728. *Organic Reactions in Aqueous Solution at Room Temperature. Part III.* The Influence of* pH *on the Self-condensation of Diacetylacetone: Constitution of Collie's Naphthalene Derivative.*

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The influence of pH on the self-condensation of diacetylacetone has been examined, and the two products 7-acetyl-3,8-dihydroxy-3,6-dimethyl-1-tetralone (III) and 2-acetyl-3,6-dimethylnaphthalene-1,8-diol (IV) have been obtained. The constitution of the latter product has been rigorously proved.

COLLIE's polyketide theory [1] of the biogenesis of some aromatic compounds was neglected by chemists for over forty years, with the single exception of Robinson. Now called the polyacetate theory, it has received a great stimulus from the tracer work of Rittenberg,[2]

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* Part II, *J.*, 1961, 5211.

[1] Collie, *Proc. Chem. Soc.*, 1907, **23**, 230; *J.*, 1907, **91**, 1806; see Stewart, "Recent Advances in Organic Chemistry," Longmans, Green, London, 5th edn., 1927, Vol. I, p. 105 *et seq.*; Robinson, "The Structural Relations of Natural Products," Clarendon Press, Oxford, 1955, pp. 7—11, 30, 44.

[2] Rittenberg and Bloch, *J. Biol. Chem.*, 1945, **160**, 417, and later papers.

and especially of Birch.[3] Collie's experimental work[4] on the self-condensation of diacetylacetone involved intermolecular condensation of two polyacetate units rather than the commoner intramolecular type of condensation studied by Birch in many examples (cf., however, musizin[5] and chimaphillin[6]). The structures of Collie's products appeared to us, however, to be inadequately founded,[4,7] so in work completed in 1958[8] we reinvestigated this aspect, choosing this approach particularly because compounds with longer $Me\cdot[CO\cdot CH_2]_n\cdots$ chains appeared relatively inaccessible. Meanwhile, Birch *et al.*[6] have brought certain clarifications into Collie's work.

Collie[4] prepared his condensation products of diacetylacetone by an indirect route, namely, by hydrolysis of dehydracetic acid with hydrochloric acid, precipitation of the barium salt of 2,6-dimethyl-4-pyrone, and treatment of this salt with acid in the cold. An excess of acid gave diacetylacetone but more careful addition, to produce a neutral or just alkaline solution, gave two products, $C_{14}H_{16}O_4$ (m. p. 137—138°; later, without explanation, given as 108—109°), and $C_{14}H_{14}O_3$ (m. p. 183—184°). Collie suggested for these the structures (II*a*) and (IV), formed from two molecules of diacetylacetone by route *a* (cf. I). Birch *et al.*[6] suggested on spectroscopic grounds that the condensation proceeds by route *b* and that there are in fact three products (IIb), m. p. 113°, (III), m. p. 137—138°, and (IV), m. p. 180°.

We found that self-condensation occurs in aqueous solution at room temperature at a suitable pH and our results are given in the Table. Since diacetylacetone dissolved very slowly at the pH's examined, it was dissolved in N-sodium hydroxide and the pH adjusted immediately; no reaction was observed in the short time at which it was at the high pH. From the melting points of our products, it appears that we obtained only compounds (III) and (IV). The tetralone (III) is precipitated in nearly pure state during the first two days within the pH range 6·8—7·9 (finally 8·4), the yield being highest (19·8%) at pH 7·1—7·2. At pH 5·5—5·6, the impure diol (IV) is formed in a total yield of 9·6% during ten days. The pure diol is best obtained after four days, in 4·8% yield, at pH 8·2 rising to 9·0, and in poorer yield and quality from pH 7·1 to 7·9 (finally 8·5). In contrast to our results, Birch *et al.*[6] obtained a benzene derivative (IIb) by neutralising the barium salt of dimethylpyrone with acetic acid to pH 6, the tetralone (III) and a trace of the naphthalenediol (IV) by neutralising the barium salt with hydrochloric acid to pH 7—8, and the diol alone by neutralising the sodium salt to pH 7.

It is obvious from all these results that there is a delicate balance in the formation of all three products depending on pH and the duration of the experiments.

In considering a rigorous proof of the structure of the more stable product (IV), it appeared to us that the many possible formulations based on a naphthalene nucleus might be divided into two types, both naphthalene diols, but one (*a*) containing one methyl and one acetonyl (CH_2Ac) group, the other (*b*) two methyl and one acetyl group.

