Plasmalogens. I. The Synthesis of 1-Alkenyl Ethers of Glycerol[1,2]

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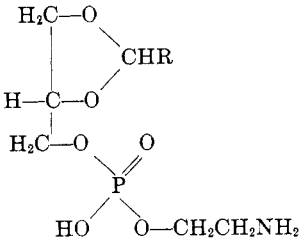
The synthesis of eight new 1-alkenyl ethers of glycerol is described. The procedure involves the reaction of an α-bromo cyclic acetal of glycerol with sodium. The unsaturated ethers were hydrogenated to yield the corresponding saturated compounds.

The plasmalogens were first isolated by Feulgen and Bersin,[5] in 1939, from horse muscle following vigorous alkaline hydrolysis of the ester phosphatides. It appeared that the aliphatic aldehyde formed an acetal bond with the glycerol skeleton, and that the phosphorus and nitrogen base (ethanolamine) was attached by ester bonding to the third hydroxy group in glycerol.

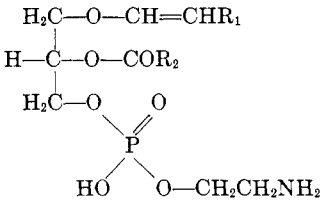


R = long chain alkyl group

This acetal structure has since served as a prototype of this class of lipids. In recent years, this chemical structure has been questioned and several alternatives have been proposed. It has been suggested that the cyclic acetal structure may be an artifact of the saponification step in the isolation procedure.

Further studies have provided strong evidence that the aldehydogenic residue in the native plasmalogens is an enol–ether, that is, not altered by mild alkaline hydrolysis. In 1954, Rapport and co-workers[6] fractionated acetal phosphatides from bovine muscle by chromatographic separation on silicic acid. Upon analysis they showed the presence of two fatty chains per atom of phosphorus, one of which was a fatty acid, and the other a fatty aldehyde. Klenk and Debuch[7] found that catalytic reduction of the ethanolamine–plasmalogen led to a complete disappearance of aldehydic reactions. Upon subsequent treatment of the reduced compound with alkali, a mixture of batyl and chimyl α-phosphoric acids was formed. They proposed three possible formulas for the plasmalogens of which the following is the presently accepted form (col. 2, top).

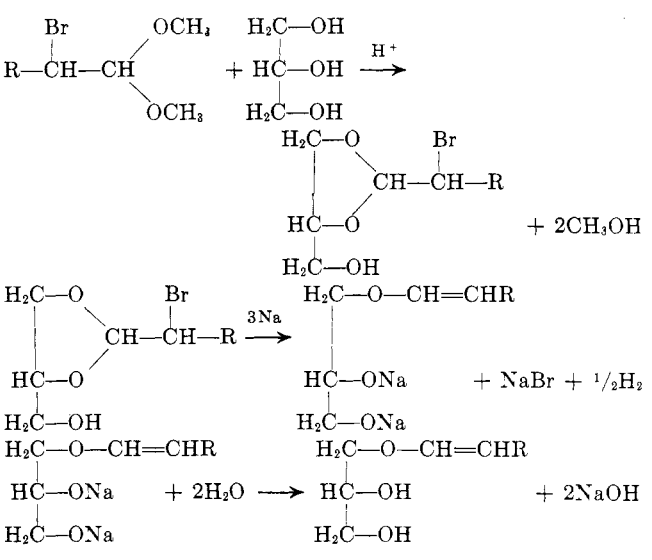
The aldehydogenic group has been shown to be on the α-carbon of the glycerol moiety.[7–11]



R = long chain alkyl group

Because of the sparse knowledge of the function of the plasmalogens and of only recent evaluation of experimental work to show the presence of an enol–ether unit, the chemical synthesis of these compounds seems worthwhile. The main objectives of the work described in this paper are to synthesize a portion of the plasmalogen molecule, namely, 1-alkenyl ethers of glycerol (α,β-unsaturated ethers of glycerol),[12] and to study some of their physical and chemical properties.

