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THE MALEIC ANHYDRIDE ADDUCTS OF TROPOLONE AND 2-METHOXYTROPONE

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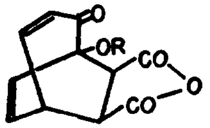
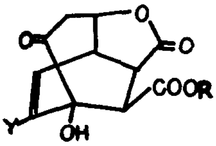
The Diels-Alder reaction of troponoid compounds has been studied using symmetric dienophiles in the cases of tropone (1,2), 2-halotropones (3), 4-methoxytropone (4), 2-methoxytropone (5), tropolone and its homologues (6,7) and halotropolones (8,9). Although crystalline adducts were obtained from all of these troponoids, only those from the first four were investigated in sufficient detail to permit reliable structures to be proposed. In light of our present knowledge on structures of these adducts (1,2,3,4, 5), the α-diketone structures proposed by Sebe and Osako (7) for the adducts from hinokitiol and maleic anhydride deserve further study. In this paper we propose structures for the tropolone- and 2-methoxytropone-maleic anhydride adducts, and suggest that the two-step reaction mechanism is favoured for the Diels-Alder reactions of troponoids in general.

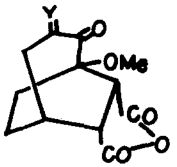
Tropolone was heated with maleic anhydride in refluxing xylene to yield, contrary to the previous report (8), two isomeric 1:1 adducts which were separated by fractional crystallization (ratio 1:1). The exo-adduct (I) (10), m.p. 175-7°, identical with the one previously isolated, possesses a simple αβ-unsaturated ketone [λmax 225 mμ (log ε 3.80), ν 1675 cm^{-1}], as well as a five-membered anhydride function (ν 1848, 1770 cm^{-1}). It gave a tetrahydro derivative (II), m.p. 210°, (ν 1840, 1780, 1705 cm^{-1}) on catalytic hydrogenation, and an acetate (III), m.p. 206°, [λmax 224 mμ (log ε 3.69), ν 1740 cm^{-1}] with hydrogen chloride in acetic anhydride. The NMR spectrum of I in acetone clearly exhibited signals due to four olefinic protons at 7.28 (q, J=11.4, 8.4), 6.08 (d, J=11.4), 6.68 (q, J=8.6, 7.2) and 6.01 ppm (d, J=8.6). The appearance of an acetate carbonyl at 1740 cm^{-1} in III also excludes an α-diketone structure. On heating with water, I afforded the γ-lactonic keto carboxylic acid (IV), m.p. 183° [λmax 281 mμ (log ε 2.15), ν 1760, 1735, 1705, 1412 cm^{-1}]. The NMR spectrum of its methyl ester (V) in $CDCl_3$, m.p. 188°



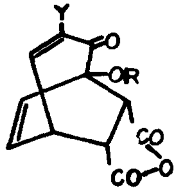
I: R=H
III: R=Ac



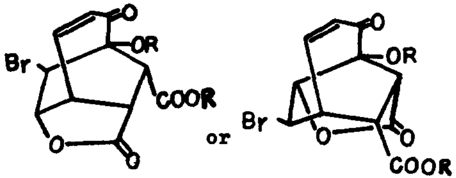
IV: R, Y=H
V: R=Me, Y=H
XIII: R=H, Y=Br



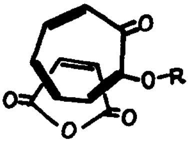
XI: Y=H$_2$
XII: Y=CH-C$_6$H$_5$



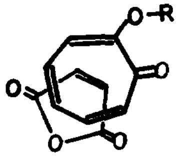
VI: R, Y=H
IX: R=CH$_3$, Y=H
XIV: R=H, Y=Br



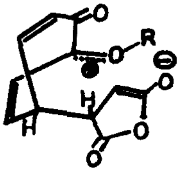
VIII: R=H
X: R=CH$_3$



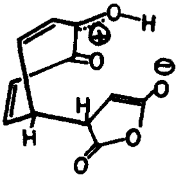
[A]



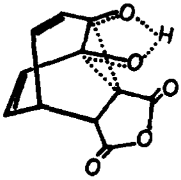
[B]



[C]



[D]



[E]

(ν 1760, 1735, 1713 cm^{-1}) showed two olefinic protons, at 6.18 (apparent d, J=3) and 6.23 ppm (apparent s), and a proton attached to the carbon bearing lactonic oxygen at 5.00 ppm (m).

