The reaction was complete after 10 hours. The mixture was diluted with water, decolorized with charcoal, and concentrated under carbon dioxide and reduced pressure to a small volume. After cooling small crystals of XI were collected on a glass filter and dried immediately over alkali in a desiccator. Dilution and reconcentration of the mother liquor yielded a second crop. The yield was 1.40 g. (91.5%), dec. 233°; the compound is readily soluble in water to give a yellow solution.

Anal. Calcd. for $C_{10}H_{12}O_4N_2 \cdot 2HBr$: C, 31.08; H, 3.62; N, 7.25. Found: C, 31.31; H, 3.50; N, 7.01.

dl-**3-Hydroxykynurenine.**—A solution of 200 mg. of XI in a little water was neutralized with dilute aqueous ammonia. Yellow needles of the free amino acid crystallized without delay. After recrystallization (charcoal) it had the decomposition point 223°; yield 101 mg. (87%). The substance is almost insoluble in alcohol, slightly soluble in cold, but readily in hot water.

Ninhydrin reaction, reddish-purple; Folin–Denis reaction, dark blue; diazo reaction, positive; ferric chloride test, blood red; Weis urochromogen reaction, positive. The compound fluoresces in ultraviolet light. When boiled with alkali it produces a jasmine-like odor. These properties agree with those shown by the +chromogen from silkworm eggs, and the behavior of the two substances on paper chromatography also showed close agreement.

Anal. Calcd. for $C_{10}H_{12}O_4N_2 \cdot H_2O$: C, 51.50; H, 5.58. Found (dried at room temperature over alkali): C, 51.46; H, 5.53. Calcd. for $C_{10}H_{12}O_4N_2$: C, 53.57; H, 5.35; N, 12.50. Found (dried for 3 hours *in vacuo* at 140°): C, 53.80; H, 5.04; N, 12.37.

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[CONTRIBUTION FROM THE DEPARTMENT OF CHEMISTRY, UNIVERSITY OF CONNECTICUT]

The Preparation of Amino Ethers and Diamines from Chloromethyl Ether and Butadiene[1]

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1-Chloro-5-methoxy-2-pentene and 3-chloro-5-methoxy-1-pentene, readily obtainable as the 1,4- and 1,2-addition products, respectively, of chloromethyl ether to 1,3-butadiene, react readily with ammonia and with amines to give the expected unsaturated amino ethers. With the secondary chloride, however, there is partial allylic rearrangement during amination, so that along with the expected product there is formed also a considerable quantity of the same amino ether as is obtained from the primary chloride. Catalytic hydrogenation then gives saturated amino ethers that react with hydrobromic or hydriodic acid to give salts of halogenated amines which with ammonia or amines yield diamines.

In searching for a method other than that of the von Braun synthesis[2] for preparing unsymmetrical disubstituted pentamethylenediamines, the following procedure was investigated.

$$ClCH_2OCH_3 + CH_2{=}CHCH{=}CH_2 \xrightarrow{ZnCl_2}$$

$$ClCH_2CH{=}CHCH_2CH_2OCH_3 \xrightarrow[(or\ NH_3)]{R_2NH} \xrightarrow{NaOH}$$

I

$$R_2NCH_2CH{=}CHCH_2CH_2OCH_3 \xrightarrow{H_2}$$

II

$$R_2N(CH_2)_5OCH_3 \xrightarrow{HX}$$

III

$$(R_2NH(CH_2)_5X)X \xrightarrow[(or\ R_2NH)]{NH_3} R_2N(CH_2)_5NH_2$$

IV V

It was found that while it has no definite advantages in synthesizing diamines it is clearly superior to existing methods for preparing dimethylamino[3] and diethylamino[4] ethers (III). There are no previously reported methods for making the unsaturated amino ethers (II).

