XII.—Interactions of Ketones and Aldehydes with Acid Chlorides—the Formation of Benzoxylefines and 1-Benzoxycamphene.

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IN the course of an investigation on the constituents of an essential oil of rue (Power and Lees, *Trans.*, 1902, 81, 1585), a mixture was isolated consisting of methyl heptyl and methyl nonyl ketones, together with methylheptyl- and methylnonyl-carbinols. To separate the two classes of substances, the mixture was boiled with an excess of benzoyl chloride in order to convert the alcohols into benzoic esters, as it was hoped that subsequent fractional distillation in a vacuum would achieve the object. Although sufficient benzoyl chloride was employed to convert the whole of the oil into ester had it consisted entirely of methylheptylcarbinol, it was observed on distillation of the product that very little of the chloride remained, and that not only had the alcohols been converted into esters, but the ketones in some manner had also formed substances of considerably higher boiling point.

Although the primary object of this experiment was not thus attained, and the separation was subsequently carried out in an entirely different way (*loc. cit.*), it appeared of interest to examine the substances formed by the interaction of the ketones mentioned and benzoyl chloride.

Methyl *n*-nonyl ketone and benzoyl chloride readily interact, with elimination of hydrogen chloride, when a mixture in molecular proportion is boiled for some hours. The condensation product is an oil of high boiling point and has the formula $C_{18}H_{26}O_2$; its formation may be represented by the equation:

With regard to the constitution of this compound, the question at issue was whether the benzoyl radicle was attached to carbon or to oxygen, or, in other words, whether the substance was a diketone or a benzoxylefine. The substance was insoluble in aqueous potassium hydroxide, and its alcoholic solution did not develop a coloration on the addition of ferric chloride, facts which excluded the possibility of its being either a β -diketone or an enolic modification of the latter. Moreover, as the compound was readily hydrolysed by warm dilute alcoholic potassium hydroxide with separation of potassium benzoate, and by hydroxylamine under the same conditions with the formation of methylnonylketoxime, it was evident that the benzoyl radicle was in

combination with oxygen, and that the substance was a benzoxy-olefine. This view of its constitution was further supported by the fact that by treatment with bromine a dibromide was formed.

The formation of an acyloxy-derivative of an olefine by interaction of a mono-oxygenated ketone with an acid chloride has not hitherto been observed. The most probable explanation of the reaction is that in the first instance the benzoyl chloride becomes attached to the carbonyl group of the ketone, forming the intermediate compound :

which, by loss of hydrogen chloride, would give rise to a compound having one or other of the two following formulæ :

It has not yet been ascertained which of the two expressions represents the substance $\text{C}_{18}\text{H}_{26}\text{O}_2$, and so it is provisionally designated *β*-benzoxyundecylene.

The above explanation of the reaction receives support from the fact that Claisen and Haase (*Ber.*, 1900, 33, 1242), in continuation of the researches of the former on substances containing the grouping $\cdot\text{CO} \cdot \text{CH}_2 \cdot \text{CO} \cdot$, have prepared ethyl O-benzoylacetate and ethyl O-acetylacetate of the respective formulæ :

by the interaction of ethyl acetoacetate with the acid chlorides in presence of pyridine, and trace the course of the reaction on the plan given above for the formation of *β*-benzoxyundecylene. In justification of their scheme, Claisen and Haase refer to an observation of Claisen's (*Ber.*, 1881, 14, 2475) that benzaldehyde readily forms an additive compound, with benzoyl bromide, of the constitution

The reaction employed in the production of *β*-benzoxyundecylene has been extended to other mono-oxygenated ketones and a mono-oxygenated aldehyde; the behaviour of a ketone with aliphatic acid chlorides was also studied. The results of these investigations and the substances obtained are as follows.

