XLI.—*Some Derivatives of the Aliphatic Glycols.*

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THE halohydrins of the glycols and their acyl derivatives and ethers of the types $AcO\cdot[CH_2]_n\cdot X$, $RO\cdot[CH_2]_n\cdot X$, and $ArO\cdot[CH_2]_n\cdot X$ (where X is a halogen atom) are important synthetic reagents. In the course of the preparation of γ-, δ-, and ε-substituted chloro-sulphides we have made use of several new compounds of this class, the preparation and properties of which we now describe.

The chlorohydrins of ethylene and trimethylene glycols are most conveniently prepared by the action of sulphur monochloride on the glycol as originally recommended for the former by Carius

(*Annalen*, 1862, **124**, 257). We have extended this reaction to tetra- and penta-methylene glycols and have obtained their chlorohydrins, but only in poor yields and in an impure state, as they decompose when redistilled under diminished pressure with liberation of hydrogen chloride and presumably of the corresponding polymethylene oxide. The *α-naphthylurethanes* of *δ-chlorobutyl* and *ε-chloroamyl alcohols* were, however, isolated.

The only substances of the type $AcO\cdot[CH_2]_n\cdot X$, where $n = 4$ or 5, hitherto known were the δ-bromobutyl and ε-bromoamyl benzoates (von Braun, *Ber.*, 1913, **46**, 1782). The conversion of trimethylene glycol into γ-chloropropyl acetate by means of acetyl chloride at 100° was recently described by Bogert and Slocum (*J. Amer. Chem. Soc.*, 1924, **46**, 763). By applying this reaction to the two higher glycols we have obtained *δ-chlorobutyl* and *ε-chloroamyl acetates* in quantity. These substances have proved suitable for the syntheses we had in view and by their means we have isolated *phenyl* and *ethyl δ-hydroxybutyl sulphides* and *phenyl* and *methyl ε-hydroxyamyl sulphides*. The chloro-sulphides derived from these hydroxysulphides are under investigation and will be described in a subsequent communication.

For certain purposes the ethers of the halohydrins are of particular value: for example, phenyl β-bromoethyl ether (Bentley, Haworth, and Perkin, J., 1896, **69**, 169; Mills and Bains, J., 1925, **127**, 2503), benzyl chloroethyl ether, and methyl iodoethyl ether (Bennett, J., 1925, **127**, 1277). A convenient method of preparation of methyl β-chloroethyl ether, which we now record, is therefore of interest. On the other hand, we have been unable to confirm the experiments of Foran (*J. Soc. Chem. Ind.*, 1925, **44**, 173) on the preparation of bromodiethyl ether.

Several ethers of this general type, derived from the higher glycols, are known, the most accessible and useful being phenyl δ-bromobutyl ether (von Braun, *loc. cit.*) and benzyl γ-chloropropyl and δ-chlorobutyl ethers (J., 1927, 472).

We have taken the opportunity of completing the series of bisphenylurethanes and bis-α-naphthylurethanes of the glycols up to pentamethylene glycol and of the α-naphthylurethanes of the corresponding chlorohydrins (compare Bickel and French, *J. Amer. Chem. Soc.*, 1926, **48**, 747). The melting points are tabulated below:

Glycol.	Ethylene.	Trimethylene.	Tetramethylene.	Pentamethylene.
Bisnaphthylurethane	176°	164°	198°	147°
Bisphenylurethane ...	157·5	137·5	180	174
Naphthylurethane of chlorohydrin	101	76	66	72

It may be noted that an alternation of higher and lower melting points occurs in the bisurethanes in which the lengthening chain is terminated by large polar groups, whereas the melting points fall with little or no alternation if the large highly polar group is at one end only. This appears to be a general phenomenon : *e.g.*, the dibenzoates of the glycols show an alternation of melting point, whereas the *p*-nitrobenzoates or the *p*-nitrobenzyl phthalates (Reid, *J. Amer. Chem. Soc.*, 1917, **39**, 1249) of the simple alcohols show a continuous fall of melting point.

Experimental.

Methyl β-Chloroethyl Ether.—Glycol monomethyl ether (57 g.), dissolved in dimethylaniline (109 g.), was cooled while thionyl chloride (98 g.) was added slowly through an upright condenser. The mixture was left over-night, dilute hydrochloric acid added, and the product extracted with ether. The ethereal solution was dried and distilled. The chloro-ether (28 g.) boiled at 90·5°/747 mm. and had $d_4^{0°}$ 1·056 and $d_4^{20°}$ 1·031. The substance dissolves in water to the extent of 8% by weight at laboratory temperature.

