saturated esters, such as the 2-ethyl-2-hexenoic esters of 1,5-pentanediol, trimethylolpropane, and pentaerythritol, afford the corresponding di-, tri-, and tetraglycidates in good yield by direct epoxidation with anhydrous peracetic acid (Table II).

EXPERIMENTAL

General procedure for ester exchange. Sodium methoxide (2–10 mole % based on epoxy ester) was dissolved in the appropriate alcohol (2–10 moles) in a still kettle equipped with a condenser maintained at −5°. Then the ester of the α, β-epoxy acid was added and the reaction mixture refluxed under reduced pressure, the kettle temperature being kept at about 40°. During the period of reflux, the low-boiling alcohol was removed from the still head until no more was obtained. The kettle residue was then cooled to room temperature, the catalyst destroyed with an equivalent of acetic acid, and the mixture filtered, if necessary. The products were isolated by fractional distillation. In some cases metallic sodium, magnesium alcoholate, or other catalyst was substituted for the sodium methoxide. A summary of the results is found in Table I.

General procedure for epoxidation. The techniques were similar to those previously described.[1] In the preparation of di- or polyepoxides an excess of 25–30% peracetic acid solution[10] in either ethyl acetate or acetone was used. The oxidations were continued until the peracetic acid consumption leveled out at its decomposition rate at the temperature employed. The volatile components were removed by feeding the reaction mixture dropwise into a kettle containing ethylbenzene under reflux at 50° under reduced pressure. The solvent, acetic acid, and excess peracetic acid were removed continuously at the still head. After removal of the excess ethylbenzene the epoxides were purified by distillation except in the cases of the trimethylolpropane and pentaerythritol esters. In these cases the epoxy esters were vacuum stripped, diluted with toluene, washed with sodium carbonate solution and water, and dried by vacuum stripping. A summary of the results is found in Table II.

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(10) B. Phillips, F. C. Frostick, Jr., and P. S. Starcher *J. Am. Chem. Soc.*, **79**, 5982 (1957); see also B. Phillips, P. S Starcher, and B. D. Ash, *J. Org. Chem.*, **23**, 1823 (1958).

[CONTRIBUTION FROM SOUTHERN REGIONAL RESEARCH LABORATORY,[1] UNITED STATES DEPARTMENT OF AGRICULTURE]

Reaction of Epichlorohydrin with Ammonia, Aniline, and Diethanolamine

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The reaction of epichlorohydrin with ammonia, aniline, and diethanolamine in various reaction media has been investigated. The hydrochloride of *N*,*N*,*N*-tris(3-chloro-2-hydroxypropyl)amine and *N*,*N*,*N*-tris(2,3-epoxypropyl)amine have been prepared from the crude reaction product of ammonia and epichlorohydrin in a 1:3 mole ratio in methanol. Formation of 1,3-dichloro-2-propanol, when ammonia or ammonium chloride and epichlorohydrin are treated in aqueous medium, has been demonstrated. *N*-(3-Chloro-2-hydroxypropyl)aniline, *N*-(2,3-epoxypropyl)aniline, and *N*,*N*-bis(2,3-epoxypropyl)-aniline have been isolated. *N*-(3-Chloro-2-hydroxypropyl)-*N*,*N*-bis(2-hydroxyethyl)amine has been prepared and it has been demonstrated that this compound slowly forms a quaternary salt, probably by cyclization.

In the synthesis of polyepoxide finishing agents for cotton, it became necessary to prepare certain *N*-substituted amine epoxides. The *N*-(3-chloro-2-hydroxypropyl)amines, obtained by addition of epichlorohydrin to an amine, were dehydrohalogenated to the respective epoxides. An interesting chlorohydroxyamine, *N*,*N*,*N*-tris(3-chloro-2-hydroxypropyl)amine (I), formed by saturating epichlorohydrin with ammonia gas at room temperature in a five-day reaction is mentioned by Fauconnier,[2] but no yields are given. In our experience with this reaction, one is apt to obtain an alcohol-insoluble resin, as it is difficult to know when epichlorohydrin is saturated. Other references to the action of epichlorohydrin and ammonia,[3–10] are concerned chiefly with aqueous ammonia, and frequently the conditions imposed could scarcely be classed as mild. The only compound definitely isolated was 1,3-diamino-2-propanol in the work by Bottoms,[5] who carried out the reaction in the presence of strong alkali. Aqueous solutions of ammonium salts, such as ammonium chloride, have been reported to react with epichlorohydrin.[11,12] The kinetics of the reaction were determined, but no products were isolated. The action of liquid ammonia on epichlorohydrin is not reported in the literature. Neither have the present investigators been successful in isolating and identifying the

