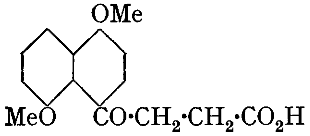
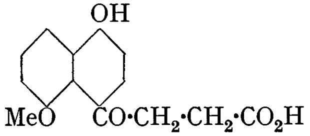
191. *Syntheses in the Phenanthrene Series. Part VII.* 5 : 9-*Dimethoxy- and* 5-*Methoxy*-1-*methylphenanthrene.*

By Peter Hill, W. F. Short, and H. Stromberg.

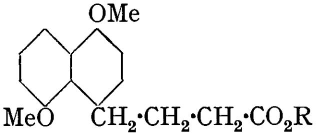
Condensation of 1 : 5-dimethoxynaphthalene with succinic anhydride in presence of aluminium chloride furnished an acid, $C_{16}H_{16}O_5$, m. p. 173·5—174°, which must be β-(4 : 8-*dimethoxy*-1-*naphthoyl*)*propionic acid* (I), since it was also obtained from succinic anhydride and the Grignard compound of 4-bromo-1 : 5-dimethoxynaphthalene (see below). In tetrachloroethane solution a smooth reaction occurred at 70° and gave an 80% yield of an *acid*, $C_{15}H_{14}O_5$, m. p. 184°. This acid afforded (I) in excellent yield on methylation and, owing to its yellow colour, we ascribe to it formula (II). Reduction of the keto-acid (I) presented considerable difficulty owing to the ease with which the side chain was removed from the molecule (compare Hill and Short, J., 1935, 1123). By using an active zinc amalgam, esterifying the product, and separating 1 : 5-dimethoxynaphthalene by distillation, a 20% yield of *methyl* γ-(4 : 8-*dimethoxy*-1-*naphthyl*)*butyrate* (III; R = Me) was obtained.



(I.)

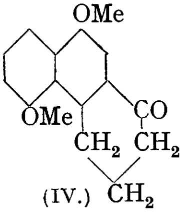


(II.)



(III.)

Dehydration of the *acid* (III; R = H) was effected with phosphoric oxide and the resulting 1-*keto*-5 : 9-*dimethoxy*-1 : 2 : 3 : 4-*tetrahydrophenanthrene* (IV) afforded 5 : 9-*dimethoxy*-1-*methyl*-3 : 4-*dihydrophenanthrene* on treatment with methylmagnesium iodide. Dehydrogenation with palladium–charcoal furnished 5 : 9-*dimethoxy*-1-*methylphenanthrene* (V), m. p. 139—140°. Oxidation of (V) under a variety of conditions produced red amorphous substances and no 5-methoxy-1-methylphenanthra-9 : 10-quinone could be isolated.



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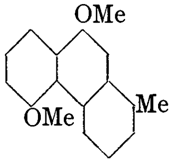
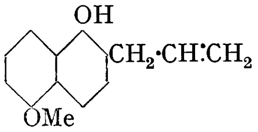
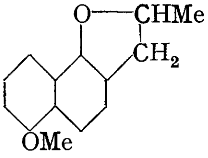


(V.)

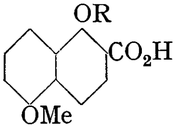


(VI.)

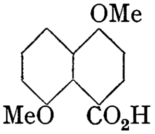
In order to establish the formula of the keto-acid (I), 5-methoxy-1-naphthol was first converted into its *allyl* ether and rearranged to 5-*methoxy*-2-*allyl*-1-*naphthol* (VI), the structure of which was determined by conversion into the *coumaran* derivative (VII). The naphthol (VI) was cryptophenolic, but could be methylated in Claisen's potash. Oxidation of the methyl ether afforded 1 : 5-*dimethoxy*-2-*naphthoic acid* (VIII; R = Me). 1-*Hydroxy*-5-*methoxy*-2-*naphthoic acid* (VIII; R = H) was obtained in excellent yield from 5-methoxy-1-naphthol by the Kolbe reaction. The hydroxyl group of this acid resisted methylation, and an excess of diazomethane produced a mixture of the *methyl* esters of 1-hydroxy-5-methoxy- and 1 : 5-dimethoxy-2-naphthoic acid.



(VII.)



(VIII.)

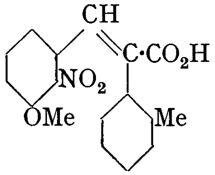


(IX.)

