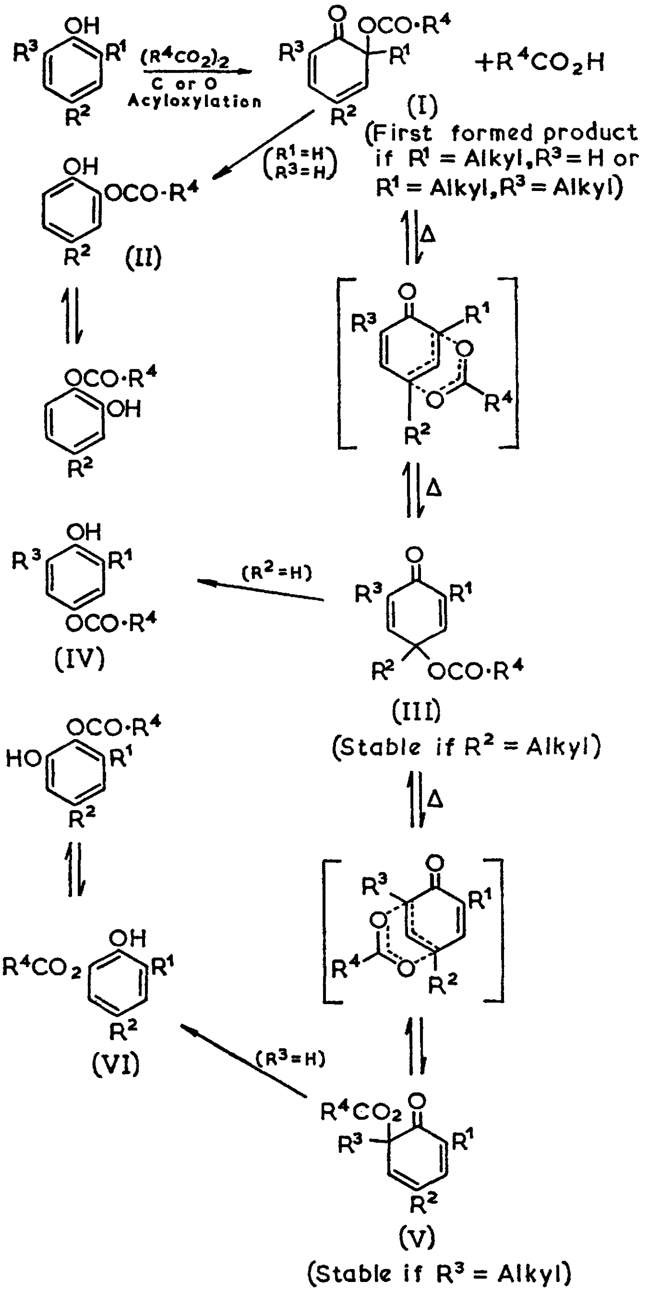
The Thermal Rearrangement of 6-Acyloxycyclohexa-2,4-dienones

By D. H. R. BARTON,* P. D. MAGNUS, and M. J. PEARSON

(*Imperial College, London, S.W.7*)

TREATMENT of phenols (having at least one *ortho*-position unsubstituted) with benzoyl peroxide in $CHCl_3$ affords[1] monobenzoylated catechols. It has been stated that, under these conditions, 2,6-dimethylphenol gave 4-benzoyloxy-2,6-dimethylphenol and the corresponding diphenoquinone. Similarly[2] 2,4,6-trimethylphenol was reported to give 4-benzoyloxy-2,4,6-trimethylcyclohexa-2,5-dienone (III; $R^1 = R^2 = R^3 = Me$, $R = Ph$.) The latter was isolated by distillation or by crystallisation after treatment with benzoyl chloride in refluxing pyridine.



