# Intramolecular Alkylation of Phenols. Part 4.[1] Base-catalysed Cyclisation of Phenolic Enones. Scope and Limitations

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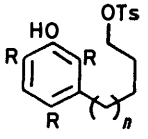
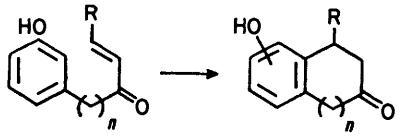
The phenolic enones (4), (5), (8), (9), and (13) cyclise readily under acidic conditions. However, neither these nor the thio-substituted phenols (11a), (13a), (14a), and (15a) closed under basic conditions. Involvement of unfavourable equilibria is disproved. Comparison is made with related successful cyclisations of the saturated ketone (38) and aldehyde (39). Preliminary results suggest that strict stereo-electronic requirements are necessary for enone ring closure and that these conditions are not met in base-catalysed 5-*Endo*- and 6-*Endo*-*Trigonal* ring closures of the phenols of general type (2; $n = 0$ and $n = 1$).

PHENOLS (1; $n = 1$, R = H, and R = Me) cyclise smoothly [2] under basic conditions. Asymmetric induction is observed [1] when R = Me and the leaving group is chiral. We have become interested in extending this mode of cyclisation to enones. The model system (2;



(1)

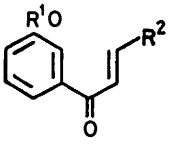


(2)

$n = 0$ and $n = 1$) was chosen for study since it was simple and yet permitted a wide range of structural variations. Anionic intramolecular 1,4-addition of phenoxide has not as yet been reported.

*Synthesis of Model Compounds.*—The phenol (3a) was synthesised from the ammonium salts obtained by a Mannich reaction with *m*-hydroxyacetophenone (Scheme 1). The enone (3a) was unstable and polymerised rapidly. However, the transient existence of (3a) was proved by trapping experiments using a series of nucleophiles (Scheme 1). The phenols (4a)—(7a) were synthesised by alcoholic sodium or potassium hydroxide-catalysed condensation of *m*-hydroxyacetophenone with the corresponding aldehydes. The phenols (8a) and (9a) were synthesised as outlined in Scheme 2. It was found necessary in order to prevent unwanted condensation products in the subsequent reactions of (8a) and (9a) to protect the α-methylene position by *gem*-dimethylation (Scheme 2). The final step in the synthesis of (8a) could not, unlike (9a), be effected with potassium t-butoxide and methyl iodide when only monomethylation occurred. However, sodium hydride in tetrahydrofuran with methyl iodide was highly effective. The propanone (10) was most conveniently synthesised in 55—60% yield by the method [3] used to prepare the corresponding 2-methoxy-isomer. It was also prepared in 39% yield by acetylating *m*-methoxyacetonitrile and then hydrolysing the resulting ketonitrile with acid. The phenol (11a) was prepared by a modification of the method of Huisman [4] (Scheme 3). We found that the reacting phenol need not be protected. However, two equivalents of base were now necessary to effect condensation to (11a) (90%). When *m*-methoxytoluene-α-thiol was used, Huisman's method [4] was adopted, *e.g.* in the synthesis of (11b) (64%). In this case the β-hydroxyketone (12) (19%) was isolated. The compounds (13b) (66%) and (14b) (90%) were similarly prepared as the sole products. This condensation of free phenols was general and was applied successfully to the oxide of Hagemann's ester and to cyclohexenone oxide to yield (13a) (50%) and (14a) (57%). The phenol (15a) was obtained from (11a) both by oxidation with *m*-chloroperbenzoic acid in methylene chloride (85%) and by hydrogen peroxide in acetic acid (85%).

*Synthesis of Expected Cyclised Products.*—Acid catalysed cyclisation of the enones (4), (5), (8), and (9) to



(3) $R^2$ = H
(4) $R^2$ = Bu$^t$
(5) $R^2$ = Ph
(6) $R^2$ = *p*-HOC$_6$H$_4$
(7) $R^2$ = *o*-HOC$_6$H$_4$

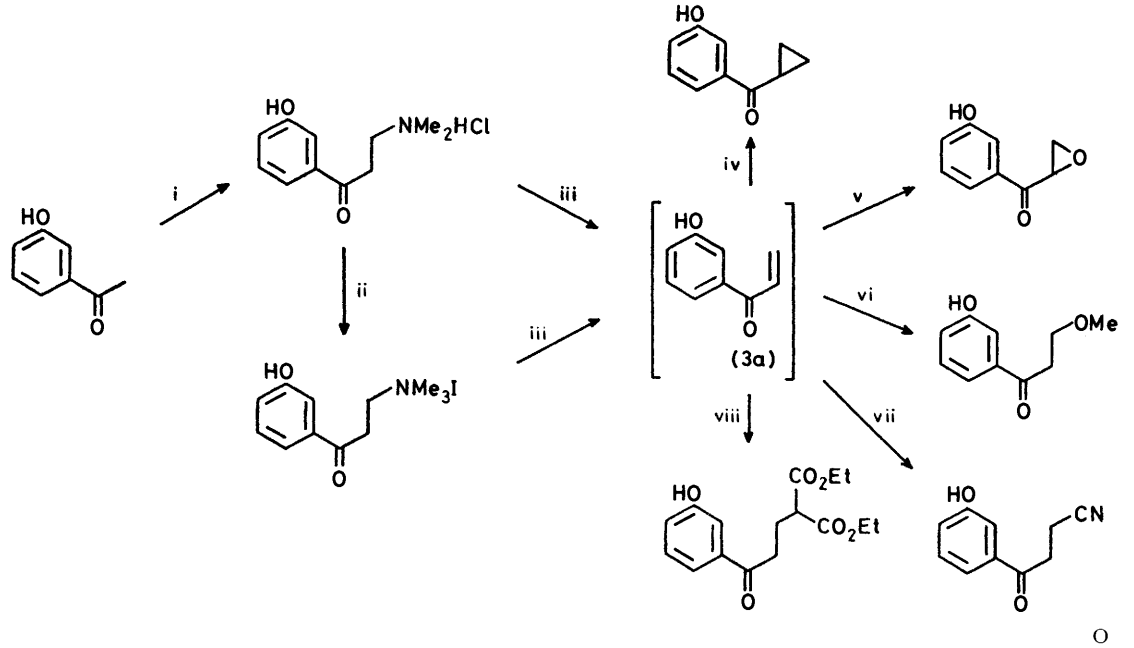
a, $R^1$ = H; b, $R^1$ = Me

(16)—(19) respectively was effected as expected [5] at room temperature with boron trifluoride–ether in nitromethane. Phenol protection was not required as a comparison of (5a) with (5b) showed (see Table). From both of these reactions the corresponding saturated ketones (20) and (21) were isolated in addition to the cyclised products. It is likely that (20) and (21) were formed *via* hydride abstraction by the intermediate

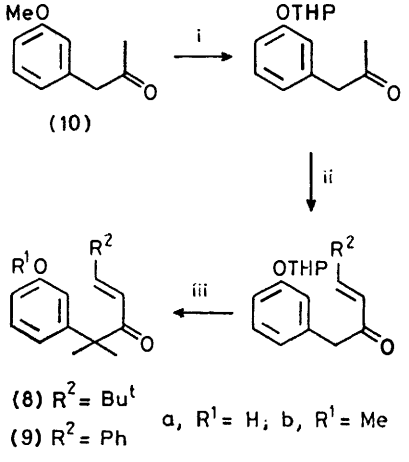
cation from diethyl ether.[6] The structure of (20) was proved by comparison with the product obtained from the hydrogenation of (5a). As is common [7] in cationic processes a high *para*- to *ortho*-alkylation ratio was observed (Table).

Although the cyclisations of (5a) and (5b) can be classified as 5-*Exo-Trigonal* [8] modes (22), such a transition state is not possible in the case of (4). A concerted conrotatory electrocyclic ring closure [9] of the pentadienyl system [10] (23) is a tempting rationale. However an $S_EAr$ mechanism [11] is more consistent with the cyclisation also of (8) and (9) under these same conditions.

The enone (13b) cyclised under these conditions but (11a), (14a), (15a) and (15b) did not. We suggest that stabilisation by the sulphur as in (24) occurred. This theory was first used by Huisman [4] to explain a related phenomenon in a similar system. It was unexpected [4] that this effect should persist in the case of the sulphones (15a) and (15b). The efficient cyclisation of (13b) must be due to the ethoxycarbonyl function. We suggest that (13b) first rearranges to the ketone (25) (Scheme 4). The cationic sites in the complex cannot both be bridged by sulphur for steric reasons and so the resonance hybrid retains sufficient electrophilicity to undergo cyclisation. Consistent with this is the observation that none of the possible [12] condensation product (26) was observed.




SCHEME 1 *Reagents:* i, HCHO, $NHMe_2HCl$, HCl (72% yield); ii, $Na_2CO_3$, then MeI (27%); iii, base; iv, $CH_2{=}\overset{\overset{O}{\uparrow}}{S}Me_2$ (57%); v, $H_2O_2$, NaOH (62%); vi, MeOH, NaOH (82%); vii, NaCH (29%); viii, $NaCH(CO_2Et)_2$ (13%)



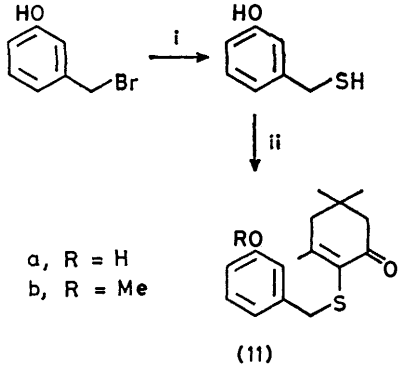

SCHEME 2 *Reagent:* i, $BBr_3$, $CH_2Cl_2$, −70 °C, then DHP, HCl (40% yield); ii, RCHO, NaOH ($R^2$ = But, 27%; $R^2$ = Ph, 44%); c, NaH, MeI, then dil. HCl ($R^2$ = But, 81%; $R^2$ = Ph, 91%)

$BF_3$-Catalysed cyclisation of enones

| Enone | Time | Isolated yield (%) | *ortho* (%) | *para* (%) |
|---|---|---|---|---|
| (4b) | 3 d | 93 | 1 | 99 |
| (5a) | 46 h | 42 | 4 | 96 |
| (5b) | 3 d | 54 | 3 | 97 |
| (8b) | 13 d | 56 | 1 | 99 |
| (9b) | 20 h | 70 | 3 | 97 |
| (13b) | 6 d | 64 | | |

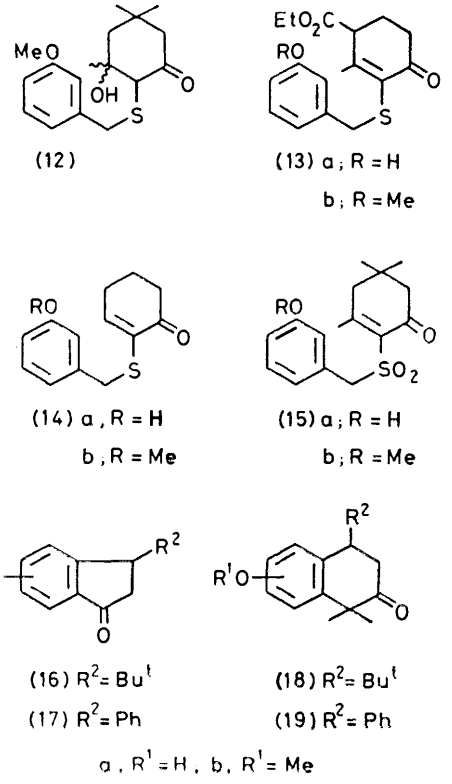
*Attempted Anionic Ring Closures. Results and Discussion.*—Phenols (4a) and (5a) did not cyclise when treated with aqueous base and in the case of (5a) a retro-aldol condensation was observed when heating above room temperature was used. Failure of these to close could be due to stereoelectronic factors [8] since each can be classified as a 5-*Endo-Trigonal* reaction (27). Since 5-*Exo-Trigonal* ring closure is permissible,[8] the phenol (6a) and its *ortho*-hydroxy-isomer (7a) which could cyclise by this route, were treated with ethylmagnesium bromide and heated in benzene. Neither

(6a) nor (7a) closed and were recovered unchanged. That cyclisation of (4a) was prevented by the steric bulk of the t-butyl group was disproved by extrapolating the results of the following intermolecular reaction.

