Intramolecular Cyclisation of Phenolic Oximes. Part I. Cyclisations with Manganese(III) Tris(acetylacetonate) [1]

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Reactions of a series of *p*-hydroxyarylpropan-2-one oximes with manganese(III) tris(acetylacetonate) resulted in intramolecular cyclisation to the corresponding spiro-isoxazolines by a two-electron oxidation in which an incipient phenoxonium ion is trapped by the oxime hydroxy-group. *o*-Hydroxyarylpropan-2-one oximes did not react in this way but gave instead benzofurans and the parent ketones.

THE unusual sponge metabolite aerothionin [2] (3), recently isolated from *Verongia* sponges, could arise *in vivo* in a number of ways. One possible route involves reduction of the spirodienone (2) formed by oxidative cyclisation of the phenolic oxime (1) which could be derived from tyrosine and ornithine.[2] Although examples of oxidative coupling of phenols [3] and of oximes [4] abound in the literature, to our knowledge the only example of oxidative cross-coupling of phenols and oximes is that described by Müller *et al.*,[5] who obtained 4-(or 2-)substituted cyclohexadienones (4) by reactions of ketone oximes with 2,4,6-tri-t-butylphenoxyl. In this and the following paper we describe attempts to effect oxidative intramolecular cyclisation of phenolic

[1] Preliminary communication, A. R. Forrester, R. H. Thomson, and S.-O. Woo, *J.C.S. Chem. Comm.*, 1973, 604.

[2] E. Fattorusso, L. Minale, G. Sodano, K. Moody, and R. H. Thomson, *J.C.S. Perkin I*, 1972, 18.

[3] H. Musso in 'Oxidative Coupling of Phenols,' ed. W. I. Taylor and A. R. Battersby, Dekker, New York, 1973.

[4] R. N. Butler, F. L. Scott, and T. A. F. O'Mahony, *Chem. Rev.*, 1973, **73**, 93; R. N. Butler, *Chem. and Ind.*, 1972, 523; J. L. Brokenshire, J. R. Roberts, and K. U. Ingold, *J. Amer. Chem. Soc.*, 1972, **94**, 7040; G. D. Mendenhall and K. U. Ingold, *ibid.*, 1973, **95**, 627, 2963.

[5] E. Müller, R. Mayer, B. Narr, A. Schick, and K. Scheffler, *Annalen*, 1961, **645**, 1.

oximes, modelled on the possible precursor (1) of aerothionin, to the corresponding spiro-isoxazolines.

RESULTS

Of the numerous oxidising agents now available for the oxidation of phenols, we concentrated on lead tetra-acetate, potassium ferricyanide, silver oxide, sodium periodate, Fremy's salt, and manganese(III) tris(acetylacetonate) (MTA). Of these, MTA was by far the most effective and most of the results described herein were obtained with this reagent. MTA was recommended, first by Dewar and his co-workers,[6] as a phenolic coupling agent since it was soluble in organic solvents and gave good yields of bisphenols not contaminated by the corresponding diphenoquinones. Surprisingly, there have been few subsequent reports [7] of its use.

Oxidation of the series of phenolic oximes (9) listed in Table 1 with MTA (2 mol. equiv.), either in boiling acetonitrile or ethanol for 5 h or at room temperature for 25 h, gave fair yields of the corresponding spiro-isoxazolines (11). These were identified by their characteristic dienone absorptions at 240 nm and 1 670 and 1 640 cm^{-1} and the correct ratio of dienone (δ 6.0—7.0) to heterocyclic proton absorptions (δ 3.0—3.7) in the n.m.r. spectra. The molecular ions fragmented by three principal pathways as illustrated for the spiro-isoxazoline (11; $R^1 = R^2 = H$, $R^3 = Me$).

Oxidation of the phenolic oxime (9; $R^1 = Bu^t$, $R^2 = R^3 = Me$) with lead tetra-acetate also gave the corresponding spiro-isoxazoline but the yield (10%) was much lower than that obtained with MTA. Sodium periodate, silver oxide, and Fremy's salt failed to effect cyclisation of the phenolic oximes (9; $R^1 = Bu^t$, $R^2 = H$, $R^3 = Me$ and $R^1 = Bu^t$, $R^2 = R^3 = Me$). The first of these reagents gave mainly the parent ketones and the other two had little effect.

Alkaline ferricyanide also failed to give spiro-isoxazolines. Instead, the phenolic oxime (9; $R^1 = Bu^t$, $R^2 = R^3 = Me$) yielded a symmetrical dimer [*M* (osmometric) 570 ± 18], a fraction whose average molecular weight (1 442; osmometric) corresponded to that of a pentamer, and benzoquinone. The dimer appears to be

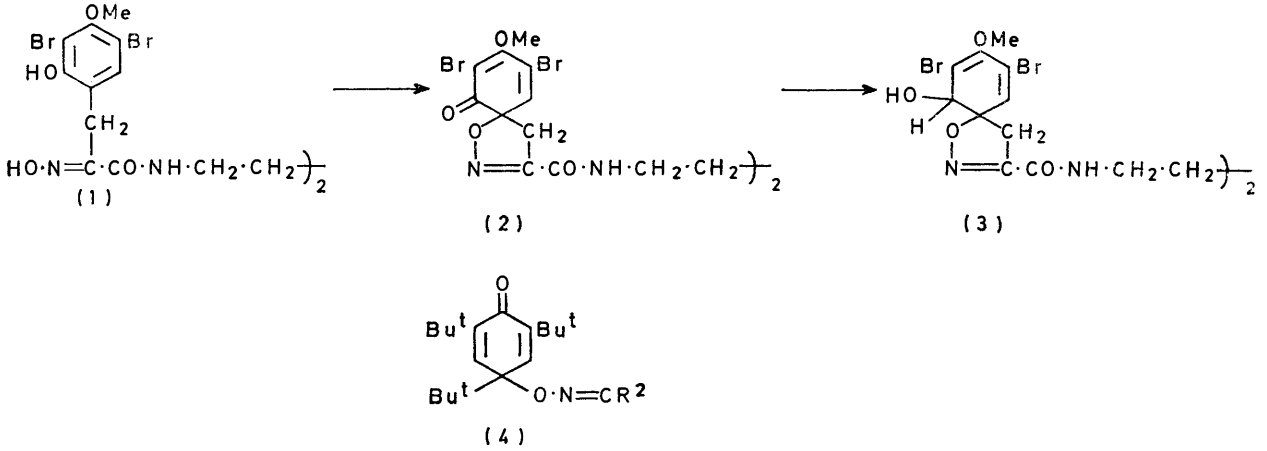


TABLE 1

Products (%) from oxidation of phenolic oximes (9) with MTA

Oxime (9)							Recovered
R^1	R^2	R^3	Solvent	Conditions *	Spiro-isoxazoline (11)	Benzoquinone †	oxime
H	H	H	MeCN	A	19		
			MeCN	B			61
H	H	Me	MeCN	A	50		3
Bu^t	H	Me	MeCN	A	40	+	3
			MeCN	B	40	+	15
			MeOH	A	60	+	
			EtOH	A	62		
Bu^t	Me	Me	MeCN	A	31	+	3
			MeCN	B	31		8
			MeOH ‡	A	25		
			MeCN–Me_2SO	B	26		
H	H	CO_2Me	MeCN	A	42		
Br	H	CO_2Me	MeCN	A	21		

* A, reflux for 5 h; B, stir in acetonitrile at room temperature for 25 h. † + Indicates trace. ‡ This oxidation also yielded the parent ketone (4%).