Neither acetone nor methyl *n*-propyl ketone interacted with benzoyl chloride. On the other hand, from methyl *n*-butyl ketone, methyl *sec.*-hexyl ketone, methyl *n*-heptyl ketone, acetophenone, camphor, and heptaldehyde, there were respectively prepared: *β*-benzoxyhexylene,

$\text{CH}_2\cdot\text{C}(\text{OBz})\cdot\text{C}_4\text{H}_9$ or $\text{CH}_3\cdot\text{C}(\text{OBz})\cdot\text{CH}\cdot\text{C}_3\text{H}_7$; β -benzoxy- γ -methylheptylene, $\text{CH}_2\cdot\text{C}(\text{OBz})\cdot\text{CHMe}\cdot\text{C}_4\text{H}_9$ or $\text{CH}_3\cdot\text{C}(\text{OBz})\cdot\text{CMe}\cdot\text{C}_4\text{H}_9$; β -benzoxy-nonylene, $\text{CH}_2\cdot\text{C}(\text{OBz})\cdot\text{C}_7\text{H}_{15}$ or $\text{CH}_3\cdot\text{C}(\text{OBz})\cdot\text{CH}\cdot\text{C}_6\text{H}_{13}$; α -benzoxy- α -phenylethylene, $\text{C}_6\text{H}_5\cdot\text{C}(\text{OBz})\cdot\text{CH}_2$; 1-benzoxycamphene,

and α -benzoxy- α -heptylene, $\text{C}_5\text{H}_{11}\cdot\text{CH}\cdot\text{CH}\cdot\text{OBz}$.

Methyl *n*-nonyl ketone did not interact with acetyl chloride when the mixture was boiled for several hours; with valeryl chloride, however, β -valeroxyundecylene, $\text{CH}_2\cdot\text{C}(\text{O}\cdot\text{CO}\cdot\text{C}_4\text{H}_9)\cdot\text{C}_9\text{H}_{19}$ or

resulted.

The fact that acetone and methyl *n*-propyl ketone does not interact with benzoyl chloride or methyl *n*-nonyl ketone with acetyl chloride is probably owing to the temperatures at which the respective mixtures boiled not being sufficiently high. On the other hand, it might be possible to effect condensation even in these cases if a tertiary base were employed as a condensing medium (compare Claisen and Haase, *loc. cit.*).

The substances described in this paper are represented as esters of the enolic form of the respective carbonyl compounds from which they are derived, or, in other words, they are esters of that class of alcohols of which the hypothetical vinyl alcohol, $\text{CH}_2\cdot\text{CH}\cdot\text{OH}$, is the simplest member. This class may be generally represented by the types

With regard to substances of these types, Erlenmeyer (*Ber.*, 1880, 13, 309; 1881, 14, 320) has stated that they are incapable of free existence, and that when, by certain reactions, they might be expected to result, the isomeric ketonic or aldehydic form, as the case may be, is produced instead. This generalisation has always held good for mono-oxygenated substances of the above types, and the only exceptions are amongst those substances which contain one or more negative oxygenated complexes attached to the carbon atom adjacent to that associated with the critical oxygen atom.

The substances described in this paper conform to Erlenmeyer's rule, and by its means the formation of methylnonylketoxime by the interaction of β -benzoxyundecylene with hydroxylamine is readily explained.

The formation of these acyloxy-olefines and of 1-benzoxycamphene would appear to represent the first instance of the direct transformation of a mono-oxygenated carbonyl compound into a derivative of its enolic form. With regard to benzoxycamphene, however, some doubt existed as to its being correctly represented by the

formula $C_8H_{14} \begin{smallmatrix} \text{CH} \\ \diagup \quad \diagdown \\ \text{C} \cdot \text{OBz} \end{smallmatrix}$, and this arose from a consideration of Forster's work on a hydroxycamphene (Trans., 1901, **79**, 644; 1902, **81**, 264), to which he assigns the highly probable constitution

This substance was produced by direct steps from 1:1-bromonitrocamphane, and Forster pointed out that the origin of the uncertainty in fixing its constitution lies in the several possibilities for the elimination of hydrogen bromide from the former compound. That an uncertainty dependent on an analogous reason can exist with regard to benzoxycamphene is apparent if the structures of 1:1-bromonitrocamphane and 1:1-chlorobenzoxycamphane—the additive compound of camphor and benzoyl chloride which is assumed to be formed in the production of benzoxycamphene—are placed side by side:

The question to be decided was whether benzoxycamphene might not possess a structure similar to that of hydroxycamphene.

