STUDIES ON THE CONDENSATION PRODUCTS OF SOME α, β -UNSATURATED CARBONYL COMPOUNDS WITH 4-HYDROXYCOUMARIN†

Sunil K. Talapatra*, Ramaprasad Chakrabarti, Pradyot K. Mukhopadhyay, Prabir K. Das and Bani Talapatra*

Department of Chemistry, University College of Science, Calcutta 700009, India.

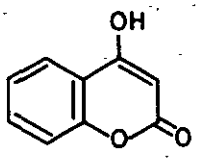
Abstract - The base catalysed condensation products of mesityl oxide and benzalacetone with 4-hydroxycoumarin have been studied. The reported structures (III) and (IX) of two condensation products are revised as (V) and (X) respectively. Chemical transformations of (V) to (VI), (VII) and (VIII) are enumerated. ^{13}C NMR spectral studies to distinguish between (IV) and (VI) and to establish structure (V) are also recorded. The plausible mechanisms for the formation of two novel compounds having the coumarin lactone ring ruptured, viz. (VIII) from (V) and the condensation product (XI) from 4-hydroxycoumarin and cinnamaldehyde have also been delineated.

In connection to our studies on the chemistry of some 4-hydroxycoumarin derivatives having potential pesticidal properties, we reinvestigated the condensation reactions of several α, β -unsaturated carbonyl compounds with 4-hydroxycoumarin, already reported by Ikawa et al[1]. The reinvestigation led not only to the revision of the structures of some of the products, but to the isolation of some novel compounds[2-4].

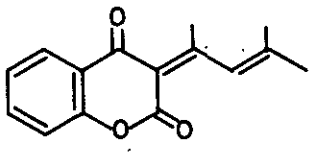
Of the two condensation products of 4-hydroxycoumarin (I) and mesityl oxide (Py, Δ, 48 hr) the hexane soluble less polar one, mp 93° (33% yield) was assigned the structure (II) while the hexane insoluble one, mp 212° (13%) was assigned the structure (III)[1]. However, the structure (II) was revised

†Presented in part in the Fifth International Congress of Pesticide Chemistry (IUPAC), Aug. 29 - Sept. 4, 1982, Kyoto, Japan, Abstracts, p. Ic-6.

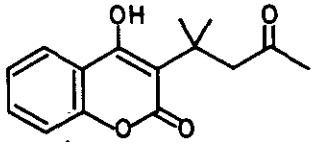
as (IV) by Hutchinson et al[5] on the basis of spectral analysis. Our studies conform to this revision and also lead to the revision of the structure of the more polar compound from (III) to (V) through its spectral features [ν_{max}(KBr) : 3330 cm^{-1}(OH group); PMR (d_6-DMSO, 100 MHz) : δ 1.40 (6H, s, gem-dimethyl), 1.64 (3H, s, $\underline{H}_3C-C<^{O}_{O}$), 1.95 (2H, s, $-C\underline{H}_2-$), 7.06 (1H, s, exchangeable with D_2O, $-O\underline{H}$) and 7.30-7.78 (4H, m, aromatic H's); the only 3H signal at δ 1.64 unambiguously discarding structure (III) having a $COCH_3$ group].



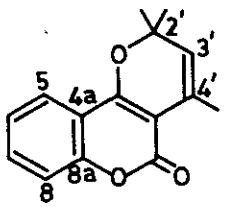
(I)



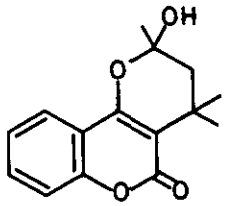
(II)



(III)



(IV)

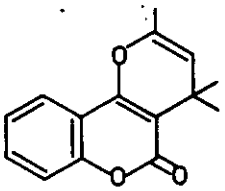


(V)

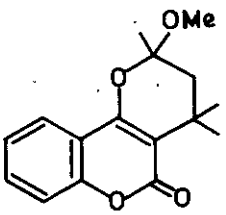
Treatment of (V) with BF_3-etherate in presence or absence of $Pb(OAc)_4$ in dry benzene (0.5 hr) afforded the dehydration product (VI) (28%), mp 110° (light petrol - ether), $C_{15}H_{14}O_3$ (M^+ 242); ν_{max}(KBr) : 1705 cm^{-1} (coumarin CO); PMR ($CDCl_3$, 90 MHz) : δ 1.45 (6H, s, gem-dimethyl), 1.94 (3H, s, olefinic $C\underline{H}_3$), 4.63 (1H, bs, vinyl H), 7.20-7.80 (4H, m, aromatic H's). The distinction between the position isomers (IV) and (VI) could also be made through ^{13}C NMR spectral studies described later.

