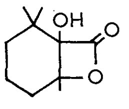
55. *The Constitution of an Oxidation Product of β-Ionone.*

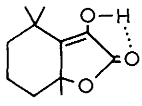
By C. J. W. Brooks, G. Eglinton, and D. S. Magrill.

Permanganate oxidation of β-ionone yields the enolic α-keto-lactone (II). Infrared absorption data are discussed.

The compound, " hydroxyionolactone," m. p. 130°, obtained by Tiemann[1] from β-ionone by permanganate oxidation, was later formulated[2] as a β-lactone (I). Doubts about this structure prompted a re-examination of the oxidation. Under conditions based on those described,[1] a product was isolated resembling Tiemann's lactone in melting point, solubility, acidic character, and reactivity towards bromine. However, Tiemann reported that hydrobromic acid reacted (under unstated conditions) to give a saturated bromolactone, formulated as $C_{10}H_{15}O_2Br$ without physical or analytical data. Our oxidation product was recovered (60%) on addition of water to its solution in 50% hydrobromic–acetic acid. The identity of the two oxidation products is thus not certain, but seems very probable. The results described below indicate that our compound has structure (II), in which the angular methyl group must be axially oriented.



(I)



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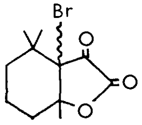

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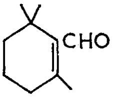
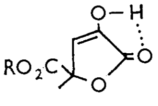
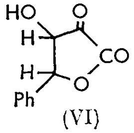


(IV)

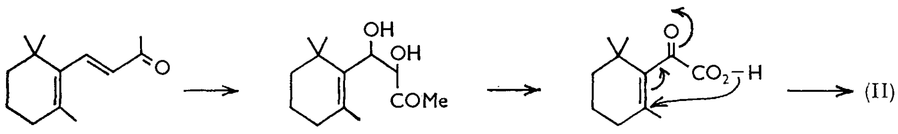


(V)



(VI)

Analyses were in accord with the formula $C_{11}H_{16}O_3$. The presence of an enolic group was shown by a strong ferric reaction. The functional groups were defined by infrared absorption bands (in dilute CCl_4; see Table) at 3507m (intramolecularly bonded OH), *ca.* 3300w (dimer? hydroxyl; absent in very dilute solution), 1760vs (αβ-unsaturated γ-lactone), and 1702m (C=C) cm.$^{-1}$ (no COOH absorption), and by ultraviolet absorption maxima [238 mμ (ε 11,400) in EtOH; 274 mμ (ε 10,000) in ethanolic 0·003N-NaOH]. These results, in particular the ultraviolet absorption, are typical of an enolised α-keto-lactone,[3] and lead to the expression (II): the formally alternative δ-lactonic structure is excluded by the infrared data. The lactone readily formed an acetate, m. p. 66—67°, and with diazomethane slowly gave what is regarded as an *O*-methyl derivative by analogy [3b,4] and from



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[1] Tiemann, *Ber.*, 1898, **31**, 857.

[2] Simonsen, " The Terpenes," Cambridge Univ. Press, 2nd edn., 1947, Vol. I, p. 128; Rodd, " Chemistry of Carbon Compounds," Elsevier, Amsterdam, 1953, Vol. II, p. 503.

[3] (*a*) Djerassi and Rittel, *J. Amer. Chem. Soc.*, 1957, **79**, 3528; (*b*) Schinz and Hinder, *Helv. Chim. Acta*, 1947, **30**, 1349; (*c*) Plattner and Jampolsky, *ibid.*, 1943, **26**, 689.

[4] Stacy, Cleary, and Gortakowski, *J. Org. Chem.*, 1957, **22**, 765.

infrared data. Bromine water was decolorised by the lactone (cf. ref. 3*b*), the product being the β-bromo-α-keto-lactone (III; possibly a mixture of stereoisomers), which showed elevated carbonyl frequencies as found in other non-enolised α-dicarbonyl compounds.[5] Pyrolysis[6] of the lactone (II) gave β-cyclocitral (IV), isolated as its 2,4-dinitrophenylhydrazone which was identical with authentic material.[7] A plausible route for the formation of the lactone (II) would involve a diol intermediate (cf. ref. 8) as in the annexed scheme.

Spectroscopic data were observed for comparison from the compounds (V; R = H, Me). The ultraviolet absorption, and in particular the " alkali shift " due to ionisation of the enol [pK_2 6·95 for the acid (V; R = H)[9]] closely resembled that found for the lactone (II). Infrared data for the ester (V; R = Me) are listed in the Table together with data for related systems. A band near 3510 cm.$^{-1}$ does not necessarily indicate an α-enolic carbonyl system, for saturated α-ketols may have (usually broader) bands in this region (*e.g.*, 3505 cm.$^{-1}$ for a D-homosteroid 17α-hydroxy-17a-ketone[10]). The saturated α-hydroxy-γ-lactone, pantolactone, absorbs at 3565 cm.$^{-1}$. Confusion is unlikely to arise with the monomer hydroxyl band of a carboxylic acid (3535—3515 cm.$^{-1}$) as the typical acid dimer hydroxyl absorption near 3000 cm.$^{-1}$, and the corresponding dimer carbonyl band (approx. 40 cm.$^{-1}$ below the monomer band) both persist to extremely high dilutions.