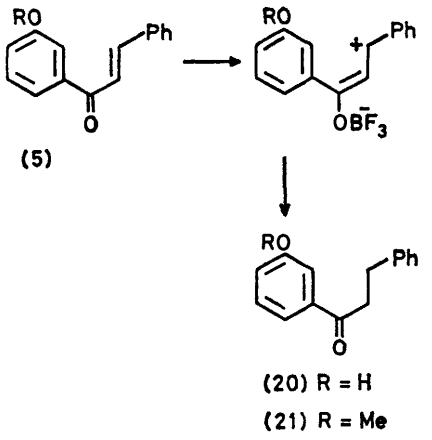



SCHEME 3 *Reagent*: i, $NH_2CNH_2$, $H_2O$, 100 °C, 2 h, then NaOH (74% yield; ii, isophorane oxide, KOH (90%)

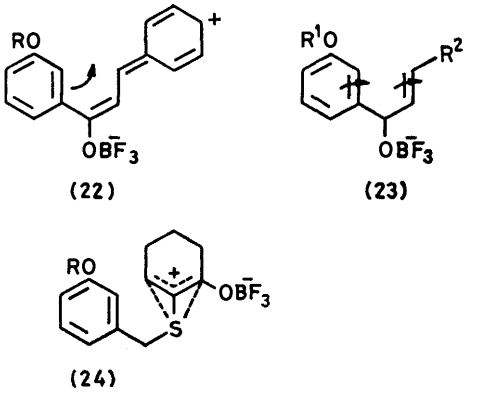
When (4a) was treated with NaOD in $D_2O$ for 19 h, the α-hydrogen was replaced by deuterium (28). Thus a facile intermolecular conjugate addition and reversal of $OD^-$ occurred unimpeded by the t-butyl group. The phenols (8a) and (9a) were investigated carefully since each can close by the permitted 6-*Endo-Trigonal* mode.[8]



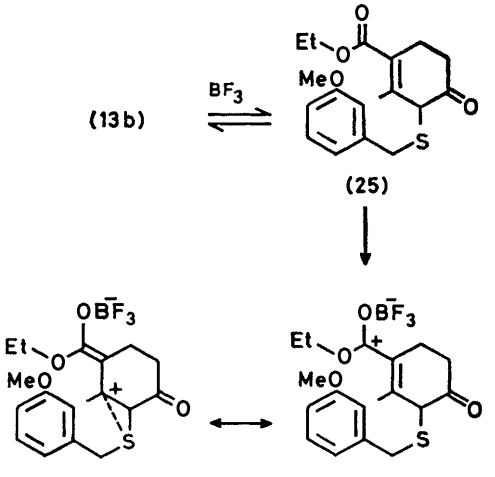

However, neither closed under a wide range of basic conditions such as aqueous sodium hydroxide at a variety of temperatures, sodium ethoxide at 80 °C for 25 h, potassium t-butoxide in t-butyl alcohol for 12 h at




20 °C, and sodium hydride in both toluene and tetrahydrofuran at reflux temperature for 16 h. Retro-aldol condensation was observed when (9a) was heated in aqueous sodium hydroxide. There are three possible reasons for the failure of (8a) and (9a) to cyclise (see Scheme 5): (*a*) an unfavourable equilibrium (K) between

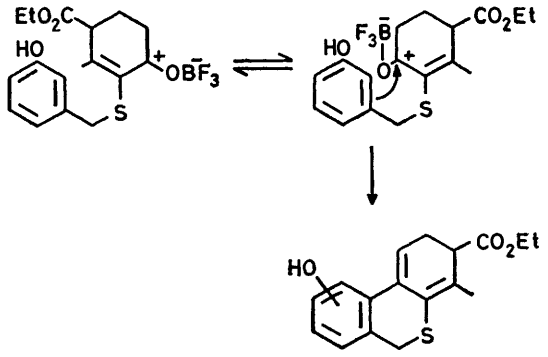



(9a) and (29); (*b*) the rate ($k_H$) of formation of (30) is slow relative to the rate of reversal of (29) to (9a), and (*c*) the rate of reaction of (9a) to (29) is so slow as to be undetectable. By comparison, in the Claisen rearrangement, of for example (31) to (33),[13] it has been found that



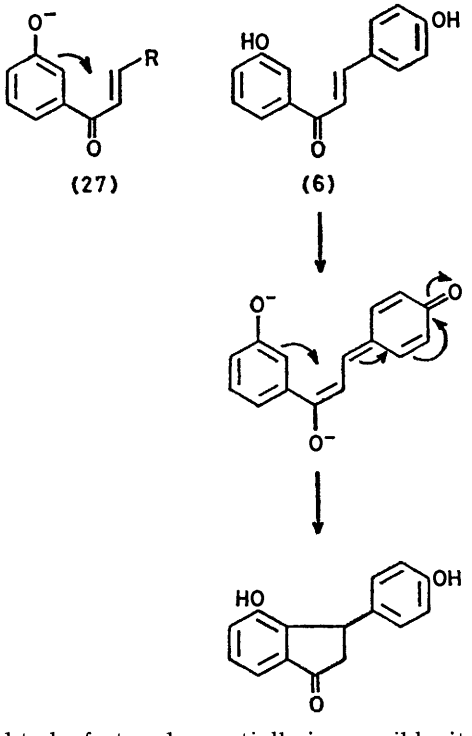

SCHEME 4

the rate $k_H$ is fast and not rate determining. Since the reaction of (29) is formally related to that of (32), the conditions employed to effect the Claisen rearrangement [14] (heating in *NN*-dimethylaniline at 193 °C) were



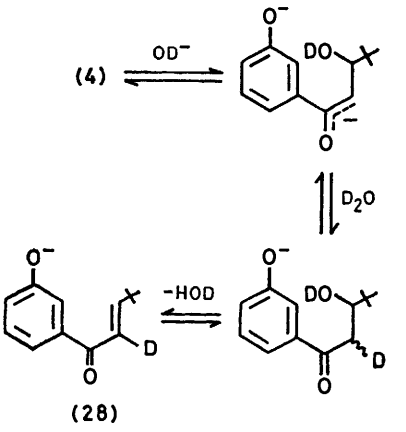
(26)

applied to (9). No reaction occurred. To confirm further that $k_H$ (Scheme 5) was not rate determining, the reaction of (9) was attempted in the presence of the powerful base lithium di-isopropylamide. No reaction occurred. To refute the unlikely possibility that (30) was unstable under basic conditions, the phenol (19a) was heated under reflux in $D_2O$–NaOD for 3 h. The phenol (34) was the only product, no (9) being detected. Therefore, since the rate of reaction of (29) can now be



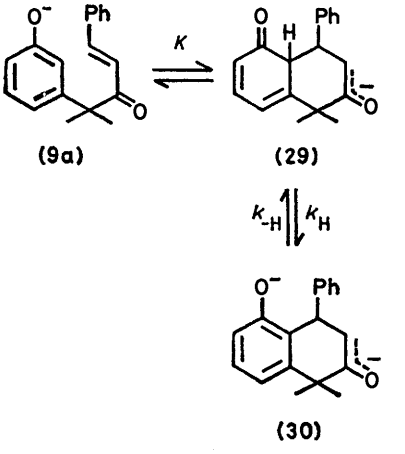
(27) (6)

expected to be fast and essentially irreversible, it follows that the failure of (9a) to cyclise is probably not due to an unfavourable equilibrium between (9a) and (29) (Scheme 5). To confirm this, a model was devised which would favour the equilibrium between (9a) and (29) (Scheme 5). The phenols (11a), (13a), (14a), and (15a) were used.



(28)

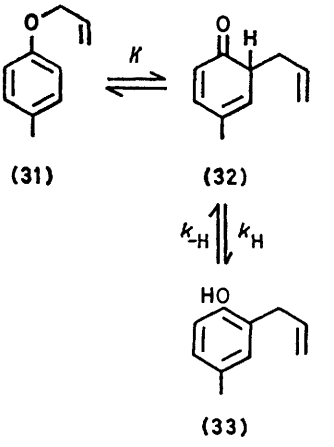
Stabilisation of the enolate (29) by *p–d* overlap can occur [15] in the respective proposed cyclised intermediates, for example (35), and hence favour $K$ (Scheme 5). This effect should be most pronounced in the case of



(9a) (29) (30)

SCHEME 5

(15a) where the initially formed product (36) has an expected [16] $pK_a \approx 6$. The $pK_a$ of (15a) is *ca.* 10. None of the phenols (11a)—(15a) closed under basic conditions which varied from sodium methoxide in methanol at reflux for 6 d, to $NaHCO_3$ in hexamethylphosphoric triamide at reflux for 24 h. We conclude

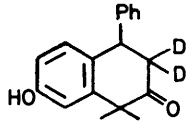


(31) (32) (33)

that the problem of cyclisation is the extremely slow rate of reaction of (9a).

On the one hand the nucleophilicity of the phenoxide, as noted for example by Crombie,[17] is an important factor in intermolecular reactions with common enones. Only strongly nucleophilic phenoxides such as that of resacetophenone react with citral or ethyl vinyl ketone but even with this phenoxide no useful reaction was observed with pent-3-en-2-one, pulegone, or mesityl oxide.[17] On the other hand, when the enone system is sufficiently reactive then phenoxides of low nucleophilicity do react. Thus the quinone methide (37) cyclises in high yield.[18] The intermediate cases (38) [19] and (39) [20] are of particular note. Both cyclise in high yield under basic conditions.

