Oxidation products from 4-methoxy-2-methyl-1-naphthol

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The oxidation of 4-methoxy-2-methyl-1-naphthol by lead(IV) oxide gives 1-hydroxy-4-methoxy-2-naphthaldehyde, 4-methoxy-1,2-naphthaquinone and a spironaphthalenenaphthopyranone. The last of these undergoes aerial oxidation in solution forming a dinaphtho-oxepinquinone.

Keywords: naphthol, oxepin, polycyclic heterocyclic compounds, oxidation

The oxidation of 4-methoxy-1-naphthol **1** by lead(IV) oxide involves the initial formation of the naphthoxyl radical **3** which undergoes *ortho–ortho* coupling *via* the mesomeric radical **5** to give finally the bisnaphthalene indigo **7**[1,2] (Scheme 1). We have now investigated the products from a similar oxidation of the related naphthol **2** in which the *ortho* methyl group prevents the occurrence of the usual coupling reaction.

Three products resulted, the hydroxymethoxynaphthaldehyde **10** (5.5%), the methoxy-1,2-naphthaquinone **14** (4.4%) and the spiroketone **15** (79%). Their structures followed from their molecular formulae, their spectral properties and mechanistic considerations. The one-electron oxidation of certain *p*-hydroxybenzyl alcohols by potassium hexacyanoferrate(III) is known[3] to lead to the formation of *p*-hydroxybenzaldehydes and the *o*-hydroxyaldehyde **10** would appear to be produced by the analogous reaction sequence shown in Scheme 2. Disproportionation[4] of the radical **6** gives the quinonemethide **8** which by addition of water forms the phenolic alcohol **9** which undergoes further oxidation in the same way to give the hydroxyaldehyde **10**. In the presence of oxygen substituted *p*-hydroxybenzaldehydes are oxidised by lead(IV) oxide to the corresponding *p*-benzoquinones[5] and a similar oxidation of the *o*-hydroxynaphthaldehyde **10** as outlined in Scheme 2 would result in the formation of the other minor product, the methoxynaphthaquinone **14**. The initial product, the radical **11,** would react with oxygen to give the peroxy radical **12** and hence the dioxetan **13**. Ring cleavage of the latter would form the *o*-naphthaquinone **14 (**together with the formyloxy radical).

The major product from the oxidation of the naphthol **2,** the spiroketone **15,** is clearly formed by a (4 + 2) cycloaddition reaction between two molecules of the quinonemethide **8** (Scheme 3). The formation of spirodimers by the one-electron oxidation of *o*-methyl-*p*-alkoxyphenols such as α-tocopherol[6] is well documented.

The spiroketone **15** proved to be very sensitive thermally, undergoing disproportionation in the mass spectrometer with the formation of a prominent $(M - 2H)^+$ ion and a much less abundant $(M + 2H)^+$ ion. On being heated *in solution* with free access of air it readily lost a methyl group and three hydrogen atoms giving, as the sole product, a red compound $C_{23}H_{14}O_4$ which we formulate as the polycyclic oxepinquinone **21**. Its NMR spectrum shows singlets corresponding to the three methoxy protons and the isolated aromatic proton H-6. The five protons H-1, -4, -8, -10 and -13 are all adjacent to oxygen functions and give rise to a down-field five-proton multiplet at ~δ 8.2 while the remaining protons (H-2, -3, -7, -11 and -12) appear as a second five-proton multiplet at ~δ 7.6. The mass spectrum provides support for the conjugated polycyclic structure, the only fragment ions of any significance being those formed by the loss of Me, 3 × CO and CHO. The formation of the oxepinquinone can be explained by the reaction sequence shown in Scheme 3 in which the acid-catalysed ring-opening of the spiroketone **15** produces the hydroxyquinone **16**. This cyclises to the quinol **17** which undergoes aerial oxidation to give the quinone **18**. Proton-transfer, facilitated by the electron shifts shown in structures **18** and **19,** produces the quinol **20** which by further aerial oxidation gives the oxepinquinone **21.** The stability of the latter may well be enhanced by mesomeric interaction of the oxepin and the quinone systems as shown in the part-structure **22.**