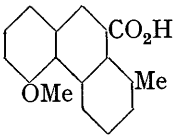
The orientation of 1 : 5-dimethoxy-2-naphthoic acid establishes the formula of the bromo-1 : 5-dimethoxynaphthalene prepared by Fischer and Bauer (*J. pr. Chem.*, 1916, **94**, 15), since carbonation of its Grignard reagent afforded the isomeric 4 : 8-*dimethoxy*-1-*naphthoic acid* (IX). The formulæ assigned to the isomeric aldehydes produced by the application of the Gattermann reaction to 1 : 5-dihydroxynaphthalene (Gattermann, *Annalen*, 1907, **357**, 341; Morgan and Vining, J., 1921, **119**, 177) and by the hydrolysis of 5-hydroxy-1-keto-2-indoxyl-1 : 2-dihydronaphthalene (Bezdzik and Friedländer, *Monatsh.*, 1909, **30**, 286) are based on their physical properties and on the assumption that a derivative of α-naphthol would undergo substitution in position 4 in the Gattermann synthesis. Oxidation of the *methyl* ethers of these aldehydes gave the acids (IX) and (VIII) respectively, so that the structures assigned to them by the earlier workers are confirmed.

For the synthesis of 5-*methoxy*-1-*methylphenanthrene*, *o*-allyltoluene (Hurd and Bollman, *J. Amer. Chem. Soc.*, 1934, **56**, 447) was oxidised to *o*-tolylacetic acid by the method described in Part IV (this vol., p. 260), and the potassium salt of this acid condensed with 2-nitro-3-methoxybenzaldehyde (Rieche, *Ber.*, 1889, **22**, 2349). The resulting 2-*nitro*-3-*methoxy*-α-o-*tolylcinnamic acid* (X) was reduced to the *amino-acid* and converted into 5-*methoxy*-1-*methylphenanthrene*-10-*carboxylic acid* (XI) by diazotisation and warming with alkali. The acid (XI) was decarboxylated by heating with quinoline and copper powder.

(X.)



(XI.)



EXPERIMENTAL.

β-(4 : 8-*Dimethoxy*-1-*naphthoyl*)*propionic Acid* (I).—(1) Powdered succinic anhydride (44 g.) and 1 : 5-dimethoxynaphthalene (Bentley, Robinson, and Weizmann, J., 1907, **91**, 106) (83 g.) were added with shaking to an ice-cold solution of aluminium chloride (118 g.) in nitrobenzene (360 c.c.). The mixture was slowly warmed to room temperature with stirring and then kept for 190 hours. The *keto-acid*, isolated in the usual way (85% yield), separated from methyl alcohol in small rods, m. p. 173·5—174° (Found : C, 66·4; H, 5·7. $C_{16}H_{16}O_5$ requires C, 66·7; H, 5·6%). The *methyl* ester separated from methyl alcohol in leaflets, m. p. 91—92° (Found : C, 67·6; H, 6·1. $C_{17}H_{18}O_5$ requires C, 67·6; H, 5·9%). Nitrobenzene is an unsuitable solvent for the preparation of large quantities of this acid, since an uncontrollable oxidation is liable to occur. When the condensation was effected in boiling carbon disulphide, a 21% yield of the keto-acid was obtained in 9 hours. (2) A Grignard solution prepared from 4-bromo-1 : 5-dimethoxynaphthalene (1 mol.), magnesium (1 atom), and ether (5 mols.) was added during ¾ hour to a boiling suspension of finely powdered succinic anhydride (1 mol.) in ether (17 mols.) and after boiling for 2 hours the yellow complex was decomposed with ice-cold, dilute sulphuric acid. The acid was extracted from the solvent with dilute sodium carbonate solution and purified by crystallisation from methyl alcohol; m. p. 173—174° (yield, 25%). Esterification with methyl-alcoholic hydrogen chloride afforded the methyl ester, m. p. and mixed m. p. 91—92°.