In 1878, Wislicenus[13] prepared vinyl ethyl ether by treating chloroacetal with metallic sodium at 130°. He observed that a vinyl ether was produced to the exclusion of a Wurtz reaction product. In 1928, Hill and Pidgeon[14] synthesized hydroxyethyl vinyl ether by adding metallic sodium to an anhydrous ethereal solution of bromoethylidene glycol. Using the same procedure, Hill[15] synthesized hydroxypropyl vinyl ether by the ac-



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(3) Abstracted from the dissertation of Allen F. Hirsch submitted to the Graduate School of the University of North Carolina in partial fulfillment of the requirements for the degree of Master of Science, 1962.

(4) Recipient of Graduate Honorable Mention in the Lunsford Richardson Pharmacy Award, 1962. American Foundation for Pharmaceutical Education Fellow.

(5) R. Feulgen and Th. Bersin, *Z. physiol. Chem.*, **260**, 217 (1939).

(6) M. M. Rapport, B. Lerner, and N. Alonzo, *Federation Proc.*, **13**, 278 (1954).

(7) E. Klenk and H. Debuch, *Z. physiol. Chem.*, **296**, 179 (1954).

(8) M. M. Rapport and R. E. Franzl, *J. Biol. Chem.*, **225**, 851 (1957).

(9) N. H. Tattrie, *J. Lipid Res.*, **1**, 60 (1959).

(10) D. J. Hanahan, H. Brockerhoff, and E. J. Barron, *J. Biol. Chem.*, **235**, 1917 (1960).

(11) G. V. Marinetti, J. Erbland, and E. Stolz, *J. Am. Chem. Soc.*, **81**, 861 (1959).

(12) It might be pointed out here that, since this term is widely used among biochemists, it is included to aid understanding.

(13) J. Wislicenus, *Ann. Chem.*, **192**, 106 (1878).

(14) H. S. Hill and L. M. Pidgeon, *J. Am. Chem. Soc.*, **50**, 2718 (1928).

(15) H. S. Hill, *ibid.*, **50**, 2725 (1928).

TABLE I

α-BROMO CYCLIC GLYCEROL ACETALS

Compound	Molecular formula	B.p., °C. (mm.)	n^tD	Temp., °C.	Yield, %	Carbon, % Calcd.	Carbon, % Found	Hydrogen, % Calcd.	Hydrogen, % Found	Bromine, % Calcd.	Bromine, % Found
2-(1′-Bromopropyl)-4-hydroxymethyl-1,3-dioxolane	$C_7H_{13}O_3Br$	105–107 (0.40)	1.4939	23.8	47	37.35	37.10	5.81	5.91	35.55	36.35
2-(1′-Bromobutyl)-4-hydroxymethyl-1,3-dioxolane	$C_8H_{15}O_3Br$	106–109 (0.60)	1.4849	23.5	80	40.18	39.95	6.32	6.29	33.40	33.29
2-(1′-Bromopentyl)-4-hydroxymethyl-1,3-dioxolane	$C_9H_{17}O_3Br$	125–130 (1.20)	1.4755	34.0	68	42.70	43.10	6.77	7.10	31.60	31.96
2-(1′-Bromoheptyl)-4-hydroxymethyl-1,3-dioxolane	$C_{11}H_{21}O_3Br$	138–142 (0.75)	1.4811	32.5	74	46.98	47.10	7.52	7.68	28.45	28.90
2-(1′-Bromooctyl)-4-hydroxymethyl-1,3-dioxolane	$C_{12}H_{23}O_3Br$	152–155 (1.00)	1.4789	27.5	76	48.81	48.95	7.79	7.81	27.11	27.16
2-(1′-Bromononyl)-4-hydroxymethyl-1,3-dioxolane	$C_{13}H_{25}O_3Br$	155–160 (0.40)	1.4810	22.0	73	50.48	51.00	8.09	8.10	26.00	26.15
2-(1′-Bromodecyl)-4-hydroxymethyl-1,3-dioxolane	$C_4H_{27}O_3Br$	156–157 (0.31)	1.4790	32.0	72	52.01	52.00	8.41	8.39	24.76	25.00

tion of sodium on bromoethylidene trimethylene glycol. By analogy, the method devised for preparing the 1-alkenyl ethers of glycerol was to treat an α-bromo cyclic acetal of glycerol with sodium. The preceding illustrates the sequence of reactions used in preparing the desired compounds (see p. 2425, col. 2, bottom).