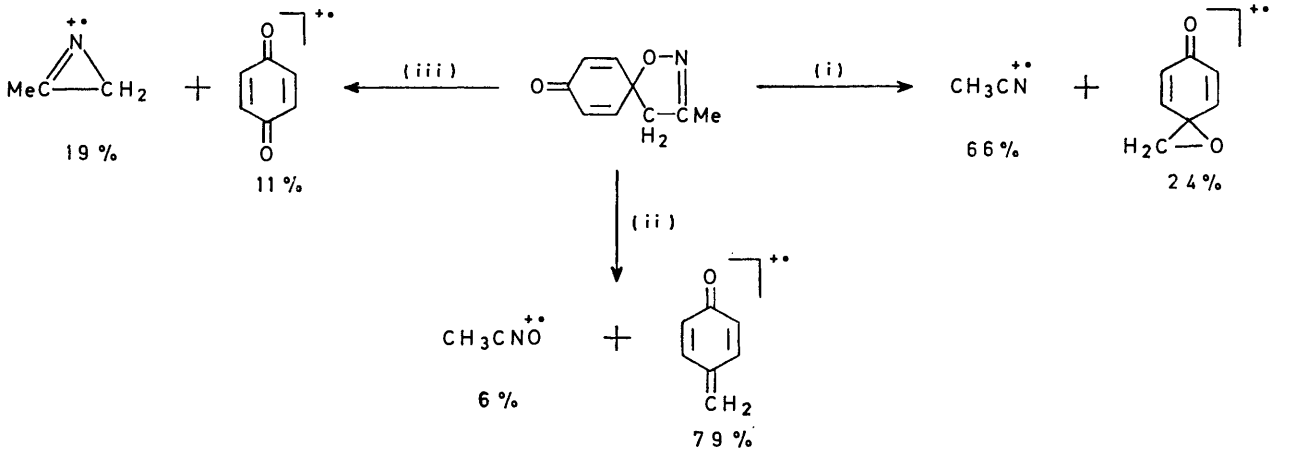
[6] M. J. S. Dewar and T. Nakaya, *J. Amer. Chem. Soc.*, 1968, **90**, 7134.

[7] Y. Omote, Y. Takizawa, and N. Sugiyama, *Bull. Chem. Soc. Japan*, 1972, **45**, 2882; H. D. Locksley and I. G. Murray, *J. Chem. Soc.* (*C*), 1970, 392; M. A. Schwartz, R. A. Holton, and S. W. Scott, *J. Amer. Chem. Soc.*, 1969, **91**, 2800.

(14; R = Me) since it displays typical dienone ($\lambda_{max.}$ 244 nm; $\nu_{max.}$ 1 670 and 1 650 cm^{-1}), oxime and phenolic hydroxy-absorption and n.m.r. signals consistent with the presence of the hydroxyimino side chain and a cyclohexa-2,5-dienone unit. The pentameric fraction also showed typical dienone, phenolic, and oximic hydroxy-absorption in the i.r. Its n.m.r. spectrum had relatively broad peaks corresponding to the presence of methyl (δ 1.4 and 1.8), methine (δ 2.86 and 3.47), dienone (δ 7.0—6.0), and aromatic protons. The exact structure of this ' pentamer ' is uncertain but a telomer such as (15) is indicated by the spectroscopic data. The phenolic oxime (9; R^1 = Bu^t, R^2 = H, R^3 = Me) with ferricyanide also gave a symmetrical dimer (14; R = H) cyclisation to the spiro-isoxazolines, the former with (18; R = H) giving only the benzofuran (*ca.* 15%) and the latter with (18; R = Bu^t) the corresponding benzofuran (56%) and parent ketone (13%).

DISCUSSION

Notwithstanding the apparently analogous intermolecular coupling [5] of stable phenoxyls and iminoxyl radicals already mentioned and the known initiation of free radical polymerisation of vinyl monomers by MTA,[8] we do not consider that the spiro-isoxazolines (11) arise from the phenolic oximes (9) by intramolecular cyclisation of the diradical intermediate (8). This conclusion is based on the following observations. (i) No



and polymeric material which in this case could not be satisfactorily fractionated.

However, the *o*-hydroxyphenylpropan-2-one oximes (18) with MTA gave none of the desired cyclohexa-2,4-dienone-spiro-isoxazolines (17). Instead the parent ketones and the corresponding benzofurans (23) (more conveniently obtained by treatment of the former with acid) were the main products (Table 2). Numerous

TABLE 2

Products (%) from oxidation of phenolic oximes (18) with MTA

Oxime (18) R	Conditions *	Benzofuran	Phenolic ketone
H	A	25	9
	B	25	10
Bu^t	A	35	10
	B	35	10
	C	28	9

* A, reflux in acetonitrile for 5 h; B, stir at room temperature in acetonitrile for 25 h; C, stir at room temperature in acetonitrile containing $H_2{}^{18}O$ for 25 h.

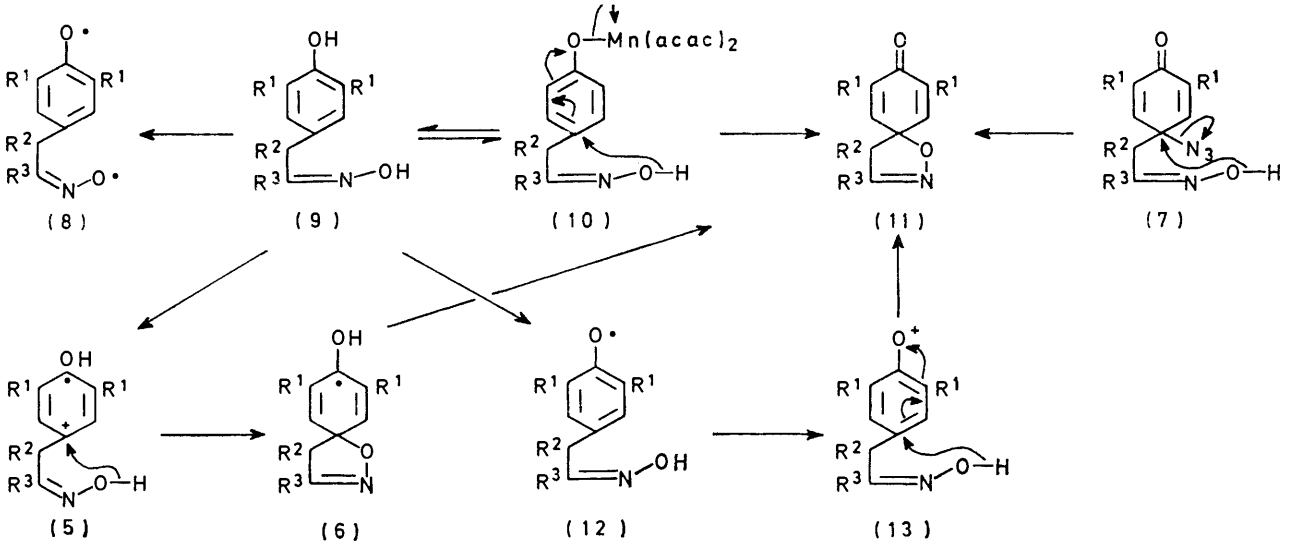
minor products were also formed in these reactions but none was identified. Data for the most abundant of these from the phenolic oxime (18; R = Bu^t) (most of which appear to contain at least part of the acetylacetone moiety) are given in the Experimental section. Lead tetra-acetate and silver oxide also failed to effect

