THE REDUCTION OF \(-\text{CH(OH)}\text{CCl}_3\) GROUP ATTACHED TO A BENZO-\(\alpha\)-PYRONE NUCLEUS

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The reduction of \(-\text{CH(OH)}\text{CCl}_3\) group in trichloro-methyl carbinols present as such or potentially formed during the course of reduction from trichloro-methylphthalide ring (A) or the heterocyclic ring (B) has been an interesting subject for investigation by numerous workers. Using zinc and boiling alcohol, Jocitsch\(^1\) found that the reaction took the course thus:

\[
\text{Ph—CH(OH)}\text{CCl}_3 \rightarrow \text{Ph—CH} = \text{CCl}_2.
\]

The best results were obtained by reducing the acetyl derivative, using the zinc in form of its shavings. Jocitsch also studied the tertiary alcohols containing the group \(\text{C(OH)}\text{CCl}_3\). According to his method of reduction, the group \(-\text{CH(OH)}\text{CCl}_3\) is converted into \(-\text{CH} = \text{CCl}_2\); and the group \(\text{C(OH)}\text{CCl}_3\) into \(\text{C} = \text{CCl}_2\).

Using zinc dust and glacial acetic acid as reducing agents, Meldrum and Alimchandani\(^2\) observed that in several compounds investigated by them, the group \(-\text{CH(OH)}\text{CCl}_3\) is reduced with the production of \(-\text{CH}_2\cdot\text{CHCl}_2\) group. In extending their study of this reduction, Meldrum and his several collaborators\(^3\) applied it to a large number of compounds including those of the type (A) and (B) shown above. On the other hand, Wheeler and
Yelburgi proved that the group $-\text{CH(OH)CX}_3$ ($X = \text{Cl}$ or $\text{Br}$) is reduced to $-\text{CH} = \text{CX}_2$ and not to $-\text{CH}_2 \cdot \text{CHX}_2$ in case of chloral- and bromal-amides.

$$R \cdot \text{CO} \cdot \text{NH} \cdot \text{CH(OH)CX}_3 \rightarrow R \cdot \text{CO} \cdot \text{NH} \cdot \text{CH} = \text{CX}_2$$

Recently Dharwarkar and Alimchandani have shown that in the case of some chloral-hydroxy-benzoic acid derivatives, the group $-\text{CH(OH)CCl}_3$ gets reduced to the unsaturated group $-\text{CH} = \text{CCl}_2$, and not to the saturated group $-\text{CH}_2 \cdot \text{CHCl}_2$ as erroneously postulated by Meldrum and collaborators. It is clear from the brief survey given above that in all the cases investigated hitherto, the group $-\text{CH(OH)CCl}_3$ is present either in the open-chain derivatives or is attached to an aromatic nucleus.

During the course of our studies on the effect of $\alpha$-substituents in the Pechmann condensation, a number of benzo-$\alpha$-pyrones (coumarins) containing $-\text{CH(OH)CCl}_3$ group in 3-position of the pyrone ring were synthesised by Kulkarni, Alimchandani and Shah. Because the reduction of $-\text{CH(OH)CCl}_3$ group attached to a benzo-$\alpha$-pyrone nucleus is hardly known, a study of the reduction of various 3-$\text{CH(OH)CCl}_3$ substituted coumarin derivatives synthesised by Kulkarni, Alimchandani and Shah was undertaken by the present authors, the reducing agents used being zinc dust and glacial acetic acid, $(a)$ in conjunction with concentrated hydrochloric acid and $(b)$ without the hydrochloric acid.

7-Hydroxy-3-(a-hydroxy-βββ-trichloro-ethyl)-4-methylcoumarin (I) on reduction by zinc dust and acetic acid gave 7-hydroxy-3-(β-chloro-vinyl)-4-methyl-coumarin (II). On carrying out the same reduction in conjunction with conc. hydrochloric acid, 7-hydroxy-3-(βββ-dichloro-ethyl)-4-methyl-coumarin (III) was obtained. Evidently, the addition of hydrochloric acid to the β-chloro-vinyl group produced by the reduction takes place with the ultimate production of the $-\text{CH}_2 \cdot \text{CHCl}_2$.

