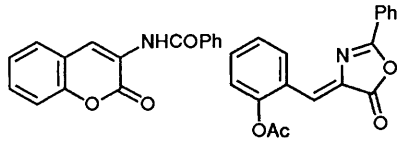
4-(2'-Hydroxyphenylmethylene)-2-phenyloxazol-5(4*H*)-one: A Comedy of Errors†

Sir John Cornforth *[a] **and Du Ming-hui**[b]
[a] *School of Chemistry and Molecular Sciences, University of Sussex, Brighton BN1 9QJ, UK*
[b] *Beijing Medical University, Beijing, People's Republic of China*

Eighteen publications since 1955 have described properties and reactions of the title compound. All these reports are erroneous and refer, variously, to three other substances. All literature reports of the analogous 4-(2'-hydroxyphenylmethylene)-2-methyloxazol-5(4*H*)-one also need revision. A convenient synthesis of the title compound **3** (R=H), its chemical and physical properties, and its rearrangement to 3-benzoylamino-1-benzopyran-2-one **1**, are reported here for the first time. A mechanism is presented for the observed course of Plöchl–Erlenmeyer syntheses with salicylaldehyde and with 2-acetoxybenzaldehyde.

Historically, the Plöchl–Erlenmeyer synthesis of oxazolones is an offshoot of Perkin's synthesis of cinnamic acids from aromatic aldehydes, acetic anhydride and sodium acetate; and even earlier[1] Perkin had studied the special case of salicylaldehyde, obtaining coumarin. Both Plöchl and Wolfrum,[2] and Erlenmeyer and Stadlin,[3] as well as Rebuffat,[4] tried the condensation of hippuric acid with salicylaldehyde and acetic anhydride.

All three papers reported 3-benzoylaminocoumarin **1**, a colourless compound melting at around 170 °C, as a product, and all observed that it was not the sole product, but they differed as to the nature of a yellow crystalline substance formed at the same time. Erlenmeyer and Stadlin recognized that this product yielded acetic acid on alkaline hydrolysis and formulated it, in part correctly, as the acetoxy oxazolone **2**, and



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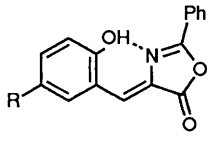


3; R = H
4; R = SO_3H
5; R = Me

their preparation, m.p. 137–138 °C, seems to be much the same as that of Rebuffat. Plöchl and Wolfrum obtained, by prolonged contact at room temperature of the three reagents without sodium acetate as catalyst, a product m.p. 160 °C. This certainly had a melting point near that of pure **2**, but their elementary analysis did not agree with this formulation. Erlenmeyer and Stadlin's product, m.p. 137–138 °C, is a mixture of **1** and **2**; we analysed by NMR spectrometry a specimen prepared by the published procedure and found a molar ratio (**1**:**2**) of 3:5. T. Asahina[5] first reported the inhomogeneity, and he obtained analytically pure **2**, m.p. 158.5 °C, by fractional precipitation with light petroleum of a benzene solution of the crude mixture, followed by recrystallization. Neuberger[6] used this separation to show that when 2-acetoxybenzaldehyde was used in place of salicylaldehyde in the condensation with hippuric acid, acetic anhydride and sodium acetate, the coumarin **1** was still formed but in smaller proportion (*ca.* 10% of crude product) relative to the oxazolone **2**. The abnormal behaviour of salicylaldehyde in the Plöchl–Erlenmeyer synthesis was mentioned in reviews by H. E. Carter[7] and by one of us.[8]

† No reprints available

The hydroxy oxazolone **3** is unmentioned in the literature before 1955. To understand the confusion beginning then and continuing until now, it should be remembered that the Plöchl–Erlenmeyer synthesis was already well known as a simple process, easily executed by following standard procedures, and mentioned in many text-books which state that condensation of arylaldehydes with hippuric acid, acetic anhydride and sodium acetate gives good yields of the corresponding 4-arylidene-2-phenyloxazolones. On this basis the expected product from salicylaldehyde would be the hydroxy oxazolone **3**, which has the same composition as the coumarin **1**; the earliest workers, with Perkin's synthesis in mind, would in contrast have expected a coumarin and were not surprised to find one. Further, the oxazolones are versatile intermediates, seldom end-products. The incentive to study the original literature in detail and to examine critically the products actually obtained was thus diminished, especially when a series of oxazolones was prepared; and one published error breeds others. In the critique that follows we have the advantage of knowing the true properties of compounds **1**, **2** and **3**.