The ultraviolet spectrum of the compound showed intense absorption over a much wider range than is normally associated with derivatives of naphthalene, though this is also recorded[9] for some substituted 2-hydroxy-1-acetonaphthones; the spectrum of 1-hydroxy-2-acetonaphthone[10] also supports the naphthalenic structure for our compound. Our figures for compound (IV) are in good agreement with those given by Birch *et al.*[6]

In the infrared spectrum, of the two expected hydroxyl bands one was observed as

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[3] *Chem. Soc. Special Publ.* No. 12, 1958, pp. 1 *et seq.*; Birch, *Fortschr. Chem. org. Naturstoffe*, 1957, **14**, 186; ref. 6 and earlier papers; *Proc. Chem. Soc.*, 1962, 3.

[4] (*a*) Collie and Myers, *J.*, 1893, **63**, 122; (*b*) Collie, *J.*, 1893, **63**, 329; (*c*) Collie and Wilsmore, *J.*, 1896, **69**, 293.

[5] Covell, King, and Morgan, *J.*, 1961, 702; cf. dianellidin in Batterham, Cooke, Duewell, and Sparrow, *Austral. J. Chem.*, 1961, **14**, 637.

[6] Birch, Cameron, and Rickards, *J.*, 1960, 4395.

[7] See Elsevier, " Encyclopaedia of Organic Chemistry," 1948, Vol. XIIB, p. 2500.

[8] J. R. Bethell, Thesis, Cambridge, 1958.

[9] Ebnöther, Meijer, and Schmid, *Helv. Chim. Acta*, 1952, **35**, 910.

[10] Cram, *J. Amer. Chem. Soc.*, 1949, **71**, 3955; Bergmann, Hirshberg, and Pinchas, *J.*, 1950, 2355.

7-Acetyl-3,8-dihydroxy-3,6-dimethyl-1-tetralone (III) and 2-acetyl-3,6-dimethylnaphthalene-1,8-diol (IV) from diacetylacetone (2·000 g.) in N-NaOH (25 ml.), followed by N-KH_2PO_4 (50 ml.), adjustment with N-HCl or N-NaOH, and dilution with water to 100 ml., all at room temp. M. p. (III) 137—138° (pure); m. p. (IV) 182—184° (pure).

Initial pH ...	5·6	6·3	6·8	7·2	7·6	7·9	8·2
(A) Product collected after 2 days:							
Final pH ...	5·5	6·2	6·7	7·1	7·7	8·4	8·8
Yield (g.) ...	Trace	0·166	0·280	0·395	0·355	0·200	Trace
Yield (%) ...	Trace	8·3	14·0	19·8	17·8	10·0	Trace
M. p.	—	128—131°	← 134—136° →				
(B) Product collected after a further 2 days:							
Final pH ...	5·5	6·2	6·6	7·1	7·7	8·5	9·0
Yield (g.) ...	0·024	0·118	0·085	0·053	0·044	0·050	0·089
Yield (%) ...	1·3	5·9	4·2	2·9	2·4	2·7	4·8
M. p.	175—180°	133—137°	130—170°	170—180°	178—181°	180—184°	182—184°
(C) Product collected after a further 6 days:							
Final pH ...	5·5	6·2	6·6	7·1	7·7	8·5	9·0
Yield (g.) ...	0·153	0·119	0·081 *	0·068 *	†	†	†
Yield (%) ...	8·3	6·4	4·4	3·7	—	—	—
M. p.	← 165—175° →		← 172—177° →		—	—	—

* Dark brown. † Indefinite, discarded.

a not very intense band at 3270 cm.$^{-1}$ and the other could not be detected, presumably because it was very weak and broad as is usual for a chelated hydroxyl group. A strong carbonyl band at 1636 cm.$^{-1}$ may be compared with values of 1680—1700 cm.$^{-1}$ for a normal ketonic group in conjugation with an aromatic ring and of 1635 cm.$^{-1}$ for acetyl with an *o*-hydroxyl group[11] (1-hydroxy-2-acetonaphthone absorbs at 1625 cm.$^{-1}$). This evidence, for a keto-group in conjugation with an aromatic ring and an *o*-hydroxyl group (chelated) rules out formulæ of type (*a*) because these would contain an unconjugated carbonyl group.

