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Reaction of Inorganic Cyanates with Halides. II. Reactions of Chlorohydrins

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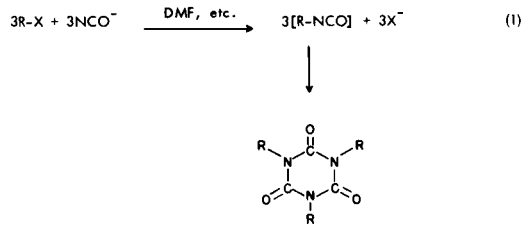
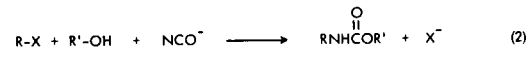
The reaction of ethylene and trimethylene chlorohydrins with cyanate ion in anhydrous dimethylformamide (DMF) forms 2-oxazolidinone and tetrahydro-2*H*-1,3-oxazin-2-one, respectively. These are the major products over a wide concentration range, and at initial chlorohydrin concentration of 1 *M* and lower, the yields are high enough to make the reaction useful for synthesis of oxazine and oxazolidine derivatives. The corresponding reaction with tetramethylene chlorohydrin gave tetrahydrofuran as the major product with the by-products being polymeric. Pentamethylene and hexamethylene chlorohydrins yield linear polyurethanes when allowed to react with cyanate in DMF. Examination of the relative rates of reaction of these chlorohydrins indicate that the mechanism by which urethanes are formed (both cyclic and polymeric) is an S_N2 displacement of chloride by cyanate ion to give an isocyanate intermediate which then reacts with an alcohol group to form urethane.

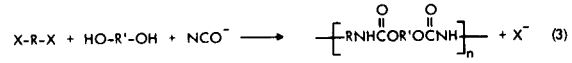
The synthesis of isocyanates and their derivatives via displacement of organic halide by cyanate has been reported (1,2). The reaction is facilitated by dipolar aprotic solvents such as dimethylsulfoxide (DMSO), dimethylformamide (DMF), *N*-methylpyrolidone (NMP), or acetonitrile. The principal isolated products are isocyanurates which arise from the trimerization of the intermediate isocyanate (eq. 1). When the displacement takes place in the



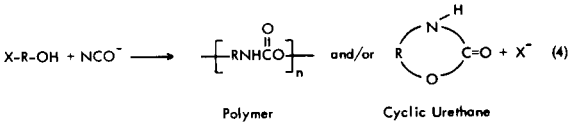
presence of alcohol, the intermediate isocyanate is trapped, and urethanes are the isolated products (3,4) (eq. 2).



Our interest in this reaction was to use polyfunctional halides and alcohols to prepare linear polyurethanes. Two general methods are possible for the production of linear polyurethanes from a halide, alcohol, and cyanate ion using the displacement reaction. The first involves reaction of a dihalide with cyanate ion in the presence of a diol (5) as shown in eq. 3. Here the stoichiometry of the dihalide and diol must be exact in order to



obtain polymers of high molecular weight. The second method circumvents this problem by the use of a halohydrin wherein both kinds of reactant groups are on the same molecule (eq. 4). Here the stoichio-

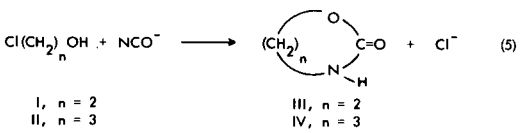


metry is fixed and necessarily in a 1:1 ratio. However, this synthesis has another disadvantage. If R is a short aliphatic radical, an internal cyclization can take place to give cyclic urethanes. In this case conditions which suppress cyclization would be necessary in order to obtain polymeric materials. Our investigation is concerned with this latter method of producing polyurethanes.

The reaction of chlorohydrins with cyanate in dipolar aprotic media was superficially studied by the Japanese (6). Since some of our results differ

significantly from their report, we would like to present our findings together with some additional observations.

