905. *Phosphates formed from Dialkyl Phosphites and 2-Methyl-1,4-naphthaquinone.*

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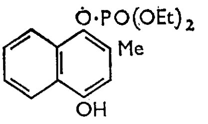
Dialkyl phosphites react with 2-methyl-1,4-naphthaquinone to give a mixture of the 1- and 4-(dialkyl phosphates). The phosphate products from the reaction with diethyl phosphite have been characterised, and the proportions of 1- and 4-phosphates obtained found to depend on the temperature of the reaction, among other factors.

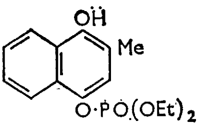
Ramirez and Dershowitz[1] reported that dimethyl and diethyl phosphite reacted with chloranil, under the influence of ultraviolet light, to give the tetrachloroquinol 1-(dialkyl phosphate). Also Diefenbach[2] has described the formation of similar dialkyl phosphates when dialkyl phosphites are heated with a number of symmetrical halogenated quinones in xylene.

In a study of the reaction of dialkyl phosphites with 2-methyl-1,4-naphthaquinone, we found that diethyl phosphite, in benzene or acetonitrile, with the addition of a catalytic amount of sodium ethoxide or potassium t-butoxide (triethylamine and 4-methylmorpholine were less effective) gave a high total yield of two crystalline isomers $C_{15}H_{19}O_5P$, m. p. 167—169° and 107—109° severally.

The infrared spectra of the isomers, although differing in some details, were very similar and showed the presence of hydroxyl and the absence of carbonyl bands. Since the monobenzoates showed no hydroxyl bands, the compounds were both monohydroxylic; thus the possibility that one was diethyl 1,4-dihydroxy-3-methyl-2-naphthylphosphonate was excluded. Alkaline hydrolysis liberated diethyl hydrogen phosphate from both compounds, as would be expected from the 1- and 4-(diethyl phosphates) of 2-methyl-1,4-naphthaquinol.

Only the high-melting isomer reacted smoothly with 1 mol. of bromine, to give a crystalline monobromo-compound; with 2 mol. of bromine, in the presence of sodium acetate, the phosphorus-containing residue was lost and 2-bromo-3-methyl-1,4-naphthaquinone was formed. In the absence of sodium acetate the quinone dibromide was obtained. These reactions indicated that the compound is the 1-(diethyl phosphate) (I).


(I)


(II)

Oxidative dephosphorylation by halogens has been described for naphthaquinol dihydrogen phosphates by Clark, Kirby, and Todd[3] and by Wieland and Pattermann.[4] The structure (I) was confirmed when its toluene-*p*-sulphonate was found to be identical (infrared spectrum and mixed m. p.) with an authentic material obtained by reaction of diethyl phosphorochloridate with 2-methyl-1,4-naphthaquinol 4-toluene-*p*-sulphonate, which had been prepared by consecutive toluene-*p*-sulphonylation and deacetylation of 2-methyl-1,4-naphthaquinol 1-acetate.[5]

Similarly the lower-melting isomer was shown to be 2-methyl-1,4-naphthaquinol 4-(diethyl phosphate) (II) from the fact that its benzoate was identical with material

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[1] Ramirez and Dershowitz, *J. Org. Chem.*, 1957, **22**, 1282.

[2] Diefenbach, G.P. 937,956.

[3] Clark, Kirby, and Todd, *Nature*, 1958, **181**, 1650.

[4] Wieland and Pattermann, *Angew. Chem.*, 1958, **70**, 313.

[5] Baker, Davies, McElroy, and Carlson, *J. Amer. Chem. Soc.*, 1942, **64**, 1096; Baker and Carlson, *ibid.*, p. 2657.

prepared by reaction of diethyl phosphorochloridate with 2-methyl-1,4-naphthaquinol 1-benzoate.[6]

In the reactions between di-isopropyl, di-n-propyl, and di-n-butyl phosphite and 2-methyl-1,4-naphthaquinone only one pure crystalline product was isolated, presumably the 1-phosphate since this predominates for the ethyl analogue under the conditions employed. It was reasonably certain, however, that the other isomer was present in the considerable quantity of oils obtained from the mother-liquors. When diethyl phosphite reacted with 2,3-dimethylnaphthaquinone there was a high yield of the single possible diethyl phosphate.

