silane had been added, the low-temperature bath was removed and the suspension was stirred for 2.5 hours prior to being heated at the reflux temperature for one hour. The reaction mixture was worked up in the usual way and the product was distilled. The yield of trimethyl-(*p*-bromophenyl)-silane, distilling at 53–56° at 0.2 mm., was 32.6 g. (79%). The constants observed were $n^{20}\text{D}$ 1.5285, $d^{20}{}_{20}$ 1.2206.

Anal. Calcd. for $C_9H_{13}BrSi$: Br, 34.9; Si, 12.2; *MR*D, 57.63.[9] Found: Br, 34.7; Si, 12.1; *MR*D, 57.53.

In subsequent preparations, the yields were between 75 and 83%, the quantities of trimethylchlorosilane used being 0.12 to 0.40 mole. Burkhard,[10] who prepared this compound from trimethylchlorosilane and *p*-bromophenylmagnesium bromide, lists the constants as $n^{20}\text{D}$ 1.5302, $d^{20}{}_4$ 1.2197.

Trimethyl-(*p*-bromophenyl)-silane and Lithium Dimethylamide.—Ten grams (0.0436 mole) of trimethyl-(*p*-bromophenyl)-silane in ether was added to lithium dimethylamide (prepared in ether from 0.057 mole of *n*-butyllithium and dimethylamine).[11] The mixture was heated at its reflux temperature with stirring for 48 hours. After hydrolysis, the ether layer was extracted with five 10-ml. portions of hydrochloric acid. From the ether layer was obtained 2.0 g. (20% recovery) of trimethyl-(*p*-bromophenyl)-silane. The aqueous portion was made basic with 20% sodium hydroxide, and the yield of what was believed to be trimethyl-(*p*-dimethylaminophenyl)-silane, distilling at 73–76° at 1 mm., was 4.7 g. (56%), $n^{20}\text{D}$ 1.5211, $d^{20}{}_{20}$ 0.9103. On the basis of the quantity of trimethyl-(*p*-bromophenyl)-silane reacting, the yield of the amine was 82.4%.

Anal. Calcd. for $C_{11}H_{19}NSi$: N, 7.25; Si, 14.51; *MR*D, 64.80.[9] Found: N, 7.22; Si, 14.35; *MR*D, 64.45.

The picrate melted at 154–156° (recrystallized from ethanol).

In a second experiment, 16.0 g. (0.070 mole) of trimethyl-(*p*-bromophenyl)-silane in ether was added to an ether suspension of lithium dimethylamide (from 0.082 mole of *n*-butyllithium and dimethylamine).[11] Most of the ether was removed by distillation and replaced with 65 ml. of pure benzene. The suspension was then refluxed for 108 hours. The yield of the supposed trimethyl-(*p*-dimethylaminophenyl)-silane obtained was 8.3 g. (62.2%), and 3.0 g. (19%) of the starting silane was recovered. The melting point of the picrate of the amination product was 153–155° (after recrystallization from 95% ethanol). The melting point of a mixture of this picrate and that of the previous run was not depressed. When adjustment was made to include only the quantity of trimethyl-(*p*-bromophenyl)-silane reacting, the yield of amine was 90.2%, $n^{20}\text{D}$ 1.5280, $d^{20}{}_{20}$ 0.9194. In another experiment, 45.8 g. (0.200 mole) of trimethyl-(*p*-bromophenyl)-silane in 150 ml. of anhydrous ether was added to lithium dimethylamide (prepared as above) at a rate to maintain gentle reflux. The gray color of the reaction mixture became orange on refluxing for 48 hours. After subsequent treatments as described above, there was recovered 1.5 g. (3.3%) of trimethyl-*p*-bromophenyl)-silane. There was also obtained 9.6 g. (24.9% yield) of trimethyl-(*m*-dimethylaminophenyl)-silane distilling at 60–61° at 0.4 mm., $n^{25}\text{D}$ 1.5324, $d^{20}{}_4$ 0.9500. On the basis of the quantity of the trimethyl-(*p*-bromophenyl)-silane reacting, the yield of the amine was 25.8%. A lower boiling fraction distilling at 34–36° at 0.55 mm., and weighing 4.5 g. gave a negative qualitative test for silicon.[12] A considerable quantity of a highly viscous residue could not be distilled under our conditions. In a check experiment, essentially the same results were obtained as in the experiment just described, and the yield of trimethyl-(*m*-dimethylaminophenyl)-silane was 25.3%.