As reported by Fukui and Kitano (6) ethylene chlorohydrin (I) and trimethylene chlorohydrin (II) form 2-oxazolidinone (III) and tetrahydro-2*H*-1,3-oxazin-2-one (IV), respectively, when allowed to react with cyanate ion in DMF (eq. 5). We find



(5)

I, n = 2
II, n = 3

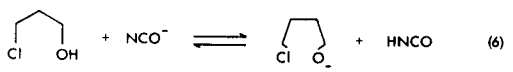
III, n = 2
IV, n = 3

that these are the major products at virtually all chlorohydrin concentrations, as shown by Table I. Even at high concentrations, less than half of the chlorohydrin is converted to polymer. Obviously, the hydroxyl on a reacting ethylene or trimethylene chlorohydrin molecule is much too available for reaction with the isocyanate group generated at the opposite end, and efficient intermolecular polymerization is inhibited.

It is interesting to note that, in general, the yields of the six-membered heterocycle are somewhat higher than the yields of the corresponding five-membered ring. This is opposite from what one would predict from the fact that ring closure to five-membered rings is usually more facile than ring closure to six-membered rings (7).

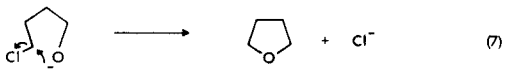
The high yields of cyclics obtained at low concentrations of chlorohydrin make this reaction a useful synthetic method for obtaining oxazolidine and oxazine derivatives. The only by-products formed are polymeric oils (containing both urethane and isocyanurate groups) which are easily separated from the cyclic products.

Contrary to the report of the Japanese workers (6) we find that a polyurethane is not the main product from the reaction of tetramethylene chlorohydrin (V) with cyanate in DMF. Most of the tetramethylene chlorohydrin undergoes cyclization to form tetrahydrofuran (THF). Quantitative gas chromatographic analysis indicates the yield of THF is at least 56%, as this amount remained in the reaction mixture after 24 hours. Some of this product could have been lost due to its high volatility. The most probable path for formation of the cyclic ether would involve an alkoxide intermediate. The weakly basic cyanate ion (K_b in water, 5×10^{-11}) can assist in forming such a species (eq. 6). The resulting



(6)

alkoxide anion would then give an intramolecular displacement of chloride to form THF (eq. 7).

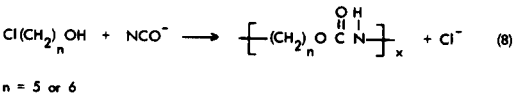


(7)

The other products isolated contain urea groups (by infrared) which suggests that isocyanic acid is reacting with any isocyanate formed to give urea-like compounds.

Pentamethylene chlorohydrin (VI) reacts with cyanate in DMF to yield a polyurethane which is isolated in 63% yield. Half of the product is a white solid (softening point 82°), and the remainder a viscous yellow oil. The infrared spectra of the oil and the solid are identical and indicate that the two products are polymers of different molecular weight. As one would anticipate, 17% of the chlorohydrin undergoes cyclization to form tetrahydropyran (THP). The yield of cyclic ether is much smaller than the corresponding yield of THF from tetramethylene chlorohydrin. This is in agreement with the general observation that five-membered rings form more readily than six-membered rings.

The corresponding reaction with hexamethylene chlorohydrin (VII) also yields a linear polyurethane which is isolated from water in 84% yield. The



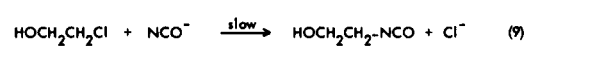
(8)

n = 5 or 6

product is a white solid (softening point 135°) which is insoluble in common solvents. Its solubility in DMF is limited to about 14.3 g./100 ml. Very little (if any) isocyanurate is formed in the polymerization of pentamethylene and hexamethylene chlorohydrins.

