cold aqueous solution with dilute sulfuric acid yielded 0.38 g. of white crystalline material which, after three recrystallizations from ether and chloroform, melted at 178.3–179.8 (dec.).

Anal. Calcd. for $C_{12}H_{16}O_5$: C, 59.97; H, 6.71. Found: C, 59.70; H, 6.80.

Dihydrocitrinin.—A suspension of 0.20 g. of the carboxylic acid derivative of compound A in a solution of 0.40 g. of methylal and 4.0 ml. of benzene saturated with dry hydrogen chloride at room temperature was heated in a sealed tube at 60° for six hours. After standing overnight the tube was opened and the clear, slightly yellow liquid was decanted from a very small amount of oil, decolorized with Darco and evaporated nearly to dryness in a stream of nitrogen. Petroleum ether was added dropwise until a tarry precipitate started to form. The clear solution was decanted from the tar and upon further addition of petroleum ether a white crystalline material separated. Four recrystallizations from hot carbon tetrachloride and cyclohexane yielded a product which melted at 169.5–170.5 (dec.).

Anal. Calcd. for $C_{13}H_{16}O_5$: C, 61.87; H, 6.39. Found: C, 61.54; H, 6.15.

Citrinin.—To a solution of 0.030 g. of dihydrocitrinin in one-half ml. of chloroform was added dropwise a molar solution of bromine in chloroform until the bromine color persisted. After standing for ten minutes the solvent was evaporated at low temperature, yielding a dark orange tar which was dissolved in a minimum amount of ethanol. Addition of hot water initiated the formation of a lemon-yellow crystalline material, which after cooling was filtered and recrystallized. Crystals were obtained which melted at 175.8–176.3° (dec.). No depression of the melting point was observed when a sample of this material was admixed with an authentic sample of citrinin.

Anal. Calcd. for $C_{13}H_{14}O_5$: C, 62.39; H, 5.64. Found: C, 62.24; H, 5.47.

Acknowledgment.—We wish to take this opportunity to express our thanks to The Schering Corporation, Bloomfield, N. J., for the citrinin used in the preparation of Compound A, and to Merck and Company, Inc., Rahway, N. J., for the analyses published in this paper. We also wish to express our appreciation to The Standard Brands Corporation, New York City, N. Y. for a grant-in-aid which made this work possible.

Summary

A synthesis of dihydrocitrinin and of citrinin has been described.

Preliminary observations indicate that the synthesis is applicable to homologs and analogs and to other derivatives of similar structure.

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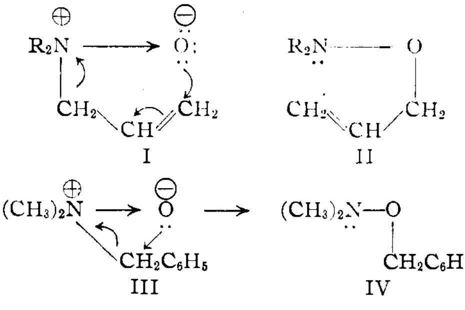
[CONTRIBUTION FROM THE DEPARTMENT OF CHEMISTRY, MASSACHUSETTS INSTITUTE OF TECHNOLOGY]

Rearrangement of Allyldialkylamine Oxides and Benzyldimethylamine Oxide[1]

BY ARTHUR C. COPE AND PHILIP H. TOWLE

Meisenheimer has shown that allylmethylaniline oxide and allylethylaniline oxide rearrange to O-allyl-N-alkyl-N-phenylhydroxylamines on heating with aqueous sodium hydroxide, and that benzylmethylaniline oxide rearranges to O-benzyl-N-methyl-N-phenylhydroxylamine under the same conditions.[2,3] These reactions have been interpreted as intramolecular, thermal rearrangements, because crotylmethylaniline was observed to rearrange with inversion of the crotyl group, yielding O-methylvinylcarbinyl-N-methyl-N-phenylhydroxylamine.[4] The fact that the rearrangement products are formed in high yield in the presence of sodium hydroxide indicates that the oxygen–carbon bond is formed essentially at the same time that the nitrogen–carbon bond is broken, for otherwise appreciable amounts of allyl alcohol and benzyl alcohol should be formed by reaction of the migrating groups (if momentarily free as carbonium ions) with hydroxyl ions. According to this interpretation, the sodium hydroxide has no function in the rearrangement other than to liberate the amine oxides from their salts.

Meisenheimer[3] reported that allyldimethylamine oxide and allyldiethylamine oxide did not rearrange on heating with aqueous sodium hydroxide, but were recovered unchanged except for small amounts which were cleaved into dimethylamine and diethylamine, respectively, and unidentified decomposition products. If the driving force for the rearrangement is a nucleophilic attack of an unshared electron pair of oxygen on the allyl or benzyl group, or the attraction of the positively charged nitrogen of the amine oxide for the electron pair attaching it to the allyl or benzyl group, the rearrangement would be expected to proceed in the aliphatic series as indicated:



A possible explanation for the difference in behavior of allyldialkylamine oxides and allylalkylaniline oxides on heating is the greater tendency of aliphatic amine oxides to hydrate,[5] since combina-

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[1] Presented at the St. Louis meeting of the American Chemical Society, Division of Organic Chemistry, Sept. 7, 1948.

[2] Meisenheimer, *Ber.*, **52**, 1667 (1919).

