69. *Halogenated Ketones. Part IV. The Application of the Friedel–Crafts Reaction to the Preparation of Halogenated Aliphatic Ketones.*

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By using aluminium chloride as condensing agent and operating in the absence of any solvent other than the acyl halide, a variety of halogenated ketones has been prepared by addition reactions employing ethylene, acetylene, vinyl chloride, and di- and tri-chloroethylene.

ONE of the few applications of the conventional Friedel–Crafts ketone synthesis in the aliphatic series is that involving the condensation of acyl halides with ethylenic and acetylenic compounds. In the simplest case the reaction can be formulated :

$$CH_3{\cdot}COCl + CH_2{:}CH_2 \longrightarrow CH_3{\cdot}CO{\cdot}CH_2{\cdot}CH_2Cl \longrightarrow CH_3{\cdot}CO{\cdot}CH{:}CH_2$$

Although known in principle for a long time (cf. Kondakoff, *Bull. Soc. chim.*, 1892, **7**, 576), in recent years it has been investigated in more detail and extended in its scope.

The earlier investigators (Krapiwin, *Chem. Zentr.*, 1910, I, 1335; Darzens, *Compt. rend.*, 1910, **150**, 707; Norris and Couch, *J. Amer. Chem. Soc.*, 1920, **42**, 2329; Wieland and Bettag, *Ber.*, 1922, **55**, 2246, and Carroll and Smith, *J. Amer. Chem. Soc.*, 1933, **55**, 370), working under the usual Friedel–Crafts conditions and employing inert diluents such as petroleum or carbon disulphide, obtained only poor yields of the halogenated ketones, often together with the vinyl ketones, and in some cases the latter compounds were formed exclusively. Since the halogenated ketones were of particular interest in this present study, it was desirable to obtain them in the best possible yields. In this connection the procedure suggested in certain patents (Schering-Kahlbaum, U.S.P., 1,737,203; I.G. Farbenind., B.P. 459,537) was of interest in that, in the absence of solvents, it was claimed that the β-halogenated ketones were the main product. It has also been claimed (Standard Oil Co., U.S.P., 2,006,198) that the same ketones can be produced, using only catalytic quantities of condensing agents (aluminium chloride, bismuth chloride, etc.), by operating at *ca.* 100° under about 50 atmospheres' pressure.

Only few examples were found in the literature of the employment of halogenated acid halides in such reactions. Carroll and Smith (*loc. cit.*) obtained a very poor yield of chloromethyl 2-chloroethyl ketone by condensation of chloroacetyl chloride with ethylene. Reactions with acetylene, leading to 2-chlorovinyl ketones, have been described by I.G. Farbenind.

$$CH_3{\cdot}COCl + HC{:}CH \longrightarrow CH_3{\cdot}CO{\cdot}CH{:}CHCl$$

(B.P. 461,080) using light petroleum as the solvent together with aluminium chloride (see also Cornillot and Alquier, *Compt. rend.*, 1935, **201**, 837). Kroeger, Sowa, and Nieuwland (*J. Org. Chem.*, 1936, I, 163) preferred to employ stannic chloride in condensations of acid chlorides with mono- and di-substituted acetylenes. The use of vinyl chloride in Friedel–Crafts reactions has been reported by I.G. Farbenind. (U.S.P. 2,137,664), and chlorovinyl ketones were obtained in reactions in light petroleum with aluminium chloride as the condensing agent.

This same condensing agent was employed in all the reactions described in the present paper; the yields obtained were very dependent upon its purity. No solvent was used other than the acyl halide itself, and in a number of instances this was observed to dissolve the aluminium chloride very readily. Vigorous agitation was essential, and in reactions in which, using molar quantities of the reagents, stirring became very difficult, in subsequent experiments the use of an excess of the acyl halide proved advantageous.

In general, the yields obtained with ethylene were better than those with acetylene, much tarry material being formed in the latter case; reactions with vinyl chloride proceeded almost quantitatively, and 1 : 2-dichloroethylene also gave an excellent yield in a condensation with chloroacetyl chloride.

Although it was to be expected that the initial product in reactions between vinyl chloride and acyl chlorides would be a 2 : 2-dichloroethyl ketone, rather than the isomeric 1 : 2-dichloroethyl compound, this point had not hitherto been established, probably because of the difficulty of isolating the dichloroethyl ketones, which tend to lose hydrogen chloride spontaneously. In a reaction utilising chloroacetyl chloride, however, it proved fairly easy to isolate the comparatively stable *chloromethyl* 2 : 2-*dichloroethyl ketone*, and this was shown to be different from the 1 : 2-dichloro-isomer prepared by addition of chlorine to chloromethyl vinyl ketone.

$$CH_3{\cdot}COCl + CH_2{:}CHCl \longrightarrow CH_3{\cdot}CO{\cdot}CH_2{\cdot}CHCl_2 \longrightarrow CH_3{\cdot}CO{\cdot}CH{:}CHCl$$

EXPERIMENTAL.

