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ACETONE-SENSITISED PHOTOISOMERISATION AND ACID-CATALYSED REARRANGEMENTS OF β,γ-UNSATURATED OXO-STEROIDS

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Essentially two types of photochemical rearrangements are observed for β,γ-unsaturated ketones. The predominant triplet reaction is formally a 1,2-acyl shift, while the predominant singlet reaction is formally a 1,3-acyl shift.[1] We report here the acetone-sensitised photoisomerisation of the β,γ-unsaturated ketones (1)[2] and (2)[3] to their epimeric ketones (3) and (4) respectively.[†] In addition, compound (4) undergoes an unusual acid-catalysed rearrangement to compound (10) via compound (8).

Acetone solutions of compounds (1) and (2) were irradiated under nitrogen, in quartz apparatus, with a medium pressure mercury lamp. The major products (3) (20%) and (4) (40%) respectively were isolated by t.l.c. No products of 1,2-acyl shift were found in the minor fractions. However, small quantities of the products obtained from irradiation of benzene solutions of compounds (1) and (2) were isolated.[†] The spectral data for compounds (3) and (4) were extremely similar to their respective parent compounds (1) and (2). A broad signal ($W\frac{1}{2}$ 20 Hz.) for the 3α-H in the ^{1}H n.m.r. spectrum of compound (3) confirmed its 5α-configuration.[§] The same configuration was indicated for compound (4) by its conversion to compound (3) by successive selective sodium borohydride reduction and methylation.

[†] The products of irradiation in benzene solution are discussed in the following paper.

[§] The use of tris(dipivalomethanato)europium allowed the separation of the signals for the 3α-H and the 3-MeO which are superimposed in $CDCl_3$.

The photoepimerisations of the ketones (1) and (2) are presumably triplet reactions ‡ occurring via the diradicals (5) and (6) respectively. It has often been assumed that α-cleavage is the initial step in the 1,2- and 1,3-acyl migrations reported for β,γ -unsaturated ketones. However, there is direct evidence for such α-cleavage only in a limited number of examples,[1c,d] and it has only been possible to observe photoepimerisations of the type described here in certain saturated ketones.[4] Recently it has been suggested that 1,2-acyl migrations could alternatively be concerted $\sigma^2_a + \pi^2_a$ cycloadditions[1b,5] or oxa-di-π-methane rearrangements in which the first step is 2,4-bonding.[6] Our failure to detect any products which result from 1,2-acyl migration appears to add to the body of negative evidence which suggests that α-cleavage is not an initial step in 1,2-acyl migration.* By implication these results therefore support the alternative concerted or oxa-di-π-methane mechanisms. Unfortunately these latter courses appear quite plausible for compounds (1) and (2) and we are unable to explain the absence of any appreciable amount of 1,2-acyl migration.

Compound (4) rearranged slowly on silica gel to the cyclo-pentanone (8). This unusual rearrangement, presumably via the enol (7), was also induced with toluene-p-sulphonic acid in ether. The 5β-methyl diketone (2) does not rearrange under similar conditions. Possibly the ability of the π -electrons of the developing 4,5-double bond to overlap with those of the departing 6-carbonyl group is a necessary condition for this rearrangement. This stereoelectronic requirement cannot be accommodated in the 5β-epimer (2). On prolonged treatment with toluene-p-sulphonic acid in ether, or on treatment with HBr in acetic acid, the cyclopentanone (8) in admixture with compound (4) gave compound (10). This rearrangement may be an aldol involving the enol (9) (path a). Alternatively, the mechanism may be similar to that described for the acid-catalysed rearrangements of bridged bicyclic β,γ -unsaturated ketones (path b).[7]

Satisfactory spectroscopic data are available for compounds (8) and (10). The i.r.

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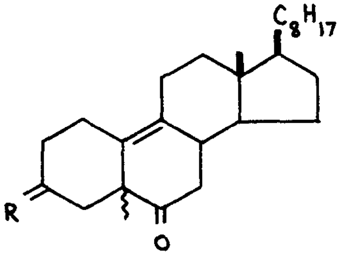
‡ The photoepimerisation of compound (2) in 10% acetone in hexane is partially quenched by naphthalene. Further experiments are required to establish the multiplicity of this reaction unequivocally.