Although cyclic ethers (THF and THP) are formed in the reaction of cyanate ion with chlorohydrins V and VI, they are unlikely intermediates to urethane products owing to their marked stability toward nucleophiles. Due to the extreme difficulty with which four-membered rings are formed (7), oxetane (trimethylene oxide) is an improbable intermediate in the trimethylene chlorohydrin reaction. In the case of ethylene chlorohydrin, however, the possibility of ethylene oxide as an intermediate cannot be ignored. Thus, two different mechanisms must be considered for the reaction of ethylene chlorohydrin with cyanate. The first, illustrated by Scheme I, involves direct S_N2 displacement of chloride by cyanate ion as the rate determining step.

SCHEME I



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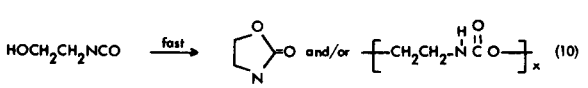
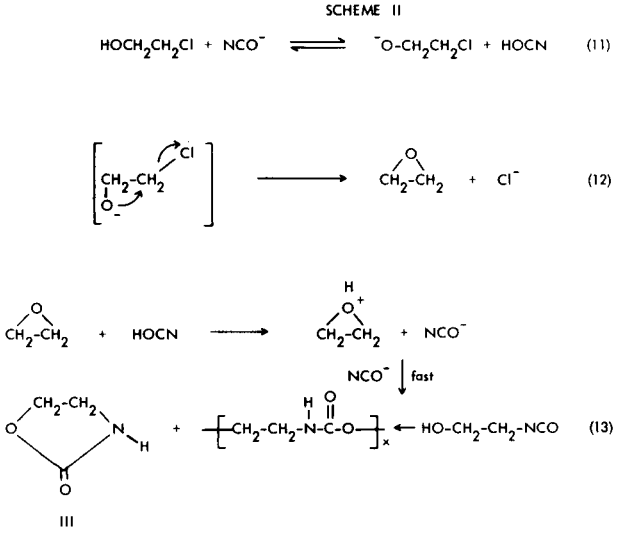


(10)

The second mechanism (Scheme II) parallels the mechanism proposed for the reaction of ethylene chlorohydrin with base to form ethylene oxide (8). The essential feature of this case is an internal S_N2 displacement of chloride by alkoxide ion.

SCHEME II



A choice between mechanisms can be made on the basis of the relative rates of reaction of the chlorohydrins with cyanate ion in DMF. If mechanism I is operating, the relative rates of reaction for all chlorohydrins should be similar since all are the same about the $-CH_2Cl$ part of the molecule. If mechanism II is correct, chlorohydrin I should react significantly faster than chlorohydrin II due to the greater ease of formation of the epoxide intermediate.

For example, the ease of ring closure of ω-bromoamines has been found to depend on the number of atoms in the resulting ring. The relative rates for these reactions are shown in Table II. Other ring closure investigations indicate, at least quantitatively, that a four-membered ring is formed with the most difficulty, if at all. The sequence which has been established for the ease of ring closure in small common rings as a function of the number of atoms in the ring is three-membered >four-membered <five-membered >six-membered >seven-membered (7).

With this in mind, the relative rates of reaction of the chlorohydrins with cyanate in DMF were determined. For this purpose, the rate of reaction of trimethylene chlorohydrin was adopted as a basis for comparison and the reaction rates of the other chlorohydrins were determined relative to this standard.

Equimolar solutions of trimethylene chlorohydrin and one of the other chlorohydrins were allowed to react with excess cyanate in DMF at 100°C. The disappearance of each chlorohydrin with time was followed by gas chromatography. The reaction outlined by Scheme I is known to follow pseudo first-order kinetics (4), since the concentration of cyanate ion in DMF is constant due to the low solubility of potassium cyanate. The kinetic expression for Scheme II indicates that this process would also be first order in chlorohydrin. From a plot of log (c_0/c) vs. time for trimethylene chlorohydrin and the other chlorohydrin in the reaction, the relative rate constants for their reaction can be determined directly by comparing the slopes of the resulting lines.

