# **200.** *Benzanthrones. Part II. The Synthesis of* 3′-*Alkyl*meso*benzanthrones. Further Observations on the Mechanism of Bally's Reaction.*

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Phenyl 7-alkyl-1-naphthyl ketones cannot be converted into 3′-alkyl*meso*benzanthrones by fusion with aluminium chloride. Ring closure of the acid chloride of o-2′-*methyl*-1′-*naphthylbenzoic acid* by the Friedel–Crafts reaction gives 3′-methyl*meso*benzanthrone, which is identical with the condensation product of anthrone and crotonaldehyde. This establishes that αβ-unsaturated aldehydes as well as ketones condense with anthrone according to Meerwein's mechanism.

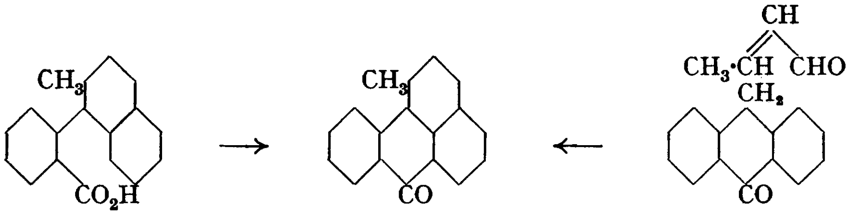
Benzylideneacetone, in which the double bond is conjugated with the phenyl group, condenses similarly and cinnamaldehyde is exceptional.

The reaction between anthrone and α-ethylglycerol in sulphuric acid to give 1′-ethyl*meso*benzanthrone is discussed.

Since Meerwein (*J. pr. Chem.*, 1918, **97**, 284) showed that anthrone added to the double bond of benzylidenemalonic ester in the presence of bases to give β-anthronyl-β-phenylethylmalonic ester, numerous other examples of different modes of condensation have been recorded. Of particular interest is the isolation of an intermediate addition compound when phenyl vinyl ketone is condensed with anthrone in the presence of sulphuric acid (Allen and Overbauch, *J. Amer. Chem. Soc.*, 1935, **57**, 1322), which is the medium in which Bally effected his synthesis of *meso*benzanthrone. It is worthy of note, however, that Meerwein was unable to isolate any such addition compound between anthrone and αβ-unsaturated aldehydes; but the structural similarity between anthrone and deoxybenzoin, which condensed with acraldehyde to give β-desylpropaldehyde (Meerwein, *ibid.*, p. 261), led him to conclude that aldehydes condense in a similar way. The intermediate compound from crotonaldehyde and anthrone (O. Y. Imray, Farb. vorm. Meister, Lucius und Brüning, E.P. 244,120) is amorphous and not characterised, and the fusion with aluminium chloride to give methyl*meso*benzanthrone, m. p. 168°, does not elucidate its structure, since we have shown that this is the 2′-methyl derivative.

Cinnamaldehyde, however, condenses with anthrone to give an intermediate product which was cyclised to 1′-phenyl*meso*benzanthrone (I.G. Farbenindustrie Akt.-ges., E.P. 297,129; *Centr.*, 1929, **100**, I, 447; Berliner, Stein, and Trautner, U.S.P. 1,713,571; *Centr.*, 1929, **100**, II, 1073), and Allen and Overbauch (*loc. cit.*) " suggest that in aldehydes the process involves 1 : 2-addition to the carbonyl group whereas with ketones 1 : 4-addition occurs."

3′-Methyl*meso*benzanthrone (II), m. p. 115°, which we have obtained by ring closure of o-2′-*methyl*-1′-*naphthylbenzoic acid* (I), is identical with the condensation product of crotonaldehyde and anthrone in the presence of sulphuric acid (Imray, *loc. cit.*). This necessitates that the latter condensation occurs by addition to the double bond as postulated by Meerwein (*loc. cit.*).

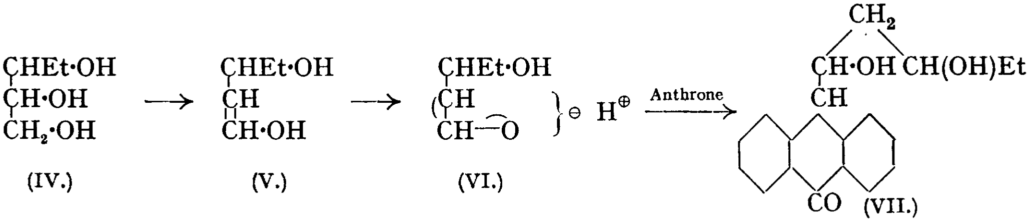


(I.) (II.) (III.)