The mechanism of these acyloxylations has been investigated.[3,4] It is generally held[5] that the *p*-benzoyloxy-compounds are not formed by 'Claisen-type' rearrangements of initially formed *o*-isomers. Indeed, where this latter type of rearrangement has been observed, it has involved pyrolysis at 450° and has been a minor pathway in a free-radical sequence.[6,7]

In contrast, based on results outlined in the sequel, we suggest that the reaction of a phenol with an acyl peroxide always results in preponderant *o*-acyloxylation. Subsequent products are formed by thermal sigmatropic [3,3]suprafacial[8] migration of the acyloxy-group around the periphery of the cyclohexadienone ring. Diagrammatically this hypothesis may be represented as in the Scheme.

p-Cresol was oxidised with benzoyl peroxide in refluxing chloroform.[1] Hydrolysis of the intermediate (II; $R^2 = Me$, $R^4 = Ph$) gave, after sublimation, 4-methylcatechol (65%). The sodium salt of *p*-cresol in ether with benzoyl peroxide at 25° likewise gave 4-methylcatechol (65%). *p*-Methoxyphenol, when treated with benzoyl peroxide in chloroform at 40° gave (over 85%) the catechol derivative (II; $R^2 = OMe$, $R^4 = Ph$).

The sodium salt of 2,4,6-trimethylphenol in ether or glyme at −20° gave a rapid reaction with benzoyl peroxide, and the *o*-dienone (I; $R^1 = R^2 = R^3 = Me$, $R^4 = Ph$) was isolated in 65% yield, $\lambda_{max.}$ 231, 275, 283, and 312 nm. (ϵ 17,700, 2400, 2500, 3200). Its n.m.r. spectrum (all n.m.r. data on the τ scale) has signals at 8·53 (3H s), 8·09 (6H m), 4·16 (1H m), 3·36 (1H m), 2·59 (3H m), and 2·04 (2H m). We repeated the reaction reported[2] to give (III; $R^1 = R^2 = R^3 = Me$, $R^4 = Ph$), and obtained the *o*-dienone as above. Use of the more electrophilic peroxide bis-*p*-nitrobenzoyl peroxide gave (I; $R^1 = R^2 = R^3 = Me$, $R^4 = C_6H_4NO_2$-*p*) (95%).

It was found that heating (I; $R^1 = R^2 = R^3 = Me$, $R^4 = Ph$) at 120° (m.p. 113°), for 1 hr. gave a mixture of *o*- and *p*-dienones. Since the work-up conditions used by the same workers,[1,2] who isolated *p*-dienone, frequently employed treatment with benzoyl chloride–pyridine, the *o*-dienone (I; $R^1 = R^2 = R^3 = Me$, $R^4 = Ph$) was exposed to these conditions, and to pyridine at reflux alone. In both cases a steady state was reached after 40 min. in which 40% of the *o*-dienone (I; $R^1 = R^2 = R^3 = Me$, $R^4 = Ph$), and 60% of the *p*-dienone (III; $R^1 = R^2 = R^3 = Me$, $R^4 = Ph$) were present (by n.m.r.). The same equilibration took place in toluene after 2 hr. The *p*-dienone (III; $R^1 = R^2 = R^3 = Me$, $R^4 = Ph$) was isolated by chromatography. Its n.m.r. spectrum is that of a symmetrical molecule 8·35 (3H s), 8·07 (6H bs), 3·26 (2H s), 2·86 (3H m), 2·05 (2H m). When (I; $R^1 = R^2 = R^3 = Me$, $R^4 = C_6H_4NO_2$-*p*) was rearranged in the same way a mixture of *o*- and *p*-dienones was formed at approximately the same rate, and in the ratio 2 : 3. The *p*-dienone (III; $R^1 = R^2 = R^3 = Me$, $R^4 = C_6H_4NO_2$-*p*) was isolated, and again n.m.r. [8·3 (3H s), 8·07 (6H s), 3·25 (2H s), 1·8

(4H d)] confirmed the structure and symmetry of the molecule.