In a typical relative rate run, a solution of ethylene- and trimethylene chlorohydrins (each 0.5 *M*) in DMF was allowed to react. In this case the disappearance of chlorohydrins and the appearance of cyclic urethanes (III and IV) was followed by gas chromatography. Since the amount of DMF in the reaction mixture is constant, it was used as an internal standard for determining the true area percents for the chlorohydrins and the percent yields of the cyclic urethanes. The data obtained are shown in Table III. The corrected v.p.c. area for each chlorohydrin was assumed to be proportional to its concentration, and a plot of log Ao/A (where Ao is the initial area % chlorohydrin and A is the area % of chlorohydrin at time, t) vs. time was made (Figure 1). The ratio of the slopes of the lines indicated that the rate constant for ethylene chlorohydrin is 1.7 times that of trimethylene chlorohydrin.

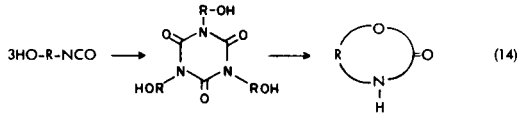
A plot of percent yield of the two cyclic urethane products vs. time is shown in Figure 2. It is interesting to note that the ethylene chlorohydrin is reacting faster but its corresponding cyclization product (III) appears more slowly.

The relative rates of reaction for the other chlorohydrins were determined in a similar manner and are shown in Table IV. The greatest difference in rate for all five chlorohydrins is less than a factor of ten.

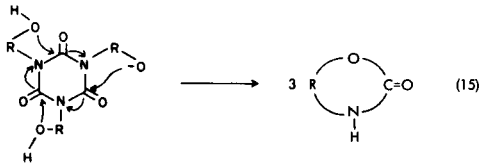
Since the rate differences are small, we do not feel that the reaction of ethylene chlorohydrin with cyanate involves ethylene oxide as an intermediate. Similarly, these data confirm our assumption (*vide supra*) that cyclic ethers are not reactive intermediates in the reaction of chlorohydrins II, V, VI, and VII.

In view of the relatively high yield of THF produced from chlorohydrin V, its enhanced reactivity reflects on the ease with which five-membered rings are formed. We conclude that Scheme I, involving direct S_N2 attack by cyanate ion, represents the route by which urethanes are formed from chlorohydrins. Similarly, the polymeric products from tetramethylene chlorohydrin can be accounted for by a direct displacement of chloride by cyanate occurring simultaneously with the cyclization to THF.

A possible product forming step not considered in Scheme I is the formation of isocyanurates, followed by a rearrangement to the corresponding cyclic urethane (eq. 14). Our data suggest that



isocyanurates are not important intermediates in the product forming reaction. The proposed mechanism of rearrangement for hydroxylalkyl isocyanurates involves a concerted internal attack on carbonyl by alkoxide (9). This process would be expected to occur only when R is ethylene or trimethylene, which lead to a transition state containing five- and six-membered rings. If isocyanurates were formed



from penta- or hexamethylene chlorohydrins, rearrangement would not occur and isocyanurates would be the products. Very little isocyanurate can be detected in the product from reaction of chlorohydrins VI or VII.

Isocyanurate could be an intermediate in the reaction of ethylene and trimethylene chlorohydrins with cyanate, but it is not probable in view of the fact that yields of cyclic urethanes are highest under conditions which are most unfavorable for trimerization (high dilution). The fact that isocyanurate is a by-product with ethylene and trimethylene chlorohydrins, but not with the others (at comparable concentrations), defies explanation at this time.

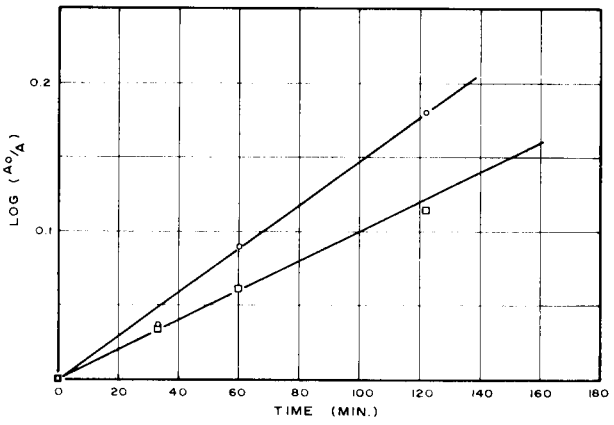


Fig. 1. Plot of Log (Ao/A) vs. Time for Reaction of Ethylene - Trimethylene Chlorohydrin Mixture.
○ = Ethylene Chlorohydrin
□ = Trimethylene Chlorohydrin