The acetyl derivative of (I), 7-acetoxy-3-(a-acetoxy-βββ-trichloro-ethyl)-4-methylcoumarin (IV) on similar reduction by zinc and acetic acid gave 7-acetoxy-3-(βββ-dichloro-ethyl)-4-methyl-coumarin (V) identical with the acetoxy derivative of (III), which is obtained directly by the reduction of (IV) in presence of conc. hydrochloric acid. The results are shown diagrammatically below : ($X = \text{H}$ in all compounds in this series)
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7:8-Dihydroxy-3-(\(\alpha\)-hydroxy-\(\beta\beta\)-trichloro-ethyl)-4-methyl-coumarin (I; \(X = OH\)) behaves exactly similarly; it gave 7:8-dihydroxy-3-(\(\beta\)-chloro-vinyl)-4-methylcoumarin (II; \(X = OH\)) and 7:8-dihydroxy-3-(\(\beta\beta\)-dichloroethyl)-4-methylcoumarin (III; \(X = OH\)) when reduced without and with conc. hydrochloric acid respectively. The acetoxy derivative (IV; \(X = OAc\)) on reduction by zinc and acetic acid only gave V (\(X = OAc\)) identical with the acetyl derivative of the coumarin III (\(X = OH\)), obtained directly on reduction in presence of conc. hydrochloric acid of the acetoxy derivative (IV).

The reduction of 5-hydroxy-4:7-dimethyl-3-(\(\alpha\)-hydroxy-\(\beta\beta\)-trichloro-ethyl)-coumarin also takes a similar course: on reduction by zinc and acetic acid (a) without conc. hydrochloric acid and (b) in the presence of the acid, it gave (a) 5-hydroxy-4:7-dimethyl-3-(\(\beta\)-chloro-vinyl)- and (b) 3-(\(\beta\beta\)-dichloroethyl)-coumarin derivatives respectively.

5:7-Dihydroxy-3-(\(\alpha\)-hydroxy-\(\beta\beta\)-trichloro-ethyl)-4-methylcoumarin on reduction by zinc and acetic acid gave a product which could not be crystallised. But its acetoxy derivative was smoothly reduced by zinc and acetic acid to 5:7-diacetoxy-3-(\(\beta\beta\)-dichloro-ethyl)-4-methyl coumarin, which was deacetylated to the corresponding 5:7-dihydroxy-derivative.

4-Methyl-3-(\(\alpha\)-hydroxy-\(\beta\beta\)-trichloro-ethyl)-1:2-a-naphtha-pyrone and 4:6 dimethyl-3-(\(\alpha\)-hydroxy-\(\beta\beta\)-trichloroethyl)-coumarin gave only one type of the reduction product, viz., 3-(\(\beta\beta\)-dichloroethyl), whether hydrochloric acid was used or not during the reduction as in the previous cases.

From the above results and those of the previous investigators on the reduction of \(-CH(OH)CCl_3\) group, it is evident that the reduction does not
proceed in a uniform manner in all cases. It is highly affected by the constitutional factors. A study of the reduction products of \(-\text{CH(OH)CCl}_3\) present in several coumarins described in this paper supports the above point. The following generalisation of the results described in this communication reveals some interesting points:

(a) On reduction with zinc and acetic acid, the group \(-\text{CH(OH)CCl}_3\) in the pyrone ring is reduced to \(-\text{CH} = \text{CHCl}\) group in case of hydroxy-coumarins, *i.e.*, those obtained from resorcinal, pyrogallol, etc.

(b) The same group \(-\text{CH(OH)CCl}_3\) is reduced to \(-\text{CH}_2 \cdot \text{CHCl}_2\) when:

(i) the reduction is carried out in conjunction with concentrated hydrochloric acid;

(ii) the phenolic group (–OH) is absent, as in case of coumarins obtained from \(\alpha\)-naphthol and \(p\)-cresol; and

(iii) the phenolic –OH group is protected by acetylation.

**Experimental**

(A) Reduction of 7-hydroxy-3-(\(\alpha\)-hydroxy-\(\beta\beta\)-trichloro-ethyl)-4-methyl-coumarin:

1. **Formation of 7-hydroxy-3-(\(\beta\)-chloro-vinyl)-4-methyl-coumarin.**—This reduction was carried out by means of zinc dust and acetic acid according to the details of Kulkarni, Alimchandani and Shah.\(^6\) The reduction product obtained melted at 254-55° (decomp.) not depressed by mixture with the sample of those authors.

2. **Formation of 7-hydroxy-3-(\(\beta\beta\)-dichloro-ethyl)-4-methylcoumarin.**—(a) The coumarin (2 g.) was dissolved in hot glacial acetic acid (30 c.c.) and the solution mixed with conc. HCl (6-7 c.c.). Zinc dust (2 g.) was gradually added with stirring. After reaction subsided, the solution was boiled for a few minutes, filtered from the unchanged zinc and the filtrate diluted with water. The reduction product was collected and crystallised from dil. alcohol, yellowish needles, m.p. 206-07°. [Found: Cl, 26·29; \(\text{C}_{12}\text{H}_{10}\text{O}_3\text{Cl}_2\) requires Cl, 26·02 per cent.]