The nuclear magnetic resonance spectrum of compound (IV) in chloroform indicated three methyl groups: two of these resonances (τ 7·60, 7·38), being rather broader than the third (7·28), were probably due to the two ring-methyl groups, and the third due to the methyl of the acetyl group. A band at τ 7·45 was thought to be due to a chelated hydroxyl group: a similar band was found at —4·02 for 1-hydroxy-2-acetonaphthone. A band at —0·25 was thought to be due to the other hydroxyl group.

In addition to (IV), there are six other possible structures of type (*b*), only two of which can be ruled out on the spectroscopic evidence, since they do not possess a hydroxy-group *ortho* to acetyl. Of the remaining five, only one, namely, (IV), has 1,8-hydroxyl groups. Little is known regarding the formation of methylene ethers from naphthalene-1,8-diols, but Carnero and Calvert[12] report that 1,8-methylenedioxynaphthalene itself may be obtained by use of methylene sulphate. We used methylene dibromide and potassium carbonate in acetone and on long refluxing obtained the methylene ether (V). The infrared spectrum of this showed no hydroxyl absorption, and a very strong band at 1677 cm.$^{-1}$, indicating a carbonyl group conjugated to an aromatic ring. As it is not possible to have two *o*-hydroxyl groups in the structure, owing to derivation from diacetylacetone, this gives good evidence for the *peri*-orientation, and therefore supports structure (IV).

Compound (IV), as well as its mono- and di-methyl ether, failed to give pure derivatives with hydroxylamine or with phenyl- or 2,4-dinitrophenyl-hydrazine, probably owing to

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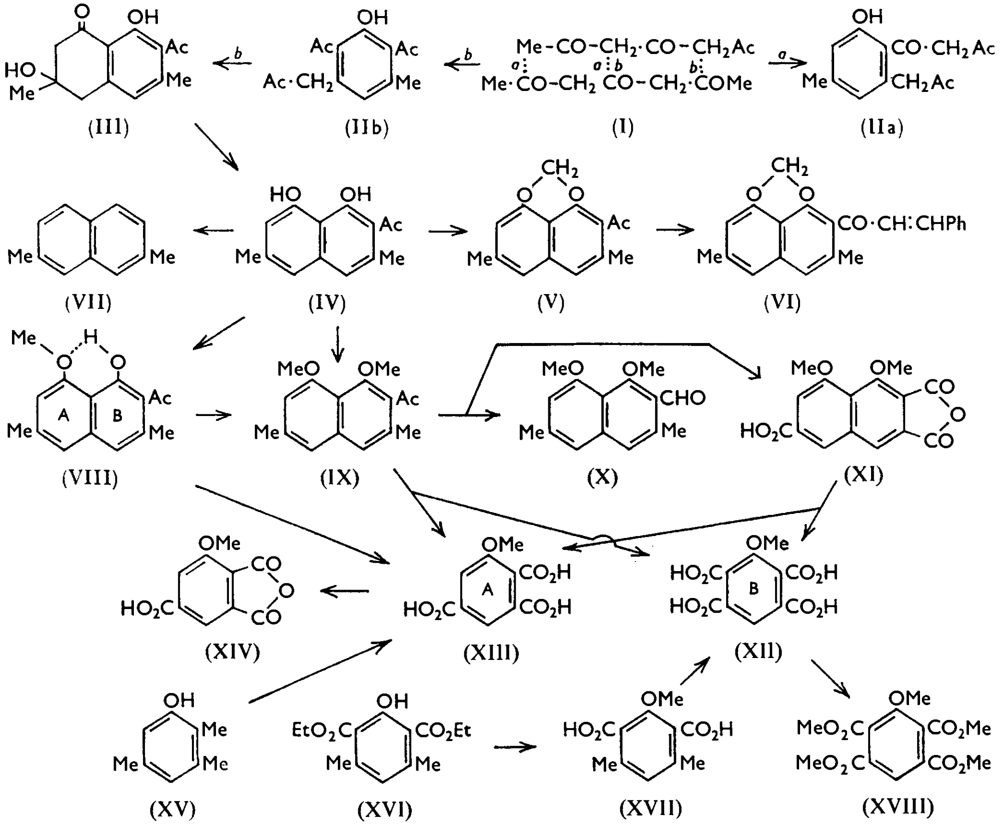
[11] Bellamy, "The Infra-red Spectra of Complex Molecules," 2nd edn., Methuen, London, 1958, p. 143.

[12] Carnero and Calvet, *Anales real Soc. españ. Fís. Quím.*, 1934, **32**, 1157.

hydrogen bonding or for steric reasons. The same applied to the methylene ether (V) which we thought would be less sterically hindered and cannot form hydrogen bonds.