The different mode of addition of cinnamaldehyde led us to investigate the condensation of benzylideneacetone, in which the phenyl group is similarly conjugated with the double bond, a state known to deactivate the ethylenic linkage. An addition compound was readily formed, but this was split into its components with 80% sulphuric acid, which was used by Allen and Overbauch to cyclise methyl β-anthronylethyl ketone, although ring closure was effected by using equal volumes of 80% sulphuric acid and acetic acid. The addition, which is undoubtedly reversible, is somewhat impeded by the proximity of the phenyl group, although the mechanism is the same.

We have reinvestigated the condensation of α-ethylglycerol and anthrone in the presence of sulphuric acid under various conditions and have been unable to isolate any 3′-ethyl-*meso*benzanthrone, which would be expected if the glycerol were dehydrated completely to β-ethylacraldehyde prior to condensation. This cannot be due to the destruction of this second isomer, for under the conditions of the experiment 3′-methyl*meso*benzanthrone was stable (see below). It does not seem that the isolation of 1′-ethyl*meso*benzanthrone is due to the formation of methyl vinyl ketone, for, apart from the evidence already put forward (Part I, J., 1938, 401), the dehydration of α-alkylglycols gives aldehydes and not ketones (Bahl and Sommelet, *Compt. rend.*, 1904, **138**, 89). It is worthy of note that the yield of benzanthrone is always greater when a glycerol is used in place of an aldehyde, and a higher concentration of sulphuric acid (80%) is used with advantage. Such high concentrations do not readily effect the formation of benzanthrones with unsaturated aldehydes and ketones (see above), which are best condensed with 30—40% sulphuric acid.

The enhanced activity of the aldehyde generated *in situ* and the different mode of condensation find a ready explanation in the dehydration of α-ethylglycerol (IV) to αγ-dihydroxy-$\Delta^{\alpha}$-pentene (V), which then rearranges to β-hydroxyvaleraldehyde (Delaby, *Compt. rend.*, 1923, **177**, 690). When the hydrogen migrates from the oxygen in the latter prototropic change, the remaining ion assumes an active form, which may be represented in the mesotropic state (VI). This then adds anthrone to give (VII), which would cyclise and undergo dehydrogenation to 1′-ethyl*meso*benzanthrone.



This explanation is equally applicable to all hydroxymethylene compounds which have been assumed simply to add anthrone to the double bond (U.S.P. 1,705,868). In fact the latter mechanism cannot be tenable for the formation of 1′-hydroxy-2′-phenyl*meso*benzanthrone from ethyl hydroxymethylenephenylacetate, which Wislicenus (*Ber.*, 1896, **29**, 742) has shown to revert to the keto-form in the presence of sulphuric acid, in which medium the condensation is effected. The explanation would furthermore account for the more ready formation of benzanthrones from hydroxymethylene compounds than from αβ-unsaturated aldehydes and ketones, and the remarkable colour changes which accompany such condensations may not be insignificant.

This condensation before complete dehydration would not cause the formation of 4-ethylquinoline from α-ethylglycerol, for according to Miller (*Ber.*, 1891, **24**, 1720; 1892, **25**, 2020, 2072) a Schiff's base is formed primarily, then another molecule of aromatic amine adds to the double bond, and ring closure is effected by fission of the amine involved in the primary condensation. The aldol condensation products, *e.g.*, benzylideneanthrone (Haller and Padova, *Compt. rend.*, 1905, **141**, 857) and methyleneanthrone (Mayer, *Annalen*, 1920, **420**, 135), unlike the addition products to the double bond (see above and Meerwein, *loc. cit.*), do not readily revert to the original constituents.

αβ-Unsaturated aldehydes and ketones condense with anthrone according to Meerwein's mechanism, whereas cinnamaldehyde and aldehydes generated *in situ* from the corresponding glycerols react as postulated by Bally and Scholl.