First we cite papers where preparation of **3** by Erlenmeyer's procedure is claimed but the undescribed product was the intermediate for a further reaction. In these cases either the acetoxy oxazolone **2** or the coumarin **1** (or both) must have been the real reagent. These papers, which describe the reaction products of **3** with ammonia and nickel-catalysed hydrogen,[9] with formic acid,[10] with six sulphanilamides,[11] with hydrazine,[12] with 2,3-dimethyl-1-phenylpyrazolin-5-one,[13] and with 2-aminoalkylbenzimidazoles,[14] need appropriate revision. The UV spectrum of a product said[15] to be **3** and to have been made by the Erlenmeyer–Stadlin procedure does not, however, correspond to **1**, **2** or **3**. For completeness we add a paper[16] where the author not only imagined that Erlenmeyer and Stadlin had reported **3**, not **2**, but claimed without experimental detail to have repeated this result; and a paper[17] where an abstract[18] wrongly makes it appear that phase-transfer hydrolysis of **3**, not **2**, was studied.

Next, we deal with claims to have made **3** where internal or independent evidence permits identification of the true product as the coumarin **1**. Two of these[19,20] used Erlenmeyer's method; the IR spectrum given for one product and the elementary analysis for the other make it certain that both products were the coumarin **1**. Condensation of hippuric acid with salicylaldehyde in dimethylformamide–sulphur trioxide[21] gave a product, m.p. 169 °C, which showed a band at 3380 cm^{-1} in the IR region. The oxazolone **3** has no band in this region (see later), but we found the N–H stretching band of the coumarin **1**

at 3370 cm^{-1}; the m.p. also agrees. Rao[22] found that condensation of hippuric acid with aromatic aldehydes in polyphosphoric acid tended to give the unstable *E* forms of 4-arylidene-2-phenyloxazolones. He applied this method to salicylaldehyde and obtained a product, m.p. 163 °C, which he thought to be the *E* form of **3**. It gave a correct analysis for **3** and showed ν_{max} 1720 cm^{-1} in tne IR spectrum. We repeated his procedure and obtained an excellent yield of coumarin **1**, m.p. 177 °C after purification. The IR spectrum agreed with Rao's finding, and this is a convenient method for making the coumarin. Kumar and Mukerjee[23] have also questioned the identity of Rao's[22] and Baltazzi and Davis's[21] products. Incidentally, Rao thought that his synthesis did not proceed *via* 2-phenyloxazol-5(4*H*)-one since he recovered hippuric acid 'unchanged' after heating it with polyphosphoric acid and pouring the mixture into ice and acid. This is not convincing: simple oxazolones are hydrolysed rapidly in aqueous acid to the parent acylamino acids.

Two papers have reported the preparation of **3** by condensations of 2-phenyloxazol-5(4*H*)1-one with salicylaldehyde[24,25] and with salicylidenebenzylamine.[25] In one paper[25] the properties (colourless; m.p. 170 °C; analysis) are those of the coumarin **1**. In a paper published at about the same time Kumar and Mukerjee[23] found that salicylaldehyde (and its anil) gave the coumarin **1** on condensation with 2-phenyloxazolone, and we have independently confirmed this using the experimental conditions given in one paper.[24] The reported[24] products of reaction of the supposed **3** with hydrazine–acetic acid, phenylhydrazine and hydroxylamine need to be re-examined.

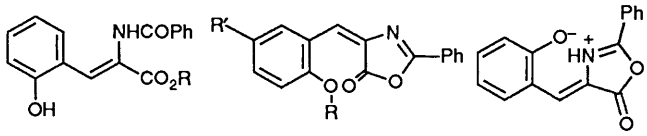
Finally, V. N. Gupta[26] thought that he had obtained **3** by treatment of the acetoxy oxazolone **2** with ice-cold concentrated sulphuric acid. His product was yellow, had m.p. 170–172 °C after crystallization from acetone, and contained 4.23% N. He reported some rearrangement to the coumarin **1** on recrystallization from ethanol or by attempts to acetylate or methylate. He had prepared **2** from crude 2-acetoxybenzaldehyde, hippuric acid, acetic anhydride and sodium acetate and was apparently unaware of Neuberger's[6] demonstration that this product already contains coumarin **1**. Our repetition of the deacetylation showed that the major product is soluble in excess of water and is evidently a sulphonic acid of **3**, probably **4**. Gupta made an error in calculating the nitrogen content of formula **3**; his nitrogen analysis agrees better with **4** (4.06%) than with **3** (5.28%). To summarize: all previous reports of the chemical and physical properties of hydroxy oxazolone **3** have referred to preparations of **1**, **2** or **4**.