Hydroxycamphene is stable in presence of alkalis, and does not react with hydroxylamine (Forster, *loc. cit.*), a behaviour which accords with its constitution, whereby a transformation into camphor would, in the first instance, involve the disruption of a trimethylene ring of

the type $\begin{array}{c} \text{CMe} \\ | \\ \text{CH} - \text{C} \cdot \text{OH} \end{array}$. Such a change is hardly likely to occur under

the influence of the agents mentioned. Benzoxycamphene, on the other hand, is hydrolysed by alkalis or hydroxylamine, yielding, however, not a hydroxycamphene stable to these reagents, but camphor and camphoroxime respectively; benzoxycamphene, therefore, on hydrolysis gives a hydroxycamphene conforming to Erlenmeyer's rule, which includes those substances of the type $>\text{C}:\text{C}(\text{OH})-$; moreover, Forster has shown that hydroxycamphene, on treatment with bromine with subsequent elimination of hydrogen bromide, affords a bromocamphor which melts at 78° , has $[\alpha]_D + 19^\circ$, and is certainly not an α -bromo-derivative. Benzoxycamphene, however, on treatment with bromine followed by elimination of benzoyl bromide, gave a bromocamphor which melted at 76° , had $[\alpha]_D + 131^\circ$, and was in

all respects identical with α -bromocamphor, $C_8H_{14} \begin{smallmatrix} \text{CHBr} \\ \diagup \quad \diagdown \\ \text{C} \text{O} \end{smallmatrix}$.

The evidence thus adduced affords conclusive proof of the correctness of the structure assigned to 1-benzoxycamphene, and of the view that it is the benzoate of enolic camphor.

EXPERIMENTAL.

In the preparation of the substances described in this paper, the ketone or aldehyde and the acid chloride, in molecular proportion, were boiled together in a reflux apparatus for 4–6 hours, and the interaction was accompanied by a copious evolution of hydrogen chloride. The isolation of the condensation product was effected by direct fractional distillation, except in the case of the substance obtained from the aldehyde. The properties of β -benzoxundecylene resemble those of the other benzoxy-derivatives described in this paper, and one description will therefore suffice for the group.

β -Benzoxundecylene, $\text{CH}_2\cdot\text{C}(\text{OBz})\cdot\text{C}_9\text{H}_{19}$ or $\text{CH}_3\cdot\text{C}(\text{OBz})\cdot\text{CH}\cdot\text{C}_8\text{H}_{17}$.

This was prepared from methyl *n*-nonyl ketone and benzoyl chloride. Fractional distillation of the product under 50 mm. pressure resulted in the separation of a quantity of unchanged material boiling below 140° (50 mm.), from the condensation product which distilled at 230 – 240° . On redistillation, the latter passed over at 233 – 235° (50 mm.) as a light yellow oil, and the yield amounted to 100 per cent. of the methyl nonyl ketone employed. On analysis:

0.0941 gave 0.2696 CO_2 and 0.0788 H_2O . $\text{C} = 78.1$; $\text{H} = 9.3$.

$\text{C}_{18}\text{H}_{26}\text{O}_2$ requires $\text{C} = 78.8$; $\text{H} = 9.5$ per cent.

2.1095 depressed the freezing point of 21.75 grams of phenol by 1.135° , whence mol. wt. = 281. $\text{C}_{18}\text{H}_{26}\text{O}_2 = 274$.

0.9624 required NaOH equivalent to 36 c.c. of a decinormal solution, instead of 35.1 c.c., the calculated amount.

β -Benzoxundecylene is insoluble in aqueous alkali hydroxides and its alcoholic solution gives no coloration with ferric chloride. Its solution in dry carbon disulphide or chloroform, cooled below 0° , instantaneously decolorises bromine, and its cold alcoholic solution reduces potassium permanganate. β -Benzoxundecylene is immediately hydrolysed by warm dilute alcoholic potash with separation of potassium benzoate.