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(1) One of the laboratories of the Southern Utilization Research and Development Division, Agricultural Research Service, U. S. Department of Agriculture.

(2) A. Fauconnier, *Compt. rend.*, **107**, 115, 250 (1888).

(3) O. Stallman, U. S. Patents **1,977,250–253** (Oct. 16, 1934).

(4) R. Stahn, U. S. Patent **2,120,513** (June 14, 1938).

(5) R. R. Bottoms, U. S. Patent **1,985,885** (Jan. 1, 1935).

(6) E. Krumbein, D.D.R. Patent **5,321** (Sept. 24, 1954).

(7) Shell Chemical Corp., N. Y., *Epichlorohydrin*, Technical Booklet SC: 49-35, 2nd. Ed., 1953. p. 26.

(8) J. H. Daniel, Jr., C. G. Landes, and J. D. Pollard, U. S. Patents **2,573,956–957** (Nov. 6, 1951).

(9) L. Darmstaedter, *Ann.*, **148**, 119 (1868).

(10) W. H. Paterson and T. Skei, U. S. Patent **2,648,633** (Aug. 11, 1953).

(11) H. K. Sen, C. Barat, and P. P. Pal, *Proc. 15th Indian Sci. Congr.* **146** (1928).

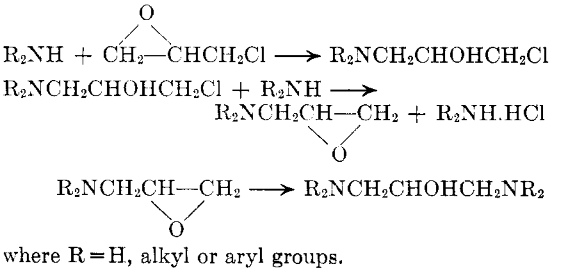
(12) S. Banerjee and H. K. Sen, *J. Indian Chem. Soc.*, **9**, 509 (1932).

products between liquid ammonia and epichlorohydrin. When the reaction was carried out in a Dewar flask in the presence of excess liquid ammonia, only a small amount of a thick yellow liquid whose analysis corresponded to a mixture of the mono- and bischlorohydroxyamines was isolated. When epichlorohydrin and liquid ammonia in a 3:1 mole ratio were treated in a bomb, only a brown, partially water-soluble resin was formed.

From exploratory experiments, it was known to us that 3% aqueous ammonia solubilized epichlorohydrin in a few hours at 25°. Certain condensation products as well as 1,3-dichloro-2-propanol (II), ammonium chloride, and possibly I were easily extracted from the mixture. It was also observed that slow addition of ammonia gas to epichlorohydrin in dioxane solution caused small quantities of ammonium chloride to precipitate. When the gas was slowly passed into a petroleum ether solution of epichlorohydrin, a clear, highly viscous liquid separated within a few hours. This liquid was dehydrohalogenated to yield some *N,N,N*-tris(2,3-epoxypropyl)amine (III). The reaction was frequently accompanied by ammonium chloride formation. With these facts in mind, it occurred to us that I should be formed if ammonia and epichlorohydrin were allowed to react in a mutual solvent such as a lower aliphatic alcohol in the absence of water. By analogy with the Sturkov reaction,[13] which is concerned with the reaction of epichlorohydrin and aromatic amine hydrochlorides, it was thought that aqueous ammonium chloride should form the desired chlorohydrin.