Results and Discussion

Our first preparation of authentic **3** was by condensation, in pyridine with triethylamine, of 2-trimethylsilyloxybenzaldehyde with 2-phenyloxazol-5(4*H*)-one. Even here, the major product was the coumarin **1**, perhaps formed *via* partial hydrolysis of the trimethylsilyloxy aldehyde by water generated in the reaction. Pure **3** was separated by flash chromatography on silica. Possession of an authentic specimen enabled us to show that **3** was formed in small amounts by Gupta's procedure, which we set out to improve. By omitting sodium acetate from the mixture of hippuric acid, 2-acetoxybenzaldehyde and acetic anhydride, we obtained a 74% yield of acetoxy oxazolone **2** that contained only traces of coumarin **1**, removed by one crystallization. We also reasoned that hydrolysis of **2** by ice-cold sulphuric acid might be favoured, and sulphonation suppressed, by adding some water to the acid. In fact, 88% sulphuric acid gave a quantitative yield of **3**; the yield fell to 96% with 92% acid and sank progressively with stronger acid, reaching 5% with undiluted acid (98.1%). The product **3** was free from coumarin; by this procedure, it is easily available in unlimited quantity.

The properties of **3** do not agree with any previous description, but Behringer and Falkenburg[27] obtained a homologue **5** from 4-chloromethylene-2-phenyloxazol-5(4*H*)-one by Friedel–Crafts condensation with *p*-cresol. The general properties, including UV and IR spectra, of **5** closely resemble those of our product. It had been thought that **5** might be a mixture of geometrical isomers because two peaks were seen in the C=O stretching region of the IR spectrum;[27] but the high resolution NMR spectrum and the chromatographic homogeneity of our substance, which also shows two IR absorption bands in the same positions, clearly mark it as a single molecular species. A further apparent anomaly in **5** was the failure to observe OH stretching absorption. This is also true of **3**, and the NMR spectrum shows a very sharp signal at δ 12.8, attenuated but not shifted when deuterium oxide is added. A strong hydrogen bond is clearly present in **3**, and the mobility on silica columns confirms this: **3** is less polar than **1** or **2**.

The oxazolone **2** has the *Z* geometry normal for a product of the Plöchl–Erlenmeyer synthesis, as was convincingly shown[28] by G. W. Kirby *et al.* Alkaline hydrolysis of **2** gave the acid **6**, which must have *Z* geometry, as shown, because it does



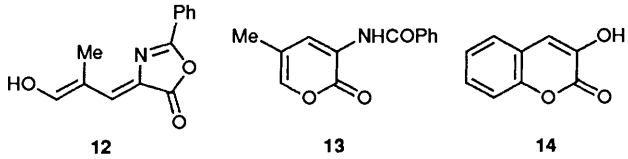
6; R = H
7; R = Me

8; R = Ac, R′ = H
9; R = H, R′ = Me
10; R = R′ = H

11

not easily cyclize to the coumarin **1**. The presumption is that the oxazolone **2** also has *Z* geometry, and further confirmation came from the preparation,[28] by UV irradiation of **2**, of a geometrical isomer, m.p. 124 °C, which on alkaline hydrolysis and acidification did form the coumarin **1**. The coumarin **1** can itself be dissolved in alkali and regenerated on acidification, as has long been known[29] for coumarin itself. The isomer of **2** is, therefore, the *E* form **8**. We find that the hydroxy oxazolone **3** is quantitatively converted into **2** by acetylation with pyridine and acetic anhydride at room temperature. It presumably also has the *Z* geometry shown, and in confirmation we find that the oxazolone **3** dissolves slowly in cold dilute alkali to yield, on acidification, the acid **6** free from coumarin **1**. The oxazolone **3** is also regenerated from the acid **6** by heat and by mild dehydrating reagents. The strong hydrogen bond in the oxazolone **3** is therefore between the phenolic hydroxy group and the oxazolone nitrogen. It is unusual to find such a strong hydrogen bond in a 7-membered ring; no doubt, a contribution from the mesoionic structure **11** adds to the stability. The oxazolone **2**, in contrast, clearly has the opposite conformation as shown: the influence of the oxazolone nitrogen is seen in the large downfield shift (to δ 8.94) of the 6′ hydrogen signal (already observed by Kirby *et al.*[28] at δ 8.95). Comparable shifts have been noted[30] and similarly interpreted in oxazolones derived from other 2-substituted benzaldehydes.