[3] Meisenheimer, Greeske and Willmersdorf, *ibid.*, **55**, 513 (1922).

[4] Kleinschmidt and Cope, THIS JOURNAL, **66**, 1929 (1944).

[5] Sidgwick, "The Organic Chemistry of Nitrogen," revised by Taylor and Baker, University Press, Oxford, 1942, p. 167.

TABLE I

TERTIARY AMINES[a]

Amine	Yield, %	B. p., °C.	n^{25}_D	d^{25}_4	Formula	Molecular refraction Calcd.	Molecular refraction Found	Analyses, % Carbon Calcd.	Carbon Found	Hydrogen Calcd.	Hydrogen Found	Nitrogen Calcd.	Nitrogen Found
Allyldimethyl[b]	39–43	64	1.3981	0.7094	$C_5H_{11}N$	28.76	28.98	70.53	70.12	13.02	12.87	16.45	16.45
Allyldiethyl[c]	79–84	111	1.4170	.7477	$C_7H_{15}N$	38.00	38.07	74.27	74.19	13.36	13.36	12.37	12.18
Allyldi-*n*-propyl[d]	76–80	153.5	1.4239	.7633	$C_9H_{19}N$	47.24	47.26	76.52	76.67	13.56	13.78	9.92	9.98
Allyldiisopropyl	57–60	147.5	1.4258	.7697	$C_9H_{19}N$	47.24	47.00	76.52	76.38	13.56	13.51	9.92	9.67
Allyldi-*n*-hexyl[e]	57–68	126 (8 mm.)	1.4411	.7935	$C_{15}H_{31}N$	74.94	75.03	79.92	80.36	13.86	13.71	6.22	6.19

[a] The secondary amines from which these compounds were prepared were obtained from Sharples Chemicals, Inc., except for dimethylamine, which was obtained from Rohm and Haas. [b] Previously described in ref. 8. [c] Previously described by Rinne, *Ann.*, **168**, 265 (1873); Liebermann and Paal, *Ber.*, **16**, 526 (1883); Kharasch and Fuchs, *J. Org. Chem.*, **10**, 159 (1945). [d] Previously described by Liebermann and Paal, *Ber.*, **16**, 527 (1883). [e] In the preparation of this compound extraction with hydrochloric acid was omitted because the amine hydrochlorides were relatively insoluble in water. The benzene suspension of amine hydrobromides was treated with an excess of aqueous sodium hydroxide, and the benzene solution of the amines (allyldi-*n*-hexylamine and di-*n*-hexylamine) was dried over potassium hydroxide and fractionated through an adiabatic, total condensation, variable take-off type column with a 1.2 × 40 cm. Vigreux section.

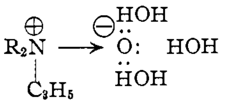
TABLE II

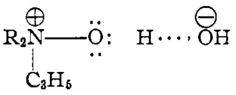
TERTIARY AMINE DERIVATIVES

Derivative	M. p., °C.	Formula	Analyses, % Carbon Calcd.	Carbon Found	Hydrogen Calcd.	Hydrogen Found	Nitrogen Calcd.	Nitrogen Found
Allyldimethylamine picrate[a]	116.2–116.8	$C_{11}H_{14}N_4O_7$	42.04	42.25	4.49	4.79	17.83	17.91
Allyldiethylamine picrate[b]	91.2–91.4	$C_{13}H_{18}N_4O_7$	45.61	45.55	5.30	5.36	16.37	16.14
Allyldi-*n*-propylamine picrate	86.8–87.4	$C_{15}H_{22}N_4O_7$	48.64	48.78	5.99	5.97	15.13	15.21
Allyldiisopropylamine picrate	113–113.6	$C_{15}H_{22}N_4O_7$	48.64	48.84	5.99	6.28	15.13	14.93
Allyldi-*n*-hexylamine picrylsulfonate[c]	116.8–117.3	$C_{21}H_{34}N_4O_9S$	48.64	48.74	6.61	6.59	10.80	10.88

[a] Ref. 3 and Knorr and Roth, *Ber.*, **39**, 1428 (1906), report m. p. 95° for allyldimethylamine picrate (possibly a lower melting dimorphous form). [b] Ref. 3 reports m. p. 94–95.5° for allyldiethylamine picrate. [c] The picrate separated as an oil which failed to crystallize.

tion with water as hydrates such as V or hydroxides (VI) would be expected to reduce the reactivity of the unshared electron pairs of the amine oxide oxygen and interfere with the rearrangements if they proceed in the manner indicated in the equations.


V


VI

Accordingly a number of aliphatic allyldialkylamine oxides (I) and benzyldimethylamine oxide (III) were investigated in order to determine whether they would rearrange under appropriate conditions to yield O-allyl-N,N-dialkylhydroxylamines (II) and O-benzyl-N,N-dimethylhydroxylamine (IV), respectively.

