## The Addition of Isoprene to 4-Methoxytoluquinone.

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The Diels–Alder addition of isoprene to 4-methoxytoluquinone affords *cis*-1 : 4 : 5 : 8 : 9 : 10-hexahydro-2-methoxy-6 : 10-dimethyl-1 : 4-dioxonaphthalene, whose constitution is proved by a series of reactions which lead to 1 : 6-dimethyl-2-naphthol. Syntheses of 1 : 6-dimethyl-, 1 : 4 : 6-trimethyl-, and 1 : 4 : 7-trimethyl-2-naphthols are recorded, and an error in the literature relating to the supposed synthesis of the latter is corrected.

THE chemistry of the adduct (I; $R^1 = R^2 = H$) formed by the Diels–Alder reaction between butadiene and 4-methoxytoluquinone has been extensively investigated by Woodward, Sondheimer, Taub, Heusler, and McLamore (*J. Amer. Chem. Soc.*, 1952, **74**, 4223). We have carried out the reaction between isoprene and 4-methoxytoluquinone as a model for the elaboration of sesquiterpenes of the eudalene class. The product, obtained in good yield, was (I; $R^1 = Me$; $R^2 = H$) and no trace of the desired adduct (I; $R^1 = H$; $R^2 = Me$) was observed.
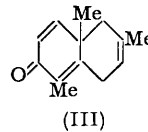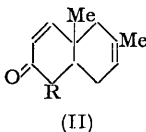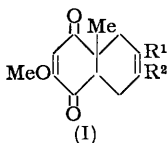


The *cis*-adduct was isomerised to the *trans*-adduct after the method of Woodward *et al.* (*loc. cit.*), then reduced with lithium aluminium hydride; the product on treatment with sulphuric acid in dioxan afforded *trans*-1 : 2 : 5 : 8 : 9 : 10-hexahydro-6 : 10-dimethyl-2-oxo-1-naphthol (II; R = OH). This compound was converted *via* established procedures successively into the acetate (II; R = OAc), deacetoxy-product (II; R = H), formyl derivative (II; R = CHO), and finally *trans*-1 : 2 : 5 : 8 : 9 : 10-hexahydro-1 : 6 : 10-trimethyl-2-oxonaphthalene (II; R = Me), which on selenium dehydrogenation gave 1 : 6-dimethyl-2-naphthol.

For comparison a sample of the latter was synthesised from 6-bromo-2-methoxy-1-methylnaphthalene (Fries, *Ber.*, 1906, **39**, 442) *via* reaction of its Grignard derivative with methyl sulphate to form 2-methoxy-1 : 6-dimethylnaphthalene, followed by demethylation of the latter.

Reduction of (II; R = Me) in the presence of palladium on charcoal (uptake of 1 mol. of hydrogen) yielded *trans*-1 : 2 : 3 : 4 : 5 : 8 : 9 : 10-octahydro-1 : 6 : 10-trimethyl-2-oxonaphthalene, characterised as its yellow 2 : 4-dinitrophenylhydrazone. Attempts to prepare the dienone (III) from the unsaturated ketone (II; R = Me) by reaction with *N*-bromosuccinimide, pyridinium bromide perbromide, or selenium dioxide were unsuccessful and the only product which could be isolated was (II; R = H) in poor yield as its 2 : 4-dinitrophenylhydrazone.

Cocker, Fateen, and Lipman (*J.*, 1951, 926) have shown that methyl *p*-xylyl ether will condense with methylsuccinic anhydride in the presence of aluminium chloride in nitrobenzene or carbon disulphide to furnish β-(4-methoxy-2 : 5-dimethylbenzoyl)-α-methylpropionic acid (the α-isomer) but they were not able to isolate the β-isomer [β-(4-methoxy-2 : 5-dimethylbenzoyl)-β-methylpropionic acid]. However, we have been able to prepare in tetrachloroethane the β-isomer which was separated from a much larger quantity of the α-isomer by fractional crystallisation. Elaboration of these compounds into the required 1 : 4 : 6-trimethyl- and 1 : 4 : 7-trimethyl-2-naphthols was carried out by classical methods. We point out, however, that in the course of this work it appears that the compounds described by Cocker *et al.* (*loc. cit.*) as 5 : 6 : 7 : 8-tetrahydro-1 : 4 : 7-trimethyl-8-oxo-2-naphthol, 5 : 6 : 7 : 8-tetrahydro-1 : 4 : 7-trimethyl-2-naphthol, and 1 : 4 : 7-trimethyl-2-naphthol are in reality the corresponding methyl ethers. This error has arisen because