If it is assumed that αβ-enones and saturated carbonyl groups have similar reactivities and since (39) cyclises but (9a) for example does not under basic conditions, it follows that stereoelectronic factors must be decisive. Dreiding models of (9a) indicate that when the phenoxide ring is oriented to permit in-line attack on C-10 [8] with maximum overlap of C-10 [21] [structure (40)], the angle of torsion between the C-9–C-10 double bond and

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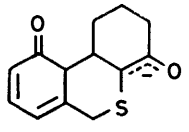


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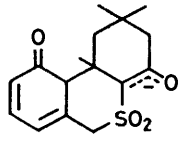


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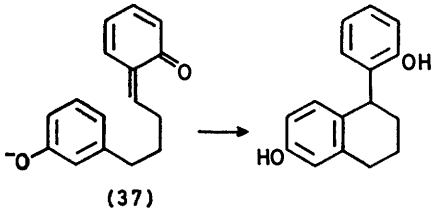


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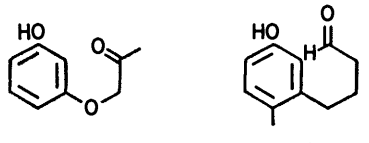
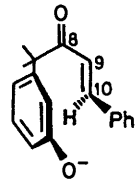



(38)




(39)

the carbonyl bond is *ca.* 30°. We suggest that this factor is at the origin of the high activation energy of (40); that unless the enone system is capable of remaining coplanar, *i.e.* of retaining its characteristics as a single functional group, in the transition state, nucleophilic attacked by the phenoxide is inhibited. The same conclusion is reached if the potential product (29) is considered. Since the enolate group in (29) is planar, a planar arrangement of the enone system in the transition state derived from (9a) would seem a reasonable requirement. The strain involved in transforming the

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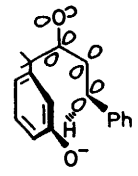


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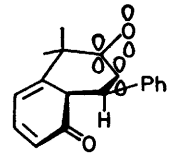


(29)

enone group in (40) to coplanarity while retaining in-line attack with maximum overlap explains the inability of (9) to react. These stereoelectronic constraints are not present in (39) which is found to cyclise by the permissible 6-*Exo-Trig* mode.[28]

Inspection of models suggests that 7- and 8-*Endo-Trig* modes meet these stereoelectronic requirements.

Finally, the reactivity of (38) suggests that maximum overlap by the phenoxide ring is not always a strict requirement. Our inability to observed an $Ar_2^{-}$-5 cyclisation of (1; $n = 0$, R = H) therefore may be the result of a reduction on the rate of cyclisation relative to the observed intermolecular processes, due to poor overlap by the phenoxide ring.

## EXPERIMENTAL

M.p.s were obtained on a Thomas-Hoover melting-point apparatus. T.l.c. was carried out on plates with Merck silica gel $HE_{254}$. Preparative thick-layer chromatography was carried out on plates coated with Kieselgel $PF_{254}$ (Merck). G.l.c. was performed with a Perkin-Elmer F 11 dual column chromatograph coupled to a Perkin-Elmer 159 recorder using a 2 m column of 2½% CEMS on Chromosorb G programmed at 150—200 °C. I.r. spectra were determined as liquid films or KBr discs with a Perkin-Elmer 257 spectrometer. $^1H$ N.m.r. spectra, unless otherwise stated, were determined for solutions in deuteriochloroform with tetramethylsilane as internal standard on a Perkin-Elmer R20A spectrometer. Light petroleum refers to that fraction of boiling range 40—60 °C.

3-*Hydroxyphenyl Vinyl Ketone* (3a).—(a) β-*Dimethylamino*-m-*hydroxypropiophenone hydrochloride*.[22] A mixture of dimethylamine hydrochloride (9.78 g, 0.12 mol), paraformaldehyde (5.40 g, 0.06 mol), concentrated hydrochloric acid (5 drops), and *m*-hydroxyacetophenone (13.6 g, 0.1 mol) in absolute ethanol (100 ml) was heated at reflux for 2 days. To the hot solution was added boiling acetone (200 ml), and the solution was cooled slowly to afford *white crystals* (16.6 g, 72%), m.p. 183—185 °C (from ethanol–acetone) (Found: C, 57.7; H, 6.9; Cl, 15.8. $C_{11}H_{16}O_2HCl$ requires C, 57.5; H, 7.0; Cl, 15.4%); $\nu_{max.}$

3 200, 2 700, and 1 675 cm; δ[$(CD_3)_2SO$] 2.85 (6 H, s, 2 × Me), 3.54 (4 H, m, 2 × $CH_2$), and 7.05—7.65 (4 H, m, ArH).

(b) *β-Dimethylamine-*m*-hydroxypropiophenone methiodide.* A solution of β-dimethylamino-*m*-hydroxypropiophenone hydrochloride (2.15 g) in water (15 ml) was neutralized with aqueous sodium carbonate (10%) and extracted with ether. The ethereal solution was dried (brine, magnesium sulphate), treated with excess methyl iodide (1 ml), and allowed to stand at 10 °C for 12 h. The white crystalline methiodide was removed by filtration, additional methyl iodide was added, and the process was repeated (twice). The combined fractions of the product were recrystallized from aqueous ethanol to give the *quaternary salt* as white crystals (900 mg, 27%), m.p. 202—205 °C (Found: C, 43.0; H, 5.4; N, 4.0. $C_{12}H_{18}O_2NI$ requires C, 42.9; H, 5.4; N, 4.2%); $\nu_{max.}$ 3 450 and 1 680 $cm^{-1}$.

*Attempted Base-catalysed Cyclisation of the Enone* (3a).—A solution of β-dimethylamino-*m*-hydroxypropiophenone methiodide (200 mg, 0.6 mmol) and sodium hydroxide (32 mg, 1.4 mmol) in water (60 ml) was heated at reflux for 9 h. The cooled solution was acidified with aqueous hydrochloric acid (5%) and extracted with ether. The ether extract were washed with brine, dried (magnesium sulphate), and the solvent removed *in vacuo* to give a viscous oil. Preparative t.l.c. (ethyl acetate–petroleum, 1 : 1) gave *m*-hydroxyacetophenone (20 mg, 25%). Similar treatment of β-dimethylamino-*m*-hydroxypropiophenone hydrochloride with aqueous sodium hydroxide as described above gave *m*-hydroxyacetophenone (17%). The n.m.r. and i.r. spectra and t.l.c. showed no evidence of the formation of any cyclised product.

*Trapping of the Enone* (3a).—(a) With *alkaline hydrogen peroxide.* To a suspension of β-dimethylamino-*m*-hydroxypropiophenone methiodide (250 mg, 0.746 mmol) and hydrogen peroxide (30%; 0.5 ml, 5.2 mmol) in methanol (5 ml) at 0 °C, sodium hydroxide (150 mg, 3.75 mmol) in water (0.8 ml) was added with stirring. The mixture was stirred for 1 h at 0 °C, diluted with water and acidified with aqueous hydrochloric acid (5%). The solution was extracted with ether. The ether layer was dried (brine, magnesium sulphate), and the solvent was removed *in vacuo*. Only one product was indicated by t.l.c. Purification by preparative t.l.c. (ethyl acetate–light petroleum, 1 : 1), gave a colourless oil of *αβ-epoxy-*m*-hydroxypropiophenone* (75 mg, 62%) (Found: C, 65.6; H, 5.1. $C_9H_8O_3$ requires C, 65.9; H, 4.9%); $\nu_{max.}$ 3 350 and 1 670 $cm^{-1}$; δ 3.05 (2 H, m, $CH_2$), 4.30 (1 H, m, CH), and 7.10—7.81 (4 H, m, ArH).

(b) With *methanol.* β-Dimethylamino-*m*-hydroxypropiophenone methiodide (250 mg, 0.746 mmol) in methanol (5 ml) was treated with sodium hydroxide (150 mg, 3.750 mmol) in water (0.8 ml) at 0 °C and the solution was stirred for 1 h at 0 °C. Work-up was as described above, followed by preparative t.l.c. (ethyl acetate–light petroleum, 1 : 1) gave *β-methoxy-*m*-hydroxypropiophenone* (96 mg, 82%), m.p. 52—55 °C (Found: C, 66.4; H, 6.7. $C_{10}H_{12}O_3$ requires C, 66.6; H, 6.7%); $\nu_{max.}$ 3 300 and 1 650 $cm^{-1}$; δ 3.21 (2 H, t, *J* 6 Hz, $COCH_2$), 3.41 (3 H, s, OMe), 3.76 (2 H, s, $OCH_2$), and 6.07—7.61 (4 H, m, ArH).

(c) With *diethyl sodiomalonate.* To a solution of sodium ethoxide (0.004 mol) in ethanol (20 ml) was added β-dimethylamino-*m*-hydroxypropiophenone hydrochloride (250 mg, 0.001 mol) and diethylmalonate (160 mg, 0.004 5 mol) at room temperature. The reaction mixture was heated at reflux for 5 h and the ethanol was removed *in vacuo*. Ether was added and the solution was acidified with aqueous hydrochloric acid (10%). The ether layer was washed with brine and dried (magnesium sulphate), and the solvent was removed *in vacuo* to give an oil. Preparative t.l.c. (ethyl acetate–light petroleum, 1 : 1) afforded the desired product (40 mg, 13%) (Found: C, 62.5; H, 6.4. $C_{16}H_{20}O_6$ requires C, 62.3; H, 6.5%); $\nu_{max.}$ 3 410, 1 730, and 1 650 $cm^{-1}$; δ 1.26 (6 H, t, *J* 7 Hz, 2 × $CO_2CMe$), 2.30 (2 H, m, $CH_2$), 3.10 (2 H, t, *J* 7 Hz), 3.55 (1 H, t, *J* 7 Hz, CH), 4.25 (4 H, q, *J* 7 Hz, 2 × $CO_2CH_2$), and 6.90—7.80 (4 H, m, ArH).

(d) With *sodium cyanide.* The β-dimethylamino-*m*-hydroxypropiophenone hydrochloride (1.15 g, 0.005 mol) in water (20 ml) was treated with sodium cyanide (0.04 g, 0.005 5 mol) and sodium hydroxide (0.6 g, 0.015 mol) and was heated under reflux for 40 min. The cooled mixture was acidified with 10% hydrochloric acid and extracted with ether. The extract was washed with water, dried (magnesium sulphate), and evaporated to give an oil. This oil was separated by preparative t.l.c. (ethyl acetate–light petroleum 1 : 1); two main bands were identified and eluted. The band of higher $R_F$ afforded 3-hydroxyacetophenone (20 mg, 2.9%), which was identical (m.p., t.l.c., i.r. and n.m.r.) with an authentic sample. The band of lower $R_F$ gave β-cyano-*m*-hydroxypropiophenone (90 mg, 10%), m.p. 87—89 °C (Found: C, 68.5; H, 5.1; N, 8.1. $C_{10}H_9O_2N$ requires C, 68.6; H, 5.2; N, 8.0%); $\nu_{max.}$ 3 420, 2 220, and 1 660 $cm^{-1}$; δ 2.70 (2 H, t, *J* 6 Hz, $CH_2CN$), 3.60 (2 H, t, *J* 6 Hz, $COCH_2$), 7.05—7.82 (4 H, m, ArH), and 8.80 (1 H, br s, OH, exchanged with $D_2O$).