In beginning this work, Meisenheimer's observation[3] concerning the stability of allyldimethylamine oxide in alkaline aqueous solution was confirmed. After the amine oxide had been heated at the reflux temperature with approximately 25% aqueous sodium hydroxide for six and one-half hours, 7.4% decomposition to dimethylamine had occurred, as determined by titration of the volatile base formed and isolation of dimethylamine picrate, and 64% of the allyldimethylamine oxide was recovered from the alkaline aqueous solution as the crystalline picrate. The susceptibility of allyldimethylamine oxide to rearrangement then was determined under conditions less favorable for hydration. Allyldimethylamine was converted into the oxide by treatment with 10% aqueous hydrogen peroxide. The excess hydrogen peroxide was decomposed in the presence of platinum foil, and the allyldimethylamine oxide solution was concentrated to a viscous sirup, which was heated at 105–110° for one-half hour. During this period a water-insoluble, volatile product formed. Further heating and distillation completed the isomerization of the amine oxide, and after redistillation the rearrangement product, O-allyl-N,N-dimethylhydroxylamine (II, R = CH_3), was isolated in 51% yield. Its structure was established by analysis, analysis of its picrate and methiodide, and direct comparison (m. p. and mixed m. p.) of these solid derivatives with corresponding derivatives of an authentic sample of O-allyl-N,N-dimethylhydroxylamine prepared by methylation of O-allylhydroxylamine with dimethyl sulfate.

In order to determine whether other allyldialkylamine oxides rearranged in a similar manner, the tertiary amines listed in Table I were first prepared and characterized as solid derivatives (Table II). These amines and benzyldimethylamine were converted to the oxides by treatment with hydrogen peroxide. The use of concentrated aqueous hydrogen peroxide or an organic solvent, to produce homogeneous reaction mixtures, was required for the oxidation of the higher molecular weight amines. Allyldiethylamine was oxidized by 10% aqueous hydrogen peroxide, and allyldi-*n*-propylamine, allyldiisopropylamine and benzyldimethylamine were oxidized with 35% aqueous hydrogen peroxide. Allyldi-*n*-hexylamine re-

TABLE III

AMINE OXIDE DERIVATIVES

Derivative	Yield, %[f]	M. p., °C.	Formula	Analyses, %					
				Carbon		Hydrogen		Nitrogen	
				Calcd.	Found	Calcd.	Found	Calcd.	Found
Allyldimethylamine oxide picrate[a]	94	135.5–136.6	$C_{11}H_{14}N_4O_8$	40.00	40.22	4.27	4.47	16.97	16.96
Allyldiethylamine oxide picrate[b]	89	138.5–138.8	$C_{13}H_{18}N_4O_8$	43.58	43.65	5.06	5.36	15.64	15.54
Allyldi-*n*-propylamine oxide picrate[c]	95	97.2–97.6	$C_{15}H_{22}N_4O_8$	46.63	46.42	5.74	5.73	14.50	14.85
Allyldiisopropylamine oxide picrate[c]	92	149.6–150.4	$C_{15}H_{22}N_4O_8$	46.63	46.87	5.74	5.97	14.50	14.71
Allyldi-*n*-hexylamine oxide picrylsulfonate[d]	..	88.8–89.6	$C_{21}H_{34}N_4O_{10}S$	47.18	46.99	6.41	6.45	10.48	10.62
Benzyldimethylamine oxide picrate[e]	96	159.4–160.0	$C_{15}H_{16}N_4O_8$	47.37	47.17	4.24	4.31	14.73	14.72

[a] Recrystallized from a mixture of absolute alcohol and dry ether. Ref. 3 reports m. p. 136°. [b] Recrystallized from absolute alcohol. Ref. 3 reports m. p. 138°. [c] Recrystallized from 95% alcohol. [d] Semicrystalline, solvated material which separated from alcohol was washed five times with pentane in a centrifuge tube to remove alcohol and triturated repeatedly with ether until the ether remained colorless. [e] Recrystallized from 80% alcohol. [f] Over-all yield from the amines to the amine oxide derivatives listed.

quired treatment with 35% aqueous hydrogen peroxide in acetone[6] or oxidation with perbenzoic acid for conversion to the amine oxide. All but one of the amine oxides were obtained in high yield, as indicated by the yields of their picrates (Table III). The yield of allyldi-*n*-hexylamine oxide could not be determined in this manner because its picrate failed to crystallize and its picrylsulfonate was crystallized with difficulty and consequent loss of material.

When the amine oxides were concentrated and heated under reduced pressure at temperatures of 80–165°, rearrangement to trialkylhydroxylamines occurred in each case. It was important to remove the excess hydrogen peroxide rather completely by treatment with platinum before the amine oxide solutions were concentrated. If substantial quantities of hydrogen peroxide remained in the solutions, explosive decomposition occurred in some cases when the residues were heated. The lower molecular weight amine oxides rearranged only after almost all of the water had been removed from their aqueous solutions, while the higher homologs rearranged in the presence of water during the distillation. The trialkylhydroxylamines which were formed were isolated in yields of 51 to 80%, and were differentiated easily from the isomeric, non-volatile amine oxides from which they were prepared by their physical properties (including volatility), and by preparation of solid derivatives.

From these results it is concluded that the rearrangement of allyl and benzyldialkylamine oxides is not essentially different from the rearrangement of allyl and benzylalkylaniline oxides.[2,3,4] It has been shown that the rearrangement takes place readily in the absence of alkali. The fact that removal of most of the water from the alkyldialkylamine oxides facilitates their rearrangement may be interpreted as indicating that hydration (represented in formulas V and VI) interferes with the rearrangement either sterically or by an effect on the dipole moment of the amine oxide or the dielectric constant of the solution. An alternate, less likely explanation which is not consistent with the case of rearrangement with inversion observed previously[4] would be isomerization by a bimolecular process, which would proceed more rapidly at higher concentrations, rather than by an intramolecular route.