From aqueous solutions of ammonia or ammonium chloride and epichlorohydrin (1:3 mole ratio) or methanol-water solutions of ammonium chloride and epichlorohydrin (1:4 mole ratio), II could always be isolated in 50 to 80% yields from the ether extract of the reaction mixture. Attempts to isolate chlorohydroxyamines from the extracted aqueous layers were unsuccessful. A pasty white solid which was soluble in alcohol and water but insoluble in acetone or dioxane was obtained. Attempts to dehydrohalogenate this solid, which contained 5.32% nitrogen, resulted in the formation of a resin which was insoluble in water and alcohol. Results of these investigations are similar to the experimental results of Claus[14] with ammonia and epichlorohydrin.

Ammonia or amines are said to add to epichlorohydrin[7,15,16] by the following series of reactions:



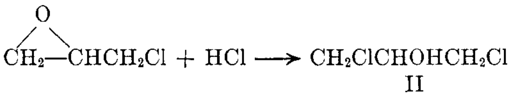
$$R_2NH + \overset{O}{CH_2-CHCH_2Cl} \longrightarrow R_2NCH_2CHOHCH_2Cl \quad (1)$$

$$R_2NCH_2CHOHCH_2Cl + R_2NH \longrightarrow R_2NCH_2\underset{O}{CH-CH_2} + R_2NH.HCl \quad (2)$$

$$R_2NCH_2\underset{O}{CH-CH_2} \longrightarrow R_2NCH_2CHOHCH_2NR_2 \quad (3)$$

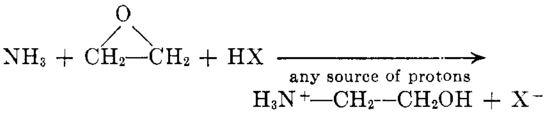
where R = H, alkyl or aryl groups.

To account for the presence of II, it is necessary to consider the presence of the amine hydrochloride. It is well known[17] that epichlorohydrin undergoes hydrolysis easily in the presence of a basic solution to form glycerol and liberate chloride ions. Also, the amine hydrochloride, on hydrolysis, produces some hydrochloric acid which reacts with epichlorohydrin according to the following well established reaction:



$$\overset{O}{CH_2-CHCH_2Cl} + HCl \longrightarrow \underset{II}{CH_2ClCHOHCH_2Cl} \quad (4)$$

Removal of the hydrochloric acid by the formation of II leaves the system alkaline. According to Eastham,[18] the reaction between ammonia and ethylene oxide in water can be represented by the following equation:



$$NH_3 + \overset{O}{CH_2-CH_2} + HX \xrightarrow[\text{any source of protons}]{} H_3N^+-CH_2-CH_2OH + X^- \quad (5)$$

A similar reaction can account for the formation of the di- and triethanolamines.

The present work has been concerned largely with the reaction of ammonia and epichlorohydrin in various solvents in attempts to prepare *N*-(3-chloro-2-hydroxypropyl)amine (IV), and *N,N*-bis(3-chloro-2-hydroxypropyl)amine (V) as well as I according to the mechanism of equation (1). Compound IV had not been isolated previously, but its hydrochloride was reported by Gabriel and Ohle[19] and Tomita.[20] Smith,[16a] from kinetic studies in which the products were not isolated, claimed that the main reaction between ammonia and epichlorohydrin is the formation of IV, which is dehydrohalogenated faster than epichlorohydrin to form the amino glycide. Neither compound V nor its hydrochloride had been reported previously. While V has not been isolated in this work, evidence points to its presence in the reaction, because occasionally when distilling III, a somewhat lower boiling epoxide or polymer has been isolated in small quantities. In this investigation, I has not been obtained in the crystalline form (m.p. 92–93° reported by Fauconnier[2]) but rather as an exceedingly viscous liquid which when stripped

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[13] I. T. Strukov, *Khim. Farm. Prom.*, No. 2, 11 (1934); through *Chem. Abstr.* **28**, 5421 (1934).

[14] A. Claus, *Ann.*, **168**, 1 (1873).

[15] A. M. Paquin, *Epoxyverbindungen und Epoxyharze*, Springer, 1958, pp. 183–186.

[16] (a) L. Smith and T. Nilsson, *J. prakt. Chem.*, **162**, 63 (1943); (b) L. Smith, S. Mattson, and S. Andersson, *Acta Univ. Lundensis*, **42**, No. 7, 1–18 (1946).

