Studies in the Baker–Venkataraman Transformation. The Auwers Synthesis of 2-Acylcoumaran-3-ones.

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The Auwers synthesis of 2-acylcoumaran-3-ones (III) from the corresponding *o*-acyloxy-ω-chloroacetophenones (I; X = Cl) is shown almost certainly to involve an internal Claisen condensation of the Baker–Venkataraman type. This result confirms an earlier suggestion by Robertson and his collaborators (*J.*, 1949, 562). Some quaternary chlorides related to ω-chloroacetophenones are described.

Jones, Mackenzie, Robertson, and Whalley (*J.*, 1949, 562) recalled a statement by Auwers (*Ber.*, 1910, **43**, 2196) that his synthesis of 2-acylcoumaran-3-ones (III) by the action of potassium carbonate in boiling benzene on *o*-acyloxy-ω-chloroacetophenones (I; X = Cl) involved the transformation of (I) into an *o*-hydroxy-diketone (II; X = Cl) which immediately cyclised. They pointed out that support was lent to Auwers's view because stage (I) ⟶ (II) of his synthesis is analogous to the Baker–Venkataraman transformation (Baker, *J.*, 1933, 1381; Mahal and Venkataraman, *Current Sci.*, 1933, **2**,

(I) (II) (III) (IV)

214) of *o*-aroyloxyacetoarones (I; X = H) into *o*-hydroxydibenzoylmethanes (II; X = H). Wheeler and his collaborators in a series of papers (*e.g.*, *Current Sci.*, 1938, **7**, 280; *J.*, 1950, 1925) have shown that this transformation involves an internal, base-catalysed, Claisen condensation between an ester and a ketone. It has now been found that, although no intermediate diketone of type (II) can be isolated, 2-acetyl-5-methylcoumaran-3-one (III; R = Me; Me at 5) is formed from 2-acetoxy-ω-chloro-5-methylacetophenone (I; R = Me; X = Cl; Me at 5) at room temperature in dioxan in the presence of one of the following Claisen condensation bases (percentage yields are given in brackets): NaH (70); KOH (45); NaOMe (26); NaOPh (23); Na_2O_2 (9); Me·C(ONa):CH·CO_2Et (7); CPh_3Na (in ether, 35). Attempts to transform the chloro-ketone thermally, alone or in liquid paraffin, at 150° for up to 2 hours, were unsuccessful. A similar negative result was obtained on use of boron trifluoride in ether. As in the normal Baker–Venkataraman reaction the yields depend to some extent on the strength of the base (Doyle, Gógan, Gowan, Keane, and Wheeler, *Sci. Proc. Roy. Dublin Soc.*, 1948, **24**, 291); weak bases such as potassium carbonate or acetate do not react at room temperature. Sodium hydride is particularly effective, and by its use a number of 2-acylcoumaran-3-ones have been prepared from the corresponding *o*-acyloxy-ω-chloroacetophenones in yields of about 70%. Powdered potassium hydroxide gives yields of up to 50%. These results confirm the view of Jones *et al.* (*loc. cit.*) that the Auwers synthesis constitutes the first known example of a Baker–Venkataraman transformation.

Attempts to replace dioxan by pyridine as a solvent in the acylcoumaranone synthesis gave unsatisfactory results owing to the formation of quaternary chlorides of the type

$(ArCO{\cdot}CH_2{\cdot}NC_5H_5)^+Cl^-$; a number of these compounds are described in the Experimental section. It was found impossible to effect a Baker–Venkataraman migration of the benzoyl group in 2-acetyl-3-benzoyloxy-5-methylbenzofuran (IV). This compound (Auwers, *Ber.*, 1910, **43**, 2200; 1912, **45**, 985) is the benzoyl derivative of the enol form of (III; R = Me; Me at 5).

Experimental

Ethanol was used for crystallisation if no solvent is mentioned.