Experimental[7]

Tertiary Amines (Table I).—Allyldimethylamine was prepared by a method similar to one described by Weston, Ruddy and Suter.[8] A 25% aqueous solution of dimethylamine (112 g.) and allyl chloride (38.3 g.) was weighed into each of six 8-oz. pressure bottles. To each bottle was added a solution of 4.8 g. of sodium hydroxide in 6 ml. of water. The bottles were capped and shaken with a mechanical shaker for eighteen hours. The mixtures became warm initially and cooled to room temperature within two hours. They were combined in a separatory funnel, and the amine layer was separated and combined with an additional quantity which separated when a solution of 60 g. of potassium hydroxide in 60 ml. of water was added to the aqueous phase. The aqueous solution was distilled, and the material boiling below 85° was added to the amine fraction, which was then distilled through an adiabatic, total condensation, variable take-off type column with a 1.1 × 30 cm. section packed with glass helices.

Allyldiethylamine was prepared by an adaptation of a procedure described by Menschutkin for similar preparations.[9] Allyl bromide (165 g., 1.37 moles) was added slowly with stirring to a solution of diethylamine (200 g., 2.74 moles) in 240 ml. of dry benzene in a 1-l. three-necked flask fitted with a stirrer, dropping funnel, reflux condenser and a thermometer dipping into the liquid. The flask was cooled intermittently to keep the reaction temperature from rising above 45–50°. After the addition was completed, the mixture was heated under reflux in a bath at 80° for two hours. After cooling, 150 ml. of concentrated hydrochloric acid and 100 ml. of water were added. The layers were separated, the benzene layer was extracted with two 50-ml. portions of 10% hydrochloric acid, and the combined acid extracts and aqueous phase were extracted with 50 ml. of benzene. The aqueous solution was made alkaline by adding a solution of 200 g. of sodium hydroxide in 500 ml. of water, and the nonaqueous phase was separated and combined with two 50-

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(6) Bruson and McCleary, U. S. Patent 2,220,835 (Nov. 5, 1940); *C. A.*, **35** 1550 (1941).

(7) Melting points are corrected and boiling points are uncorrected. In calculation of molecular refractions the Eisenlohr values were used (Eisenlohr, *Z. physik. Chem.*, **75**, 605 (1911)), and 2.48 for nitrogen in the hydroxylamine derivatives (Bruhl, *Ber.*, **26**, 2508 (1893)). We are indebted to Mr. S. M. Nagy and Mrs. Louise W. Spencer for analyses.

(8) Weston, Ruddy and Suter, THIS JOURNAL, **65**, 674 (1943).

(9) Menschutkin, *J. Russ. Phys. Chem. Soc.*, **31**, 43 (1899); *Chem Zentr.*. **70**. I. 1067 (1899).

ml. ether extracts of the water solution. The combined amine and ether extracts were dried over solid potassium hydroxide and fractionated through a 1.1 × 30 cm. helix-packed column. Other allyldialkylamines listed in Table I were prepared in essentially the same manner as allyldiethylamine. Benzyldimethylamine was obtained in 83% yield by methylation of benzylamine with formaldehyde and formic acid.[10]

Solid derivatives which were prepared from the tertiary amines are listed in Table II. They were made by heating the reactants briefly in 95% alcohol, and were recrystallized from absolute alcohol.

Amine Oxides.—The tertiary amines were converted to the oxides by reaction with hydrogen peroxide according to the following procedures. Small-scale preparations or aliquot portions of larger scale oxidations were treated with picric acid or picrylsulfonic acid in order to characterize the amine oxides which were formed, and to determine their yields by the weights of solid derivatives which were isolated (Table III).