*Attempted Synthesis of 3′-Alkyl*meso*benzanthrones.*—An alkylbenzene was condensed with succinic anhydride in the presence of aluminium chloride to give a β-*p*-alkylbenzoyl-propionic acid. By using a mixture of nitrobenzene and tetrachloroethane in this reaction (compare Fieser and Seligman, *J. Amer. Chem. Soc.*, 1937, **59**, 883), we obtained a purer substance in a greater yield than by the method of Krollpfeiffer and Schäfer (*Ber.*, 1923, **56**, 620). This was reduced by Martin's modification (*J. Amer. Chem. Soc.*, 1936, **58**, 1438) of Clemmensen's method (*Ber.*, 1913, **46**, 1837), and the ethyl ester condensed with ethyl oxalate in the presence of potassium ethoxide (Auwers and Möller, *J. pr. Chem.*, 1925, **109**, 124; Fieser and Hershberg, *J. Amer. Chem. Soc.*, 1935, **57**, 1851; Fieser and Holmes, *ibid.*, 1936, **58**, 2319) to give an ethyl α-oxalyl-*p*-alkylphenylbutyrate. This was hydrolysed and cyclised to a 7-alkyl-3 : 4-dihydro-1-naphthoic acid, which was dehydrogenated to a 7-alkyl-1-naphthoic acid. The Friedel–Crafts reaction with the acid chloride and benzene gave the phenyl 7-alkyl-1-naphthyl ketone, which was characterised as its 2 : 4-dinitrophenylhydrazone.

Attempts to cyclise the ketone by Scholl's condensation with aluminium chloride failed to give any 3′-alkyl*meso*benzanthrone. The product with dinitrophenylhydrazine gave a precipitate which was undoubtedly a mixture and could not be purified. The precipitation, however, was more rapid than with the original ketone, a fact indicative of a β-benzoylnaphthalene (Cahn, Jones, and Simonsen, J., 1933, 444); and it seems probable that the benzoyl group had migrated under the influence of aluminium chloride to give a mixture of 2- and 3-benzoyl-7-alkylnaphthalene, a migration comparable with that observed by Fieser and Peters (*J. Amer. Chem. Soc.*, 1932, **54**, 3742).

*Synthesis of 3′-Methyl*meso*benzanthrone.*—2-Methyl-1-naphthylamine was converted into 1-*iodo*-2-*methylnaphthalene*, which was condensed with methyl *o*-iodobenzoate by the Ullmann reaction, and the product hydrolysed to give o-2′-*methyl*-1′-*naphthylbenzoic acid*. Ring closure of the acid chloride of this acid by the Friedel–Crafts reaction gave 3′-methyl*meso*benzanthrone. Attempts to cyclise the acid with sulphuric acid gave only sulphonation products: these must be formed prior to or during ring closure, since the 3′-methyl*meso*benzanthrone itself was stable to sulphuric acid at 100°. This method was not attempted originally on account of the close spatial similarity of 1-iodo-2-methylnaphthalene with 2 : 6-dimethyliodobenzene in which the steric effects of the methyl groups inhibited self-condensation by the Ullmann reaction (Mayer, *Ber.*, 1911, **44**, 2298).

## EXPERIMENTAL.

β-p-*Ethylbenzoylpropionic Acid.*—A mixture of ethylbenzene (55 g.; 0·5 mol.), succinic anhydride (50 g.; 0·5 mol.), nitrobenzene (75 c.c.), and tetrachloroethane (225 c.c.) was cooled to − 5°, and aluminium chloride (135 g.; 1 mol.) added slowly during 2 hours. The whole was maintained at 0° for 3 days with occasional stirring. The product was poured on ice and acidified with hydrochloric acid, and the solvent removed by steam-distillation. The semi-solid substance precipitated on cooling was dissolved in sodium carbonate solution and re-precipitated. The dried material was crystallised from benzene–petroleum (b. p. 60—70°), from which β-*p*-ethylbenzoylpropionic acid separated in prismatic needles, m. p. 107—108°. Yield, 80% of the theoretical (Found: C, 69·8; H, 6·8; *M*, monobasic, 206·6. Calc. for $C_{12}H_{14}O_3$: C, 69·9; H, 6·8%; *M*, 206·1). Muhr (*Ber.*, 1895, **28**, 3217) gives m. p. 90° and Krollpfeiffer and Schäfer (*loc. cit.*) give m. p. 98—99°.