Action of Hydroxylamine.—Sodium (3.31 grams) dissolved in absolute alcohol (50 c.c.) was added to a solution of hydroxylamine hydrochloride (10 grams) in water (20 c.c.); β -benzoxundecylene (10 grams) dissolved in alcohol (20 c.c.) was then introduced, and the

mixture boiled for 6 hours. After removing some of the alcohol, water was added and the liquid extracted with ether, the ethereal solution was washed first with water and then with dilute sodium carbonate solution to remove benzoic acid; it was then dried with anhydrous potassium carbonate and the ether removed. The product was an oil which soon formed a crystalline paste; this was drained on a porous tile and the dry, crystalline substance recrystallised from dilute alcohol, from which it separated as long needles melting at 46° . On analysis:

0.1062 gave 0.2788 CO_2 and 0.1206 H_2O . $\text{C} = 71.6$; $\text{H} = 12.6$.

$\text{C}_{11}\text{H}_{23}\text{ON}$ requires $\text{C} = 71.4$; $\text{H} = 12.4$ per cent.

This substance is therefore methylnonylketoxime, which melts at 46° .

The aqueous solution, from which the oxime had been extracted by ether, when acidified with sulphuric acid and warmed for some time on the water-bath, gave, on cooling, a quantity of benzoic acid.

Action of Bromine.—To a solution of β -benzoxyundecylene (10 grams) in dry carbon disulphide (20 c.c.) at 0° , dry bromine (6 grams), also dissolved in dry carbon disulphide (20 c.c.), was slowly added in the dark. The bromine was instantly absorbed without any formation of hydrogen bromide, and as soon as the whole had been decolorised the carbon disulphide was removed in a current of dry air. The product was a thick, light yellow oil and weighed 16 grams. In order to remove the last traces of carbon disulphide prior to analysis, a small portion was allowed to remain in a vacuum over solid paraffin for some time. On opening the desiccator, it was observed that the substance showed a tendency to lose hydrogen bromide; it was therefore analysed without delay:

0.3608 gave 0.273 AgBr . $\text{Br} = 32.2$.

$\text{C}_{18}\text{H}_{26}\text{O}_2\text{Br}_2$ requires $\text{Br} = 37.0$ per cent.

It is thus seen that β -benzoxyundecylene forms a dibromide, which, however, is somewhat unstable.

Action of Heat on the Dibromide.—The dibromide was distilled under 50 mm. pressure; decomposition rapidly ensued, and fractions boiling below 170° and at 170 — 190° were collected.

The former, on redistillation under the ordinary pressure, came over at 220 — 230° as a heavy, strongly fuming liquid. When mixed with alcohol, much heat was developed, and when boiled with water it slowly dissolved, forming a clear solution, from which a quantity of benzoic acid separated on cooling. This fraction would thus seem to be benzoyl bromide.

The fraction which distilled at 170 — 190° , on redistillation under

50 mm. pressure, gave a colourless oil which contained bromine in quantity, but did not fume. The amount available did not admit of further purification. Taking into consideration the constitution of β -benzoxynundecylene and the character of the substances formed by decomposition of 1-benzoxycamphene dibromide (p. 153), the product was in all probability a bromo-derivative of methyl nonyl ketone, $C_{11}H_{21}OBr$, containing the bromine atom attached to one or other of the carbon atoms adjacent to the carbonyl group. The determination of the exact position of this bromine atom would decide between the two possibilities for the constitution of β -benzoxynundecylene (compare p. 146).

β -Benzoxynonylene, $CH_2:C(OBz) \cdot C_7H_{15}$ or $CH_3 \cdot C(OBz) : C \cdot HC_6H_{13}$.

This was prepared from methyl *n*-heptyl ketone and benzoyl chloride and the yield amounted to somewhat more than 100 per cent. of the ketone employed. It boils at 210—211° under 50 mm. pressure. On analysis :

0.1251 gave 0.3555 CO_2 and 0.1000 H_2O . $C = 77.5$; $H = 8.9$.