We recently reported[31] the hydroxyallylideneoxazolone **12** and noted that it rearranged to the pyranone **13** when melted or recrystallized from acetone. It was that finding which made us look in the literature for analogous examples and thus gradually to uncover the situation, paraphrased in our title, surrounding

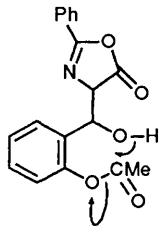


12 **13** **14**

the analogue **3**. We find that **3**, like its homologue **5**,[27] rearranges smoothly to the coumarin **1** when warmed in pyridine with triethylamine (pyridine alone is slower). When the oxazolone **3** is melted, or heated at 210–220 °C for a few minutes in sulpholane, some rearrangement to **1** can be detected, but it is much slower than with **12** and imperceptible on recrystallization from boiling acetone, chloroform, carbon tetrachloride or ethyl acetate. In acetic acid with a little aqueous mineral acid, the oxazolone **3** is destroyed on warming, but the product is almost totally alkali-soluble and shows the intense green ferric reaction characteristic of 3-hydroxycoumarin **14**: smooth rearrangement to the coumarin **1** does not occur under these conditions, nor does it take place in cold 88% sulphuric acid when **3** is prepared from **2**. The early reports[2,3,4] of formation of **1** from the acetoxyoxazolone **2** by heating it with alcohol, acid, or alkali can now be discounted as unproven since all the preparations already contained **1** and no yields were given; but if there is truth in any of them, our findings do indicate that **1** was not formed *via* **3**. With dilute aqueous alkali, as reported above, the oxazolone ring is opened by hydrolysis without rearrangement. With dilute methanolic potassium hydroxide the methyl ester **7** of the acid **6** is formed almost quantitatively. The homologue **5** was said to form with aqueous alcoholic alkali a blood-red solution from which **5** could be recovered after acidification.[27] With **3** under these conditions the colour, presumably that of the anion, fades rapidly; it is less unstable if acetone replaces alcohol and excess of alkali is avoided. The patented[32] rearrangement of **3** to **1**, by passing an alternating current through an acetonitrile solution containing diphenylanthracene and tetrabutylammonium chloride, is another jest in our comedy of errors, since the origin of **3** was unstated and all substances reported as **3** at that time were **1**, or contained **1**. In contrast there is no reason to doubt the rearrangement of the homologue **5** to the corresponding coumarin by UV light:[33] this is a recognised procedure for isomerizing *Z* oxazolones to the *E* forms (*cf.* ref. 28) and rearrangement of the *E* form **9** to the coumarin would predictably be fast. Similarly the rearrangements of **5** and **3** in pyridine presumably proceed by prior isomerization to the *E* forms **9** and **10**, since pyridine is a known reagent (though by an unknown mechanism) for effecting this change in oxazolones.[34]

Concomitant formation of **1** and **2** in Plöchl–Erlenmeyer syntheses can now be discussed. The facts are that with salicylaldehyde, **1** is a major product. When 2-acetoxybenzaldehyde replaces salicylaldehyde, **1** is still formed, but less of it relative to **2**, and still less when sodium acetate is also omitted. The possibility that **1** is generated from **2** was tested by setting up a mock reaction mixture in which acetic anhydride, acetic acid, sodium acetate and **2** were present in the proportions expected at the end of a synthesis. When this mixture was heated for four times as long as in a normal synthesis, formation of a little **1** was observed. The quantity was far smaller than the amounts usually found with shorter reaction times. Thus **2** is not a major source of **1** in normal conditions for the synthesis, and a similar doubt is cast on the importance of any mechanism whereby a phenolic group is transiently set free by attack of acetate ion or acetic acid on a phenolic acetate.