This is the preferred procedure even though the products are not entirely pure. By hydrogenating the 1-alkenyl ethers it was found that those with a carbon chain length of ten and eleven atoms were less pure than the shorter chain compounds. For these longer chain 1-alkenyl ethers it was necessary to fractionate very carefully in order to obtain a compound of high purity. The shorter chain ethers absorbed the correct amount or almost the correct amount of hydrogen, and therefore, it was assumed that these were relatively pure. This was verified in some cases by assaying them by the method of Siggia.[16]

A study was made of the stability of the 1-alkenyl ethers. After seventy days at room temperature, it was found by assaying according to the method of Siggia,[16] that the 1-alkenyl ether content of 3-(1-decenyloxy)-1,2-propanediol was constant.

Experimental[17]

α-Bromo Dimethylacetals—All of the α-bromo dimethylacetals, except 2-bromo-1,1-dimethoxyhendecane, were prepared by a modification of the bromination technique used by Kuhn and Grundman.[18] The boiling points and refractive indices of these compounds correspond satisfactorily to those reported in the literature.[19,20] The method of Bedoukian[19] was employed for preparing 2-bromo-1,1-dimethoxyhendecane.

α-Bromo Cyclic Glycerol Acetals.—The method employed in preparing the α-bromo cyclic glycerol acetals was similar to the procedure used by Piantadosi, *et al.*,[21] in preparing cyclic glycerol acetals. They showed that the transacetalation reaction afforded a five-membered ring. By analogy, it is believed that the transacetalation reaction between an α-bromo dimethacetal and glycerol also affords the five-membered cyclic acetal. However, since this point was not believed to be crucial in arriving at the final product, no further investigation was made in this direction.

The preparation of 2-(1′-bromohexyl)-4-hydromethyl-1,3-dioxolane[22] is given as an example of the method used for the entire series of α-bromo cyclic glycerol acetals.

In a two-necked flask equipped with a stirrer and a distilling head to collect the methanol, were placed 57.6 g. of reagent grade glycerol, 74.8 g. of 2-bromo-1,1-dimethoxyheptane and approximately 75 mg. of sulfosalicyclic acid. The reaction mixture was heated gradually with vigorous stirring on an oil bath until the theoretical quantity of methanol was obtained. The temperature of the oil bath was kept at 130–140°. The reaction mixture was allowed to cool with stirring. The acidic catalyst was neutralized with 30 ml. of 5% potassium carbonate solution. The acetal was extracted with 200 ml. of ether, and the aqueous layer was washed several times with ether. The combined ether extracts were washed with 5% sodium carbonate and cold water and then dried over sodium carbonate. The ether was removed under reduced pressure, and the resulting oil upon distillation gave a 79% yield of a colorless liquid, b.p. 129–133° (0.95 mm.); n^{31}D 1.4798.

Anal. Calcd. for $C_{10}H_{19}BrO_3$: C, 44.95; H, 7.17; Br, 29.91. Found: C, 44.85; H, 7.24; Br, 30.18.

The compounds listed in Table I were prepared in an analogous manner.

It is probable that some decomposition occurred during the distillation of the longer chain α-bromo cyclic glycerol acetals as evidenced by the pink coloration of the distillate. This observation suggested that the source of impurity in formation of the unsaturated ethers could be due to this distillation step. With this in mind it was decided to initiate an experiment utilizing an undistilled long chain α-bromo cyclic acetal and note if any change resulted in the purity of the resulting 1-alkenyl ether. Consequently, when undistilled 2-(1′-bromodecyl)-4-hydroxymethyl-1,3-dioxolane was condensed with metallic sodium in the usual manner, the purity of the resulting unsaturated ether was not significantly improved. Fractionation of the reaction mixture afforded a small fraction of 96.8% purity as well as several less pure fractions (see Table II).

α-Bromo Cyclic Acetal of Trimethylene Glycerol.—The transacetalation reaction was employed to form the α-bromo cyclic acetal of trimethylene glycol. The procedure was identical to that used for glycerol. The synthesis of 2-(1′-bromohexyl)-1,3-dioxane resulted in a yield of 82% of a colorless liquid, b.p. 97–100° (1.05 mm.); $n^{24.5}$D 1.4750.