Trimethyl-(*m*-dimethylaminophenyl)-silane.—To 0.442 g. (0.0636 g. atom) of lithium wire (cut into pieces of less than 1 cm. in length) in 25 ml. of anhydrous ether was added 5.80 g. (0.0289 mole) of *m*-bromodimethylaniline (kindly provided by S. D. Rosenberg and F. J. Marshall) in 20 ml. of anhydrous ether at a rate to maintain gentle reflux. After completion of addition, the solution was stirred for 2 hours at reflux temperature. The excess lithium was filtered off and there was added to the solution 3.12 g. (0.0289 mole) of trimethylchlorosilane in 35 ml. of anhydrous ether. A white precipitate formed during this addition. Hydrolysis of the reaction mixture was carried out after refluxing overnight. The ether layer was extracted several times with 20 ml. portions of 1:1 concd. HCl. The acid layer was separated, made basic with 20% KOH, and ether-extracted several times. This ether extract was dried over anhydrous Na_2SO_4, the solvent distilled, and the remaining liquid vacuum distilled. There was obtained 2.6 g. (46.4% yield) of material distilling at 59–60° at 0.4 mm., $n^{25}\text{D}$ 1.5312, $d^{20}{}_4$ 0.9484.

Anal. Calcd. for $C_{11}H_{19}NSi$: Si, 14.51; *MR*D, 64.80.[9] Found: Si, 14.41, 14.36; *MR*D, 63.9.

Trimethyl-(*p*-dimethylaminophenyl)-silane.—This compound was prepared[3] in 78.6% yield from 8.20 g. (0.075 mole) of trimethylchlorosilane and 0.079 mole of *p*-dimethylaminophenyllithium. The constants observed were $n^{20}\text{D}$ 1.5362, and $d^{20}{}_4$ 0.9254. The constants previously reported were $n^{20}\text{D}$ 1.5338, $d^{20}{}_4$ 0.9249.[3] The picrate melted at 154–156°, and the melting point of a mixture of this picrate with that of each amination product from the first two experiments described was 154–155°.

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[9] Molar refractions were calculated from the values of R. O. Sauer, THIS JOURNAL, **68**, 954 (1946); E. L. Warrick, *ibid.*, **68**, 2455 (1946).

[10] C. E. Burkhard, *ibid.*, **68**, 2103 (1946).

[11] H. Gilman, N. N. Crounse, S. P. Massie, R. A. Benkeser and S. M. Spatz, *ibid.*, **67**, 2106 (1945).

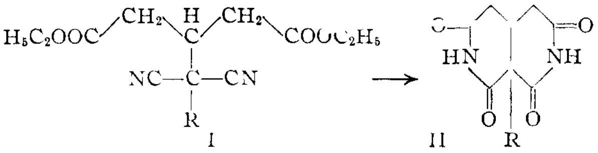
[12] H. Gilman, R. K. Ingham and R. D. Gorsich, *ibid.*, **76**, 918 (1954).

A New Synthesis of 2,7-Naphthyridine Derivatives[1]

BY B. M. ISELIN AND K. HOFFMANN

RECEIVED DECEMBER 15, 1953

Gabriel and Colman[2] described the preparation of 1,4-dihydroxy-2,7-naphthyridine starting from pyridine-3,4-dicarboxylic acid (cinchomeronic acid). There exists, to our knowledge, no other report in the literature on the synthesis of this ring system. In continuation of our earlier studies on the intramolecular cyclization of ω-cyanocarboxylic acids[3] we condensed monosubstituted malononitriles with ethyl β-bromoglutarate to give the diester I which, on treatment with sulfuric acid in glacial acetic acid, yielded the perhydro-2,7-naphthyridine derivatives II.



a, R = C_6H_5
b, R = C_2H_5

When ethyl was the substituent in position 9 (IIb) the oxo groups were eliminated by reduction with lithium aluminum hydride to give perhydro-9-ethyl-2,7-naphthyridine as the main product. A minor fraction consisted of a compound which still contained one oxygen function. Re-

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[1] Number 7 on Alkyleneimides. For No. 6 see E. Tagmann, E. Sury and K. Hoffmann, *Helv. Chim. Acta*, **37**, 185 (1954).