* 1,2-Acyl migration was not observed in those compounds which were shown to undergo α-cleavage.[1c,d]

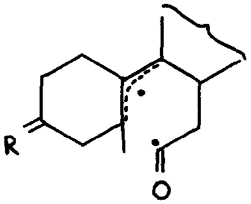


(1) 5β, R = β-MeO,H

(2) 5β, R = O

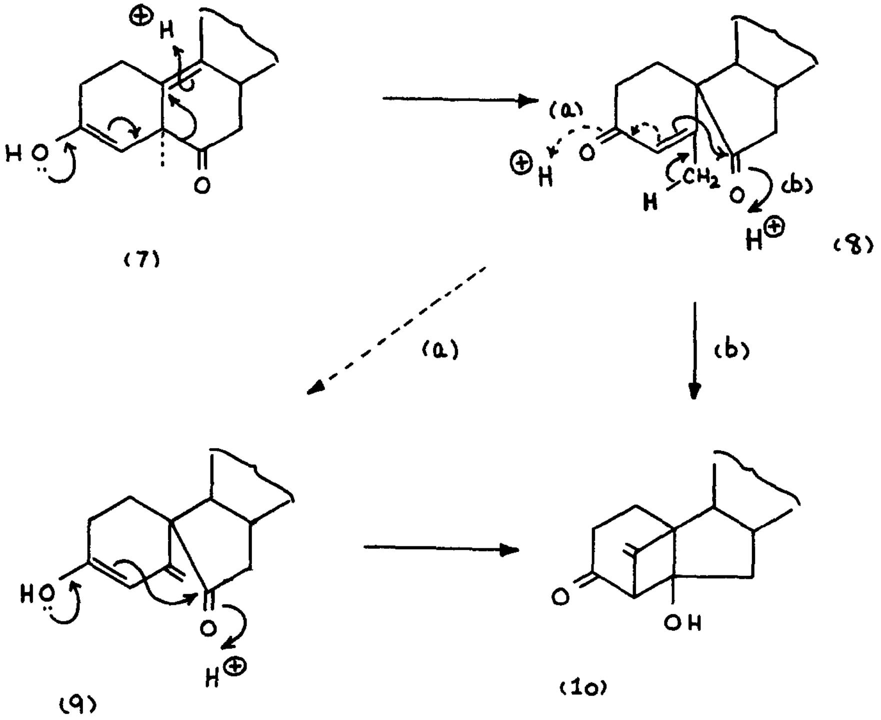
(3) 5α, R = β-MeO,H

(4) 5α, R = O



(5) R = β-MeO,H

(6) R = O



spectrum of compound (8) shows the presence of an α,β-unsaturated ketone ($\nu_{max.}$ 1667 cm.$^{-1}$) and a cyclopentanone ($\nu_{max.}$ 1743 cm.$^{-1}$). The A-ring enone structure is confirmed by the u.v. [$\lambda_{max.}$ (EtOH) 242 nm.] and the ^{1}H n.m.r. [τ 3.99 (m, 4-H) and 7.93 (d, 5-Me)] spectra. The ^{1}H n.m.r. spectrum of compound (10) confirms the presence of the exocyclic methylene group (τ 5.17 and 5.26, m) and the bridgehead proton (τ 7.00, broad s.). The main functional groups of compound (10) are confirmed by the i.r. spectrum [3500 (OH), 3080 (=CH_2), and 1720 (cyclohexanone) cm.$^{-1}$]

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References

1. (a) W.M.Horspool, Specialist Periodical Reports, Photochemistry, 1970, 1, 192;
    (b) E.Baggiolini, K.Schaffner, and O.Jeger, Chem.Comm., 1969, 1103;
    (c) K.Kojima, K.Sakai, and K.Tanabe, Tetrahedron Letters, 1969, 1925, 3399;
    (d) E.F.Kiefer and D.A.Carlson, Tetrahedron Letters, 1967, 1617.
2. Y.F.Shealy and R.M.Dodson, J.Org.Chem., 1951, 16, 1427.
3. (a) J.W.Blunt, M.P.Hartshorn, and D.N.Kirk, J.Chem.Soc.(C), 1968, 635;
    (b) V.A.Petrow, O.Rosenheim, and W.W.Starling, J.Chem.Soc., 1938, 677.
4. G.Quinkert, Pure Appl.Chem., 1964, 9, 607.
5. R.B.Woodward and R.Hoffmann, Angew.Chem.Internat.Edn., 1969, 8, 781.
6. (a) W.G.Dauben, M.S.Kellogg, J.I.Seeman, W.A.Spitzer, J.Amer.Chem.Soc., 1970, 92, 1786;
    (b) S.Domb and K.Schaffner, Helv.Chim.Acta., 1970, 53, 677.
7. H.Hart and G.M.Love, Tetrahedron Letters, 1971, 2267.