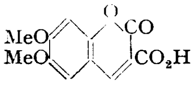
182. *The Chemistry of Fungi. Part IX.* 3 : 4-*Dihydrocoumarins.*

By F. M. Dean, Alexander Robertson, and W. B. Whalley.

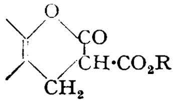
The preparation of typical 3 : 4-dihydrocoumarin-3-carboxylic acids and 3-acetyl-3 : 4-dihydrocoumarins by hydrogenation of the corresponding coumarin derivatives is described. From an examination of the properties of these products it has been concluded that *O*-dimethylcitromycin is not a derivative of 3 : 4-dihydrocoumarin as proposed in Part III (*loc. cit.*).

It is probable that the "diacetyl" derivative of 3 : 4-dihydrocoumarin described by Kaestner (*loc. cit.*) is 6-acetoacetyl-3 : 4-dihydrocoumarin.

From the evidence then available it was concluded in Part III (*J.*, 1949, 848) that citromycin and its dimethyl ether possessed a linear type of structure which could be envisaged as a cyclisation product of a 3 : 4-dihydrocoumarin derivative type (III; R = Ac). Further, the methylene group in the 4-position of the coumarin residue (III) was considered to be involved in the novel oxidation $\dot{:}CH_2 \longrightarrow \dot{:}CH(OH) \longrightarrow \dot{:}CO$ effected with ozone and in the hydroxylation process with lead tetra-acetate, a view which appeared to receive support from studies on the oxidation of xanthens under similar conditions Part VIII (*J.*, 1949, 1567). The experiments described in the present communication were undertaken during our search for collateral evidence in support of the proposed structure for *O*-dimethylcitromycin and had three objectives: (*a*) to investigate the preparation of dihydrocoumarins of types (II) and (III; R = H) which could be employed as intermediates in the synthesis of (III; R = Ac) and hence of *O*-dimethylcitromycin; (*b*) to compare the 2 : 4-dinitrophenylhydrazone of (III; R = H) with the corresponding derivative, m. p. 282° (decomp.), of a product which was considered to be (III; R = H) (Part III, *loc. cit.*); and (*c*) to examine the behaviour of compounds of types (II) and (III; R = H) towards lead tetra-acetate and hydrolytic agents because compounds having structures (II) and (III; R = H) would provide a closer analogy with *O*-dimethylcitromycin than do the xanthens (Part VIII, *loc. cit.*).



(I.)



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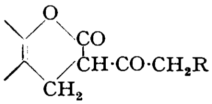


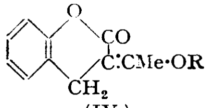
(III.)

The preparation of 3 : 4-dihydrocoumarin-3-carboxylic acids containing a quinol nucleus by the hydrogenation of the corresponding coumarin-3-carboxylic acids has been extensively studied by Smith and his collaborators (see, *e.g.*, *J. Amer. Chem. Soc.*, 1936, **58**, 304) who have also described the preparation of 6-hydroxy- and 6-methoxy-3-acetyl-5 : 7 : 8-trimethyl-3 : 4-dihydrocoumarin by the hydrogenation of 6-hydroxy-3-acetyl-5 : 7 : 8-trimethylcoumarin and its methyl ether (*ibid.*, 1937, **59**, 667). In the present work similar methods have been employed.

The hydrogenation of coumarin-3-carboxylic acid in the form of its sodium salt with a palladium–charcoal catalyst gave a mixture of the expected 3 : 4-*dihydrocoumarin*-3-*carboxylic acid* with its hydrated derivative, 2-*hydroxybenzylmalonic acid*, which became the main product when 3 : 4-dihydrocoumarin-3-carboxylic acid, which separated initially on acidification of the filtered reaction mixture, was kept in contact with the mother-liquor. Methyl 2-hydroxybenzylmalonate was prepared by means of diazomethane and on distillation gave an almost quantitative yield of *methyl* 3 : 4-*dihydrocoumarin*-3-*carboxylate* which was also formed by the hydrogenation of coumarin-3-carboxylic acid in methanol. The hydrogenation of 6 : 7-*dimethoxycoumarin*-3-*carboxylic acid* (I) as its sodium salt furnished a mixture of 6 : 7-dimethoxy-3 : 4-dihydrocoumarin-3-carboxylic acid (II; R = H) and the corresponding benzylmalonic acid which on distillation in a vacuum gave rise to 6 : 7-dimethoxy-3 : 4-dihydrocoumarin. Treatment of the mixed acids with an excess of ethereal diazomethane gave the esters from which *methyl* 6 : 7-*dimethoxy*-3 : 4-*dihydrocoumarin*-3-*carboxylate* (II; R = Me) was isolated. When it was found that the acid chloride of 3 : 4-dihydrocoumarin-3-carboxylic acid could not be obtained by one or other of the standard methods, the preparation of other members of this series was abandoned.

Application of the hydrogenation process to 3-acetylcoumarin gave an excellent yield of 3-*acetyl*-3 : 4-*dihydrocoumarin* apparently as a keto–enol equilibrium mixture, in all probability (IV; R = H) and (V), from which the pure keto-form giving a negative ferric reaction was isolated. Acetylation of the mixture gave the *acetate* (IV; R = Ac) of the enolic compound which, as expected, did not react with ketonic reagents. The independent synthesis of 3-acetyl-

3 : 4-dihydrocoumarin in small yield by the interaction of 2-(*ethyl carbonato*)*benzylacetone* and ethyl carbonate in the presence of sodium served to confirm the structure of the compound. In contrast to the behaviour of the parent 3-acetylcoumarin the hydrogenation of 6 : 7-dimethoxy-3-acetylcoumarin was much slower and the main product was 6 : *7-dimethoxy-3-ethylcoumarin* accompanied by only small amounts of the required 6 : *7-dimethoxy-3-acetyl-3* : *4-dihydrocoumarin* (III; R = H), the 2 : 4-dinitrophenylhydrazone, m. p. 228°, of which was not identical with the product, m. p. 282° (decomp.), obtained from *O*-dimethylcitromycin (Part III, *loc. cit.*); the yield of (III; R = H) was slightly increased when platinum–charcoal was employed as the catalyst in place of palladium–charcoal. Consequently we examined the hydrogenation of a number of analogous 3-acetylcoumarins under similar conditions.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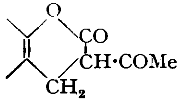
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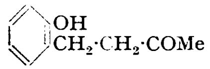
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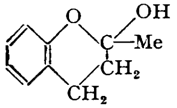
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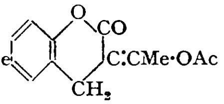
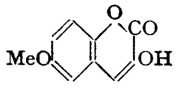

(VIII.)


(IX.)