Cocker *et al.* (*loc. cit.*) assumed with some justification (see *e.g.* an earlier paper by these workers, *J.*, 1950, 1781) that demethylation has occurred during the cyclisation of the (+)-isomer to the tetralone in 80% sulphuric acid.

## EXPERIMENTAL

1 : 4 : 5 : 8 : 9 : 10-*Hexahydro*-2-*methoxy*-6 : 10-*dimethyl*-1 : 4-*dioxonaphthalene* (I; $R^1$ = Me, $R^2$ = H).—4-Methoxytoluquinone (71·5 g.), isoprene (105 g.), benzene (200 c.c.), and a trace of quinol were heated at 90—100° in a sealed tube for 6 days, then filtered through glass wool, and concentrated to a small volume. Addition of light petroleum (b. p. 60—80°; 250 c.c.) gave the crude cis-*diketone* (87·9 g.), m. p. 115—118° (from light petroleum) (Found : C, 71·0; H, 7·3. $C_{13}H_{16}O_3$ requires C, 70 9; H, 7·3%). Reduction of the *cis*-diketone (1·4 g.) with lithium aluminium hydride in tetrahydrofuran afforded the pure cis-*glycol* (0·4 g.), m. p. 130—132° (from benzene) (Found : C, 69·6; H, 8·9. $C_{13}H_{20}O_3$ requires C, 69·6; H, 9·0%).

trans-1 : 4 : 5 : 8 : 9 : 10-*Hexahydro*-2-*methoxy*-6 : 10-*dimethyl*-1 : 4-*dioxonaphthalene.*—A solution of sodium dithionite (1·9 g.) in N-sodium hydroxide (12·5 c.c.) was added dropwise under nitrogen to the *cis*-diketone (10 g.) and sodium dithionite (0·6 g.) in dioxan (20 c.c.) at 70°. N-Sodium hydroxide was then added until all the solid disappeared. The solution was inoculated with a small quantity of powdered *trans*-diketone (obtained in small scale preliminary experiments), then diluted with water (250 c.c.), acidified with N-hydrochloric acid, and cooled in ice. The precipitated trans-*diketone* (6·3 g.) was filtered off and crystallised from methanol to m. p. 127—128° (Found : C, 70·8, 70·8; H, 7·4, 7·4. $C_{13}H_{16}O_3$ requires C, 70·9; H, 7·3%).

trans-1 : 2 : 5 : 8 : 9 : 10-*Hexahydro*-6 : 10-*dimethyl*-2-*oxo*-1-*naphthol* (II; R = OH).—Reduction of *trans*-diketone (10 g.) with lithium aluminium hydride in tetrahydrofuran afforded a crude oily *trans*-glycol (3·9 g.) which yielded pure *trans*-1 : 4 : 5 : 8 : 9 : 10-hexahydro-2-methoxy-6 : 10-dimethylnaphthalene-1 : 4-diol, m. p. 164—165° (from benzene). The crude *trans*-glycol (2 g.) and 2N-sulphuric acid (9 c.c.) in dioxan (11 c.c.) were kept at room temperature for 24 hr., then extracted with ether, to furnish the trans-*ketol* (0·54 g.), m. p. 58° [from light petroleum (b. p. 60—80°)] (Found : C, 74·5; H, 8·4. $C_{12}H_{16}O_2$ requires C, 75·0; H, 8·4%). The acetate (II; R = OAc) had m. p. 60° (from light petroleum) (Found : C, 71·7; H, 7·7. $C_{14}H_{18}O_3$ requires C, 71·8; H, 7·7%).