trace of intermolecularly coupled products, linked C to C, N to O, N to N, or O to C, was detected in the oxidations which produced spiro-isoxazolines. It is unlikely that the oxime and phenolic hydroxy-groups would be oxidised at rates sufficiently similar to prevent cross-coupled products being formed. (ii) Oxidation of equimolar mixtures of 2,6-di-t-butylphenol and acetoxime with MTA gave no intermolecularly coupled products, only the bisphenol and diphenoquinone. (iii) Little reaction occurred when either the anisyl oxime (16; R^1 = Me, R^2 = H, R^3 = Me) or the phenolic oxime methyl ether (16; R^1 = H, R^2 = Me, R^3 = CO_2Me) was treated with MTA; production of the phenoxyl from (16; R^1 = H, R^2 = Me, R^3 = CO_2Me) should not be impeded by protection of the oxime hydroxy-group and *vice versa* for (16; R^1 = OMe, R^2 = H, R^3 = Me). (iv) Oxidants such as silver oxide and alkaline ferricyanide which are known [3] one-electron oxidants of phenols gave no spiro-isoxazolines; indeed the latter gave intermolecularly coupled products probably formed by coupling and cross coupling of phenoxyl and phenoxyl-iminoxyl radicals, respectively. (v) When the phenolic oxime (9; R^1 = Bu^t, R^2 = H, R^3 = Me) or 2,4,6-tri-t-butylphenol was oxidised with

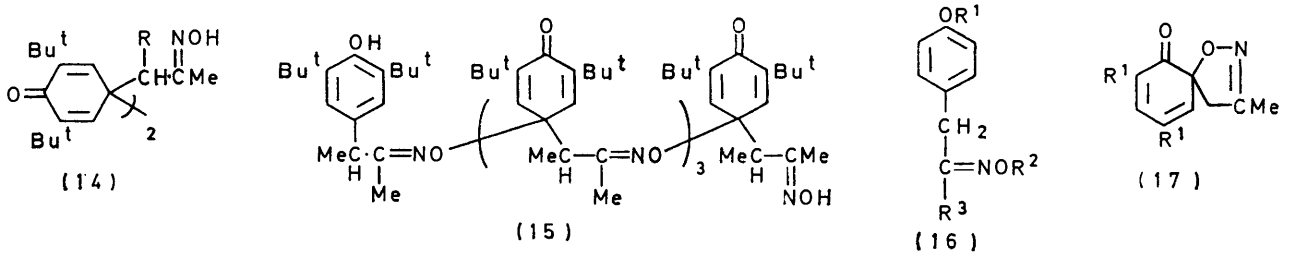
[8] E. G. Kastning, H. Naarmann, H. Reis, and C. Berding, *Angew. Chem. Internat. Edn.*, 1965, **4**, 322; Y. Nishikawa, Y. Nakamura, and S. Kawaguchi, *Bull. Chem. Soc. Japan*, 1972, **45**, 155.

silver oxide in the cavity of an e.s.r. spectrometer, intense spectra of the corresponding phenoxyls were observed which disappeared on addition of MTA. In contrast, the spectrum of neither a phenoxyl nor an iminoxyl was observed when either of the phenolic oximes (9; $R^1 = Bu^t$, $R^2 = H$, $R^3 = Me$) and (9; $R^1 = Bu^t$, $R^2 = R^3 = Me$) or 2,4,6-tri-t-butylphenol was treated with MTA. Addition of MTA to a solution of an aryl t-butyl nitroxide merely caused its e.s.r. spectrum to be broadened slightly.

The most likely alternative to the diradical mechanism is one involving an incipient phenoxonium ion. The first step of such a process would require formation of a manganese–phenol complex (10), heterolysis of the Mn–O bond of which with simultaneous nucleophilic attack by the oxime hydroxy-group at the *para*-carbon atom would lead to the spiro-isoxazoline (11) (Scheme 1). If such is the case then it should be possible to divert the course of the reaction by adding a nucleophile which could compete with the oxime hydroxy-group at the cyclisation stage. An initial attempt to do so by oxidising the phenolic oxime (9; $R^1 = Bu^t$, $R^2 = H$, $R^3 = Me$) in the presence of ethanol was unsuccessful, and indeed led to an increase in the yield of cyclised product. However, when this phenolic oxime was oxidised with MTA in dimethyl sulphoxide–acetonitrile containing sodium azide the yield of spiro-isoxazoline (11; $R^1 = Bu^t$, $R^2 = H$, $R^3 = Me$) was depressed to 10% and an organic azide was also formed. Unfortunately this azide could not be obtained completely free from the starting phenolic oxime, which was insoluble in alkali. The slightly impure azide had i.r. absorption at 3 620 (phenolic OH), 3 300 (oxime OH), 2 100 (N_3), and 1 660 and 1 640 cm^{-1} (dienone). Its n.m.r. spectrum showed, in addition to weak signals due to the original phenolic oxime, peaks at δ 1.2 (t-butyl), 1.8 (methyl), 2.72 (methylene), and 6.63 (dienone). The mass spectrum had a weak molecule ion peak at *m/e* 318 corresponding to $C_{17}H_{26}N_4O_2$. On this evidence we consider this product to be the azido-dienone (7; $R^1 = Bu^t$, $R^2 = H$, $R^3 = Me$) formed by the azide anion reacting at the *para*-position of the manganese–phenol complex. Successive chromatographic separations of the azide fraction reduced the proportion of phenol present but did not eliminate it. Interestingly, significant amounts of the spiro-isoxazolines were produced during these purification stages and on storage, presumably by intramolecular nucleophilic displacement of the azide group. The product mixture from similar oxidations of the phenolic oxime (9; $R^1 = Bu^t$, $R^2 = R^3 = Me$) was even more complex. The azido-dienone (7; $R^1 = Bu^t$, $R^2 = R^3 = Me$), the spiro-isoxazoline (11; $R^1 = Bu^t$, $R^2 = R^3 = Me$), and the starting phenolic oxime (9; $R^1 = Bu^t$, $R^2 = R^3 = Me$) had very



SCHEME 1



similar R_F values and could not be satisfactorily separated by chromatography. However, successive separations did give the spiro-isoxazoline in 10% yield, and a fraction which had i.r. bands at 3 622 (phenol OH), 3 300 (oxime OH), 2 100 (N_3), and 1 670 and 1 650 cm^{-1} (dienone). Oxidation of the phenolic oxime (9; $R^1 = R^2 = H$, $R^3 = Me$) with MTA in the presence of azide ion gave no azido-dienone, only spiro-isoxazoline.

These observations could also be accommodated by a radical-cation mechanism in which initial one-electron transfer giving (5) is followed by capture of the nucleophile and subsequent one-electron oxidation of the ensuing bicyclic intermediate (6). However, the aforementioned e.s.r. evidence is against this process, radical-cation formation normally being favoured only for oxidations in highly acidic media. The further possibility that a phenoxyl (12), formed either by loss of a proton from the radical cation (5) or by homolytic cleavage of the Mn–O bond of the manganese–phenolic oxime complex(12), is oxidised to the corresponding free phenoxonium ion (13) which intramolecularly cyclises is also discounted both on energetic grounds and for the same reasons as given earlier to exclude the diradical mechanism.