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[18] A. M. Eastham, B. de B. Darwent, and P. W. Beaubien, *Can. J. Chem.*, **29**, 575 (1951).

[19] S. Gabriel and H. Ohle, *Ber.*, **50**, 819 (1917).

[20] M. Tomita, *Z. physiol. Chem.*, **158**, 42 (1926).

under vacuum gave a clear plastic solid. The analysis of the crude material points largely to I contaminated with V. Compound III was the main product on dehydrohalogenation.

The reaction between ammonia and epichlorohydrin appears to take several courses, depending on the amount of water present in the system. Thus, in absolute ethanol, absolute methanol, or petroleum ether, it has been established that I has been formed, because the triepoxy derivative (III) can be prepared from the reaction product, and there is no evidence for the formation of II as a byproduct. Small amounts of ammonium chloride were present. However, when an aqueous medium is used, as in the Strukov reaction, II always occurred and could either be extracted from the aqueous solution or distilled from the mixture. In aqueous medium, about one-third of the epichlorohydrin was used in forming II and the reaction required three to five days for completion.

A number of investigations have been concerned with the aniline-epichlorohydrin reaction,[21-24] but only in recent years[25,26] have relatively mild conditions been used. Homer[26] prepared *N*,*N*-bis-(3-chloro-2-hydroxypropyl)aniline (VI) by a modified Strukov reaction,[13] which required a reaction time of three to five days, and further converted the chlorohydrin to *N*,*N*-bis(2,3-epoxypropyl)-aniline (VII). In this investigation, if dioxane were substituted for part of the water in the solvent medium, the reaction was complete within five hours. One objective of the present work was to obtain *N*-(3-chloro-2-hydroxypropyl)aniline (VIII) and *N*-(2,3-epoxypropyl)aniline (IX), which Homer did not report. The only mention of the latter compound is in the work of Zetzsche and Aeshlimann[23] who isolated a few drops of a liquid having the correct nitrogen content from the mixture of aniline and epichlorohydrin in toluol, which was kept at a high temperature for four days. According to Dains,[24] aniline and epichlorohydrin form no solid or readily purified derivative under mild conditions. In this investigation, when aniline (0.2 mole) and epichlorohydrin (0.3 mole) were treated in aqueous ethanol at the reflux temperature according to the method of Davies and Savige,[25] a mixture of mono- and bischlorohydrins which could not be distilled without decomposition was obtained. We have found that the desired chlorohydrin can be prepared by the reaction of aniline and epichlorohydrin with or without solvents. When aqueous alcohol is used as the solvent medium, about a third of the starting material is converted to water-soluble quaternary compounds, whereas only 5–6% of quaternary compounds is obtained when no solvent is used. The evidence for compound formation was deduced from the sharp increase in viscosity, and decrease in hydrobromic acid titration as performed by the Durbetaki Method.[27]

Little has been reported in regard to the action of epichlorohydrin on the three ethanolamines other than the work of Pierce and Wotiz[28] on diethanolamine. The latter neither isolated nor characterized their reaction products. Exploratory experiments showed that mono-, di-, and triethanolamines react exothermically with epichlorohydrin. The ionic chlorine content of the reaction mixture increases with time even when the reaction temperature has been kept under 30°. Reactions other than those illustrated in Equations 1–5 have been reported, especially with secondary amines, where some form of cyclization has been encountered.[29-31] We have found a similar phenomenon in the exceedingly vigorous reaction between diethanolamine and epichlorohydrin. It was found that initially, the liquid reaction product from the diethanolamine–epichlorohydrin reaction is 20–25% insoluble in chloroform or dioxane and gels on standing. After a week at 25°, practically all the reaction product is chloroform insoluble. The change is quite rapid if dioxane is the reaction medium or if the reaction product is heated in an oven at 70° for a few hours. The decrease in solubility in chloroform has been found to be accompanied by an increase in ionic chlorine content and a decrease in trivalent nitrogen content caused by a quaternization of the desired *N*-(3-chloro-2-hydroxypropyl)-amine. Apparently in the reaction of amines and epichlorohydrin, a considerable variety of products may be obtained by varying temperature, molar ratio of reactants, reaction media, and the basicity of the amine.[32]

EXPERIMENTAL

Preparation of crude N,N,N-tris(3-chloro-2-hydroxypropyl)amine (I) *from ammonia and epichlorohydrin.* To 200 ml. of chilled methanol (1°) in a stoppered flask, ammonia gas or liquid ammonia was added until 4.8 g. (0.282 mole) were absorbed. Then 78.3 g. (0.846 mole) of Fisher[33] reagent

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(21) A. Fauconnier, *Compt. Rend.*, **106**, 605 (1888).

