Experimental[9]

Preparation of S,S'-(β-Chloroethyl) Dithiolcarbonate (II).—A modification of the procedure of Ringsdorf and Overberger[2] was used. Ethylene sulfide was prepared by the method of Searles and Lutz[10] in 45% yield, b.p. 55–56°. To a mixture of 98 g. (1.0 mole) of phosgene and 0.5 ml. of pyridine was added 60 g. (1.0 mole) of ethylene sulfide over a period of 4 hr. The reaction temperature was maintained below 8°. (Caution: the reaction is extremely exothermic but may have an induction period. Not more than 15 g. of ethylene sulfide should be added before the exothermic reaction is observed.) The reaction temperature was then allowed to rise to 50° and an additional 60 g. of ethylene sulfide [total amount, 120 g. (2.0 moles)] was added. The mixture was heated at 50° for 3 hr. after addition was completed. Fractional distillation of the reaction mixture yielded a forerun of S-(β-chloroethyl) chlorothiolformate, 26.8 g. (17%), b.p. 67–69° (5 mm.), lit.[2] b.p. 67.5° (5 mm.), and S,S'-(β-chloroethyl) dithiolcarbonate (II), 142.5 g. (65%), b.p. 124–126° (2.0 mm.). The product solidified on standing and was recrystallized from methanol, m.p. 40–41°, lit.[2] b.p. 96–97° (0.1 mm.), m.p. 40–41°.

Dehydrohalogenation of S,S'-(β-Chloroethyl) Dithiolcarbonate (II).—A 1.5-*M* solution of potassium *t*-butoxide was prepared by dissolving 26.4 g. (0.67 g.-atom) of potassium metal in 450 ml. of anhydrous *t*-butyl alcohol. A solution of II, 70 g. (0.32 mole) in 100 ml. of *t*-butyl alcohol was heated to 60°, and the potassium *t*-butoxide solution was added slowly. The temperature rose to 75° during addition. The mixture was maintained at 75° for 1 hr., then cooled to room temperature. After neutralization with glacial acetic acid, the potassium chloride formed during the reaction was removed by centrifugation. The solvent was evaporated under reduced pressure and a trace of hydroquinone was added as an inhibitor.

The residue was fractionally distilled through a 30-cm. spinning band column to yield the following components.

(a) S-Vinyl-O-*t*-butyl thiolcarbonate (III), 6.0 g. (11.6%), had b.p. 60.5–61° (15 mm.), n^{25}_{D} 1.4642. Dehydrohalogenation of S-(β-chloroethyl) chlorothiolformate gave b.p. 50° (6 mm.), $n^{21.2}_{\mathrm{D}}$ 1.4601.[11]

Anal. Calcd. for $C_7H_{12}O_2S$: C, 52.47; H, 7.55; S, 20.01. Found: C, 52.45; H, 7.46; S, 19.79.

(b) S,S'-Divinyl dithiolcarbonate (I), 9.5 g. (20%), had b.p. 77–77.5° (16 mm.), n^{25}_{D} 1.5780.

Anal. Calcd. for $C_5H_6OS_2$: C, 41.2; H, 4.12; S, 43.8. Found: C, 41.13; H, 4.22; S, 43.62.

(c) S-(β-Chloroethyl)-O-*t*-butyl thiolcarbonate (IV), 9.1 g. (14.5%), had b.p. 48–49° (0.5 mm.), n^{25}_{D} 1.4722; lit.[11] b.p. 51–52° (0.9 mm.), $n^{21.2}_{\mathrm{D}}$ 1.4693.

Anal. Calcd. for $C_7H_{13}ClO_2S$: C, 42.74; H, 6.66; S, 16.30; Cl, 18.05. Found: C, 42.85; H, 6.65; S, 16.45; Cl, 18.01.

The n.m.r. spectrum consisted of a complex multiplet centering around 6.61 and a single peak at 8.52 τ.

Since there was a discrepancy between the refractive index observed and that which was previously reported,[11] compound IV was independently synthesized by the following procedure. S-β-(Chloroethyl) chlorothiolformate, 35.7 g. (0.25 mole), was added to a solution of *t*-butyl alcohol, 18.5 g. (0.25 mole), and pyridine, 20 g. (0.25 mole) in 100 ml. of chloroform. The mixture was refluxed for 24 hr., cooled, and washed sequentially with water, 5% hydrochloric acid, 5% sodium carbonate, and water. After drying the chloroform solution with anhydrous magnesium sulfate, the solvent was evaporated under reduced pressure.