The extent to which the stereochemistry of the oxime group affects the cyclisation of the phenolic oximes was difficult to gauge since the stereochemistry of only one (9; $R^1 = R^2 = R^3 = H$) of the substrates listed in Table 1 is known with certainty. This has the favourable *syn*-arrangement of the oxime hydroxy-group and *p*-hydroxybenzyl group. Four others existed ostensibly in one unknown configuration (n.m.r.) and the sixth (9; $R^1 = Bu^t$, $R^2 = H$, $R^3 = Me$) was a mixture (*ca.* 1 : 1) of isomers. Hence, we conclude either that these four oximes have the *syn*-arrangement or that they exist to an undetectably (n.m.r.) small extent in the *syn*-form and equilibration between the two forms is rapid under the reaction conditions. Since all the oxidations listed in Table 1 also gave a precipitate of basic manganese(II) acetylacetonate we surmise that the Mn^I species formed in the oxidation step (10) ⟶ (11) rapidly disproportionates as shown:

$$Mn^{III} + ArOH \longrightarrow Mn^{I} + \text{product}$$

$$Mn^{I} + Mn^{III} \longrightarrow 2Mn^{II}$$

The alternative initial disproportionation: $2Mn^{III} \longrightarrow Mn^{II} + Mn^{IV}$, followed by two electron oxidation by Mn^{IV} seems unlikely in view of previous work [9] on oxidations with Mn^{III} acetate.

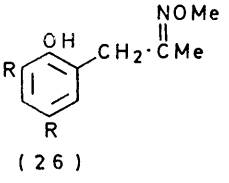
Attempts to extend the scope of these intramolecular cyclisations met with little success. Other phenols with potentially suitable nucleophilic substituents in the 4-position, *viz.*, {27; R = $[CH_2]_3$·OH, CH_2·C(=NOH)·NH_2, CH_2·CH(NH_2)·CO_2Me, CH_2C(=N·NHR)Me, CH=CH·NO_2, or CH_2·CO·CO_2H} failed to yield the corresponding spirodienones under the conditions used for the phenolic oximes (9) and *o*-phenylphenols did not give dibenzofuran. Attempted oxidation of even the homologous phenolic oxime [27; R = CH_2·CH_2·C(=NOH)Me], *m*-hydroxybenzaldehyde oxime, and the tetralone oxime (28) with MTA also failed to give cyclised products (see Experimental section).

The main reason for our failure to obtain spiro-isoxazolines from the *ortho* series of phenolic oximes (18) and MTA is almost certainly the proximity of their phenolic and oximic hydroxy-groups. Both groups can bind to the same metal atom as indicated in (19a) ⟷ (19b), thus removing the structural features necessary for cyclisation as suggested for the *para*-isomers (9). Efforts to circumvent this difficulty by oxidising the

[9] D. R. Rosseinsky, *J. Chem. Soc.*, 1963, 1181; P. J. Andrulis, M. J. S. Dewar, R. Dietz, and R. L. Hunt, *J. Amer. Chem. Soc.*, 1966, **88**, 5473.

oxime methyl ethers (26; R = H or Bu^t) were unavailing.

The most likely route to the phenolic ketones is that shown in Scheme 2 [path (a)], this being similar to previous proposals for the deoximation of oximes with lead tetra-acetate [10] and with thallium nitrate.[11] Although the small quantity of water required for such a process could easily be present as an impurity in the 'dry' acetonitrile (0.006% required) only partial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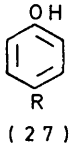
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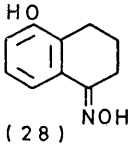
(28)

support for this suggestion was gained by conducting the oxidation in acetonitrile containing [^{18}O]water (21%). The incorporation of ^{18}O into the ketone (25; R = Bu^t) (1.3%) was low, suggesting that other paths to the ketone must also be important.

Of the several possible reaction sequences leading to the benzofurans, cyclodehydration by way of (24) of the ketone is of minor importance. In separate experiments it was shown that refluxing the ketones (25; R = Bu^t or H) in acetonitrile gave only 1—2% of the benzofurans (23; R = Bu^t or H). Alternatively the phenolic hydroxy-group could add to the imino-group to give a nitrosodihydrobenzofuran (21) [path (b)], loss of nitroxyl (HNO) from which would yield the product (23), but we have no evidence to support this sequence. Nor could we detect (n.m.r.) ring tautomers (20) of the phenolic oximes, dehydroxylamination of which would also yield the benzofurans, *i.e.* (20) ⟶ (23).

EXPERIMENTAL

T.l.c. refers to separations on silica gel plates. Known compounds were identified by direct comparison (t.l.c., i.r., and m.p.) with authentic specimens. Spectra were measured for samples in ethanol (u.v.), Nujol (i.r.), or deuteriochloroform (n.m.r.) unless otherwise stated. Petrol refers to light petroleum, b.p. 40—60°.

Starting Materials.—(i) *Aldehydes and ketones.* 1-(2-Hydroxy-3,5-di-t-butylphenyl)propan-2-one,[12] *p*-hydroxyphenylpyruvic acid,[13] 3-(4-hydroxy-3,5-di-t-butylphenyl)-butan-2-one,[14] *p*-hydroxyphenylpropan-2-one,[15] 3,5-dibromo-4-hydroxyphenylpyruvic acid,[16] *o*-hydroxyphenylpropan-2-one,[17] 4-(*p*-methoxyphenyl)butan-2-one,[18] 4-(*p*-hydroxyphenyl)butan-2-one,[19] and 3,4-dihydro-5-hydroxynaphthalene-1(2*H*)-one [20,21] were prepared by literature methods. 1-(4-*Hydroxy*-3,5-*di-t-butylphenyl*)*propan*-2-*one*, m.p. 84.5—85.5° (from petrol) (Found: C, 77.9; H, 9.9. $C_{17}H_{26}O_2$ requires C, 77.9; H, 9.9%), $\nu_{max.}$ 3 520 and 1 710 cm^{-1}, was prepared [14] from 2,6-di-t-butylphenol and bromoacetone. The product had to be separated chromatographically from unchanged phenol and 1-(2,6-*di-t-butylphenoxy*)*propan*-2-*one*, m.p. 50—51° (from petrol) (Found: C, 77.9; H, 10.0. $C_{17}H_{26}O_2$ requires C, 77.9; H, 9.9%), $\nu_{max.}$ 1 730 cm^{-1}.