1-Alkenyl Ethers of Glycerol.—The preparation of 3-(1-heptenyloxy)-1,2-propanediol is presented as an example of the procedure for the entire series of 1-alkenyl ethers of glycerol.

In a three-necked flask equipped with a stirrer, reflux condenser, and inlet and outlet tubes for nitrogen, were placed 65.9 g. of 2-(1′-bromohexyl)-4-hydroxymethyl-1,3-dioxolane and 400 ml. of anhydrous ether. To this, under a nitrogen atmosphere, was slowly added 16.5 g. of metallic sodium cut in small pieces. The addition of sodium caused the ether to reflux and to form a cloudy solution. After all the sodium was added the solution was stirred at room temperature for 2.5 days and then refluxed for 5 hr. As the reaction proceeded, the solution turned green and then blue-green, with formation of a precipitate. The blue-

(16) S. Siggia and R. L. Edsberg, *Anal. Chem.*, **20**, 762 (1948).

(17) All microanalyses were performed by Spang Microanalytical Laboratory, Ann Arbor, Mich., and Dr. G. Weiler and Dr. F. B. Strauss, Microanalytical Laboratory, Oxford, England. Boiling points and melting points reported herein are uncorrected. Infrared spectra were determined with a Perkin-Elmer Infracord spectrophotometer Model 137B.

(18) R. Kuhn and C. Grundmann, *Chem. Ber.*, **70**, 1894 (1937).

(19) P. Z. Bedoukian, *J. Am. Chem. Soc.*, **79**, 889 (1957).

(20) A. Kirrman, *Ann. chim.* (Paris), **11**, 223 (1928).

(21) C. Piantadosi, C. E. Anderson, E. A. Brecht, and C. L. Yarbro, *J. Am. Chem. Soc.*, **80**, 6613 (1958).

(22) This compound may also be written as being derived from methanol. Accordingly, a correct name is 2-(1′-bromohexyl)-1,3-dioxolane-4-methanol.

TABLE II
1-ALKENYL ETHERS OF GLYCEROL

Compound	Molecular formula	B.p., °C. (mm.)	n^tD	Temp., °C.	Yield, %	Carbon, % Calcd.	Carbon, % Found	Hydrogen, % Calcd.	Hydrogen, % Found	M.p., °C., of 2,4-dinitrophenylhydrazone derivative[e]
3-(1-Butenyloxy)-1,2-propanediol	$C_7H_{14}O_3$	101–102 (0.45)	1.4691	22.0	57	57.49	56.96	9.67	9.54	123
3-(1-Pentenyloxy)-1,2-propanediol	$C_8H_{16}O_3$	97–100 (0.52)	1.4674	25.5	46	59.97	59.92	10.07	9.99	97
3-(1-Hexenyloxy)-1,2-propanediol	$C_9H_{18}O_3$	88–90 (0.08)	1.4674	22.5	40	62.03	61.80	10.41	10.47	103
3-(1-Octenyloxy)-1,2-propanediol	$C_{11}H_{22}O_3$	135–138 (1.00)	1.4670	27.0	51	65.30	65.19	10.96	11.15	95–96
3-(1-Nonenyloxy)-1,2-propanediol	$C_{12}H_{24}O_3$	122–123 (0.18)	1.4660	26.0	76	66.63	66.58	11.18	11.26	93–94
3-(1-Decenyloxy)-1,2-propanediol[a]	$C_{13}H_{26}O_3$	128–131 (0.21)	1.4648	23.5	68	67.78	67.94	11.38	11.28	104
3-(1-Hendecenyloxy)-1,2-propanediol[b]	$C_{14}H_{28}O_3$	156 (0.18)	1.4687	24.2	Not calcd.[d]	68.81	68.94	11.55	11.54	103
3-(1-Hendecenyloxy)-1,2-propanediol[c]	$C_{14}H_{28}O_3$	132 (0.11)	1.4672	23.6	Not calcd.[d]					