(e) With *dimethyloxosulphonium methylide.*[23] To a suspension of powdered trimethyloxosulphonium iodide (1.5 g, 0.007 mol) in dimethylsulphoxide (10 ml), 80% sodium hydride (mineral oil dispersion; 210 mg, 0.007 mol) was added in one portion. Vigorous evolution of hydrogen ensued which ceased after 15 min to give a milky white mixture. The solid of β-dimethylamino-*m*-hydroxypropiophenone hydrochloride (0.461 g, 0.002 mol) was added in one portion with stirring and slight cooling in a cold water-bath. The reaction mixture was stirred at room temperature for 30 h, poured into cold water, and extracted with chloroform. The chloroform extracts were washed several times with water, dried (sodium sulphate), and evaporated to leave a pale yellow oil. The sole product (t.l.c.) was purified by preparative t.l.c. [(ether–light petroleum (2 : 3)] to yield *cyclopropyl 3-hydroxyphenyl ketone* (185 mg, 57%) (Found: C, 74.2; H, 6.0. $C_{10}H_{10}O_2$ requires C, 74.1; H, 6.2%); $\nu_{max.}$ 3 300 and 1 645 $cm^{-1}$; δ 1.20 (4 H, m, 2 × $CH_2$), 2.69 (1 H, m, CH), 7.11—7.85 (4 H, m, ArH), and 8.88 (1 H, s, OH, exchanged with $D_2O$).

*1-(3-Hydroxyphenyl)-4,4-dimethylpent-2-en-1-one* (4a).—A solution of 3-hydroxyacetophenone (1.36 g, 0.01 mol), pivaldehyde (0.860 g, 0.01 mol), and potassium hydroxide (1.23 g, 0.022 mol) in 95% ethanol (15 ml) and water (10 ml) was stirred at room temperature for 10 days. The mixture was acidified with 10% hydrochloric acid and extracted with ether. The ether extract was washed with water, dried (magnesium sulphate), and evaporated. The residual oil was chromatographed on silica gel (90 g). Elution with 50% ether–light petroleum afforded the *enone* (4; $R^1$ = H) (1.5 g, 74%), m.p. 60—62° (Found: C, 76.2; H, 8.3. $C_{13}H_{16}O_2$ requires C, 76.3; H, 7.9%); $\nu_{max.}$ 3 300, 1 650, and 980 $cm^{-1}$; δ 1.12 (9 H, s, 3 × Me), 6.80 (1 H, d, *J* 17 Hz), 7.21 (1 H, d, *J* 17 Hz), and 7.2—7.7 (4 H, m, ArH).

1-(3-*Methoxyphenyl*-4,4-*dimethylpent*-2-*en*-1-*one* (4b).—A mixture of the enone (4a) (480 mg, 0.002 53 mol), potassium carbonate (324 mg, 0.002 53 mol), and methyl iodide (0.5 ml) in acetone (5 ml) was refluxed for 12 h. Isolation in the usual manner gave the *enone* (4b) (417 mg, 81%) (Found: C, 77.1; H, 8.2. $C_{14}H_{18}O_2$ requires C, 77.0; H, 8.3%); $\nu_{max.}$ 1 650 and 980 $cm^{-1}$; δ 1.11 (9 H, s, 3 × Me), 3.81 (3 H, s, OMe), 6.81 (1 H, d, *J* 17 Hz), 7.21 (1 H, d, *J* 17 Hz), and 7.1—7.6 (4 H, m, ArH).

3′-*Hydroxychalcone* (5a).—To a cold mixture of 3-hydroxyacetophenone (1.36 g, 0.01 mol) and benzaldehyde (1.06 g, 0.01 mol) in 95% ethanol (15 ml) was added aqueous potassium hydroxide [KOH (1.23 g) in water (10 ml)] with stirring. The mixture was allowed to stir at room temperature for 2 h, cooled (ice-bath), and acidified with 10% hydrochloric acid. The solidified product was removed by filtration. Recrystallization from aqueous ethanol gave the enone (5a) as yellow needles (1.96 g, 87%), m.p. 124—125 °C (lit.,[24] m.p. 127—128 °C) (Found: C, 80.3; H, 5.5. Calc. for $C_{15}H_{12}O_2$: C, 80.3; H, 5.4%); $\nu_{max.}$ 3 300, 1 660, and 975 $cm^{-1}$; δ 6.05—7.05 (m).

3′-*Methoxychalcone* (5b).—A solution of the enone (5a) (400 mg, 0.001 79 mol) and methyl iodide (0.5 ml) in acetone (5 ml) was treated with potassium carbonate (246 mg, 0.001 79 mol) and heated under reflux for 12 h. After cooling, the solvent was removed *in vacuo*, and the residue was diluted with water and extracted with ether. The extract was washed with aqueous sodium hydroxide (5%) and water, dried (magnesium sulphate), and evaporated. The residue was purified by preparative t.l.c. (ether–light petroleum, 1 : 4) to give the *enone* (5b) (383 mg, 90%) (Found: C, 80.4; H, 6.0. $C_{16}H_{14}O_2$ requires C, 80.6; H, 5.9%); $\nu_{max.}$ 1 660 and 975 $cm^{-1}$; δ 3.86 (3 H, s, OMe) and 6.05—7.05 (11 H, m).

3′,4-*Dihydroxychalcone* (6a).—To a cold solution of 3-hydroxyacetophenone (6 g, 0.044 mol) and 4-hydroxybenzaldehyde (5.4 g, 0.044 mol) in 95% ethanol (30 ml), aqueous sodium hydroxide (5.3 g, 0.132 mol) in water (20 ml) was added with stirring and the mixture allowed to stir at room temperature for 6 h. The mixture was cooled and acidified with 10% hydrochloric acid. The crude yellow solid was collected and recrystallised from aqueous ethanol to give yellow needles of the dihydroxychalcone (6a) (7.5 g, 71%), m.p. 188—190 °C (lit.,[24] m.p. 192—194 °C) (Found: C, 74.8; H, 5.2. Calc. for $C_{15}H_{12}O_3$: C, 74.9; H, 5.0%); $\nu_{max.}$ 3 390, 1 640 and 970 $cm^{-1}$; δ[$(CD_3)_2CO$] 6.81—8.15 (m).

2,3′-*Dihydroxychalcone* (7a).—To a solution of 3-hydroxyacetophenone (6 g, 0.044 mol) and 2-hydroxybenzaldehyde (5.6 g, 0.046 mol) in 95% ethanol (20 ml), a solution of sodium hydroxide (6 g, 0.15 mol) in water (30 ml) was added with stirring and warmed at 60 °C for 40 min. The mixture was then allowed to stir at room temperature for 2 days. The product was isolated, after acidification by 10% hydrochloric acid, and recrystallised from aqueous ethanol to yield 2,3′-*dihydroxychalcone* (7a) as yellow needles (7 g, 66%), m.p. 93—95 °C (Found: C, 74.6; H, 5.1. $C_{15}H_{12}O_3$ requires C, 74.9; H, 5.0%); $\nu_{max.}$ 3 350, 1 630, and 975 $cm^{-1}$; δ[$(CD_3)_2CO$] 6.7—8.4 (m).

m-*Methoxyphenylacetone* (10).—*Method A*.[3] To a solution of *m*-methoxybenzaldehyde (27.2 g, 0.2 mol) and nitroethane (20 g, 0.22 mol) in toluene (30 ml) was added n-butylamine (5 ml). The solution was heated to produce a rapid reflux for 20 h. The toluene solution was placed in a flask equipped with a high-speed stirrer, condenser, and a dropping funnel, and water (100 ml), powdered iron (50 g), and ferric chloride (0.8 g) were added. With vigorous stirring the suspension was heated to about 50 °C, and concentrated hydrochloric acid (120 ml) was added over 2 h. Heating and stirring were continued for an additional 30 min. The suspension was then subjected to steam distillation until 1.5 l had been collected. The toluene layer was removed, and the aqueous layer extracted with toluene. The combined toluene layers were stirred for 30 min with a solution of sodium bisulphite (8 g) in water (100 ml). The toluene layer was washed with water, dried ($Na_2SO_4$), and evaporated to give a yellow oil. Fractional distillation afforded pure m-*methoxyphenylacetone* (10) (18.2—19.7 g, 55—60%), b.p. 99—101° at 1.25 mmHg (Found: C, 73.0; H, 7.5. $C_{10}H_{12}O_2$ requires C, 73.1; H, 7.4%); $\nu_{max.}$ 1 705 $cm^{-1}$; δ 2.15 (3 H, s, COMe), 3.68 (2 H, s, $ArCH_2$), 3.80 (3 H, s, OMe), and 6.5—7.5 (4 H, m, ArH).

*Method B*. To sodium hydride [80% dispersion in mineral oil (1.6 g, 0.05 mol)] was added ethyl acetate (15 ml) in one portion with stirring at room temperature. *m*-Methoxybenzyl cyanide (4.4 g, 0.03 mol) was then added over 5 min; the reaction was exothermic and was cooled when necessary. After complete addition, the mixture was refluxed gently for 10 min. After cooling a solid mass of the sodium salt was isolated by filtration and dissolved in cold water, and the solution was washed with ether. The aqueous layer was acidified with 10% hydrochloric acid and extracted with ether. The ether extract was washed with water, dried (magnesium sulphate), and evaporated to give 1-cyano-3-(*m*-methoxyphenyl)propan-2-one (only one spot as indicated by t.l.c.) (5 g, 88%); $\nu_{max.}$ 2 200 and 1 700 $cm^{-1}$; δ 2.29 (3 H, s, COMe), 3.88 (3 H, s, OMe), 4.70 (1 H, s), and 6.9—7.6 (4 H, m, ArH). This product was used in the next step without purification.

A suspension of 1-cyano-3-(*m*-methoxyphenyl)propan-2-one (1.5 g) in 50% sulphuric acid was heated at 120—130 °C with vigorous stirring for 30 min. The cold mixture was extracted with ether, washed with water, 10% sodium hydroxide, and water, and dried (magnesium sulphate). After evaporation, the residual oil was purified by preparative t.l.c. [ether–light petroleum (2 : 3)] to yield *m*-methoxyphenylacetone (10) (0.575 g, 44%), which was identical (t.l.c., i.r., and n.m.r.) with the specimen previously prepared.

m-*Hydroxyphenylacetone*.—To a solution of *m*-methoxyphenylacetone (3 g) in dry dichloromethane (20 ml) at −70 °C under nitrogen was added boron tribromide (4 ml) dropwise. The mixture was stirred at −70 °C for 1 h and then allowed to warm to room temperature (2 h). The product was isolated as usual to give m-*hydroxyphenylacetone* as an oil (2.1 g, 78%) (Found: C, 72.1; H, 6.7. $C_9H_{10}O_2$ requires C, 72.0; H, 6.6%); $\nu_{max.}$ 3 350 and 1 695 $cm^{-1}$; δ 2.12 (3 H, s, COMe), 3.61 (2 H, s, $ArCH_2$), 6.6—7.4 (4 H, m, ArH), and 7.51 (1 H, br, OH).

m-*Tetrahydropyranyloxyphenylacetone*.—A cold mixture of *m*-hydroxyphenylacetone (1 g) and dihydropyran (4 ml) was treated with concentrated hydrochloric acid (3 drops) with stirring. The mixture was then allowed to stir at room temperature for 24 h. The crude oil was purified by dry column chromatography (ether–light petroleum, 3 : 7) to give m-*tetrahydropyranyloxyphenylacetone* (800 mg, 50.6%) (Found: C, 72.0; H, 7.9. $C_{14}H_{18}O_3$ requires C, 71.8; H, 7.7%); $\nu_{max.}$ 1 710 $cm^{-1}$; δ 1.4—2.1 (6 H, br, 3 × $CH_2$), 2.12 (3 H, s, COMe), 3.67 (2 H, s, $ArCH_2$), 3.3—4.2 (2 H, m), 5.45 (1 H, m), and 6.7—7.5 (4 H, m, ArH).