trans-1 : 2 : 5 : 8 : 9 : 10-*Hexahydro*-6 : 10-*dimethyl*-2-*oxonaphthalene* (II; R = H).—Zinc dust (112 g.) was added to a vigorously stirred refluxing solution of the acetate (13·1 g.) in acetic anhydride (112 c.c.). After 10 min. the zinc was filtered off and the acetic anhydride removed *in vacuo* through a Vigreux column. An ethereal solution of the residue was washed successively with dilute sulphuric acid, sodium hydrogen carbonate solution, and water, dried ($Na_2SO_4$), and then concentrated. Distillation of the residue (9·4 g.) furnished the trans-*ketone* (5·2 g.), b. p. 79—83°/0·1 mm. (Found : C, 81·3; H, 9·3. $C_{12}H_{16}O$ requires C, 81·8; H, 9·2%).

trans-1 : 2 : 5 : 8 : 9 : 10-*Hexahydro*-6 : 10-*dimethyl*-6-*oxo*-1-*naphthaldehyde* (II; R = CHO). —Ethyl formate (21 c.c.) was added to a well-stirred suspension of sodium methoxide (7 g.) in dry benzene (45 c.c.) under nitrogen followed by the dropwise addition of the *trans*-ketone (9·5 g.) in benzene (45 c.c.) during 1 hr. at 0°. After dilution of the mixture with benzene (40 c.c.) stirring was continued for a further 20 hr. at room temperature. The solution was washed with ice-cold sulphuric acid, then extracted with cold 0·3N-potassium hydroxide. Acidification of the alkaline extract afforded an oil. A solution of this in ether–benzene (1 : 1) was washed with water, dried ($Na_2SO_4$), and concentrated *in vacuo* to yield the crude *aldehyde* (7·7 g.). (For analysis, a sample was distilled at 95—100°/0·05 mm. Found : C, 76·5; H, 7·9. $C_{13}H_{16}O_2$ requires C, 76·5; H, 7·9%.) The absorption spectrum in ethanol showed maxima at 240 and 312 mμ; ε = 6600 and 3500, respectively.

trans-1 : 2 : 5 : 8 : 9 : 10-*Hexahydro*-1 : 6 : 10-*trimethyl*-2-*oxonaphthalene* (II; R = Me).—The aldehyde (7·5 g.), sodium ethoxide (3 g.), and methyl iodide (6 g.) were refluxed for 3 hr. in absolute ethanol (30 c.c.). The solution was concentrated, and a solution of the residue in ether washed with water and concentrated. The residue (6·8 g.) distilled to furnish crude *trans*-1 : 2 : 5 : 8 : 9 : 10-hexahydro-1 : 6 : 10-trimethyl-2-oxo-1-naphthaldehyde (5·1 g.), b. p. 65—110°/0·1 mm. (light absorption : max. 228 mμ; ε = 12,000 in EtOH). The crude methylated derivative (5·1 g.) in dioxan (230 c.c.) was set aside with ice-cold potassium hydroxide (6·5 g.) in water (230 c.c.) for 3 hr., then saturated with salt, and extracted with ether. After concentration and distillation pure trans-1 : 2 : 5 : 8 : 9 : 10-*hexahydro*-1 : 6 : 10-*trimethyl*-2-*oxonaphthalene* (2·4 g.) was obtained, b. p. 60—70°/0·1 mm. (Found : C, 81·6; H, 9·3. $C_{13}H_{18}O$ requires C, 82·1; H, 9·6%). The absorption spectrum measured in ethanol showed a maximum

at 226 mμ (ε = 12,100). The 2 : 4-*dinitrophenylhydrazone* had m. p. 165—166° (from *n*-butanol) (Found : C, 61·0; H, 5·6. $C_{19}H_{22}O_4N_4$ requires C, 61·6; H, 6·0%).

trans-1 : 2 : 3 : 4 : 5 : 8 : 9 : 10-*Octahydro*-1 : 6 : 10-*trimethyl-2-oxonaphthalene.*—The *trans*-hexahydro-compound (50 mg.) in ethanol took up 1 mol. of hydrogen in 10 min. in the presence of palladium on charcoal (50 mg.). The catalyst was filtered off and the resulting solution treated with an ethanolic solution of 2 : 4-dinitrophenylhydrazine hydrochloride, yielding the 2 : 4-dinitrophenylhydrazone (61 mg.) of the *trans*-octahydronaphthalene as yellow crystals (from *n*-butanol), m. p. 164—166° (Found : N, 16·2. Calc. for $C_{19}H_{24}O_4N_4$ : N, 15·0%).