[2] S. Gabriel and J. Colman, *Ber.*, **35**, 1358 (1902).

[3] E. Tagmann, E. Sury and K. Hoffmann, *Helv. Chim. Acta*, **35**, 1235 (1952).

duction of this latter substance gave, again, a mixture in which the fully reduced 2,7-naphthyridine derivative prevailed.

When R was phenyl (IIa) the only product obtained on reduction with lithium aluminum hydride was mono-oxo-perhydro-9-phenyl-2,7-naphthyridine. Contrary to the corresponding 9-ethyl derivative this compound was hardly attacked by repeated treatment with lithium aluminum hydride.

Common to the reductions described is the observation that one oxygen function is reduced with difficulty only. This fact suggests the steric arrangement of the naphthyridine ring system to be of such a nature that one oxo group (presumably in position 1 or 8) is shielded from the attack of lithium aluminum hydride by the neighboring aryl or alkyl substituent.

Experimental

Ethyl β-Bromoglutarate.—To a solution of 40 g. (0.15 mole) of redistilled phosphorus tribromide in 30 ml. of dry benzene was added slowly 5 ml. of dry pyridine. The solution was cooled in an ice–salt-bath and a mixture of 81.6 g. (0.4 mole) of ethyl β-hydroxyglutarate,[4] 60 ml. of anhydrous benzene and 3 ml. of dry pyridine was added with stirring over a period of 2 hours, the temperature being maintained at −5 to −3°. After stirring for an additional two hours at this temperature the reaction mixture was allowed to stand for 30 hours at 20°. It was then diluted with 200 ml. of ether, extracted with 2 *N* sulfuric acid and cold 2 *N* sodium carbonate solution, washed with water and evaporated *in vacuo*. Fractional distillation of the crude product yielded 49.0 g. (46%) of the bromo compound boiling at 95–100° (0.5 mm.); n^{20}_D 1.4542. Even after repeated redistillation the bromine content was somewhat low (Calcd. for $C_9H_{15}O_4Br$: 29.92. Found: 27.66) due to decomposition during the distillation.

A sample of the bromo compound was dehydrohalogenated by treatment with *s*-collidine for 30 minutes at 140°. The resulting ethyl glutaconate, b.p. 126–129° (11 mm.), n^{20}_D 1.4474, was saponified by refluxing with a mixture of 10 parts of glacial acetic acid and one part of 85% sulfuric acid; from the concentrated solution glutaconic acid separated which, after recrystallization from a little water, melted at 135–136° (reported[5] 137–138°); neut. equiv. 66 (calcd. 65.05).

Ethyl β-(Phenyldicyanomethyl)-glutarate (Ia).—A solution of 28.4 g. (0.2 mole) of phenylmalonitrile[6] in 100 ml. of dry xylene (b.p. 139–140°) was added dropwise over a period of 15 minutes to a stirred suspension of sodium ethylate, freshly prepared from 4.6 g. (0.2 atom) of sodium, in 100 ml. of dry xylene. The mixture was heated to 130° until no more alcohol distilled. After cooling to 80° a solution of 67 g. (0.25 mole) of ethyl β-bromoglutarate in 100 ml. of dry xylene was slowly added with stirring within 30 minutes to the suspension of the sodium salt of phenylmalonitrile. Stirring was continued for one hour at 80° and for 3 hours at reflux temperature. The cooled mixture was extracted with 5 *N* sodium hydroxide solution and the organic layer was washed with water, dried and evaporated to dryness under diminished pressure. On fractional distillation 27.7 g. (42%) of Ia boiling at 143–145° (0.05 mm.) was obtained.

Anal. Calcd. for $C_{18}H_{20}O_4N_2$: N, 8.53. Found: N, 8.23.

From the alkaline aqueous extracts 10.2 g. (35%) of unchanged phenylmalonitrile was recovered.

Ethyl β-(Ethyldicyanomethyl)-glutarate (Ib).—Condensation of ethylmalonitrile[7] with ethyl β-bromoglutarate in the same manner gave the diester Ib, b.p. 102–105° (0.02 mm.); the yields were somewhat lower (21–27%).

