155. *A Comparison of the Rates of Formation of Six- and Seven-membered Ring Compounds from ω-Chloro-sulphides.*

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The rates of formation in solution of cyclic sulphonium salts, from alkyl sulphides having a chlorine atom attached to the last carbon atom of the chain, have been studied for compounds yielding six- and seven-membered ring products. The reaction is in each case smooth and of the first order, and the six-membered ring is found to be formed 75 times as fast as the seven-membered. This ratio is almost identical with that found in an earlier study for the ratio of the speeds of formation of five- and six-membered rings of similar type. Although these reactions appear in general to proceed to completion, the possibility is noted that they are reversible and incomplete.

IN an earlier paper (Bennett, Heathcoat, and Mosses, J., 1929, 2567) an account was given of the formation of compounds containing five- and six-membered heterocyclic rings from ω-chloro-sulphides. The phenyl ω-chloroalkyl sulphides underwent ring closure smoothly at measurable speeds. Of the alkyl ω-chloroalkyl sulphides, that giving rise to the five-membered ring reacted too rapidly for measurement. It was shown that the speeds of ring closure of a five- and a six-membered ring in 50% acetone solution at 80° were in the ratio of 76 : 1.

We now report a similar study of substances yielding six- and seven-membered ring compounds. An examination of *phenyl* 6-*chlorohexyl sulphide* showed that, heated in various solvents at temperatures up to 200°, it either gave no sign of cyclisation or did so to a minor extent. This was not surprising in view of the difficulty of closure of a seven-membered ring which is here superposed upon the known slowness of reaction of alkyl chlorides with the sulphur atom when directly attached to the benzene nucleus. *Ethyl* 6-*chlorohexyl sulphide,* however, undergoes ring closure smoothly under these conditions and rapidly enough for study in comparison with the corresponding *ethyl 5-chloroamyl sulphide*. In each case the reaction appears to be of the first order, and the speed of formation of the six-membered ring is found to be about 75 times as great as that of the seven-membered. The replacement of the methyl group attached to the sulphur atom by an ethyl group caused a fall in velocity of ring closure in the ratio 3 : 2.

As in the earlier work, the observations have been made at two temperatures, but the uncertainty as to whether the reaction is really complete, in view of the known reversibility of sulphonium-salt formation, makes a more detailed examination of each reaction desirable before the results could safely be used to calculate the activation energy of the reaction. At the same time, any reversal of the reaction is slight, and the observed velocities are not seriously in error.

EXPERIMENTAL.

Attempt to detect Ring Closure in Phenyl 6-Chlorohexyl Sulphide.—The substance, prepared as described by Bennett and Mosses (J., 1931, 1699), gave no sign of chlorion formation after 29 hours' heating in boiling 70% acetic acid or after 26 hours in boiling 70% aqueous acetone. After 72 hours in the latter solvent, liberation of chlorion was 13% of that possible. The substance was also heated in ethylene glycol at its b. p. (198°); after 16 hours the liberated chlorion was 25% of that possible. As both hydrolysis and glycolysis were probable alternative reactions involving liberation of hydrogen chloride, these figures in any case only indicate an upper limit to the extent of any ring formation occurring.

Preparation of Hexamethylene Chlorohydrin.—This substance had not hitherto been prepared, Bennett and Mosses having made use of the chloroacetin. Hexamethylene glycol was subjected to the action of hydrochloric acid in the presence of paraffin under the special conditions described by Bennett and Mosses (*loc. cit.*, p. 1698), and, after repeated fractional distillation under diminished pressure, finally with a glass spiral column, *hexamethylene chlorohydrin* was obtained as a colourless liquid, b. p. 116—117°/19 mm., 112°/17 mm. (Found : C, 53·1; H, 9·5; Cl, 26·2. $C_6H_{13}OCl$ requires C, 52·7; H, 9·6; Cl, 26·0%).

Preparation of Ethyl 6-Chlorohexyl Sulphide.—Potassium ethylthioxide was heated for ½ hr. with hexamethylene chlorohydrin in alcoholic solution, and after passage of steam to remove volatile material, the ethyl hydroxyhexyl sulphide was removed in ether, dried with potassium carbonate, and distilled, forming a colourless oil, b. p. 134—136°/17 mm. This hydroxy-sulphide (6·5 g.), dissolved in diethylaniline (8·6 c.c.), was kept at 55° while thionyl chloride (3·7 c.c. in an equal volume of carbon tetrachloride) was added drop by drop. After a further ¾ hr.'s heating on the steam-bath, water and more carbon tetrachloride were added, and the extract washed twice with hydrochloric acid and then successively with dilute sodium carbonate solution and with water and dried over sodium sulphate. On distillation there was thus obtained *ethyl 6-chlorohexyl sulphide* as a pale straw-coloured oil of persistent unpleasant odour; b. p. 128—131°/26 mm. (Found : C, 53·4; H, 9·4; Cl, 19·6. $C_8H_{17}ClS$ requires C, 53·2; H, 9·9; Cl, 19·7%).

Ethyl chlorohexyl sulphide was heated in 50% aqueous acetone solution in a sealed tube at 100° for 90 hrs., and the solution diluted and extracted with ether to remove any unchanged oil. The solution was then concentrated and chloroplatinic acid added.