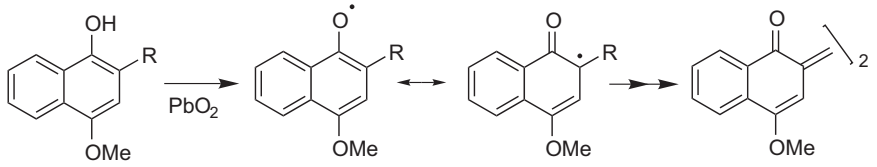
The spiroketone **15** has been shown previously[7] to be the sole product when the naphthol **2** is oxidised using silver(I) oxide. When heated by itself *in the solid state* the spiroketone was found[7] to give rise to a complex mixture of products some of which on further oxidation with silver(I) oxide gave the oxepinquinone **21** described in the present work. It is apparent that there are significant differences between the oxidising properties of lead(IV) oxide and silver(I) oxide in such reactions and also that the thermal decomposition of the spiroketone **15** in solution follows a completely different pathway to that in the solid state.

Experimental

General

IR spectra were measured using KBr discs, and UV absorptions using ethanolic solutions. ^{1}H NMR spectra were recorded for $CDCl_3$ solutions at 100 MHz using Me_4Si as internal standard. Mass spectra were obtained using EI at 70eV. 'Light petroleum' refers to the fraction b.p. 60–80°C.

Oxidation of 4-methoxy-2-methyl-1-naphthol **2**: A mixture of 4-methoxy-2-methyl-1-naphthyl acetate (**2** acetate)[8] (500 mg, 2.17 mmol) and 3% methanolic potassium hydroxide (30 ml) was boiled under reflux under nitrogen for 0.5 h, added to lM-sulfuric acid (50 ml) and shaken with chloroform (4 × 50 ml). The dried (Na_2SO_4)



1; R = H **2**; R = Me **3**; R = H **4**; R = Me **5**; R = H **6**; R = Me **7**

