

hibited the reaction, but the essential nature of the reaction was not extensively studied. It was the purpose of this investigation to at least make a beginning in this direction.

Experimental

Reagents. Preparation of Trimethyl Phosphate.—This preparation is given in some detail since the general method for alkyl phosphates given in "Organic Syntheses"⁷ is inapplicable because of the high solubility of trimethyl phosphate in water.

One pound (454 g., 8.4 moles) of sodium methylate⁸ is suspended in 1200 ml. of dry C.P. benzene in a 3-neck, round-bottom, 5-liter flask, fitted with a reflux condenser, stirrer, and dropping funnel. To the flask is added in such a manner as to keep the temperature between 50 and 60°, 255 ml. (428 g., 2.8 moles) of phosphorus oxychloride, taking approximately four hours to complete the addition. The reaction is exothermic. The reaction mixture is allowed to stand overnight, and then most of the benzene layer is decanted off. The remaining sodium chloride is extracted with an additional 750 ml. of benzene in a Soxhlet extractor. The combined benzene solutions are concentrated under reduced pressure and the residue is distilled to yield 333.5 g. of trimethyl phosphate, b.p. 94° (22 mm.); n_D^{20} 1.3960; yield 85%.

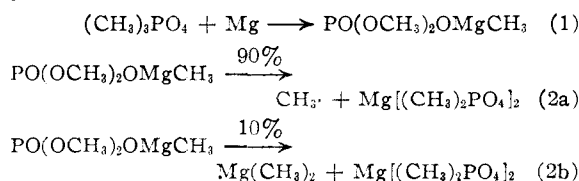
The Reaction.—Metallic magnesium reacts with trimethyl phosphate, slowly at room temperature, vigorously at elevated temperatures. The reaction appears to be autocatalytic, and it is convenient to induce the room temperature reaction by initial heating for several minutes at temperatures just below boiling (ca. 160–170°). It may also be induced by the introduction of several crystals of iodine. Immediately vigorous reaction begins, the reaction vessel can be cooled down to room temperature, where it will continue at an appreciate rate. It is necessary, under these conditions, to cool the reaction vessel in a water-bath as the reaction is strongly exothermic.

Reaction is accompanied by the evolution of a gas which in a typical case contained 71.1% methane, 6.7% ethane, 13.8% acetylene, a trace of ethylene and no hydrogen, and the formation of a blackish-gray sludge. This sludge clings tenaciously to the magnesium particles and slows the reaction, and even may cause it to terminate before the magnesium is totally consumed.

The sludge may be separated from the supernatant liquid and, upon treatment with water, acetylene, identified by the formation of cuprous acetylide, is evolved, and white, gelatinous magnesium hydroxide is precipitated, indicating that one component of the sludge is probably magnesium carbide. Upon filtering off the magnesium hydroxide and evaporating the resulting solution to dryness, a glassy, difficultly crystallizable substance, soluble in water and methanol, is formed.

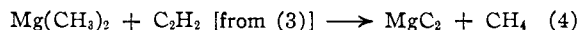
This solid residue upon solution in water, gave a qualitative test for magnesium, but none for phosphate. However, after heating with dilute hydrochloric acid, a positive test for phosphate ion was obtained, suggesting that the material was either magnesium monomethyl phosphate ($Mg(CH_3)PO_4$) or magnesium dimethyl phosphate ($Mg[(CH_3)_2PO_4]_2$). The magnesium content of the product was determined by standard gravimetric procedures, with the following results: found 9.3%; calcd. for $MgCH_3PO_4$, 18.1%; calcd. for $Mg[(CH_3)_2PO_4]_2$, 8.9%. The agreement is not too good, but it is quite evident that the data favor the supposition that the material is magnesium dimethyl phosphate.

A possible mechanism for this reaction might be postulated as



(7) A. H. Blatt (Ed.), "Organic Syntheses," Coll. Vol. II, John Wiley and Sons, Inc., New York, N. Y., 1943, pp. 109–111.

(8) Obtainable in one-pound containers of minimum 95% purity from the Mathieson Chemical Company, Niagara Falls, N. Y.



The mode of formation of the MgC_2 is suggested by the analogous preparation of this compound from C_2H_5MgBr and C_2H_2 by Rueggeberg.⁹ The hypothesized Grignard-like intermediate must, however, be extremely short-lived, since attempts to carry out Grignard methylations with aldehydes and ketones proved fruitless. Its existence is consistent, however, with the fact that small amounts of water inhibit this reaction.⁶

Acknowledgments.—The author wishes to acknowledge the continued advice and encouragement of Dr. Walter Schlesinger. Thanks are due to Dr. H. Adler of the Victor Chemical Company and Mr. William J. Bannister of the Commercial Solvents Corporation for advice on the synthesis of trimethyl phosphate.