[a] This was assayed by the method of Siggia[16] and found to have a 1-alkenyl ether content of only 76.4%. It was carefully refractionated through a molecular still and yielded a colorless liquid at a glasscol temperature of 146° and a pressure of 0.07 mm.; n^{25}D 1.4672. This fraction had a 1-alkenyl ether content of 91.7% and gave the following analysis: C, 67.84; H, 11.42. [b] This was obtained from the reaction of the distilled cyclic acetal fraction. [c] This was obtained from the reaction of the undistilled cyclic acetal fraction. [d] This was carefully fractionated into many small fractions and no over-all yield was calculated. The constants given are for the purest fraction obtained. The 1-alkenyl ether content of the fraction with a b.p. of 156° at 0.18 mm. was 87.4% and that of the fraction with a b.p. of 132° at 0.11 mm. was 96.8%. [e] The melting point of the 2,4-dinitrophenylhydrazone derived from 3-(1-heptenyloxy)-1,2-propanediol was 104–105°.

TABLE III
SATURATED ETHERS OF GLYCEROL

Compound	Molecular formula	B.p., °C. (mm.)	n^tD	Temp., °C.	Carbon, % Calcd.	Carbon, % Found	Hydrogen, % Calcd.	Hydrogen, % Found
3-Butoxy-1,2-propanediol	$C_7H_{16}O_3$	67–69 (0.06)	1.4467	22.2	56.73	56.70	10.87	10.54
3-Pentyloxy-1,2-propanediol	$C_8H_{18}O_3$	106 (1.00)	1.4445	23.5	59.23	59.01	11.18	11.00
3-Hexyloxy-1,2-propanediol	$C_9H_{20}O_3$	97–98 (0.32)	1.4511	21.2	61.33	61.21	11.43	11.20
3-Heptyloxy-1,2-propanediol	$C_{10}H_{22}O_3$	97–98 (0.10)	1.4518	23.2	63.12	62.93	11.65	11.39
3-Nonyloxy-1,2-propanediol	$C_{12}H_{26}O_3$	145–148 (1.10)	1.4542	24.0	66.01	65.74	12.00	11.84
3-Decyloxy-1,2-propanediol	$C_{13}H_{28}O_3$	120 (0.10)	1.4550	26.0	67.19	67.01	12.15	12.00
3-Hendecyloxy-1,2-propanediol	$C_{14}H_{30}O_3$	164–167 (0.90)	1.4550	21.3	68.18	67.75	12.27	12.06

green solution was passed through a wire filter to remove the unchanged sodium. Water, just sufficient to dissolve the sodium bromide, was added. The aqueous layer was washed with ether, and the combined ether extracts were washed with a small quantity of water and dried over anhydrous potassium carbonate. The ether was removed, under reduced pressure, and the resulting oil, upon distillation, gave a 54% yield of a colorless liquid, b.p. 108–109° (0.5 mm.); $n^{30.5}$D 1.4648.

Anal. Calcd. for $C_{10}H_{20}O_3$: C, 63.79; H, 10.71. Found: C, 62.98; H, 10.45.

The compounds listed in Table II were prepared in an analogous manner.

The infrared spectra of all of the 1-alkenyl ethers of glycerol showed hydroxyl absorption at 2.9, methylene absorption at 3.4 and 6.84,[23] strong –O–C=CH– absorption at 6[24] in the form of a doublet, enol-ether absorption at 8.6.[25] and out-of-plane deformation vibrations of the hydrogens attached to the double bond at 10.7μ, indicating the compounds are of the *trans* configuration. Further studies are now being conducted in this laboratory on the configuration and its conversion to the naturally occurring form.[26,27]

The 1-alkenyl ether linkage is easily cleaved to the starting aldehyde by acid. Thus all of the unsaturated ethers gave corresponding 2,4-dinitrophenylhydrazones. The melting points found for these derivatives (Table II) agreed favorably with those in the literature.[28,29]

1-Alkenyl Ether of Trimethylene Glycol.—1-Alkenyl ether of trimethylene glycol was prepared in a manner analogous to that used in preparing the 1-alkenyl ethers of glycerol. Distillation of 3-(1-heptenyloxy)-1-propanol afforded a 63% yield of a colorless liquid; b.p. 106–108° (2.6 mm.); $n^{30.2}$D 1.4502.

Anal. Calcd. for $C_{10}H_{20}O_2$: C, 69.73; H, 11.70. Found: C, 69.43; H, 11.86.