1 : 6-*Dimethyl-2-naphthol.*—The *trans*-ketone (II; R = Me; 0·5 g.) was heated for 10 hr. with selenium (1 g.) at 300—330°, and the mixture then cooled, powdered, and exhaustively extracted with chloroform, from which the phenolic portion was isolated with 5% sodium hydroxide. Sublimation at 50—60°/0·1 mm. yielded the crude solid phenol (81 mg.) which after several crystallisations from light petroleum (b. p. 60—80°) afforded pure 1 : 6-dimethyl-2-naphthol, m. p. 106—107° (Found : C, 83·8; H, 7·2. Calc. for $C_{12}H_{12}O$ : C, 83·7; H, 7·0%).

The Grignard derivative of 6-bromo-2-methoxy-1-methylnaphthalene (1·5 g.) was prepared by refluxing it in dry ether (75 c.c.) with magnesium turnings (0·3 g.) in an atmosphere of dry nitrogen. After all the magnesium had dissolved methyl sulphate (1·8 g.) in ether (50 c.c.) was added and the mixture refluxed for a further hour, set aside at room temperature overnight, then decomposed with dilute hydrochloric acid. The ethereal extract was concentrated, yielding crude 2-methoxy-1 : 6-dimethylnaphthalene (1·3 g.). A mixture of this compound (0·5 g.), 48% hydrobromic acid (20 c.c.), and acetic acid (4 c.c.) was refluxed for 4 hr., then diluted with water, and extracted with ether. Extraction of the ethereal solution with 5% sodium hydroxide afforded the crude naphthol (80 mg.) which was crystallised to constant m. p. 105—106° from light petroleum (b. p. 60—80°) (Found : C, 83·6; H, 6·9%). There was no depression of m. p. on admixture with the sample synthesised by the route described above.

1 : 4 : 7-*Trimethyl-2-naphthol.*—β-(4-*Methoxy-2 : 5-dimethylbenzoyl*)-α-*methylpropionic acid.* Methyl *p*-xylyl ether (27·2 g.) was condensed with methylsuccinic anhydride (24 g.) by the use of aluminium chloride (67 g.) in nitrobenzene (200 c.c.). The crude acid (40 g.) was crystallised from aqueous ethanol to constant m. p. 151—152° (lit. 140°) (Found, in a sublimed sample : C, 66·9; H, 7·3. Calc. for $C_{14}H_{18}O_4$ : C, 67·2; H, 7·3%). The semicarbazone (from aqueous ethanol) had m. p. 174—175° (lit. 166°) (Found : N, 13·2. Calc. for $C_{15}H_{21}O_4N_3$ : N, 13·6%).

γ-(4-*Methoxy-2 : 5-dimethylphenyl*)-α-*methylbutyric acid.* The keto-acid (37 g.) was reduced by amalgamated zinc to the required butyric acid (22·5 g.), m. p. 100—101° (from aqueous ethanol) (lit. 89—90°) (Found : C, 70·5; H, 8·7. Calc. for $C_{12}H_{20}O_3$ : C, 71·2; H, 8·5%).

1 : 2 : 3 : 4-*Tetrahydro-7-methoxy-2 : 5 : 8-trimethylnaphthalene.* The butyric acid (9 g.) was heated with concentrated sulphuric acid at 70° for 10 min. and yielded the methoxy-tetralone (6·5 g.), m. p. 71—72° (from benzene–light petroleum) (Found : C, 77·1; H, 8·7; OMe, 14·2. Calc. for $C_{14}H_{18}O_2$ : C, 77·0; H, 8·3; OMe, 14·2%). Cocker *et al.* (*loc. cit.*) recorded m. p. 75° for their " hydroxy-tetralone."

5 : 6 : 7 : 8-*Tetrahydro-1 : 4 : 7-trimethyl-8-oxo-2-naphthol.* The foregoing ketone (5·3 g.), refluxed with 47% hydrobromic acid (65 c.c.) for 3 hr., furnished the *hydroxy-tetralone* (4·5 g.), m. p. 151° (from benzene–light petroleum) (Found : C, 76·3; H, 8·1. $C_{13}H_{16}O_2$ requires C, 76·4; H, 7·9%).