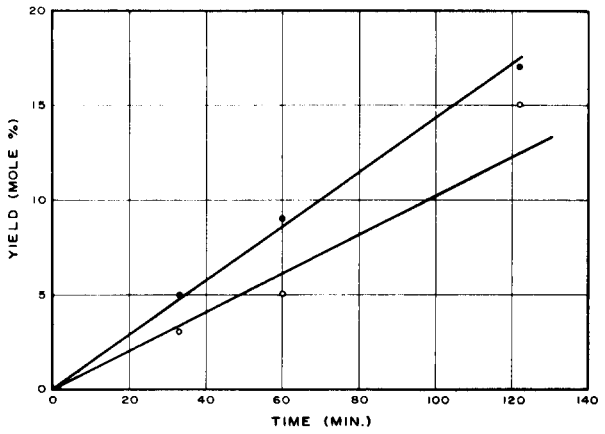


Fig. 2. Yields of Cyclic Products vs. Time for Reaction of Ethylene - Trimethylene Chlorohydrin Mixture.
○ = 2-Oxazolidinone
● = Tetrahydro-1,3-oxazine-2-one

TABLE I

Effect of Concentration on Cyclization

Chlorohydrin	Initial Conc. moles/l. in DMF	% Yield Cyclic Urethane (a)
Ethylene	0.1	94.0 (b)
Ethylene	1.0	78.2 (c)
Ethylene	5.0	58.8 (b)
Trimethylene	0.1	93.8 (d)
Trimethylene	1.0	89.1 (b)
Trimethylene	5.0	82.6 (d)

(a) Based on chlorohydrin. (b) Yield obtained by v.p.c. analysis of crude material remaining after removing DMF under vacuum. (c) Isolated cyclic urethane plus cyclic trapped in polymer as determined by G.C. (d) Analysis of total reaction mixture by v.p.c.

TABLE II (7)

Relative Rates for the Reaction

Atoms in Ring	3	4	5	6
Relative Rate	71	1.0	60,000	1,000

TABLE III

Data for Reaction of Ethylene-Trimethylene Chlorohydrin Mixture

Time	Ethylene Chlorohydrin			Mole % Yield	Trimethylene Chlorohydrin			Mole % Yield
(min.)	Area	Ao/A	Log (Ao/A)	III	Area	Ao/A	Log (Ao/A)	IV
0	4.00	1.000	0.000	0	4.20	1.000	0.000	0.0
33	3.68	1.087	0.036	3	3.88	1.082	0.034	5
60	3.26	1.227	0.089	5	3.65	1.151	0.061	9
122	2.64	1.515	0.180	15	3.22	1.304	0.115	17

TABLE IV

Relative Rates of Reaction of Chlorohydrins With Cyanate Ion in DMF

Chlorohydrin	Relative Rate of Reaction
Ethylene	1.7
Trimethylene	1.0
Tetramethylene	5.1
Pentamethylene	0.8
Hexamethylene	0.7

EXPERIMENTAL

Melting points were taken on a Fisher-Johns hot stage melting point apparatus and are uncorrected. Infrared spectra were obtained on a Perkin-Elmer model 21 spectrometer using potassium bromide discs for solids. Gas chromatographic analyses were run on an F and M model 720 gas chromatograph with injection block temperature of 350°, detector temperature 370°, and helium flow rate of 100 ml./min. being standard for all analyses.

Materials.

DMF (Matheson, Coleman and Bell, b.p. 152-154°) was purified by first stirring overnight with calcium hydride in a closed flask. The hydrogen evolved was vented through a mineral oil bubbler. The DMF was decanted to a clean flask and a small amount of fresh calcium hydride was added, followed by distillation at 45 mm. Hg. through an 18 in. vigreaux column. A heart cut was taken for use in all runs.