Use of methanolic benzene medium in the above reaction yielded (30%) the ketal (VII), the methyl ether of (V), mp 120° (chloroform - light petrol), $C_{16}H_{18}O_4$ (M^+ 274) [ν_{max}(KBr) 1705 cm^{-1} (coumarin C=O); PMR ($CDCl_3$, 100 MHz): δ 1.41, 1.52, 1.65 (each 3H, s, three $C\underline{H}_3$'s), 1.88, 2.14 (each 1H, d, J=13 Hz, $-C\underline{H}_2-$), 3.28 (3H, s, $-OC\underline{H}_3$) and 7.22-7.83 (4H, m, aromatic H's)].

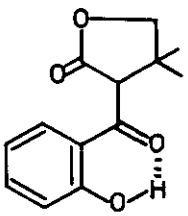
The above reactions when carried out in presence of $Pb(OAc)_4$ afforded, in addition to the compounds (VI) or (VII), another novel compound (VIII) (4%) - a γ-lactone derivative formed by the rupture of the coumarin lactone moiety. The compound (VIII), mp 142° (chloroform - light petrol), $C_{13}H_{14}O_4$ (M^+ 234) possesses an o-hydroxyacetophenone type[6] chromophore [λ_{max}(EtOH) : 257 nm (log ε 4.21) and 331 (3.82)] and showed $FeCl_3$- colouration. The IR [ν_{max}(KBr): 3510 cm^{-1}(OH), 1779 (γ-lactone C=O), 1660 (conjugated chelated C=O)] and the PMR spectral data in $CDCl_3$ (100 MHz) [δ 1.0, 1.4 (each 3H, s, two- CH_3's), 2.29, 2.61 (each 1H, d, J=17Hz, $-CH_2-$), 5.52 (1H, s, -CO-CH-CO-), 6.86-7.60 (4H, m, aromatic H's) and 11.86 (1H, s, disappearing on D_2O shake, -OH)] are fully consistent with the derived structure (VIII).



(VI)



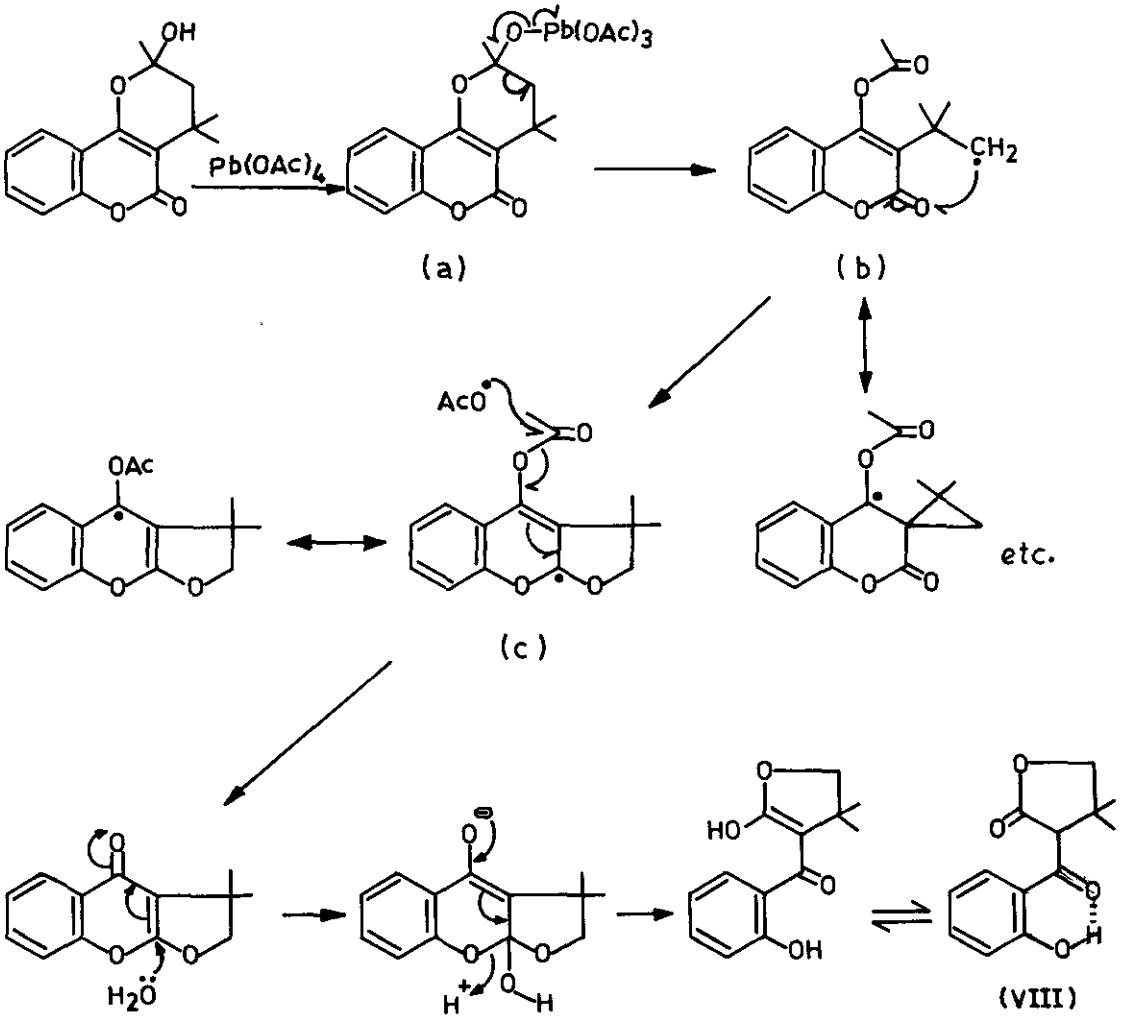
(VII)