Distillation of the residue through a 30-cm. spinning band column yielded S-β-(chloroethyl)-O-*t*-butyl thiolcarbonate, 30 g. (60%), b.p. 72° (5.0 mm.), n^{25}_{D} 1.4719. The purity was checked by redistilling at a different pressure, b.p. 100° (14 mm.), n^{25}_{D} 1.4719. From the results, it is apparent that the refractive index reported here is a better value.

Anal. Calcd. for $C_7H_{13}ClO_2S$: C, 42.74; H, 6.66; S, 16.30; Cl, 18.05. Found: C, 42.76; H, 6.62; S, 16.03; Cl, 18.06.

(d) S-Vinyl-S'-β-chloroethyl dithiolcarbonate (VI), 0.9 g. (1.5%), had b.p. 83.5–84° (2.0 mm.), n^{25}_{D} 1.5684.

Anal. Calcd. for $C_5H_7ClOS_2$: C, 32.88; H, 3.83; S, 35.05; Cl, 19.45. Found: C, 32.94; H, 3.81; S, 34.76; Cl, 19.43.

(e) S-β-(Vinylmercapto)ethyl-S'-vinyl dithiolcarbonate (V), 6.0 g. (9%), had b.p. 112–113° (1.8 mm.), n^{25}_{D} 1.5958; by the same procedure but reported[2] as S,S'-divinyl dithiolcarbonate it had b.p. 73–74° (0.04 mm.), $n^{21.2}_{\mathrm{D}}$ 1.5967. Further purification by eluting from a "florisil" column with hexane and redistillation yielded a fraction, b.p. 109.5–110° (0.5 mm.), n^{25}_{D} 1.5998.

Anal. Calcd. for $C_7H_{10}OS_3$: C, 40.74; H, 4.85; S, 46.62; mol. wt., 206. Found: C, 40.76; H, 4.86; S, 46.59; mol. wt., 210.

Dehydrohalogenation of II in Presence of Ethylene Sulfide.—Ethylene sulfide, 10 g. (0.16 mole), and II, 35 g. (0.16 mole), were dissolved in 100 ml. of *t*-butyl alcohol and heated to 50°. A 1.5-*M* solution of potassium *t*-butoxide, 250 ml., was added at a rate which maintained the temperature between 50° and 60°. The mixture was stirred for 2 hr. after addition was completed and was worked up as described above.

Fractional distillation of the residue under reduced pressure yielded a forerun of I, 2.0 g. (8.5%), and IV, 2.5 g. (8.0%), a fraction composed primarily of V, 3.5 g. (11.0%), and a pale yellow oil, 5.0 g. (12.0%), b.p. 158–164° (0.2 mm.), n^{25}_{D} 1.6114.

Anal. Calcd. for $C_9H_{14}OS_4$: C, 40.6; H, 5.27; S, 48.2. Found: C, 40.32; H, 4.98; S, 47.26.

Acknowledgment.—We gratefully acknowledge the support of this work by the National Institute of Health under Grant No. AI-01425-09, and by the United States Air Force under Contract No. AF33-(616)-6866, monitored by the Materials Laboratory, Wright Air Development Center, Wright-Patterson Air Force Base, Ohio.

---

[9] Analyses by the Schwarzkopf Microanalytical Laboratory, Woodside, N. Y.

[10] D. Searles and E. F. Lutz, *J. Am. Chem. Soc.*, **80**, 3168 (1958).

[11] C. G. Overberger, H. Ringsdorf, and N. Weinshenker, *J. Org. Chem.*, **27**, 4331 (1962).

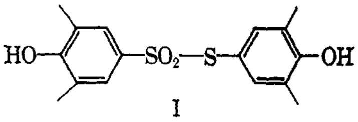
Reactions of Thionyl Chloride with 2,6-Dimethylphenol

H. H. TAKIMOTO AND G. C. DENAULT

Chemical Propulsion Department, Laboratories Division,
Aerospace Corporation, El Segundo, California

Received September 30, 1963

The reactions of phenols with thionyl chloride result in the formation of nuclear substitution products[1] in addition to chlorosulfinates. For example, bis(4-hydroxyphenyl) sulfide and tris-(4-hydroxyphenyl)-sulfonium chloride are reported[2] to be obtained as the major products of the phenol–thionyl chloride reaction. Where aluminum chloride was added, the corresponding sulfoxides[3] were formed. The preparation of a thiolsulfonate using the above reaction, however, has not been reported. In this report there is described the reaction of 2,6-dimethylphenol with excess thionyl chloride leading to the preparation of 3,5-dimethyl-4-hydroxyphenyl 3,5-dimethyl-4-hydroxybenzenethiolsulfonate (I). The structure of I was established by the synthesis of its dimethyl ether by an independent route. Furthermore, the treatment of 2,6-dimethylphenol with thionyl chloride to yield the sulfoxide and the sulfide is described.