(22) T. Fukagawa, *Ber.*, **68B**, 1344 (1935).

(23) F. Zetzsche and F. Aeschlimann, *Helv. Chim. Acta*, **9**, 708 (1926).

(24) F. B. Dains, R. Q. Brewster, J. S. Blair, and W. C. Thompson, *J. Am. Chem. Soc.*, **44**, 2637 (1922).

(25) W. Davies and W. E. Savige, *J. Chem. Soc.*, 890 (1950).

(26) R. F. Homer, *J. Chem. Soc.*, 3690 (1950).

(27) A. J. Durbetaki, *Anal. Chem.*, **28**, 2000 (1956).

(28) J. S. Pierce and J. J. Wotiz, *J. Am. Chem. Soc.*, **66**, 879 (1944).

(29) R. Rothstein and K. Binovic, *Compt. rend.*, **236**, 1050 (1953).

(30) D. L. Heywood and B. Phillips, *J. Am. Chem. Soc.*, **80**, 1257 (1958).

(31) N. S. Drozdov and O. M. Cherntzov, *J. Gen. Chem. (USSR)*, **4**, 969 (1934); through *Chem. Abstr.*, **29**, 2148 (1935).

(32) J. B. McKelvey, Beverly G. Webre, and E. Klein, *J. Org. Chem.*, **24**, 614 (1959).

(33) Trade names have been used to identify materials used in the work, and such use does not imply endorsement or recommendation by the U. S. Department of Agriculture over other products not mentioned.

grade epichlorohydrin (b.p. 114–116°) were added and the solution was stirred in a water bath overnight at 26°. After 16 hr., the odor of ammonia had disappeared. The final solution (*p*H 8) did not give a precipitate with silver nitrate, but in time a brown mirror formed. Volume reduction in a rotary evaporator yielded 76.7 g. of a clear, glassy solid which did not flow at 25°. It did not crystallize at Dry Ice temperatures nor could it be recrystallized from alcohol or dioxane. It was not soluble in absolute ether or dioxane, but dissolved when a few milliliters of methanol were added to either solvent. No ammonium chloride precipitated from its dioxane solution. The product was quite soluble in water, 15% sodium hydroxide, and dilute hydrochloric acid. It was slightly soluble in acetone or methyl ethyl ketone. It did not form an insoluble picrate or a quaternary salt with methyl iodide. The aqueous solution gave a slight turbidity with silver nitrate and then a silver mirror.

Anal. Calcd. for $C_9H_{18}Cl_3NO_3$: Cl, 36.15. N, 4.75. Found: Cl, 34.84. N, 5.17.

That I is present in the above ammonia-epichlorohydrin reaction product may be proved by the precipitation of its hydrochloride (X) after the crude reaction mixture is treated with excess hydrochloric acid. A 15–25% yield of X, (m.p. 175°) could be obtained by recrystallization of the solvent-free crude hydrochlorides from ethanol or acetone at Dry Ice temperatures.

Anal. Calcd. for $C_9H_{18},Cl_3NO_3.HCl$(X): total Cl, 42.9; ionic Cl, 10.73, N, 4.2. Found: total Cl, 42.2; ionic Cl, 10.86. N, 4.19.

When a 1:1 mole ratio of epichlorohydrin (92.5 g.) and ammonia gas (17 g.) was mixed in methanol, a cloudiness developed in a few days. At the end of 15 days, ammonia could still be detected, and 10.5 g. (0.2 mole) of ammonium chloride had precipitated showing the chloride end of the epichlorohydrin molecule was attacked. Evaporation of the methanol revealed a sticky, white solid which was not investigated.