(b) 7-Acetoxy-3-(\(\alpha\)-acetoxy-\(\beta\beta\)-trichloro-ethyl)-4-methylcoumarin was similarly reduced as above. The reduction product was found to be identical with the above product.

3. **Formation of 7-acetoxy-3-(\(\beta\beta\)-dichloro-ethyl)-4-methylcoumarin.—**(a) The above reduction product (0·5 g.) was dissolved in acetic anhydride (7 c.c.) in presence of conc. sulphuric acid (4 drops). The clear solution was shaken for about 10-15 minutes and poured into water. The solid was collected and
crystallised from rect. spirit, rhombic plates, m.p. 101-02°. [Found: Cl, 22.9; \(C_{14}H_{12}O_4\) requires Cl, 22.54 per cent.] It does not exhibit any fluorescence.

(b) The above substance was also obtained directly by reducing 7-acetoxy-3-(\(\alpha\)-acetoxy-\(\beta\)\(\beta\)-trichloro-ethyl)-4-methylcoumarin (0.5 g.) by adding zinc dust (0.7 g.) to its acetic acid solution in the usual way, m.p. 101-02° (yield 0.3 g). The mixed melting point of this compound with the derivative obtained by (a) was unchanged.

4. De-acetylation of the above acetoxy derivative.—The acetoxy derivative (1 g.) was suspended in methyl alcohol (10 c.c.) and conc. \(H_2SO_4\) (8 c.c.) added; the mixture was refluxed on water-bath for an hour and a half. After cooling, it was diluted with water and the substance obtained crystallised from acetic acid (animal charcoal), m.p. 206-07°, the mixed m.p. with 7-hydroxy-3-(\(\beta\)\(\beta\)-dichloro-ethyl)-4-methylcoumarin obtained above remaining undepressed.

(B) Reduction of 7:8-dihydroxy-3-(\(\alpha\)-hydroxy-\(\beta\)\(\beta\)-trichloroethyl)-4-methylcoumarin:

1. Formation of 7:8-dihydroxy-3-(\(\beta\)-chboro-vinyl) 4-methylcoumarin.—The procedure followed by Kulkarni, Alimchandani and Shah was employed and the reduction carried out as usual. The reduction product crystallised from alcohol, needles, m.p. 231-32°. The mixed melting point was also undepressed.

2. Formation of 7:8-dihydroxy-3-(\(\beta\)\(\beta\)-dichloro-ethyl)-4-methylcoumarin.—(a) The coumarin (8 g.) dissolved in acetic acid (100 c.c.) and mixed with conc. \(HCl\) (30 c.c.) was slowly treated with zinc (7 g.). Vigorous reaction took place. When the reaction subsided, the unchanged zinc was removed and the filtrate diluted with water. The product crystallised from acetic acid and then from benzene, hexagonal prisms, m.p. 195-96°, yield 5 g. [Found: Cl, 24.73; \(C_{12}H_{19}O_4\) requires 24.52 per cent.]

(b) The same reduction product was obtained by carrying out the reduction of 7:8-di-acetoxy-3-(\(\alpha\)-acetoxy-\(\beta\)\(\beta\)-trichloro-ethyl)-4-methylcoumarin in presence of conc. \(HCl\) as before.

The acetyl derivative prepared by acetic anhydride-pyridine method crystallised from alcohol, needles, m.p. 163-164°. [Found: Cl, 18.88; \(C_{14}H_{12}O_4\) requires Cl, 19.0 per cent.]

The same acetyl derivative was obtained by the reduction of 7:8-di-acetoxy-3-(\(\alpha\)-acetoxy-\(\beta\)\(\beta\)-trichloro-ethyl)-4-methylcoumarin using zinc dust and acetic acid as usual.
The de-acetylation of the substance by conc. sulphuric acid in methyl alcoholic solution gave the corresponding 7:8-di-hydroxy-coumarin identical in all respects with the same substance described already.

(C) Reduction of 5-hydroxy-4:7-dimethyl-3-(α-hydroxy-βββ-trichloro-ethyl)-coumarin:

1. Formation of 5-hydroxy-4:7-dimethyl-3-(β-chloro-vinyl)-coumarin.—
The coumarin (1 g.) was suspended in hot acetic acid (15 c.c.) and zinc dust (1 g.) added gradually as in previous cases. As the reaction proceeded, the substance went into solution. The reduction product was isolated as before and crystallised from dil. alcohol, diamond-shaped crystals, m.p. 251-52°. [Found: Cl, 14:24; C_{15}H_{17}O_{3}CL requires Cl, 14:16 per cent.]