(9) W. H. C. Rueggeberg, *THIS JOURNAL*, **65**, 602 (1943).

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The Preparation of Suberone (Cycloheptanone)

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The first step of a convenient procedure by means of which suberone can be obtained in comparatively large quantities consists in the condensation of cyclohexanone with nitromethane to form 1-(nitromethyl)-cyclohexanol. Upon electrolytic reduction of the latter substance, suspended in dilute sulfuric acid, a solution of 1-(aminomethyl)-cyclohexanol sulfate was obtained. Direct treatment of the solution with nitrous acid, without isolation of the sulfate, yielded suberone. The same route from cyclohexanone to suberone has been described by Dauben, *et al.*,¹ but these investigators employed catalytic reduction to convert 1-(nitromethyl)-cyclohexanol into the corresponding 1-(aminomethyl) derivative.

Recently, Wood and Cadorin² reported that interaction of cyclohexanone (2 moles) and nitromethane (1.5 moles) in methanol solution, in the presence of a very small amount (4 g.) of sodium hydroxide, yielded 1-(nitromethyl)-cyclohexanol in 51% yield.

Prior to their publication we had prepared large quantities of 1-(nitromethyl)-cyclohexanol by the use of sodium hydroxide as a condensation agent, and found that by reaction of cyclohexanone (1 mole), nitromethane (1 mole) and sodium hydroxide (1.25 moles) in methanol, and isolation of 1-(nitromethyl)-cyclohexanol in the form of its sodium derivative, the cyclohexanol can be isolated in 64–72% yields. The same yields were obtained by the use of fourfold quantities.

We have found that the cyclohexanol, suspended in dilute sulfuric acid, can be reduced electrolytically by the use of lead electrodes to 1-(amino-

(1) Hyp J. Dauben, Jr., H. J. Ringold, R. H. Wade and A. G. Anderson, Jr., *THIS JOURNAL*, **73**, 2359 (1951).

(2) T. F. Wood and R. J. Cadorin, *ibid.*, **73**, 5504 (1951).

methyl)-cyclohexanol³ which can be isolated as the sulfate in 77–83% yield, as the acid sulfate in the same yield or as the hydrochloride in 76% yield.

For the preparation of suberone it is not necessary to isolate the 1-(aminomethyl)-cyclohexanol. The reaction mixture obtained from the electrolytic reduction was treated directly with sodium nitrite; the yield of suberone, based on 1-(nitromethyl)-cyclohexanol, was 50–57%.

Experimental Part

1-(Nitromethyl)-cyclohexanol.—A solution prepared from 98.1 g. (1 mole) of cyclohexanone,⁴ 61.0 g. (1 mole) of nitromethane⁴ and 600 cc. of methanol was stirred, cooled to 5° and a solution of 50.0 g. (1.25 moles) of sodium hydroxide in 75 cc. of water was added at such a rate that the temperature of the mixture could be maintained below 10° by the use of an ice-bath. Precipitation of the colorless sodium derivative of the condensation product began after about one-third of the alkali had been added. After complete addition of the alkali (about one-half hour was required), the thick suspension was stirred and cooled for one-half hour. The sodium derivative was then filtered, suspended in 500 cc. of water, stirred and 80 cc. of acetic acid added. The mixture was extracted three times with 200-cc. portions of ether and the combined ether extracts were washed with sodium bicarbonate solution and then with water until the water became neutral. The ether solution was dried with magnesium sulfate and the solvent removed on a steam-bath. Upon distillation, 106 g. (67%) of product was obtained; b.p. 129–133° (19 mm.); d_{20}^{20} , 1.1589; n_D^{20} , 1.4875. In other experiments the yields varied from 64–72%.

1-(Aminomethyl)-cyclohexanol.—The apparatus employed for the reduction consisted of three cells (see drawing) connected in series. The cathode chamber of each cell consisted of a lead-plate cathode and a cylindrical porous cup which was 8 cm. in diameter and 12.5 cm. in height. The cathode chamber was placed between the two lead plates of the anode which was immersed in about 700 cc. of 10% sulfuric acid contained in a 2-liter beaker.

1-(Nitromethyl)-cyclohexanol (53.0 g., $\frac{1}{3}$ mole) was added in two equal portions to each porous cup which contained 400 cc. of 10% sulfuric acid; the first portion was added at the beginning of the operation, the second 4 hours later. The material was kept in suspension in the acid by efficient mechanical stirring. Reduction of the nitro alcohol was effected with an 8-ampere current and a current density of 0.067 ampere/cm.² for a period of 9 hours. Continuous water-cooling around the beakers maintained the operating temperature of each cell at approximately 30° throughout the procedure.