2-Chloroethanol and 3-chloro-1-propanol (Eastman white label grade) were analyzed by gas chromatography and used as received.

4-Chloro-1-butanol (Eastman, pract.) was distilled through an 18 in. spinning band column. The fraction boiling 90-93° at 27 mm. Hg. was used for all runs.

Pentamethylene chlorohydrin obtained from Columbia Organics was distilled through an 18 in. Vigreaux column and the fraction boiling 92-95° at 8 mm. Hg. was used.

Hexamethylene chlorohydrin (Columbia Organics) was distilled through a Vigreaux column and the fraction boiling 100-103° at 8 mm. Hg. was used.

Potassium cyanate (J. T. Baker) was dried overnight in a vacuum oven at 60° and stored in a desiccator prior to use.

The apparatus used for all runs was a three-necked reaction flask fitted with a mechanical stirrer, a reflux condenser with a bubbler to maintain a constant head of nitrogen in the flask, and a thermometer with thermowatch. The nitrogen was allowed to sweep through the apparatus for a few minutes before adding reactants, and a nitrogen atmosphere maintained in the reaction flask during reaction.

2-Oxazolidinone (III) from Ethylene Chlorohydrin (I).

In a typical run 40.3 g. (0.5 mole) 2-chloroethanol was brought to mark at 500 ml. with DMF. This solution was allowed to react with 48.6 g. (0.6 mole) of potassium cyanate for 24 hours at 100°. The cooled reaction mixture was filtered, and the DMF distilled from the filtrate at high vacuum leaving a yellow oil (42.8 g.). The oil was dissolved in acetone and decanted from the insoluble fraction (~ 1 g.); an additional 0.7 g. separated upon warming on the steam bath. Cooling the acetone solution to -10° and seeding with an authentic sample of III yielded 13.0 g. of III, m.p. 87-88° (literature (10) m.p. 88-90°). The IR spectrum matches the published spectrum for 2-oxazolidinone (11). Concentration of the mother liquor yielded an additional 6.4 g. of III. The soluble material obtained by evaporating the acetone was a yellow oil (22 g.) which was characterized by IR as a mixture of urethane and isocyanurate. The oil was analyzed by gas chromatography on a 2 ft. x 1/4 in. column packed with 5% Versamid 900 on Diatoport W, programmed from 100° to 300° at 10°/min. using DMF as an internal standard. This procedure indicated that the oil contained 14 g. of III which was not separated during crystallization; overall yield of III, 76.7%. The analysis was the same when the oil was injected "on column," which indicates that none of the isocyanurate present was rearranging in the vaporization block to give 2-oxazolidinone.

Tetrahydro-2*H*-1,3-oxazin-2-one (IV) from Trimethylene Chlorohydrin (II).

Forty-seven and three-tenths g. (0.5 mole) 3-chloro-1-propanol and 48.6 g. (0.6 mole) of potassium cyanate were allowed to react as in the preceding example. After filtering, the DMF was stripped off to yield 53.4 g. of a viscous yellow oil. The oil was analyzed by gas chromatography (same conditions as for III) using an internal standard and was found to contain 45 g. of IV (89% yield). Pure IV (40 g.), m.p. 82-83° was isolated from the oil by successive crystallizations from cold (-10°) acetone. The reported melting point for IV is 82-83° (12).

The soluble fraction obtained by removal of the acetone from the last filtrate was a yellow oil (10 g.). Quantitative analysis of this oil by gas chromatography indicated the oil was 45% IV. Again, the same analysis was obtained when the oil was injected "on column."

Reaction of Tetramethylene Chlorohydrin (V) with Cyanate in DMF.