We suggest that the major pathways to **1** and **2** diverge during the aldol condensation with 2-phenyloxazol-5(4*H*)-one. The intermediacy of this oxazolone in Plöchl–Erlenmeyer syntheses is supported by good evidence.[7,35] The initial aldol condensation product between the oxazolone and 2-acetoxybenzaldehyde is the 4-(α-hydroxybenzyl)oxazolone **15**, in which an easy base-catalysed intramolecular transacetylation, as indicated by the arrows, can be expected. The product **16** can either be acetylated on the phenolic hydroxy group, before or after loss of acetic acid, to yield the oxazolone **2**, or it can rearrange, by a second intramolecular process catalysed by base



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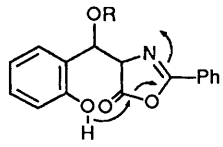
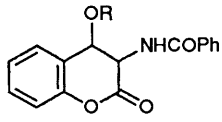


16; R = Ac
17; R = H



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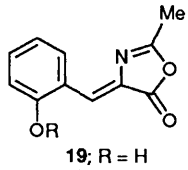
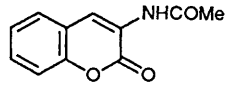
and acid and indicated by arrows, to the hydrocoumarin **18** which loses acetic acid to yield **1**. When salicylaldehyde is a starting material, some of it must escape acetylation before the aldol condensation; otherwise, the product would have the same composition as with 2-acetoxybenzaldehyde. The resulting aldol intermediate **17** can rearrange directly to a hydrocoumarin; this explains, we suggest, why a higher proportion of **1** is formed from salicylaldehyde than from 2-acetoxybenzaldehyde in the usual procedure, and why, as also postulated by Kumar and Mukerjee,[24] reaction of 2-phenyloxazol-5(4*H*)-one with salicylaldehyde in non-acetylating conditions seems to give exclusively **1** without **3**. The composition of the final products depends on the relative rates of several competing processes under the reaction conditions used. The proposed mechanism led to a testable prediction that 2-acetoxybenzaldehyde with 2-phenyloxazol-5(4*H*)-one should give, under non-acetylating conditions, a product containing more of coumarin **1** than is formed in our preferred procedure (above) for making **2**, when acetic anhydride is present in excess. In fact, we found that the product of this condensation (in benzene with triethylamine) was a 1:3 mixture of coumarin **1** and acetoxyoxazolone **2**, containing a small amount of the hydroxy oxazolone **3**.

As epilogue we mention the analogous 2-methyloxazolone **19**. Dakin[36] obtained from acetylglycine, acetic anhydride and salicylaldehyde a product which he formulated as the acetoxy oxazolone **20**. Shaw, McMillan and Armstrong[37] showed



19; R = H
20; R = Ac



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conclusively that the product was the coumarin **21**; they could isolate no other product under any conditions tried, even when 2-acetoxybenzaldehyde was used (our view of this finding is that the second of the intramolecular rearrangements postulated above occurs more rapidly with a 2-methyloxazolone). But meanwhile Dakin's version had been cited in reviews[7,35] and, so potent is the spell of the orthodox, reports of the reactions of the hydroxy oxazolone **19** with a considerable variety of reagents have appeared.[11,13,14,38–41] In truth, **19** and **20** are both unknown compounds, though genuine 4-(2-acetoxyphenylmethylene)-2-methyloxazol-5(4*H*)-one analogues (for example,[6] from gentisic aldehyde) have certainly been made.

Experimental

General.—Melting points marked (K) were taken on a Kofler hot stage; all others in an Electrothermal apparatus. All NMR spectra were measured at 360 MHz and *J* values are in Hz. IR spectra were run with paraffin mulls and UV spectra in ethanol. 'Hexanes' means the hexane fraction of light petroleum; solvent mixtures are by volume.