When the known[9] *o*-dienone (I; $R^1 = R^2 = R^3 = R^4 =$ Me) was exposed to refluxing pyridine (24 hr.), a mixture of *o*- and *p*-dienones was formed in the ratio 2 : 3 (by n.m.r.). In all these rearrangements it is possible to establish the same ratio of *o* : *p*-dienone starting with the pure *p*-dienone.

Having demonstrated the case when R^2 = Me we looked at the case where R^2 = H. Reaction of the sodium salt of 2,6-dimethylphenol in ether with benzoyl peroxide at −20°, gave (I; $R^1 = R^3$ = Me, R^2 = H, R^4 = Ph) (52%), $\lambda_{max.}$ 304, 284, 275, and 231 nm. (ϵ 4700, 3600, 3000, 18,100). The methyl signals at 8·56 (3H s), and 8·08 (3H d) confirmed the structure. Using bis-*p*-nitrobenzoyl peroxide in chloroform on 2,6-dimethylphenol, the *o*-dienone (I; $R^1 = R^3$ = Me, R^2 = H, $R^4 = C_6H_4NO_2$-*p*) was formed (72%). Exposure of (I; $R^1 = R^3$ = Me, R^2 = H, R^4 = Ph) to refluxing pyridine gave 4-benzoyloxy-2,6-dimethylphenol in good yield. When (I; $R^1 = R^3$ = Me, R^2 = H, $R^4 = C_6H_4NO_2$-*p*) was heated as above 4-(*p*-nitrobenzoyloxy)-2,6-dimethylphenol (IV; $R^1 = R^3$ = Me, $R^4 = C_6H_4NO_2$-*p*) was formed in excellent yield.

2,4-Dimethylphenol reacted with bis-*p*-nitrobenzoyl peroxide in chloroform to give the *o*-dienone (I; $R^1 = R^2$ = Me, R^3 = H, $R^4 = C_6H_4NO_2$-*p*) (33%), (VI; $R^1 = R^2$ = Me, $R^4 = C_6H_4NO_2$-*p*) (40%) and a trace of *p*-dienone (III; $R^1 = R^2$ = Me; R^3 = H, $R^4 = C_6H_4NO_2$-*p*) (3%). When (I; $R^1 = R^2$ = Me, R^3 = H, $R^4 = C_6H_4NO_2$-*p*) was heated under reflux in toluene, t.l.c. demonstrated that the *p*-dienone (III; $R^1 = R^2$ = Me, R^3 = H, $R^4 = C_6H_4NO_2$-*p*) was formed first, and slowly rearranged to the catechol derivative (VI; $R^1 = R^2$ = Me, $R^4 = C_6H_4NO_2$-*p*).

o-Acyloxylation reactions should have value in synthesis. All compounds were fully characterised by i.r., u.v., and n.m.r. spectroscopy and by quantitative elemental analysis.

(*Received, March 29th,* 1969; *Com.* 439.)

[1] S. L. Cosgrove and W. A. Waters, *J. Chem. Soc.*, 1949, 3189.
[2] S. L. Cosgrove and W. A. Waters, *J. Chem. Soc.*, 1951, 388.
[3] C. Walling and R. B. Hodgdon, *J. Amer. Chem. Soc.*, 1958, **80**, 228.
[4] D. B. Denney and D. Z. Denney, *J. Amer. Chem. Soc.*, 1960, **82**, 1389.
[5] A. J Waring, *Adv. Alicyclic Chem.*, 1966, **1**, 167.
[6] E. Zbiral, F. Wessely, and E. Lahrmann, *Monatsh.*, 1960, **91**, 331.
[7] E. Zbiral, O. Saiko, and F. Wessely, *Monatsh.*, 1964, **95**, 512.
[8] R. B. Woodward and R. Hoffmann, *J. Amer. Chem. Soc.*, 1965, **87**, 2511.
[9] F. Wessely and F. Sinwel, *Monatsh.*, 1965, **81**, 1055.