The addition of chloromethyl ether to butadiene, described by Straus and Thiel[5] as a sealed tube reaction tube reaction was run in larger quantities with equally good yields by passing butadiene gas through the chloromethyl ether. Emerson, Deebel and Longley[6] used a similar procedure to add several different chloro ethers to butadiene. The amination of the 1,4-addition product (I) with ammonia, dimethylamine or diethylamine produces the expected amino ether. The 1,2-addition product, 3-chloro-5-methoxy-1-pentene may also be aminated to produce otherwise unavailable amines. However, some rearrangement to (II) occurs in the latter reaction.

The possibility of preparing unsymmetrical pentamethylenediamines from the amino ethers (II) was demonstrated by splitting N,N-diethyl-5-methoxy-1-pentanamine with hydriodic acid and aminating the resulting N,N-diethyl-5-iodo-1-pentanamine with ammonium hydroxide.

Experimental

Chloromethyl ether was prepared by the method of Marvel and Porter.[7] Amines were isolated by acidifying the reaction mixture, evaporating the solvent and freeing the amine from its salt with saturated sodium hydroxide. They were dried over sodium hydroxide pellets prior to distillation. Reductions were accomplished at 30 lb. gage pressure using a Raney nickel catalyst. Neutral equivalents were obtained by titrating the amine with 0.1 *N* hydrochloric acid using a methyl red indicator.

Preparation of the Chloromethoxypentenes.—One thousand forty-six grams (13 moles) of chloromethyl ether was placed in a 3-l. flask equipped with a reflux condenser, a thermometer extending into the liquid and a sintered glass bubbling tube. Seven grams of freshly fused zinc chloride was added. Butadiene, measured with a flow meter, was passed into the solution. By confining the flow to 0.6 mole per hour and cooling the reaction flask with running water, the temperature was kept between 30 and 40°. When 14 moles of butadiene had been passed in, the volume of the purple-brown solution became constant at twice its original volume, and the reaction was then considered complete. Unreacted chloromethyl ether was hydrolyzed by shaking the reaction mixture with water. The product was extracted with ether and washed successively with dilute sodium bisulfite solution and water. The ether was removed and the remaining light yellow liquid distilled at 10 mm. through a 4-ft. helices-packed column. At 36°, 410 ml.

(1) From the M.S. thesis of W. F. Brill, June, 1948.
(2) von Braun, *Ber.*, **43**, 2864 (1910).
(3) Clark, *J. Chem. Soc.*, **103**, 1689 (1913).
(4) Elderfield, THIS JOURNAL, **68**, 1579 (1946).
(5) Straus and Thiel, *Ann.*, **525**, 151 (1936).
(6) Emerson, Deebel and Longley, *J. Org. Chem.*, **14**, 696 (1949).
(7) Marvel and Porter, "Organic Synthesis," Coll. Vol. II, John Wiley and Sons, Inc., 1940, p. 474.

(27%) of 3-chloro-5-methoxy-1-pentene, $n^{20}D$ 1.4575, was collected. At 56°, 600 ml. (41%) of 1-chloro-5-methoxy-2-pentene, $n^{20}D$ 1.4540, was collected. The lower boiling isomer was thermally rearranged into the higher boiling isomer in 25% yield by the procedure of Straus and Thiel.[5]

5-Methoxy-2-pentene-1-amine.—By shaking 134 ml. of 1-chloro-5-methoxy-2-pentene (1.0 mole) with 745 ml. (10 moles) of ammonium hydroxide for 48 hours and treating the reaction mixture in the usual manner, 65 ml. of a brown oil was obtained. Distillation through a 4-ft. helices-packed column yielded 35 ml. (27%) of product boiling between 64–64.8° (10 mm.), $n^{20}D$ 1.4508, d^{20}_4 0.897, b.p. 173.5° (760 mm.), neut. equiv., 116 (calcd. 115). By simple vacuum distillation of the residue, 32 ml. (30%) of higher boiling material giving a Hinsberg test for secondary amine was obtained.

The picrate of the primary amino ether, prepared from an ether solution of picric acid and recrystallized from butyl alcohol, melted at 110–110.5°. *Anal.* Calcd. for $C_{12}H_{16}O_8N_4$: C, 41.86; H, 4.68. Found: C, 41.92; H, 4.76. The substituted α-naphthylurea was prepared in heptane and recrystallized from alcohol–water, m.p. 121–122°. Calcd. for $C_{17}H_{20}O_2N_2$: C, 71.79; H, 7.10. Found: C, 72.36; H, 7.17.

