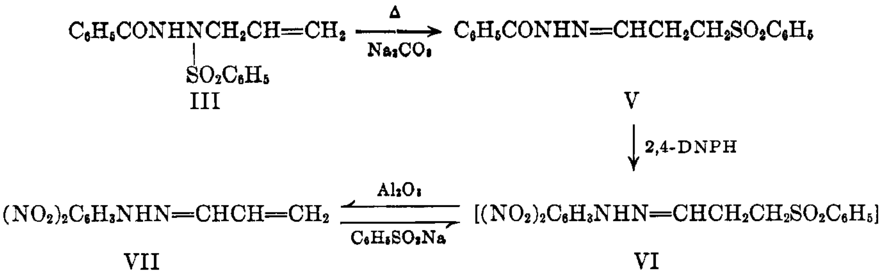
The position of the allyl group in III was established by a study of the phenyl ring resonances of several unsymmetrically substituted hydrazides. These were found to fall into two classes: those which were very complex and split and those which showed virtually no splitting. The phenyl resonances of $C_6H_5SO_2NHNCH_3COC_6H_5$, $C_6H_5SO_2N(C_3H_5)NCH_3COC_6H_5(C_3H_5{=}\text{allyl})$, and $C_6H_5SO_2NCH_3NCH_3COC_6H_5$ fell in the latter class while those of $C_6H_5SO_2N(C_3H_5)NHCOC_6H_5$, $C_6H_5SO_2NCH_3NHCOC_6H_5$ and $C_6H_5SO_2NHNHCOC_6H_5$ were of the complex type. From a comparison of the spectra of these compounds with those of $C_6H_5SO_2NH_2$, $C_6H_5SO_2NHCH_3$, $C_6H_5SO_2N(CH_3)_2$, $C_6H_5CONH_2$, $C_6H_5CONHCH_3$, and $C_6H_5CON(CH_3)_2$ it can be shown that only compounds which have a proton remaining on the nitrogen adjacent to the carbonyl give rise to highly split phenyl resonances. This fact enables one to establish the position of the allyl group in question.

An explanation for the simplification of the NMR patterns of compounds which are substituted on the nitrogen next to the carbonyl will be published elsewhere.

(4) R. L. Shriner and R. L. Fuson, "The Systematic Identification of Organic Compounds," John Wiley and Sons, Inc., N. Y., 3rd ed., p. 171.

(5) Michael addition of sulfinic acids to α,β-unsaturated carbonyl compounds is known. See Houben-Weyl, "Methoden der Organischen Chemie," Vol. 9, G. Thieme, Stuttgart, Germany, 1955, p. 355.

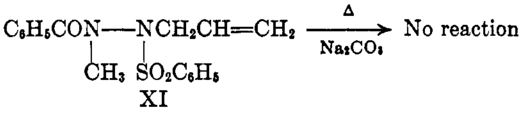
(6) We are indebted to Dr. G. V. D. Tiers of the Minnesota Mining and Manufacturing Co., Minneapolis, Minn., for these NMR spectra and their interpretation.



$$\underset{\mathrm{III}}{C_6H_5CONH\underset{|\atop SO_2C_6H_5}{N}CH_2CH{=}CH_2} \xrightarrow[Na_2CO_3]{\Delta} \underset{\mathrm{V}}{C_6H_5CONHN{=}CHCH_2CH_2SO_2C_6H_5}$$

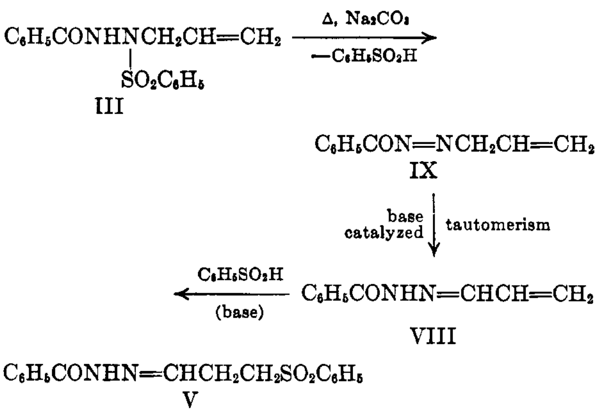
$$\mathrm{V} \xrightarrow{2,4\text{-DNPH}} \underset{\mathrm{VI}}{[(NO_2)_2C_6H_3NHN{=}CHCH_2CH_2SO_2C_6H_5]}$$

$$\underset{\mathrm{VII}}{(NO_2)_2C_6H_3NHN{=}CHCH{=}CH_2} \underset{C_6H_5SO_2Na}{\overset{Al_2O_3}{\rightleftharpoons}} \mathrm{VI}$$