Five and forty-five one hundredths g. (0.05 mole) of 4-chloro-1-butanol was brought to mark at 50.0 ml. with 42.07 g. of DMF. This

solution was allowed to react with 4.86 g. (0.06 mole) of potassium cyanate at 100° for 24 hours. Samples of the reaction solution were taken initially and at 24 hours and were analyzed for tetrahydrofuran by gas chromatography (2 ft. x ¼ in. column packed with 10% 1,2,3-triscyanoethoxypropane on Chromosorb W, temperature programmed 30° to 180° at 10°/min.) using the DMF as an internal standard. This indicated 2.04 g. (56.4% yield) of THF was formed during the reaction. The cooled reaction mixture was filtered, and the insoluble materials stirred with water to yield 1.25 g. of a white solid. The DMF was distilled from the filtrate to yield a pasty residue which yielded a soluble oil (1.36 g.) and an insoluble solid (0.07 g.) when treated with acetone. All isolated products were polymeric, and their IR spectra indicated that urethane, alcohol, isocyanurate, and possibly some urea groups were present.

Polyurethane from Pentamethylene Chlorohydrin (VII).

Thirty and six-tenths g. (0.25 mole) of pentamethylene chlorohydrin was brought to mark at 250.0 ml. with DMF. This solution was allowed to react with 24.3 g. (0.3 mole) of potassium cyanate for 24 hours at 100°. Gas chromatographic analysis (2 ft. x ¼ in. column packed with Carbowax 20M on Diatoport S, temperature programmed from 30° to 250° at 10°/min.) of samples taken before and after reaction indicated that ~17% of the pentamethylene chlorohydrin formed tetrahydropyran. The cooled reaction mixture was filtered, and the DMF distilled from the filtrate to yield a tacky solid. Stirring this solid with acetone at room temperature gave 6.0 g. of an insoluble white solid. Cooling the acetone filtrate gave an additional 5.1 g. of solid, softening point 82°. The acetone soluble fraction (11.7 g.) was a yellow oil. The IR spectra of all the products were nearly identical having absorption maxima at 3320 cm^{-1} (N-H), 1695 cm^{-1} (C=O), 1540 cm^{-1} (C-N-H), 1255 cm^{-1} (C-O), 1067 cm^{-1} (C-O), 733 cm^{-1} $(-(CH_2)_4-)$. There was only a slight absorption at 760 cm^{-1} (isocyanurate). This spectrum is consistent with a linear polyurethane structure.

Polyurethane from Hexamethylene Chlorohydrin (VII).

Sixty-eight and twenty-five one hundredths g. (0.5 mole) of 6-chloro-1-hexanol was brought to mark at 500 ml. with DMF. This solution was allowed to react with 48.6 g. (0.6 mole) of potassium cyanate at 100° for 20 hours.

The precipitated materials were removed from the cooled reaction mixture by filtration and stirred with water to remove inorganic material. The water insoluble fraction was separated and dried to yield 30.3 g. of a white solid, softening point 135-137°.

The DMF soluble materials were precipitated from the filtrate by addition of water. The crude white solid was separated and washed with water to yield 31.9 g. of a white powder (softening point 80-83°) when dried. The combined products represent a yield of 88.4% based on chlorohydrin converted.

The IR spectra of both fractions indicate a linear polyurethane containing very little isocyanurate. Absorption maxima were observed at 3310 cm^{-1} (N-H), 1693 cm^{-1} (C=O), 1544 cm^{-1} (C-N-H), 1256 cm^{-1} (C-O), 1058 cm^{-1} (C-O), and 730 cm^{-1} $(-(CH_2)_4-)$. There was only a slight absorption at 760 cm^{-1} (isocyanurate).

Gas chromatographic analysis (same conditions as for previous example) of samples taken before and after reaction indicated that the conversion of chlorohydrin was 93%.

Relative Rates of Reaction, Ethylene (I) and Trimethylene (II) Chlorohydrins.

A mixture of 2.37 g. (0.025 mole) 3-chloro-1-propanol and 2.01 g. (0.025 mole) of 2-chloroethanol was brought to mark at 50.0 ml. with DMF. This solution was allowed to react with 4.86 g. (0.060 mole) of potassium cyanate at 100°. Samples of the reaction were taken as noted in Table III and analyzed by gas chromatography for both chlorohydrins (Carbowax 20M column) and cyclic urethanes (Versamid 900 column) using the DMF as an internal standard to determine the true chlorohydrin areas shown in Table III. The amounts of cyclic urethanes present were determined by comparison with standard solutions of the cyclics in DMF. The ratio of the slopes of the lines in Figure 1 indicate k_I/k_{II} is 1.7.