Anal. Calcd. for $C_{14}H_{20}O_4N_2$: N, 9.99. Found: N, 10.35.

Perhydro-1,3,6,8-tetraoxo-9-phenyl-2,7-naphthyridine (IIa).—A mixture of 9.85 g. (0.03 mole) of the diester Ia, 30 ml. of acetic acid and 2 ml. of 85% sulfuric acid was refluxed for 5 hours. The 2,7-naphthyridine derivative which separated in the course of the reaction was filtered and washed with water and acetone; yield 5.81 g. (71%), m.p. 303–304°. Recrystallization from dioxane did not raise the melting point.

Anal. Calcd. for $C_{14}H_{12}O_4N_2$: C, 61.76; H, 4.44; N, 10.29. Found: C, 61.73; H, 4.64; N, 10.02.

The corresponding **9-ethyl derivative (IIb)** was prepared from the diester Ib; it melted at 280–282° after recrystallization from dioxane–ether; yield 62%.

Anal. Calcd. for $C_{10}H_{12}O_4N_2$: C, 53.57; H, 5.39; N, N, 12.50. Found: C, 53.38; H, 5.56; N, 12.38.

Reduction of Perhydro-1,3,6,8-tetraoxo-9-phenyl-2,7-naphthyridine (IIa).—A suspension of 5.44 g. (0.02 mole) of IIa in 50 ml. of anhydrous tetrahydrofuran was added under nitrogen with stirring to a slurry of 3.8 g. (0.1 mole) of lithium aluminum hydride in 50 ml. of dry tetrahydrofuran at 60° over a period of one hour. After refluxing for 2 hours the reaction mixture was cooled, diluted with 100 ml. of ether and water (15 ml.) was added carefully with stirring. The inorganic material was dissolved by addition of 150 ml. of 10% sulfuric acid and the organic phase containing 0.46 g. of neutral material (mostly starting material) was separated. The aqueous phase was made alkaline by addition of 30% sodium hydroxide solution and thoroughly extracted with chloroform, the separation of the layers being effected by centrifugation. Evaporation of the dried extracts gave 2.76 g. of basic material from which 0.99 g. (21%) of crystalline **perhydro-monoöxo-9-phenyl-2,7-naphthyridine** separated on addition of acetone. After recrystallization from methanol–acetone–ether it melted at 174–176°.

Anal. Calcd. for $C_{14}H_{18}ON_2$: C, 73.01; H, 7.88; N, 12.17. Found: C, 72.73; H, 7.80; N, 11.91.

The remaining material consisted of a viscous gum which decomposed on attempted distillation.

The hydrochloride was prepared by addition of an equivalent amount of hydrochloric acid, dissolved in ethanol, to the alcoholic solution of the base; m.p. 322–324° after recrystallization from ethanol.

Anal. Calcd. for $C_{14}H_{19}ON_2Cl$: C, 63.03; H, 7.18; N, 10.50. Found: C, 63.04; H, 7.13; N, 10.35.

On treatment of 1.15 g. (0.005 mole) of the monoöxo-compound with 3.8 g. (0.1 mole) of lithium aluminum hydride in the same manner 0.59 g. (51%) of the starting material was recovered. It was not possible to obtain a completely reduced product such as resulted under these conditions from IIb (see below).

Reduction of Perhydro-1,3,6,8-tetraoxo-9-ethyl-2,7-naphthyridine (IIb).—The reduction of 27 g. (0.12 mole) of IIb with lithium aluminum hydride was carried out as described above. After decomposition with water the mixture was filtered through a sintered glass funnel and the inorganic material was extracted several times with hot tetrahydrofuran. The filtrate was evaporated to dryness under diminished pressure. Fractional distillation of the crude base gave two fractions.

Fraction 1, 10.2 g. (50%), b.p. 75–78° (0.03 mm.), consisted of the fully reduced **perhydro-9-ethyl-2,7-naphthyridine.**

Anal. Calcd. for $C_{10}H_{20}N_2$: C, 71.37; H, 11.98; N, 16.65. Found: C, 71.24; H, 11.77; N, 16.68.

Dihydrochloride, m.p. 292–293°.