Hydroxyl and carbonyl stretching frequencies for α-enolic carbonyl compounds.

	ν_{OH}	$\Delta\nu_{\frac{1}{2}}$ [a]	ε_a	ν_{OH} (dimer?)	ν_{CO}	$\Delta\nu_{\frac{1}{2}}$ [a]	ε_a	$\nu_{C=C}$	ε_a
Lactone [a] (II)	3507	26	195	(3350) †	1760	13	(1400)	1702	(120)
Lactone [a] (V; R = Me) ...	3516	30	130	(3348) †	1787 [d]	12	(880)	1697	(130)
Lactone [b] (VI)	(3509)	*	*	*	(1776)	*	*	(1709)	*
Lactone [c] from iresin	3546	*	*	3333	1757	*	*	1681	*
3-Methylcyclopentane-1,2-dione [a]	3505	29	110	—	1723	9	620	1677	590
Maltol [a] (2-hydroxy-3-methyl-4-pyrone).........	3398	65	70	—	1640	11	1510	1679	150

Values in parentheses are approximate. * Not measured. † Band reduced to insignificance by dilution. [a] Present work: CCl_4 solutions. [b] Ref. 11: CH_2Cl_2 solution (cited as μ). The β-hydroxyl group may contribute to the band recorded. [c] Ref. 3*a*: $CHCl_3$ solution. [d] Ester-carbonyl absorption at 1748 cm.$^{-1}$, $\Delta\nu_{\frac{1}{2}}$ [a] 17, ε_a 530.

In the α-hydroxy-γ-pyrone, maltol (see Table), in which an α-enolic carbonyl group forms part of a larger conjugated system, the monomer hydroxyl band is broader and of lower frequency. When examined in the solid or liquid state, α-enolic lactones, like diosphenols, exhibit strong hydroxyl absorption in the range 3300—3400 cm.$^{-1}$ [*e.g.*, lactone (II), 3350 (KBr); α-oxo-β-hydroxy-γ-phenylbutyrolactone[11] (VI), *ca.* 3367 (Nujol); tetrahydrogentiogenins,[12] *ca.* 3300 (KBr) cm.$^{-1}$]; the monomer band is insignificant. The carbonyl band tentatively attributed to a dimeric form of lactone (II) occurs at 1737 cm.$^{-1}$ (KBr) [cf. lactone (VI), *ca.* 1748 cm.$^{-1}$ (Nujol); α-oxo-βγ-diphenylbutyrolactone,[11] *ca.* 1730 cm.$^{-1}$ (Nujol)]. The bands ascribed to double-bond stretching vibrations in lactones (II), (V), and (VI) are at frequencies somewhat above the usual range.

EXPERIMENTAL

Unless otherwise specified, ultraviolet absorption data (determined with a Unicam S.P. 500 spectrophotometer) are for EtOH solutions, and infrared data for CCl_4; apparent extinction coefficients (ε_a) are in l. mole^{-1} cm.$^{-1}$. Infrared measurements were made as described elsewhere[13] with a Unicam S.P. 100 infrared spectrometer equipped with a prism-grating double

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[5] Alder, Schäfer, Esser, Krieger, and Reubke, *Annalen*, 1955, **593**, 23.

[6] Schinz and Rossi, *Helv. Chim. Acta*, 1948, **31**, 1953.

[7] Naves and Ardizio, *Bull. Soc. chim. France*, 1954, 330.

[8] Wiberg and Saegebarth, *J. Amer. Chem. Soc.*, 1957, **79**, 2822; Waters, *Quart. Rev.*, 1958, **12**, 277.

[9] Montgomery and Webb, *J. Biol. Chem.*, 1956, **221**, 359.

[10] Wendler, Taub, Dobriner, and Fukushima, *J. Amer. Chem. Soc.*, 1956, **78**, 5027.

[11] Dahn and Hauth, *Helv. Chim. Acta*, 1957, **40**, 2249, 2261.

[12] Korte, *Chem. Ber.*, 1954, **87**, 769.

[13] Brooks, Eglinton, and Morman, *J.*, 1961, 106.

monochromator. Light petroleum refers to the fraction of b. p. 40—60°. Microanalyses were performed by Mr. J. M. L. Cameron and his associates.