3-Acetyl-6-methyl- and *6-methoxy-3-acetyl-coumarin* behaved normally, giving the respective 3 : *4-dihydrocoumarins.* On the other hand *3-acetyl-7-methyl-* and *7-methoxy-3-acetyl-coumarin* gave only small yields of the 3 : *4-dihydrocoumarins* which were separated from the main products of the reaction by taking advantage of the fact that 3-acetyl-3 : 4-dihydrocoumarins readily form chelated derivatives on treatment with aqueous copper acetate. From 3-acetyl-7-methylcoumarin the principal hydrogenation product was a compound which was readily differentiated from *7-methyl-3-ethylcoumarin* and appeared to be *7-methyl-3-1′-hydroxyethyl-coumarin.* With 7-methoxy-3-acetylcoumarin the main product was *7-methoxy-3-ethylcoumarin*, whilst 7-hydroxy-3-acetylcoumarin gave only the corresponding 3-ethylcoumarin.

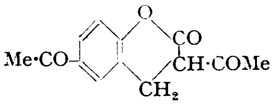
In their behaviour towards oxidising and hydrolytic agents the 3 : 4-dihydrocoumarin derivatives which have been examined showed a marked contrast to *O*-dimethylcitromycin under comparable conditions. 3 : 4-Dihydrocoumarin-3-carboxylic acid and its methyl ester, and 3-acetyl-3 : 4-dihydrocoumarin together with its 6-methyl and 6-methoxy-derivatives, readily underwent dehydrogenation with lead tetra-acetate, regenerating the parent coumarin derivatives which did not appear to be accompanied by detectable amounts of products oxygenated at the 4-position. In this connection it is of interest to note that 6-methoxy- and 6 : 7-dimethoxy-3-acetyl-3 : 4-dihydrocoumarin are readily dehydrogenated to the corresponding coumarins when solutions of the compounds are exposed to atmospheric oxygen, whilst in an alcoholic solution of 2 : 4-dinitrophenylhydrazine the 2 : *4-dinitrophenylhydrazone* of 3-acetyl-3 : 4-dihydrocoumarin is oxidised to the 2 : *4-dinitrophenylhydrazone* of 3-acetylcoumarin. The action of lead tetra-acetate clearly proceeds by the replacement of the active hydrogen atom in the 3-position of the 3-carboxy- or 3-acetyl-dihydrocoumarin by an acetoxy-group followed by the loss of acetic acid and the formation of the coumarin system. This reaction mechanism is in keeping with the failure of the reagent to dehydrogenate 3 : 4-dihydrocoumarin, its 6 : 7-dimethoxy-derivative, or the *acetate* (VIII) of the enolic form of 6-methyl-3-acetyl-3 : 4-dihydrocoumarin. On ozonolysis 6-methoxy-3-acetyl-3 : 4-dihydrocoumarin furnished a mixture from which *3-hydroxy-6-methoxycoumarin* and 2-hydroxy-4-methoxybenzaldehyde were isolated, but a search failed to reveal the presence of 4-hydroxy-6-methoxy-3-acetylcoumarin.

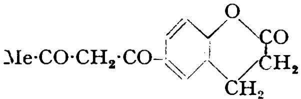
In their behaviour on hydrolysis with acidic and alkaline reagents 3-acetyl-3 : 4-dihydrocoumarins differ markedly from *O*-dimethylcitromycin. With these reagents the lactone ring of the dihydrocoumarin is opened and carbon dioxide is then eliminated, resulting in the formation of 2-hydroxybenzylacetones which, in the examples studied, have been isolated in the ketonic and cyclic forms represented by types (VI) and (VII) respectively. The alkali-insoluble cyclic forms readily give the 2 : 4-dinitrophenylhydrazones derived from the ketones.

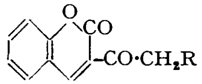
From our examination of the properties of 3 : 4-dihydrocoumarins it now seems reasonably certain that the citromycin molecule does not contain a 3 : 4-dihydrocoumarin residue as suggested in Part III (*loc. cit.*). Hydrolysis of citromycin or its dimethyl ether under a variety of conditions (Part III and unpublished work) has failed to yield products containing a

2-hydroxybenzylacetone nucleus. Further, the proposed formulæ for citromycin and its ether (Part III) implied that in the degradation of the ether to 2-hydroxy-4 : 5-dimethoxyacetophenone and -benzoic acid with alkali the methylene group in the 4-position of the 3 : 4-dihydrocoumarin residue was oxidised, whereas the authentic 3 : 4-dihydrocoumarin derivatives examined do not undergo degradation in this way.

In the course of exploratory experiments on the synthesis of 3-acetyl-3 : 4-dihydrocoumarins by alternate routes we examined the reaction reported by Kaestner (" Newer Methods of Preparative Organic Chemistry," 1948, New York, p. 296) by which 3 : 4-dihydrocoumarin is stated to be acetylated with the aid of boron trifluoride, giving the 3 : 6-diacetyl derivative (X). On the basis of this result it seemed reasonable to expect that 3 : 4-dihydrocoumarins substituted in the 6-position would give the 3-acetyl derivative (type III, R = H). This reaction failed, however, in the case of 6 : 7-dimethoxy-3 : 4-dihydrocoumarin, a result which led us to examine the diacetyl derivative of 3 : 4-dihydrocoumarin described by Kaestner who did not, however, record the melting point of the compound. Though our investigation is not yet complete, it appears that the compound is not 3 : 6-diacetyl-3 : 4-dihydrocoumarin (X), but, from the following considerations is, in all probability, 6-acetoacetyl-3 : 4-dihydrocoumarin (XI) :


(X.)


(XI.)


(XII.)

(*a*) Kaestner's compound gives a deep-red ferric reaction typical of compounds containing the group ·CO·CH$_2$·CO·, whereas 3-acetyl-3 : 4-dihydrocoumarins invariably give a characteristic intense purple ferric reaction which we would not expect to be modified by the presence of an acetyl group in the 6-position.

(*b*) The compound is hydrolysed with 2N-aqueous sodium hydroxide to a product believed to be 6-acetyl-3 : 4-dihydrocoumarin (cf. Kaestner *loc. cit.*), whereas dihydrocoumarins *C*-acetylated in the 3-position invariably give a 2-hydroxybenzylacetone derivative.

(*c*) With lead tetra-acetate the compound reacts rapidly yielding an oil which retains the red ferric reaction—a property in keeping with the acetoxylation of a β-diketone, *i.e.*, CO·CH$_2$·CO ⟶ ·CO·CH(O·COMe)·CO·, whereas a dihydrocoumarin of the type (X) would be expected to undergo dehydrogenation yielding 3 : 6-diacetylcoumarin which would not give a ferric reaction.

(*d*) As far as we are aware β-ketonic esters cannot be prepared by the boron trifluoride–acetic anhydride method, and dihydrocoumarins substituted in the 6-position do not appear to form the corresponding 3-acetyl-3 : 4-dihydrocoumarins by this method. The latter compounds form comparatively stable complexes with boron trifluoride which do not react further and hence we were unable to prepare, by this route, 3-acetoacetyl-3 : 4-dihydrocoumarins cyclisation of which might be expected to give compounds having the type of structure proposed for *O*-dimethylcitromycin in Part III (*loc. cit.*). It would appear, therefore, that in Kaestner's preparation acetylation of dihydrocoumarin occurs first in the 6-position and, as the methyl of the *C*-acetyl group is more reactive than the α-methylene of an ester or lactone, further acetylation then takes place giving the 6-acetoacetyl derivative (XI) by way of the boron trifluoride complex. It is of interest to note that the acetylation of 3-acetylcoumarin (XII; R = H) by the same method gave 3-acetoacetylcoumarin (XII; R = Ac) which Trenknerowna (*Roczniki Chem.*, 1936, **16**, 6, 10) has synthesised by an independent route and which has a ferric reaction similar to Kaestner's compound.