(*Z*)-4-(2′-*Acetoxyphenylmethylene*)-2-*phenyloxazol*-5(4H)-*one* **2**.—Acetic anhydride (15 ml) was added with swirling during 5 min to a cooled (below −10 °C) mixture of salicylaldehyde (18.3 g) and dry pyridine (40 ml). The cooling bath was removed; after 1 h the mixture was placed in a bath at 35 °C and 0.5 h later was distilled at *ca.* 0.5 mmHg pressure into a cold trap: this removed pyridine, acetic acid and excess of anhydride. The residue of 2-acetoxybenzaldehyde, which crystallized on cooling, was mixed with hippuric acid (27 g of 98%) and acetic anhydride (38 ml) and stirred at 60–65 °C (bath) for 18 h. The semi-solid product was cooled in ice; the crystals (32.9 g; m.p. 157–159 °C) were collected and washed with chilled diethyl ether (50 ml). An additional 1.2 g was recovered from the filtrate but preparatively this is not profitable. The total product (34.1 g, 74%) showed a trace of coumarin **1** by TLC (chloroform–hexanes 1:1; silica; 2–3 developments; **1** and **2** were resolved with difficulty on silica with all solvent systems tried). It was taken up in boiling chloroform (*ca.* 100 ml), filtered hot, concentrated to crystallization at *ca.* 500 mmHg pressure, cooled in ice, and collected. The acetoxy oxazolone **2** (26.75 g) formed pale yellow prisms, m.p. 162 °C (lit.,[5] 158.5 °C), and was free from coumarin **1** by TLC and by NMR; λ_{max}/nm 385 (ε/dm^3 mol^{-1} cm^{-1} 19 500), 365 (29 900) and 350sh (24 500); δ_H($CDCl_3$) 8.94 (1 H, dd, $J_{1,2}$ 7.9, $J_{1,3}$ 1.8, 6′-H), 8.175 (2 H, d, *J* 7.6, 2″, 6″-H of Ph group), 7.36 (1 H, s, exocyclic H), 7.18 (dd, $J_{1,2}$ 8.02, $J_{1,3}$ 1.33, 3′-H), 2.425 (3 H, s; $COCH_3$) and 7.62–7.37 (5 H, m; remaining aromatic H).

3-*Benzoylamino*-1-*benzopyran*-2-*one* **1**.—(*a*) Salicylaldehyde (1.22 g, 10 mmol) and hippuric acid (1.79 g, 10 mmol) were stirred in polyphosphoric acid (12 g; Aldrich) at 90–100 °C for 100 min. The mixture was diluted with water and the discoloured crystalline solid was collected (2.65 g, 100%). Two crystallizations from ethanol (charcoal) removed the colour and a final crystallization from carbon tetrachloride gave the coumarin **1** as white woolly needles, m.p. 177 °C (lit.,[42] 176 °C). Products from this and other preparations (below) were identified with a specimen, m.p. 175–176 °C, m.p. 174–176 °C (K), prepared by an early procedure;[3] comparison was by TLC, m.p., and mixed m.p. The spectra were run with material crystallized from carbon tetrachloride); λ_{max}/nm 326 (ε, 21 300); ν_{max}/cm^{-1} 3370, 1715 and 1665; δ_H($CDCl_3$) 8.88 (1 H, s, 4-H), 8.86 (1 H, s, NH), 7.94 (2 H, d, *J* 7.3, 2′, 6′-H of Bz group) and 7.64–7.32 (7 H, m).

(*b*) 2-Phenyloxazol-5(4*H*)-one (0.16 g, 1 mmol) was stirred in *tert*-butyl alcohol (2 ml) with salicylaldehyde (0.15 g, 1.23 mmol) and pyridine (2 drops). After 1 h the solid (0.1 g) was collected and recrystallized from chloroform–methanol, yielding the coumarin **1**; m.p. 173–176 °C (K). A like result was obtained in ethanol.

(*c*) 2-Phenyloxazol-5(4*H*)-one (0.32 g, 2 mmol) and salicylaldehyde (0.24 g, 2 mmol) were heated under reflux for 1.5 h in 1,4-dioxane (5 ml) containing piperidine (0.2 ml). Recrystallization (ethanol) of the residue from evaporation at low pressure gave the coumarin **1** (0.3 g); m.p. 173–176 °C (K).

