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

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TREATMENT of phenols (having at least one ortho-position unsubstituted) with benzoyl peroxide in $CHCl_3$ affords¹ monobenzoylated catechols. It has been stated that,



under these conditions, 2,6-dimethylphenol gave 4-benzoyloxy-2,6-dimethylphenol and the corresponding diphenoquinone. Similarly² 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 held⁵ that the *p*-benzoyloxycompounds 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 freeradical 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 signatropic [3,3]suprafacial⁸ 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; $\mathbb{R}^2 = Me$, $\mathbb{R}^4 = Ph$) 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; $\mathbb{R}^2 = OMe$, $\mathbb{R}^4 = Ph$).

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, λ_{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 reported² 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; $R^1 = R^2 =$ $R^3 = Me$, $R^4 = C_6 H_4 NO_2 - p$) 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; $R^1 = R^2 = R^3 = Me$, $R^4 = C_6 H_4 NO_2 - p$) 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 known⁹ 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%), λ_{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, $R^2 = H$, $R^4 = C_6 H_4 NO_2 - p$) 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

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2,4-Dimethylphenol reacted with bis-p-nitrobenzoyl peroxide in chloroform to give the o-dienone (I; $R^1 = R^2 = Me$, $R^3 = H$, $R^4 = C_6 H_4 NO_2 - p$) (33%), (VI; $R^1 = R^2 = Me$, $R^4 = C_6 H_4 NO_2 - p$ (40%) and a trace of p-dienone (III; $R^1 = R^2 = Me; R^3 = H, R^4 = C_6 H_4 NO_2 - p$ (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; $R^1 = R^2 = Me$, $R^4 = C_6 H_4 NO_2 - p$).

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.

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