EXPERIMENTAL.

3 : 4-*Dihydrocoumarin*-3-*carboxylic Acid*.—The sodium salt of coumarin-3-carboxylic acid in water (150 ml.) was prepared as a slurry from the acid (4 g.) and sodium hydrogen carbonate (2·1 g.) and subjected to hydrogenation with a palladium–charcoal catalyst (from 1 g. of charcoal and 0·4 g. of palladium chloride) and hydrogen at 62 lbs./sq. in. for 4 hours. On acidification with hydrochloric acid the filtered solution deposited during 10 minutes 3 : 4-*dihydrocoumarin*-3-*carboxylic acid* as a mass of fine needles (Found : C, 62·5; H, 4·5. $C_{10}H_8O_4$ requires C, 62·5; H, 4·2%) which had m. p. 142° after recrystallisation from water or ethyl acetate; the yield was somewhat variable, but in general about 2·5 g. were obtained from 4 g. of coumarin-3-carboxylic acid. This dihydro-acid is sparingly soluble in warm ligroin and readily soluble in alcohol or aqueous sodium hydrogen carbonate, and on being kept at 150—160° for 15 minutes decomposed with the evolution of carbon dioxide, giving a quantitative yield of 3 : 4-dihydrocoumarin, b. p. 178°/0·1 mm., which was identified by being converted into the

hydrazide, m. p. 166°, of melilotic acid (undepressed on admixture with an authentic specimen) (Pschorr and Einbeck, *Ber.*, 1905, **38**, 2070, gave m. p. 164—165°). Prepared by means of diazomethane, *methyl* 3 : 4-*dihydrocoumarin*-3-*carboxylate* formed colourless prisms, m. p. 98—100°, from 85% alcohol, insoluble in aqueous sodium hydrogen carbonate and slowly soluble in 2N-aqueous sodium hydroxide (Found : C, 64·2; H, 5·0. $C_{11}H_{10}O_4$ requires C, 64·1; H, 4·9%).

When the crude 3 : 4-dihydrocoumarin-3-carboxylic acid was left in contact with the acidified mother-liquor the solid dissolved, and on being kept for several weeks the solution gradually deposited 2-*hydroxybenzylmalonic acid* in large colourless prisms, m. p. 142° (decomp.), readily soluble in aqueous sodium hydrogen carbonate [Found : C, 57·0; H, 4·9%; equiv. (by titration), 109·4. $C_{10}H_{10}O_5$ requires C, 57·2; H, 4·8%; equiv., 105]. A small quantity of this malonic acid was occasionally obtained from the solution left after the separation of 3 : 4-dihydrocoumarin-3-carboxylic acid. Although a mixture of this dibasic acid and 3 : 4-dihydrocoumarin-3-carboxylic acid did not show a depression in the melting point, it was clear that the two substances were not identical. Esterification of the dibasic acid with ethereal diazomethane yielded a liquid which, on distillation in a vacuum at 134—136°/0·5 mm., was completely converted into methyl 3 : 4-dihydrocoumarin-3-carboxylate, m. p. and mixed m. p. 98°, after purification.

Hydrogenation of coumarin-3-carboxylic acid (10 g.) in methanol (200 ml.) with a palladium–charcoal catalyst and hydrogen at 100 lbs./sq. in. gave an oil which, on distillation in a vacuum, partly crystallised. The solid, which slowly separated, was freed from adhering liquid by means of a porous tile and recrystallised from ethyl acetate–ligroin, giving methyl 3 : 4-dihydrocoumarin-3-carboxylate, m. p. and mixed m. p. 97—98° (Found : C, 63·9; H, 4·8%). This compound reacted with warm 50% hydrazine hydrate solution, giving the 2-*hydroxybenzylmalonodihydrazide* which formed large colourless prisms, m. p. 236—240° (decomp.), from warm water (Found : C, 50·1; H, 5·8; N, 23·5. $C_{10}H_{14}O_3N_4$ requires C, 50·4; H, 5·9; N, 23·8%). The oil left after the separation of the crude methyl 3 : 4-dihydrocoumarin-3-carboxylate appeared to consist mainly of 3 : 4-dihydrocoumarin since it gave the hydrazide, m. p. and mixed m. p. 166°, of melilotic acid.

Dehydrogenation of 3 : 4-*Dihydrocoumarin*-3-*carboxylic Acid.*—When powdered lead tetra-acetate (1 g.) was added to a solution of the acid (0·5 g.) in acetic acid (10 ml.) a white lead salt separated during 3 hours, and the mixture then had a negative starch–iodide reaction. Treatment of the solid with warm dilute nitric acid gave a yellow solution which on being cooled deposited coumarin-3-carboxylic acid in colourless prisms (0·18 g.), m. p. 202°, identical with an authentic specimen. When the acid was replaced by methyl 3 : 4-dihydrocoumarin-3-carboxylate (0·5 g.) in the foregoing experiment and the mixture kept for 24 hours and then diluted with water, methyl coumarin-3-carboxylate separated in colourless needles, m. p. 119—120°, after purification, identified by comparison with an authentic specimen.

6 : 7-*Dimethoxycoumarin*-3-*carboxylic Acid* (I).—2-Hydroxy-4 : 5-dimethoxybenzaldehyde (3 g.) and sodium cyanoacetate (50 ml. of a solution prepared according to Phelps and Tillotson, *Amer. Journ. Science*, 1908, **26**, 275) were caused to react by means of sodium hydroxide (10 g.) in water (10 ml.) during 24 hours. Acidification of the reaction mixture with hydrochloric acid furnished a deep-yellow product which was heated under reflux with concentrated hydrochloric acid (20 ml.) and water (30 ml.) for 10 minutes, giving rise to the *coumarin*-3-*carboxylic acid*. Recrystallised from alcohol, this compound formed lemon-yellow needles (3 g.), m. p. 266° (decomp.), insoluble in water or ligroin and readily soluble in ethyl acetate, chloroform, or aqueous sodium hydrogen carbonate (Found : C, 57·5; H, 3·9. $C_{12}H_{10}O_6$ requires C, 57·6; H, 4·0%). Prepared by means of ethereal diazomethane, the *methyl* ester separated from alcohol in yellow prisms, m. p. 212°, soluble in benzene or ethyl acetate (Found : C, 59·3; H, 4·6. $C_{13}H_{12}O_6$ requires C, 59·1; H, 4·6%). Alcoholic solutions of the acid or its ester exhibited an intense blue fluorescence.