No pure product could be obtained from compound (IV) or its monomethyl (VIII) or dimethyl ether (IX) by the haloform reaction in aqueous or aqueous-dioxan solution. When the dimethyl ether in acetic acid was treated with three molecules of bromine, a tribromo-derivative (IV; CO·CBr$_3$ replacing COMe) was formed; its nuclear magnetic resonance spectrum in chloroform showed that the three ring-hydrogen atoms were still present. Attempted hydrolysis of this compound under various conditions to the acid was unsuccessful.

The presence of the acetyl group was supported by the preparation of the benzylidene derivative (VI) of the methylene ether (V).



On repeating Collie's distillation of compound (IV) with zinc dust, we obtained a dimethylnaphthalene, probably the 2,7-isomer.[13]

The spectrum of the ether (VIII) had the strongest band at 1693 (non-chelated CO), a strong band at 1633 (chelated CO, or high aromatic band as usually associated with a naphthalene nucleus), and a medium band at 3345 cm.$^{-1}$ (non-chelated OH). This suggests interchange of the hydroxyl and the methoxyl group in structure (VIII), because in the latter we should have expected a strong hydrogen bond between the 1-hydroxyl group and the 2-acetyl group to be easily detectable in the infrared spectrum, as for the parent diol (IV); but, as will be seen later, on chemical grounds it must have the structure (VIII). The dimethyl ether (IX) has a normal carbonyl band at 1694 cm.$^{-1}$ and no hydroxyl

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[13] Rodd, " Chemistry of Carbon Compounds," Elsevier, Amsterdam, Vol. IIIB, p. 1287.

absorption. An analogy for our mono-ether (VIII) is the 8-methyl ether of musizin,[5] which has the constitution (IV) minus the 6-methyl group: musizin itself has a strong band at 1630 cm.$^{-1}$ (conjugated, chelated carbonyl), and the 1-methyl ether a strong band at 1694 cm.$^{-1}$ (conjugated, unchelated carbonyl), but the 8-methyl ether unexpectedly had a strong band only at 1686 cm.$^{-1}$; Covell *et al.*[5] suggest hydrogen-bonding between the 1-hydroxyl group and the 8-ether-oxygen atom, as indicated in our formula (VIII).

The nuclear magnetic spectrum of the mono-ether (VIII) showed a methoxyl group at $\tau = 6{\cdot}00$ and a hydroxyl group at $\tau = 0{\cdot}25$. In the simpler compound 1-hydroxy-2-acetonaphthone, where the hydroxyl group must be chelated with the carbonyl group, the hydroxyl value is $-4{\cdot}02$.

When the monomethyl ether (VIII) was oxidised with alkaline permanganate, a methoxybenzenetricarboxylic acid was obtained which on sublimation gave an anhydride; both the acid and its anhydride melted at 264—266°. The m. p. of 6-methoxytrimellitic acid (XIII) has been variously reported as 230°, 251°, and 258°. We synthesised this acid from 2,3,5-trimethylphenol (XV) by methylation and oxidation. It was found to melt at 264—266° and to be identical with our oxidation product.

In contrast to the monomethyl ether (VIII) the dimethyl ether (IX), on oxidation with alkaline permanganate, gave a mixture of 6-methoxytrimellitic acid (XIII) with a larger amount of what we assumed to be 3-methoxypyromellitic acid (XII). We synthesised the latter from the ester (XVI) [14] by methylation, hydrolysis, and oxidation. Since the tetracarboxylic acid (XII) and its dianhydride did not have sharp m. p.s., the specimens from both sources were converted by diazomethane into the tetramethyl esters (XVIII) which proved to be identical.

Less vigorous oxidation of the dimethyl ether, by prolonged treatment with alkaline ferricyanide at 60°, produced two compounds, each containing both rings intact. One was the aldehyde (X), probably produced by the route $\mathrm{R{\cdot}COMe} \longrightarrow \mathrm{R{\cdot}CO{\cdot}CO_2H} \longrightarrow \mathrm{R{\cdot}CHO} + \mathrm{CO_2}$. The second compound was a tricarboxylic acid, best isolated as its anhydride, which must have the structure (XI) because it was readily oxidised by alkaline permanganate to acids (XIII) and (XII).

Thus, mainly on chemical grounds but with fully supporting physical evidence, the structure of Collie's compound (IV) is proved conclusively.