Preparation of N,N,N-tris(2,3-epoxypropyl)amine (III). When 53.4 g. (0.19 mole) of the above mentioned crude chlorohydrin formed in methanol was agitated for a 0.5 hr. in 150 ml. of dioxane at 25° with 42 g. of powdered 87% potassium hydroxide (0.64 mole), there was obtained after stripping the solvent 37.3 g. (0.2 mole) of a lemon colored oil. Substitution of 98% sodium hydroxide for potassium hydroxide and lowering of temperature to 1–5° resulted in a similar yield of crude oil. When these crude oils were distilled at reduced pressure, they resinified violently, after only a small portion had distilled. Dilution of the crude oils with anhydrous ether or especially carbon tetrachloride caused separation of small amounts of a waxy solid which was insoluble in water and common solvents.

Anal. Found N, 8.1; Cl, 0.0; ash, 0.0.

The undistilled, but solvent treated epoxides showed oxirane oxygen contents of 23%. The purified oils obtained by use of potassium hydroxide and sodium hydroxide could be distilled to give yields of 30 and 56%, respectively, based on the epichlorohydrin.

When 12 g. of the partially purified epoxide was distilled, approximately 6 g. of water-white distillate, b.p. 123–124°, 2 mm., was obtained.

Anal. Calcd. for $C_9H_{15}NO_3$ (III): N, 7.6; oxirane oxygen, 25.9. Found: N, 7.4; oxirane oxygen, 25.8; n_D^{25} 1.4737; d_4^{25} 1.1214.

Compound III was soluble in water, aqueous alkali and acids, carbon tetrachloride, and benzene, but was insoluble in aliphatic hydrocarbons. Within a few weeks, III turned to a hard brown resin insoluble in common solvents. However, it has been kept in a dessicator over phosphorus pentoxide for several months. Methyl iodide and III (4:1 mole ratio) reacted at 26° to form a viscous, water-soluble, noncrystalline mass.

Anal. Calcd. for $C_{10}H_{18}INO_3$: I, 38.8; oxirane oxygen, 14.7. Found: I, 36.9; oxirane oxygen, 12.4.

Preparation of the hydrochloride of N,N,N-tris(3-chloro-2-hydroxypropyl)amine (X). When III was dissolved in dry ether and gassed with dry hydrogen chloride, a brown viscous mass which barely flowed was formed. When a similar experiment was conducted in absolute methanol, a thick viscous mass was formed after evaporation of the solvent.

Anal. Found: N, 4.1; Cl, 36.7.

After long standing, crystals separated from the brown viscous mass. Recrystallization from absolute ethanol yielded white crystals (*X*), m.p. 175°; lit.,[2] m.p. 173°. Pure *X* was soluble in methanol.

Anal. Calcd. for $C_9H_{18}Cl_3NO_3.HCl$ (X): total Cl, 42.9; ionic Cl, 10.72. N, 4.2. Found: total Cl, 42.1; ionic Cl, 10.80 N, 4.2.

Preparation of N,N,N-tris(3-chloro-2-hydroxypropyl)amine (I) *from its hydrochloride* (X). When X was treated with silver oxide, a light yellow oil which solidified within a few days was formed. Analysis of the oil by the method of Durbetaki[27] indicated a trivalent nitrogen content of 18.2% instead of the theoretical 4.75% for I. Hence, silver oxide not only reacted with the ionic chlorine of X but also caused dehydrohalogenation with the resultant formation of epoxide. These results were similar to those obtained by Tomita[20] with compound IV.

Results of potentiometric titrations of X with sodium hydroxide showed that the first rapid reaction was between sodium hydroxide and the ionic chloride and hydrogen ions. The slower reactions were due to the dehydrohalogenation of the chlorohydrins with the resultant formation of epoxides. Therefore, an exact equivalent of sodium hydroxide solution was added to an aqueous solution of X, and the resultant solution was extracted immediately with chloroform. After the chloroform was stripped, a colorless viscous oil was obtained. Continued evacuation at 2 mm. resulted in a waxy solid which did not flow at room temperature.

Anal. Calcd. for $C_9H_{18}Cl_3NO_3$: total Cl, 36.15; ionic Cl, 0.0; trivalent N, 4.75; total N, 4.75. Found: ionic Cl, 0.60; trivalent N, 4.56; total N, 4.38.