N,N-Dimethyl-5-methoxy-2-penten-1-amine.—Ninety grams (2.0 moles) of dimethylamine and 68 ml. (0.5 mole) of the primary chloroether were left in a stainless steel autoclave for 24 hours. The reaction mixture was acidified and washed with ether. Fractionation of the free amine through a 2-ft. Vigreux column gave 40 ml. (46%) of product boiling at 57° (10 mm.), $n^{20}D$ 1.4348, d^{20}_4 0.835, b.p. 176.5° (760 mm.), neut. equiv., 142.6 (calcd. 143.0).

The picrate prepared as above melted at 74–74.8°. *Anal.* Calcd. for $C_{12}H_{18}O_8N_4$: C, 45.15; H, 5.42; N, 15.05. Found: C, 45.11; H, 5.55; N, 15.14.

N,N-Diethyl-5-methoxy-2-penten-1-amine.—To 134 ml. (1.0 mole) of 1-chloro-5-methoxy-2-pentene in 100 ml. of ether, 90 g. (2.0 moles) of diethylamine was slowly added. After one day, the reaction mixture was acidified and washed with ether. Fractionation of the free amine through a 2-ft. Vigreux column gave 125 ml. (61%) of product boiling at 86° (10 mm.), $n^{20}D$ 1.4423, d^{20}_4 0.843, b.p. 207° (760 mm.), neut. equiv., 171 (calcd. 171). *Anal.* Calcd. for $C_{10}H_{20}N$: C, 70.10; H, 12.37; N, 8.18. Found: C, 70.02; H, 12.31; N, 8.30.

N,N-Dimethyl-5-methoxy-1-penten-3-amine.—To 67.3 g. (0.5 mole) of 3-chloro-5-methoxy-1-pentene in 600 ml. of 50% ethanol, 90 g. (2 moles) of dimethylamine was added. After 12 days the amines were isolated in the usual manner. Distillation through a 2-ft., helices-packed column gave 35 ml. (42%) of product boiling at 48° (10 mm.), $n^{20}D$ 1.4340, d^{20}_4 0.851, b.p. 162° (760 mm.), neut. equiv., 146 (calcd. 143). In addition 10 ml. (12%) of N,N-dimethyl-5-methoxy-2-penten-1-amine boiling at 56° (10 mm.) was obtained.

The picrate was recrystallized from absolute alcohol, m.p. 82–83.1°. *Anal.* Calcd. for $C_{12}H_{18}O_8N_4$: C, 45.15; H, 5.42; N, 15.05. Found: C, 44.66; H, 5.12; N, 15.32.

5-Methoxy-1-pentanamine.—Catalytic hydrogenation with Raney nickel of 12.8 ml. (0.1 mole) of 5-methoxy-2-penten-1-amine in absolute alcohol followed by simple vacuum distillation yielded 6 ml. of product, $n^{20}D$ 1.4269, d^{20}_4 0.906, b.p. 163° (760 mm.). The picrate (m.p. 75–76°), hydrochloride (m.p. 133–134.5°), and substituted phenylthiourea (m.p. 61–62.5°) were difficult to purify.

The benzenesulfonamide formed as an oil and was crystallized by dissolving it in toluene and slowly cooling in a Dry Ice–methanol-bath. The white precipitate, washed with heptane, melted at 44–44.5°. *Anal.* Calcd. for $C_{12}H_{19}O_3NS$: C, 55.99; H, 7.46. Found: C, 56.15; H, 7.49.

The substituted α-naphthylurea was prepared in heptane and recrystallized from alcohol and water, m.p. 128–130°. *Anal.* Calcd. for $C_{17}H_{22}O_2N_2$: C, 71.29; H, 7.76. Found: C, 71.26; H, 7.72.