(*Z*)-4-(2′-*Hydroxyphenylmethylene*)-2-*phenyloxazol*-5(4H)-*one* **3**.—(*a*) 2-Phenyloxazol-5(4*H*)-one (1.65 g, 10.2 mmol) and 2-trimethylsilyloxybenzaldehyde[43] (1.94 g, 10 mmol; b.p. 62 °C/0.3 mm) were mixed in pyridine (1 ml) and triethylamine (3 drops) was added. The heat immediately evolved was controlled by water cooling; the mixture separated into two liquid layers. After 2 h the mixture was evaporated at low pressure and treated with methanol. The yellow crystalline precipitate was collected, dissolved in 1,2-dimethoxyethane (30 ml), and warmed briefly after addition of hydrochloric acid (2 mol dm^{-3}; 2 ml). Water was added; the fine yellow needles (1.1 g) were collected. A portion (0.2 g) of this was subjected to flash chromatography on silica (50 ml) in chloroform–hexanes (2:1). From the first eluates the *hydroxy oxazolone* **3** was obtained (40 mg) and recrystallized from carbon tetrachloride; m.p. 188–189 °C (for other properties, see (*b*) below). The last eluates yielded the coumarin **1** (160 mg); after recrystallization from carbon tetrachloride, it had m.p. 177 °C alone or mixed with authentic material.

(*b*) Water (4.18 ml) was added to stirred ice-cooled sulphuric acid (98.1%; 20 ml). Solid 4-(2′-acetoxyphenylmethylene)-2-phenyloxazol-5(4*H*)-one (2 g) was added during 2 min and cooling was continued for 40 min; the solid dissolved after 35 min. The solution was poured onto ice (130 g) and dichloromethane (50 ml). On warming to room temperature the layers separated; the organic layer was separated, washed (20 ml saturated aqueous $NaHCO_3$), filtered through magnesium sulphate, and evaporated. The orange crystalline residue (1.73 g; 100%) was free from starting material and from coumarin **1** by TLC; m.p. 188–190 °C. Other experiments with less dilute acid gave the following yields (% acid, % yield): 92, 96; 94, 85; 96, 61; 98, 5. In these experiments the starting material took longer to dissolve and increasing amounts of water were needed to give clear solutions in the work-up. The product from all experiments was recrystallized from chloroform yielding orange prisms, m.p. 191 °C (Found: C, 72.5; H, 3.9; N, 5.3. $C_{16}H_{11}NO_3$ requires C, 72.4; H, 4.2; N, 5.3%); λ_{max}/nm 408 (ε, 17 300), 396 (17 500), 340sh (14 400), 329 (15 400); ν_{max}/cm^{-1} 1815, 1780, 1645, 1603; δ_H($CDCl_3$) 12.77 (1 H, s, OH), 8.10 (2 H, d, *J* 7.6, 2″, 6″ of Ph) and 7.7–6.9 (8 H, m). The compound showed a green fluorescence in solution and (unlike **1** and **2**) a directly visible orange spot on TLC.

Reactions of the Hydroxy Oxazolone **3**.—(a) *Alkaline hydrolysis*. The hydroxy oxazolone (530 mg, 2 mmol) was rubbed in a mortar with aqueous sodium hydroxide (0.5 mol dm^{-3}; 8 ml). After 2.5 h an additional 4 ml of alkali effected complete dissolution; hydrochloric acid (2 mol dm^{-3}) was then slowly added. The crystalline precipitate (520 mg) was collected and dried; a sample dissolved completely in aqueous sodium hydrogen carbonate. Crystallization from aqueous 1,2-dimethoxyethane and from acetic acid gave rectangular prisms, m.p. 200–202 °C with bubbling (lit.,[5] 199.5 °C with decomp.) of (*Z*)-2-benzoylamino-3-(2′-hydroxyphenyl)acrylic acid **6**; δ_H(CD_3SOCD_3) 12.55 (1 H, br s, CO_2H), 10.1 and 9.8 (2 H, s, NH and OH), 7.94 (2 H, d, *J* 7.3, 2, 6 H of Ph group), 7.69 (1 H, s, 3-H), 7.6–7.55 (2 H, m), 7.52–7.48 (2 H, m), 7.18–7.13 (1 H, m), 6.90 (1 H, d, *J* 8, 3′-H) and 6.74 (1 H, t, *J* 7.5, 5′-H). The substance gave a yellow melt in which the hydroxy oxazolone **3** and the coumarin **1** were detectable by TLC; when boiled in carbon tetrachloride with a little acetic anhydride the substance went slowly into solution and the washed ($NaHCO_3$) solution on evaporation left a crystalline residue, indicated by TLC to be a mixture of the hydroxy oxazolone **3** and a little acetoxy oxazolone **2**.