Preparation of Esters of ω-Chloro-2-hydroxyacetophenones.—The esters listed below (numbered for reference) were, unless otherwise stated, prepared by heating the phenol and acid chloride at 160° for 4 hr. (Auwers, *Annalen*, 1909, **364**, 167): 2-Benzoyloxy-ω-chloroacetophenone (1) had m. p. 82—83°. Auwers and Jordan (*J. pr. Chem.*, 1924, **107**, 354) give m. p. 75—82° (Found: C, 65·9; H, 4·2; Cl, 12·4. Calc. for $C_{15}H_{11}O_3Cl$: C, 65·6; H, 4·0; Cl, 12·9%); *ω-chloro-2-α-naphthoyloxyacetophenone* (2) crystallised in prisms, m. p. 102—103° (Found: C, 70·0; H, 4·2; Cl, 11·1. $C_{19}H_{13}O_3Cl$ requires C, 70·3; H, 4·0; Cl, 10·9%); *ω-chloro-2-β-naphthoyloxyacetophenone* (3) formed prisms, m. p. 103—104° (Found: C, 70·6; H, 4·0; Cl, 11·1%); *ω-chloro-4-methoxy-2-β-naphthoyloxyacetophenone* (4) separated in needles, m. p. 124—125° (Found: C, 68·3; H, 4·4; Cl, 10·7; OMe, 9·2. $C_{20}H_{15}O_4Cl$ requires C, 67·7; H, 4·2; Cl, 10·0; OMe, 8·7%); 2-acetoxy-ω-chloro-5-methylacetophenone (5) (Auwers, *Ber.*, 1910, **43**, 2197) was prepared by using acetic anhydride with perchloric acid; 2-benzoyloxy-ω-chloro-5-methylacetophenone (6) was previously prepared by Auwers (*Annalen*, 1909, **364**, 167) as was 2-*p*-anisoyloxy-ω-chloro-5-methylacetophenone (7) (Auwers, *Ber.*, 1910, **43**, 2197); *ω-chloro-5-methyl-2-p-nitrobenzoyloxyacetophenone* (8), which was prepared by the pyridine–acid chloride method (yield, less than 50%), crystallised in pale yellow prisms, m. p. 141—142° (Found: C, 57·7; H, 3·5; N, 4·3; Cl, 10·3. $C_{16}H_{12}O_5NCl$ requires C, 57·6; H, 3·6; N, 4·2; Cl, 10·6%); *ω-chloro-2-cinnamoyloxy-5-methylacetophenone* (9) separated from ligroin in prisms, m. p. 96—97° (Found: C, 69·0; H, 4·6; Cl, 11·3. $C_{18}H_{15}O_3Cl$ requires C, 68·7; H, 4·8; Cl, 11·3%); *ω-chloro-5-methyl-2-β-naphthoyloxyacetophenone* (10) formed prisms, m. p. 129—130° (Found: C, 70·8; H, 4·4; Cl, 10·8. $C_{20}H_{15}O_3Cl$ requires C, 70·9; H, 4·4; Cl, 10·5%).

Base-catalysed Conversion of Esters of ω-Chloro-2-hydroxyacetophenones into 2-Acylcoumaran-3-ones.—A mixture of the ester, dioxan (10 parts), and a base (more than 1 equiv. per mol. of ester) was shaken at room temperature for 2—5 hr., and acidified with dilute sulphuric acid. The acylcoumaranone formed was recovered by filtration or by extraction with ether. The ethereal solution was shaken with saturated aqueous cupric acetate, and the cupri-acylcoumaranone obtained was crystallised, and decomposed by dilute sulphuric acid.

The following 2-acylcoumaran-3-ones were thus prepared; the numbers are those assigned to the parent esters. The bases used and the yields of products are discussed in the introduction: *2-Benzoylcoumaran-3-one* (1) crystallised in brown-yellow needles, m. p. 82—83°, which gave a brown ethanolic ferric colour (Found: C, 75·7; H, 4·2. $C_{15}H_{10}O_3$ requires C, 75·6; H, 4·2%); *2-α-naphthoylcoumaran-3-one* (2) formed pale yellow needles, m. p. 173—175°, exhibiting a green ethanolic ferric colour (Found: C, 79·2; H, 4·4. $C_{19}H_{12}O_3$ requires C, 79·1; H, 4·2%); *2-β-naphthoylcoumaran-3-one* (3) crystallised in orange-yellow plates, m. p. 153—154°, which produced a green-brown colour with ethanolic ferric chloride (Found: C, 79·2; H, 4·5%); *6-methoxy-2-β-naphthoylcoumaran-3-one* (4) separated from ligroin in yellow cubes, m. p. 116—117°, giving a green ethanolic ferric colour (Found: C, 75·9; H, 4·7; OMe, 9·8. $C_{20}H_{14}O_4$ requires C, 75·4; H, 4·4; OMe, 9·7%); 2-acetyl-5-methylcoumaran-3-one (5) (Auwers, *Ber.*, 1910, **43**, 2200; 1912, **45**, 984) (Found: C, 69·5; H, 5·3. Calc. for $C_{11}H_{10}O_3$: C, 69·4; H, 5·3%) formed a *cupric* derivative which separated from benzene in green needles, m. p. 270—276° (decomp.) [Found: C, 59·9; H, 4·2; Cu, 14·3. $(C_{11}H_9O_3)_2Cu$ requires C, 59·8; H, 4·1; Cu, 14·4%]. When this acylcoumaranone was prepared by using as base ethyl sodioacetoacetate, its copper derivative by reason of its insolubility in ethanol was readily separated from ethyl cupriacetoacetate, which is soluble in that solvent. The technique of Hauser and Hudson (*Org. Reactions*, 1942, **1**, 284) was used in the application of triphenylmethylsodium to the preparation of this acylcoumaranone (No. 5); 2-benzoyl-5-methylcoumaran-3-one (6) (Found: C, 76·8; H, 4·9. Calc. for $C_{16}H_{12}O_3$: C, 76·3; H, 4·8%) had previously been synthesised by Auwers (*Ber.*, 1910, **43**, 2197; see also Auwers and Auffenberg, *Ber.*, 1919, **52**, 105), as had 2-*p*-anisoyl-5-methylcoumaran-3-one (7) (*Ber.*, 1910, **43**, 2199) (Found: C, 72·0; H, 5·0. Calc. for $C_{17}H_{14}O_4$: C, 72·3; H, 4·9%); *5-methyl-2-p-nitrobenzoylcoumaran-3-one* (8) separated from benzene in yellow crystals, m. p. 213—214°, exhibiting a