(VIII)

Thus, the above reactions established the structure (V) and not (III) for the more polar condensation product. A ketomethyl group in a compound as in (III) would be converted into the $-COCH_2OAc$ group on treatment with $Pb(OAc)_4$ and BF_3-etherate[7-9]. On the other hand, lead tetraacetate may have some function in the formation of (VIII). According to the most reasonable concept, oxidation of tertiary alcohol function [here the hemi-ketal OH group in (V)] occurs by $Pb(OAc)_4$ and during this oxidation, fragmentation becomes the major reaction path. In this particular case, three possible modes of fragmentation of (a) may occur, of which one possible mode gives rise to a radical(b) primary as well as homoallylic, which has certain amount of contribution towards resonance as shown (Scheme 1); once it is formed, it collapses on to the coumarin carbonyl oxygen. The resulting resonance stabilised radical (c) picks up an acetate radical to lose a molecule of acetic anhydride and takes up a molecule of water to form the final product (VIII) as shown in Scheme 1.

Scheme 1. Plausible mechanism for the formation of (VIII) from (V)



^{13}C NMR spectroscopic studies on (IV), (VI) and (VII) have been made, which provided a method for characterising the isomers (IV) and (VI). Chemical shift and degree of protonation of each carbon were determined by noise decoupled (ND) and single frequency off-resonance decoupled (SFORD)[10,11] spectra respectively. δ_C expressed in ppm assignable to each carbon atom[12] of the compounds (IV), (VI) and (VII) are summarised in Table 1.

The resonance signal at 102.2 ppm in the ^{13}C NMR spectrum of (VII) clearly showed the presence of a -O-$\overset{|}{C}$-O- type moiety in the ketal (VII) and consequently in the corresponding hemiketal (V). Hence, the dehydration product

of (V) and the isomer of the former must be (VI) and (IV) respectively, thus ruling out the alternate possibilities. Furthermore, the resonance signals of C-2', C-3' and C-4' of (IV), (VI) and (VII) are in good agreement with the respective structure derived on the basis of the fact that either of (IV) and (VI) contains four saturated carbons including one tertiary, while (VII) possesses six such saturated carbons of which two are tertiary.