Scheme 1

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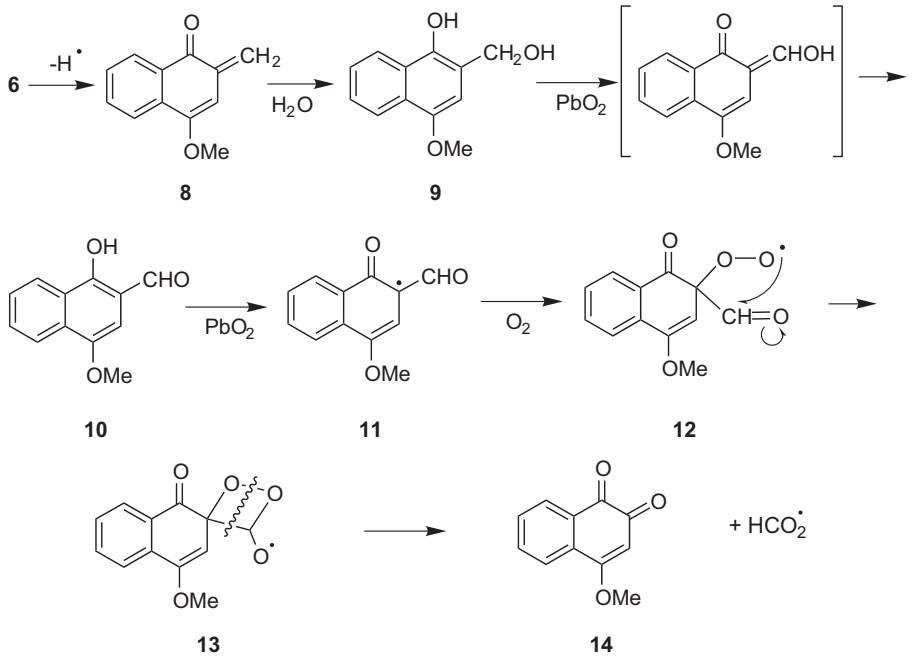
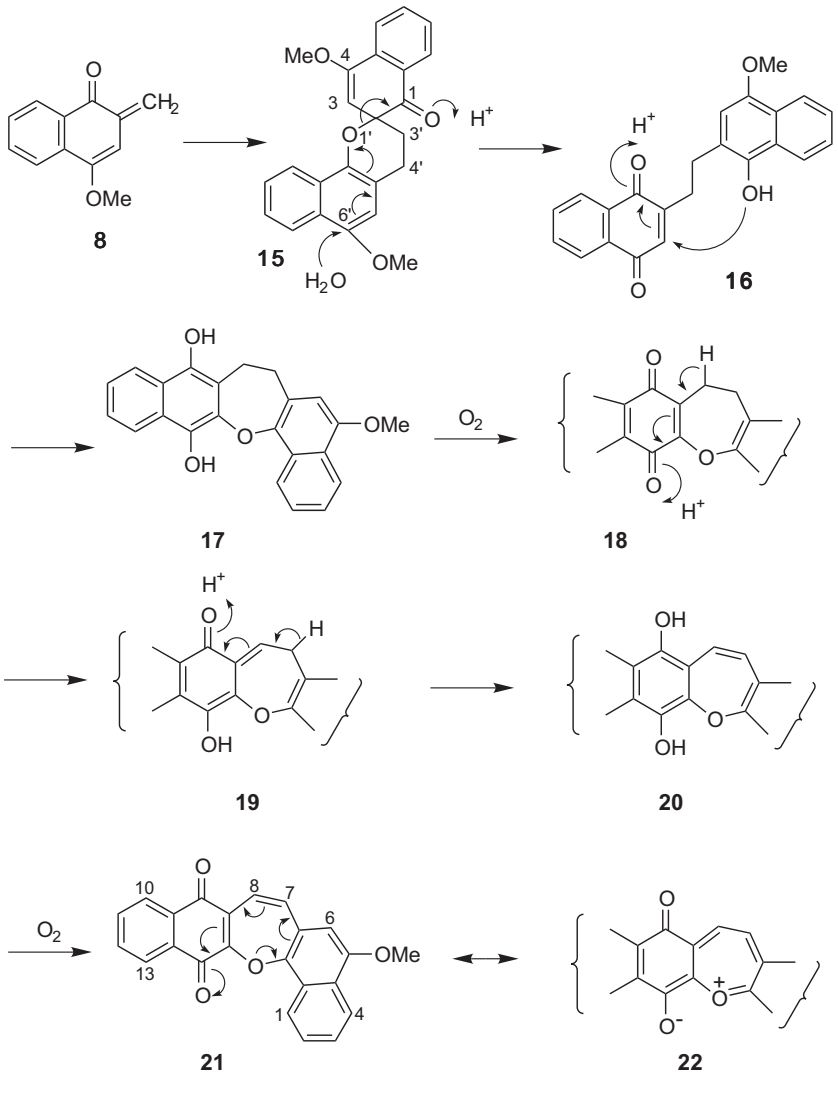


Scheme 2



Scheme 3

chloroform solution containing the naphthol **2** was warmed on the steam-bath with lead(IV) oxide (5 g, 20.92 mmol) for 5 min, cooled and filtered and the filtrate was treated twice more with lead(IV) oxide in the same manner. Finally the filtrate was concentrated and subjected to PLC on silica gel (Merck, GF_{254}) using chloroform as irrigant; three products were obtained.

(a) The fastest-moving was 1-hydroxy-4-methoxy-2-naphthaldehyde **10** (24 mg, 0.12 mmol, 5.5%) which crystallised from methanol as pale yellow needles m.p. 98–99°C (lit.,[9] 99–100°C) (Found: C, 71.0; H, 4.8. $C_{12}H_{10}O_3$ requires C, 71.3, H, 5.0%); ν_{max}/cm^{-1} 1645 and 1627 (hydrogen-bonded C=O) and 755 (4 adjacent ArH); λ_{max}/nm 254infl (log ε 4.17), 264 (4.26), 274 (4.26), 297 (3.45), 306infl (3.35), 322infl (3.25) and 394 (3.66); δ_H 3.98 (3H, s, MeOAr), 6.71 (1H, s, H-3), 7.46–7.78 (2H, m, H-6 and -7), 8.20 (1H, dd, J = 7.0 and 2.0 Hz, H-8), 8.42 (1H, dd, J = 7.0 and 2.0 Hz, H-5), 9.88 (1H, s, ArCHO) and 12.32 (1H, s, ArOH).