Saturated Ethers of Glycerol.—The 1-alkenyl ethers of glycerol were hydrogenated to yield the corresponding saturated ethers. Proof of structure was established by comparing the physical constants of the saturated ether made in this manner with the physical constants of an identical saturated ether prepared differently. An indication of purity, relative to the proper degree of unsaturation, was established by the amount of hydrogen absorbed.

The hydrogenation of 3-(1-octenyloxy)-1,2-propanediol is given as a representative of the hydrogenation of all the unsaturated ethers.

Into a hydrogenation jar were placed 40 g. of 3-(1-octenyloxy)-1,2-propanediol, 150 ml. of absolute ethanol, and 1 g. of platinum oxide. After being shaken for 30 min. in the Paar low pressure hydrogenator, this mixture took up 15.5 p.s.i. of hydrogen. The calculated value of hydrogen uptake was 16.44 p.s.i. The

(23) G. Fox and J. Martin, *Proc. Roy. Soc.*, **162**, 419 (1937).
(24) H. Rosenkrantz and M. Gut, *Helv. Chim. Acta*, **36**, 1000 (1953).
(25) G. W. Stacy, J. W. Cleary, and M. J. Gortatowski, *J. Org. Chem.*, **22**, 765 (1957).
(26) H. R. Warner and W. E. M. Lands, *J. Am. Chem. Soc.*, **85**, 60 (1963).
(27) W. T. Norton, E. L. Gottfried, and M. M. Rapport, *J. Lipid Res.*, **3**, 456 (1962).
(28) C. D. Hodgman, "Tables for Identification of Organic Compounds," Chemical Rubber Publishing Co., Cleveland, Ohio, 1960, pp. 68–74.
(29) C. F. H. Allen, *J. Am. Chem. Soc.*, **52**, 2955 (1930).

catalyst was filtered and the alcohol removed by distillation. Upon vacuum distillation, 33 g. of a colorless liquid, b.p. 135–136° (0.85 mm.), $n^{25}D$ 1.4503, was collected.

Anal. Calcd. for $C_{11}H_{24}O_3$: C, 64.66; H, 11.84. Found: C, 64.29; H, 11.88.

The constants for the other saturated ethers are listed in Table III.

The infrared spectra of all of the saturated ethers of glycerol were similar to the spectra of the 1-alkenyl ethers except for the absence of the absorption bands at 6, 8.6, and 10.7 μ, which is in agreement with the saturated structure.

The saturated ethers of glycerol gave a positive periodic acid test substantiating the α-position of the 1-alkenyl ether linkage on the glycerol moiety.

The saturated ether, 3-octyloxy-1,2-propanediol, was alternatively synthesized by refluxing the sodium salt of isopropylidene glycerol with octyl bromide to form the octyl ether. The ketal linkage was cleaved by acid hydrolysis, and the product was distilled to yield a colorless liquid, boiling at 130° (0.65 mm.); $n^{28}D$ 1.4490. The boiling points and refractive indexes of the two saturated ethers indicate that the compounds are identical and, therefore, substantiate the proposed structure of the 1-alkenyl ether.

Saturated Ether of Trimethylene Glycol.—A hydrogenation, similar to that previously mentioned, was carried out on 3-(1-heptenyloxy)-1-propanol to yield 3-heptyloxy-1-propanol. The product was a colorless liquid recovered by distillation, b.p. 75–75.5° (0.08 mm.); $n^{24.5}D$ 1.4385.

Anal. Calcd. for $C_{10}H_{22}O_2$: C, 68.86; H, 12.72. Found: C, 69.42; H, 12.01.