Table 1. ^{13}C NMR ($CDCl_3$) signals of (IV), (VI) and (VII)

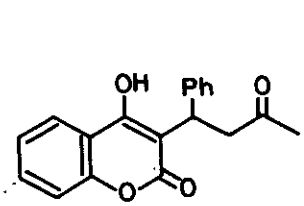
Compound	Spectrum run at	δ_C (ppm) of						
		C-2	C-3	C-4	C-4a	C-5	C-6	C-7
(IV)	20 MHz	159.46	101.51	159.14	115.03	123.27	123.27	131.53
(VI)	25.2 MHz	161.9	108.5	156.3	115.3	123.8	124.6	132.4
(VII)	25.2 MHz	161.5	111.0	156.8	116.7	123.5	124.3	131.9

Compound	δ_C(ppm) of							
	C-8	C-8a	C-2'	C-3'	C-4'	$-\underline{C}H_3$	$>C(\underline{C}H_3)_2$	$-O\underline{C}H_3$
(IV)	115.60	152.62	79.43	122.62	126.75	19.94	27.46	-
(VI)	117.1	153.4	143.8	112.1	32.0	19.4	30.7	-
(VII)	117.0	153.4	102.2	49.1	31.4	29.9	24.0,27.5	50.4

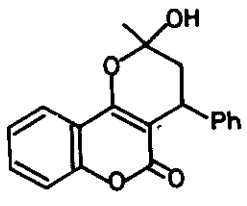
Again, the structure (IX) for the base catalysed reaction product (35%) of 4-hydroxycoumarin and benzalacetone as proposed earlier[1] is revised by us as (X) through spectral (IR, PMR and MS) analysis. The spectral data of the product (X), mp 162°, $C_{19}H_{16}O_4$ (M^+ 308);[ν_{max} (KBr) : 1678 cm^{-1} (coumarin C=O); PMR ($CDCl_3$, 90 MHz) : δ 1.66 (3H, s, $-C\underline{H}_3$), 2.38, 3.45 (each 1H, d, J=20 Hz, $-C\underline{H}_2-$), 4.17 (1H, m, Ar-$\overset{1}{C}\underline{H}$-Ph), 7.14-8.0 (9H, m, aromatic H's)] clearly indicated the absence of a ketomethyl group as proposed in (IX).

The condensation reaction of 4-hydroxycoumarin and cinnamaldehyde is being reported for the first time. 4-Hydroxycoumarin was refluxed with cinnamaldehyde in water containing traces of pyridine for 14 hr. The reaction mixture on cooling and extracting with chloroform yielded a mixture of two products,

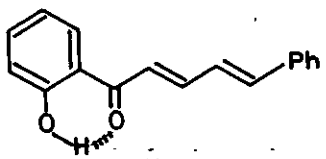
separated by chromatography over silica gel. The yellow compound (XI), mp 157° (chloroform - light petrol), $C_{17}H_{14}O_2$ (M^+ 250), [λ_{max}(EtOH) : 358 nm (log ε 4.44) and 243 (3.96), reminiscent of o-hydroxyacetophenone type[6] chromophore; ν_{max} (KBr) : 1615 cm^{-1} (highly conjugated carbonyl group); PMR ($CDCl_3$, 80 MHz) : δ 7.12-7.35 (13H, m, aromatic and olefinic H's) and 12.78 (1H, s, D_2O exchanged, -OH)] was obtained in lower yield (~ 15%).



(IX)



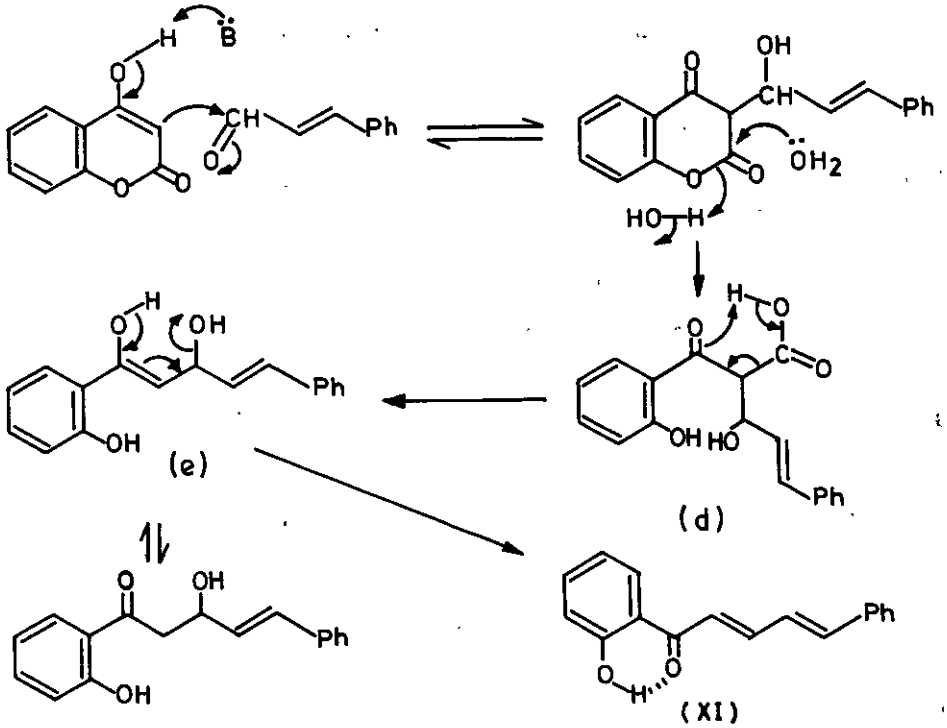
(X)