(ii) *Oximes.* The following were prepared from the corresponding ketones by standard procedures: [22] p-*hydroxyphenylpropan*-2-*one oxime*, m.p. 169—170° (from chloroform) (Found: C, 65.7; H, 6.9; N, 8.3. $C_9H_{11}NO_2$ requires C, 65.4; H, 6.7; N, 8.5%); 1-(4-*hydroxy*-3,5-*di-t-butylphenyl*)*propan*-2-*one oxime*, m.p. 124—125° (from petrol) (Found: C, 73.5; H, 9.5; N, 5.1. $C_{17}H_{27}NO_2$ requires C, 73.6; H, 9.7; N, 5.1%); 3-(4-*hydroxy*-3,5-*di-t-butylphenyl*)*butan*-2-*one oxime*, m.p. 133.5—135.5° (from petrol) (Found: C, 74.4; H, 9.8; N, 5.1. $C_{18}H_{29}NO_2$ requires C, 74.2; H, 10.0; N, 4.8%); 3,5-*dibromo*-4-*hydroxyphenylpyruvic acid oxime*,* m.p. 215—216° (Found: C, 35.0; H, 2.0; N, 3.9%; *M*, 350.8742. $C_9H_7{}^{79}Br_2NO_4$ requires C, 30.6; H, 2.0; N, 4.0%; *M*, 350.8743); o-*methoxyphenylpropan*-2-*one oxime*, m.p. 79—81° (from benzene–petrol) (Found: C, 67.1; H, 7.4; N, 7.6. $C_{10}H_{13}NO_2$ requires C, 67.0; H, 7.2; N, 7.8%); o-*hydroxyphenylpropan*-2-*one oxime*, m.p. 80—81° (from benzene) (Found: C, 65.4; H, 6.5; N, 8.5. $C_9H_{11}NO_2$ requires C, 65.4; H, 6.7; N, 8.5%); 1-(2-*hydroxy-di-t-butylphenyl*)-*propan*-2-*one oxime*, m.p. 123—124° (from aqueous methanol) (Found: C, 73.4; H, 9.9; N, 4.8. $C_{17}H_{27}NO_2$ requires C, 73.6; H, 9.7; N, 5.1%); 4-(p-*methoxyphenyl*)-*butan*-2-*one oxime*, m.p. 67—70° (from petrol) (Found: C, 68.6; H, 8.1; N, 7.5. $C_{11}H_{15}NO_2$ requires C, 68.4; H, 7.8; N, 7.3%); 4-(p-*hydroxyphenyl*)*butan*-2-*one oxime*, m.p. 97.5—100° (from benzene) (Found: C, 66.7; H, 7.3; N, 7.8. $C_{10}H_{13}NO_2$ requires C, 67.0; H, 7.3; N, 7.8%). *p*-Hydroxyphenylacetaldehyde oxime [23] was obtained by reduction of 1-(*p*-hydroxyphenyl)-2-nitroethene.[24] *Methyl* p-*hydroxyphenylpyruvate oxime*, m.p. 135.5—137° (from chloroform) (Found: C, 57.1; H, 5.0; N, 6.5. $C_{10}H_{11}NO_4$ requires C, 57.4; H, 5.3; N, 6.7%), was prepared by esterification of the corresponding acid oxime [25] with diazomethane. An alternative preparation of *o*-hydroxyphenylpropan-2-one oxime from *o*-methoxyphenylpropan-2-one oxime by demethylation with boron tribromide was also used.

(iii) *Miscellaneous.* 3-(*p*-Hydroxyphenyl)propan-1-ol [25] and 3-(*p*-hydroxyphenyl)-2-aminopropionic acid [26] were

* Satisfactory carbon analysis could not be achieved for products containing high percentage of bromine.

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prepared by literature methods. The following are new. p-*Hydroxyphenylacetamide oxime*, from *p*-hydroxybenzyl cyanide and hydroxylamine, had m.p. 185—186° (from ethanol) (Found: C, 57.7; H, 6.2; N, 16.7. $C_8H_{10}N_2O_2$ requires C, 57.8; H, 6.0; N, 16.9%); p-*hydroxyphenylpyruvate* O-*methyloxime*, m.p. 144.5—145.5° (from ether–chloroform) (Found: C, 57.4; H, 5.0; N, 6.5. $C_{10}H_{11}NO_4$ requires C, 57.4; H, 5.3; N, 6.7%), 1-(2-*hydroxy*-3,5-*di-t-butylphenyl*)*propan*-2-*one* O-*methyloxime*, b.p. 107—109° at 0.2 mmHg (Found: C, 74.4; H, 9.9; N, 4.6. $C_{18}H_{19}NO_2$ requires C, 74.2; H, 10.0; N, 4.8%), and o-*hydroxyphenylpropan*-2-*one* O-*methyloxime*, m.p. 76.5—77.5 (from benzene) (Found: C, 67.2; H, 7.3; N, 8.1. $C_{10}H_{13}NO_2$ requires C, 67.0; H, 7.3; N, 7.8%), were prepared from the corresponding ketones by treatment with methoxyamine. Methylation of *p*-hydroxyphenylpyruvic acid *O*-methyloxime with diazomethane gave *methyl* p-*hydroxyphenylpyruvate* O-*methyloxime*, b.p. 135—140° at 2 mmHg (Found: C, 59.0; H, 6.0; N, 6.0. $C_{11}H_{13}NO_4$ requires C, 59.1; H, 5.8; N, 6.3%). 1-(4-*Hydroxy*-3,5-*di-t-butylphenyl*)*propan*-2-*one hydrazone* had m.p. 116—118° (Found: C, 74.0; H, 9.9; N, 9.9. $C_{17}H_{28}N_2O$ requires C, 73.9; H, 10.2; N, 10.1%); 1-(4-*hydroxy*-3,5-*di-t-butylphenyl*)*propan*-2-*one phenylhydrazone* had m.p. 124—128° (Found: C, 78.5; H, 9.3; N, 8.3. $C_{23}H_{32}N_2O$ requires C, 78.4; H, 9.2; N, 8.0%).

General Procedure for Oxidation of Phenolic Oximes and Derivatives with MTA.—A solution of the phenolic oxime and MTA [27] (2 mol. equiv.) in dry acetonitrile was heated under reflux in an atmosphere of nitrogen for 5 h. The precipitate which separated was then collected and the filtrate was evaporated. The black solid remaining was either chromatographed (p.l.c.) on silica or directly dissolved in chloroform. In the latter case the solution was extracted in turn with saturated aqueous disodium ethylenediaminetetra-acetate, 2M-sodium hydroxide, and water; the resulting solution was then dried and evaporated, and the residue was chromatographed as above. In the latter procedure phenolic components were recovered from the alkaline extracts in the usual way.

(i) *p*-Hydroxyphenylpropan-2-one oxime (495 mg) and MTA (2.11 g) in acetonitrile (20 ml) gave, after direct chromatography of the crude product on silica with petrol–ethyl acetate (1 : 1), 3-*methyl*-1-*oxa*-2-*azaspiro*[4.5]*deca*-2,6,9-*trien*-8-*one* (11; $R^1 = R^2 = H$, $R^3 = Me$) (260 mg, 17%), plates, m.p. 70.5—73° (from benzene) (Found: C, 66.5; H, 5.8; N, 8.4%; M^+, 163.0631. $C_9H_9NO_2$ requires C, 66.2; H, 5.5; N, 8.6%; *M*, 163.0633), $\nu_{max.}$ 1 680 and 1 640 cm^{-1}, $\lambda_{max.}$ 235 nm (log ε 4.13), δ 2.07 (3 H, s, Me), 3.18 (2 H, s, CH_2), 6.23 (2 H, d, *J* 10 Hz, 2CH=), and 6.87 (2 H, d, *J* 10 Hz, 2CH=), *m/e* 163 (50%, M^+), 122 (24, $M - CH_3CN$), 121 (100, $M - CH_3CNH$), 108 (11, $M - C_3H_5N$), 106 (79, $M - CH_3CNO$), 78 (57, $M - CH_3CNO - CO$), 57 (6, CH_3CNO), 55 (19, C_3H_5N), and 41 (66, CH_3CN).