$C_{16}H_{22}O_2$ requires $C = 78.0$; $H = 8.9$ per cent.

2.062 required NaOH equivalent to 8.6 c.c. of a normal solution, instead of 8.4 c.c., the calculated amount.

β -Benzoxy- γ -methylheptylene,

$CH_2:C(OBz) \cdot CH(CH_3) \cdot C_4H_9$ or $CH_3 \cdot C(OBz) : C(CH_3) \cdot C_4H_9$.

This was prepared from methyl *sec*.-hexyl ketone and benzoyl chloride and the yield amounted to 100 per cent. of the ketone employed. It boils at 197—200° under 50 mm. pressure. On analysis :

0.1163 gave 0.3288 CO_2 and 0.0896 H_2O . $C = 77.1$; $H = 8.6$.

$C_{15}H_{20}O_2$ requires $C = 77.6$; $H = 8.6$ per cent.

1.947 required NaOH equivalent to 8.6 c.c. of a normal solution, instead of 8.4 c.c., the calculated amount.

β -Benzoxyhexylene, $CH_2:C(OBz) \cdot C_4H_9$ or $CH_3 \cdot C(OBz) : CH \cdot C_3H_7$.

This was prepared from methyl *n*-butyl ketone and benzoyl chloride. The yield of condensation product was small as compared with that of the higher homologues, but a further amount was obtained by boiling the mixture of unchanged ketone and benzoyl chloride, separated from the higher boiling condensation product, for a further 4 hours. In this way, 13 grams of β -benzoxyhexylene boiling at 170—175° under 50 mm. pressure were obtained from 19 grams of ketone :

0.0932 gave 0.2591 CO₂ and 0.0665 H₂O. C = 75.8; H = 7.9.

C₁₃H₁₆O₂ requires C = 76.5; H = 7.8 per cent.

1.919 required NaOH equivalent to 9.7 c.c. of a normal solution, instead of 9.4 c.c., the calculated amount.

α-Benzoxo-α-phenylethylene, C₆H₅·C(OBz)·CH₂.

This was prepared from acetophenone and benzoyl chloride, and the yield amounted to 80 per cent. of the ketone employed. It boils at 229—230° under 50 mm. pressure. On analysis:

0.1059 gave 0.3097 CO₂ and 0.0515 H₂O. C = 79.8; H = 5.4.

C₁₅H₁₂O₂ requires C = 80.3; H = 5.4 per cent.

0.8594 required NaOH equivalent to 38.8 c.c. of a decinormal solution, instead of 38.4 c.c., the calculated amount.

1-Benzoxycamphene, C₈H₁₄ $\begin{matrix} \text{CH} \\ | \\ \text{C} \cdot \text{O} \cdot \text{CO} \cdot \text{C}_6\text{H}_5 \end{matrix}$.

Camphor (50 grams) was dissolved in benzoyl chloride (50 grams) and the solution vigorously boiled for 6 hours. The product, when fractionated, yielded first a considerable proportion of unchanged material, and then, at a much higher temperature, a small amount (6 grams) of a nearly colourless oil which distilled at 210—220° under 50 mm. pressure. This operation was repeated several times, and in this way a considerable quantity of the oil was obtained; this substance, when redistilled, boiled at 215—220° under 50 mm. pressure. Benzoxycamphene is slightly lævorotatory, having α_D - 1.5° in a 25 mm. tube. On analysis:

0.1202 gave 0.3477 CO₂ and 0.0844 H₂O. C = 78.9; H = 7.8.

0.0986 „ 0.2850 CO₂ „ 0.0704 H₂O. C = 78.8; H = 7.9.

C₁₇H₂₀O₂ requires C = 79.7; H = 7.8 per cent.

0.8869 depressed the freezing point of 23 grams of phenol by 1.058°, whence mol. wt. = 269. C₁₇H₂₀O₂ = 256.

2.018 required NaOH equivalent to 7.85 c.c. of a normal solution, instead of 7.9 c.c., the calculated amount.