On the other hand, the endo-adduct (VI), m.p. 155-7.5°, showed UV and IR spectra [λmax 223 mμ (log ε 3.73), ν 1850, 1790, 1665 cm^{-1}] similar to those of I, suggesting the presence of the same groupings in VI as in I. NMR spectra of VI in acetone exhibited four olefinic protons at 7.35 (q, J=10.7, 8.3), 5.88 (d, J=10.7), 6.52 (q, J=8.9, 7.6) and 5.88 ppm (d,J=8.9). Hydrolysis of VI under the same condition as in I afforded the corresponding dicarboxylic acid (VII), m.p. 132-4°, which still retains an $\alpha\beta$-unsaturated carbonyl group [λmax 226 mμ (log ε 3.70), ν 1740, 1675 cm^{-1}]. Bromination of VII in alkaline solution yielded a liquid bromo-γ-lactone (VIII) [λmax 230 mμ (log ε 3.80), ν 1790, 1730, 1678 cm^{-1}].

2-Methoxytropone was heated with maleic anhydride in refluxing xylene to give, as the sole product, the endo-adduct (IX), m.p. 182-3° which contains an $\alpha\beta$-unsaturated carbonyl and a five membered anhydride group [λmax 224 mμ (log ε 3.76), ν 1860, 1780, 1675 cm^{-1}]. <u>endo</u>-Orientation of the anhydride group was deduced from Alder-Stein bromination to give the bromo-γ-lactone (X), m.p. 190-1° [λmax 229 mμ (log ε 3.91), ν 1770, 1730, 1665 cm^{-1}]. The location of the methoxyl group on the bridge-head position was concluded on the following basis: Catalytic hydrogenation of IX forms the corresponding tetrahydro derivative (XI), m.p. 170-1° [λmax 302 mμ (log ε 1.71), ν 1863, 1780, 1710 cm^{-1}] which afforded a pale-yellow liquid benzylidene derivative (XII) [λmax 289 mμ (log ε 3.40)].

The sharp contrast of the reaction of tropolone, giving two adducts (I and VI), and 2-methoxytropone, giving only one adduct (IX), can best be explained in terms of the two step reaction mechanism (11). Of the two possible orientations (A and B) of the two reactants, both of which fulfill the requirement "maximum accumulation of unsaturation", A is preferred to B, because the electron-releasing hydroxyl or methoxyl group on the diene part is facing the electron-attracting carbonyl group on the dienophile. Thus, the electrophilic attack by the dienophile is facilitated at the 5-position and the resulting intermediate C is stabilized by electrostatic attraction. The formation of the <u>endo</u>-adduct I and IX from C is straight forward. In the case of tropolone, however, C can easily rearrange to D by shift of the hydroxyl hydrogen; bond formation from D resulting in the <u>exo</u>-adduct VI. The intermediates C and D might be represented by a single structure E.

The reaction of 3-bromotropolone and maleic anhydride has been reported (9) to give, after hydrolysis, two adducts XIII, m.p. 232-3° and XIV, m.p. 183-4°. Although structures were not proposed by the original workers, these adducts should be represented by XIII and XIV, respectively, on the basis provided, and in view of the present study.

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10) UV and IR spectra were measured for methanol solutions and KBr discs, respectively. NMR spectra were measured at 60 MHz. Chemical shifts (δ) are expressed in ppm from internal TMS, and coupling constants (J) in Hz. All compounds described in this paper gave satisfactory analytical values.

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