$$\underset{\mathrm{XI}}{C_6H_5CO\underset{|\atop CH_3}{N}{-}\underset{|\atop SO_2C_6H_5}{N}CH_2CH{=}CH_2} \xrightarrow[Na_2CO_3]{\Delta} \text{No reaction}$$

sodium *p*-toluenesulfinate yields a mixture of V and the corresponding *p*-toluenesulfonyl derivative. Furthermore, when 2-allyl-1-benzoyl-1-methyl-2-benzenesulfinylhydrazide, XI, was heated in ethylene glycol as in the case of III, the compound, XI, was recovered unchanged. This fact shows that when elimination of benzenesulfinic acid from III is blocked by the presence of a methyl group, the rearrangement does not occur. A mechanism consistent with all of the facts to date is shown below.



$$\underset{\mathrm{III}}{C_6H_5CONH\underset{|\atop SO_2C_6H_5}{N}CH_2CH{=}CH_2} \xrightarrow[-C_6H_5SO_2H]{\Delta,\ Na_2CO_3} \underset{\mathrm{IX}}{C_6H_5CON{=}NCH_2CH{=}CH_2}$$

$$\mathrm{IX} \xrightarrow[\text{catalyzed}]{\text{base}} \text{tautomerism} \quad \underset{\mathrm{VIII}}{C_6H_5CONHN{=}CHCH{=}CH_2}$$

$$\mathrm{VIII} \xrightarrow[\text{(base)}]{C_6H_5SO_2H} \underset{\mathrm{V}}{C_6H_5CONHN{=}CHCH_2CH_2SO_2C_6H_5}$$

The yield of V from III is sensitive to the base used, time of heating, temperature, and solvent. Most of our studies involved the use of sodium carbonate since bases such as pyridine, collidine, and triethylamine did not bring about the rearrangement, while stronger bases, such as metallic hydroxides, afforded much resinous material. When ethylene glycol was used as solvent, the optimum temperature was in the 120–140° range, the optimum time approximately two minutes, and the yield was about 50%. After this study had been completed, an experiment comparable to the optimum was carried out in dimethylformamide. Since the yield was 78%, studies on other solvent systems are obviously in order.

The over-all result of the rearrangement, III→V, is to convert an allyl halide (for this was used to allylate I) to a 3-benzenesulfonyl derivative of propanal. Since the latter can readily be treated to afford a derivative of acrolein, conversion of an allyl halide to an α,β-unsaturated carbonyl compound is another possible over-all result. Other features of this new reaction are under investigation.

An interesting side light in this study is afforded by noting the good yield of III by allylation of the sodium salt of I with allyl bromide. When methylation of I was carried out with methyl sulfate or methyl iodide at room temperature, a mixture of methylated products was obtained[7] from which 2 - benzenesulfonyl - 1 - benzoyl - 2 - methylhydrazine was obtained in only 57% yield, together with other methylation products the structure of which will be discussed in a separate paper.

EXPERIMENTAL[8]

Materials. The arylsulfonylbenzhydrazides were prepared by reaction of benzhydrazide with the appropriate arylsulfonyl chloride. The sodium salts[2b] precipitated when sodium ethoxide was added to an alcoholic solution of arylsulfonyl hydrazide.

2-Allyl-1-benzoyl-2-benzenesulfonylhydrazide, III. To a vigorously stirred solution of 60 g. of sodium 1-benzoyl-2-benzenesulfonylhydrazide in 350 ml. of water, 24 g. of allyl bromide was added dropwise during 2 hr. After approximately half the halide had been added, a white solid appeared Stirring was continued for 1/2 hr. after the addition was completed. The solid was collected, washed with water and recrystallized from aqueous ethanol to give 50 g. (80%) of III as white platelets, m.p. 104–105°.

The analytical sample, m.p. 108.1–109.1° (cor.) was obtained after several recrystallizations from aqueous ethanol.

Anal. Calcd. for $C_{16}H_{16}N_2O_3S$: C, 60.8; H, 5.1; N, 8.9; S, 10.1. Found: C, 60.9; H, 5.2; N, 8.9; S, 10.1.

The above procedure was followed for the subsequent allylations.

1-Benzoyl-2-p-toluenesulfonylhydrazide. By adding 95 g. of *p*-toluenesulfonyl chloride to a stirred mixture of 67.3 g. of benzhydrazide in 500 ml. of water containing 20 g. of sodium hydroxide[2b] there was obtained 115 g. (78%) of colorless 1-benzoyl-2-*p*-toluenesulfonylhydrazide, m.p. 163–164°, after recrystallization from aqueous ethanol.