Hydrolysis by Alcoholic Potassium Hydroxide.—An alcoholic solution of 1-benzoxycamphene (10 grams) and potassium hydroxide (3 grams), when boiled for 45 minutes, yielded a mixture of camphor (6 grams) and potassium benzoate. The former was identified by its specific rotation, [α]_D + 33.5°, and by its oxime, which melted at 118°.

Action of Hydroxylamine.—This reagent was employed in alcoholic solution in the manner described under β-benzoxoundecylene. The final products were benzoic acid and camphoroxime, the latter being

identified by its melting point, 115—116°, and its specific rotation, $[\alpha]_D - 42.1^\circ$.

Action of Bromine.—1-Benzoxycamphene, when subjected to the action of bromine in the manner indicated under β -benzoxyundecylene, afforded a heavy, yellow oil, which, when distilled under 30 mm. pressure, yielded two fractions, one distilling below 150° and the other at 150—170°. The first fraction, when redistilled under the ordinary pressure, boiled at 220—230° and was identified as benzoyl bromide. The higher fraction, which solidified after some hours, was drained on a porous tile and recrystallised several times from light petroleum; it separated in needles melting at 75—76°, and was identified as a bromocamphor.

This compound was also produced when 1-benzoxycamphene (2 grams), dissolved in cold glacial acetic acid (50 c.c.) containing several grams of anhydrous potassium acetate in solution, was slowly treated with bromine, added drop by drop, until present in slight excess. The product, when poured into water containing sulphurous acid, yielded a heavy oil, which subsequently crystallised on shaking with warm dilute sodium carbonate solution. This substance, when recrystallised from methyl alcohol, melted sharply at 75—76° and did not depress the melting point of α -bromocamphor. That it was α -bromocamphor was further shown by a determination of its specific rotation in ethyl alcohol, which proved to be $[\alpha]_D + 131^\circ$.

α -Benzoxy- α -heptylene, $C_5H_{11} \cdot CH:CH \cdot O \cdot CO \cdot C_6H_5$.

This was prepared from *n*-heptaldehyde and benzoyl chloride. In this operation, large quantities of benzoic acid are produced, and on this account the product is conveniently purified by agitation with sodium carbonate solution in the presence of ether. The dried ethereal extract yielded two fractions, one boiling at 190—200° and the other at 205—275°, under 50 mm. pressure. The lower fraction, on redistillation, passed over almost entirely at 195° under 50 mm. pressure. On analysis:

0.1162 gave 0.3262 CO_2 and 0.0900 H_2O . C = 76.6; H = 8.6.

$C_{14}H_{18}O_2$ requires C = 77.1; H = 8.3 per cent.

This fraction, which consists therefore of α -benzoxy- α -heptylene, resembles in all respects the benzoxy-derivatives prepared from the ketones. The yield amounted to 50 per cent. of the aldehyde employed.

The higher fraction, which distilled at 205—275° under 50 mm. pressure, doubtless consisted of condensation products of *n*-heptaldehyde (compare Perkin, *Trans.*, 1883, 43, 45). The formation of a large amount of benzoic acid, which occurs in the preparation of

α -benzoxy- α -heptylene but not in the other condensations described in this paper, is explained by the fact that these condensations of *n*-heptaldehyde are accompanied by an elimination of water.

β -Valeroxyundecylene,

This was prepared from methyl *n*-nonyl ketone and valeryl chloride, and the yield amounted to 80 per cent. of the ketone employed. It boils at 185—190° under 50 mm., has a valerian-like odour, and closely resembles β -benzoxyundecylene in its properties. On analysis:

0.1009 gave 0.2795 CO_2 and 0.1081 H_2O . $\text{C} = 75.5$; $\text{H} = 11.9$.

$\text{C}_{16}\text{H}_{30}\text{O}_2$ requires $\text{C} = 75.6$; $\text{H} = 11.8$ per cent.

1.737 required NaOH equivalent to 6.9 c.c. of a normal solution, instead of 6.8 c.c., the calculated amount.

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