Methyl 6 : 7-*Dimethoxy*-3 : 4-*dihydrocoumarin*-3-*carboxylate* (II; R = Me).—Hydrogenation of the foregoing coumarin-3-carboxylic acid (0·5 g.), dissolved in water (25 ml.) containing sodium hydrogen carbonate (0·17 g.), with 20% palladium–charcoal (1 g.) and hydrogen at 60 lbs./sq. in. for 4 hours gave a mixture consisting mainly of 2-hydroxy-4 : 5-dimethoxybenzylmalonic acid with small amounts of 6 : 7-dimethoxy-3 : 4-dihydrocoumarin-3-carboxylic acid which could not be conveniently separated. Recrystallised from water this product formed colourless needles (0·3—0·45 g.), m. p. 120° (decomp.), readily soluble in aqueous sodium hydrogen carbonate [Found : C, 50·5; H, 5·5%; equiv. (by titration) 135. Calc. for $C_{12}H_{12}O_6$: C, 57·1; H, 4·8%; equiv., 252. Calc. for $C_{12}H_{14}O_6,H_2O$: C, 50·0; H, 5·6%; equiv., 138]. On distillation at 155—160°/0·14 mm., the recrystallised product (1 g.) gave 6 : 7-dimethoxy-3 : 4-dihydrocoumarin (0·7 g.), m. p. 79—80° (Part II, *J.*, 1949, 565), and on treatment with an excess of ethereal diazomethane furnished an oil (1 g.) which, on being kept, deposited *methyl* 6 : 7-*dimethoxy*-3 : 4-*dihydrocoumarin*-3-*carboxylate* (II; R = Me) (0·1 g.), insoluble in cold dilute aqueous sodium hydroxide. Since it was readily soluble in alkali and on distillation at 190/0·1 mm. gave (II; R = Me) (0·7 g.), the residual oil appeared to be mainly methyl 2-hydroxy-4 : 5-dimethoxybenzylmalonate. Recrystallised from ethanol, the ester (II; R = Me) formed rectangular prisms, m. p. 151—152° (Found : C, 58·4; H, 5·3. $C_{13}H_{14}O_6$ requires C, 58·6; H, 5·3%). Lead tetra-acetate (0·16 g.) in acetic acid (8 ml.) was added during 1 hour to a solution of methyl 6 : 7-dimethoxy-3 : 4-dihydrocoumarin-3-carboxylate (0·1 g.) in acetic acid (8 ml.), and 3 hours later the mixture was diluted with water (50 ml.), giving methyl 6 : 7-dimethoxycoumarin-3-carboxylate which slowly separated in long lemon-yellow needles, m. p. 212°, identical with an authentic specimen.

3-*Acetyl*-3 : 4-*dihydrocoumarin.*—(*a*) 3-Acetylcoumarin (Knoevenagel, *Ber.*, 1898, **31**, 732) formed a 2 : 4-*dinitrophenylhydrazone* which separated from acetic acid in orange prisms, m. p. 257—258° (decomp.) (Found : C, 55·2; H, 3·5; N, 14·9. $C_{17}H_{12}O_6N_4$ requires C, 55·4; H, 3·3; N, 15·3%).

A suspension of 3-acetylcoumarin (5 g.) in methanol (200 ml.) was agitated with palladium–charcoal (from 1 g. of charcoal and 0·1 g. of palladium chloride) and hydrogen at 60 lbs./sq. in. at room temperature for 1 hour and the filtered reaction mixture evaporated in a vacuum at 40°, leaving a colourless residue (4·8 g.), m. p. ~58°; traces of mineral acid in the catalyst or evaporation at higher temperatures caused decomposition of the product. Recrystallisation of the residual solid from aqueous methanol or benzene–ligroin gave 3-*acetyl*-3 : 4-*dihydrocoumarin* in colourless elongated plates, m. p. 62°, giving a deep-purple ferric reaction in alcohol (Found : C, 69·8; H, 5·2. $C_{11}H_{10}O_3$ requires C, 69·5; H, 5·3%). This compound is insoluble in aqueous sodium hydrogen carbonate, sparingly soluble in cold ligroin, and readily soluble in benzene, alcohol, chloroform, or 1% aqueous sodium hydroxide. The *oxime* separated from aqueous alcohol in colourless prisms, m. p. 174° (decomp.) after becoming reddish-brown at 160—170°, which are readily soluble in dilute aqueous sodium hydroxide (Found : C, 65·0; H, 5·4; N, 6·6. $C_{11}H_{11}O_3N$ requires C, 64·4; H, 5·4; N, 6·8%). Crystallised from alcohol, the *semicarbazone* was obtained in colourless prisms, m. p. 188°, which exhibited a royal-blue ferric reaction in alcohol and were instantly soluble in cold 2N-aqueous sodium hydroxide (Found : C, 58·2; H, 5·5; N, 17·3. $C_{12}H_{13}O_3N_3$ requires C, 58·3; H, 5·3; N, 17·0%). The 2 : 4-*dinitrophenylhydrazone* separated from ethyl acetate in yellow needles, m. p. 174° (Found : C, 55·3; H, 3·7; N, 14·9. $C_{17}H_{14}O_6N_4$ requires C, 55·1; H, 3·8; N, 15·1%). When the crude hydrazone was allowed to remain in contact with the excess of 2 : 4-dinitrophenylhydrazine solution for about a week, its colour changed to deep orange. Recrystallised from ethyl acetate the product then gave the 2 : 4-dinitrophenylhydrazone of 3-acetylcoumarin in orange prisms, m. p. 258° (decomp.), identified by comparison with an authentic specimen. Addition of aqueous copper acetate to an alcoholic solution of 3-acetyl-3 : 4-dihydrocoumarin gave a precipitate of the insoluble copper derivative from which the dihydrocoumarin was regenerated by treatment with cold dilute mineral acid and ether, followed by evaporation of the dried ethereal liquor.

A mixture of 3-acetyl-3 : 4-dihydrocoumarin (0·5 g.), acetic anhydride (2 ml.), and pyridine (2 ml.) was warmed on the steam-bath for 10 minutes, kept for 24 hours, and poured into an excess of dilute hydrochloric acid. The resulting oily O-*acetyl* derivative solidified in contact with a little alcohol and then crystallised from aqueous alcohol in slender prisms (0·4 g.), m. p. 65—66°, insoluble in cold dilute aqueous sodium hydroxide and having a negative ferric reaction (Found : C, 67·5; H, 5·4. $C_{13}H_{12}O_4$ requires C, 67·2; H, 5·2%). Mixed with the parent compound the acetyl derivative had m. p. 38—50°.

During numerous hydrogenation experiments with 3-acetyl-3 : 4-dihydrocoumarin it was found that the m. p. of the product varies between 58° and 63° but the product which separated from alcoholic solvents usually had m. p. 62° and, when fused, allowed to solidify, and then re-heated, this material melted again at 62°. After being kept for several months a sample, which originally had m. p. 62°, melted at 66°. On one occasion the spontaneous evaporation of a dilute benzene–light petroleum (b. p. 60—80°) solution of a sample, m. p. 62°, which had been crystallised several times from dilute methanol, gave large prisms, m. p. 67°, which appeared to be the pure keto-form (V), since it had a negative ferric reaction in alcohol and instantaneously gave the 2 : 4-dinitrophenylhydrazone, m. p. 172°, identical with that obtained from the material, m. p. 62°. When a solution of this apparently pure keto-compound in alcohol was warmed, cooled, and treated with a drop of aqueous ferric chloride it gave the intense purple colour, indicating the presence of the enolic form in the solution. Repeated fusion, followed by cooling, of the pure keto-compound gave the product, m. p. 62°. A mixture of the latter and the keto-compound, m. p. 67°, had m. p. 63—66° which changed to 62° on repeated fusion.