---

(7) Ph.D. thesis of E. G. Caflisch, Jr., Ohio State University (1954).

(8) Those melting points marked corrected (cor.) were taken in a Hershberg melting point apparatus with a short stem thermometer calibrated by the Bureau of Standards. Microanalyses were carried out by Galbraith Microanalytical Laboratories of Knoxville, Tenn., and Battelle Memorial Institute of Columbus, Ohio. Infrared spectra were obtained with a Baird double beam spectrometer.

Anal. Calcd. for $C_{14}H_{14}N_2O_3S$: N, 9.7. Found: N, 9.6.

***Sodium salt** of 1-benzoyl-2-p-toluenesulfonylhydrazide.* As in the analogous case,[2b] from 115 g. of 1-benzoyl-2-*p*-toluenesulfonylhydrazide 93 g. (75%) of crude sodium salt was obtained as fine white needles. This material was used in the following reaction.

2-Allyl-1-benzoyl-2-p-toluenesulfonylhydrazide. Allylation of 90 g. of the above sodium salt as for the analogous benzenesulfonyl compound produced the allyl derivative as colorless needles, m.p. 165–166°, in 65% yield.

Anal. Calcd. for $C_{17}H_{18}N_2O_3S$: C, 61.8; H, 5.5. Found: C 62.0; H, 5.7.

1-Benzoyl-1-methyl-2-benzenesulfonylhydrazide.[7] To a cooled, stirred solution containing 25 g. of methylhydrazine, 70 ml. of pyridine and 14 g. of sodium hydroxide in 100 ml. of water, were added dropwise to 25.4 g. of benzoyl chloride. After stirring an additional 15 min., 32 g. of benzenesulfonyl chloride was slowly added. The solution was poured into 1 l. of water and allowed to stand over night. The colorless solid was recrystallized from 50% ethanol to produce 23 g. (57%) of 1-benzoyl-1-methyl-2-benzenesulfonyl hydrazide,[7] m.p. 145–146°.

2-Allyl-1-benzoyl-1-methyl-2-benzenesulfonylhydrazide, XI. The above methyl derivative was converted[2b] to the colorless sodium salt in 65% yield. This material was allylated as described. From 8 g. of the sodium salt, 6 g. (70%) of XI, m.p. 82–83°, after recrystallization from chloroform–petroleum ether, b.p. 90–110°, was obtained.

Anal. Calcd. for $C_{17}H_{18}N_2O_3S$: N, 8.5. Found: N, 8.5.

Rearrangement of allyl derivatives. 3-Benzenesulfonylpropionaldehydebenzhydrazone, V. In a typical example, 1 g. of anhydrous sodium carbonate was added to a solution of 10 g. of III in 50 ml. of dimethylformamide (DMF) maintained at 120°. The temperature rapidly rose 10–15°. After 2 min. the solution was cooled in an ice bath, and decanted from excess sodium carbonate into a mixture of 5 ml. of concentrated hydrochloric acid and 150 ml. of water. A colorless solid which separated over several hours was collected, washed with water, and dried. Recrystallization from chloroform–petroleum ether, b.p. 90–110°, gave 7.8 g. (78%) of V as lustrous blades, m.p. 147–148° (cor.).

Anal. Calcd. for $C_{16}H_{16}N_2O_3S$: C, 60.8; H, 5.1; N, 8.9; S, 10.1. Found: C, 60.6; H, 4.9; N, 9.0; S, 10.4.

In earlier work, the reaction was carried out in ethylene glycol. The following yields of V were obtained after 2-min. heating periods at the temperatures indicated in parentheses: 25% (80°); 37% (100°); 45% (120°); 47% (140°); and 40% (160°). In a similar way the yields of V obtained after heating at 130° for various times (in parentheses) were determined: 22% 0.5 (min.); 47% (1.0 min.); 49% (2.0 min.); 43% (4.0 min.); and 38% (6.0 min.).

3-Toluenesulfonylpropionaldehydebenzhydrazone, X. On heating 2-allyl-1-benzoyl-2-*p*-toluenesulfonylhydrazide as in the analogous benzenesulfonyl case, the toluenesulfonyl derivative was obtained in 75% yield as colorless needless, m.p. 137–138°.

Anal. Calcd. for $C_{17}H_{18}N_2O_3S$: C, 61.8; H, 5.5. Found: C, 61.8; H, 5.7.

Attempted rearrangement of 2-allyl-1-benzoyl-1-methyl-2-benzenesulfonylhydrazide, XI. Compound XI was heated at 120° in DMF. Anhydrous sodium carbonate was added and the temperature maintained for 2 min. A conventional work-up yielded starting material in almost quantitative yield.