Formation of 1,3-dichloro-2-propanol (II) *from epichlorohydrin.* When 92.5 g. epichlorohydrin (1.0 mole) and 5.6 g. of ammonia (0.33 mole) were allowed to react in 300 ml. of water, the time required for complete solution was 3 days at room temperature with stirring. When the clear, colorless, aqueous solution was extracted with ether, 18 g. (0.14 mole) of a colorless liquid resulted (b.p. 172–174°).

Anal. Calcd. for $C_3H_6Cl_2O$: Cl, 55.0. Found: Cl, 54.8.

When 5.35 g. (0.1 mole) of ammonium chloride dissolved in 150 ml. of water (*p*H 5) was agitated with 27.7 g. (0.3 mole) of epichlorohydrin the *p*H rose to 7–8 in 2.5 hr. The epichlorohydrin layer had approximately disappeared in a day, and the solution was homogeneous and colorless in 3 days. The clear liquor which was ether extracted, dried and distilled, yielded 11 g. (0.08 mole) of liquid; b.p. 171–173°; d_4^{25}, 1.3513; lit. b.p. 174°; d_4^{20}, 1.361.

Anal. Calcd. for C_3H_5ClO: Cl, 55.0. Found: Cl, 54.6; N, 0.0.

Reinvestigation of the Strukov reaction. When 17.4 g. (0.1 mole) of *p*-phenetidine hydrochloride (m.p. 235°) was partially dissolved in 150 ml. of water and 27.8 g. (0.3 mole) of epichlorohydrin was added, there resulted a yellow, two-layer mixture. A cloudiness developed within 2 hr., and a deep red to brown-black color developed overnight. After 4.5 days, there resulted a brown oily mass of crystals on the bottom of the flask, while the water layer was a deep pink. The ether extract of the water layer contained 6.4 g. of a red liquid which when distilled yielded 4.0 g. (0.03 mole) of a water-white liquid (b.p. 170–171°).

Anal. Calcd. for II: Cl, 55.0. Found: Cl, 54.5.

A carbon tetrachloride extract of the brown insoluble mass yielded 15 g. of a crystalline solid (m.p. 80°).

Anal. Calcd. for $C_2H_5OC_6H_4N(CH_2CHOHCH_2Cl)_2$: Cl, 22.0. Found: Cl, 21.7.

Some unchanged *p*-phenetidine hydrochloride from the ether extracted water layer was also obtained. The reaction did not go to completion, and on the basis of the phenetidine, a 46% yield of purified *N,N*-bis(3-chloro-2-hydroxypropyl)*p*-phenetidine was obtained.

Preparation of N-(3-chloro-2-hydroxypropyl)aniline (VIII). To 9.3 g. (0.1 mole) of Eastman[33] White Label aniline was added 9.25 g. (0.1 mole) of epichlorohydrin in a stoppered flask. After thorough mixing, a 0.1-g. sample of the liquid required 12.72 ml. of 0.0856*N* hydrobromic acid in glacial acetic acid for a Durbetaki[27] titration. A like aliquot was titrated with only 6.40 ml. of the acid after 90 hr. of reaction time. The time of efflux in an Ostwald viscometer was 128.6 sec. at the start and over 12 hr. after a reaction time of 90 hr. The reaction mixture was dissolved in ether and washed with water four times. After the ether solution was dried and stripped, 17 g. of a thick, reddish brown oil was obtained.

Anal. Calcd. for $C_9H_{12}ClNO$: Cl, 19.1; N, 7.5. Found: Cl, 18.9; N, 7.0.

Attempts to distill the oil at 2 mm. resulted in decomposition at 158–160° with formation of a thick, resinous polymer.

Preparation of N-(2,3-epoxypropyl)aniline (IX). To 18.5 g. of epichlorohydrin (0.2 mole) was added 18.6 g. of aniline (0.2 mole) and the reaction mixture was allowed to stand at 25° for 5 days in a stoppered flask. The product was extracted with ether, washed with water, dried, and agitated with 15 g. of powdered potassium hydroxide for 3 hr. at 25°. After filtration and evaporation of the ether, 28 g. remained. On vacuum distillation at 2–3 mm. pressure, 2.3 ml. of a compound which proved to be aniline was collected at 56–58°, and then the temperature rose to 101–103°. A portion of the material resinified in the flask. The fraction collected at 101–103° was redistilled and boiled at 99–101° at 1–2 mm. pressure. A 50% yield was obtained. The product was a light lemon-colored, almost odorless liquid (d_4^{26} 1.1042) and was insoluble in water.