(*b*) Ethyl chloroformate (2·0 g.) was added drop-wise to a vigorously agitated solution of 2-hydroxybenzylacetone (Harries, *Ber.*, 1891, **24**, 3180) (2 g.) in a slight excess of N-aqueous sodium hydroxide, and one hour later the resulting 2-(*ethyl carbonato*)*benzylacetone* was isolated with ether and purified by distillation, being obtained as a colourless oil (1·7 g.), b. p. 125—128°/0·2 mm., readily soluble in the usual organic solvents except ligroin (Found : C, 66·9; H, 6·9. $C_{13}H_{16}O_4$ requires C, 66·1; H, 6·9%). A mixture of this ketone (1·7 g.), pulverised sodium (1 g.), and ethyl carbonate (10 g.) was kept at 80° for 3 hours and the resulting flocculent precipitate was collected, washed with ether, dried, and dissolved in water covered with a layer of ether. This mixture was saturated with carbon dioxide, the ethereal layer was separated and evaporated, a solution of the oily residue in a little alcohol was treated with saturated aqueous copper acetate, and the resulting green precipitate (80 mg.) was washed with water, alcohol, and ether and decomposed with 5% sulphuric acid in the presence of ether, giving 3-acetyl-3 : 4-dihydrocoumarin (50 mg.) which formed colourless prisms, m. p. 62—63°, from light petroleum (b. p. 60—80°), identical with a specimen prepared by method (*a*), and gave the 2 : 4-dinitrophenylhydrazone, m. p. and mixed m. p. 170°. Left in contact with 2 : 4-dinitrophenylhydrazine solution the latter derivative gave rise to the 2 : 4-dinitrophenylhydrazone of 3-acetylcoumarin, m. p. 257—258° (decomp.).

When the pale yellow solution of 3-acetyl-3 : 4-dihydrocoumarin (0·5 g.) in N-aqueous sodium hydroxide (6 ml.) was heated on the steam-bath for ½ hour a pale yellow oil (negative ferric reaction) separated and was isolated from the cooled mixture with ether. Acidification of the residual alkaline liquor, followed by extraction with ether, gave a small amount of a phenolic product. These compounds, which are respectively 2-hydroxy-2-methylchroman and its isomeride 2-hydroxybenzylacetone (Harries, *Ber.*, 1891, **24**, 3180), have a characteristic pleasant odour and give the same 2 : 4-*dinitrophenylhydrazone*, which forms bright yellow prisms, m. p. 152°, identified by comparison with an authentic specimen (Found : C, 55·3; H, 4·5; N, 16·3. $C_{16}H_{16}O_5N_4$ requires C, 55·8; H, 4·7; N, 16·3%).

When lead tetra-acetate (1·1 g.) was added to a solution of 3-acetyl-3 : 4-dihydrocoumarin (0·5 g.) in acetic acid (15 ml.) the mixture became slightly warm and the lead salt gradually dissolved. 2 Hours later the resulting pale yellow solution gave a negative test for quadrivalent lead and, on the addition of an excess of water, deposited 3-acetylcoumarin as an oil which quickly solidified and then crystallised from dilute methanol in pale yellow prisms, m. p. 123°, undepressed on admixture with an authentic specimen. The 2 : 4-dinitrophenylhydrazone had m. p. and mixed m. p. 258° (decomp.).

3-*Acetyl*-6-*methyl*-3 : 4-*dihydrocoumarin*.—Prepared by the hydrogenation of 3-acetyl-6-methylcoumarin (Chuit and Bolsing, *Bull. Soc. chim.*, 1915, **35**, 89) (2 g.), 3-*acetyl*-6-*methyl*-3 : 4-*dihydrocoumarin* (1·9 g.) separated from ligroin and then dilute alcohol in colourless prisms, m. p. 71—73°, soluble in hot water, alcohol, or ethyl acetate, and giving an intense purple ferric reaction in alcohol (Found : C, 71·1; H, 5·7. $C_{12}H_{12}O_3$ requires C, 70·6; H, 5·9%). The 2 : 4-*dinitrophenylhydrazone* formed orange-yellow prisms, m. p. 195—196°, from ethyl acetate (Found : C, 56·0; H, 4·1; N, 14·3. $C_{18}H_{16}O_6N_4$ requires C, 56·3; H, 4·2; N, 14·6%). The *semicarbazone* separated from alcohol and then methanol in colourless prisms or needles, m. p. 265° (decomp.), readily soluble in 2N-aqueous sodium hydroxide and giving a royal-blue ferric reaction in alcohol (Found : C, 59·9; H, 6·0; N, 16·4. $C_{13}H_{15}O_3N_3$ requires C, 59·7; H, 5·8; N, 16·1%).

Acetylation of 3-acetyl-6-methyl-3 : 4-dihydrocoumarin (2 g.) with acetic anhydride (6 ml.) and pyridine (3 ml.) at room temperature for 16 hours gave an oily solid which, after having been drained on a porous tile, was crystallised from dilute alcohol and then dilute methanol, giving the *acetate* (VIII) of the enolic form of the coumarin in colourless shining plates, m. p. 125° (Found : C, 68·1; H, 5·8. $C_{14}H_{14}O_4$ requires C, 68·3; H, 5·7%). This compound, which is soluble in benzene and in hot ligroin, gives a negative ferric reaction in alcohol and does not react with 2 : 4-dinitrophenylhydrazine.

A solution of 3-acetyl-6-methyl-3 : 4-dihydrocoumarin (1 g.) in 2N-sodium hydroxide (10 ml.) was heated on the steam-bath for ½ hour, cooled, and extracted with ether. Evaporation of the dried ethereal extract left a neutral oil, whilst saturation of the residual alkaline liquor with carbon dioxide followed by extraction with ether gave a phenolic oil These phenolic and neutral products, which had similar odours and became purple on being heated, appear to be 2-hydroxy-4-methylbenzylacetone and its cyclic form, 2-hydroxy-2 : 6-dimethylchroman, respectively, since they give rise to the same 2 : 4-*dinitrophenylhydrazone*, forming orange plates, m. p. 165—166°, from dilute alcohol, readily soluble in 1% aqueous sodium hydroxide (Found : C, 57·4; H, 5·4. $C_{17}H_{18}O_5N_4$ requires C, 57·0; H, 5·0%).

Oxidation of 3-acetyl-6-methyl-3 : 4-dihydrocoumarin (1 g.) with lead tetra-acetate (2·1 g.) in acetic acid (15 ml.) at room temperature for 2 hours gave 3-acetyl-6-methylcoumarin (0·85 g.) which formed pale yellow plates, m. p. 131°, from methanol, identical with an authentic specimen. The 2 : 4-*dinitrophenylhydrazone* separated from ethyl acetate in orange prisms, m. p. 256—258°, undepressed on admixture with an authentic specimen (Found : N, 14·9. $C_{18}H_{14}O_6N_4$ requires N, 14·7%).