Friedel–Crafts Reactions with Olefins and Acetylene. General Method.—The acid chloride (at least 1 mol.) is cooled (ice–salt) and freshly finely-powdered aluminium chloride (1 mol.) is added with stirring. The flask and contents are then weighed and the olefin (or acetylene) passed into the mixture with vigorous stirring at room temperature (cooling is usually necessary) until no further increase in weight is observed. The gain in weight varies from 50 to 100% of the theoretical; only rarely does it approach or attain the theoretical value. The mixture is then poured, with stirring, on crushed ice and extracted thoroughly (best with chloroform), and the extracts are washed, dried (Na_2SO_4), and evaporated. On distillation under reduced pressure of the products from ethylene, etc., varying quantities of the lower-boiling vinyl ketones are usually obtained. The Table lists the substances prepared by this method.

Ketone.	Reagents.	Yield, %.	B. p.	n_D.	Found.	Reqd.
Methyl 2-chloroethyl [1]	$CH_2{:}CH_2$, $CH_3·COCl$	40	48°/15 mm.	—	—	—
Chloromethyl 2-chloroethyl [2]	,, $CH_2Cl·COCl$	45	81/2·5 mm.	1·4785 (17°)	—	—
Di-(2-chloroethyl) [3]	,, $CH_2Cl·CH_2·COCl$	30	74/0·8 mm.	1·4726 (18)	Cl, 44·6%	Cl, 45·75%
Bromomethyl 2-*chloroethyl*	,, $CH_2Br·COCl$	65	81/1 mm.	1·5054 (17)	Ag halide, 12·0 mg.	Ag halide, 12·1 mg.
Chloromethyl 2-*bromoethyl*	,, $CH_2Cl·COBr$	35	80/0·4 mm.	1·4960 (14)	Ag halide, 10·9 mg.	Ag halide, 11·3 mg.
Bromomethyl 2-*bromoethyl*	,, $CH_2Br·COBr$	60	77/0·1 mm.	1·5327 (18)	Br, 68·5%	Br, 69·6%
1-*Chloroethyl* 2-*chloroethyl*	,, $CH_3·CHCl·COCl$	60	64—65/1·5 mm.	1·4631 (20)	Cl, 44·5%	Cl, 45·75%
1-*Chloroethyl* 2-*bromoethyl*	,, $CH_3·CHCl·COBr$	60	78/1 mm.	1·4853 (22)	Ag halide, 10·6 mg.	Ag halide, 10·4 mg.
Chloromethyl 2-*chlorovinyl*	$CH{\vdots}CH$, $CH_2Cl·COCl$	40	71—74/10 mm.	1·5122 (17)	Cl, 53·5%	Cl, 51·1%
Bromomethyl 2-*chlorovinyl*	,, $CH_2Br·COCl$	30	65—68/2 mm.	1·5220 (16·5)	Ag halide, 13·7 mg.	Ag halide, 13·3 mg.
Chloromethyl 2-*bromovinyl*	,, $CH_2Cl·COBr$	40	80/11 mm.	1·5310 (14)	Ag halide, 12·1 mg.	Ag halide, 12·5 mg.
Bromomethyl 2-bromovinyl	,, $CH_2Br·COBr$	40	80—85/2·5 mm.	1·5486 (14)	— [6]	—
Methyl 2-chlorovinyl [4]	$CH_2{:}CHCl$, $CH_3·COCl$	90	74/100 mm.	1·4649 (18)	—	—
Chloromethyl 2 : 2-*dichloroethyl*	,, $CH_2Cl·COCl$	94 [7]	92/1·2 mm. (m. p. 28) [8]	—	Cl, 57·1%	Cl, 60·7%
Chloromethyl 1 : 2 : 2-*trichloroethyl* [5]	$CHCl{:}CHCl$, $CH_2Cl·COCl$	75	92—94/3 mm.	1·5123 (18)	Cl, 68·0%	Cl, 67·55%

[1] Excess of acetyl chloride was found desirable in this reaction. [2] Carroll and Smith, *loc. cit.* [3] I.G. Farbenind., B.P. 459,537. [4] Cornillot and Alquier, *loc. cit.*; I.G. Farbenind, B.P. 461,080. This product was isolated by distillation in steam after extraction. [5] See below for experimental procedure. [6] This material could not be analysed since it decomposed very rapidly, almost immediately after distillation. [7] Yield of crystalline product, 60%. [8] Needles from light petroleum (b.p. 40—60°).