(ii) 1-(4-Hydroxy-3,5-di-t-butylphenyl)propan-2-one oxime (554 mg) and MTA (1.41 g) in acetonitrile (120 ml) gave, after direct chromatography of the crude product with petrol–ethyl acetate (4 : 1), 3-*methyl*-7,9-*di-t-butyl*-1-*oxa*-2-*azaspiro*[4.5]*deca*-2,6,9-*trien*-8-*one* (11; $R^1 = Bu^t$, $R^2 = H$, $R^3 = Me$) (200 mg, 40%), needles, m.p. 118—120° (from petrol) (Found: C, 74.0; H, 9.2; N, 5.3%; M^+, 275.1881. $C_{17}H_{25}NO_2$ requires C, 74.2; H, 9.1; N, 5.1%; *M*, 275.1885), $\nu_{max.}$ 1 670 and 1 650 cm^{-1}, $\lambda_{max.}$ 245 nm (log ε 3.97), δ 1.22 (18 H, s, 2Bu^t), 2.05 (3 H, s, Me), 2.98 (2 H, s, CH_2), and 6.54 (2 H, s, 2CH=), *m/e* 275 (19%, M^+), 234 (3, $M - CH_3CN$), 220 (27, $M - C_3H_5N$), 218 (53, $M - CH_3CNO$), 203 (93, $M - Bu^t - Me$), 161 (93, $M - 2Bu^t$), 57 (80, CH_3CNO), 55 (C_3H_5N), and 41 (100, CH_3CN); 2,6-di-t-butylbenzoquinone (trace); and unchanged phenolic oxime (20 mg).

The oxidation was repeated as above but with (*a*) stirring for 25 h at room temperature instead of heating under reflux for 5 h; or (*b*) methanol, or (*c*) ethanol in place of acetonitrile as solvent. The yields of spiro-isoxazoline obtained were (*a*) 40%, (*b*) 60%, and (*c*) 62%, respectively.

The phenolic oxime (277 mg), MTA (704 mg), and sodium azide (325 mg) in dimethyl sulphoxide (12.5 ml) and acetonitrile (15 ml) were stirred at room temperature for 25 h. Work-up as before gave the spiro-isoxazoline (30 mg, 11%) and a fraction (125 mg) containing two components with very similar R_F values. This fraction showed $\nu_{max.}$ (film) 3 620 (OH), 3 300 (=NOH), 2 100 (N_3), and 1 660 and 1 640 cm^{-1} (dienone), but could not be satisfactorily purified by further chromatography. Each attempt yielded a small amount of the spiro-isoxazoline and a fraction with an increasingly intense band at 3 620 cm^{-1}.

(iii) 3-(4-Hydroxy-3,5-di-t-butylphenyl)butan-2-one oxime (582 mg) and MTA (1.41 g) in acetonitrile (120 ml) gave, after direct chromatography of the crude product using petrol–ethyl acetate (4 : 1), 3,4-*dimethyl*-7,9-*di-t-butyl*-1-*oxa*-2-*azaspiro*[4.5]*deca*-2,6,9-*trien*-8-*one* (11; $R^1 = Bu^t$, $R^2 = R^3 = Me$) (160 mg, 31%), m.p. 105—106° (from petrol) (Found: C, 75.0; H, 9.3; N, 5.0%; M^+, 289.2046. $C_{18}H_{27}NO_2$ requires C, 74.7; H, 9.3; N, 4.8%; *M*, 289.2042), $\nu_{max.}$ 1 670 and 1 648 cm^{-1}, $\lambda_{max.}$ 245 nm (log ε 4.03), δ 1.01 (3 H, d, *J* 7 Hz, Me), 1.2 (18 H, s, 2Bu^t), 2.0 (3 H, s, Me), 3.21 (1 H, q, *J* 7 Hz, CH_3CH), 6.48 (1 H, d, *J* 3 Hz, CH=), and 6.57 (1 H, d, *J* 3 Hz, CH=), *m/e* 289 (15%, M^+), 232 (63, $M - CH_3CNO$), 217 (100, $M - Bu^t - Me$), 175 (75, $M - 2Bu^t$), 69 (30, C_4H_7N), 57 (18, MeCNO), and 41 (14, MeCN); 2,6-di-t-butylbenzoquinone (trace); and unchanged phenolic oxime (21 mg).

The oxidation was repeated as above but with (*a*) stirring for 25 h at room temperature instead of heating under reflux for 5 h; or (*b*) methanol or (*c*) acetonitrile (90 ml) and dimethylsulphoxide (30 ml) as solvent. Work-up as before gave the spiro-isoxazoline [(*a*) 31, (*b*) 25, and (*c*) 26%, respectively].

The phenolic oxime (291 mg), MTA (704 mg), and sodium azide (325 mg) in dimethyl sulphoxide (12.5 ml) and acetonitrile (15 ml) were stirred at room temperature for 25 h. Work-up as before gave the spiro-isoxazoline (30 mg, 10%) and a fraction (130 mg) containing three components of very similar R_F values, two of which corresponded (R_F) to the starting phenolic oxime and the spiro-isoxazoline. This fraction showed $\nu_{max.}$ (film) 3 622 (OH), 3 300 (NOH), 2 110 (N_3), and 1 670 and 1 650 cm^{-1} (dienone CO), and could not be further purified by chromatography.

(iv) *p*-Hydroxyphenylacetaldehyde oxime (405 mg) and MTA (2.11 g) in acetonitrile (100 ml) gave, after direct chromatography of the crude black product with ether–chloroform (1 : 4), 1-*oxa*-2-*azaspiro*[4.5]*deca*-2,6,9-*trien*-8-*one* (11; $R^1 = R^2 = R^3 = H$) (75 mg, 19%) as an oil, b.p. 109—113° at 1.0 mmHg (Found: C, 64.2; H, 4.6; N, 9.3%; M^+, 149.0481. $C_8H_7NO_2$ requires C, 64.4; H, 4.7; N, 9.4%; *M*, 149.0477), $\nu_{max.}$ (film) 1 685 and 1 640 cm^{-1},

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$\lambda_{max.}$ 231 nm (log ε 4.18), δ 3.19 (2 H, d, *J* 2 Hz, CH_2), 6.25 (2 H, d, *J* 10 Hz, 2CH=), 6.89 (2 H, d, *J* 10 Hz, 2CH=), and 7.29 (1 H, t, *J* 2 Hz, CH), *m/e* 149 (46%, M^+), 122 (49, *M* − HCN), 106 (100, *M* − HCNO), 78 (99, *M* − HCNO − CO), 43 (7, HCNO), 41 (4, C_2H_3N), and 27 (5, HCN).

Repetition of the above oxidation with stirring for 25 h gave only unchanged phenolic oxime (61%) and a complex mixture from which none of the above spiro-isoxazoline could be isolated.

(v) Methyl (*p*-hydroxyphenyl)pyruvate oxime (418 mg) and MTA (1.78 g) in acetonitrile (100 ml) gave a yellow oil which was chromatographed using ether–chloroform (1 : 9) to give *methyl* 8-*oxo*-1-*oxa*-2-*azaspiro*[4.5]*deca*-2,6,9-*triene*-3-*carboxylate* (11; $R^1 = R^2 = H$, $R^3 = CO_2Me$) (170 mg, 42%), m.p. 83—84° (from ether) (Found: C, 58.1; H, 4.3; N, 6.9%; M^+, 207.0530. $C_{10}H_9NO_4$ requires C, 58.0; H, 4.3; N, 6.8%; *M*, 207.0532), $\nu_{max.}$ 1 715, 1 675, and 1 638 cm^{-1}, $\lambda_{max.}$ 239.5 nm (log ε 4.35), δ 3.4 (2 H, s, CH_2), 3.93 (3 H, s, OMe), 6.29 (2 H, d, *J* 10 Hz, 2CH=), and 6.89 (2 H, d, *J* 10 Hz, 2CH=), *m/e* 207 (14%, M^+), 148 (24, *M* − CO_2Me), 106 (29, *M* − CO_2MeCNO), 85 (73, CO_2MeCN), and 83 (100).