The product was isolated as the sulfate (a), acid sulfate (b) or hydrochloride (c). In each instance the reaction mixtures from 3 cells were combined.

(a) The reaction mixture, if necessary adjusted to pH 4–5, was filtered, the filtrate evaporated to dryness and the neutral sulfate was recrystallized several times from ethanol-water; yield 137–148 g. (77–83%); m.p. 266–267°.

Anal. Calcd. for $2C_7H_{15}ON \cdot H_2SO_4$: N, 7.87; S, 9.00. Found: N, 7.86; S, 9.13.

(b) The reaction mixture was treated with sulfuric acid until the pH was 1–2, filtered, the filtrate evaporated to dryness and the acid sulfate was recrystallized several times from ethanol-ether; yield 175 g. (77%); m.p. 132–133°.

Anal. Calcd. for $C_7H_{15}ON \cdot H_2SO_4$: N, 6.17; S, 14.11. Found: N, 6.12; S, 14.28.

(c) The pH of the reaction mixture was adjusted to 4–5 and after the filtered solution had been evaporated almost to dryness, it was made alkaline by the addition of solid sodium hydroxide. The mixture was extracted with ether and the extract, after it had been dried with magnesium sulfate, was treated with hydrogen chloride. The precipitated hydro-

(3) This compound, in the form of the acetate, was obtained by Hyp J. Dauben, Jr., *et al.*, ref. 1, from the corresponding nitromethyl derivative in 91% yield by the use of a Raney nickel catalyst. However, a small portion of the isolated acetate was not entirely pure.

(4) The Eastman Kodak Company product was used without further purification.

(5) Hyp J. Dauben, Jr., *et al.*, ref. 1, b.p. 132–133° (18.5 mm.).

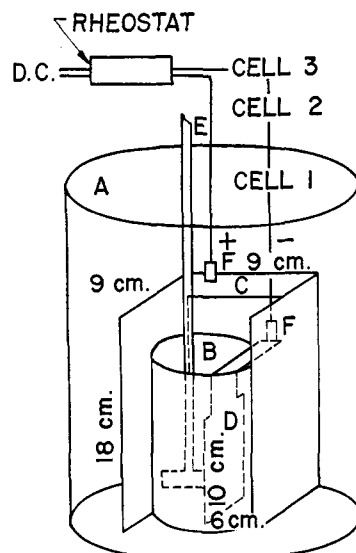


Fig. 1.—A, beaker; B, porous cup; C, lead anode; D, lead cathode; E, stirrer; F, clamp.

chloride was recrystallized several times from absolute ethanol; yield 126 g. (76%); m.p. 213–214°.⁶

Suberone.—The reaction mixture, obtained from the electrolytic reduction, was adjusted to a pH of 4, stirred, cooled to 0–5° and maintained at this temperature during the dropwise addition of 83 g. (1.2 moles) of sodium nitrite dissolved in 300 cc. of water. A pale yellow oil began to separate at the surface of the solution shortly after the addition of the nitrite was begun. During a two-hour period the mixture was stirred, allowed to warm to room temperature and the pH was maintained at 5–6. The mixture was heated on a steam-bath, under a reflux condenser, for one hour. The oily layer was separated, the aqueous layer extracted with ether, the oil and extract combined, and the solution was washed with aqueous sodium bicarbonate and then with water until the latter became neutral. The ether solution was dried with magnesium sulfate, the solvent removed and the residue fractionated. The suberone (56–64 g., 50–57%) boiled at 66–70° (16 mm.); d_{20}^{20} , 0.9490; n_D^{20} , 1.4608; 2,4-dinitrophenylhydrazone, m.p. 146–147°.⁷

(6) B. Tchoubar (*Bull. soc. chim. France*, 160 (1949)), m.p. 190°; M. W. Goldberg and H. Kirchensteiner (*Helv. Chim. Acta*, 26, 293 (1943)), m.p. 210–212°; ref. 3, m.p. 215–216°.

(7) O. L. Brady (*J. Chem. Soc.*, 756 (1931)), m.p. 148°; ref. 3, m.p. 146°.

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Explosion in the Synthesis of N¹⁵-Labeled Urea

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For some time now we have been using the method of Cavalieri, Blair and Brown¹ for the synthesis of uric acid containing N¹⁵ in the 1- and 3-positions. The first step of this method is the synthesis of urea from N¹⁵H₄NO₃ and diphenyl carbonate, using copper powder as a catalyst. Ammonia containing N¹⁵ is generated, swept with nitrogen gas through a drying tower, and into a bomb tube of Pyrex glass containing the diphenyl carbonate and copper powder. The bomb tube is immersed in liquid nitrogen throughout the proce-

(1) L. F. Cavalieri, V. E. Blair and G. E. Brown, *THIS JOURNAL*, 70, 1240 (1948).