134. *Formation of the Indene Nucleus. Part III.*

By (the late) (Mrs.) O. Blum-Bergmann.

1 : 3-*Diphenyl*-2-p-*anisylpropane*-2 : 3-*diol* (I), on dehydration, gives in fair yield 1-*phenyl*-2-p-*anisylindene* (II) according to a mechanism discussed in previous papers. The isomeric 1 : 2-*diphenyl*-3-p-*anisylpropane*-2 : 3-*diol* (III) gives no indene derivative under analogous conditions.

The synthesis of 1 : 3-*diphenyl*-2 : 3-*dimethylhydrindene* (IV) and 1-*phenyl*-2-*benzyl*-1-*methylhydrindene* (V) is reported. A substance previously described by Koelsch as (II) proves to be the isomeric 3-*phenyl*-2-*anisyl* compound (II*a*).

It has been shown previously (*Ber.*, 1932, **65**, 109; J., 1935, 1020) that alkylhydrobenzoins may be converted by two-fold dehydration into β-arylindenes. The reaction does not occur regularly and the factors governing the possible dehydration processes are not yet clear. Experiments with a pair of structural isomerides which behave differently are now reported. 1 : 3-*Diphenyl*-2-p-*anisylpropane*-2 : 3-*diol* (I), easily prepared from phenyl-*p*-anisoylcarbinol and benzylmagnesium chloride, is partly monoacetylated (compare Orékhoff, *Bull. Soc. chim.*, 1919, **25**, 109; Cobler, Thesis, Berlin, 1932, p. 18) by boiling acetyl chloride, and partly dehydrated to form 1-*phenyl*-2-p-*anisylindene* (II). Pinacolinic rearrangement does not occur under the influence of acetyl chloride, but one of the rearrangement products was obtained directly in the preparation of (I). As, according to Tiffeneau and Lévy (*Bull. Soc. chim.*, 1931, **49**, 1617, 1661), benzylhydrobenzoin loses its secondary hydroxyl on rearrangement and as anisyl migrates in preference to benzyl, this *product* should be (I*a*).

$CH_2Ph\cdot C(OH)(C_6H_4\cdot OMe)\cdot CHPh\cdot OH$

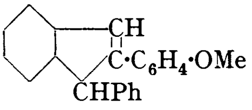
(I.)

$CH_2Ph\cdot CO\cdot CHPh\cdot C_6H_4\cdot OMe$

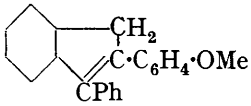
(I*a*).

$CH_2Ph\cdot CPh(OH)\cdot CH(OH)\cdot C_6H_4\cdot OMe$

(III.)



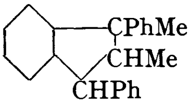
(II.)



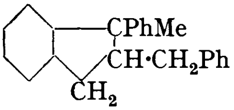
(II*a*.)

The isomeric 1 : 2-*diphenyl*-3-p-*anisylpropane*-2 : 3-*diol* (III), on the other hand, gave no indene derivative on treatment with boiling acetyl chloride or with phosphoric oxide in boiling benzene, rearrangement taking place. Besides the rearranged substance, which proved identical with the ketone (I*a*), a product isomeric with (III) was obtained; its structure could not be elucidated and it may be the hydrate of a second rearrangement product.

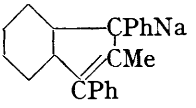
For comparison purposes in similar investigations, 1 : 3-*diphenyl*-2 : 3-*dimethylhydrindene* (IV) and 1-*phenyl*-2-*benzyl*-1-*methylhydrindene* (V) were synthesised by the following methods : (1) The easily accessible 3-phenyl-2-methylindone gave with phenylmagnesium bromide the expected carbinol; this was etherified and treated with sodium metal, the cleavage product (VI) methylated, and the resulting 1 : 3-*diphenyl*-2 : 3-*dimethylindene* hydrogenated, giving (IV). This synthesis is completely analogous to



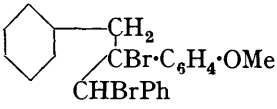
(IV.)



(V.)



(VI.)



(VII.)

that of the " dimeric *as*-diphenylethylene " described by Bergmann and Weiss (*Annalen*, 1930, **480**, 49). (2) From ββ-diphenylbutyric acid, 3-phenyl-3-methyl-1-hydrindone was obtained; its *benzylidene* derivative, on reduction with amalgamated zinc and hydrochloric acid gave (V) directly. This is remarkable, as Borsche (*Ber.*, 1919, **52**, 2077) had observed large resinification on Clemmensen reduction of simpler αβ-unsaturated ketones (compare Dippy and Lewis, *Rec. Trav. chim.*, 1937, **56**, 1001).