EXPERIMENTAL

Diacetylacetone (I).—Dehydracetic acid (100 g.) and concentrated hydrochloric acid (500 ml.) were boiled until the evolution of carbon dioxide ceased (about ½ hr.). The solution was then evaporated under reduced pressure, leaving a semi-solid mass that was dissolved in 10% sodium hydroxide solution. A solution of barium hydroxide (240 g.) in boiling water was added and the yellow precipitate of barium dimethylpyrone was collected and at once dissolved in an excess of 15% hydrochloric acid. This acid solution was extracted with ether, evaporation of which gave an oil which was distilled, to give diacetylacetone (53 g.), b. p. 96—97°/7—8 mm., m. p. 49°.

7-*Acetyl*-3,8-*dihydroxy*-3,6-*dimethyl*-1-*tetralone* (III).—The preparation of diacetylacetone was followed as far as the formation of barium dimethylpyrone. This was made into a paste with water and carefully neutralised with 15% hydrochloric acid until the solid had almost completely dissolved. The neutral solution was filtered; pale yellow crystals of the tetralone, m. p. 135—138°, were gradually deposited, that, recrystallised from aqueous acetic acid, had m. p. 137—138° (Found: C, 67·4; H, 6·5. Calc. for $C_{14}H_{16}O_4$: C, 67·7; H, 6·5%).

2-*Acetyl*-3,6-*dimethylnaphthalene*-1,8-*diol* (IV).—(*a*) 7-Acetyl-3,8-dihydroxy-3,6-dimethyl-1 tetralone (III) (0·1 g.) was boiled for a few minutes with glacial acetic acid. On cooling, needles of the diol, m. p. 182—184° were deposited [Found: C, 73·2; H, 6·3%; *M* (Rast), 232. Calc. for $C_{14}H_{14}O_3$: C, 73·0; H, 6·1%; *M*, 230], $\lambda_{\max.}$ (in EtOH) 228, 264, 307, 321, 357 mμ (log ε 4·57, 4·32, 3·61, 3·56, 3·66), $\nu_{\max.}$ (in Nujol) 3270, 1636s, 1600(sh), 1583s cm.$^{-1}$.

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[14] Prelog, Metzler, and Jeger, *Helv. Chim. Acta*, 1947, **30**, 675; Bethell and Maitland, Part II, *J.*, 1961, 5211.

(*b*) For larger quantities,[15] diacetylacetone (30 g.) and a few drops of piperidine were heated on a boiling-water bath. Piperidine (3—4 drops) was added every half hour. After 3 hr. the semi-solid mass was dissolved in boiling glacial acetic acid. On cooling, the diol (13 g.) separated as bright yellow needles, m. p. 182—184°. The diacetyl derivative [4b] was prepared by heating the diol (5·0 g.) with acetic anhydride (20 ml.) and a few drops of pyridine for 3 hr.; it formed colourless crystals (5·2 g.), m. p. 167—169°, from ethanol.

2-*Acetyl*-3,6-*dimethyl*-1,8-*methylenedioxynaphthalene* (V).—The diol (IV) (2·0 g.) was refluxed with methylene dibromide (5·0 g.), potassium carbonate (4·0 g.), and acetone (150 ml.). Methylene dibromide (5·0 g.) was added after 12 hr. and refluxing continued for a further 53 hr. Most of the acetone was removed, water added to dissolve the inorganic material, and the mixture extracted with ether (250 ml. total). The ether extract was washed with 10% sodium hydroxide solution, then with water, dried, and evaporated to give an oil which readily crystallised. Recrystallisation from ethanol gave the pale yellow *methylene ether* (0·65 g.), m. p. 123—124°, raised to 124—125° on sublimation at 110°/2 × 10^{-2} mm. [Found: C, 74·4; H, 5·7%; *M* (Rast), 254. $C_{15}H_{14}O_3$ requires C, 74·4; H, 5·8%; *M*, 242], $\nu_{max.}$ (in Nujol) 1677vs, 1668sh, 1644s, 1610s, 1589s $cm.^{-1}$.