*5,5-Dimethyl-1-(3-tetrahydropyranyloxyphenyl)hex-3-en-2-one*.—A mixture of *m*-tetrahydropyranyloxyphenylacetone (1.2 g, 0.005 mol), pivaldehyde (962 mg, 0.01 mol), and sodium hydroxide (150 mg) in water (30 ml) was heated at 65 °C under nitrogen for 4 days. The cooled mixture was dissolved in dichloromethane and washed with water. The dried dichloromethane solution was evaporated and the residue purified by preparative t.l.c. (ether–light petroleum, 3 : 7); two main bands were identified and eluted. The band of higher $R_F$ afforded *5,5-dimethyl-1-(3-tetrahydropyranyloxyphenyl)hex-3-en-2-one* (402 mg, 27%) (Found: C, 75.5; H, 8.5. $C_{19}H_{26}O_3$ requires C, 75.5; H, 8.6%); $\nu_{max.}$ 1 680, 1 620, and 970 $cm^{-1}$; δ 1.05 (9 H, s, 3 × Me), 1.4—2.0 (6 H, m, 3 × $CH_2$), 3.81 (2 H, s, $ArCH_2$), 5.45 (1 H, br), 6.10 (1 H, d, *J* 17 Hz), 6.95 (1 H, d, *J* 17 Hz), and 6.8—7.5 (4 H, m, ArH); that of lower $R_F$ was unchanged *m*-tetrahydropyranyloxyphenylacetone (400 mg, 33%).

*1-(3-Hydroxyphenyl)-1,1,5,5-tetramethylhex-3-en-2-one* (8a).—To a mixture of sodium hydride [mineral oil dispersion (80%) (700 mg, 0.002 9 mol)] and methyl iodide (2 ml) in tetrahydrofuran (12 ml) was added 5,5-dimethyl-1-(3-tetrahydropyranyloxyphenyl)hex-3-en-2-one (400 mg, 0.001 32 mol) in tetrahydrofuran (2 ml) with stirring. The mixture was refluxed for 6 h, cooled, diluted with water, and extracted with dichloromethane. The extract was dried and evaporated. The residue [one spot (t.l.c.)] was 1,1,5,5-tetramethyl-1-(3-tetrahydropyranyloxyphenyl)hex-3-en-2-one (418 mg); $\nu_{max.}$ 1 690, 1 620, and 970 $cm^{-1}$; δ 0.92 (9 H, s, 3 × Me), 4.6 (6 H, s, 2 × Me), 1.4—2.2 (6 H, m, 2 × $CH_2$), 5.44 (1 H, m), 5.9 (1 H, d, *J* 17 Hz), 7.3 (1 H, d, *J* 17 Hz), and 6.8—7.4 (4 H, m, ArH). To a solution of this product (400 mg) in ether (3 ml) and methanol (3 ml) was added 10% hydrochloric acid (10 ml) and the resulting solution was stirred at room temperature overnight. Addition of water, extraction with ether, drying, evaporation, and preparative t.l.c. [ether–light petroleum (3 : 7)] gave *1-(3-hydroxyphenyl)-1,1,5,5-tetramethylhex-3-en-2-one* (8a) (250 mg, 84%) (Found: C, 78.3; H, 9.0. $C_{16}H_{22}O_2$ requires C, 78.0; H, 9.0%); $\nu_{max.}$ 3 350, 1 685, 1 620, and 970 $cm^{-1}$; δ 0.92 (9 H, s, 3 × Me), 1.48 (6 H, s, 2 × Me), 5.96 (1 H, d, *J* 17 Hz), and 6.75—7.40 (5 H, m).

*1-(3-Methoxyphenyl)-5,5-dimethylhex-3-en-2-one*.—A mixture of *m*-methoxyphenylacetone (1 g, 0.006 mol), pivaldehyde (524 mg, 0.006 mol), and sodium hydroxide (100 mg) in water (20 ml) was heated at 70 °C under nitrogen for 65 h. After cooling, the mixture was extracted with dichloromethane and washed with water. The dried dichloromethane solution was evaporated and the residue purified by dry column chromatography (ether–light petroleum, 3 : 7). The band of higher $R_F$ gave *1-(3-methoxyphenyl)-5,5-dimethylhex-3-en-2-one* (896 mg, 64%) (Found: C, 77.4; H, 8.6. $C_{15}H_{20}O_2$ requires C, 77.5; H, 8.7%); $\nu_{max.}$ 1 670, 1 620, and 980 $cm^{-1}$; δ 1.07 (9 H, s, 3 × $CH_3$), 3.75 (3 H, s, OMe), 3.80 (2 H, s, $ArCH_2$), 6.10 (1 H, d, *J* 17 Hz), 6.95 (1 H, d, *J* 17 Hz), and 6.75—7.40 (4 H, m, ArH); that of lower $R_F$ gave unchanged *m*-methoxyphenylacetone (220 mg, 22%).

*1-(3-Methoxyphenyl)-1,1,5,5-tetramethylhex-3-en-2-one* (8b).—(a) *Attempted dimethylation with potassium t-butoxide*. A solution of 1-(3-methoxyphenyl)-5,5-dimethylhex-3-en-2-one (170 mg, 0.73 mmol) in t-butyl alcohol (4 ml) was added dropwise to a mixture of potassium t-butoxide (164 mg, 1.46 mmol) in t-butyl alcohol (4 ml) and methyl iodide (0.5 ml). After 2.5 h (under nitrogen) at reflux temperature the product was isolated and was shown (n.m.r.) to be the monomethylated product, 1-(3-methoxyphenyl)-1,5,5-trimethylhex-3-en-2-one (150 mg); $\nu_{max.}$ 1 680, 1 620, and 980 $cm^{-1}$; δ 1.01 (9 H, s, 3 × Me), 1.42 (3 H, d, *J* 7.5 Hz, Me), 3.81 (3 H, s, OMe), 4.05 (1 H, d, *J* 7.5 Hz, CH), 6.05 (1 H, d, *J* 17 Hz), 7.50 (1 H, d, *J* 17 Hz) and 6.7—6.8 (4 H, m, ArH). A solution of this monomethylated enone (140 mg), potassium t-butoxide (80 mg), and methyl iodide (0.5 ml) in t-butyl alcohol (4 ml) was refluxed for 16 h. An oil (150 mg) which was isolated in the normal manner was shown (t.l.c., n.m.r.) to be a mixture of starting material and *the required enone* (8b) in the ratio 1 : 1. A solution of this mixture (140 mg) with methyl iodide (0.5 ml) in tetrahydrofuran (4 ml) was treated with sodium hydride (80%, 30 mg) and refluxed for 3.5 h to yield the *enone* (8b) (143 mg) (Found: C, 78.0; H, 9.3. $C_{17}H_{24}O_2$ requires C, 78.4; H, 9.3%); $\nu_{max.}$ 1 685, 1 620, and 980 $cm^{-1}$; δ 0.93 (9 H, s, 3 × Me), 1.48 (6 H, s, 2 × Me), 3.81 (3 H, s, OMe), 5.90 (1 H, d, *J* 17 Hz), 6.95 (1 H, d, *J* 17 Hz), and 6.74—6.80 (4 H, m, ArH).

(b) *Dimethylation with sodium hydride*. To a suspension of sodium hydride (80%, 138 mg, 0.005 8 mol) and methyl iodide (2 ml) in tetrahydrofuran (6 ml) was added a solution of 1-(3-methoxyphenyl)-5,5-dimethylhex-3-en-2-one (670 mg, 0.002 9 mol) in tetrahydrofuran (5 ml) and the mixture was heated under reflux for 5 h when the reaction was complete (t.l.c.). The cooled solution was acidified with hydrochloric acid (10%) and extracted with dichloromethane. The extract was washed with water, dried (sodium sulphate), and evaporated to give an oil, which was purified by preparative t.l.c. (ether–light petroleum, 3 : 7) to yield the enone (8b) (645 mg, 86%), identical (i.r., n.m.r., and t.l.c.) with the specimen from method (a).

*4-Phenyl-1-(3-tetrahydropyranyloxyphenyl)but-3-en-2-one*.—A mixture of *m*-tetrahydropyranyloxyphenylacetone (800 mg, 0.003 7 mol), benzaldehyde (390 mg, 0.003 7 mol), and sodium hydroxide (100 mg) in water (30 ml) was heated at 65 °C (under nitrogen) for 24 h. The cooled mixture was extracted with dichloromethane and washed with water. The dichloromethane solution was dried and evaporated, and the residue separated by preparative t.l.c. (ether–light petroleum, 3 : 7) to yield *4-phenyl-1-(3-tetrahydropyranyloxyphenyl)but-3-en-2-one* (520 mg, 44%) (Found: C, 78.3; H, 7.0. $C_{21}H_{22}O_3$ requires C, 78.2; H, 6.8%); $\nu_{max.}$ 1 675 and 975 $cm^{-1}$; δ 1.4—2.0 (6 H, m, 3 × $CH_2$), 3.4—4.1 (2 H, m, $OCH_2$), 3.91 (2 H, s, $ArCH_2$), 5.45 (1 H, m), 6.81 (1 H, d, *J* 16 Hz), 7.69 (1 H, d, *J* 16 Hz), and 6.9—7.7 (9 H, m, ArH).

*1-(3-Hydroxyphenyl)-4-phenylbut-3-en-2-one*.—A mixture of 4-phenyl-1-(3-tetrahydropyranyloxyphenyl)but-3-en-2-one (300 mg) in ether (2 ml) and 15% hydrochloric acid (20 ml) was stirred at room temperature for 6 h. Preparative t.l.c. (ether–petroleum, 2 : 3) gave *1-(3-hydroxyphenyl)-4-phenylbut-3-en-2-one* (171 mg, 77%), m.p. 102—104 °C (from hexane–ether) (Found: C, 80.5; H, 6.2. $C_{16}H_{14}O_2$ requires C, 80.6; H, 5.9%); $\nu_{max.}$ 3 350, 1 675, and 975 $cm^{-1}$; δ 3.19 (2 H, s, $ArCH_2$), 6.80 (1 H, d, *J* 16 Hz), 7.71 (1 H, d, *J* 16 Hz), 6.7—7.7 (9 H, m, ArH), and 8.1 (1 H, br, OH).