Remarks on 1-*Phenyl*-2-p-*anisylindene* (II).—Koelsch (*J. Amer. Chem. Soc.*, 1936, **58**, 1331) assigned formula (II) to a substance, m. p. 120—122°, which he obtained by decomposition of the dibromide (VII). This reaction, however, in the case of the methoxyl-free compound, is known to give a substance containing a methylene group (Orékhoff, *Chem. Zentr.*, 1923, I, 1620; Blum-Bergmann, J., 1935, 1020), so formula (II*a*) would be preferable for Koelsch's compound. The close relationship between our substance (m. p. 188—188·5°) and that of Koelsch is shown by the fact that they both give, in alkaline solution, the same benzylidene derivative, one of the starting materials undergoing allylic rearrangement (II $\rightarrow$ II*a*). That this applies to the isomer, m. p. 188—188·5°, follows from the observation that it is isomerised into the lower-melting product by sodium ethoxide, a reaction which is known to produce isomers containing a methylene group in similar cases.

EXPERIMENTAL.

1 : 3-*Diphenyl*-2-p-*anisylpropane*-2 : 3-*diol* (I).—When phenyl-*p*-anisoylcarbinol (24·2 g.), m. p. 106° (Tiffeneau and Lévy, *Compt. rend.*, 1931, **192**, 287; *Bull. Soc. chim.*, 1931, **49**, 725), was added in small portions to an ethereal solution of benzylmagnesium chloride (7·3 g. of magnesium; 38·1 g. of benzyl chloride, *i.e.*, 3 mols.), a vigorous reaction took place and the product quickly crystallised. The mixture was boiled for 4 hours and decomposed with ice and dilute sulphuric acid, whereupon most of the dihydroxy-compound separated spontaneously, contaminated by one of the possible rearrangement products. They were separated by fractional crystallisation from benzene–light petroleum. The *dihydroxy-compound* (I) crystallised first in colourless needles (10 g. from 15·7 g. of the crude product) and was recrystallised from propyl alcohol or glacial acetic acid; m. p. 155—156·5° (Found : C, 79·0; H, 6·7. $C_{22}H_{22}O_3$ requires C, 79·0; H, 6·6%). Then white clusters appeared, which, on recrystallisation from glacial acetic acid, formed prisms, m. p. 134—135·5° (Found : C, 83·5; H, 6·5. $C_{22}H_{20}O_2$ requires C, 83·5; H, 6·3%). The ethereal solution, after separation of the solid phase, was evaporated; from the oily residue, on trituration with alcohol, 2·85 g. of the diol were isolated.

Dehydration of (I).—When the foregoing glycol (3 g.) was boiled with acetyl chloride (30 c.c.), the product partly crystallised. After 5 hours, the mixture was cooled, and the solid filtered off and washed with light petroleum (yield, 1·63 g.). The substance, which analysis indicated to be a *monoacetyl* derivative of (I), was recrystallised from propyl alcohol, then from glacial acetic acid until the m. p. was constant at 178—179·5°. It gave the same orange-red reaction with sulphuric acid as the diol (I) itself (Found : C, 76·6; H, 6·4. $C_{24}H_{24}O_4$ requires C, 76·6; H, 6·4%).

The filtrate from this substance, on removal of the excess of acetyl chloride, gave 1-*phenyl*-2-p-*anisylindene* (II) (0·85 g.); it was recrystallised from methyl ethyl ketone, then from glacial acetic acid, and formed colourless needles, which gave a yellow liquid at 188—188·5° (Found : C, 88·7; H, 6·0. $C_{22}H_{18}O$ requires C, 88·6; H, 6·0%).