Anal. Calcd. for $C_9H_{11}NO$: N, 9.4; oxirane oxygen, 10.7. Found: N, 9.4; oxirane oxygen, 10.8.

Preparation of N,N-bis(2,3-epoxypropyl)aniline (VII). To a mixture of 100 ml. water and 85 ml. of dioxane were added 25.9 g. of aniline hydrochloride (0.2 mole) and 37.0 g. of epichlorohydrin (0.4 mole). The resulting clear solution deposited a heavy oil in about 4–5 hours. When the oil was dehydrohalogenated with powdered potassium hydroxide in ether, approximately a 50% yield of VII was obtained, b.p. 185–187°, 10–12 mm.; lit. b.p. 165°, 1 mm. In contrast to IX, VII is reasonably stable.

Anal. Calcd. for $C_{12}H_{15}NO_2$: N, 6.8; oxirane oxygen, 15.6. Found: N, 6.7; oxirane oxygen, 15.4.

Preparation of N-(3-chloro-2-hydroxypropyl)N,N-bis(2-hydroxyethyl)amine (XI). According to the procedure of Pierce and Wotiz[28] 42 g. (0.4 mole) of diethanolamine (Union Carbide Chemicals Company)[33] was added to 40 g. (0.44 mole) of epichlorohydrin, after the individual reactants had been chilled to 6°. Agitation in an ice and salt bath kept the temperature from rising above 10–11°, during the vigorous initial exothermic reaction. The material was kept at this temperature for 3 hr., at the end of which time the temperature was increased to 18–20°, and finally, to 26° overnight. After evacuation under a bell-jar, the resultant clear, slightly viscous liquid was soluble in water (*p*H 8) or methanol, and gave a strong chloride ion test. It could not be distilled without decomposition at 2–3 mm. pressure. Only partial solubility resulted when it was mixed with chloroform or dioxane. By the Volhard titration, it contained 2.75% ionizable chlorine (15.5% of the theoretical chlorine content).

Anal. Calcd. for $C_7H_{16}ClNO_3$: total Cl, 18.0; ionizable Cl, 0.0; N, 7.1; trivalent N, 7.1. Found: total Cl, 18.6; ionizable Cl (Volhard), 2.8. N, (Kjeldahl), 6.7; trivalent N (Durbetaki), 7.1.

When 40 g. of the above product was added to 150 ml. of chloroform, approximately 11–12 g. of a turbid liquid separated. The chloroform soluble product (XI) appeared initially in good yield (75%).

Anal. Found: trivalent N (Durbetaki), 6.6.

It slowly quaternized on standing. Attempts to dehydrohalogenate the chloroform soluble portion of XI with powdered caustic only resulted in the formation of a thick, water-soluble, liquid polymer which could not be distilled.

The chloroform insoluble liquid was stripped of excess solvent and analyzed. Now 77% of the total chlorine was ionic, and very little of the nitrogen was in the trivalent state. It would appear reasonable to believe that the chloroform insoluble, waxy solid is the dihydrochloride of 2,5-bis-(2-hydroxyethylaminylmethyl)-*p*-dioxane by analogy to the work of Heywood and Phillips.[29]

Anal. Calcd. for $C_{14}H_{30}N_2Cl_2O_6$: ionizable Cl, 18.06; N, 7.1. Found: total Cl, 19.1; ionizable Cl (Volhard), 14.71; N (Kjeldahl), 6.4; trivalent N (Durbetaki), 0.6.

The formation and identification of such polymers containing quaternary ammonium ions are of interest in the preparation of ion exchange celluloses such as "ECHTEOLA",[34] but are beyond the scope of this investigation.

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[34] E. A. Peterson and H. A. Sober, *J. Am. Chem. Soc.*, **78**, 751 (1956).