brown ethanolic ferric colour (Found: C, 64·3; H, 3·8; N, 4·4. $C_{16}H_{11}O_5N$ requires C, 64·6; H, 3·7; N, 4·7%); the m. p. of 2-cinnamoyl-5-methylcoumaran-3-one (9), which was obtained from the corresponding ester (9), was not depressed by addition of an authentic sample prepared by Auwers's method (*Ber.*, 1912, **45**, 985) by condensation of benzaldehyde with 2-acetyl-5-methylcoumaran-3-one (5); *5-methyl-2-β-naphthoylcoumaran-3-one* (10) crystallised in yellow needles, m. p. 125—126°, ethanolic ferric colour brown green (Found: C, 79·5; H, 4·7. $C_{20}H_{14}O_3$ requires C, 79·5; H, 4·6%).

Action of Tertiary Bases on ω-Chloroacetophenones.—A solution of ω-chloro-2-hydroxy-5-methylacetophenone in pyridine was heated at 60° for 30 min. The precipitated *1-(2-hydroxy-5-methoxyphenacyl)pyridinium chloride* separated from ethanol–ether in needles, m. p. 235°. This compound gave a purple colour with ethanolic ferric chloride, and its aqueous solution contained ionic chlorine (Found: C, 63·4; H, 5·4; N, 5·5; Cl, 13·5. $C_{14}H_{14}O_2NCl$ requires C, 63·8; H, 5·3; N, 5·3; Cl, 13·5%); *1-(2-acetoxy-5-methylphenacyl)pyridinium chloride*, which was similarly prepared in a yield of over 70% from ester No. 5, crystallised from ethanol–ether in needles, m. p. 258—260°. This compound did not give a colour with ethanolic ferric chloride, but produced ionic chlorine in aqueous solution (Found: C, 62·8; H, 5·5; N, 4·5; Cl, 10·9. $C_{16}H_{16}O_3NCl$ requires C, 63·0; H, 5·2; N, 4·4; Cl, 11·6%); *N-(2-acetoxy-5-methylphenacyl)-dimethylanilinium chloride* precipitated from a solution of the corresponding ester (5) in the base, after the mixture had been heated at 100° for 8 hr. and kept at room temperature for 14 days. The product crystallised from ethanol–ether in needles, m. p. 162—163°. The ethanolic ferric reaction was negative, and the aqueous solution contained chloride ions (Found: C, 65·1; H, 6·1; N, 4·0. $C_{19}H_{22}O_3NCl$ requires C, 65·6; H, 6·3; N, 4·0%).

In an experiment on the preparation of ω-chloro-2-α-naphthoyloxyacetophenone (ester No. 2), a mixture of the ketone (3 g.), α-naphthoyl chloride (3·4 g.), and pyridine (15 ml.) was kept at room temperature for 25 min. and acidified. Extraction of the resulting precipitate with hot ligroin removed the required ester (1·7 g.). The residual *1-(2-α-naphthoyloxyphenacyl)-pyridinium chloride* separated in plates (1·1 g.), m. p. 190—191°, which did not exhibit an ethanolic ferric reaction. The aqueous solution contained ionic chlorine (Found: C, 68·7, 68·2; H, 4·8, 4·7; N, 3·4; Cl, 8·6. $C_{24}H_{18}O_3NCl,H_2O$ requires C, 68·3; H, 4·7; N, 3·3; Cl, 8·4%).

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