Factors influencing the proportions of the isomers are not yet fully understood but reaction temperature is one of them. At low temperatures the 1-phosphate predominates and at high temperatures the 4-phosphate: thus at 5° yields of 1- and 4-(diethyl phosphate) were 60% and 18% respectively and at 80° were 20% and 36%.

EXPERIMENTAL

2-*Methyl*-1,4-*naphthaquinol* 1- *and* 4-(*Diethyl Phosphate*).—(*a*) A solution of 2-methyl-1,4-naphthaquinone (34·4 g., 0·2 mole) in dry benzene (300 ml.) containing ethanol (60 ml.) was stirred under nitrogen and cooled to −2°. A mixture of diethyl phosphite (40·8 g., 0·3 mole) and a solution from sodium (1·0 g.) in absolute ethanol (40 ml.) was added at such a rate that the temperature did not rise above 6°. The addition was complete in 20 min. and the mixture was stirred for a further 10 min., by which time it was pale yellow and some solid had been deposited. The mixture was extracted with N-sodium hydroxide, the alkaline extracts were acidified with concentrated hydrochloric acid, and the precipitated oil was extracted with chloroform (400 ml.) in three portions. The chloroform solution was treated with charcoal, filtered, and evaporated *in vacuo*. A solid remained which was triturated with cyclohexane, filtered off, and washed with cyclohexane, followed by light petroleum (b. p. 40—60°), leaving colourless crystals (49 g.), m. p. 140—160°. Evaporation of the cyclohexane solution gave a dark brown solid, which was treated with carbon tetrachloride, set aside at 0°, and then collected as coloured crystals (9·1 g.), m. p. 106—112°. Two recrystallisations of the high-melting material, from acetone, gave colourless felted rods (37·3 g., 60%), m. p. 167—169°, of 2-*methyl*-1,4-*naphthaquinol* 1-(*diethyl phosphate*) (Found: C, 58·3; H, 6·3; P, 9·9. $C_{15}H_{19}O_5P$ requires C, 58·1; H, 6·2; P, 10·0%).

Working up the mother-liquors gave crystals (4·2 g.), m. p. 103—108°, which were combined with those of m. p. 106—112° and recrystallised from carbon tetrachloride; 2-*methyl*-1,4-*naphthaquinol* 4-(*diethyl phosphate*) (11·2 g., 18%) crystallised as colourless prisms, m. p. 107—109° (Found: C, 58·3; H, 6·1; P, 10·1%).

The 4-phosphate gave a 3,5-*dinitrobenzoate*, m. p. 154—155°, by the standard procedure using phosphorus pentachloride and 3,5-dinitrobenzoic acid (Found: C, 52·5; H, 3·9; N, 5·5; P, 6·1. $C_{22}H_{21}O_{10}N_2P$ requires C, 52·5; H, 4·2; N, 5·6; P, 6·1%).

(*b*) A boiling solution of 2-methyl-1,4-naphthaquinone (17·2 g., 0·1 mole) in dry benzene containing diethyl phosphite (20·4 g., 0·15 mole) was stirred under nitrogen. The heating-bath was then removed and a solution from sodium (1·0 g.) in ethanol (25 ml.) was added dropwise during a few minutes. A vigorous reaction took place which was complete within a minute. After cooling, the mixture was worked up as in (*a*) above, 28% of 4-phosphate and 20% of 1-phosphate being obtained.

Reaction of 2-*Methyl*-1,4-*naphthaquinol* 1-(*Diethyl Phosphate*) *with Bromine*.—(*a*) To a solution of the compound (3·1 g., 0·01 mole) in warm acetic acid was added bromine (0·01 mole) in acetic acid (10 ml.). An immediate reaction gave a colourless solution which was poured into water (200 ml.). The white crystalline 3-*bromo-derivative* (3·5 g.), m. p. 123—125·5°, was filtered off, washed with water and light petroleum, and dried. Recrystallisation from light petroleum (b. p. 100—120°; 50 ml.)–benzene (2 ml.) gave material (2·8 g.), m. p. 124—126·5° (Found: C, 47·3; H, 5·6; Br, 20·5; P, 8·0. $C_{15}H_{18}BrO_5P$ requires C, 46·3; H, 5·7; Br, 20·5; P, 8·0%).