(vi) Methyl (3,5-dibromo-4-hydroxyphenyl)pyruvate oxime (367 mg) and MTA (880 mg) in acetonitrile (50 ml) gave, after chromatography of the crude black product in petrol–ethyl acetate (1 : 1), *methyl* 7,9-*dibromo*-8-*oxo*-1-*oxa*-2-*azaspiro*[4.5]*deca*-2,6,9-*triene*-3-*carboxylate* (11; R^1 = Br, R^2 = H, $R^3 = CO_2Me$) (75 mg, 21%), m.p. 199—200° (from ethyl acetate) (Found: C, 32.7; H, 2.2; Br, 44.0; N, 4.1%; M^+, 362.8736. $C_{10}H_7Br_2NO_4$ requires C, 32.9; H, 1.9; Br, 43.8; N, 3.8%; *M*, 362.8742), $\nu_{max.}$ 1 752 and 1 680 cm^{-1}, $\lambda_{max.}$ (MeOH) 212 and 259 nm (log ε 3.94 and 4.17), δ (CD_3COCD_3) 3.68 (2 H, s, CH_2), 3.84 (3 H, s, OMe), and 7.68 (2 H, s, 2CH=), *m/e* 365 (8%, M^+), 306 (50, *M* − CO_2Me), 286 (81), 284 (85), 280 (10, *M* − CO_2MeCN), 266 (51, *M* − $CO_2MeC_2H_2N$), 264 (100, *M* − CO_2MeCNO), and 59 (67, CO_2Me).

(vii) Methyl (*p*-hydroxyphenyl)pyruvate *O*-methyloxime (335 mg) and MTA (1.06 g) in acetonitrile gave only starting material (80%).

(viii) 4-(*p*-Methoxyphenyl)butan-2-one oxime (358 mg) and MTA (704 mg) in acetonitrile (50 ml) gave only starting material (85%).

(ix) 4-(*p*-Hydroxyphenyl)butan-2-one oxime (537 mg) and MTA (2.11 g) in acetonitrile (100 ml) gave 4-(*p*-hydroxyphenyl)butan-2-one (90 mg, 18%), unchanged phenolic oxime (60 mg, 11%), and small quantities of several unidentified products.

(x) *o*-Hydroxyphenylpropan-2-one oxime (250 mg) and MTA (1.1 g) in acetonitrile (30 ml) gave 2-methylbenzofuran [12] (50 mg, 25%) and *o*-hydroxyphenylpropan-2-one [12] (20 mg, 9%).

When the oxidation was repeated, with stirring for 25 h at room temperature instead of heating under reflux for 5 h, 2-methylbenzofuran (51 mg, 25%) and *o*-hydroxyphenylpropan-2-one (22 mg, 12%) were produced.

(xi) (*a*) 1-(2-Hydroxy-3,5-di-t-butylphenyl)propan-2-one oxime (554 mg) and MTA (1.41 g) in acetonitrile (120 ml) gave, after direct chromatography of the crude product in benzene–chloroform (1 : 1), 2-methyl-5,7-di-t-butylbenzofuran [26] (170 mg, 35%), b.p. 125—129° at 0.55 mmHg (Found: C, 83.9; H, 9.7. Calc. for $C_{17}H_{24}O$: C, 83.6; H, 9.8%), δ 1.35 (9 H, s, Bu^t), 1.50 (9 H, s, Bu^t), 2.44 (3 H, s, Me), 6.28br (1 H, s, CH=), 7.15 (1 H, d, *J* 2 Hz, ArH), and 7.31 (1 H, d, *J* 2 Hz, ArH); 1-(2-hydroxy-3,5-di-t-butylphenyl)propan-2-one [12] (55 mg, 10%), m.p. 127—128° (Found: M^+, 262.1919. Calc. for $C_{17}H_{26}O$: *M*, 262.1933), δ (enol and keto forms respectively) 1.30 (9 H, s, Bu^t), 1.35 and 1.40 (9 H, s, Bu^t), 1.72 and 2.32 (3 H, s, Me), 3.15 and 3.70 (2 H, s, CH_2), 6.92 (1 H, d, *J* 2 Hz, ArH), and 7.09 (1 H, d, *J* 2 Hz, ArH); and an unidentified product (100 mg, 15%), m.p. 62—63° (from petrol) (Found: C, 76.1; H, 9.7; N, 3.9%; M^+, 318.2251), $\nu_{max.}$ 1 761 and 1 718 cm^{-1}, $\lambda_{max.}$ 218 and 275 nm (log ε 3.49 and 3.94), δ 1.3 (9 H, s, Bu^t), 1.34 (9 H, s, Bu^t), 2.14 (3 H, s, Me), 2.32 (4 H, s, Me and CH), 7.3 (3 H, s, Me), 7.08 (1 H, d, *J* 2 Hz, ArH), and 7.28 (1 H, d, *J* 2 Hz, ArH).

When the above oxidation was repeated with stirring at room temperature for 25 h instead of heating under reflux for 5 h, 2-methyl-5,7-di-t-butylbenzofuran (172 mg, 35%), the parent ketone (55 mg, 10%), and the unidentified product (105 mg, 16%) were obtained.

(*b*) The oxime (277 mg) and MTA (770 mg) in acetonitrile (30 ml) and $H_2{}^{18}O$ (0.5 ml; 21.6% enrichment) was stirred for 25 h at room temperature. Work up as in (*a*) gave the benzofuran (70 mg, 28%) and the ketone (25 mg, 9%). The mass spectrum of the ketone showed $M/(M + 2) = 27.6$; that produced in (*a*) showed $M/(M + 2) = 46.0$.

(xii) 1-(2-Hydroxy-3,5-di-t-butylphenyl)propan-2-one *O*-methyloxime (291 mg) and MTA (704 mg) in acetonitrile (50 ml) gave only starting material (206 mg, 70%).

(xiii) *o*-Hydroxyphenylpropan-2-one *O*-methyloxime (358 mg) and MTA (1.41 g) in acetonitrile (50 ml) gave starting material (220 mg, 62%).

(xiv) 3,4-Dihydro-5-hydroxynaphthalen-1(2*H*)-one oxime [21] (531 mg) and MTA (2.11 g) in acetonitrile (100 ml) gave starting material (266 mg, 50%) and an intractable mixture.

(xv) 2,6-Di-t-butylphenol (618 mg) and acetaldehyde oxime (1.1 g) in acetonitrile (50 ml) with MTA (1.06 g) gave 3,3′,5,5′-tetra-t-butyl-1,1′-diphenoquinone [28] (32 mg, 5%) and 4,4′-dihydroxy-3,3′,5,5′-tetra-t-butylbiphenyl [29] (75 mg, 12%).

(xvi) *Other substrates*. In separate experiments (*a*) 1-(4-hydroxy-2,6-di-t-butylphenyl)propan-2-one hydrazone (522 mg); (*b*) *p*-hydroxyphenylacetamide oxime (498 mg); (*c*) 1-(4-hydroxy-2,6-di-t-butylphenyl)propan-2-one phenylhydrazone (704 mg); (*d*) 1-*p*-hydroxyphenyl-2-nitroethane; (*e*) *m*-hydroxybenzaldehyde oxime (548 mg); (*f*) *o*-phenylphenol; (*g*) 3-(*p*-hydroxyphenyl)propan-1-ol (456 mg); (*h*) tyrosine methyl ester (250 mg); (*i*) *p*-hydroxyphenylpyruvic acid (360 mg); and (*j*) 1-(2-hydroxy-3,5-di-t-butylphenyl)propan-2-one in acetonitrile (50 ml) were treated with MTA (2 mol. equiv.) in the usual way to give (*a*) the parent ketone (63 mg, 12%) and 2,6-di-t-butylbenzoquinone (50 mg, 12%); (*b*) an intractable mixture; (*c*) an intractable mixture; (*d*) starting material (320 mg, 80%); (*e*) starting material (230 mg, 42%); (*f*) an intractable mixture; (*g*) starting material (137 mg, 30%); (*h*) starting material (150 mg, 68%); (*i*) an intractable mixture; and (*j*) starting material (200 mg, 41%), respectively.