γ-p-*Ethylphenylbutyric Acid.*—Amalgamated zinc (100 g.; 6 mols.), water (70 c.c.), concentrated hydrochloric acid (175 c.c.), toluene (200 c.c.), and β-*p*-ethylbenzoylpropionic acid (55 g.; 1 mol.) were heated together under reflux for 30 hours, concentrated hydrochloric acid (50 c.c.) being added every 6 hours. The toluene layer was separated, the solvent removed by steam-distillation, and the residue crystallised from either hexane or benzene–petroleum, from which γ-*p*-ethylphenylbutyric acid separated in leaflets, m. p. 74°. Yield, 48 g. (94%) (Found: C, 74·7; H, 8·4; *M*, monobasic, 190·9. Calc. for $C_{12}H_{16}O_2$: C, 75·0; H, 8·4%; *M*, 192·1). Krollpfeiffer and Schäfer (*loc. cit.*) give m. p. 69—70°. The *ethyl* ester had b. p. 146—147°/8 mm. (Found: C, 76·3; H, 9·3. $C_{14}H_{20}O_2$ requires C, 76·3; H, 9·2%).

7-*Ethyl*-3 : 4-*dihydro*-1-*naphthoic Acid.*—Potassium (1·8 g.; 1 mol.) was finely powdered under toluene, which was then replaced with dry ether (100 c.c.), and treated with ethyl alcohol (3·2 g.; 1·60 mols.). When the potassium had dissolved, ethyl oxalate (10 g.; 1·5 mols.) and then ethyl γ-*p*-ethylphenylbutyrate (10 g.; 1 mol.) were added, and the whole kept overnight. After refluxing for 6 hours, the product was poured into ice-cold dilute sulphuric acid and extracted with ether, and the ethereal solution dried over anhydrous sodium sulphate. Removal of the solvent left a light yellow oil, ethyl α-oxalyl-γ-*p*-ethylphenylbutyrate, which was not further purified. The yellow oil was refluxed directly with 20% by volume sulphuric acid (80 c.c.) for 24 hours with stirring, the mixture cooled and extracted with ether, the ethereal solution extracted with alkali, and the extract acidified. The dried precipitate was extracted with boiling hexane, in which the dicarboxylic acid (1 g.; see below) was insoluble. The solution on cooling deposited light yellow prisms, m. p. 118—120°, which on being further purified by distillation (b. p. about 170°/4 mm.) and recrystallisation gave 7-*ethyl*-3 : 4-*dihydro*-1-*naphthoic acid* in colourless crystals, m. p. 120° (Found : C, 77·3; H, 7·3; *M*, monobasic, 202·5. $C_{13}H_{14}O_2$ requires C, 77·2; H, 7·0%; *M*, 202·1). Yield, 2·5 g., *i.e.*, 27% of the theoretical calculated on the ethylphenylbutyrate.

Attempts to obtain this compound by hydrolysis of the above oxalyl ester with 15% by volume sulphuric acid to give α-keto-δ-*p*-ethylphenylvaleric acid and then esterification and ring closure with 65% sulphuric acid as recommended by Fieser and co-workers (*J. Amer. Chem. Soc.*, 1936, **58**, 2319; 1938, **60**, 2258) resulted in the isolation of 7-*ethyl*-3 : 4-*dihydronaphthalene*-1 : 2-*dicarboxylic acid*, which separated in tiny crystals, m. p. 165°, from benzene–alcohol (Found : C, 68·6; H, 5·9; *M*, dibasic, 246. $C_{14}H_{14}O_4$ requires C, 68·3; H, 5·7%; *M*, 246), and the corresponding *anhydride*, which crystallised from hexane in tiny yellow prisms, m. p. 117—118° (Found : C, 73·4; H, 5·3. $C_{14}H_{12}O_3$ requires C, 73·7; H, 5·3%). This acid anhydride was obtained by direct ring closure of ethyl α-oxalyl-γ-*p*-ethylphenylbutyrate (compare Auwers and Möller, *loc. cit.*), so the formation of the α-*keto*-acid could not have been effected.