6-*Methoxy*-3-*acetylcoumarin*.—A few drops of piperidine were added to a mixture of 2-hydroxy-4-methoxybenzaldehyde (Tiemann and Muller, *Ber.*, 1881, **14**, 1990) (10 g.) and ethyl acetoacetate (10 ml.), and the reaction was completed by heating the deep-yellow solution on the steam-bath for 10 minutes. On being cooled the reaction mixture deposited 6-*methoxy*-3-*acetylcoumarin* as a yellow crystalline mass which, after the addition of alcohol (10 ml.), was collected and purified from this solvent, forming brilliant yellow plates (12 g.), m. p. 182—183° (Found : C, 65·9; H, 4·8. $C_{12}H_{10}O_4$ requires C, 66·0; H, 4·6%). The 2 : 4-*dinitrophenylhydrazone* separated from ethyl acetate in diamond-shaped plates, m. p. 242—243° (Found : N, 14·3. $C_{18}H_{14}O_7N_4$ requires N, 14·1%).

6-*Methoxy*-3-*acetyl*-3 : 4-*dihydrocoumarin*.—Hydrogenation of the foregoing coumarin (1 g.) in methanol (200 ml.) with palladium–charcoal and hydrogen at 60 lbs./sq. in., followed by evaporation of the filtered reaction mixture in a vacuum at 40°, gave a gummy solid (0·95 g.) which was purified by repeated crystallisation from alcohol and then light petroleum (b. p. 60—80°), furnishing 6-*methoxy*-3-*acetyl*-3 : 4-*dihydrocoumarin* in pale yellow prisms, m. p. 82—84°. It was observed during the purification from alcohol that each time the compound was dissolved in the solvent a small amount of a highly insoluble yellow product was formed which was found to be 6-methoxy-3-acetylcoumarin arising by the atmospheric oxidation of the 3 : 4-dihydrocoumarin in alcoholic solution. Purified from alcohol, the 6-methoxy-3-acetylcoumarin formed yellow needles, m. p. and mixed m. p. 182—183°, and gave the 2 : 4-dinitrophenylhydrazone, m. p. 242°. When the isolation and purification of the hydrogenation product were carried out in an atmosphere of nitrogen, 6-methoxy-3-acetyl-3 : 4-dihydrocoumarin was obtained in colourless prisms, m. p. 82—84°, giving a purple ferric reaction in alcohol (Found : C, 65·6; H, 5·3. $C_{12}H_{12}O_4$ requires C, 65·5; H, 5·5%). On exposure to air alcoholic solutions of this compound absorb oxygen and give a quantitative yield of 6-methoxy-3-acetylcoumarin. The 2 : 4-*dinitrophenylhydrazone* separated from ethyl acetate in light-orange spearheads, m. p. 184—185° (Found : C, 54·0; H, 4·0; N, 14·0. $C_{18}H_{16}O_7N_4$ requires C, 54·0; H, 4·0; N, 14·0%). The *semicarbazone* formed large flat prisms, m. p. 188—189°, from alcohol, readily soluble in 2N-aqueous sodium hydroxide and giving a royal-blue colour with alcoholic ferric chloride, unaffected on dilution with water (Found : C, 56·3; H, 5·4; N, 14·8. $C_{13}H_{15}O_4N_3$ requires C, 56·3; H, 5·4; N, 15·2%).

Hydrolysis of 6-methoxy-3-acetyl-3 : 4-dihydrocoumarin (1 g.) with 0·5N-aqueous sodium hydroxide (20 ml.) on the steam-bath for 30 minutes gave the neutral 2-hydroxy-6-methoxy-2-methylchroman and the phenolic 2-hydroxy-5-methoxybenzylacetone, each of which furnished the 2 : 4-*dinitrophenylhydrazone* of 2-hydroxy-5-methoxybenzylacetone, forming scarlet rectangular prisms, m. p. 156°, from dilute alcohol (Found : C, 54·6; H, 5·0; N, 14·9. $C_{17}H_{18}O_6N_4$ requires C, 54·5; H, 4·8; N, 15·0%). When the coumarin was heated under reflux with N-alcoholic hydrochloric acid for 45 minutes the same mixed product was obtained, giving the 2 : 4-dinitrophenylhydrazone, m. p. 156°.

Oxidation of 6-*Methoxy*-3-*acetyl*-3 : 4-*dihydrocoumarin*.—(*a*) Dehydrogenation of 6-methoxy-3-acetyl-3 : 4-dihydrocoumarin (0·5 g.) in acetic acid (10 ml.) with lead tetra-acetate (1 g.) proceeded rapidly, giving 6-methoxy-3-acetylcoumarin, m. p. and mixed m. p. 182°, which formed the 2 : 4-dinitrophenylhydrazone, m. p. 242—243°.

(*b*) A slow stream of ozone and oxygen was led into a solution of the dihydrocoumarin (1 g.) in chloroform (75 ml.) maintained at 0° for 75 minutes, the solvent was removed in a vacuum, and the residue treated with water. Next day the water was decanted and on treatment with a little ether the residual oil gave crystalline 3-hydroxy-6-methoxycoumarin which separated from ethyl acetate in pale yellow prisms, m. p. 208—209°, giving an intense deep green ferric reaction in alcohol and identified by comparison with an authentic specimen. The ethereal filtrate from the crude 3-hydroxy-6-methoxycoumarin contained 2-hydroxy-5-methoxybenzaldehyde which was identified by conversion into the 2 : 4-*dinitrophenylhydrazone*, m. p. 263°, undepressed on admixture with an authentic sample (Found : N, 17·1. $C_{14}H_{12}O_6N_4$ requires N, 16·9%).

3-*Hydroxy*-6-*methoxycoumarin* (IX).—A mixture of 2-hydroxy-5-methoxybenzaldehyde (2 g.), aceturic acid (2·5 g.), acetic acid (3 ml.), acetic anhydride (10 ml.), and sodium acetate (1·6 g.) was heated on the steam-bath for 2 hours. The colourless crystalline product which separated from the cooled reaction mixture was removed, the residual liquor was diluted with water, and the yellow precipitate collected, washed with a little alcohol and then with ether to remove traces of resinous material. The crude azlactone (0·5 g.) was then boiled with 2N-hydrochloric acid (20 ml.) for 4 hours and the resulting 3-*hydroxy*-6-*methoxycoumarin* (0·3 g.) was isolated by filtration from the cooled reaction mixture. Crystallised from alcohol (charcoal) and then from ethyl acetate, the compound formed pale-fawn-coloured prisms, m. p. 208—210°, readily soluble in 1% aqueous sodium hydroxide and giving a characteristic deep-green ferric reaction (Found : C, 62·6; H, 4·3. $C_{10}H_8O_4$ requires C, 62·5; H, 4·2%).

Hydrogenation of 3-*Acetyl*-7-*methylcoumarin*.—This coumarin (Chuit and Bolsing, *Bull. Soc. chim.*, 1915, **35**, 84) formed a 2 : 4-*dinitrophenylhydrazone*, separating from acetic acid or ethyl acetate in masses of slender yellow needles, m. p. 225—226° (Found : N, 14·6. $C_{18}H_{14}O_6N_4$ requires N, 14·7%).