β-(4-*Hydroxy*-8-*methoxy*-1-*naphthoyl*)*propionic Acid*.—Powdered aluminium chloride (2·7 mols.) was added in portions to succinic anhydride (1 mol.), 1 : 5-dimethoxynaphthalene (1 mol.), and tetrachloroethane (10 mols.) at 40°, and the mixture slowly warmed to 74° (4 hours). The *keto-acid*, isolated in the usual way, crystallised from methyl alcohol in long yellow plates, m. p. 184° (decomp.) (Found : C, 65·75; H, 5·25. $C_{15}H_{14}O_5$ requires C, 65·7; H, 5·1%). Methylation in 3*N*-sodium hydroxide (2·5 mols.) with methyl sulphate (1·5 mols.) at 35—60° afforded β-(4 : 8-dimethoxy-1-naphthoyl)propionic acid in quantitative yield.

γ-(4 : 8-*Dimethoxy*-1-*naphthyl*)*butyric Acid*.—The keto-acid (I) was not reduced by prolonged boiling with zinc or copper–zinc in presence of aqueous sodium hydroxide and ammonia, and after numerous trials the following method was devised. 460 G. of zinc dust were amalgamated (2—3 minutes) with 400 c.c. of 5% mercuric chloride solution, the liquid decanted, and a hot solution of the keto-acid (100 g.) in acetic acid (800 c.c.) added to the amalgam. The mixture was boiled and 600 c.c. of concentrated hydrochloric acid were added during 7—10 minutes, and the mixture boiled for 1 hour. After most of the acetic acid had been removed in steam, the liquid was filtered, and the organic material separated from the excess of zinc by extraction with ether. The solution was dried and evaporated, and the residue dissolved in concentrated methyl-alcoholic hydrogen chloride (600 c.c.). After boiling for 2 hours the crude ester was collected in the usual way and distilled. Fraction (1), b. p. up to 216°/0·8 mm., consisted of 1 : 5-dimethoxynaphthalene; fraction (2), b. p. 216—225°/0·8 mm., solidified on cooling, and there was a considerable resinous residue. Crystallisation of fraction (2) from ice-cold methyl alcohol or light petroleum (b. p. 40—60°) furnished *methyl* γ-(4 : 8-*dimethoxy*-1-*naphthyl*)*butyrate* in glistening plates, m. p. 67—67·5° (Found : C, 70·9; H, 7·05. $C_{17}H_{20}O_4$ requires C, 70·8; H, 6·9%). Saponification with alcoholic potash gave the *acid* (III), which crystallised from acetic acid in rounded hexagons, m. p. 154° (Found: C, 69·9; H, 6·6. $C_{16}H_{18}O_4$ requires C, 70·1; H, 6·6%). The overall yield was 20%.

1-*Keto*-5 : 9-*dimethoxy*-1 : 2 : 3 : 4-*tetrahydrophenanthrene*.—Phosphoric oxide (15 g.) was added in portions with shaking to a boiling solution of the acid (III) (3 g.) in benzene (50 c.c.), and the mixture was boiled for 3 hours, decomposed with ice, and repeatedly extracted with ether. The solvent layer was washed with dilute sodium carbonate solution to remove unchanged acid (0·9 g.), dried, and evaporated. Crystallisation of the residue from alcohol (charcoal) gave the cyclic *ketone* (1·9 g.) in long, colourless plates, m. p. 124° (Found : C, 75·0; H, 6·3. $C_{16}H_{16}O_3$ requires C, 75·0; H, 6·2%). The 2 : 4-*dinitrophenylhydrazone* was a crimson microcrystalline powder, m. p. 295° (decomp.) (Found : N, 12·9. $C_{22}H_{20}O_6N_4$ requires N, 12·8%).

5 : 9-*Dimethoxy*-1-*methyl*-3 : 4-*dihydrophenanthrene*.—A solution of the preceding cyclic ketone (4·6 g.) in dry benzene (50 c.c.) was added to an ice-cold solution of methylmagnesium iodide (from methyl iodide, 1·8 c.c., magnesium, 0·65 g., and ether, 20 c.c.), and the mixture boiled for 1 hour. The complex was decomposed in the usual way, and the product distilled. The main fraction (3·4 g.), b. p. 220—230°/0·9 mm., consisted of the unsaturated compound with a little unchanged ketone, and a fraction (0·7 g.) of higher b. p. of unchanged ketone. The mixture was separated by crystallisation from absolute alcohol, 5 : 9-*dimethoxy*-1-*methyl*-3 : 4-*dihydrophenanthrene* being obtained in colourless plates, m. p. 111—111·5° (Found : C, 80·0; H, 6·75. $C_{17}H_{18}O_2$ requires C, 80·3; H, 7·1%).