Ethylhexamethylenesulphonium chloroplatinate, $[Et{\cdot}S(CH_2)_6]_2PtCl_6$, was thus obtained in yellow crystals somewhat readily soluble in water (Found : C, 27·8; H, 4·9; Pt, 27·5. $C_{16}H_{34}Cl_6S_2Pt$ requires C, 27·9; H, 4·6; Pt, 27·5%).

Preparation of Ethyl 5-Chloroamyl Sulphide.—The corresponding hydroxy-sulphide was obtained by boiling 5-chloroamyl acetate (18 g.) with an aqueous-alcoholic solution of potassium ethylthioxide (8·5 c.c. of ethylthiol with 6·5 g. of potassium hydroxide in 20 c.c. of 60% alcohol) for ½ hr., and heating for a further ½ hr. after addition of more potassium hydroxide (2 mols.). The alcohol was evaporated, the mixture cooled, the oily layer removed, the liquor extracted with ether, and the combined extracts dried over potassium carbonate. On distillation, 12·4 g. of ethyl 5-hydroxyamyl sulphide, b. p. 135°/20 mm., were obtained.

To this hydroxy-sulphide, dissolved in 15 c.c. of diethylaniline at 50—60°, thionyl chloride (6·25 c.c. in an equal volume of carbon tetrachloride) was added drop by drop, and the mixture heated for 1 hr. on the steam-bath. After addition of water the product was collected in carbon tetrachloride and the extract washed twice with hydrochloric acid and then successively with aqueous sodium carbonate and with water and dried over sodium sulphate. Distillation yielded *ethyl 5-chloroamyl sulphide* as a pale yellow oil of characteristic and persistent odour; b. p. 122°/25 mm. (Yield 64% of the calculated) (Found: C, 50·9; H, 9·2. $C_7H_{15}SCl$ requires C, 50·5; H, 9·1%).

When an aqueous acetone solution of this sulphide which had been boiled for several hours was evaporated, some unchanged oil removed in ether, and the aqueous solution further concentrated, it yielded on addition of chloroplatinic acid *ethylpentamethylenesulphonium chloroplatinate* in orange-yellow crystals readily soluble in water (Found: Pt, 28·8. $C_{14}H_{30}Cl_6S_2Pt$ requires Pt, 29·1%).

Reaction-velocity Measurements.—Equal volumes of an M/20-solution of the chloro-sulphide in acetone were placed in each of a number of glass tubes, an equal volume of water added, and the tube sealed and heated at constant temperature. A tube was removed and opened at certain intervals of time and the chlorion in solution was determined gravimetrically as silver salt. Time was measured in minutes, and k is calculated from $k = (1/t) \log_e a/(a - x)$.

(a) *Closure of the seven-membered ring.*

(1) Each tube contained 20 c.c. of 50% aqueous acetone with 0·09188 g. of ethyl 6-chlorohexyl sulphide. Temp. 100·0°.

t, mins.	0	300	420	480	600	900	1080	1500	∞
AgCl, g.	—	0·0150	0·0183	0·0201	0·0274	0·0339	0·0371	0·0459	0·0730
$k \times 10^4$	—	7·68	6·87	6·72	7·83	6·95	6·57	6·60	Mean 7·03

(2) As in (1), except that the concentration was halved.

t, mins.	0	480	600	900	∞
AgCl, g.	—	0·0102	0·0141	0·0184	0·0365
$k \times 10^4$	—	6·83	8·15	7·78	Mean 7·58

(3) 20 C.c. of 50% aqueous acetone with 0·07648 g. of sulphide. Temp. 116·0°.

t, mins.	0	180	240	360	∞
AgCl, g.	—	0·0237	0·0293	0·0376	0·06075
$k \times 10^4$	—	27·4	27·4	26·8	Mean 27·2

(b) *Closure of the six-membered ring.*

(1) Each tube contained 20 c.c. of 50% aqueous acetone with 0·08415 g. of ethyl 5-chloroamyl sulphide. Temp. 68·6°.

t, mins.	0	15	45	75	105	135	165	195	∞
AgCl, g.	—	0·0052	0·0124	0·0210	0·0274	0·0325	0·0382	0·0416	0·0725
$k \times 10^3$	—	—	4·68	4·56	4·51	4·40	4·54	4·38	Mean 4·51

(2) As in (1). Temp. 80·4°.

t, mins.	0	15	30	40	50	60	70	90	∞
AgCl, g.	—	0·0111	0·0194	0·0248	0·0299	0·0361	0·0396	0·0442	0·0725
$k \times 10^3$	—	11·06	10·39	10·46	10·88	11·50	11·28	10·46	Mean 10·8

(3) Each tube contained 20 c.c. of 50% aqueous acetone with 0·0828 g. of ethyl 5-chloroamyl sulphide. Temp. 88·6°.

t, mins.	0	10	15	20	25	30	∞
AgCl, g.	—	0·0147	0·0204	0·0264	0·0289	0·0349	0·0690
$k \times 10^3$	—	24·0	23·3	24·2	21·6	23·5	Mean 23·3

Extrapolating the figures for the closure of the six-membered ring from 68·6° and 88·6°, we get $k_{100^\circ} = 0·0530$.

The ratio of velocities of closure of six- and seven-membered rings at 100° is therefore 0·0530/0·000703 = 75.

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