Extraction of the acid product of the hydrolysis with 15% sulphuric acid from the unchanged ester by means of alkali resulted in the isolation of β-(p-*ethylphenyl*)*ethylmalonic acid*, which crystallised from benzene in prisms, m. p. 145° (Found : C, 66·3; H, 6·8. $C_{13}H_{16}O_4$ requires C, 66·1; H, 6·8%). Compare Auwers and Möller (*loc. cit.*).

7-*Ethyl*-1-*naphthoic Acid.*—The above dihydro-acid (2 g.; 1 mol.) and sulphur (0·4 g.; 1·2 mols.) were heated together at 200—210° until hydrogen sulphide was no longer evolved (about 1 hour). The product was distilled in a vacuum and recrystallised from hexane, from which 7-*ethyl*-1-*naphthoic acid* was obtained in thin colourless leaflets, m. p. 126° (Found : C, 77·9; H, 6·2; *M*, monobasic, 199·3. $C_{13}H_{12}O_2$ requires C, 77·8; H, 6·1%; *M*, 200·1). Yield, 1·5 g. (75%).

*Methyl Naphthalene*-1 : 7-*dicarboxylate.*—The above acid (0·4 g.) was oxidised by alkaline potassium ferricyanide by the method of Weissgerber and Kruber (*Ber.*, 1919, **52**, 352) to give an amorphous solid, m. p. about 280° (yield, 0·3 g.; 75%). It was esterified with methyl sulphate, and the product crystallised from ethyl alcohol, from which methyl naphthalene-1 : 7-dicarboxylate separated in tiny prisms, m. p. 86° (Found : C, 68·9; H, 5·2. Calc. for $C_{14}H_{12}O_4$ : C, 68·8; H, 5·0%). Ruzicka and Melson (*Helv. Chim. Acta*, 1931, **14**, 397) give m. p. 86—87°.

7-*Methyl*-3 : 4-*dihydro*-1-*naphthoic Acid.*—γ-*p*-Tolylbutyric acid (Barnett and Sanders, J., 1933, 434) was esterified and converted into ethyl α-oxalyl-γ-*p*-tolylbutyrate as above. This was refluxed for 30 hours with 25% sulphuric acid (80 c.c.), the concentration raised to 32% (by vol.), and the whole refluxed for a further 14 hours. 7-*Methyl*-3 : 4-*dihydro*-1-*naphthoic acid*, worked up as above, crystallised from benzene in colourless leaflets, m. p. 153—154° (Found : C, 76·7; H, 6·4. $C_{12}H_{12}O_2$ requires C, 76·6; H, 6·4%). Yield, 20% of the theoretical calculated on the butyric ester.

7-*Methyl*-3 : 4-*dihydronaphthalene*-1 : 2-*carboxylic acid* obtained as a by-product insoluble in benzene, crystallised from alcohol–benzene in small prisms, m. p. 192° (Found : C, 76·2; H, 5·1. $C_{13}H_{12}O_4$ requires C, 76·2; H, 5·2%).

7-Methyl-1-naphthoic acid, obtained as above, crystallised from benzene in colourless leaflets, m. p. 147°. Dziewoński and Brand (*Bull. Acad. Polonaise*, 1933, *A*, 99) give m. p. 147° (Found : C, 77·1; H, 5·4. Calc. for $C_{12}H_{10}O_2$ : C, 77·4; H, 5·4%).

*Phenyl* 7-*Alkyl*-1-*naphthyl Ketones.*—The acid chloride (4·5 g.; 1 mol.) in benzene (12 c.c.) and carbon disulphide (10 c.c.) was treated with aluminium chloride (2·3 mols.) and heated for 5 hours on the water-bath. The product, worked up in the usual way, failed to crystallise after distillation under reduced pressure, and was identified in the form of the 2 : 4-dinitrophenylhydrazone, prepared according to the method of Cahn, Jones, and Simonsen (J., 1933, 444), which was obtained in two modifications (*cis* and *trans*); the α-isomer crystallised from pyridine and the β-isomer was obtained by dilution of the mother-liquor and crystallisation from dilute pyridine :

*Phenyl* 7-*methyl*-1-*naphthyl ketone* 2 : 4-*dinitrophenylhydrazone.* α-Isomer, red microscopic crystals, m. p. 256—257° (Found : N, 13·0. $C_{24}H_{18}O_4N_4$ requires N, 13·1%). The β-isomer was not isolated in a pure state.