Allyldimethylamine (20 g.) was added slowly to 171 g. (about 100% molar excess) of 10% aqueous hydrogen peroxide in a 500-ml. flask fitted with a stirrer, dropping funnel, thermometer and reflux condenser. During the addition the temperature of the mixture was maintained at 8–10° by cooling with an ice-bath. The turbid mixture became homogeneous after two hours, and was allowed to warm to room temperature and stirred for twelve hours. The solution was extracted with three 50-ml. portions of ether to remove any amine still present. Approximately 12 sq. cm. of platinum foil (cleaned by treatment with boiling dilute nitric acid, heated to redness in a flame, and cooled) was added to the solution to catalyze the decomposition of the excess hydrogen peroxide. The rate of evolution of oxygen decreased after one and one-half hours, and the decomposition was allowed to continue for twenty-four hours at room temperature. The solution was decanted from the platinum into a solution of 53.8 g. (0.24 mole) of picric acid in 1570 ml. of water at 80°. The solution was heated at 70–80° for fifteen minutes, cooled slowly, and after crystallization started was placed in an ice-bath and stirred until the crystallization appeared to be complete. The yield of allyldimethylamine oxide picrate, m. p. 135–136°, was 72.7 g. (94%). Allyldiethylamine oxide picrate was prepared in the same way. Allyldiisopropylamine (41.2 g.) was added to 35% hydrogen peroxide (82.4 g., about 200% molar excess) with stirring but without cooling. After nineteen hours the aqueous layer was separated and the amine was returned to the flask and again stirred with 80 g. of 35% hydrogen peroxide for twenty-one hours. The process was repeated a third time, and after five hours a homogeneous solution was obtained. The excess hydrogen peroxide in the combined aqueous solutions was decomposed by adding platinum foil at 0° and allowing the solution to stand, initially at 0° and finally at room temperature, until the oxygen evolution became very slow. An aliquot portion of the solution was used for the preparation of allyldiisopropylamine oxide picrate by the procedure described above. Allyldi-*n*-propylamine was oxidized in the same manner as its isomer, except that one treatment with 35% hydrogen peroxide proved to be sufficient to complete the oxidation, as evidenced by formation of a homogeneous solution. Allyldi-*n*-propylamine also was converted to the oxide (isolated as the picrate in 89% yield) by treatment with a 7% solution of hydrogen peroxide in *t*-butyl alcohol[11] for two days at room temperature. Allyldi-*n*-hexylamine (5.1 g.) in 21 ml. of acetone was oxidized by heating under reflux with 5 ml. of 35% aqueous hydrogen peroxide for five hours. The solution was cooled, platinum foil was added, and after oxygen evolution became slow the acetone was removed under reduced pressure. Water (15 ml.) was added to the residue, and the mixture (which formed two layers) was extracted with 10 ml. of pentane, which formed a third layer, to remove any allyldi-*n*-hexylamine which might be present. Allyldi-*n*-hexylamine oxide picrylsulfonate was prepared by adding picrylsulfonic acid in acetone, but it was isolated in poor yield, probably because of difficulties encountered in its crystallization. Allyldi-*n*-hexylamine oxide also was prepared by oxidation of the amine with perbenzoic acid in chloroform solution, and isolated in poor yield as the picrylsulfonate. Benzyldimethylamine (25 g.) was stirred with 35 g. of 35% aqueous hydrogen peroxide at room temperature. The mixture became homogeneous after one hour, and was stirred overnight. Excess hydrogen peroxide was decomposed by adding clean platinum foil and allowing the solution to stand until oxygen evolution became slow, and an aliquot portion of the solution was used for the preparation of benzyldimethylamine oxide picrate.

Stability of Allyldimethylamine Oxide in Alkaline Aqueous Solution.—Allyldimethylamine oxide hydrochloride was prepared from the picrate by a method used by Meisenheimer for similar conversions.[12] Allyldimethylamine oxide picrate (30 g., 90.9 millimoles) was shaken with 70 ml. of nitrobenzene, 70 ml. of ether and 15 ml. of concentrated hydrochloric acid until the picrate dissolved. Water (1 ml.) was added to facilitate separation of the layers, and the acid layer was withdrawn and combined with three successive 3-ml. portions of concentrated hydrochloric acid used to extract the ether–nitrobenzene solution. The acid solution was extracted with three 25-ml. portions of ether and diluted to 250 ml. with water. A Kjeldahl determination on an aliquot of this solution showed the presence of 1.080 g. of nitrogen (equivalent to 77.1 millimoles) in the solution (85% yield of allyldimethylamine oxide hydrochloride from the picrate). The allyldimethylamine oxide hydrochloride solution was placed in a 500-ml. round-bottomed flask, which was attached to a reflux condenser connected to two receivers in series containing standard hydrochloric acid. The inlet tubes to these receivers dipped below the surface of the acid, so that any base distilled into them would be absorbed. A solution of 120 g. of sodium hydroxide in 150 ml. of water was added to the allyldimethylamine oxide hydrochloride solution and the mixture was heated under reflux for six hours. After this period steam was passed through the reflux condenser while the basic solution was boiled for thirty minutes, so that any volatile bases would distil into the standard acid. The standard acid in the first receiver was diluted to 250 ml. Titration of aliquots showed that 5.6 millimoles of a volatile base had been neutralized, and Kjeldahl determinations on aliquots showed the presence of 0.081 g. of nitrogen (equivalent to 5.8 millimoles), in agreement with the acidimetric titration. The standard acid in the second receiver was found to have absorbed a negligible amount of volatile base, and was discarded. The volatile base was liberated by adding a solution of 30 g. of sodium hydroxide in 100 ml. of water to the acid solution (combined with the titrated samples), and steam distilled with about 40 ml. of water into a solution of 1.33 g. of picric acid in 26 ml. of alcohol. Dimethylamine picrate (1.5 g.) was obtained after concentration, and after recrystallization weighed 1.42 g. (5.2 millimoles), m. p. and mixed m. p. with a known sample 156–157°.

The original alkaline solution remaining after the period of reflux and distillation of the volatile base was neutralized with concentrated hydrochloric acid, concentrated to a volume of less than 1 l., and diluted to 1 l. with water. A Kjeldahl determination on an aliquot showed the presence of 0.985 g. of nitrogen (equivalent to 70.3 millimoles). After preliminary experiments on methods of isolating allyldimethylamine oxide picrate from small aliquots of the solution, the remainder was concentrated to dryness under reduced pressure, yielding sodium chloride containing some organic material. This residue was dried by refluxing with benzene and removing the water in the condensate with a continuous separator, and the benzene was then removed under reduced pressure. The residue

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[10] Clarke, Gillespie and Weisshaus, THIS JOURNAL, **55**, 4571 (1933).

[11] Milas and Sussman, *ibid.*, **58**, 1302 (1936).