1 : 2-*Diphenyl*-3-p-*anisylpropane*-2 : 3-*diol* (III).—The necessary benzoyl-*p*-anisylcarbinol was prepared from anisaldehyde cyanohydrin (Knorr, *Ber.*, 1904, **37**, 3172) and phenylmagnesium bromide by the method of McKenzie and Luis (*Ber.*, 1932, **65**, 794). The m. p. of our preparation was 88—89°, which is also given by Asahina and Terasaka (*Chem. Zentr.*, 1923, II, 434) and Jenkins (*J. Amer. Chem. Soc.*, 1933, **55**, 3048; 1934, **56**, 682); McKenzie and Luis (*loc. cit.*), McKenzie, Luis, Tiffeneau, and Weill (*Bull. Soc. chim.*, 1929, **45**, 414), and Arnold and Fuson (*J. Amer. Chem. Soc.*, 1936, **58**, 1295) give m. p. 100—101°. As our preparation gives the same yellow colour reaction with sulphuric acid as the substance, m. p. 100—101° (Luis, J., 1932, 2547), they are dimorphic forms rather than isomerides (*p*-anisoylphenylcarbinol has m. p. 106° and gives a green colour in sulphuric acid).

From 10 g. of anisaldehyde cyanohydrin, 8·5—8·7 g. of benzoyl-*p*-anisylcarbinol were obtained, which crystallised from ligroin or dilute alcohol in prismatic needles, m. p. 88—89° (Found : C, 74·5; H, 5·9; OMe, 13·0. Calc. for $C_{15}H_{14}O_3$: C, 74·4; H, 5·8; OMe, 12·8%).

It was characterised by its *oxime* (1 g. of the carbonyl compound in 5 c.c. of alcohol boiled with 0·7 g. of hydroxylamine hydrochloride and 0·4 g. of sodium hydroxide in water for 3 hours), which separated from benzene in silky needles containing about 0·5 mol. of benzene (Found : C_6H_6, 15·2. $C_{15}H_{15}O_3N,0{\cdot}5C_6H_6$ requires C_6H_6, 13·0%). The benzene-free oxime had m. p. 121—122·5° (Found : N, 5·4; OMe, 12·4. $C_{15}H_{15}O_3N$ requires N, 5·4; OMe, 12·1%).

Benzoyl-*p*-anisylcarbinol (1 g.) was isomerised quantitatively within 4 hours by boiling glacial acetic acid (3 g.) containing concentrated hydrochloric acid (2 g.). The mixture was poured into water, and the *p*-anisoylphenylcarbinol extracted with ether and crystallised from alcohol; m. p. and mixed m. p. 106° (for other means of isomerisation, see Luis, J., 1932, 2547; Julian and Passler, *J. Amer. Chem. Soc.*, 1932, **54**, 4756; Buck and Ide, *ibid.*, 1933, **55**, 855).

Benzoyl-*p*-anisylcarbinol (6·1 g.) was added to an ethereal solution of benzylmagnesium chloride (prepared from 1·82 g. of magnesium and 9·48 g. of benzyl chloride). After 5 hours' boiling, the mixture was decomposed with cold dilute sulphuric acid, and the ethereal solution, to which ethyl acetate was added in order to prevent spontaneous crystallisation, evaporated. The solid residue (7·5 g.) crystallised from alcohol in prisms, m. p. 161—163°, of 1 : 2-*diphenyl*-3-p-*anisylpropane*-2 : 3-*diol* (Found : C, 79·2; H, 6·7; OMe, 9·1. $C_{22}H_{22}O_3$ requires C, 79·0; H, 6·6; OMe, 9·3%).

Dehydration. The dihydroxy-compound (III) (2·5 g.) was dissolved in boiling benzene (35 c.c.), and phosphoric oxide (1·5 g.) added in small portions. The vigorous reaction produced a light brown, resinous mass, which was treated with ether and ice-water. The oily product was distilled in a vacuum (b. p. 255—259°; yield, 2·1 g.) and then triturated with alcohol. Slow fractional crystallisation from light petroleum gave brilliant prisms (A) and white needles (B), which were separated mechanically. The prisms (A), after recrystallisation from alcohol or light petroleum, had m. p. 48—49·5°; analysis pointed to the formula $C_{22}H_{22}O_3$ (Found : C, 78·9; H, 6·5; OMe, 10·0; *M*, in camphor, 323, 310. Calc. : C, 79·0; H, 6·6; OMe, 9·3; *M*, 334). The needles (B) crystallised well from propyl alcohol or glacial acetic acid; m. p. and mixed m. p. with the product described on p. 724, 134—135° (Found: C, 83·4; H, 6·5; OMe, 9·8. Calc. for $C_{22}H_{20}O_2$: C, 83·5; H, 6·3; OMe, 9·9%). Acetyl chloride gave the same products as treatment with phosphoric oxide.