5 : 9-*Dimethoxy*-1-*methylphenanthrene*.—Dehydrogenation of the dihydro–compound was effected by heating at 300—330° for 2 hours with 10% palladium–charcoal (0·6 part), and the product purified by crystallisation. 5 : 9-*Dimethoxy*-1-*methylphenanthrene* separated from absolute alcohol in thin, irregular plates, m. p. 139—140° (Found : C, 81·5; H, 6·3. $C_{17}H_{16}O_2$ requires C, 80·95; H, 6·3%). The *picrate* consisted of crimson needles, m. p. 200° (Found : C, 57·3; H, 3·9. $C_{17}H_{16}O_2,C_6H_3O_7N_3$ requires C, 57·4; H, 3·95%).

5-*Methoxy*-1-*naphthyl Allyl Ether*.—A mixture of 5-methoxy-1-naphthol (Fischer and Bauer, *J. pr. Chem.*, 1916, **94**, 15) (27·4 g.), acetone (34 c.c.), allyl bromide (14·8 c.c.), and potassium carbonate (26 g.) was boiled gently under reflux for 19 hours. The product was shaken with hot water, and the light brown solid dissolved in ether, washed with sodium hydroxide solution to remove unchanged naphthol (3·3 g.), dried, and evaporated. Recrystallisation of the residue from ligroin (charcoal) gave colourless plates of the *allyl* ether, m. p. 103° (Found : C, 78·7; H, 6·45. $C_{14}H_{14}O_2$ requires C, 78·5; H, 6·5%). This compound was insoluble in Claisen's potash (*Annalen*, 1926, **449**, 86) and did not couple with benzenediazonium chloride. The yield was 55% and a liquid cryptophenolic by-product was formed.

5-*Methoxy*-2-*allyl*-1-*naphthol*.—The preceding allyl ether was heated at 240° (oil-bath) under a pressure of 22 mm. for 1½ hours and then distilled. The distillate, b. p. 200—202°/9 mm., crystallised from light petroleum (b. p. 60—80°) in slightly coloured, long rods, m. p. 82—83° (Found : C, 78·6; H, 6·5. $C_{14}H_{14}O_2$ requires C, 78·5; H, 6·5%). 5-*Methoxy*-2-*allyl*-1-*naphthol* is insoluble in 5*N*-sodium hydroxide, but dissolves in Claisen's potash. Yield, 73%.

1 : 5-*Dimethoxy*-2-*allylnaphthalene*.—Addition of methyl sulphate (54 c.c.) to a solution of the naphthol (4·6 g.) in Claisen's potash (124 c.c.) with occasional cooling afforded a 75% yield of the *methyl* ether, b. p. 186—187°/10 mm., which separated from ice-cold methyl alcohol in colourless plates, m. p. 24—25° (Found : C, 78·8; H, 7·1. $C_{15}H_{16}O_2$ requires C, 79·0; H, 7·0%). Oxidation of this compound with 3% aqueous potassium permanganate (equivalent to 5 atoms of oxygen) produced 1 : 5-*dimethoxy*-2-*naphthoic acid* (below), which was identified as its methyl ester.

5-*Methoxy*-1-*methyl*-1 : 2-*dihydro*-α-*naphthafuran*.—5-Methoxy-2-allyl-1-naphthol and ⅛th of its weight of dry pyridine hydrochloride were heated at 220° (oil-bath) for 2—3 minutes in an atmosphere of nitrogen, and the mixture poured into hot water and washed by decantation. The solid was triturated with Claisen's potash, and washed with water. Extraction with hot methyl alcohol removed a black, sparingly soluble oil and the product was purified by successive crystallisations from 60% alcohol (charcoal) and methyl alcohol. The *coumaran* derivative formed colourless, rectangular plates, m. p. 116°, and was phototropic (Found: C, 78·4; H, 6·5; *M*, Rast, 210. $C_{14}H_{14}O_2$ requires C, 78·5; H, 6·5%; *M*, 214).

1-*Hydroxy*-5-*methoxy*-2-*naphthoic Acid.*—An intimate mixture of 5-methoxy-1-naphthol and potassium bicarbonate (2 parts) was heated for 3 hours in a sealed tube at 220°, and the product dissolved in a large volume of water and filtered from a small amount of resin. Acidification of the filtrate precipitated the *acid* (yield, over 90%), which separated from methyl alcohol in white crystals which rapidly turned yellow on exposure to light, m. p. 212·5—213° (decomp.) (Found: C, 66·2; H, 4·6. $C_{12}H_{10}O_4$ requires C, 66·1; H, 4·6%).