When the hydrogenation of the coumarin (2 g.) was effected by the procedure employed in the case of 6-methyl-3-acetylcoumarin the colourless product left on evaporation of the filtered reaction mixture had m. p. 80—90°, and gave a purple ferric reaction in alcohol. Crystallisation of this material several times alternately from aqueous methanol and benzene–ligroin and then from alcohol and benzene gave a *substance* in colourless prisms (1 g.), m. p. 129·5—130·5°, which was sparingly soluble in benzene and did not react with 2 : 4-dinitrophenylhydrazine or give a ferric reaction (Found : C, 70·8; H, 5·8. $C_{12}H_{12}O_3$ requires C, 70·6; H, 5·9%). This product dissolved slowly in hot 2N-aqueous sodium hydroxide and on acidification with dilute hydrochloric acid the original material, m. p. 128°, was obtained. It was not identical either with 7-methylcoumarin, m. p. 128° (the mixture of two compounds melted at 88—110°), or with 3-ethyl-7-methylcoumarin.

Treatment of the alcoholic mother-liquors left from the purification of the foregoing product with an excess of saturated copper acetate gave an amorphous green precipitate (1·2 g. from 3 g. of 3-acetyl-7-methylcoumarin) which, after having been washed with water, methanol, and then with ether, was decomposed with a mixture of 5% sulphuric acid and ether. Evaporation of the ethereal liquor gave 3-*acetyl*-7-*methyl*-3 : 4-*dihydrocoumarin* which formed colourless platelets (0·56 g.), m. p. 95—97°, from dilute alcohol, readily soluble in the usual organic solvents except ligroin and giving a purple ferric reaction in alcohol (Found : C, 70·9; H, 5·8. $C_{12}H_{12}O_3$ requires C, 70·6; H, 5·9%). The 2 : 4-*dinitrophenylhydrazone* separated from ethyl acetate in yellow needles, m. p. 190—192° (Found : C, 56·1; H, 4·2; N, 14·3. $C_{18}H_{16}O_6N_4$ requires C, 56·4; H, 4·2; N, 14·6%).

7-*Methyl*-3-*ethylcoumarin* was prepared by the butyrylation of 2-hydroxy-4-methylbenzaldehyde (3 g.) with butyric anhydride (5 g.) and sodium butyrate (5 g.) at 170° for 5hours and subsequent treatment of the reaction mixture with water. Crystallised from light petroleum (b. p. 60—80°), the coumarin (1·6 g.) formed colourless flat needles, m. p. 63—64°, soluble in alcohol or ethyl acetate (Found : C, 76·6; H, 6·6. $C_{12}H_{12}O_2$ requires C, 76·6; H, 6·4%).

7-*Methoxy*-3-*acetylcoumarin*.—Condensation of 4-*O*-methylresorcylaldehyde (6 g.) and ethyl aceto-acetate (6 ml.) by means of a little piperidine gave rise to 7-*methoxy*-3-*acetylcoumarin* which separated from ethyl acetate in pale yellow prisms (8 g.), m. p. 173—174° (Found : C, 66·0; H, 4·5. $C_{12}H_{10}O_4$ requires C, 66·1; H, 4·6%), showing in alcohol an intense blue fluorescence. Prepared by the pyridine method, the *oxime* formed almost colourless prisms, m. p. 217°, from alcohol and then ethyl acetate (Found : N, 5·6. $C_{12}H_{11}O_4N$ requires N, 6·0%). The 2 : 4-*dinitrophenylhydrazone* crystallised from ethyl acetate in tiny scarlet rhombs, m. p. 257—258° (decomp.) (Found : N, 14·1. $C_{18}H_{14}O_7N_4$ requires N, 14·1%).

Hydrogenation of 7-*Methoxy*-3-*acetylcoumarin*.—This coumarin (2 g.) was hydrogenated in methanol (300 ml.) with hydrogen at 60 lbs./sq. in. and palladium-charcoal (from 1 g. of charcoal and 0·3 g. of palladium chloride) during 2½ hours at room temperature. The colourless, filtered reaction mixture, which gave only a comparatively faint purple ferric reaction and only traces of a precipitate with 2 : 4-dinitrophenylhydrazine solution, was concentrated in a vacuum at below 50°, giving a crystalline solid (0·5 g.) which consisted mainly of 7-*methoxy*-3-*ethylcoumarin*. Recrystallised from methanol and then ethyl acetate–ligroin, this compound formed colourless prisms, m. p. 98—100°, (Found : C, 70·1; H, 5·8. $C_{12}H_{12}O_3$ requires C, 70·6; H, 5·9%) undepressed on admixture with an authentic sample (cf. below).

Concentration of the liquor left after the separation of the crude 7-methoxy-3-ethylcoumarin furnished a solution which gave a purple ferric reaction and on treatment with an excess of aqueous copper acetate gave the copper derivative of 7-*methoxy*-3-*acetyl*-3 : 4-*dihydrocoumarin*; the amount of this derivative obtained was variable, the maximum being 0·2 g. from 2 g. of 7-methoxy-3-acetyl-coumarin. Decomposition of the crude copper compound was effected with 5% sulphuric acid (20 ml.) containing ether (20 ml.) (agitate) during 2 hours at room temperature, and the ethereal solution was separated, washed with aqueous sodium hydrogen carbonate, dried, and evaporated, leaving the dihydrocoumarin which formed colourless, elongated, flat prisms, m. p. 82·5—84·5°, from light petroleum (b. p. 60—80°) and gave an intense purple ferric reaction in alcohol (Found : C, 65·8; H, 5·4. $C_{12}H_{12}O_4$ requires C, 65·5; H, 5·5%).

An authentic specimen of 7-methoxy-3-ethylcoumarin was prepared by heating a mixture of 4-*O*-methylresorcylaldehyde (3 g.), sodium butyrate (6 g.), and butyric anhydride (6 g.) at 160° for 4 hours. The reaction mixture was boiled with water to decompose the excess of anhydride, cooled, and extracted with ether. Evaporation of the ethereal solution, which had been washed successively with N-aqueous sodium hydroxide and water and then dried, left a brown oil which partly solidified and on purification from methanol and then ethyl acetate–ligroin, gave 7-methoxy-3-ethylcoumarin in colourless prisms, m. p. 99—100°, soluble in alcohol, ethyl acetate, or chloroform (Found : C, 70·7; H, 6·0%).

Hydrogenation of 7-*Hydroxy*-3-*acetylcoumarin*.—This coumarin, m. p. 236°, was prepared by the condensation of β-resorcylaldehyde and ethyl acetate with a little pyridine (compare Weiss and Merksammer, *Monatsh.*, 1928, **50**, 115) and gave a 2 : 4-*dinitrophenylhydrazone*, forming scarlet needles, m. p. 302—303° (decomp.), from ethyl acetate (Found : N, 14·7. $C_{17}H_{12}O_7N_4$ requires N, 14·6%).