I

---

[1] W. E. Bissinger and F. E. Kung, *J. Am. Chem. Soc.*, **70**, 2664 (1948), and references cited therein.

[2] A. Luttringhaus and K. Hauschild, *Ber.*, **72B**, 887 (1939).

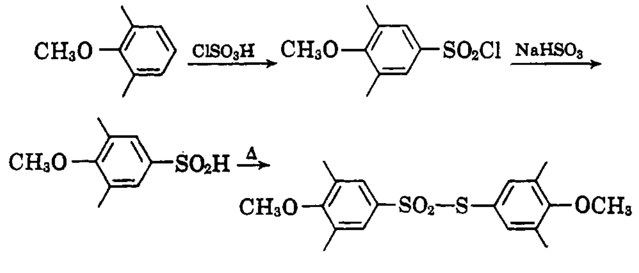
[3] S. Oae and C. Zalut, *J. Am. Chem. Soc.*, **82**, 5359 (1960).

Bissinger and Kung[1] had reported that the reaction of phenol with thionyl chloride was extremely sensitive to reaction conditions. Similarly, in the present work the course of the reaction was influenced greatly by the reaction temperature, stoichiometry, order of addition, degree of stirring, etc. Even when the same apparent reaction conditions were used in two runs, identical results were not always obtained.

The thiolsulfonate (I) is obtained by the reaction of thionyl chloride with 2,6-dimethylphenol in diethyl ether followed by hydrolysis. The infrared spectrum of I exhibited strong absorption bands at 7.66 and 8.95 μ, characteristic of a sulfonyl group.[4] Further bands in the region of 11.2 μ indicated no adjacent hydrogen on the benzene ring[4] supporting the presence of a substituent on the 4-position of 2,6-dimethylphenol. An ultraviolet spectrum taken on I in ethanol showed absorption maxima at 245 mμ (log ε 4.108) and at 278 (4.108). These values are in agreement with ultraviolet spectra of other thiolsulfonates.[5]

I was readily converted to the corresponding diacetate with acetic anhydride and pyridine or to the dimethyl ether with dimethyl sulfate. Attempted thermolytic decomposition of I in nitrobenzene according to the report of Kice, *et al.*,[6] yielded only a trace amount of bis(3,5-dimethyl-4-hydroxyphenyl) sulfide. This decomposition reaction apparently proceeds smoothly only for allylic type thiosulfonates.

As a part of the structure proof, the synthesis of the dimethyl ether of I was carried out. Thus, 2,6-dimethylanisole was converted to 3,5-dimethyl-4-methoxybenzenesulfonyl chloride which was then reduced to 3,5-dimethyl-4-methoxybenzene sulfinic acid. Disproportionation of this sulfinic acid by heating in cyclohexane yielded 3,5-dimethyl-4-methoxyphenyl 3,5-dimethyl-4-methoxybenzenethiolsulfonate. This compound was shown to be identical with the dimethyl ether prepared from I.



The ease of disproportionation of the above sulfinic acid suggests that in the original reaction, I resulted *via* the following scheme. Thionyl chloride reacted with 2,6-dimethylphenol to yield the benzenesulfinyl chloride. Hydrolysis of the latter compound to the sulfinic acid followed by disproportionation produced compound I.

$$RSO_2H \longrightarrow RSO_3H + RSO_2SR$$

Such disproportionation of sulfinic acids is well-known.[7] It is of interest to note that 2,6-dimethylanisole upon treatment with thionyl chloride followed by hydrolysis under the same condition failed to yield the thiolsulfonate. This result may indicate that the initial formation of the phenyl chlorosulfinate may be a necessary step prior to its rearrangement or reaction with another thionyl chloride to yield the benzenesulfinyl chloride, at least under the conditions described.