2-*Cinnamoyl*-3,6-*dimethyl*-1,8-*methylenedioxynaphthalene* (VI).—The above methylene ether (V) (250 mg.) was warmed with freshly distilled benzaldehyde (1·0 g.) and ethanol (2 ml.). When dissolution was complete, 30% aqueous sodium hydroxide (6 drops) was added and the mixture kept at 100° until it solidified. The solid was triturated with a small quantity of water, filtered, and recrystallised from ethanol, giving the pale yellow *benzylidene derivative* (245 mg.), m. p. 129—130° (Found: C, 79·6; H, 5·5. $C_{22}H_{18}O_3$ requires C, 80·0; H, 5·5%).

Zinc-duct Distillation of 2-*Acetyl*-3,6-*dimethylnaphthalene*-1,8-*diol* (IV).—The diol (2·5 g.) was heated with zinc dust (14 g.). The vapour evolved condensed to a dark oil from which a small quantity of wax sublimed at 100°/14 mm. This was resublimed to give, probably, 2,7-dimethylnaphthalene (14 mg.), m. p. 89—90°, mixed m. p. 94—96° (Found: C, 92·4; H, 8·0. Calc. for $C_{12}H_{12}$: C, 92·3; H, 7·7%).

2-*Acetyl*-8-*methoxy*-3,6-*dimethyl*-1-*naphthol* (VIII).—Dimethyl sulphate (40 g.) was added in 2 hr. to the 1,8-diol (IV) (5·0 g.) in 5% potassium hydroxide solution (50 ml.) at 80°. Whenever the mixture became acid, as shown by the appearance of a flocculent yellow precipitate, sufficient 20% potassium hydroxide solution was added to re-dissolve the precipitate. The mixture was then extracted with ether (250 ml.), and the extract washed with 20% potassium hydroxide solution until no yellow precipitate was obtained on acidification of the aqueous layer. The ethereal solution was then washed with water, dried, and evaporated to a residue which on recrystallisation from light petroleum (80 ml.; b. p. 60—80°) gave the crude *monomethyl ether*. Further recrystallisation (charcoal) gave colourless needles (1·2 g.), m. p. 133—134°, unexpectedly virtually insoluble in alkali (Found: C, 73·8; H, 6·5. $C_{15}H_{16}O_3$ requires C, 73·8; H, 6·6%). The dimethyl ether remained in the mother-liquors. The *monoacetyl derivative* was prepared by heating the ether (VIII) (1·0 g.) with acetic anhydride (5 ml.) and a few drops of pyridine for 2½ hr., forming colourless crystals (0·9 g.), m. p. 86—88°, from 50% aqueous ethanol (Found: C, 71·3; H, 6·3. $C_{17}H_{18}O_4$ requires C, 71·3; H, 6·3%).

2-*Acetyl*-1,8-*dimethoxy*-3,6-*dimethylnaphthalene* (IX).—The diol (IV) (5·0 g.) was refluxed with potassium carbonate (20 g.), methyl iodide (40 g.), and acetone (100 ml.). After 2 days methyl iodide (20 g.) was added and refluxing continued for a further 2 days. Most of the acetone and the excess of methyl iodide were removed, water was added, and the mixture extracted with ether (250 ml. total). The ether extract was washed with 5% potassium hydroxide solution, then with water, dried, and evaporated to give an oil which readily crystallised. Two recrystallisations from ethanol gave the *dimethyl ether* (2·4 g.), m. p. 99—101°, raised to 101—102° on sublimation at 95°/5 × 10^{-3} mm. (Found: C, 74·3; H, 7·3. $C_{16}H_{18}O_3$ requires C, 74·4; H, 7·0%).

1,8-*Dimethoxy*-3,6-*dimethyl*-2-*tribromoacetylnaphthalene*.—Bromine (930 mg.) in acetic acid (6 ml.) was added dropwise, with stirring, to 2-acetyl-1,8-dimethoxy-3,6-dimethylnaphthalene (IX) (500 mg.) in acetic acid (7 ml.). Then the mixture was heated on a boiling-water bath for 15 min. On cooling, the *tribromo-derivative* (220 mg.) was deposited; it had m. p. 161—168° raised by two recrystallisations from ethanol to 172—174° (Found: C, 38·6; H, 3·4. $C_{16}H_{15}Br_3O_3$ requires C, 38·8; H, 3·1%), τ 1·98, 3·17, 3·30 (all aromatic C–H) 5·95; 6·17 (MeO) 7·32, 7·42 (*C*-Me).

[15] See Collie and Reilly, *J.*, 1922, **121**, 1984; Kaushal, *J. Indian Chem. Soc.*, 1946, **23**, 16.