Anal. Calcd. for $C_{10}H_{22}N_2Cl_2$: Cl, 29.40. Found: Cl, 28.74.

Fraction 2, 3.5 g. (16%), b.p. 125–130° (0.03 mm.), was **perhydro-monoöxo-9-ethyl-2,7-naphthyridine.**

Anal. Calcd. for $C_{10}H_{18}ON_2$: C, 65.89; H, 9.96. Found: C, 66.06; H, 10.05.

Hydrochloride: m.p. 264–265°.

Anal. Calcd. for $C_{10}H_{19}ON_2Cl$: Cl, 16.21. Found: Cl, 16.25.

The latter substance (2.73 g., 0.015 mole) was treated again with 0.05 mole of lithium aluminum hydride. On fractional distillation 1.28 g. (51%) of the fully reduced

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[4] H. L. Lochte and P. L. Pickard, THIS JOURNAL, **68**, 721 (1946).

[5] E. Buchner, *Ber.*, **27**, 881 (1894).

[6] J. C. Hessler, *Am. Chem. J.*, **32**, 119 (1904).

[7] J. C. Hessler, *ibid.*, **22**, 169 (1899).

naphthyridine derivative and 0.54 g. (20%) of unchanged starting material was obtained.

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p-t-Butylphenylphosphonic Acid

BY GENNADY M. KOSOLAPOFF

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The chemical literature does not record the preparation of alkylphenylphosphonic acids, which carry radicals higher than methyl, as pure individual substances. It was necessary to obtain some *p-t*-butylphenylphosphonic acid for some of our work on organophosphorus compounds. This afforded a comparison of the results of synthesis by two routes. The Friedel–Crafts synthesis, the technique of which was reported earlier,[1] gave a mixture of products from which the desired substance was isolated after considerable purification work. The diazonium fluoborate method yielded the desired substance in pure state in a 55% yield.

Experimental Part

The Friedel–Crafts Method.—The reaction was run according to the previously described procedure,[1] with employment of 67 g. of *t*-butylbenzene, 270 g. of phosphorus trichloride, 45 g. of aluminum chloride, and 115 g. of absolute ethanol. Distillation afforded but 21.5 g. of product, which boiled at 165–180° at 2–3 mm., with considerable resinous residue. The distillate of diethyl *t*-butylphenylphosphonate was hydrolyzed with concentrated hydrochloric acid at reflux and yielded some 10 g. of the *p*-isomer of the free acid, m.p. 199–200°, after repeated crystallization from water. When the distillation residue was extracted with warm 1% sodium hydroxide and the extract was acidified, there was obtained a mixture of phosphonic and phosphinic acids which, after repeated crystallization from glacial acetic acid, gave 10.4 g. of bis-*p-t*-butylphosphinic acid, m.p. 211–212°. The residual material appeared to consist of a mixture.

The Diazonium Fluoborate Method.—Acetanilide was alkylated with isobutyl bromide, with aluminum chloride catalyst, in tetrachloroethane[2] yielding 45% *p-t*-butylacetanilide, m.p. 169° (from dilute alcohol). This was refluxed for six hours with concentrated hydrochloric acid (20 g. of amide was employed) and the solution was directly employed for diazotization with 6.9 g. of sodium nitrite. The solution of the diazonium salt was treated with sodium fluoborate, in the usual manner, yielding 16 g. of *p-t*-butylphenyldiazonium fluoborate. This, after thorough drying, was suspended in dry dioxane and treated with 10 ml. of phosphorus trichloride, followed by 2 g. of dry cuprous bromide. The usual treatment of the reaction mixture[3] resulted in isolation of 55% pure *p-t*-butylphenylphosphonic acid, which formed long needles, m.p. 199.5–200° (from water). A very small amount (0.15 g.) of the corresponding phosphinic acid, m.p. 211–212° (from acetic acid) was obtained from the water-insoluble material formed in the reaction. Mixed melting points with specimens obtained from the Friedel–Crafts synthesis, described above, showed no depressions.

Anal. Calcd. for $C_{10}H_{15}O_3P$: P, 14.5; equiv. wt., 107. Found: P, 14.3, 14.4; equiv. wt., 106, 107.5. Calcd. for $C_{20}H_{27}O_2P$: equiv. wt., 330. Found: equiv. wt., 328, 329.