The addition of aluminum chloride to the reaction of 2,6-dimethylphenol with thionyl chloride in carbon tetrachloride using an excess of the phenol yielded bis-(3,5-dimethyl-4-hydroxyphenyl) sulfoxide (II). Sulfoxides have been reported[2,8] to be formed in the presence of aluminum chloride. This product probably resulted from a Friedel–Crafts reaction of the thionyl chloride on phenols. A strong sulfoxide band[4] at 9.85 μ was observed in the infrared spectrum taken on a potassium bromide disk of II. An ultraviolet spectrum in ethanol exhibited maximum absorption at 254 mμ (log ε 4.24).

Although the treatment of phenol and thionyl chloride has been reported[2,9] to yield the corresponding sulfide, chlorophenol, and sulfonium chloride, in the present study using 2,6-dimethylphenol only bis(3,5-dimethyl-4-hydroxyphenyl) sulfide and 2,6-dimethyl-4-chlorophenol were obtained. The ultraviolet spectrum of III taken in ethanol exhibited maxima at 236 mμ (log ε 4.17) and 252 (4.20).

Experimental[10,11]

3,5-Dimethyl-4-hydroxyphenyl 3,5-Dimethyl-4-hydroxybenzenethiolsulfonate (I).—A solution of 2,6-dimethylphenol (4.88 g.) dissolved in 20 ml. of diethyl ether was slowly added to 15 ml. of ice-cold thionyl chloride. A vigorous evolution of hydrogen chloride was observed immediately with the solution undergoing a color change of yellow to green and back to yellow. The solution was refluxed for 2 hr., then cooled in an ice bath and a mixture of 20 ml. of water and 50 ml. of diethyl ether was added cautiously. The addition of water resulted in vigorous foaming and evolution of gas. Additional water (100 ml.) and ether (50 ml.) were added and the mixture was stirred at room temperature overnight. A white solid which had precipitated was separated by filtration yielding 3.75 g. of the product. Recrystallization from toluene gave white needles melting at 184–186° dec. with rapid heating. The observed melting point values varied with the rate of heating. Upon standing for a few weeks it decomposed at a lower temperature.

Anal. Calcd. for $C_{16}H_{18}O_4S_2$: C, 56.77; H, 5.36; S, 18.95. Found: C, 57.04; H, 5.37; S, 18.85.

Diacetate of I.—Acetic anhydride (8 ml.) was added to a solution of I (1.0 g.) in 10 ml. of pyridine. The solution was refluxed for 2 hr., allowed to cool to room temperature, and then the dark mixture was poured onto crushed ice. The white solid which precipitated was separated by filtration to yield 1.24 g. of product melting at 212–220° dec. Recrystallizations from toluene–dioxane gave a compound melting at 238–240° dec.

Anal. Calcd. for $C_{20}H_{22}O_6S_2$: C, 56.85; H, 5.24; S, 15.18. Found: C, 57.13; H, 5.16; S, 15.12.

Dimethyl Ether of I.—Freshly distilled dimethyl sulfate (5 ml., 6.5 g.) was added dropwise to a mixture of anhydrous potassium carbonate (2.5 g.) and I (3.38 g.) in 50 ml. of acetone. The mixture was refluxed for 4 hr. and then filtered to remove the inorganic salts. The volatiles were removed under reduced pressure, and the residue was dissolved in hot cyclohexane, treated with decolorizing carbon, and concentrated. White needles (3.42 g.) melting at 122–125° were obtained. An analytical sample was prepared by further recrystallizations from cyclohexane showing λ_{max}^{EtOH} 242 mμ (log ε 4.165).

---

[4] L. J. Bellamy, "The Infrared Spectra of Complex Molecules," John Wiley and Sons, Inc., New York, N. Y., 1954, Chap. 22.

[5] G. Leandri, A. Mangini, and A. Tundo, *J. Chem. Soc.*, 52 (1957).

[6] (a) J. L. Kice, F. M. Parham, and R. M. Simons, *J. Am. Chem. Soc.*, **82**, 834 (1960); (b) J. L. Kice and F. M. Parham, *ibid.*, **82**, 6168 (1960); (c) J. L. Kice and R. Engebrecht, *J. Org. Chem.*, **27**, 4654 (1962).

[7] E. Wellisch, E. Gipstein, and O. J. Sweeting, *ibid.*, **27**, 1810 (1962), and references cited therein.