6-*Methoxytrimellitic Acid* (XIII).—2,3,5-Trimethylanisole [16] (1·5 g.) was refluxed for 4 hr. with potassium permanganate (10 g.) and sodium carbonate (5 g.) in water (200 ml.). After cooling, the mixture was acidified with concentrated hydrochloric acid and treated with 20% sodium sulphite solution until colourless. The solution was continuously extracted with ether, giving, after removal of the ether, a slightly discoloured residue, which was triturated with ether (10 ml.) and collected (480 mg.). Recrystallisation from water gave 6-methoxytrimellitic acid, m. p. 264—266° (Found: C, 50·3; H, 3·4. Calc. for $C_{10}H_8O_7$: C, 50·0; H, 3·4%). Sublimation at 200°/1 × 10^{-3} mm. gave the anhydride (XIV), m. p. 264—266° (Found: C, 54·3; H, 2·9. Calc. for $C_{10}H_6O_6$: C, 54·1; H, 2·7%).

Diethyl 2-*Methoxy*-4,6-*dimethylisophthalate*.—Diethyl 2-hydroxy-4,6-dimethylisophthalate [14] (XVI) (20 g.) was refluxed with potassium carbonate (20 g.) and methyl iodide (40 g.) in acetone (100 ml.) for 6 hr., then cooled, water was added to dissolve the inorganic material, and the whole was extracted with ether. The extract was washed with 5% sodium hydroxide solution, then with water, and dried (Na_2SO_4). Removal of the ether gave an oil which was distilled, to give the *methyl ether* (16·5 g.), b. p. 160°/1 mm. (Found: C, 64·0; H, 7·5. $C_{15}H_{20}O_5$ requires C, 64·3; H, 7·2%).

2-*Methoxy*-4,6-*dimethylisophthalic Acid* (XVII).—The above methyl ether (11·0 g.) was refluxed with sodium hydroxide (22 g.) in 50% ethanol (220 ml.) for 9 hr. The mixture was then distilled until 130 ml. of distillate had been collected. Water (50 ml.) was added and the solution acidified with hydrochloric acid; the *acid* (8·0 g.) was precipitated as needles, having m. p. 245—246° which was not raised by recrystallisation from water or by sublimation (Found: C, 58·9; H, 5·5. $C_{11}H_{12}O_5$ requires C, 58·9; H, 5·4%).

3-*Methoxypyromellitic acid* (XII).—2-Methoxy-4,6-dimethylisophthalic acid (XVII) (5·0 g.) was refluxed with potassium permanganate (15·5 g.) and sodium carbonate (8·0 g.) in water (300 ml.) for 4½ hr. The mixture was then cooled, acidified with concentrated hydrochloric acid, treated with 20% sodium sulphite solution until colourless, and continuously extracted with ether, yielding 3-*methoxypyromellitic acid* (5·0 g.). When recrystallised from water with, possibly, slight decomposition, this had m. p. 237—240° (decomp.) (Found: C, 46·8; H, 3·3%; equiv., 69. $C_{11}H_8O_9$ requires C, 46·5; H, 2·8%; equiv., 71). On sublimation at 200°/2 × 10^{-2} mm. the *dianhydride*, m. p. 236—238° (decomp.), was formed (Found: C, 53·5; H, 1·4. $C_{11}H_4O_7$ requires C, 53·2; H, 1·6%).

Tetramethyl 3-*Methoxypyromellitate* (XVIII).—3-Methoxypyromellitic acid (XII) (2·0 g.) in methanol (25 ml.) was treated with ethereal diazomethane until the yellow colour was permanent. After 2 hr. evaporation gave the *tetramethyl ester* (1·9 g.), m. p. 108—109° (from ethanol) (Found: C, 53·0; H, 4·8. $C_{15}H_{16}O_9$ requires C, 52·9; H, 4·7%).

Oxidation of 2-*Acetyl*-8-*methoxy*-3,6-*dimethyl*-1-*naphthol* (VIII).—The monomethyl ether (VIII) (500 mg.) was refluxed for 4 hr. with potassium permanganate (5·0 g.) and sodium carbonate (2·5 g.) in water (100 ml.). The mixture was then cooled, acidified with concentrated hydrochloric acid, and treated with 20% sodium sulphite solution until colourless. The solution was continuously extracted with ether to give, after removal of the ether, an almost colourless product (225 mg.) that, after recrystallisation from water, was identical (m. p. and mixed m. p.) with 6-methoxytrimellitic acid (XIII) and gave the anhydride upon sublimation.