The acetyl derivative obtained by acetic anhydride-pyridine method (2½ hours refluxing on water-bath) crystallised from alcohol in needles, m.p. 148-49°. [Found: Cl, 11:92; C_{16}H_{13}O_{4}Cl requires Cl, 12:12 per cent.]

2. Formation of 5-hydroxy-4:7-dimethyl-3-(ββ-di-chloro-ethyl)-coumarin.—The above reduction was carried out in presence of conc. HCl (4 c.c.) and the reduction product isolated as before; first crystallised from alcohol and then from ethyl acetate, needles, m.p. 242°. [Found: Cl, 24:83; C_{16}H_{12}O_{4}Cl_{2} requires Cl, 24:69 per cent.]

The acetyl derivative prepared as before crystallised from dilute alcohol, rectangular plates, m.p. 157°. [Found: Cl, 21:30; C_{15}H_{14}O_{4}Cl_{2} requires Cl, 21:54 per cent.]

(D) Formation of 5:7-di-acetoxy-3-(ββ-dichloro-ethyl)-4-methylcoumarin:

5:7-Diacetoxy-3-(α-acetoxy-βββ-trichloro-ethyl)-4-methylcoumarin (2 g.) was reduced by means of zinc dust (2.5 g.) and acetic acid (25 c.c.) as in previous cases. The product crystallised from dil. alcohol, rectangular rods, m.p. 121-22°. [Found: Cl, 18:91; C_{16}H_{14}O_{4}Cl_{2} requires Cl, 19:0 per cent.]

De-acetylation of the above 5:7-diacetoxy-coumarin derivative.—The de-acetylation was effected by sulphuric acid (7 c.c.) in methyl alcohol solution (1 g. in 10 c.c.) by refluxing for 1½ hours on water-bath. The solution was diluted with water and the substance obtained crystallised from dil. alcohol, thin flakes, m.p. 246-47°. [Found: Cl, 24:67; C_{12}H_{10}O_{4}Cl_{2} requires Cl, 24:52 per cent.]

(E) Formation of 4-methyl-3-(ββ-di-chloroethyl)-1:2-α-naphthia-pyrene:

4-Methyl-3-(α-hydroxy-βββ-trichloro-ethyl)-1:2-α-naphthia-pyrene (2.5 g.) was reduced by zinc (2.5 g.) in its acetic acid solution (30 c.c.) and the product isolated as before. It first crystallised from dichlorobenzene and
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then from xylene, m.p. 221–22° (yield, 1.5 g.). [Found: Cl, 22.71; \(\text{C}_{18}\text{H}_{12}\text{O}_2\text{Cl}_3\) requires Cl, 23.09 per cent.]

The same product was obtained by carrying out the reduction in presence of conc. HCl (4 c.c. for 1 g. of the coumarin).

**Formation of 4:** 6-dimethyl-3-\((\beta\beta\beta\text{-dichloro-ethyl})\)-coumarin.—4:6-Dimethyl-3-(a-hydroxy-\(\beta\beta\beta\text{-trichloro-ethyl})\)-coumarin (1 g.) was reduced as before (zinc 1 g. + acetic acid 15 c.c.). The product crystallised from alcohol in rectangular plates, m.p. 206–07°. [Found: Cl, 25.84; \(\text{C}_{12}\text{H}_{12}\text{O}_2\text{Cl}_2\) requires Cl, 26.16 per cent.]

A better yield is obtained if the above reduction is carried out in conjunction with conc. HCl (4 c.c. for 1 g. of the coumarin).

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**Summary**

The reduction of \(-\text{CH(OH)}\text{CCl}_3\) group attached to a benzo-\(\alpha\)-pyrone nucleus has been studied for the first time, the reducing agents used being zinc dust and glacial acetic acid either in conjunction with conc. HCl or without it. It is found that the course of the reduction is highly affected by the constitutional factors. The following generalisation is made in this connection:

\(a\) on reduction with zinc and acetic acid, the group \(-\text{CH(OH)}\text{CCl}_3\) in the pyrone ring is reduced to \(-\text{CH} = \text{CHCl}\) group in case of hydroxy-coumarins; \(b\) the same group \(-\text{CH(OH)}\text{CCl}_3\) is reduced to \(-\text{CH}_3\text{CHCl}_2\) group if (i) the reduction is carried out in conjunction with conc. HCl; (ii) the phenolic group \(-\text{OH}\) is either absent or is protected by acetylation.

**REFERENCES**

2. Meldrum and Alimchandani *J. Ind. C. S.*, 1925, 2, 1; 1929, 6, 253; *J.*, 1921, 204.