Derivatives of Dicyanamide[1]

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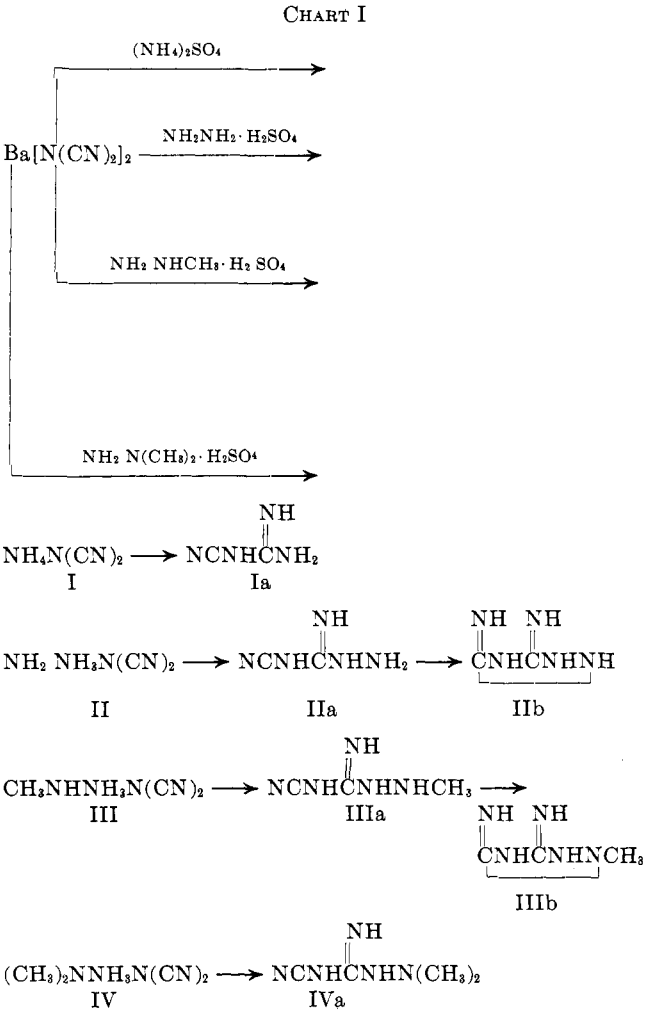
The reaction of barium dicyanamide with the sulfate salts of ammonia, hydrazine, N-methylhydrazine, and N,N-dimethylhydrazine was investigated. Infrared spectroscopy was used to establish whether the reaction products were the salts of dicyanamide or the rearranged products. The preparation and characterization of ammonium and hydrazine dicyanamide is reported. The latter compound was found to be thermally unstable, and its rate of decomposition was determined.

In our study of N-cyano compounds, it was of interest to prepare and characterize the ammonium and hydrazine salts of dicyanamide, $HN(CN)_2$. American Cyanamide Company has prepared[2] a variety of aliphatic amine salts of dicyanamide by treating calcium dicyanamide with the amine sulfate; some aliphatic amine salts of dicyanamide rearrange spontaneously to substituted dicyanamides at room temperature, while others are quite stable and frequently require the application of considerable amount of heat in order to effect this rearrangement.

The reaction of barium dicyanamide with the sulfate salts, of ammonia, hydrazine, N-methylhydrazine, and N,N-dimethylhydrazine was investigated in this laboratory to determine whether the reaction products were the salts of dicyanamide or the rearranged materials as shown in Chart I. It was expected that the initial products of these reactions would be ammonium dicyanamide (I), hydrazine dicyanamide (II), N-methylhydrazine dicyanamide (III), and N,N-dimethylhydrazine dicyanamide (IV). These salts might be stable or might rearrange to N-cyanoguanidine (Ia), N-cyano-N′-aminoguanidine (IIa), N-cyano-N′-methylaminoguanidine (IIIa), and N-cyano-N′-dimethylaminoguanidine (IVa), respectively. Compounds IIa and IIIa could rearrange further by cyclizing to give guanazole (IIb) and methylguanazole (IIIb). Since the salts and the rearrangements products are isomeric and would have the same empirical formula and similar physical properties, it would be necessary to find a method to distinguish unequivocally between them. Infrared spectroscopy, *via* the potassium bromide pellet technique, seemed to offer the best method for the identification of the products. The salts I–IV should exhibit the strong absorption of C≡N; the rearranged cyanoguanidines Ia–IVa would have the characteristic absorption of both C≡N and C=N; while the cyclic compounds IIb and IIIb would have only the C=N vibration.

CHART I



(1) Presented before the Division of Organic Chemistry at the 145th National Meeting of the American Chemical Society, New York, N. Y., September, 1963.

(2) "Cyanamide New Product Bulletin," Coll. Vol. II, December, 1950.