Relative Rates of Reaction, Trimethylene (II) and Tetramethylene (V) Chlorohydrins.

A mixture of 2.47 g. (0.0228 mole) of 4-chloro-1-butanol and 2.37 g. (0.025 mole) of 3-chloro-1-propanol was brought to mark at 50.0 ml. with DMF. This solution was allowed to react at 100° with 4.86 g. (0.060 mole) of potassium cyanate with samples of the reaction taken initially and periodically as noted below. The samples were analyzed by v.p.c. (carbowax 20M column) using the DMF as an internal standard to determine the true area of each chlorohydrin. A plot of log (Ao/A) vs. time indicates that k_V/k_{II} is 5.1

Time at Temp. (min.)	Trimethylene Chlorohydrin Area	Ao/A	Log (Ao/A)	Tetramethylene Chlorohydrin Area	Ao/A	Log (Ao/A)
0	4.50	1.000	0.000	4.30	1.000	0.000
30	3.84	1.172	0.069	2.17	1.982	0.297
65	3.26	1.380	0.140	1.01	4.257	0.629

Relative Rates of Reaction, Trimethylene (II) and Pentamethylene (VI) Chlorohydrins.

A mixture of 2.36 g. (0.025 mole) of 3-chloro-1-propanol and 3.06 g. (0.025 mole) of pentamethylene chlorohydrin was brought to mark at 50.0 ml. with DMF. This solution was allowed to react at 100° with 4.86 g. (0.060 mole) of potassium cyanate with samples of the reaction taken initially and at times noted below. The samples were analyzed by v.p.c. (Carbowax 20M column) using the DMF as an internal standard to determine the true area of each chlorohydrin. A plot of log Ao/A vs. time indicates that the relative rate of reaction k_{VI}/k_{II} is 0.8.

Time at Temp. (min.)	Trimethylene Chlorohydrin Area	Ao/A	Log (Ao/A)	Pentamethylene Chlorohydrin Area	Ao/A	Log (Ao/A)
0	4.10	1.000	0.000	4.80	1.000	0.000
30	3.77	1.088	0.037	4.66	1.030	0.013
60	3.45	1.188	0.075	4.34	1.106	0.044
180	2.61	1.571	0.196	3.29	1.459	0.164

Relative Rates of Reaction, Trimethylene (II) and Hexamethylene (VII) Chlorohydrins.

A mixture of 3.41 g. (0.025 mole) of hexamethylene chlorohydrin and 2.36 g. (0.025 mole) of 3-chloro-1-propanol was brought to mark at 50.0 ml. with DMF. The mixture was allowed to react with 4.86 g. (0.060 mole) of potassium cyanate at 100° and samples were taken initially and at various times during the reaction. Analysis of the samples was done by v.p.c. (Carbowax 20M column) using the DMF as an internal standard to determine the true areas of the chlorohydrins. A plot of log Ao/A vs. time for each chlorohydrin indicated the relative rate of reaction, k_{VII}/k_{II} is 0.7.

Time at Temp. (min.)	Trimethylene Chlorohydrin Area	Ao/A	Log (Ao/A)	Hexamethylene Chlorohydrin Area	Ao/A	Log (Ao/A)
0	4.30	1.000	0.000	6.00	1.000	0.000
30	3.54	1.215	0.085	5.32	1.128	0.052
60	3.54	1.215	0.085	5.12	1.172	0.069
120	3.02	1.424	0.154	4.88	1.230	0.090
180	1.31	3.282	0.516	2.33	2.575	0.411

Acknowledgment.

The authors wish to thank Mr. Axel Lubeck for carrying out the gas chromatographic analyses.

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Received December 16, 1965 Littleton, Colorado 80121