αβ-*Dimethylcinnamic Acid.*—This was prepared by Rupe, Steiger, and Fiedler's method (*Ber.*, 1914, **47**, 63; compare Burton and Shoppee, J., 1935, 1156; Ruzicka and Ehmann, *Helv. Chim. Acta*, 1932, **15**, 140) from acetophenone, ethyl α-bromopropionate, and zinc. The ester, obtained by treating the crude condensation product with 3 vols. of 85% formic acid (3 hours at 150°), had b. p. 134—136°/18 mm. The acid, prepared by means of methyl-alcoholic potash, had b. p. 169°/16 mm. and crystallised spontaneously, forming a mass melting at 57—67°. It can be separated into the pure *cis-trans*-isomers by crystallisation from light petroleum (b. p. 80—100°) : from 0·5 g. of the mixture there separates 0·13 g. of thin needles, which after recrystallisation from the same solvent have m. p. 108·5—110° (Found : C, 74·9; H, 7·0. Calc. for $C_{11}H_{12}O_2$: C, 75·0; H, 6·8%); the mother-liquor of the 0·13 g. leaves, on evaporation, hexagons, which are conveniently recrystallised from 20% acetic acid, forming plates, m. p. 105—107° (Found : C, 75·1; H, 6·9%).

ββ-*Diphenyl*-α-*methylbutyric Acid.*—The mixture of isomeric αβ-dimethylcinnamic acids (19·5 g.) was dissolved in benzene (250 c.c.) and, after addition of powdered aluminium chloride (17 g.), kept at room temperature for 7 days; the brown mass was then decomposed with ice and concentrated hydrochloric acid. The benzene layer was extracted with sodium carbonate solution and evaporated; the residue, after trituration with and recrystallisation from light petroleum (b. p. 40—80°), gave 2 : 3-dimethylindone (1·3 g.), m. p. 78—79°. On acidification, the alkaline extract gave a viscous oil, which was isolated by ether extraction and triturated with light petroleum (b. p. 80—100°). The ββ-*diphenyl*-α-*methylbutyric acid* thus obtained crystallised from 70% acetic acid or 70% methyl alcohol in prismatic needles (10·3 g.), m. p. 124—126° (Found : C, 80·3; H, 7·2. $C_{17}H_{18}O_2$ requires C, 80·3; H, 7·1%). The light petroleum mother-liquor contained an oil, which after distillation (b. p. 167—175°/15·5 mm.) crystallised spontaneously (yield, 5·5 g.); it was recrystallised from 50% acetic acid, forming leaflets, m. p. 132—133·5°. The analysis showed that, under the influence of aluminium chloride, partial transfer of hydrogen had taken place (compare Pummerer and Binapfl, *Ber.*, 1921, **54**, 2768; 1922, **55**, 3095), β-phenyl-α-methylbutyric acid (Rupe, Steiger, and Fiedler, *loc. cit.*) being formed (Found : C, 74·4; H, 8·1. Calc. for $C_{11}H_{14}O_2$: C, 74·1; H, 7·9%).

ββ-*Diphenyl*-α-*methylbutyryl chloride* (9·3 g.) was obtained from the acid (9·8 g.) and warm thionyl chloride (30 c.c.) and was immediately distilled; b. p. 188—189°/17 mm. (Found : C, 75·2; H, 6·5; Cl, 13·1. $C_{17}H_{17}OCl$ requires C, 74·8; H, 6·2; Cl, 13·0%).

3-*Phenyl*-2 : 3-*dimethyl*-1-*hydrindone*.—When powdered aluminium chloride (5·2 g.) was added in small portions to a solution of the foregoing chloride (9·3 g.) in carbon disulphide (30 c.c.), a vigorous reaction occurred; after 2 hours' boiling, the mixture was decomposed with cold hydrochloric acid, and the *hydrindone* obtained as a viscous oil (7·6 g.), b. p. 189—192°/16 mm. (Found: C, 86·5; H, 7·0. $C_{17}H_{16}O$ requires C, 86·4; H, 6·8%). It was recovered mostly unchanged after treatment with phenylmagnesium bromide and therefore could not be utilised for the preparation of (IV).