(XI)

This hitherto unknown highly conjugated compound showed $FeCl_3$-colouration. Under the reaction condition, thermodynamically more stable trans-trans diene is expected to be formed; but because of overlapping with aromatic protons, no pmr evidence could be provided. The formulation (XI) was, however, confirmed from its identity with the product obtained from the base catalysed condensation of o-hydroxyacetophenone and cinnamaldehyde. The formation of (XI) necessarily involves the base-catalysed condensation of 4-hydroxycoumarin with cinnamaldehyde followed by an irreversible base-catalysed breakdown of the coumarin lactone ring giving rise to the β-keto-acid (d), which under the reaction condition easily decarboxylates to afford the enediol (e). The latter, in turn, on losing the elements of water furnished the final product (XI) (Scheme 2).

Scheme 2. Possible mechanism for the formation of (XI)



From the results received in the foregoing reactions, it is evident that in the condensation of 4-hydroxycoumarin with mesityl oxide, both carbonyl addition and Michael type addition occur, whereas with benzalacetone only Michael addition takes place and cinnamaldehyde gives rise to carbonyl addition presumably due to its higher carbonyl activity than benzalacetone. Further experiments with several other α,β-unsaturated carbonyl compounds are in progress with a view to finding out the generality, if any, of this type of reactions.

ACKNOWLEDGEMENTS

We thank Professor N. Takahashi (Tokyo University, Japan) and Dr. B.C. Das (CNRS, France) for various spectral measurements and the University Grants Commission, New Delhi for financial assistance.

REFERENCES

1. M. Ikawa, M.A. Stahmann and K.P. Link, J. Amer. Chem. Soc., 1944, 66, 901.
2. B. Talapatra, R. Chakrabarti, P. Mukhopadhyay and S.K. Talapatra, Abstracts, Convention of Chemists (India), 1977, ORG-142, p.65.

3. S.K. Talapatra, A. Basak, P. Das, B.C. Maiti and B. Talapatra, Abstracts, Symposium on Recent Developments in Organic Chemistry (Calcutta), 1979, p.32.

4. R. Chakrabarti, Ph.D. Dissertation, 1981, Calcutta University.

5. D.W. Hutchinson and J.A. Tomlinson, Tetrahedron Letters, 1968, 5027.

6. O.W. Wheeler and L.A. Kaplan, 'Organic Electronic Spectral Data', Interscience Publishers, New York, 1956-1957, Vol.III, p.152.

7. J.D. Cocker, H.B. Hembest, G.W. Phillips, G.P. Slater and D.A. Thomas, J. Chem. Soc., 1965, 6.

8. G.W.K. Cavill and D.H. Solomon, J. Chem. Soc., 1955, 4426.

9. J.W. Ellis, J. Org. Chem., 1969, 34, 1154; Chem. Commun., 1970, 7, 406.

10. J.B. Stothers, 'Carbon-13 NMR Spectroscopy', Academic Press, New York, 1972.

11. G.C. Levy and G.L. Nelson, 'Carbon-13 Nuclear Magnetic Resonance for Organic Chemists', Wiley-Interscience, New York, 1972.

12. K.K. Chan, D.D. Giannini, A.H. Cain, J.D. Roberts, W. Porter, W.F. Trager, Tetrahedron, 1977, 33, 899.

Received, 29th August, 1983