Rearrangement of 2-allyl-1-benzoyl-2-benzenesulfonylhydrazide, III, in the presence of sodium p-toluenesulfinate. A mixture of 5 g. of III, 7.5 g. of sodium *p*-toluenesulfinate and 1 g. of sodium carbonate in 25 ml. of DMF was heated to 120° for 2 min., then cooled and poured into 100 ml. of water containing 2.5 ml. of concentrated hydrochloric acid. Careful recrystallization of the colorless solid from chloroform–petroleum ether, b.p. 90–110°, resulted in the isolation of 2.0 g. of X.

Acrolein benzhydrazone. A solution of 60 g. of benzhydrazide and 35 g. of freshly distilled acrolein in 500 ml. of ethanol was allowed to stand in an evaporating dish in a hood for 3 days. The resulting yellow-white solid was recrystallized from methanol to produce 60 g. (78%) of fine colorless needles of acrolein benzhydrazone,[9] m.p. 182–183°.

3-Benzenesulfonylpropionaldehyde benzhydrazone, V. A mixture of 3.5 g. of acrolein benzhydrazone and 4.1 g. of sodium benzenesulfinate in 25 ml. of DMF was held at 120° for 2 min. The solution was cooled and poured into slightly acid water to yield a colorless solid. After recrystallization from chloroform–petroleum ether, b.p. 90–110°, 3.6 g. of colorless crystals were obtained. The m.p., mixed m.p., and infrared spectrum were identical with those found for V formed by the rearrangement of III.

Reactions of 3-benzenesulfonylpropionaldehyde benzhydrazone. 1. With benzaldehyde. A few drops of benzaldehyde were added to a solution of 1 g. of V dissolved in 10 ml. of 95% ethanol. The warmed solution rapidly turned yellow. Upon the addition of water to incipient crystallization and cooling, benzaldehyde benzhydrazone crystallized as fine white needles, m.p. and mixed m.p. with an authentic sample,[10] m.p. 206.0–206.5°.

2. With semicarbazide hydrochloride. A solution containing 1 g. of V in 10 ml. of 95% ethanol was made turbid with water. The turbidity was removed with a drop of ethanol and then 1 g. of semicarbazide hydrochloride and 1.5 g. of sodium acetate were added.[11] The solution was shaken, placed in a boiling water bath and allowed to cool to room temperature. Upon scratching the walls of the container 3-benzenesulfonylpropionaldehyde semicarbazone separated as white platelets of m.p. 161–162° (cor.).

Anal. Calcd. for $C_{10}H_{13}N_3O_3S$: C, 47.1; H, 5.1; N, 16.5. Found: C, 47.1; H, 4.8; N, 16.5.

3. With 2,4-dinitrophenylhydrazine. Treatment of V with 2,4-dinitrophenylhydrazine reagent[12] gave 3-benzenesulfonylpropionaldehyde 2,4-dinitrophenylhydrazone, VI, as bright yellow needles, m.p. 193–195° dec., on crystallization from dimethylacetamide–benzene.

Anal. Calcd. for $C_{15}H_{14}N_4O_6S$: N, 14.8; S, 8.5. Found: N, 14.9; S, 8.3.

Acrolein 2,4-dinitrophenylhydrazone, VII, *and benzaldehyde benzhydrazone.* A solution of VI in benzene was passed through a column of activated alumina.[13] Crystallization of the eluted material from ethanol yielded acrolein 2,4-dinitrophenylhydrazone, VII, as orange needles, m.p. 164.5–165.0° (cor.). The m.p. of a mixture with a known sample[14] m.p. 165.0–165.5° (cor.) was not depressed. The identity of the two samples was confirmed by comparing the infrared spectra in chloroform solution.

The mother liquors obtained from the filtration of the above yellow compound, VI, were carefully neutralized with sodium carbonate solution and decolorized with activated charcoal. A few drops of benzladehyde were added and the solution left overnight. Fine white needles separated and were shown to be benzaldehyde benzhydrazone, m.p. 206–207° (cor.), not depressed when mixed with a known sample[10] of the same m.p.

COLUMBUS 10, OHIO

---

[9] K. Von Auwers and P. Heimke, *Ann.*, **458**, 202 (1927).

[10] T. Curtius and G. Struve, *J. prakt. Chem.*, (2), **50**, 301 (1894).

[11] R. L. Shriner and R. C. Fuson, "The Systematic Identification of Organic Compounds," John Wiley and Sons, Inc., New York, N. Y., 1948, p. 171.

[12] Ref. 11, p. 111.

[13] Fisher Scientific Co.

[14] Ref. 11, p. 283.