Oxidation of β-Ionone.—The β-ionone used was 98% pure as shown by gas–liquid chromatography and ultraviolet spectrometry. A solution of potassium permanganate (40 g.) in water (600 ml.) was added dropwise, in 2½ hr., to a stirred solution of β-ionone (20 g.) in acetone (220 ml.) and water (60 ml.), at 0—5°. Then sodium acetate (*ca.* 5 g.) was added, and the mixture was treated with sulphur dioxide, saturated with sodium chloride, and extracted with ether (4 × 300 ml.). The combined ether phases were extracted with saturated sodium hydrogen carbonate solution (4 × 100 ml.). Acidification of the alkaline phase and ether-extraction yielded a yellow oil (11 g.), which after several extractions with boiling water gave a waxy solid, m. p. *ca.* 122°: the infrared spectrum (Nujol) indicated the presence of carboxylic acid impurities. Recrystallisation from water followed by sublimation at 70°/0·1 mm. gave the lactone (II), 2,4,5,6,7,7a-*hexahydro*-3-*hydroxy*-4,4,7a-*trimethylbenzofuran*-2-*one*. The m. p. was obscured by extensive sublimation, and was unsharp (129—131°) whether determined on the Kofler block or in a capillary tube (Found: C, 67·4; H, 8·0. $C_{11}H_{16}O_3$ requires C, 67·35; H, 8·2%). The compound gave a red-violet colour with ferric chloride, and failed to give a 2,4-dinitrophenylhydrazone under the usual conditions.

Reactions of the Oxidation Product (II).—(i) The lactone (25 mg.) was kept overnight with pyridine (0·2 ml.) and acetic anhydride (0·15 ml.). The *acetate*, after sublimation and recrystallisation from ether–light petroleum, formed prisms (15 mg.), m. p. 66—67° (Found: C, 65·5; H, 7·15. $C_{13}H_{18}O_4$ requires C, 65·5; H, 7·6%), $\lambda_{max.}$ 216·5 mμ (ε 14,000) (cf. ref. 3*c*), $\nu_{max.}$ 1787vs and 1776vs (lactone and enolic acetate CO), 1677 (conjugated C=C) cm.$^{-1}$.

(ii) The lactone (29 mg.) was kept at 5° for 24 hr. with ethereal diazomethane (3 mol.); one drop of methanol and a further 2 mol. of diazomethane were then added. The solution was worked up after a further 24 hr., yielding the impure methyl ether as an oil which after two short-path distillations at 0·1 mm. amounted to 11 mg. (Found: C, 67·85; H, 8·75. Calc. for $C_{12}H_{18}O_3$: C, 68·55; H, 8·65%), $\lambda_{max.}$ 226 mμ (ε 11,000), $\nu_{max.}$ 1763 (ε_a 1150) (lactone CO), 1660 (ε_a 110) (C=C), 2868 and 2845 (C–H of OMe) cm.$^{-1}$.

(iii) A suspension of the lactone (80 mg.) in water (25 ml.) was shaken while bromine water (2 ml.; 35 mg./ml.) was added during 10 min. The precipitated *bromo-derivative* (III) recrystallised from ether–light petroleum as prisms (65 mg.), m. p. 166—173° (forming a glass: further recrystallisation did not improve the m. p.) (Found: C, 48·2; H, 5·65; Br, 29·25. $C_{11}H_{15}O_3Br$ requires C, 48·0; H, 5·5; Br, 29·05%), apparent $\lambda_{max.}$ (in ether) *ca.* 225 mμ (ε 3000), $\nu_{max.}$ 1810 (ε_a *ca.* 650), 1781 (ε_a *ca.* 290) cm.$^{-1}$ (no OH absorption).

(iv) The lactone (50 mg.) was kept under nitrogen in a tube containing a cold finger, immersed for 10 min. in a bath at 300°. The volatile oil (14 mg.) recovered had $\lambda_{max.}$ 246 mμ: the intensity of absorption was consistent with the presence of 63% of pure β-cyclocitral,[7] which was isolated as the 2,4-dinitrophenylhydrazone and, recrystallised from ether–light petroleum (yield, 6·5 mg.), had m. p. and mixed m. p. 171—172°, $\lambda_{max.}$ (in $CHCl_3$) 386 mμ (ε 26,000). The infrared spectrum (KCl disc) was identical with that of an authentic sample.[7]

α-Enolic Lactones.—γ-Carboxy-α-oxo-γ-valerolactone (V; R = H), isolated from commercial pyruvic acid,[14] had m. p. 115—116°, $\lambda_{max.}$ 237 mμ (ε 6200) (in 0·003N-NaOH–EtOH), 270 mμ (ε ~8000) (in 0·003N-HCl–EtOH), 234 mμ (ε 6400), isosbestic point, 249 mμ (ε 4000), $\nu_{max.}$ (Nujol) 3300—2400 (CO_2H), 1770 (γ-lactone), *ca.* 1713 (CO_2H), 1670 and 1655 (C=C?) cm.$^{-1}$, and was insoluble in carbon tetrachloride. The *methyl ester* (V; R = Me), prepared with the calculated amount of diazomethane at −30° and purified by short-path distillation, formed viscous gum (Found: C, 44·75; H, 5·25. $C_7H_8O_5,H_2O$ requires C, 44·2; H, 5·3%), $\lambda_{max.}$ 234·5 mμ (ε *ca.* 6000) (in 0·003N-NaOH–EtOH), 270 mμ (ε *ca.* 6000), isosbestic point, 249 mμ (ε *ca.* 3000).

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[14] Hughes and Watson, *J.*, 1929, 1945.