[12] Meisenheimer, *Ann.*, **385**, 120 (1911).

was extracted thoroughly with absolute alcohol, which was concentrated, leaving a residue which was dried with benzene as before and re-extracted with 50 ml. of absolute alcohol. The alcohol solution was concentrated to 10 ml., diluted with 50 ml. of water, and warmed with 14.5 g. of freshly precipitated silver oxide. The silver chloride which was formed and excess silver oxide were removed by filtration, and a solution of 15.9 g. of picric acid in 325 ml. of water at 80° was added to the filtrate. The allyldimethylamine oxide picrate which separated was recrystallized from alcohol; yield 14.8 g., m. p. 135.2–136.2°, which was not depressed by a known sample. This yield amounted to 64% of the amount of allyldimethylamine oxide hydrochloride employed, taking into account the aliquots removed for analyses and preliminary experiments.

Rearrangement of Allyldimethylamine Oxide to O-Allyl-N,N-dimethylhydroxylamine.—An aqueous solution of allyldimethylamine oxide prepared by oxidizing 20 g. (0.24 mole) of allyldimethylamine with 10% aqueous hydrogen peroxide, followed by decomposition of the excess hydrogen peroxide in the presence of platinum, was concentrated to a thick sirup under reduced pressure at a bath temperature of 60–65°. Two 50-ml. portions of absolute alcohol, three 50-ml. portions of benzene and finally 50 ml. of absolute alcohol were added and distilled under reduced pressure in order to remove water from the residue. The resulting pale yellow, viscous sirup was heated in a nitrogen atmosphere under a reflux condenser at a bath temperature of 105–110° for thirty minutes. The liquid became dark yellow and separated into two layers. The condenser was set for distillation, and the liquid was distilled by gradually raising the bath temperature to 140° during a period of four hours. The distillate, which collected in two layers, was separated, and the aqueous layer was extracted with 10 ml. of ether. The organic layer and the ether extract were combined, dried over potassium hydroxide and distilled through an adiabatic, total condensation, variable take-off type column with a 1.5 × 15 cm. section packed with glass helices. The yield of O-allyl-N,N-dimethylhydroxylamine was 12.2 g. (51%), b. p. 83°; n^{25}_{D} 1.3982; d^{25}_{4} 0.7939; M_D calcd. 30.05, found 30.77.

Anal. Calcd. for $C_5H_{11}NO$: C, 59.37; H, 10.96; N, 13.85. Found: C, 59.15; H, 10.73; N, 13.98.

O-Allyl-N,N-dimethylhydroxylamine picrate was prepared by heating the reactants in alcohol solution and was recrystallized from a mixture of alcohol and ether; m. p. 92.5–93.5°.

Anal. Calcd. for $C_{11}H_{14}N_4O_8$: C, 40.00; H, 4.27; N, 16.97. Found: C, 39.80; H, 4.26; N, 17.07.

O-Allyl-N,N-dimethylhydroxylamine (1 g.) and methyl iodide (1.4 g.) reacted to give a white, crystalline methiodide. The mixture was allowed to stand in a refrigerator for twenty-four hours, the solid was pressed dry on a suction filter, and recrystallized from a mixture of absolute alcohol and dry ether; m. p. 129° (dec.).

Anal. Calcd. for $C_6H_{14}NOI$: C, 29.64; H, 5.81; N, 5.76; I, 52.21. Found: C, 29.25; H, 5.95; N, 5.62; I, 53.00.

Synthesis of O-Allyl-N,N-dimethylhydroxylamine for Comparison with the Rearrangement Product.—Hydroxyurethan was prepared according to the method of Jones[13] and alkylated with allyl bromide under conditions similar to those employed previously.[4,13,14] It was found to be important to use moderately dilute solutions in the alkylation in order to obtain a high proportion of O-allylhydroxyurethan in the product; in concentrated solution the yield of this compound was less than 5% and O,N-diallylhydroxyurethan was the principal product. Hydroxyurethan (159 g.) in 330 ml. of absolute alcohol was converted into the potassium salt with a solution of 86.8 g. of potassium hydroxide in 330 ml. of absolute alcohol. Allyl bromide (195.5 g.) was added with cooling at room temperature, and the mixture was heated under reflux for two hours. After separation of the two products with 10% sodium hydroxide[4] the acidic fraction yielded 134.2 g. (61%) of O-allylhydroxyurethan, b. p. 107° (12.5 mm.), n^{25}_{D} 1.4429, and the neutral fraction yielded 25.2 g. of O,N-diallylhydroxyurethan, b. p. 91–92° (8.5 mm.), n^{25}_{D} 1.4436. O-Allylhydroxyurethan (134 g.) was hydrolyzed to O-allylhydroxylamine by heating with a solution of 120 g. of potassium hydroxide in 280 ml. of water for two hours under reflux. The product was steam distilled into dilute hydrochloric acid, and O-allylhydroxylamine hydrochloride was isolated by concentration under reduced pressure. After twice adding absolute alcohol and removing it under reduced pressure the yield was 91 g. (90%), m. p. 169–170°. After recrystallization from absolute alcohol and dry ether the m. p. was 170.6–170.8°.[4,15]