N,N-Dimethyl-5-methoxy-1-pentanamine.—This compound was prepared both by hydrogenation of 5.2 ml. (0.025 mole) of purified N,N-dimethyl-5-methoxy-2-penten-1-amine and also directly from 225 ml. (2.7 moles) of chloromethyl ether omitting all intermediate distillations; yield 80 ml. (15%), $n^{20}D$ 1.4199, d^{20}_4 0.822, b.p. 176° (760 mm.), neut. equiv., was 143 (calcd. 145). These physical constants agree with the reported[8] values.

The picrate melted at 88.5–89.5°. *Anal.* Calcd. for $C_{14}H_{22}N_4O_8$: C, 44.91; H, 5.93; N, 15.0. Found: C, 44.8; H, 5.72; N, 15.71.

N,N-Diethyl-5-methoxy-1-pentanamine.—This compound was prepared by hydrogenation of 0.1 mole of the pure unsaturated amino ether and also directly from 0.8 mole of 1-chloro-5-methoxy-2-pentene without isolating the intermediate unsaturated amino ether; yield 80 ml. (48%), $n^{20}D$ 1.4290, d^{20}_4 0.828, b.p. 206.7° (760 mm.), neut. equiv., of 171 (calcd. 173). Since a crystalline derivative could not be prepared the liquid compound itself was analyzed. *Anal.* Calcd. for $C_{10}H_{23}ON$: C, 69.28; H, 13.40; N, 8.08. Found: C, 70.43; H, 13.44; N, 8.70.

N,N-Dimethyl-1-methoxy-3-pentanamine.—Reduction of 14.39 g. (0.1 mole) of 3-dimethylamino-5-methoxy-2-pentene in ether solution was accomplished in the usual way; b.p. 165–165.5° (760 mm.), $n^{20}D$ 1.4238, d^{20}_4 0.830, neut. equiv., 148 (calcd. 145).

The picrate melted at 76.1–76.9°. *Anal.* Calcd. for $C_{14}H_{22}N_4O_8$: C, 44.91; H, 5.93; N, 15.0. Found: C, 45.07; H, 5.62; N, 15.72.

5-Iodo-1-pentanamine Hydroiodide.—To 12 ml. (0.1 mole) of 5-methoxy-1-pentanamine, 70 g. (0.3 mole) of constant boiling hydrogen iodide was added drop by drop. After heating on a steam-bath for five hours, the solution was evaporated to dryness. The product was recrystallized from acetone and washed with ether. It was identified by its benzamide which melted at 54–55°, agreeing exactly with the reported melting point.[9]

N,N-Dimethyl-5-bromo-1-pentanamine Hydrobromide.—Undistilled N,N-dimethyl-5-methoxy-1-pentanamine, prepared from 68 ml. (0.5 mole) of chloro ether, was split with 454 g. of constant boiling hydrobromic acid in the manner described in the previous case. The yield of brown powder was 70 g. (50% based on the chloroether).

N,N-Diethyl-5-iodo-1-pentanamine Hydroiodide.—Boiling 31.2 ml. (0.25 mole) of N,N-diethyl-5-methoxy-1-pentanamine with 130 g. of constant boiling hydriodic acid and treating as above produced a heavy red sirup which could not be crystallized.

N,N-Diethylcadaverine.—The sirupy N,N-diethyl-5-iodo-1-pentanamine hydroiodide obtained above was aminated with 1.5 moles of ammonium hydroxide. After four days, the reaction mixture was treated in the usual manner and the free amine extracted with benzene. After removal of the benzene, fractionation through a 14-inch Vigreux column at 4 mm. yielded 5 ml. of product (20% yield based on the amino ether), $n^{20}D$ 1.4532, d^{20}_4 0.890, b.p. 226° (760 mm.). The picrate, formed as an oil from an ether solution of picric acid and crystallized from benzene, melted at the reported[10] 110°.

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(8) Clarke, *J. Chem. Soc.*, **103**, 1689 (1913).
(9) von Braun and Steindorff, *Ber.*, **38**, 174 (1905).
(10) von Braun, *ibid.*, **43**, 2873 (1910).