*Attempted Cyclisation of 1-(3-Hydroxyphenyl)-4-phenylbut-3-en-2-one*.—The phenol (150 mg, 0.63 mmol) with sodium hydroxide (25 mg, 0.63 mmol) in water (20 ml) was stirred at room temperature for 4 h. Only starting material was obtained. Longer reaction time and higher temperature produced undesired condensation and decomposition products.

1-(3-*Hydroxyphenyl*)-1,1-*dimethyl*-4-*phenylbut*-3-*en*-2-*one* (9a).—To a mixture of potassium t-butoxide (600 mg) in t-butyl alcohol (20 ml) and methyl iodide (2 ml) was added 4-phenyl-1-(3-tetrahydropyranyloxyphenyl)but-3-en-2-one (400 mg) in t-butyl alcohol (5 ml) with stirring. The mixture was gently refluxed for 2 h. The cooled mixture was extracted with ether, washed with water, and dried (sodium sulphate). Evaporation afforded 1,1-dimethyl-4-phenyl-1-(3-tetrahydropyranyloxyphenyl)but-3-en-2-one as the only product (t.l.c.) (417 mg, 85%); $\nu_{max.}$ 1 680 and 970 $cm^{-1}$; δ 1.55 (6 H, s, 2 × Me), 1.5—2.1 (6 H, m, 3 × $CH_2$), 3.31—4.2 (2 H, m, $OCH_2$), 5.45 (1 H, m), 6.62 (1 H, d, *J* 16 Hz), 6.8—7.7 (9 H, m, ArH), and 7.71 (1 H, d, *J* 16 Hz). Hydrolysis of this material (300 mg) in ether (2 ml) containing 15% hydrochloric acid (20 ml) at room temperature for 20 h, followed by preparative t.l.c. (ether–light petroleum, 3 : 7), gave 1-(3-*hydroxyphenyl*)-1,1-*dimethyl*-4-*phenyl*-3-*but*-3-*en*-2-*one* (9a) (215 mg, 91%) (Found: C, 81.2; H, 6.7. $C_{18}H_{18}O_2$ requires C, 81.2; H, 6.8%); $\nu_{max.}$ 3 350, 1 670, and 980 $cm^{-1}$; δ 1.51 (6 H, s, 2 × Me), 6.61 (1 H, d, *J* 15 Hz), 7.70 (1 H, d, *J* 15 Hz), and 6.8—7.7 (9 H, m, ArH).

1-(3-*Methoxyphenyl*)-4-*phenylbut*-3-*en*-2-*one*.[25]—A mixture of *m*-methoxyphenylacetone (1.95 g, 0.011 9 mol), benzaldehyde (1.26 g, 0.011 9 mol), and sodium hydroxide (200 mg) in water (60 ml) was heated at 68—70 °C under nitrogen for 24 h. The cooled solution was extracted with dichloromethane, washed with water, dried (sodium sulphate), and evaporated to give an oil. Preparative t.l.c. (ether–light petroleum, 3 : 7) afforded 1-(3-*methoxyphenyl*)-4-*phenylbut*-3-*en*-2-*one* (2.67 g, 87%) (Found: C, 81.0; H, 6.4. $C_{17}H_{16}O_2$ requires C, 80.9; H, 6.4%); $\nu_{max.}$ 1 680 and 980 $cm^{-1}$; δ 3.75 (3 H, s, OMe), 3.88 (2 H, s, $ArCH_2$), 6.80 (1 H, d, *J* 16 Hz), 7.65 (1 H, d, *J* 16 Hz), and 6.7—7.7 (9 H, m, ArH).

1-(3-*Methoxyphenyl*)-1,1-*dimethyl*-4-*phenylbut*-3-*en*-2-*one* (9b).—To a mixture of potassium t-butoxide (314 mg, 0.002 8 mol) in t-butyl alcohol (5 ml) and methyl iodide (1 ml) was added 1-(3-methoxyphenyl)-4-phenylbut-3-en-2-one (350 mg, 0.001 38 mol) in t-butyl alcohol (5 ml) dropwise with stirring. The mixture was refluxed for 3 h. After cooling, the solution was evaporated to yield a residue, which was diluted with water and extracted with dichloromethane. The crude oil was purified by preparative t.l.c. (ether–light petroleum, 3 : 7) to give the *enone* (9b) (300 mg, 78%) (Found: C, 80.8; H, 7.3. $C_{19}H_{20}O_2$ requires C, 81.2; H, 7.2%); $\nu_{max.}$ 1 680 and 980 $cm^{-1}$; δ 1.52 (6 H, s, 2 × $CH_2$), 3.80 (3 H, s, $OCH_2$), 6.12 (1 H, d, *J* 16 Hz), 7.72 (1 H, d, *J* 16 Hz), and 6.18—7.6 (9 H, m, ArH).

2-(3-*Hydroxybenzylthio*)-3,5,5-*trimethylcyclohex*-2-*en*-1-*one* (11a).—A mixture of *m*-hydroxybenzyl bromide (4.7 g, 0.025 mol) and thiourea (2.5 g, 0.032 mol) in water (20 ml) was refluxed for 2 h under nitrogen. After cooling, a solution of sodium hydroxide (3 g) in water (30 ml) was added and heating was continued for 3 h. The cooled solution was acidified with hydrochloric acid (10%) and extracted with ether. The ether extract was washed with water, dried (magnesium sulphate), and evaporated to give *m*-hydroxytoluene-α-thiol [26] (2.6 g, 74%); δ 3.60 (2 H, s, $ArCH_2$) and 6.71—7.42 (4 H, m, ArH).

A mixture of this thiol (500 mg, 0.003 6 mol) and isophorone oxide [27] (660 mg, 0.004 3 mol) was treated with aqueous potassium hydroxide (403 mg, 0.007 2 mol) in water (12 ml) with vigorous stirring at room temperature under nitrogen. The mixture was stirred for 4 h, then cooled and acidified with hydrochloric acid (10%). The precipitate was extracted with dichloromethane, washed with brine, dried (sodium sulphate), and evaporated to give a pale yellow solid. Recrystallization from dichloromethane–hexane gave the *enone* (11a) (901 mg, 90%), m.p. 118—119 °C (Found: C, 69.3; H, 7.4; S, 11.2. $C_{16}H_{20}O_2S$ requires C, 69.5; H, 7.3; S, 11.6%); $\nu_{max.}$ 3 300 and 1 655 $cm^{-1}$; δ 0.92 (6 H, s, 2 × Me), 2.01 (3 H, s, Me), 2.22 (2 H, s, $CH_2$), 2.30 (2 H, s, $CH_2$), 3.88 (2 H, s, $ArCH_2$), and 6.65—7.40 (4 H, m, Ar).

2-(3-*Methoxybenzylthio*)-3,5,5-*trimethylcyclohex*-2-*en*-1-*one* (11b).—A mixture of *m*-methoxybenzyl bromide (1 g, 0.005 mol) and thiourea (492 mg, 0.006 5 mol) in water (5 ml) was heated under reflux for 2 h under nitrogen. After cooling, a solution of sodium hydroxide (390 mg) in water (20 ml) was added and heating was continued for 3 h. Isolated in the normal manner, *m*-methoxytoluene-α-thiol (490 mg, 64%) formed an oil, δ 3.60 (2 H, s, $ArCH_2$), 3.77 (3 H, s, OMe), and 6.72—7.41 (4 H, m, ArH).

A mixture of this thiol (720 mg, 0.004 7 mol) and isophorone oxide (800 mg, 0.005 mol) was treated with aqueous potassium hydroxide (0.7%, 8 ml) at room temperature under nitrogen. The mixture was vigorously stirred for 2 h. The cooled solution was acidified with hydrochloric acid (10%) and extracted with dichloromethane. Preparative t.l.c. (ether–light petroleum, 3 : 7) of the crude oil gave two bands. The band of higher $R_F$ afforded the *enone* (11b) (871 mg, 64%) (Found: C, 70.3; H, 7.5; S, 11.2. $C_{17}H_{22}O_2S$ requires C, 70.3; H, 7.6; S, 11.0%); $\nu_{max.}$ 1 666 $cm^{-1}$; δ 0.91 (6 H, s, 2 × Me), 1.98 (3 H, s, Me), 2.22 (2 H, s, $CH_2$), 2.30 (2 H, s, $CH_2$), 3.78 (3 H, s, OMe), 3.90 (2 H, s, $ArCH_2$), and 6.63—7.35 (4 H, m, ArH). The band of lower $R_F$ gave 3-*hydroxy*-2-(3-*methoxybenzylthio*)-3,5,5-*trimethylcyclohexanone* (12) (274 mg, 19%) (Found: C, 66.6; H, 7.9; S, 10.3. $C_{17}H_{24}O_3S$ requires C, 66.2; H, 7.8; S, 10.4%); $\nu_{max.}$ 3 450 and 1 700 $cm^{-1}$; δ 1.05 (3 H, s, Me), 1.15 (3 H, s, Me), 1.32 (3 H, s, Me), 1.55—2.22 (4, m, 2 × $CH_2$), 3.01 (1 H, br s, CH), 3.65 (2 H, s, $ArCH_2$), 3.82 (3 H, s, OMe), and 6.52—7.42 (4 H, m, ArH).

*Ethyl* 3-(3-*Hydroxybenzylthio*)-2-*methyl*-4-*oxocyclohex*-2-*ene*-1-*carboxylate* (13a).—A mixture of *m*-hydroxytoluene-α-thiol (250 mg, 0.001 78 mol) and the oxide of Hagemann's ester [27] (396 mg, 0.002 mol) was treated with aqueous potassium hydroxide (120 mg in water 15 ml) as described previously, for 6 h. Purification of the crude product with preparative t.l.c. (ether–light petroleum, 2 : 3) gave the *enone* (13a) (285 mg, 50%) (Found: C, 64.0; H, 6.2; S, 9.8. $C_{17}H_{20}O_4S$ requires C, 63.7; H, 6.3; S, 10.0%); $\nu_{max.}$ 3 360, 1 720, and 1 670 $cm^{-1}$; δ 1.25 (3 H, t, *J* 7 Hz, $CO_2CH_2Me$), 2.03 (3 H, s, Me), 2.11—2.80 (4 H, m, 2 × $CH_2$), 3.35 (1 H, t, *J* 6 Hz, Me), 3.85 (2 H, s, $ArCH_2$), 4.21 (2 H, q, *J* 7 Hz, $CO_2CH_2Me$), and 6.65—7.45 (4 H, m, ArH).