*Phenyl 7-ethyl-1-naphthyl ketone 2 : 4-dinitrophenylhydrazone.* α-Isomer, red microscopic crystals, m. p. 223—224° (Found : C, 68·5; H, 4·4; N, 13·0. $C_{25}H_{20}O_4N_4$ requires C, 68·2; H, 4·5; N, 12·7%). The β-isomer, orange red crystals, m. p. 200—210° (Found : C, 68·0; H, 4·5; N, 12·8%), was not obtained free from the α-form.

*Phenyl 1-naphthyl ketone 2 : 4-dinitrophenylhydrazone.* α-Isomer, red microscopic crystals, m. p. 246—247° (Found : 67·1; H, 4·1; N, 13·4. $C_{23}H_{16}O_4N_4$ requires C, 67·0; H, 3·9; N, 13·6%). β-Isomer, orange-yellow crystals, m. p. 243—244°, mixed m. p. with α-isomer 220° (Found : C, 67·1; H, 4·0; N, 13·6%).

*Synthesis of 3′-Methyl*meso*benzanthrone.*—The procedure adopted was in every respect similar to that described in Part I (*loc. cit.*).

2-Methylaceto-1-naphthalide crystallised from benzene in silky needles, m. p. 200° (Found : C, 78·4; H, 6·5; N, 7·0. Calc. for $C_{13}H_{13}ON$ : C, 78·4; H, 6·6; N, 7·0%). Lesser and Glaser (*Annalen*, 1913, **402**, 39) give m. p. 188°.

1-*Iodo-2-methylnaphthalene* was obtained as a yellow mobile liquid, b. p. 155°/3 mm.; yield, 56% (Found : I, 47·2. $C_{11}H_9I$ requires I, 47·4%).

Iodomethylnaphthalene (5 g.; 1 mol.), methyl *o*-iodobenzoate (10 g.; 2 mols.), and copper-bronze (6 g.; 5·0 mols.) were heated at 180—190° for 5 hours. The resulting o-*2′-methyl-1′-naphthylbenzoic acid* crystallised from methyl alcohol in colourless cubes, m. p. 188—189° (Found : C, 82·3; H, 5·3. $C_{18}H_{14}O_2$ requires C, 82·4; H, 5·4%).

3′-Methyl*meso*benzanthrone, prepared in theoretical yield from the acid chloride by the Friedel–Crafts reaction, crystallised from methyl alcohol in fine yellow needles, m. p. 115° (Found : C, 88·6; H, 5·1. Calc. for $C_{18}H_{12}O$ : C, 88·5; H, 5·0%). The m. p. was not depressed by the product obtained by condensation of crotonaldehyde and anthrone in the presence of sulphuric acid. Imray (E.P. 244,120) gives m. p. 113—114°.

*Methyl β-Phenyl-β-anthronylethyl Ketone.*—Benzylideneacetone (5 g.; 1·1 mols.), anthrone (6 g.; 1 mol.), and methyl alcohol (35 c.c.) were warmed on a water-bath, and piperidine added drop by drop until all the anthrone had dissolved. The solution was cooled to 0° and after 12 hours the crystalline precipitate was filtered off and recrystallised from methyl alcohol, from which *methyl β-phenyl-β-anthronylethyl ketone* separated in colourless prisms, m. p. 116—117° (Found : C, 84·8; H, 6·0. $C_{24}H_{20}O_2$ requires C, 84·7; H, 5·9%). Yield, 66%.

*3′-Phenyl-1′-methyl*meso*benzanthrone.*—The above ketone (2·5 g.), acetic acid (25 c.c.), 80% sulphuric acid (25 c.c.), and arsenic oxide (2 g.) were heated for 2 hours on a steam-bath. The deep red solution was poured on ice, filtered, treated with sodium hydroxide and sodium hyposulphite, filtered, and washed. The dried product was extracted with hot acetic acid, precipitated with water, and crystallised from methyl alcohol, from which 3′-phenyl-1′-methyl-*meso*benzanthrone was obtained in yellow rosettes, m. p. 176°, undepressed by the product obtained by the condensation of anthrone with benzylideneacetone in sulphuric acid (U.S.P. 1,705,868).

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