Attempt to repeat Foran's Preparation of Bromodiethyl Ether.—The account given (Foran, *loc. cit.*) of the action of sodium ethoxide on ethylene dibromide was unconvincing, because it was hardly to be expected that the product of b. p. 128° would be separated sufficiently by distillation from ethylene dibromide (b. p. 131°) and diethoxyethane (b. p. 123·5°), both of which must be present. No evidence of any kind as to the homogeneity of the product was recorded, nor was any analysis reported. We therefore tried to repeat this experiment, but could not isolate any appreciable amount of the fraction in question. In the original, 18 g. of sodium are described as being dissolved in 45 c.c. of absolute alcohol. As this was found to be impossible, the latter figure is probably a misprint. We used either 180 c.c. or 450 c.c. of alcohol. The chief product of the reaction appears to be vinyl bromide, which escapes. Finally we abandoned the attempt to obtain enough of the liquid to test its homogeneity.

Ethylene and Trimethylene Chlorohydrins.—The liquid obtained by Carius's method (*loc. cit.*) is filtered from the sulphur and subjected at once to fractional distillation. The addition of pieces of marble on redistillation is advantageous. This reaction with trimethylene glycol was first mentioned by Derick and Bissell (*J. Amer. Chem. Soc.*, 1916, **38**, 2478) and is recommended by Gough and King (J., 1928, 2439). It renders trimethylene chlorobromide a readily accessible substance (compare Conant, Segur, and Kirner, *J. Amer. Chem. Soc.*, 1924, **46**, 1882).

By the action of 3 : 5-dinitrobenzoyl chloride on trimethylene chlorohydrin we obtained *γ-chloropropyl 3 : 5-dinitrobenzoate*, which formed colourless plates, m. p. 77°, from light petroleum (Found : N, 10·0; Cl, 12·1. $C_{10}H_9O_6N_2Cl$ requires N, 9·7; Cl, 12·3%).

γ-Chloropropyl Acetate.—Trimethylene glycol (37 g.) and acetic anhydride (1 mol.) were heated for a few minutes on the steam-bath, the acetic acid was distilled off under diminished pressure, and sulphur chloride (1 mol.) added. After the mixture had been heated at 100° for 4 hours, it was fractionated; the liquid of b. p. 66°/14 mm. was pure δ-chloropropyl acetate (yield, 68%) (Found : Cl, 26·3. Calc. : Cl, 26·5%).

γ-Hydroxydipropyl Sulphide.—Propyl mercaptan (1 mol.), γ-chloropropyl acetate (1 mol.), and sodium hydroxide (1 mol. in aqueous alcohol) were heated under reflux for 1 hour. An excess of alkali was then added and the mixture boiled to hydrolyse the ester. The solvent was distilled in steam, the product removed in ether, and the aqueous liquor further extracted twice with this solvent. The extracts were dried over sodium sulphate and distilled. *γ-Hydroxydipropyl sulphide* was obtained as an oil of characteristic, unpleasant odour, b. p. 112°/16 mm. (yield, 54%) (Found : S, 23·6. $C_6H_{14}OS$ requires S, 23·9%). The liquid, which is sparingly soluble in water, had $d_4^{20°}$ (vac.) 0·9794, $n_\alpha^{20°}$ 1·47789, whence $[R_L]_\alpha = 38·91$ (calc., 39·21). It was converted by phenylcarbimide into the *phenylurethane*, $C_3H_7·S·C_3H_6·O·CO·NHPh$, which formed colourless microscopic plates, m. p. 36° (Found : N, 5·8. $C_{13}H_{19}O_2NS$ requires N, 5·5%). β-Hydroxyethyl butyl sulphide (Whitner and Reid, *J. Amer. Chem. Soc.*, 1921, **43**, 636) yields the isomeric *phenylurethane*, $C_4H_9·S·C_2H_4·O·CO·NHPh$, which forms colourless plates, m. p. 44·5°, from light petroleum (Found : N, 5·9%).

Tetramethylene Glycol.—The glycol was prepared from the mixture of the dibromide with benzonitrile obtained by von Braun and Lemke's method (*Ber.*, 1922, **55**, 3526). This mixture (a quantity found by density measurements to contain 100 g. of the dibromide) was heated under reflux for 4—5 hours with potassium acetate (100 g.) and glacial acetic acid (33 g.) and then distilled under diminished pressure. Benzonitrile was removed from the product by fractional distillation at atmospheric pressure with a good column, the portion boiling above 210° being practically pure tetramethylene diacetate. This ester (100 g.) was heated at 160—170° for 3 hours with calcium hydroxide (36 g. of calcium oxide with 25 g. of water), the pressure reduced, and the product distilled off. The liquid was subjected to the same process with half the amount of lime and after a final redistillation the pure glycol was obtained, b.p. 127°/20 mm., which solidified on standing (yield, 61%).