[8] C. Courtot and P. Chiffert, *Compt. rend.*, **194**, 986 (1932).

[9] P. Carré and D. Libermann, *ibid.*, **196**, 275 (1933).

[10] All melting points are uncorrected.

[11] Analyses were performed by Micro-Tech Laboratories, Skokie, Ill., and by Mr. S. Hotta of Aerospace Corp.

Anal. Calcd. for $C_{18}H_{22}O_4S_2$: C, 58.99: H, 6.05; S, 17.49. Found: C, 59.19; H, 5.94; S, 17.40.

3,5-Dimethyl-4-methoxybenzenesulfonyl Chloride.—Chlorosulfonic acid (50 g., 28 ml.) was added dropwise to an ice-cold solution of 2,6-dimethylanisole (10 g.) in 50 ml. of chloroform. The temperature was kept below 8° during the addition and considerable evolution of hydrogen chloride was observed as the mixture turned dark brown. After the addition of the chlorosulfonic acid was completed, the mixture was allowed to warm to room temperature and then stirred for 30 min. The contents of the flask were poured onto 250 g. of crushed ice and 100 ml. of chloroform was added. The organic layer was separated, washed with cold water, and dried over calcium sulfate. The removal of the solvent under reduced pressure yielded a light brown oil (15.29 g.) which later crystallized, m.p. 40–45°. Recrystallizations from petroleum ether (b.p. 60–90°) gave 3,5-dimethyl-4-methoxybenzenesulfonyl chloride as a white crystalline solid melting at 44–46°.

From the above benzenesulfonyl chloride and concentrated ammonium hydroxide solution, 3,5-dimethyl-4-methoxybenzenesulfonamide, m.p. 131–132°, was prepared.

Anal. Calcd. for $C_9H_{13}NO_3S$: C, 50.21; H, 6.08; N, 6.51. Found: C, 50.37; H, 5.95; N, 6.41.

In contrast to the above results, Baliah and Uma[12] have reported that 3,5-dimethyl-4-methoxybenzenesulfonyl chloride is a yellow oil and the sulfonamide derived from it melts at 108–110°.

3,5-Dimethyl-4-methoxybenzenesulfinic Acid.—A mixture of 3,5-dimethyl-4-methoxybenzenesulfonyl chloride (2.35 g.), sodium bisulfite (2.08 g.), and sodium hydroxide (0.04 g.) was gently heated in 100 ml. of water for 4 hr. In order to keep the mixture alkaline, 50% sodium hydroxide was added periodically. During the heating period, the sulfonyl chloride gradually dissolved until finally a clear solution was obtained. The solution was cooled to 0° and carefully was acidified with dilute sulfuric acid while keeping the mixture cold in an ice bath. A copious quantity of white solid precipitated during the acidification. The solid was separated and dried under vacuum yielding 1.68 g. of product melting at 83–90°. This solid was unstable and decomposed upon standing at room temperature. The product was used immediately after isolation for the next step. An analytical sample, m.p. 86–89°, was obtained by dissolving the product in cold diethyl ether and then concentrating the solution under vacuum until a white solid separated.

Anal. Calcd. for $C_9H_{12}O_3S$: C, 53.98; H, 6.04. Found: C, 54.2; H, 6.18.

Disproportionation of 3,5-Dimethyl-4-methoxybenzenesulfinic Acid.—A solution of freshly prepared 3,5-dimethyl-4-methoxybenzenesulfinic acid (1.0 g.) in 80 ml. of cyclohexane was refluxed for 1 hr. The white solid gradually dissolved during the heating period and a brown oil separated. The supernatant clear solution was decanted, and the brown oil was extracted twice with 15-ml. portions of hot cyclohexane. The cyclohexane solutions were combined and concentrated to yield a white solid (0.55 g.) melting at 121–124°. A mixture melting point with the dimethyl ether prepared from I showed no depression and the infrared spectra of the samples were identical.

Bis(3,5-dimethyl-4-hydroxyphenyl) Sulfoxide.—Anhydrous aluminum chloride (4.45 g.) was added to a well-stirred, ice-cold solution of 2,6-dimethylphenol (6.1 g.) dissolved in 50 ml. of carbon tetrachloride. Thionyl chloride (2.4 ml.) was added then to the above cold solution over a period of 5 min. The reaction mixture was stirred at room temperature for 2 hr. and was decomposed by pouring onto 100 g. of crushed ice containing 5 ml. of concentrated hydrochloric acid. The solid which precipitated was separated and washed with water. The crude product (7.21 g.) melted at 184–198° dec. Recrystallizations from either acetonitrile or ethyl acetate yielded a white product (5.39 g.) with a lower melting point of 167–167.5° dec.