Freshly distilled dimethyl sulfate (52 g.) was added slowly with stirring and cooling to O-allylhydroxylamine hydrochloride (22.5 g.) in 200 ml. of 10% aqueous sodium hydroxide. The solution became turbid and two layers separated within three-quarters of an hour. An additional 5.2 g. of dimethyl sulfate and 40 ml. of 10% sodium hydroxide was added, and the mixture was heated under reflux for one-half hour and stirred at room temperature for twelve hours. The solution was extracted with 50- and 25-ml. portions of ether, which were dried over sodium sulfate and distilled. The O-allyl-N,N-dimethylhydroxylamine was converted into solid derivatives for comparison with derivatives prepared from O-allyl-N,N-dimethylhydroxylamine obtained by rearrangement. O-Allyl-N,N-dimethylhydroxylamine picrate was recrystallized from absolute alcohol; m. p. 92.6–93°, which was not depressed by mixture with the picrate obtained from the rearrangement product.

Anal. Calcd. for $C_{11}H_{14}N_4O_8$: C, 40.00; H, 4.27; N, 16.97. Found: C, 39.81; H, 4.23; N, 17.36.

Another sample of the O-allyl-N,N-dimethylhydroxylamine prepared by this synthesis was converted to the methiodide, which was recrystallized from a mixture of absolute alcohol and dry ether; m. p. and mixed m. p. with the methiodide prepared from the rearrangement product 129° (dec.).

Anal. Calcd. for $C_6H_{14}NOI$: C, 29.64; H, 5.81; N, 5.76; I, 52.21. Found: C, 29.60; H, 5.84; N, 5.66; I, 52.11.

Both samples of the methiodide decomposed suddenly within fifteen seconds when placed in a melting-point bath heated to 128–129°. If placed in the bath at a temperature below 120°, they darkened slowly and charred between 200 and 250°. If placed in the bath at temperatures between 120 and 128° they decomposed, but not within fifteen seconds and not always at the same temperature.

O-Allyl-N,N-diethylhydroxylamine.—An aqueous solution prepared by oxidizing 50 g. of allyldiethylamine with 10% aqueous hydrogen peroxide was treated with platinum to decompose the excess hydrogen peroxide and concentrated to a thick pale yellow sirup. The flask containing the sirup was attached to a condenser set for distillation, nitrogen was introduced through a capillary, and the flask was immersed in a bath at 125°. O-Allyl-N,N-diethylhydroxylamine began to distil along with water remaining in the amine oxide sirup within fifteen minutes, and the distillation was continued by raising the bath temperature as necessary until only a small dark residue remained. The product was separated, combined with two 15-ml. ether extracts of the aqueous layer, and dried over magnesium sulfate. The solution was distilled through a total condensation type column with a 1.5 × 15 cm. section packed with glass helices. The yield of O-allyl-N,N-diethylhydroxylamine was 33.9 g. (59%), b. p. 126°; n^{25}_{D} 1.4118; d^{25}_{4} 0.8018; M_D calcd. 39.28, found 40.07.

Anal. Calcd. for $C_7H_{15}NO$: C, 65.09; H, 11.70; N, 10.84. Found: C, 65.18; H, 11.60; N, 10.66.

O-Allyl-N,N-diethylhydroxylamine picrate was pre-

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(13) Jones, *Am. Chem. J.*, **20**, 40 (1898).

(14) Hecker, *ibid.*, **50**, 444 (1913).

(15) Brady and Peakin, *J. Chem. Soc.*, 226 (1930).

pared as a derivative and recrystallized from absolute alcohol; m. p. 78.8–79.4°.

Anal. Calcd. for $C_{13}H_{18}N_4O_8$: C, 43.58; H, 5.06; N, 15.64. Found: C, 43.22; H, 5.13; N, 15.42.

In two preparations, the rearrangement was conducted by concentrating the aqueous solution of allyldiethylamine oxide at atmospheric pressure. The solution was added from a dropping funnel to a distilling flask immersed in a bath at 150–155° as rapidly as water distilled from the solution. The O-allyl-N,N-diethylhydroxylamine distilled with steam after most of the water had distilled. The distillate was extracted with ether, which was dried over magnesium sulfate and fractionated. The yields were poorer (42 and 44%) than in the preparations in which the amine oxide was concentrated under reduced pressure before rearrangement.

O-Allyl-N,N-diisopropylhydroxylamine.—The aqueous solution of allyldiisopropylamine oxide (277 ml.) described under the preparation of the picrate was divided, 25 ml. being used for preparation of the picrate and the remainder for rearrangement according to the following procedure. The solution was heated in an oil-bath at 125° for twenty minutes, and then distilled rapidly at a pressure of 75 mm. The organic layer was separated from the distillate and combined with two 25-ml. extracts of the aqueous layer. After drying over magnesium sulfate the product was distilled through the total condensation type column with a 1.5 × 16 cm. section packed with glass helices. The yield of O-allyl-N,N-diisopropylhydroxylamine was 27.5 g. (67%), b. p. 92–93° (100 mm.); $n^{25}\mathrm{D}$ 1.4248; d^{25}_4 0.8223; $M\mathrm{D}$ calcd. 48.52, found 48.88.

Anal. Calcd. for $C_9H_{19}NO$: C, 68.74; H, 12.18; N, 8.91. Found: C, 68.58; H, 12.23; N, 9.16.