(*b*) The compound (3·1 g., 0·01 mole) in warm acetic acid (30 ml.) containing anhydrous

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[6] Lindlar, U.S.P. 2,839,570.

sodium acetate (4·2 g., 0·05 mole) was treated with bromine (0·022 mole) in acetic acid (22 ml.), left for 2 hr., and poured into water (200 ml.), and the yellow precipitate (2·05 g.), m. p. 138—148°, was washed with water and dried. Recrystallisation from ethanol gave yellow crystals (1·4 g.), m. p. 148—150° undepressed on admixture with 2-bromo-3-methyl-1,4-naphthaquinone, m. p. 152—154°.

2-*Methyl*-1,4-*naphthaquinol* 1-*Benzoate*-4-(*Diethyl Phosphate*).—(*a*) The phosphate (1·25 g.) of m. p. 107—109° was treated in pyridine (10 ml.) with benzoyl chloride (1·5 ml.), left overnight, and poured into dilute sulphuric acid and ice. A precipitated gum was extracted with benzene, washed twice with dilute sodium hydroxide solution and then with water, recovered by evaporation *in vacuo*, and dried by addition and evaporation of acetonitrile *in vacuo*. A colourless oil (1·7 g.) remained which slowly crystallised. Recrystallisation from ether–light petroleum (b. p. 40—60°) and then from cyclohexane gave needles of the *benzoate*, m. p. 84·5—86° (Found: C, 63·9; H, 5·2; P, 7·5. $C_{22}H_{23}O_6P$ requires C, 63·9; H, 5·6; P, 7·5%).

There was no depression of the m. p. on admixture with material prepared as in (*b*) and the infrared spectra were identical.

(*b*) 2-Methyl-1,4-naphthaquinol 1-benzoate[6] (1·39 g., 0·005 mole) was suspended in dry carbon tetrachloride (10 ml.), and diethyl phosphite (0·7 g.) was added, followed by triethylamine (0·5 g.). The benzoate rapidly dissolved and heat was evolved. After being cooled, the mixture was set aside overnight. Triethylamine hydrochloride was filtered off and the filtrate was washed with 2N-sodium hydroxide and water, and then evaporated. The oily residue was finally dried by addition and evaporation of acetonitrile *in vacuo*. The oil (1·6 g.) crystallised when scratched and had m. p. 74—80°. Recrystallisation from ether–light petroleum (b. p. 40—60°) gave two crops: prisms (320 mg.), m. p. 75—83°, and needles (640 mg.), m. p. 83·5—85°; the former recrystallised from ether–light petroleum as needles (200 mg.), m. p. 84·5—85·5°; the needles recrystallised as a mixture of prisms (m. p. 74°) and needles, but recrystallisation from a more dilute solution gave only needles, m. p. 83·5—85°. There was no significant difference between the infrared spectra of the prisms and needles and both gave satisfactory analyses [Found, in material dried *in vacuo* at 40°: (*a*) prisms: C, 63·8; H, 5·6; P, 7·5; (*b*) needles: C, 64·1; H, 5·3; P, 7·7%].

2-*Methyl*-1,4-*naphthaquinol* 4-*Benzoate* 1-(*Diethyl Phosphate*).—2-Methyl-1,4-naphthaquinol 1-(diethyl phosphate) (1·55 g.) was treated in pyridine with benzoyl chloride (1·25 g.) overnight. The product, isolated as usual, was dried by addition and evaporation, *in vacuo*, of alcohol and then crystallised (2·5 g.). Recrystallised twice from ether–light petroleum (b. p. 40—60°), this *ester* had m. p. 82—83°, depressed on admixture with the isomer, and differing from it in the detail of the infrared spectra (Found, in material dried *in vacuo* at 40°: C, 63·9; H, 5·6; P, 7·3%).

2-*Methyl*-1,4-*naphthaquinol* 1-(*Diethyl Phosphate*) 4-*Toluene*-p-*sulphonate*.—2-Methyl-1,4-naphthaquinol 1-(diethyl phosphate) (m. p. 167—169°) (3·1 g.) was treated in pyridine with toluene-*p*-sulphonyl chloride. Two recrystallisations of the resulting *ester* (4·0 g.) from cyclohexane gave plates (2·0 g.), m. p. 93—94° (Found, in material dried *in vacuo* at 60°: C, 56·9; H, 5·4; P, 6·6. $C_{22}H_{25}O_7PS$ requires C, 56·9; H, 5·4; P, 6·7%); there was no depression of the m. p. on admixture with authentic ester, prepared as below, and the infrared spectra were identical.