1 : 3-*Diphenyl*-2-*methyl*-1-*indenol*.—An ethereal solution of phenylmagnesium bromide (from 4·9 g. of magnesium and 20·9 c.c. of bromobenzene) and 3-phenyl-2-methylindone (22 g.) (Bergmann and Weiss, *Annalen*, 1930, **480**, 73) was boiled for 2 hours, and the crystalline cake decomposed with ice and ammonium chloride. The crude carbinol (34 g.), which would not crystallise, was boiled for 4 hours with methyl alcohol (340 c.c.) and concentrated hydrochloric acid (17 c.c.), most of the solvent distilled off (250 c.c.), and the residue treated with water and ether. The *methyl* ether crystallised spontaneously after distillation (b. p. 215—220°/10 mm.). It was triturated with methyl alcohol and recrystallised from alcohol, forming prisms (18·8 g.), m. p. 71—72·5°. With concentrated sulphuric acid it gave a brown-red colour (Found: C, 88·8; H, 6·5. $C_{23}H_{20}O$ requires C, 88·5; H, 6·4%).

1 : 3-*Diphenyl*-2 : 3-*dimethylindene* (VI, with Me instead of Na).—The foregoing ether (5 g.) in ethereal solution was shaken with sodium powder for 3 days, lemon-yellow, silky needles of the sodium compound (VI) separating. After addition of an excess of methyl iodide (6 c.c.) the colourless ethereal solution was washed with water, dried, and evaporated, and the residue triturated with alcohol and recrystallised from the same solvent or from light petroleum (b. p. 40—60°), forming cubic crystals (3·9 g.), m. p. 68·5—69·5° (Found: C, 93·4; H, 6·9. $C_{23}H_{20}$ requires C, 93·2; H, 6·8%).

1 : 3-*Diphenyl*-2 : 3-*dimethylhydrindene* (IV).—The foregoing hydrocarbon (3 g.) was catalytically hydrogenated in boiling propyl alcohol (15 c.c.) in presence of palladised barium sulphate (1·5 g.) for 6 hours. The solvent was evaporated, and the residue triturated with alcohol. 1 : 3-*Diphenyl*-2 : 3-*dimethylhydrindene* separated from the same solvent or from glacial acetic acid in octahedra (2·1 g.), m. p. 97·5—98·5° (Found: C, 92·7; H, 7·5; *M*, in camphor, 310, 328. $C_{23}H_{22}$ requires C, 92·6; H, 7·4%; *M*, 298). The mother-liquor contained a viscous oil, b. p. 222—223°/10 mm., which may have contained isomeric forms of the crystalline hydrocarbon but was not investigated.

2-*Benzylidene*-3-*phenyl*-3-*methyl*-1-*hydrindone*.—A mixture of 3-phenyl-3-methyl-1-hydrindone (1·1 g.) (Blum-Bergmann, *Ber.*, 1932, **65**, 118) and benzaldehyde (0·53 g.) was dissolved in alcohol (20 c.c.) at 50°, and 25% alcoholic potassium hydroxide (5 drops) added. The brown mixture was kept at 0° for 2 days and then poured into water. The *product*, isolated by extraction with ether, crystallised spontaneously; recrystallised from methyl alcohol, it formed stout prisms (0·4 g.), m. p. 121—122° (Found: C, 89·3; H, 5·8. $C_{23}H_{18}O$ requires C, 89·0; H, 5·8%).

1-*Phenyl*-2-*benzyl*-1-*methylhydrindene* (V).—The preceding benzylidene derivative (1 g.) was boiled with amalgamated zinc wool (8 g.) and concentrated hydrochloric acid until the metal had dissolved. The *product* was extracted in ether, washed with sodium hydroxide solution, dried, and recovered. The residue crystallised on treatment with acetone and was recrystallised from propyl alcohol, forming long white needles (0·6 g.), m. p. 117—118·5° (Found: C, 92·2; H, 7·5. $C_{23}H_{22}$ requires C, 92·6; H, 7·4%).

Experiments with 1-*Phenyl*-2-p-*anisylindene* (II).—(a) The indene derivative (1 g.) was suspended in boiling propyl alcohol (50 c.c.), and sodium ethoxide solution and benzaldehyde added according to Koelsch's prescription (*loc. cit.*). The clear, reddish solution deposited, on standing, a bright yellow precipitate of the benzylidene derivative, which, after recrystallisation from propyl alcohol, formed needles, m. p. 192—193°, as reported by Koelsch.

(b) When a suspension of the indene derivative (0·5 g.) in propyl alcohol (10 c.c.) was treated with a solution of sodium (0·1 g.) in alcohol (2·5 c.c.), the temperature rose markedly and a clear solution was formed. On standing, the isomeric indene (II*a*) was precipitated; it separated from alcohol in silky needles, m. p. 120—121°, as stated by Koelsch (*loc. cit.*).

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