The *bis-α-naphthylurethane* of this glycol was crystallised twice from *n*-butyl alcohol, from which it separated in colourless needles with a straight extinction, m. p. 198° (Found : N, 6·4. $C_{26}H_{24}O_4N_2$ requires N, 6·5%).

The Action of Sulphur Monochloride on Tetramethylene Glycol.—The glycol (30 g.) and sulphur chloride (38 g.; 0·85 mol.) were warmed together on the steam-bath for 6 hours and then at 150° in an oil-bath for 3 hours. The sulphur having been removed by filtration, the liquid and the acetone washings of the sulphur were distilled. A fraction boiling at 86°/15 mm. (yield, 15 g.) consisted of crude *δ-chlorobutyl alcohol*, but when this was redistilled (under reduced pressure) it disappeared, much hydrogen chloride being produced. From the crude liquid the *α-naphthylurethane* of *δ-chlorobutyl alcohol* was isolated by heating it with α-naphthylcarbimide for 1 hour at 100°. It crystallised from light petroleum in minute colourless plates, m. p. 66° (Found : Cl, 12·9. $C_{15}H_{16}O_2NCl$ requires Cl, 12·8%).

δ-Chlorobutyl Acetate.—A stout-walled tube, containing tetramethylene glycol (10—15 g.) and an inner tube containing acetyl chloride (1 mol.), was sealed and heated in a boiling water-bath for 8 hours. The cold product was rinsed out with acetone and, after two distillations, pure *δ-chlorobutyl acetate* was obtained as a colourless liquid of pleasant odour, b. p. 87°/17 mm., 98°/32 mm. (yield, 88%) (Found : Cl, 23·5. $C_6H_{11}O_2Cl$ requires Cl, 23·55%).

This substance is also obtainable by heating the glycol with sulphur chloride and acetylating the product. The following physical constants were observed : $d_{4^\circ}^{0^\circ}$ (vac.) 1·1024, $d_{4^\circ}^{20^\circ}$ (vac.) 1·0803; $n_\alpha^{20^\circ}$ 1·43811, $n_\beta^{20^\circ}$ 1·44369, $n_\gamma^{20^\circ}$ 1·45130; whence $[R_L]_\alpha =$ 36·6 (calc., 36·2), $[R_L]_\beta = 37·00$ (calc., 36·78), and $[R_L]_\gamma = 37·55$ (calc., 37·10).

Condensation of Ethyl and Phenyl Mercaptans with δ-Chlorobutyl Acetate.—Chlorobutyl acetate (15 g. in 20 c.c. of methyl alcohol) was added to a solution of ethyl mercaptan (6·5 g.) and potassium hydroxide (6 g. in 6 c.c. of water and 10 c.c. of methyl alcohol), and the mixture boiled under reflux for ½ hour. Potassium hydroxide (10 g. in aqueous alcohol) was added, and boiling continued for ½ hour to hydrolyse the ester. The liquid was then acidified with acetic acid, and the alcohol evaporated. The upper layer of oil was removed, and the aqueous phase twice extracted with ether. The solution was dried over sodium sulphate and distilled in a vacuum. *Ethyl δ-hydroxybutyl sulphide* was obtained as a colourless oil of characteristic, unpleasant odour, b. p. 120°/19 mm. (yield, 71%) (Found : S, 23·7. $C_6H_{14}OS$ requires S, 23·9%). The liquid

had $d_{4^\circ}^{20^\circ}$ (vac.) 0·9794, $n_\alpha^{20^\circ}$ 1·48118, whence $[R_L]_\alpha = 39{\cdot}00$ (calc., 39·21).

The *phenylurethane*, EtS·$[CH_2]_4$·O·CO·NHPh, forms colourless microscopic plates, m. p. 37° (Found: N, 5·9. $C_{13}H_{19}O_2NS$ requires N, 5·5%).

Chlorobutyl acetate (10 g.) was added to a solution of thiophenol (7·3 g.) in alcoholic potassium hydroxide (3·8 g. in aqueous methyl alcohol) and the mixture was boiled for ½ hour and then for a further equal period after the addition of more alkali (7·6 g. of potassium hydroxide). The whole was finally acidified with acetic acid, and the alcohol distilled off. A little water was added to dissolve salts which had separated, the upper layer was removed, and the solution twice extracted with ether. The ethereal solution was washed with water, dried over sodium sulphate, and evaporated. The residue, after being heated at 100° in a stream of air at 20 mm., solidified. This *phenyl δ-hydroxybutyl sulphide* crystallised from light petroleum in colourless needles, m. p. 24° (yield, 96%) (Found: S, 17·4. $C_{10}H_{14}OS$ requires S, 17·6%). It was insoluble in water, but readily soluble in most organic solvents. Phenylcarbimide readily converted it into the *phenylurethane*, PhS·$[CH_2]_4$·O·CO·NHPh, which formed colourless plates, m. p. 68·5°, from light petroleum (Found: N, 4·9. $C_{17}H_{19}O_2NS$ requires N, 4·65%).