O-Allyl-N,N-diisopropylhydroxylamine picrate decomposed on attempted recrystallization but was analytically pure as it crystallized on preparation in 95% alcohol; m. p. 86.4–87.2°.

Anal. Calcd. for $C_{15}H_{22}N_4O_8$: C, 46.63; H, 5.74; N, 14.50. Found: C, 46.41; H, 6.01; N, 14.59.

O-Allyl-N,N-di-*n*-propylhydroxylamine.—An aqueous solution of allyldi-*n*-propylamine oxide was prepared by oxidizing 50 g. of allyldi-*n*-propylamine with 35% hydrogen peroxide, treated with platinum to decompose hydrogen peroxide, and rearranged under the conditions described for preparation of O-allyl-N,N-diisopropylhydroxylamine. The yield of O-allyl-N,N-di-*n*-propylhydroxylamine was 44.5 g. (80%), b. p. 100–101° (100 mm.); $n^{25}\mathrm{D}$ 1.4209; d^{25}_4 0.8125; $M\mathrm{D}$ calcd. 48.52, found 49.07.

Anal. Calcd. for $C_9H_{19}NO$: C, 68.74; H, 12.18; N, 8.91. Found: C, 68.78; H, 12.24; N, 9.05.

O-Allyl-N,N-di-*n*-propylhydroxylamine picrylsulfonate was prepared by heating the reactants in 95% alcohol and was recrystallized from the same solvent; m. p. 106.8–107.7°.

Anal. Calcd. for $C_{15}H_{22}N_4O_{10}S$: C, 40.00; H, 4.92; N, 12.44. Found: C, 40.27; H, 4.96; N, 12.47.

O-Allyl-N,N-di-*n*-hexylhydroxylamine.—Allyldi-*n*-hexylamine (5.1 g.) was oxidized with hydrogen peroxide in acetone by the procedure described under preparation of the amine oxide picrate. An aqueous suspension (two layers) of the amine oxide was concentrated under reduced pressure, with much difficulty because of foaming. The residue was heated with an electric heating mantle and distilled at 1 mm., also with foaming. The organic layer of the distillate was separated, combined with ether extracts of the aqueous layer, and redistilled through a short Vigreux column at 0.5 mm. Foaming interfered with the distillation, which was accomplished by heating the liquid as little as possible and directing an infrared lamp at its surface. The yield of O-allyl-N,N-di-*n*-hexylhydroxylamine was 3.73 g. (68%), b. p. 77–81° (0.5 mm.). A redistilled analytical sample had b. p. 93–94° (1 mm.); $n^{25}\mathrm{D}$ 1.4381; d^{25}_4 0.8245; $M\mathrm{D}$ calcd. 76.23, found 76.79.

Anal. Calcd. for $C_{15}H_{31}NO$: C, 74.62; H, 12.94; N, 5.80. Found: C, 74.93; H, 12.87; N, 5.70.

Unsuccessful attempts were made to prepare the following derivatives of O-allyl-N,N-di-*n*-hexylhydroxylamine in crystalline form: picrate, picrylsulfonate, perchlorate, diliturate, styphnate, methiodide and methyl *p*-toluenesulfonate.

O-Benzyl-N,N-dimethylhydroxylamine.—Benzyldimethylamine (25 g.) was oxidized by stirring with 35 g. of 35% aqueous hydrogen peroxide for five hours, while the mixture was immersed in a water-bath at room temperature to dissipate the heat of reaction. The solution was diluted with 25 ml. of water and stirred in the presence of platinum foil for two days. The aqueous solution was extracted with 10 ml. of pentane and concentrated under reduced pressure with a bath temperature of 45°. The residual sirup was dried by adding three successive 25-ml. portions of benzene and removing them under reduced pressure. The residue was distilled at a bath temperature of 85–165° and 15–10 mm. The organic layer was separated from the distillate, combined with ether extracts of the aqueous layer, and distilled through an adiabatic, total condensation type column with a 1.5 × 15 cm. Vigreux section. The yield of O-benzyl-N,N-dimethylhydroxylamine was 17 g. (61%), b. p. 79–80° (15 mm.); $n^{25}\mathrm{D}$ 1.4920; d^{25}_4 0.9474; $M\mathrm{D}$ calcd. 45.38; found 46.30.

Anal. Calcd. for $C_9H_{13}NO$: C, 71.49; H, 8.66; N, 9.26. Found: C, 71.81; H, 8.76; N, 9.16.

O-Benzyl-N,N-dimethylhydroxylamine picrate was prepared by heating the reactants in 95% alcohol and was recrystallized from the same solvent; m. p. 111.6–112.4°.

Anal. Calcd. for $C_{15}H_{16}N_4O_8$: C, 47.37; H, 4.24; N, 14.73. Found: C, 47.10; H, 4.45; N, 14.96.

Summary

Allyldialkylamine oxides rearrange on heating, yielding O-allyl-N,N-dialkylhydroxylamines. Allyldimethylamine oxide does not undergo the rearrangement in alkaline aqueous solution, but does rearrange on heating after most of the water has been removed from its aqueous solution by distillation. Benzyldimethylamine oxide rearranges in a similar manner to yield O-benzyl-N,N-dimethylhydroxylamine. The rearrangement provides a satisfactory synthetic route for the preparation of O-allyl-N,N-dialkylhydroxylamines and O-benzyl-N,N-dimethylhydroxylamine.

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