2-*Methyl*-1,4-*naphthaquinol* 1-*Acetate* 4-*Toluene*-p-*sulphonate*.—2-Methyl-1,4-naphthaquinol 1-acetate[5] (10·8 g.) in dry pyridine (50 ml.) gave its 4-*toluene*-p-*sulphonate* (14 g.), plates, m. p. 128—130° (from ethanol) (Found, in material dried *in vacuo* at 80°: C, 65·3; H, 5·0. $C_{20}H_{19}O_5S$ requires C, 64·9; H, 4·9%).

2-*Methyl*-1,4-*naphthaquinol* 4-*Toluene*-p-*sulphonate*.—The last-mentioned diester (12·6 g.) was heated in ethanolic 3·9N-hydrogen chloride (50 ml.) for 2 hr. After evaporation *in vacuo* the residual *toluene*-p-*sulphonate* recrystallised from methanol as rods (9·8 g.), m. p. 158—159° (Found, in material dried *in vacuo* at 80°: C, 65·6; H, 4·9. $C_{18}H_{16}O_4S$ requires C, 65·9; H, 4·9%).

2-*Methyl*-1,4-*naphthaquinol* 1-(*Diethyl Phosphate*) 4-*Toluene*-p-*sulphonate*.—2-Methyl-1,4-naphthaquinol 4-toluene-*p*-sulphonate (1 g.) was suspended in dry carbon tetrachloride (12 ml.), and diethyl phosphite (0·42 g.) was added, followed by triethylamine (0·3 g.). The mixture was set aside overnight. Unchanged material and triethylamine hydrochloride were then filtered off and the hydrochloride was extracted with water, leaving 0·53 g. of starting material.

The carbon tetrachloride solution was washed with dilute acid, 2N-sodium hydroxide, and finally three times with water, and evaporated *in vacuo*. The residual *phosphate* crystallised and was dried (yield, 350 mg.; m. p. 76—82°). Two recrystallisations from cyclohexane gave colourless plates (140 mg.), m. p. 92·5—94° (Found, in material dried *in vacuo* at 60°: C, 57·1; H, 5·0; P, 6·9%).

Di-n-propyl, Di-isopropyl, and Di-n-butyl Phosphates of 2-*Methyl*-1,4-*naphthaquinol*.—The details of the preparations were as for the diethyl phosphates above, with the same molar quantities, but the alcohol used was that from which the particular phosphite was derived. In each of these experiments only one pure crystalline compound was isolated but a considerable amount of material remained in the mother-liquors. The *products* are tabulated.

2-Methyl-1,4-naphthaquinol dialkyl phosphate : alkyl group	M. p.	Yield (%)	Found (%)			Formula	Required (%)		
			C	H	P		C	H	P
n-Propyl	111—113°	49	60·7	7·1	9·0	$C_{17}H_{23}O_5P$	60·4	6·9	9·2
Isopropyl	147—150	37	60·3	7·1	9·5	$C_{17}H_{23}O_5P$	60·4	6·9	9·2
n-Butyl	71—73	45	62·2	7·3	8·5	$C_{19}H_{27}O_5P$	62·3	7·4	8·5

2,3-*Dimethyl*-1,4-*naphthaquinol Diethyl Phosphate*.—To 2,3-dimethylnaphthaquinone (1·9 g., 0·01 mole), dissolved in benzene (15 ml.), diethyl phosphite (2·8 g., 0·02 mole) was added followed by a N-solution (2 ml.) of potassium t-butoxide in benzene. The warm mixture was set aside until it had cooled to room temperature and was then evaporated *in vacuo*. The residue separated from cyclohexane as colourless crystals (2·5 g.), m. p. 120—123° (Found, in material dried *in vacuo* at 80°: C, 58·8; H, 6·5; P, 9·3. $C_{16}H_{21}O_5P$ requires C, 59·3; H, 6·5; P, 9·6%).

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