The saturated 2-chloroethyl ketones are reasonably stable; samples of the bromomethyl and chloromethyl ketones kept in glass bottles for several months without undue precautions did not undergo any extensive deterioration. Chloromethyl 2 : 2-dichloroethyl ketone did not decompose appreciably at 0°, but, on storage at the ordinary temperature, hydrogen chloride was rapidly evolved leaving a residue of polymeric material.

The 2-halogeno-vinyl ketones polymerise very readily; hydrogen halide is copiously evolved, and the final product is a brittle black solid. Thus methyl 2-chlorovinyl ketone polymerises completely in less than a week, quinol being without effect in inhibiting this polymerisation.

Chloromethyl 1 : 2 : 2-*Trichloroethyl Ketone.*—To a mixture of 1 : 2-dichloroethylene (100 c.c.) and chloroacetyl chloride (22·6 g.), heated under reflux on the steam-bath, powdered aluminium chloride (27 g.) was added with stirring during 1 hour. After a further two hours' heating, the product (see Table) was isolated in the manner described above.

Treatment with semicarbazide acetate in alcohol gave the *semicarbazone* of *chloromethyl* 1 : 2-*dichlorovinyl ketone*, m. p. 142° (Found : N, 18·2. $C_5H_6ON_3Cl_3$ requires N, 18·2%). Hydroxylamine likewise gave the *oxime* of the unsaturated ketone, m. p. 118° (Found : N, 7·25. $C_4H_4ONCl_3$ requires N, 7·45%).

An identical semicarbazone was obtained from the product derived from the tetrachloro-ketone by shaking it with 10% sodium carbonate solution for an hour, distilling (b. p. 70—75°/1 mm.), and treating with semicarbazide acetate.

Chloromethyl Vinyl Ketone.—A mixture of chloromethyl 2-chloroethyl ketone (47 g.) and diethylaniline (50 g.) was kept overnight at the ordinary temperature. It was then diluted with ether, and the ethereal solution was washed thoroughly with dilute hydrochloric acid and dried. The residue obtained on evaporation was distilled under reduced pressure, a little quinol being placed in each receiver. The *vinyl ketone* (17·4 g.; 50%) was obtained as a pale yellow oil with a lachrymatory acrid odour, b. p. 84°/107 mm., 74—75°/57 mm.; $n_D^{20°}$ 1·4708 (Found : Cl, 35·1. C_4H_5OCl requires Cl, 33·9%). In the absence of quinol the ketone polymerises extremely rapidly giving viscous materials which are not depolymerised on redistillation.

When treated with chlorine at − 10°, the ketone gave a slightly impure trichloro-ketone, presumably chloromethyl 1 : 2-dichloroethyl ketone, in 60% yield, b. p. 61°/0·6 mm., $n_D^{13°}$ 1·4981 (Found : Cl, 57·3. $C_4H_5OCl_3$ requires Cl, 60·7%). This could not be induced to crystallise either by cooling or inoculation with the isomeric chloromethyl 2 : 2-dichloroethyl ketone. On warming it with a solution of potassium iodide in acetone, free iodine and a precipitate of potassium chloride were rapidly produced.

Heptachlorobutan-2-*one.*—Finely powdered aluminium chloride (50 g.) was added to a stirred mixture of trichloroacetyl chloride (60 g.) and trichloroethylene (130 g.) during 30 minutes, after which the mixture was refluxed on the steam-bath for 3 hours with vigorous stirring. The dark solution was poured on ice, and the product was taken up in ether, the ethereal extract being thoroughly washed with sodium hydrogen carbonate solution before being dried and evaporated. Distillation gave two fractions : (i) b. p. *ca.* 80°/1 mm. (6 g.); (ii) b. p. 130—150° (bath temp.)/1 mm., a semi-solid mass. Fraction (ii) was washed with a little cold acetone and crystallised from light petroleum, giving large crystals of *heptachlorobutan*-2-*one* (12 g.), m. p. 182° (Found : C, 15·2; H, 0·45. C_4HOCl_7 requires C, 15·3; H, 0·32%). The compound has a camphor-like odour and is only slightly irritant to the eyes.

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