(b) *Methanolysis*. The hydroxy oxazolone (265 mg, 1 mmol) suspended in methanol (5 ml) was treated with one small drop (*ca.* 15 mg KOH) of aqueous potassium hydroxide (40%). An orange–red colour developed and persisted while the oxazolone dissolved, then faded. Water was added and the methanol was removed at low pressure. The crystalline solid (264 mg) was collected and recrystallized from ethyl acetate. *Methyl* (Z)-2-*benzoylamino*-3-(2′-*hydroxyphenyl*)*acrylate* **7** was obtained as white prisms, m.p. 189–190 °C with previous yellowing (Found: C, 68.7; 4.9; N, 4.7. $C_{17}H_{15}NO_4$ requires C, 68.8; H, 5.1; N, 4.7%); δ_H(CD_3SOCD_3) 10.16 and 9.94 (2 H, s, NH and OH), 7.94 (2 H, d, *J* 7.4, 2, 6-H of Ph group), 7.65 (1 H, s, 3-H), 7.6–7.55 (2 H, m), 7.53–7.49 (2 H, m), 7.18 (1 H, m), 6.90 (1 H, d, *J* 8, 3′-H), 6.76 (1 H, t, *J* 7.5, 5′-H) and 3.72 (3 H, s, Me). The melted substance dissolved in chloroform to a yellow solution showing,

on TLC, spots corresponding to the hydroxy oxazolone **3** and to the coumarin **1**. The ester **7** was also formed, in poor yield and accompanied by methyl benzoate, by the action of cold methanolic hydrogen chloride on **3**.

(c) *Rearrangement.* The hydroxy oxazolone (265 mg, 1 mmol) in pyridine (2 ml) and triethylamine (0.1 ml) was heated at 90 °C for 40 min. The nearly colourless solution was diluted with water and the crystalline precipitate (234 mg; a little more separated when the pyridine was neutralized) was collected and recrystallized from ethyl acetate. The white felted needles had m.p. 175–176 °C alone or mixed with authentic coumarin **1**. The hydroxy oxazolone when heated at the melting-point for 0.5 h, or in sulpholane at 200–220 °C for a few min, showed on TLC some rearrangement to the coumarin **1**.

(*d*) *Acetylation.* Pyridine (0.2 ml) and acetic anhydride (0.2 ml) were mixed and added to the hydroxy oxazolone (0.1 g). Dissolution and crystallization of product were immediate. Water was added and the crystalline solid (115.6 mg; 99.7%) was collected; m.p. 161–162 °C alone or mixed with authentic **2**; homogeneous by TLC.

Experiments Related to Mechanism.—(*a*) The acetoxy oxazolone **2** (307 mg, 1 mmol), sodium acetate (82 mg, 1 mmol, freshly fused), acetic acid (0.18 ml, 3 mmol) and acetic anhydride (0.1 ml, 1.1 mmol) were heated in boiling water for 4 h. Much of the acetoxy oxazolone remained undissolved. Water was added to the cooled mixture and the total solid was collected; m.p. 161 °C, only 1 °C below that of the starting **2**. The crystals were washed quickly with chloroform which was then evaporated. This gave a small amount of material still melting above 155 °C but showing a trace of coumarin **1** by TLC.

(*b*) To 2-acetoxybenzaldehyde (164 mg, 1 mmol) and 2-phenyloxazol-5(4*H*)-one (161 mg, 1 mmol) in benzene (2.5 ml) was added triethylamine (0.14 ml, 1 mmol). The mixture became warm, a slight orange colour developed, and a small second liquid phase separated. After 40 min water and dilute hydrochloric acid were added, followed by diethyl ether. The organic layer was washed (aqueous $NaHCO_3$) and evaporated; the residue on treatment with a little carbon tetrachloride afforded yellow crystals (90 mg), m.p. 136–150 °C. Analysis of this product by NMR in $CDCl_3$ showed it to be a mixture of the coumarin **1** and the acetoxy oxazolone **2** in molar ratio 1:3. A spot corresponding to the hydroxy oxazolone **3** was seen in the TLC of the crude reaction product and more faintly in that of the crystals. The mother liquor on concentration yielded further crystals (10 mg) which on recrystallization from ethyl acetate yielded the coumarin **1**, m.p. 177 °C alone or mixed with authentic material. When the acetoxy oxazolone **2** was left for 1 week in benzene with triethylamine and water (1 equiv. each), the product after evaporation and collection with methanol was pure **2**, m.p. and mixed m.p. 161–162 °C.

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