*Ethyl* 3-(*Methoxybenzylthio*)-2-*methyl*-4-*oxocyclohex*-2-*ene*-1-*carboxylate* (13b).—A mixture of *m*-methoxytoluene-α-thiol (500 mg, 0.003 24 mol) and the oxide of Hagemann's ester (720 mg, 0.003 64 mol) was treated with aqueous potassium hydroxide [100 mg in water (20 ml)] for 1.5 h. Isolation of the product followed by preparative t.l.c. (ether–light petroleum, 3 : 7) gave the *enone* (13b) (701 mg, 66%) (Found: C, 64.2; H, 6.7; S, 9.6. $C_{18}H_{22}O_4S$ requires C, 64.6; H, 6.6; S, 9.6%); $\nu_{max.}$ 1 725 and 1 670 $cm^{-1}$; δ 1.24 (3 H, t, *J* 7 Hz, $CO_2CH_2Me$), 2.07 (3 H, s, Me), 210—2.70 (4 H, m, 2 × $CH_2$), 3.30 (1 H, t, *J* 6 Hz, CH), 3.80 (3 H, s, OMe), 3.92 (3 H, s, $ArCH_2$), 4.18 (2 H, q, *J* 7 Hz, $CO_2CH_2Me$), and 6.65—7.41 (4 H, m, ArH).

2-(3-*Hydroxybenzylthio*)*cyclohex*-2-*en*-1-*one* (14a).—A mix-

ture of *m*-hydroxytoluene-α-thiol (500 mg, 0.003 6mol) and cyclohex-2-en-1-one oxide [27] (500 mg. 0.004 5 mol) was treated with aqueous potassium hydroxide (400 mg in water, 20 ml) with vigorous stirring at room temperature, under nitrogen for 1.5 h. Extractive work-up yielded a crude product which was purified by preparative t.l.c. (ethyl acetate–light petroleum, 1 : 1) to give the *enone* (14a) (480 mg, 57%) (Found: C, 66.5; H, 6.1; S, 13.2. $C_{13}H_{14}O_2S$ requires C, 66.6; H, 6.0; S, 13.7%); $\nu_{max.}$ 3 300 and 1 655 $cm^{-1}$; δ 1.92 (2 H, m, $CH_2$), 2.41 (4 H, m, 2 × $CH_2$), 3.90 (2 H, s, $ArCH_2$), and 6.65—7.40 (5 H, m, C=CH and ArH).

2-(3-*Methoxybenzylthio*)*cyclohex*-2-*en*-1-*one* (14b).—A mixture of *m*-methoxytoluene-α-thiol (500 mg, 0.003 24 mol) and cyclohex-2-en-1-one oxide (500 mg, 0.004 5 mol) was treated with aqueous sodium hydroxide [100 mg, in water (15 ml)] as described previously, for 3.5 h. The mixture was acidified with aqueous hydrochloric acid (10%), extracted with chloroform, and washed with water, dried (sodium sulphate), and concentrated to give an oil which was purified by preparative t.l.c. (ether–light petroleum, 2 : 3) to yield the *enone* (14b) (723 mg, 90%) (Found: C, 67.8; H, 6.4; S, 12.6. $C_{14}H_{16}O_2S$ requires C, 67.7; H, 6.4; S, 12.9%); $\nu_{max.}$ 1 670 $cm^{-1}$; δ 1.92 (2 H, m, $CH_2$), 2.40 (4 H, m, 2 × $CH_2$), 3.80 (3 H, s, OMe), 3.89 (2 H, s, $ArCH_2$), and 6.70—7.31 (5 H, m, C=CH and ArH).

2-*Hydroxybenzyl* 2,4,4-*Trimethylcyclohex*-1-*enyl Sulphone* (15a).—(a) *Hydrogen peroxide method.* To a solution of the enone (11; R = H) (340 mg) in acetic acid (20 ml) was added hydrogen peroxide solution (30%; 5 ml). The mixture was stirred for 15 h at room temperature, diluted with water, and extracted with dichloromethane. The extract was washed with water, dried (sodium sulphate), and evaporated *in vacuo* to give an oil. Preparative t.l.c. (ethyl acetate–light petroleum, 2 : 3) gave the *enone* (15a) (322 mg, 85%) (Found: C, 62.5; H, 6.5; S, 10.2. $C_{16}H_{20}O_4S$ requires C, 62.3; H, 6.4; S, 10.4%); $\nu_{max.}$ 3 350, 1 655, 1 300, and 1 100 $cm^{-1}$; δ 0.91 (6 H, s, 2 × Me), 2.11 (3 H, s, Me), 2.37 (4 H, s, 2 × $CH_2$), 4.58 (2 H, s, $ArCH_2$), and 6.60—7.45 (4 H, m, ArH).

(b) m-*Chloroperbenzoic acid method.* To a solution of the enone (11a) (500 mg, 0.001 8 mol) in dichloromethane (40 ml) was added *m*-chloroperbenzoic acid (85%; 806 mg, 0.004 mol). The mixture was stirred at room temperature for 2 h. The solution was poured into water and extracted with dichloromethane. The extract was washed with saturated aqueous sodium hydrogencarbonate and water, dried (sodium sulphate), and the solvent removed *in vacuo* to afford an oil. Preparative t.l.c. (ethyl acetate–light petroleum, 2 : 3) gave the enone (15a) (472 mg, 85%), identical with the specimen from method (a) (i.r., n.m.r., and t.l.c.).

2-*Methoxybenzyl* 2,4,4-*Trimethoxycyclohex*-1-*enyl Sulphone* (15b).—To a solution of the enone (11; R = Me) (290 mg) in acetic acid (8 ml) was added hydrogen peroxide solution (30%; 4 ml) and the reaction mixture stirred at room temperature for 17 h. Extractive work-up as described previously followed by preparative t.l.c. (ether–light petroleum, 3 : 7) afforded the *enone* (15b) (270 mg, 84%) (Found: C, 63.5; H, 6.9; S, 9.5. $C_{17}H_{22}O_4S$ requires C, 63.4; H, 6.8; S, 9.9%); $\nu_{max.}$ 1 670, 1 300, and 1 120 $cm^{-1}$; δ 0.92 (6 H, s, 2 × Me), 2.13 (3 H, s, Me), 2.26 (4 H, s, 2 × $CH_2$), 3.81 (3 H, s, OMe), 4.61 (2 H, s, $ArCH_2$), and 6.75—7.50 (4 H, m, ArH).

*Acid-catalysed Cyclisation of the Enone* (4b).—To a solution of the enone (4b) (192 mg, 0.88 mmol) in nitromethane (5 ml) at room temperature under nitrogen was added boron trifluoride–ether (250 mg, 1.75 mmol). The mixture was stirred for 46 h, poured into ice–water, and extracted with dichloromethane. The extract was washed with brine, dried (sodium sulphate), and the solvent was removed to afford an oil. Preparative t.l.c. (ether–light petroleum, 1 : 5) gave 6-*hydroxy*-3-*t*-*butyl*-2,3-*dihydroinden*-1-*one* (16b) (182 mg, 95%), m.p. 51—53 °C (Found: C, 77.2; H, 8.4. $C_{14}H_{18}O_2$ requires C, 77.0; H, 8.3%); $\nu_{max.}$ 1 700 $cm^{-1}$; δ 0.90 (9 H, s, 3 × Me), 2.60—2.75 (2 H, m, $COCH_2$), 3.20 (1 H, br t, *J* 5 Hz, ArCH), and 7.10—7.65 (3 H, m, ArH), which was shown by g.l.c. to contain the 4-hydroxy-isomer in the ratio 1 : 99.

*Acid-catalysed Cyclisation of the Enone* (5a).—To a solution of the enone (5a) (290 mg, 1.29 mmol) in nitromethane (8 ml) at room temperature under nitrogen was added boron trifluoride–ether (367 mg, 2.58 mmol). The reaction mixture was stirred for 46 h and poured into ice–water. The solution was extracted with dichloromethane and the extract was dried (brine, sodium sulphate). Removal of solvents *in vacuo*, followed by preparative t.l.c. (ether–light petroleum, 2 : 3) afforded two products. The band of lower $R_F$ gave 6-*hydroxy*-3-*phenylindan*-1-*one* (17a) (122 mg, 42%), m.p. 180—182 °C (from ether–pentane) (Found: C, 80.2; H, 5.3. $C_{15}H_{12}O_2$ requires C, 80.3; H, 5.4%); $\nu_{max.}$ 3 300 and 1 670 $cm^{-1}$; δ 2.30—3.51 (2 H, AB of ABX, $J_{AB}$ 18, $J_{AX}$ 7, $J_{BX}$ 3 Hz, $COCH_2$), 4.61 (1 H, dd, X of ABX, $J_{AX}$ 7, $J_{BX}$ 3 Hz, ArCH), and 7.01—7.80 (8 H, m, ArH), which was shown by g.l.c. after methylation to contain the 4-hydroxy-isomer in the ratio 4 : 96. The band of higher $R_F$ gave 1-(3-*hydroxyphenyl*)-3-*phenylpropan*-1-*one* (20) (45 mg 15%), m.p. 105—106 °C (Found: C, 80.0; H, 6.2. $C_{15}H_{14}O_2$ requires C, 79.6; H, 6.2%); $\nu_{max.}$ 3 300 and 1 680 $cm^{-1}$; δ 3.01—3.51 (4 H, m, 2 × $CH_3$) and 7.11—7.80 (9 H, m, ArH).

*The Ketone* (20).—To a solution of the enone (5a) (200 mg) in ethyl acetate (5 ml) was added platinum oxide catalyst (20 mg) and the mixture was shaken under hydrogen (40 lbf $in^{-2}$) for 10 min, filtered, and the solution evaporated to give an oil. Preparative t.l.c. (ether–light petroleum, 3 : 7) gave the ketone (20) (149 mg, 74%), identical (m.p., t.l.c., i.r., and n.m.r.) with the sample obtained by the previous method.

*Acid-catalysed Cyclisation of the Enone* (5b).—To a solution of the enone (5b) (216 mg, 0.91 mmol) in nitromethane (6 ml) at room temperature under nitrogen was added boron trifluoride–ether (259 mg, 1.82 mmol), and the solution was stirred for 3 d. The solution was poured into ice–water, and the product extracted with dichloromethane. The extract was dried and evaporated. Preparative t.l.c. (ether–light petroleum, 3 : 7) yielded two products, the band of lower $R_F$ affording 6-*methoxy*-3-*phenylindan*-1-*one* (17b) (117 mg, 54%), m.p. 69—71 °C (Found: C, 80.4; H, 5.8. $C_{16}H_{14}O_2$ requires C, 80.6; H, 5.9%); $\nu_{max.}$ 1 670 $cm^{-1}$; δ 2.45—3.51 (2 H, AB of ABX, $J_{AB}$ 18, $J_{AX}$ 7, $J_{BX}$ 3 Hz, $COCH_2$), 3.88 (3 H, s, OMe), 4.55 (1 H, dd, X of ABX, $J_{AX}$ 7, $J_{BX}$ 3 Hz, ArCH), and 7.50—7.71 (8 H, m, ArH), which was shown, as above, to contain 3% of the 4-hydroxy-isomer (g.l.c.). The band of higher $R_F$ afforded 1-(3-*methoxyphenyl*)-3-*phenylpropan*-1-*one* (21) (16 mg, 7%) (Found: C, 80.1; H, 6.6. $C_{16}H_{16}O_2$ requires C, 80.0; H, 6.7%); $\nu_{max.}$ 1 680 $cm^{-1}$; δ 2.90—3.45 (4 H, m, 2 × $CH_2$), 3.86 (3 H, s, OMe), and 7.01—7.81 (9 H, m, ArH).