1 : 5-*Dimethoxy*-2-*naphthoic Acid.*—(1) An ethereal solution of diazomethane (2·5 mols.) was added to a suspension of the preceding acid in dry ether, kept for 160 hours, and evaporated to dryness, and the residue recrystallised from methyl alcohol. A small crop of crystals (A) was removed, the filtrate evaporated, and the residue recrystallised from chloroform–light petroleum (b. p. 60—80°), giving elongated plates of *methyl* 1 : 5-*dimethoxy*-2-*naphthoate*, m. p. 80—81° (Found: C, 68·2; H, 5·7. $C_{14}H_{14}O_4$ requires C, 68·3; H, 5·7%). Hydrolysis with alcoholic potash afforded 1 : 5-*dimethoxy*-2-*naphthoic acid*, which separated from alcohol in clusters of small rods, m. p. 151—152° (Found: C, 67·1; H, 5·2. $C_{13}H_{12}O_4$ requires C, 67·2; H, 5·2%). Recrystallisation of (A) from benzene–light petroleum (b. p. 40—60°) furnished colourless plates, m. p. 118—119° (Found: C, 67·1; H, 5·2. $C_{13}H_{12}O_4$ requires C, 67·2; H, 5·2%). This compound was only slightly soluble in aqueous sodium hydroxide, and when Claisen's potash was added to a solution in ligroin, a white sodium salt was precipitated. Saponification afforded 1-hydroxy-5-methoxy-2-naphthoic acid, m. p. 212·5—213° (decomp.), so (A) must be *methyl* 1-*hydroxy*-5-*methoxy*-2-*naphthoate*. (2) 1 : 5-Dimethoxy-2-naphthaldehyde (Bezdzik and Friedländer, *loc. cit.*) was oxidised by the slow addition of warm 0·3% aqueous potassium permanganate (equivalent to 1 atom of oxygen), and the acid collected and recrystallised from alcohol. It melted at 151—152° alone and when mixed with the acid prepared by method (1).

4 : 8-*Dimethoxy*-1-*naphthoic Acid.*—(1) Solid carbon dioxide was added to a Grignard solution prepared from 4-bromo-1 : 5-dimethoxynaphthalene (1 mol.), magnesium (1 atom), and ether (5 mols.), and the acid isolated in the usual way. 1 : 5-*Dimethoxy*-4-*naphthoic acid*, obtained in 32% yield, crystallised from alcohol in hexagonal plates, m. p. 222·5° (decomp.) (Found: C, 66·9; H, 5·2. $C_{13}H_{12}O_4$ requires C, 67·2; H, 5·2%). Methylation with diazomethane gave a quantitative yield of the *methyl* ester, which crystallised from methyl alcohol in elongated plates, m. p. 173—173·5° (Found: C, 68·1; H, 5·7. $C_{14}H_{14}O_4$ requires C, 68·3; H, 5·7%). When the acid was boiled with hydrobromic–acetic acid, decarboxylation occurred and 1 : 5-dihydroxynaphthalene was formed. (2) Methylation of 4 : 8-dihydroxy-1-naphthaldehyde (Morgan and Vining, *loc. cit.*) with methyl sulphate (2 mols.) and 10% aqueous sodium hydroxide (2·3 mols.) furnished the *dimethyl* ether, which crystallised from methyl alcohol in colourless plates, m. p. 131—131·5° (Found: C, 72·3; H, 5·6. $C_{13}H_{12}O_3$ requires C, 72·2; H, 5·6%). Oxidation under the conditions specified for the isomeric aldehyde produced 4 : 8-dimethoxy-1-naphthoic acid (methyl ester, m. p. 173°) identical with that produced by method (1).