Anal. Calcd. for $C_{16}H_{18}O_3S$: C, 66.17; H, 6.25; S, 11.04. Found: C, 66.14; H, 6.42; S, 11.06.

Bis(3,5-dimethyl-4-hydroxyphenyl) Sulfide.—A procedure similar to that described by Oae and Zalut[3] was used.

Thionyl chloride (12 ml., 17.5 g.) was added to a cold solution of 2,6-dimethylphenol (52.0 g.) dissolved in 50 ml. of chloroform. The yellow solution was allowed to stand at room temperature for 2 days. During this time a white crystalline solid precipitated from the reaction mixture. The solid was separated and recrystallized from cyclohexane to yield white needles (31.69 g.) melting at 121–122°, lit.[13] m.p. 121.5–122°.

Anal. Calcd. for $C_{16}H_{18}O_2S$: C, 70.03; H, 6.61; S, 11.68. Found: C, 69.79; H, 6.58; S, 11.51.

From the chloroform filtrate, 2,6-dimethyl-4-chlorophenol, m.p. 80–81°, was obtained.

Acknowledgment.—The authors are indebted to Dr. L. Krbechek and Dr. L. Schieler for many helpful discussions and the interest expressed in this work. The authors are also grateful to Mr. S. Hotta for infrared and ultraviolet spectral measurements and assistance in the laboratory.

---

[12] V. Baliah and M. Uma, *J. Indian Chem. Soc.*, **40**, 381 (1963).

[13] J. L. Binder, J. C. Ambelang, and F. J. Webb, *J. Am. Chem. Soc.*, **81**, 3608 (1959).

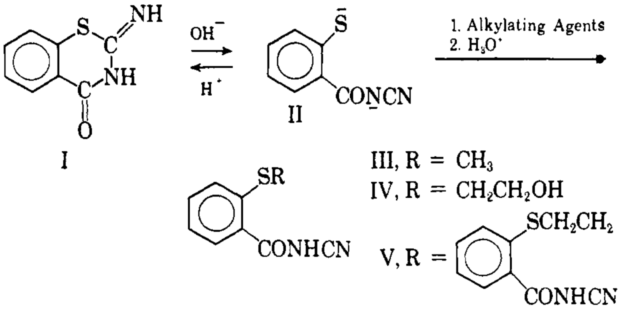
Ring Cleavage of 2,3-Dihydro-2-imino-4*H*-1,3-benzothiazin-4-one[1]

JOHN C. HOWARD

Biochemistry Department, Medical College of Georgia, Augusta, Georgia

Received July 29, 1963

In connection with another problem we observed that the title compound (I) was insoluble in concentrated ammonia at 50°, but dissolved in excess warm 10% sodium hydroxide and evolved hydrogen immediately in the cold with sodium hydride. Neutralization of the basic solutions regenerated I. As at least two equivalents of base were required to effect complete solution, it appeared reasonable that a ring cleavage of I to the disodium salt of *o*-mercaptobenzoyl cyanamide (II) was occurring. This was shown to be so by the reaction of these solutions with methyl iodide. A good yield of *o*-(methylthio)benzoyl cyanamide (III) was obtained, identical with III prepared from *o*-(methylthio)benzoyl chloride and sodium cyanamide. The reaction of I with ethylene oxide and ethylene bromide gave, respectively, *o*-(2-hydroxyethylthio)benzoyl cyanamide (IV) and the 1,2-bis substituted ethane V.



The acidity of acylcyanamides (or N-cyanoacetamides) has inspired little interest since the dissociation constants were determined conductimetrically by Bader[2] nearly 75 years ago. He discovered that the acetyl, butyryl, and benzoyl cyanamides gave pK_a's of 3.82, 3.95, and 2.7, respectively. We found III to have a pK_a of 2.81

---

[1] This work was supported by Grant CY-05906 from the National Institutes of Health and the Medical College of Georgia Professional Research Fund, and was presented at the 145th National Meeting of the American Chemical Society, New York, N. Y., September, 1963.

[2] R. Bader, *Z. phys. Chem.*, **6**, 304 (1890).