*Acid-catalysed Cyclisation of the Enone* (8b).—To a

solution of the enone (8b) (320 mg, 1.23 mmol) in nitromethane (15 ml) at room temperature under nitrogen was added boron trifluoride–ether (350 mg, 2.46 mmol), and the solution was stirred for 13 h. Work-up and chromatography, as before, yielded two bands, the band of higher $R_F$ being the starting material (67 mg, 21%) (i.r., n.m.r., and t.l.c.). The band of lower $R_F$ gave *7-methoxy-1,1-dimethyl-4-t-butyl-3,4-dihydronaphthalen-2(1H)-one* (18b) (180 mg, 56%), m.p. 101—102 °C (from dichloromethane–light petroleum) (Found: C, 78.4; H, 9.3. $C_{17}H_{24}O_2$ requires C, 78.4; H, 9.3%); $\nu_{max.}$ 1 705 $cm^{-1}$; δ 0.88 (9 H, s, 3 × $CH_3$), 1.40 (3 H, s, $CH_3$), 1.52 (3 H, s, $CH_3$), 2.90 (3 H, m, $COCH_2CH$), 3.85 (3 H, s, $OCH_3$), and 6.68—7.22 (3 H, m, ArH), which was shown, as above, to contain 1% of the 5-methoxy-isomer (g.l.c.).

*Acid-catalysed Cyclisation of the Enone* (9b).—To a solution of the enone (9b) (142 mg, 5.07 mmol) in nitromethane (6 ml) was added boron trifluoride–ether (152 mg, 1.07 mmol) and the solution was stirred for 20 h under nitrogen at room temperature. Work-up and preparative t.l.c. as before yielded *7-methoxy-1,1-dimethyl-4-phenyl-3,4-dihydronaphthalen-2(1H)-one* (19b) (99 mg, 70%), m.p. 80—83 °C (Found: C, 80.9; H, 7.2. $C_{19}H_{20}O_2$ requires C, 81.3; H, 7.2%); $\nu_{max.}$ 1 700 $cm^{-1}$; δ 1.49 (6 H, s, 2 × Me), 2.75—3.11 (2 H, m, $COCH_2$), 3.81 (3 H, s, OMe), 4.41 (1 H, t, *J* 6 Hz, ArCH), and 6.50—7.61 (8 H, m, ArH), which was shown, as above, to contain 5% of the 5-methoxy-isomer (g.l.c.).

*Acid-catalysed Cyclisation of the Enone* (13b).—To a solution of the enone (13b) (470 mg, 0.001 4 mol) in nitromethane (8 ml) at room temperature under nitrogen was added boron trifluoride–ether (400 mg, 0.002 8 mol) and the solution was stirred for 6 d. Work-up and chromatography as before afforded *ethyl 8-methoxy-10b-methyl-4-oxo-1,2,3,4,4a,10b-hexahydro-6H-dibenzo[b,d]thiopyran-1-carboxylate* (301 mg, 64%), m.p. 145—147 °C (from MeOH) (Found: C, 64.2; H, 6.7; S, 9.5. $C_{18}H_{22}O_4S$ requires C, 64.6; H, 6.6; S, 9.6%); $\nu_{max.}$ 1 725 and 1 700 $cm^{-1}$; δ 1.01 (3 H, t, *J* 6 Hz, $CO_2CH_2Me$), 1.36 (3 H, s, Me), 2.05—3.12 (4 H, m, 2 × $CH_2$), 3.21—4.41 (5 H, m), 3.78 (3 H, s, OMe), 5.22 (1 H, s, SCHCO), and 6.56—7.45 (3 H, m, ArH).

*Attempted Acid-catalysed Cyclisation of the Enone* (11b).—To a solution of the enone (11b) (270 mg, 0.93 mmol) in nitromethane (6 ml) at room temperature under nitrogen was added boron trifluoride–ether (270 mg, 1.9 mmol) and the solution was stirred for 11 d. The solution was poured into cold water and extracted with dichloromethane. The extract was washed with brine, dried, and evaporated to give an oil (260 mg) established (i.r., n.m.r., and t.l.c.) as starting material.

Similar treatment of the enones (14b), (15a), and (15b) with boron trifluoride as described above obtained only starting material.

*Attempted Base-catalysed Cyclisation of the Enone* (5a).—A solution of the enone (5a) (152 mg, 0.001 mol) in aqueous sodium hydroxide [80 mg, 0.002 mol, in $H_2O$ (5 ml)] was stirred at room temperature for 5 h. The mixture was acidified with aqueous hydrochloric acid (5%) and extracted with ether. The ether extracts were washed with water, dried (magnesium sulphate), and the solvent was removed *in vacuo* to afford a pale yellow solid (128 mg, 84%). I.r., n.m.r., and t.l.c. established the identity of the product with the starting material. Use of refluxing temperature produced *m*-hydroxyacetophenone and benzaldehyde in addition to the starting material. Attempted aqueous sodium hydroxide-catalysed cyclisation of the enone (4a) under the above conditions gave starting material.

*Deuterium Incorporation into the Enone* (4a).—Sodium metal (9.9 mg, 0.043 mmol) was allowed to react with deuterium oxide (0.6 ml) and the enone (4a) (40 mg, 0.02 mmol) was added. The reaction mixture was stirred at room temperature for 19 h. T.l.c. and n.m.r. established the product to be the starting material with incorporation of two deuterium atoms; δ 1.12 (9 H, s, 3 × Me), 7.20 (1 H, s, vinyl proton), and 7.21—7.70 (4 H, m, ArH).

*Attempted Base-catalysed Cyclisation of the Enone* (6a).—To a solution of the enone (6a) (300 mg, 0.001 25 mol) in ether (6 ml) at room temperature under nitrogen was added ethylmagnesium bromide [from magnesium (61 mg), ethyl bromide (273 mg, 0.002 5 mol), and ether (5 ml)] and the mixture was stirred for 5 min. The ether was removed *in vacuo*. Benzene (20 ml) was added and the reaction mixture was heated at reflux for 2 d, and quenched by the addition of saturated aqueous ammonium chloride, after cooling. The solution was extracted with ether and the ethereal solution was dried (brine, magnesium sulphate). Removal of the solvent *in vacuo* gave a yellow solid (270 mg, 90%) identical (i.r., n.m.r., and t.l.c.) with starting material.

Similar treatment of the enone (7a) with ethylmagnesium bromide as described above gave only starting material.

*Attempted Base-catalysed Cyclisation of the Enone* (8a).—To a solution of the enone (8a) (190 mg, 0.78 mmol) in t-butyl alcohol (4 ml) and tetrahydrofuran (8 ml) was added potassium t-butoxide (90 mg, 0.80 mmol) under nitrogen. The mixture was heated at reflux for 15 h. The solution was cooled, acidified with aqueous hydrochloric acid (5%), and extracted with ether. The extracts were dried (brine, magnesium sulphate) and solvent was removed *in vacuo* to afford a pale yellow oil (150 mg, 79%) identical (i.r. and n.m.r.) with starting material.

Similar treatment of the enone (8a) (100 mg) in tetrahydrofuran (6 ml) and t-butyl alcohol (2 ml) with potassium t-butoxide (80 mg) at room temperature for 13 d gave only starting material.

*Attempted Base-catalysed Cyclisation of the Enone* (9a).—A solution of the enone (9a) (145 mg, 0.64 mmol) in aqueous sodium hydroxide [40 mg, 1 mmol, in water (50 ml)] was stirred at room temperature for 16 h and acidified with aqueous hydrochloric acid (10%). The solution was extracted with ether and the ethereal solution was dried (brine, magnesium sulphate). Removal of the solvent *in vacuo* gave an oil (140 mg, 97%) which was shown to be identical with starting material (i.r., n.m.r., and t.l.c.). Use of a higher temperature (reflux, 3 h) produced a mixture of 1-(3-hydroxyphenyl)-1,1-dimethylpropan-2-one and starting material in the ratio 1 : 1 (n.m.r.).

Base-catalysed cyclisation of the enone (9a) was also attempted under the following conditions: sodium methoxide in methanol (reflux, 8 h), sodium ethoxide in ethanol (reflux, 26 h), potassium t-butoxide in t-butyl alcohol–tetrahydrofuran (room temperature, 17 h), sodium hydride in tetrahydrofuran (room temperature, 16 h), sodium hydride in toluene (reflux, 16 h), and lithium di-isopropylamide (0 °C—room temperature, 2 h). All attempts were unsuccessful, no cyclisation of the enone (9a) was observed, and the starting material was recovered. Use of a higher reaction temperature (heating in *NN*-dimethylaniline at 193 °C, 2 h) produced decomposition products.

*Base-catalysed Deuterium Incorporation into the Phenol*

(19a).—Sodium metal (31 mg, 1.35 mmol) was allowed to react with deuterium oxide (1 ml) and the phenol (19a) (120 mg, 0.45 mmol) was added. The mixture was refluxed for 3 h. N.m.r. analysis showed 90% of the deuteriated product (34), δ 1.50 (6 H, s, 2 × Me), 4.40 (1 H, s, CH), and 6.50—7.61 (8 H, m, ArH).

*Attempted Base-catalysed Cyclisation of the Enone* (11a).—Sodium metal (33 mg, 1.44 mmol) was allowed to react with methanol (30 ml), and the enone (11a) (200 mg, 0.72 mmol) was added under nitrogen. The solution was heated at reflux for 15 h. The reaction mixture was cooled and acidified with aqueous hydrochloric acid (5%). The mixture was poured into water (100 ml) and extracted with ether. The extracts were washed with brine and dried (magnesium sulphate). Removal of the solvent *in vacuo* gave a yellow solid (190 mg, 95%) identical (i.r., n.m.r., and t.l.c.) with starting material.

In addition under the following conditions starting material was recovered: sodium methoxide in methanol (reflux, 6 d), ethylmagnesium bromide in ether (reflux, 2 d), pyrrolidine in benzene (reflux, 23 h), pyridine (140 °C, 24 h), sodium n-butoxide in n-butyl alcohol (reflux, 2 d), sodium hydrogencarbonate in hexamethylphosphoric triamide (230 °C, 24 h), and *NN*-dimethylaniline (reflux, 15 h).

*Attempted Base-catalysed Cyclisation of the Enone* (13a) *and the Enone* (14a).—Heating (13a) and (14a) with sodium methoxide in methanol at refluxing temperature for 22 h was unsuccessful. No cyclisation was observed.

*Attempted Base-catalysed Cyclisation of the Enone* (15a).—The enone (15a) was unchanged after heating with sodium methoxide in methanol at reflux for 17 h and 42 h Use of sodium hydride in tetrahydrofuran (reflux, 22 h) produced many decomposition products in addition to the starting material.

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[28] *Note added in proof.* Subsequent to the date of submission a 6-*Exo-Trig* reaction, involving intramolecular phenoxide attack on an enone, albeit a complex system, has been observed (R. S. Atkinson and J. E. Miller, *J.C.S. Perkin I*, 1979, 3017).