4 : 8-*Dihydroxy*-1-*naphthoic Acid.*—Cautious fusion of 4 : 8-dihydroxy-1-naphthaldehyde with potassium hydroxide (5 parts) at 180—200° produced 4 : 8-*dihydroxy*-1-*naphthoic acid*, which separated from ether–ligroin as a sandy, micro-crystalline powder, m. p. 213° (decomp.) (Found: C, 64·9; H, 4·3. $C_{11}H_8O_4$ requires C, 64·7; H, 3·9%). Methylation with methyl sulphate and alkali gave 4 : 8-dimethoxy-1-naphthoic acid, m. p. 219—220° (decomp.).

o-*Tolylacetic Acid.*—*o*-Allyltoluene, b. p. 83—85°/28 mm., obtained in 65% yield from *o*-tolylmagnesium iodide and allyl bromide (compare Hurd and Bollman, *loc. cit.*), was oxidised at 0° with 5% aqueous potassium permanganate (equivalent to 6 atoms of oxygen) and acetic acid (7·2 mols.). *o*-Tolylacetic acid, b. p. 165—170°/12 mm., m. p. 85—88°, isolated as in previous cases (this vol., p. 262), was obtained in 53% yield and 24% of *o*-allyltoluene was recovered.

2-*Nitro*-3-*methoxybenzaldehyde.*—The recorded methods for the nitration of *m*-methoxybenzaldehyde (Rieche, *loc. cit.*; Friedländer and Scheiber, *Ber.*, 1895, **28**, 1385; Hodgson and Beard, J., 1926, 154; 1927, 2380; Tröger and Sabewa, *J. pr. Chem.*, 1927, **117**, 124) are conflicting; the following method gave reproducible results and was applied to the nitration of 20—50 c.c. batches of the aldehyde. *m*-Methoxybenzaldehyde (20 c.c.) was added in one portion with shaking to 85% nitric acid (*d* 1·48; 79 c.c., previously freed from nitrous acid by addition of 2·5 g. of urea) cooled below − 1°. The temperature was then allowed to rise slowly, but was prevented from exceeding 24—25° by occasional cooling. After 30—35 minutes, the mixture was poured into ice-water, and the solid was collected, washed with water, dried, and dissolved in hot benzene (17 c.c.). The crystals deposited on cooling were recrystallised from acetic acid

(46 c.c.) and melted at 102° (yield, 26%). By extracting the solid obtained from the benzene and acetic acid mother-liquors with hot ligroin and recrystallising the sparingly soluble portion from acetic acid, a further quantity of the aldehyde was isolated (total yield, 30%).

2-*Nitro*-3-*methoxy*-α-o-*tolylcinnamic Acid.*—This acid was obtained in 56% yield by heating dry potassium *o*-tolylacetate (1 mol.), 2-nitro-3-methoxybenzaldehyde (1 mol.), and acetic anhydride (10 mols.) on the steam-bath for 27 hours. Recrystallisation from acetic acid afforded slightly coloured, well-defined, octahedral crystals, m. p. 220° (Found: N, 4·4. $C_{17}H_{15}O_5N$ requires N, 4·5%).

2-*Amino*-3-*methoxy*-α-o-*tolylcinnamic Acid.*—Reduction of the preceding acid with ferrous sulphate (7·7 mols.) and ammonia, and crystallisation of the product from benzene, afforded the *amino-acid* in clusters of yellow needles, m. p. 205—206° (Found: C, 71·9; H, 6·0. $C_{17}H_{17}O_3N$ requires C, 72·1; H, 6·0%).

5-*Methoxy*-1-*methylphenanthrene*-10-*carboxylic Acid.*—A suspension of the amino-acid in excess of dilute sulphuric acid (5%) was stirred at 50° and diazotised with sodium nitrite (1·8 mols.), during ½ hour. The mixture was made alkaline, warmed at 90° for a few minutes, and filtered hot. Acidification of the filtrate and recrystallisation of the precipitate from acetic acid gave a 43% yield of 5-*methoxy*-1-*methylphenanthrene*-10-*carboxylic acid*, which crystallised in large, colourless plates, m. p. 224—225° (Found: C, 76·5; H, 5·3. $C_{17}H_{14}O_3$ requires C, 76·7; H, 5·3%).

5-*Methoxy*-1-*methylphenanthrene*, obtained by heating the preceding acid for 2 hours at 225—230° with quinoline (5 parts) and copper powder (0·5 part), crystallised from methyl alcohol in long hexagonal rods, m. p. 76—77° (Found: C, 86·3; H, 6·25. $C_{16}H_{14}O$ requires C, 86·5; H, 6·3%). The *picrate* separated from alcohol in brick-red needles, m. p. 180—181° (Found: C, 58·5; H, 3·6; N, 9·5. $C_{16}H_{14}O,C_6H_3O_7N_3$ requires C, 58·6; H, 3·8; N, 9·3%).

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