(b) The next fraction afforded 4,6′-dimethoxy-1*H*-spiro[naphthalene-2,2′-(3′,4′-dihydronaphtho[1,2-*b*]pyran)]-1-one **15** (320 mg, 0.86 mmol, 79%) which crystallised from light petroleum-dichloromethane as pale yellow plates, m.p. 286–288°C (decomp.) (Found: C, 77.2; H, 5.2. $C_{24}H_{20}O_4$ requires C, 77.4; H, 5.4%. Found by MS: $(M–2H)^+$, 370.1203. $C_{24}H_{18}O_4$ requires M, 370.1205); ν_{max}/cm^{-1} 1690 (aromatic ketone C=O), 1648 (ArC =C) and 762 (4 adjacent ArH); λ_{max}/nm 251 (log ε 4.66), 305infl (3.71), 312infl (3.77), 324 (3.33) and 337 (3.82); δ_H 2.05–2.38 (2H, m, ArCH$_2$C*H*$_2$R), 2.93 (2H, t, J = 7.0 Hz, ArC*H*$_2$CH$_2$R), 3.73 (3H, s, MeO at C-6'), 3.94 (3H, s, MeO at C-4), 5.34 (1H, s, H-3′), 6.49 (1H, s, H-5), 7.30-7.85 (5H, m, ArH) and 7.90–8.28 (3H, m, ArH).

(c) The final fraction crystallised from benzene to give 4-methoxy-1,2-naphthaquinone **14** (18 mg, 0.10 mmol, 4.4%) as yellow needles m.p. 190°C (lit.,[10] 190°C) [Found: $(M + 2H)^+$, 190.0624. $C_{11}H_{10}O_3$ requires M, 190.0630); *m/z* 190 (8%, M + 2H), 188 (3, M), 175 (8, M + 2H–Me), 160 (100, M–CO), 159 (28, M + 2H–MeO), 131 (9, 160–CHO), 129 (9, 160–MeO), 102 (71, C_8H_8) and 76 (9, C_6H_6); ν_{max}/cm^{-1} 1700 and 1647 (quinone C=O) and 770 (4 adjacent ArH); λ_{max}/nm 251 (log ε 4.26), 256 (4.26), 275infl (3.93), 339 (3.16) and 414 (3.15); δ_H 4.00 (3H, s, MeOR), 5.96 (1H, s, H-3), 7.35–7.95 (3H, m, H-5, -6 and -7) and 8.10 (1H, dd, J = 6.0 and 2.0 Hz, H-8). This was identical with an authentic specimen.[10]

Aerial oxidation of the spironaphthalenenaphthopyranone **15**: A solution of the spiro compound **15** (100 mg, 0.27 mmol) in light petroleum (25 ml) and dichloromethane (25 ml) was boiled gently for 10 min with free access of air and the resulting deep red solution was evaporated. Separation of the residue by PLC using dichoromethane gave unchanged starting material (70 mg, 0.19 mmol, 70%) and 5-methoxydinaphtho[1,2-*b*: 2′,3′–*f*]oxepin-9,14-quinone **21** (4 mg, 0.01 mmol, 4.2%) which crystallised from light petroleum as deep red needles m.p. 236–238°C (lit.,[7] 241°C) (Found: M^+, 354.0880. $C_{23}H_{14}O_4$ requires M, 354.0892); *m/z* 354 (100%, M), 339 (40, M–Me), 226 (8, 339–3CO–CHO) and 177 (4, M^{2+}); ν_{max}/cm^{-1} 1673 and 1646 (quinone C=O), 1595 (aromatic C =C) and 770 (4 adjacent ArH); λ_{max}/nm 241 (log ε 4.34), 274infl (4.45), 281 (4.47), 319 (4.19), 330infl (4.15) and 502 (3.95); δ_H 4.01 (3H, s, MeOAr), 6.89 (1H, s, H-6), 7.46-7.80 (5H, m, H-2, -3, -7, -11 and -12) and 7.95–8.32 (5H, m, H-1, -4, -8, -10 and -13).

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