Oxidation of 2-*Acetyl*-1,8-*dimethoxy*-3,6-*dimethylnaphthalene* (IX).—(*a*) *With potassium permanganate*. A suspension of the dimethyl ether (IX) (2·0 g.) in water (50 ml.) containing sodium hydroxide (5·0 g.) was refluxed while 5% potassium permanganate solution was added in small portions until the colour was permanent (~300 ml.). The mixture was worked up as above, giving a colourless product m. p. 210—230° (decomp.) (650 mg.). Recrystallisation from water gave a small quantity of 6-methoxytrimellitic acid (XIII), m. p. 250—263° (mixed with authentic acid, m. p. 255—263°). The filtrate was concentrated and gave 3-methoxypyromellitic acid (XII), m. p. 225—233° (decomp.) [mixed with authentic acid, m. p. 230—240° (decomp.); the dianhydride was obtained on sublimation]. The identity of the second acid was further confirmed by conversion into the tetramethyl ester, m. p. and mixed m. p. 108—109°, with diazomethane by the procedure given above for 3-methoxypyromellitic ester.

(*b*) *With potassium ferricyanide*. A suspension of the dimethyl ether (IX) (1·0 g.) in a solution of potassium ferricyanide (100 g.) and potassium hydroxide (15 g.) in water (300 ml.) was heated at 60°. More potassium ferricyanide (20 g.) and potassium hydroxide (3 g.) were

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[16] Auwers and Borsche, *Ber.*, 1915, **48**, 1723.

added after 2 days and again after 4 days. After a week the mixture was extracted with ether, yielding a pale yellow product (200 mg.). This recrystallised from ethanol, giving 1,8-*dimethoxy-*3,6-*dimethyl*-2-*naphthaldehyde* (X), m. p. 122—124° (Found: C, 73·8; H, 6·3. $C_{15}H_{16}O_3$ requires C, 73·8; H, 6·6%).

The alkaline aqueous solution, after the ether-extraction, was acidified with dilute sulphuric acid and continuously extracted with ether, giving a pale brown *acid* (210 mg.), m. p. 285—286°. Precipitation by acid from a solution of the sodium salt gave a paler product, m. p. 290—291° (Found: equiv., 102. A dimethoxynaphthalenetricarboxylic acid requires equiv., 107). Sublimation at $250°/1 \times 10^{-2}$ mm. gave 1,8-*dimethoxynaphthalene*-2,3,6-*tricarboxylic acid* 2,3-*anhydride* (XI), m. p. 290—291° (Found: C, 59·1; H, 3·2. $C_{15}H_{10}O_7$ requires C, 59·6; H, 3·3%).

Oxidation of 1,8-*Dimethoxynaphthalene*-2,3,6-*tricarboxylic Acid.*—The crude acid (200 mg.) was refluxed with sodium hydroxide (800 mg.) in water (25 ml.) while 5% potassium permanganate solution was added in small portions (14·7 ml., approx. theor.) until an excess was present. The mixture was then cooled, acidified with concentrated hydrochloric acid, and treated with 20% sodium sulphite solution until colourless. The solution was continuously extracted with ether, yielding a colourless product (126 mg.). Recrystallisation from water gave 6-methoxytrimellitic acid (XIII), m. p. 259—260° (mixed m. p. 263—264°); 3-methoxypyromellitic acid (XII), m. p. 225—235° (mixed m. p. 230—238°), was obtained from the filtrate.

Infrared Spectra.—These were obtained with a Perkin–Elmer model 21 infrared spectrometer with a rock-salt prism.

Ultraviolet Spectra.—A Cary model 14 recording spectrophotometer was used.

Nuclear Magnetic Resonance Spectra.—These were obtained at 40 Mc./sec. by using a Varian Associates V4300B spectrometer and 12″ electromagnet with flux stabilisation and sample spinning. Positions of references are quoted as chemical shifts on the τ scale [τ ($SiMe_4$) $= 10{\cdot}00$] and have been measured against the solvent resonances ($CHCl_3$, $\tau = 2{\cdot}75$; C_6H_{12}, $\tau = 8{\cdot}56$); side bands generated by a Muirhead-Wigan D695A decade oscillator were used.

We are indebted to Dr. N. Sheppard for assistance in determining and interpreting the spectra. One of us (J. R. B.) thanks the Department of Scientific and Industrial Research for a maintenance grant.

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[*Received, February* 16*th*, 1962.]