Hydrogenation of the coumarin (1 g.) by the procedure employed for its 7-methyl ether gave a tan-coloured crude product (1 g.), m. p. 70—100°, giving a faint violet ferric reaction in alcohol and forming, in dilute aqueous sodium hydroxide, a solution which had a brilliant blue fluorescence. A solution of this solid in a little hot alcohol was warmed with saturated aqueous sodium hydrogen sulphite (3 ml.) on the steam-bath for 15 minutes and on cooling the mixture deposited crystalline material which was collected and again treated with warm alcohol and aqueous sodium hydrogen sulphite, finally giving 7-hydroxy-3-ethylcoumarin as a monohydrate in colourless shining needles, m. p. 128—129°, giving a negative ferric reaction (Fichter and Goldhaber, *Ber.*, 1904, **37**, 2382, record m. p. 123—124°) (Found : C, 63·2; H, 5·7. Calc. for $C_{11}H_{10}O_3,H_2O$: C, 63·5; H, 5·8%). Methylation of this compound by the potassium carbonate–methyl iodide method during 2 hours gave 7-methoxy-3-ethylcoumarin which separated from aqueous methanol in colourless prisms, m. p. 98—100°, undepressed on admixture with an authentic specimen.

Hydrogenation of 6 : 7-*Dimethoxy*-3-*acetylcoumarin*.—The *oxime* of this coumarin (Part II, *loc. cit.*) formed colourless slender needles, m. p. 218°, from alcohol (Found : N, 5·3. $C_{13}H_{13}O_5N$ requires N, 5·3%). The 2 : 4-dinitrophenylhydrazone had m. p. 282—283° (decomp.) and not 280° (decomp.) as given in Part II (*loc. cit.*).

Hydrogenation of the coumarin (2 g.) in methanol with palladium–charcoal and hydrogen at 60 lbs./sq. in. during 5—6 hours gave, after filtration, a colourless solution which gave a faint ferric reaction and became yellow on exposure to air.

Evaporation of the solution in an atmosphere of nitrogen, followed by extraction of the residue with a little hot methanol, left unchanged 6 : 7-dimethoxy-3-acetylcoumarin, m. p. 228°. On cooling, the methanolic extract deposited 6 : 7-*dimethoxy*-3-*ethylcoumarin* in pale yellow needles, m. p. 108—109°, identical with an authentic specimen (Found : C, 66·7; H, 5·9. $C_{13}H_{14}O_4$ requires C, 66·7; H, 6·0%). The latter specimen was prepared by the butyrylation of 2-hydroxy-4 : 5-dimethoxybenzaldehyde with butyric anhydride and sodium butyrate at 170° for 6 hours and on crystallisation from ethyl acetate–light petroleum (b. p. 60—80°) was obtained in large prisms, m. p. 108—109° (Found : C, 66·6; H, 5·9%).

When a platinum–charcoal catalyst was employed in the hydrogenation and the product was subjected to prolonged fractional crystallisation in an atmosphere of nitrogen there was obtained, in addition to 6 : 7-dimethoxy-3-ethylcoumarin, a small amount of 6 : 7-*dimethoxy*-3-*acetyl*-3 : 4-*dihydrocoumarin* (III; R = H). By treatment of several batches of filtered hydrogenation-liquor with an excess of aqueous copper acetate a small amount of the copper derivative of the latter coumarin was obtained which was washed with warm alcohol, chloroform, and ether and decomposed with dilute sulphuric acid and ether in the usual manner giving 6 : 7-dimethoxy-3-acetyl-3 : 4-dihydrocoumarin, forming colourless prisms, m. p. 164—166°, from alcohol (Found : C, 62·2; H, 5·6. $C_{13}H_{14}O_5$ requires C, 62·4; H, 5·6%). This compound was soluble in chloroform, ethyl acetate, benzene, or warm 1% aqueous sodium hydroxide and gave a purple ferric reaction in alcohol. Formed in the usual manner, the 2 : 4-dinitrophenylhydrazone was obtained as an orange yellow precipitate, m. p. 228°, which could not be satisfactorily recrystallised.

6-*Acetoacetyl*-3 : 4-*dihydrocoumarin* (XI).—A solution of 3 : 4-dihydrocoumarin (3 g.) in acetic anhydride (8 ml.) at 0° was saturated with boron trifluoride (from 22 g. of potassium fluoroborate) and treated with ice-water 24 hours later. The boron fluoride complex of the diketone then slowly separated from the reaction mixture in pale yellow needles (2·3 g.), m. p. 120°. Decomposition of this (1 g.) with boiling water (3 ml.) containing hydrated sodium acetate (10 g.) during 10 minutes gave 6-acetoacetyl-3 : 4-dihydrocoumarin, which was isolated from the cooled mixture with ether, purified by way of its copper derivative, and crystallised from ligroin or dilute alcohol, forming a hydrate in small colourless prisms (0·7 g.) giving a deep-red ferric reaction (Found : C, 62·3; H, 5·8. Calc. for $C_{13}H_{12}O_4,H_2O$: C, 62·4; H, 5·6%) (cf. Kaestner, *loc. cit.*).

3-*Acetoacetylcoumarin* (XII; R = Ac).—A mixture of 3-acetylcoumarin (3 g.), acetic acid (10 ml.), and acetic anhydride (6 ml.) was saturated at room temperature with boron trifluoride, and ½ hour later the red viscous liquid was poured into water (50 ml.). Extraction of the washed, flocculent, orange-yellow product (3·7 g.) with alcohol removed viscous reddish impurities and left the boron fluoride complex of 3-acetoacetylcoumarin as a mass of orange crystals (2·3 g.), which, on recrystallisation from acetic acid formed yellow plates, m. p. 268°, sparingly soluble in organic solvents and giving a green flame test. On being heated on the steam-bath with acetic acid (50 ml.) and hydrated sodium acetate (2 g.) this compound (2·4 g.) slowly dissolved; after ½ hour water was added until the solution became faintly opalescent; 3-acetoacetylcoumarin (XII; R = Ac) separated from the cooled mixture in pale yellow prisms (1·5 g.), and, on recrystallisation from alcohol and then acetic acid, had m. p. 152—153° (Found : C, 67·5; H, 4·4. Calc. for $C_{13}H_{10}O_4$: C, 67·8; H, 4·4%). This compound, which gave a red ferric reaction in alcohol, was readily soluble in 2N-aqueous sodium hydroxide and insoluble in aqueous sodium carbonate. The 2 : 4-dinitrophenylhydrazone and the oxime were obtained as amorphous solids which could not be induced to crystallise (cf. Trenknerowna, *Roczniki Chem.*, 1936, **16**, 6, 10, who states that the compound gives a blood-red ferric reaction and forms cream-yellow needles or blunt prisms, m. p. 143—144°).

Hydrogenation of this coumarin by the procedure employed for 3-acetylcoumarin gave a gummy product which was resolved by means of ether into unchanged 3-acetoacetylcoumarin and a small amount of a *substance* which formed elongated needle-shaped plates, m. p. 177—178°, from alcohol, giving a negative ferric reaction (Found : C, 67·1; H, 5·4. $C_{13}H_{12}O_4$ requires C, 67·2; H, 5·2%). It did not appear to react with 2 : 4-dinitrophenylhydrazine.

UNIVERSITY OF LIVERPOOL.

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