5 : 6 : 7 : 8-*Tetrahydro-1 : 4 : 7-trimethyl-2-naphthol.* The hydroxy-tetralone (1·17 g.) was reduced by amalgamated zinc to the required *hydroxy-tetralin* (550 mg.), m. p. 99—100° (from aqueous ethanol) (Found : C, 81·9; H, 9·5. $C_{13}H_{18}O$ requires C, 82·0; H, 9·5%). Methylation with methyl sulphate and alkali yielded the methoxy-tetralin, m. p. 29° (Found : OMe, 14·5. Calc. for $C_{14}H_{20}O$ : OMe, 14·2%). Cocker *et al.* (*loc. cit.*) record m. p. 32° for their " hydroxytetralin."

1 : 4 : 7-*Trimethyl-2-naphthol.* The hydroxy-tetralin (250 mg.) was heated with selenium (700 mg.) at 330—350° for 1 hr. and yielded the *naphthol* (110 mg.) which was extracted from the mixture with methanol and crystallised from aqueous ethanol; it had m. p. 141—142° (Found : C, 83·8; H, 7·6. $C_{13}H_{14}O$ requires C, 83·8; H, 7·6%). Light absorption : max., 240, 275, 290, 300, 335 mμ; log ε = 4·70, 3·50, 3·71, 3·62, 3·22, respectively in ethanol.

1 : 4 : 6-*Trimethyl-2-naphthol.*—1 : 2 : 3 : 4-*Tetrahydro-7-methoxy-3 : 5 : 8-trimethyl-1-oxonaphthalene.* Methyl *p*-xylyl ether (27·2 g.) was condensed with methylsuccinic anhydride (24 g.) by use of aluminium chloride (67 g.) in tetrachloroethane. The crude acids were fractionally crystallised from aqueous ethanol, furnishing pure β-(4-methoxy-2 : 5-dimethylbenzoyl)-β-methyl-propionic acid (7·2 g.), m. p. 89—91°, which did not form a semicarbazone. Reduction of the acid with amalgamated zinc gave the oily γ-phenylbutyric acid (5·2 g.), which was heated

directly in concentrated sulphuric acid at 70° for 10 min. to yield 1 : 2 : 3 : 4-*tetrahydro*-7-*methoxy*-3 : 5 : 8-*trimethyl*-1-*oxonaphthalene* (1·6 g.), m. p. 74° (from benzene–light petroleum) (Found : C, 77·1; H, 8·3; OMe, 11·9. $C_{14}H_{18}O_2$ requires C, 77·0; H, 8·3; OMe, 14·2%).

5 : 6 : 7 : 8-*Tetrahydro*-1 : 4 : 6-*trimethyl*-8-*oxo*-2-*naphthol*. The foregoing ketone (1·6 g.), refluxed with hydrobromic acid, gave the *hydroxy-tetralone* (550 mg.), m. p. 176° (from aqueous ethanol) (Found : C, 76·1; H, 8·1. $C_{13}H_{16}O_2$ requires C, 76·4; H, 7·9%).

5 : 6 : 7 : 8-*Tetrahydro*-1 : 4 : 6-*trimethyl*-2-*naphthol*. The hydroxy-tetralone (550 mg.) was reduced by amalgamated zinc to the required *hydroxy-tetralin* (360 mg.), m. p. 106—107° (from benzene–light petroleum) (Found : C, 82·0; H, 9·5. $C_{13}H_{18}O$ requires C, 82·0; H, 9·5%).

1 : 4 : 6-*Trimethyl*-2-*naphthol*. The tetrahydronaphthol (160 mg.) was heated with selenium, yielding the *naphthol* (72 mg.), m. p. 116—117° (from aqueous ethanol) (Found : C, 83·4; H, 8·4. $C_{13}H_{14}O$ requires C, 83·8; H, 7·6%). Light absorption in ethanol : max., 235, 285, 340 mμ; log ε = 4·59, 3·50, 3·16, respectively.

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