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[1] G. M. Kosolapoff and W. F. Huber, THIS JOURNAL, **69**, 2020 (1947).

[2] G. S. Kolesnikov, "Syntezy Organicheskikh Soedinenii," Sbornik 1, 134, Acad. Sci. U.S.S.R., Moscow, 1950.

[3] G. O. Doak and L. D. Freedman, THIS JOURNAL, **73**, 5658 (1951).

Bromomethylcyclobutane

BY ROBERT C. KRUG, LOUIS W. SMITH AND CHARLES E. FRY

RECEIVED JANUARY 4, 1954

Bromomethylcyclobutane (I) was prepared in 59% yield by the addition of hydrogen bromide to methylenecyclobutane in the presence of benzoyl peroxide. The anilide from I was prepared and after repeated recrystallizations from petroleum ether was found to melt at 80.0–81.0°. For comparison the anilide from bromocyclopentane (II) was prepared and the melting point of the compound after recrystallization from carbon tetrachloride was found to be 160.1–161.2°. The lack of simple derivatives of II prompted the preparation of the corresponding α-naphthalide. A mixture of the two anilides melted over the range 80–136°. These data plus the data available on the melting points of the anilides derived from the simpler aliphatic halides show that the four carbon ring compound did not undergo ring enlargement or ring rupture during the peroxide-catalyzed addition of hydrogen bromide.

Thus, it is found that the addition of hydrogen bromide to methylenecyclobutane in the presence of benzoyl peroxide proceeds smoothly, and on the basis of the well-known peroxide effect the addition product is assigned the structure corresponding to I.

Experimental[1]

Methylenecyclobutane.—Crude pentaerythrityl bromide[2] was converted to methylenecyclobutane by the procedure of Slabey[3] with the exception that sodium carbonate and sodium iodide were not present in the reaction mixture. The presence of these substances caused considerable frothing during the debromination.

Bromomethylcyclobutane.—Methylenecyclobutane (b.p. 38.5–39.5° at 707 mm., $n^{25}D$ 1.4120–1.4160) was dissolved in an equal volume of 30–60° petroleum ether to which benzoyl peroxide was added in a ratio of 0.03 mole of peroxide to one mole of olefin. Hydrogen bromide was generated by the dropwise addition of bromine to tetralin, and a second flask of tetralin was used to scrub the gas free of bromine. The gas was then passed into the petroleum ether solution of methylenecyclobutane in a glass vessel cooled to −6°. No hydrogen bromide was evolved at the exhaust until the addition had proceeded for 2.5 hours. Hydrogen bromide was passed into the solution for an additional 30 minutes to ensure maximum conversion. The solution from the reactor was washed with water to remove excess hydrogen bromide and with ferrous sulfate solution to remove the peroxide. The liquid, dried over calcium chloride, was distilled to give crude bromomethylcyclobutane in 59% yield. Redistillation gave a product having a boiling range of 121–123° at 710 mm. with a refractive index of $n^{25}D$ 1.4704.

Anal. Calcd. for C_5H_9Br: C, 40.29; H, 6.09; Br, 53.62. Found: C, 40.39; H, 6.13; Br, 53.79.

Anilide from Bromomethylcyclobutane.—The anilide was prepared by the conversion of 16.4 g. (0.11 mole) of bromomethylcyclobutane to the Grignard reagent and the subsequent reaction of this reagent with an ether solution containing 9.5 g. (0.08 mole) of phenyl isocyanate. Upon hydrolysis of this reaction mixture and the evaporation of the ether an oil was obtained. The oil was subjected to mild steam distillation for 5 minutes after which the residual oil was separated from the water. The oil solidified upon cooling, and the solid was crystallized from methanol followed by successive recrystallizations from petroleum ether to give a solid melting at 80.0–81.0° (cor.).

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[1] Analyses performed by Oakwold Laboratories, Alexandria, Virginia, and Micro-Tech Laboratories, Skokie, Illinois.

[2] H. B. Schurink, "Organic Syntheses," Coll. Vol. II, John Wiley and Sons, Inc., New York, N. Y., 1943, p. 476.

[3] V. A. Slabey, THIS JOURNAL, **68**, 1335 (1946).