Oxidation of Phenolic Oximes with Other Oxidising Agents. —(1) *Silver oxide*. (*a*) 3-(4-Hydroxy-3,5-di-t-butylphenyl)butan-2-one oxime (500 mg) in benzene (70 ml) was shaken for 24 h with silver oxide (440 mg). The silver residues were collected and the filtrate was evaporated to give an oil, chromatography of which using petrol–benzene

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(1 : 1) gave 2,6-di-t-butyl-1,4-benzoquinone (45 mg, 12%) and the starting material (250 mg).

(*b*) *p*-Hydroxyphenylbutan-2-one oxime (143 mg) was oxidised with silver oxide as described in (*a*) to give a complex mixture from which only the starting material (80 mg) was obtained by chromatography.

(*c*) 1-(2-Hydroxy-3,5-di-t-butylphenyl)propan-2-one oxime (100 mg) was oxidised with silver oxide (170 mg) as described in (*a*) to give 2-methyl-5,7-di-t-butylbenzofuran (50 mg, 56%) and the parent ketone (12 mg, 13%).

(2) *Potassium ferricyanide.* (*a*) 3-(4-Hydroxy-3,5-di-t-butylphenyl)butan-2-one oxime (0.58 g) in benzene (30 ml) was added to a well stirred solution of potassium ferricyanide (1.58 g) and sodium hydroxide (1.4 g) in water (35 ml), both solutions having been purged with nitrogen. Stirring under nitrogen was continued for 3 h before the organic layer was separated, washed with water, and dried. Removal of the solvent left an oil which was chromatographed using petrol–ethyl acetate (9 : 1) to give (i) a *pentamer* (15) (200 mg) as a yellow solid, m.p. 98.5—100° [Found: C, 74.9; H, 9.0; N, 5.2%; *M* (osmometric), 1 442 ± 43. $C_{90}H_{137}N_5O_{10}$ requires C, 74.6; H, 9.5; N, 4.8%; *M*, 1 447], $\nu_{max.}$ 3 615, 3 495, 1 670, and 1 650 cm^{-1}, δ 0.86 (15 H, s, 5CH*Me*), 1.14 (90 H, s, 10Bu^t), 1.39 (6 H, s, 2Me), 1.74 (9 H, s, 3Me), 2.86 (4 H, m, 4C*H*Me), 3.47 (1 H, m, C*H*Me), 6.48br (8 H, s, 8CH=), 6.95br (2 H, s, ArH), and 7.23br (s, OH); (ii) a *dimer* as a yellow solid, m.p. 57—59.5° [Found: C, 74.7; H, 9.0; N, 5.0%; *M* (osmometric), 570 ± 18. $C_{36}H_{56}N_2O_4$ requires C, 74.5; H, 9.7; N, 4.8%; *M*, 580], $\nu_{max.}$ 3 495—3 320, 1 670, and 1 650 cm^{-1}, $\lambda_{max.}$ 220 and 244 nm (log ε 3.60 and 3.99), δ 1.08 (6 H, d, *J* 9 Hz, 2CH*Me*), 1.21 (36 H, s, 4Bu^t), 1.13 (6 H, s, 2Me), 2.06 (2 H, q, *J* 9 Hz, 2CH), 6.51 (2 H, d, *J* 2 Hz, 2CH=), 6.61 (2 H, d, *J* 2 Hz, 2CH=), and 7.01br (1 H, s, OH); (iii) 2,6-di-t-butylbenzoquinone (trace).

(*b*) 1-(4-Hydroxy-3,5-di-t-butylphenyl)propan-2-one oxime (0.55 g) was oxidised as described in (*a*) with alkaline potassium ferricyanide. Chromatography of the crude product gave a *dimer* (100 mg, 18%) as a yellow oil [Found: C, 74.3; H, 9.2; N, 4.9%; *M* (osmometric), 575 ± 18. $C_{34}H_{52}N_2O_4$ requires C, 73.9; H, 9.4; N, 5.1%; *M*, 552], $\nu_{max.}$ 3 480—3 200, 1 670, and 1 650 cm^{-1}, $\lambda_{max.}$ 225sh and 244 nm (log ε 3.24 and 3.54), δ 1.16 (6H, s, 2Me), 1.22 (18 H, s, 2Bu^t), 1.28 (18 H, s, 2Bu^t), 1.82 (2 H, s, CH_2), 2.18 (2 H, s, CH_2), 6.66br (1 H, s, CH=), 6.85 (1 H, d, *J* 2 Hz, CH=), and 7.75br (1 H, s, OH), and polymeric material.

(3) *Fremy's salt.* 3-(4-Hydroxy-3,5-di-t-butylphenyl)-butan-2-one oxime (0.58 g) in acetone (90 ml) was mixed with a solution of Fremy's salt (0.54 g) in water (200 ml) and 0.5M-potassium dihydrogen phosphate solution (40 ml). The mixture was shaken until the purple colour of the Fremy's salt had faded (10 min) and then the acetone was removed by evaporation. The precipitate which separated was collected and crystallised to give the starting material (400 mg, 70%).

(4) *Lead tetra-acetate.* (*a*) 3-(4-Hydroxy-3,5-di-t-butylphenyl)butan-2-one oxime (200 mg) and lead tetra-acetate (710 mg) were stirred in benzene (30 ml) for 40 h under nitrogen. After removal of the inorganic residues the solution was washed with water, and dried. Evaporation left a gum which was chromatographed in benzene to give 3,4-dimethyl-7,9-di-t-butyl-1-oxa-2-azaspiro[4.5]deca-2,6,9-trien-8-one (11; R^1 = Bu^t, R^2 = R^3 = Me) (21 mg, 10%), identical with that obtained by oxidation of this phenolic oxime with MTA.

(*b*) *o*-Hydroxyphenylpropan-2-one oxime (250 mg) was oxidised with lead tetra-acetate (1.05 g) in benzene as described in (*a*) to give 2-methylbenzofuran (28 mg, 15%) and several other, unidentified products.

(5) *Sodium periodate.* (*a*) 3-(4-Hydroxy-3,5-di-t-butylphenyl)butan-2-one oxime (100 mg) in water was shaken with sodium periodate (200 mg) for 16 h. The mixture was extracted with ether and the extracts were washed with water, and then dried. Evaporation gave the starting material (80 mg).

(*b*) *p*-Hydroxyphenylpropan-2-one oxime (100 mg) was oxidised with sodium periodate (260 mg) in water–acetone (100 ml; 1 : 1) as described in (*a*). Chromatography of the crude product in benzene–chloroform (1 : 3) gave *p*-hydroxyphenylpropan-2-one (40 mg, 44%).

(6) *Lead dioxide.* (*a*) *m*-Hydroxybenzaldehyde oxime (0.55 g) in ether (50 ml) was stirred at room temperature for 72 h with lead dioxide (2.86 g). After removal of the lead residues the filtrate was evaporated to give an oil, chromatography of which with chloroform–ether (4 : 1) gave *m*-hydroxybenzaldehyde (50 mg, 10%) and the starting material (201 mg, 36%).

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