Pentamethylene Glycol.—The mixture of pentamethylene dibromide and benzonitrile obtained by the action of phosphorus pentabromide on benzoylpiperidine (yield, 50%) was converted through the diacetate into the glycol by the method given for its lower homologue above (yield, 90%).

The glycol readily reacted with phenyl- and α-naphthyl-carbimides. The *bisphenylurethane*, NHPh·CO·O·$[CH_2]_5$·O·CO·NHPh, crystallised thrice from ethyl alcohol, formed minute colourless needles, m. p. 174° (Found: N, 8·5. $C_{19}H_{22}O_4N_2$ requires N, 8·2%). The *bis-α-naphthylurethane* was obtained in colourless microscopic plates, m. p. 147° (Found: N, 6·5. $C_{27}H_{26}O_4N_2$ requires N, 6·3%).

The Action of Sulphur Chloride on Pentamethylene Glycol.—The glycol (30 g.) was heated, as in the case of the lower homologue, with sulphur chloride (35 g.; 0·9 mol.). A fraction of b. p. 114°/16 mm. was separated and redistilled (12·5 g.) (Found: Cl, 36·1. $C_5H_{11}OCl$ requires Cl, 28·9%). This liquid was free from hydrogen chloride but evidently contained pentamethylene dichloride. From it was isolated the *α-naphthylurethane* of *ε-chloroamyl alcohol*, $C_{10}H_7$·NH·CO·O·$[CH_2]_5Cl$, in colourless needles, m. p. 72° (Found: Cl, 12·2. $C_{16}H_{18}O_2NCl$ requires Cl, 12·15%).

ε-Chloroamyl Acetate.—The reaction between pentamethylene

glycol and acetyl chloride was carried out as with the lower homologue. The product differed in that it contained a large amount of free hydrogen chloride. After two distillations the fraction of b. p. 104°/20 mm. was separated and redistilled, finally with a little acetic anhydride to acetylate any chlorohydrin present. *ε-Chloroamyl acetate* was isolated as a colourless liquid of pleasant odour, b. p. 103°/18 mm. (yield, 41%) (Found: Cl, 21·8. $C_7H_{13}O_2Cl$ requires Cl, 21·6%). The substance has $d_4^{20°}$ (vac.) 1·0648, $n_\alpha^{20°}$ 1·43791, whence $[R_L]_\alpha = 40·56$ (calc., 40·79).

Condensation of Methyl and Phenyl Mercaptans with ε-Chloroamyl Acetate.—Methyl mercaptan, prepared as described by Arndt (*Ber.*, 1921, **54**, 2236), was passed into methyl alcohol cooled in a good freezing mixture. To this solution, potassium hydroxide (4·2 g. in 5 c.c. of water and 20 c.c. of methyl alcohol) and chloroamyl acetate (12·3 g.) were added and the mixture was boiled for ½ hour. An excess of alkali was added, and the boiling repeated to hydrolyse the ester. The product was isolated as described for the isomeric ethyl hydroxybutyl sulphide. *Methyl ε-hydroxyamyl sulphide* was obtained as a colourless oil of unpleasant odour, b. p. 121°/16 mm. (Found: S, 23·75. $C_6H_{14}OS$ requires S, 23·9%) (yield, 56%). The liquid has $d_4^{20°}$ (vac.) 0·9846, $n_\alpha^{20°}$ 1·488185, whence $[R_L]_\alpha = 39·44$ (calc., 39·21), and is converted by phenylcarbimide at 100° into the *phenylurethane*, $MeS·[CH_2]_5·O·CO·NHPh$, which forms colourless microscopic plates, m. p. 43·5° (Found: N, 5·9. $C_{13}H_{19}O_2NS$ requires N, 5·5%).

The condensation with thiophenol was carried out as with the lower homologue. *Phenyl ε-hydroxyamyl sulphide*, $PhS·[CH_2]_5·OH$, was obtained in flat colourless needles, m. p. 31·5°, from light petroleum (Found: S, 16·3. $C_{11}H_{16}OS$ requires S, 16·3%). It is almost insoluble in water, soluble in most organic solvents. The *phenylurethane*, $PhS·[CH_2]_5·O·CO·NHPh$, crystallises from light petroleum in colourless plates, m. p. 59° (Found: N, 4·7. $C_{18}H_{21}O_2NS$ requires N, 4·45%).

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