

105. The Stereoisomeric $\alpha\alpha'$ -Di-(1-naphthyl)succinic Acids.

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The ethyl meso- and dl- $\alpha\alpha'$ -di-(1-naphthyl)succinates, and thence the corresponding acids and their anhydrides, have been synthesised from ethyl 1-naphthylacetate. Their respective structures may be inferred from the resemblance of the stereoisomers to the meso- and dl-diphenylsuccinates, which have already been explicitly oriented (Wren and Still, J., 1915, **107**, 444). The dinaphthyl compounds failed to undergo internal condensation comparable with the cyclisation of the diphenyl analogues to diphenylsuccindone.

It has long been known that the symmetrical diphenylsuccinic acids easily undergo ring closure with formation of the diketone diphenylsuccindone (Reimer, *Ber.*, 1881, **14**, 1806; Roser, *Annalen*, 1888, **247**, 153). The following work on the $\alpha\alpha'$ -di-(1-naphthyl)succinic acids is the outcome of an attempt to prepare, by a somewhat similar cyclisation involving the carboxyl groups with their respective *peri*-positions in the naphthalene nuclei, a hexacyclic dihydric phenol for oxidation to one of the possible isomers of the dyes anthanthrone and the dibenzpyrenequinones.

The preparation of the dinaphthylsuccinic acids, in the form of their ethyl esters, was accomplished in the manner described by Wren and Still (*loc. cit.*, p. 446) for the analogous ethyl diphenylsuccinates, that is, the oxidative condensation of two molecules of the arylacetic ester by iodine in presence of sodium ethoxide. The requisite ester was synthesised from either 1-naphthylmethyl chloride or bromide through the related nitrile, a very pure specimen of which was obtained by dehydration of 1-naphthylacetamide, and this was converted into ethyl 1-naphthylacetate as described by Wislicenus and Elvert (*Ber.*, 1916, **49**, 2823).

The product separating after treatment of an ethereal solution of the naphthylacetic ester with alcohol-free sodium ethoxide and iodine contained only one of the stereoisomeric di-(1-naphthyl)succinates, but when the ether-soluble residues, much contaminated with iodinated products, were dissolved in alcohol, further small amounts of crystalline solid were sometimes obtained from which a lower-melting di-(1-naphthyl)succinic ester was isolated. This corresponds closely to experience in the diphenylsuccinic ester series, for Wren and Still, by resolving the low-melting, more soluble product, were able to assign definite configurations to the two isomerides. An attempt to do this with the dinaphthylsuccinic esters was unsuccessful, because the vitreous strychnine and brucine salts could not be crystallised, but the close resemblance which we have found in the properties of the respective isomers of the two series appears to justify the view that the higher-melting, less soluble succinic ester—obtained in yields varying with the quality of the sodium ethoxide from 20 to 40%—is also a meso-compound, while its more soluble isomer is a racemate.

Hydrolysis of the meso-ester, with hydrochloric acid under pressure, gave meso- $\alpha\alpha'$ -di-(1-naphthyl)succinic acid, whereas under alkaline conditions rearrangement to the isomeric dl-acid occurred. This resembles the behaviour of the meso-diphenylsuccinate, and it affords an alternative route to the racemic ester, which is formed on esterification in the usual manner.

Probably because of its general insolubility, the meso-acid is less reactive than its racemic isomer. Thus, in preparing the acid anhydrides, prolonged heating with acetyl chloride in a sealed tube was required for the meso-compound, whereas the dl-acid reacted with the dehydrating agent boiling under atmospheric pressure. For this reason, the ring-closure experiments outlined in the experimental section were largely confined to the racemates. Sulphuric acid, so successful in the preparation of diphenylsuccindone, apparently leads to sulphonation. Other cyclising agents having any action on the dl-acid or its ethyl ester, except thionyl chloride which gave an unidentified product, either destroyed the compound or led to the formation of the dinaphthylsuccinic anhydride.

It is possible that the tendency to anhydride formation may be overcome and ring closure favoured by using di-(1-naphthyl)fumaric acid in place of the succinic acids. Experiments on its synthesis were only at a preliminary stage, in 1939, when the work had to be interrupted.

EXPERIMENTAL.

1-Naphthylmethyl Chloride and Bromide.—For the chloride we used Cambron's modification (*Canadian J. Res.*, 1939, **17B**, 10) of the Blanc synthesis from naphthalene, paraform, and hydrochloric acid (*Bull. Soc. chim.*, 1923, **33**, 313). Since our work was done, the method has been still further improved by Fieser and Gates (*J. Amer. Chem. Soc.*, 1940, **62**, 2335) and by Grummit and Buck (*ibid.*, 1943, **65**, 295). The first experiments on the dinaphthylsuccinic acids (King, 1933), however, started with 1-naphthylmethyl bromide, prepared from 1-methylnaphthalene as described by Mayer and Oppenheimer (*Ber.*, 1916, **49**, 2137; see also Wislicenus and Elvert, *loc. cit.*, and Olivier and Wit, *Rec. Trav. chim.*, 1937, **56**, 853), except that bromination at 180° gave a cleaner product and a somewhat better yield. The fraction of the extremely lachrymatory product of b. p. 145–150°/1 mm., yield 35–40%, crystallised from light petroleum in

highly refracting rhombic tablets, m. p. 55° (lit., 45—46° to 56°) (Found: C, 43.8; H, 2.7. Calc. for $C_{11}H_9Br$: C, 44.0; H, 2.7%).

1-Naphthylacetoneitrile.—As indicated by Wislicenus and Elvert (*loc. cit.*), the conversion of naphthylmethyl bromide into the nitrile by use of potassium cyanide occurs exothermally, but the yield is lower than when 1-naphthylmethyl chloride is used. The distilled product, usually described as a liquid at ordinary temperatures (cf., however, Briggs and Wilson, J., 1941, 500), readily solidified and had m. p. ca. 34° after softening above 25°.

When 1-naphthylacetamide (10 g.) (Boessneck, *Ber.*, 1883, 16, 641) was heated under reflux with thionyl chloride (15—20 c.c.), it slowly dissolved (25—30 mins.), and by evaporation 1-naphthylacetoneitrile, b. p. 192°/18 mm., was obtained as a solid, m. p. 35—37° (Found: C, 86.2; H, 5.6. Calc. for $C_{12}H_9N$: C, 86.2; H, 5.4%).

Ethyl 1-Naphthylacetate.—Conversion of the nitrile into the ester followed the method of Wislicenus and Elvert (*loc. cit.*) except that absolute ethanol was used to avoid formation of 1-naphthylacetamide, obtained when the alcohol was not anhydrous. Crude naphthylacetic acid can be converted into the pure ester, b. p. 183°/17 mm., by means of thionyl chloride, the resulting acid chloride, b. p. 180°/17 mm., being poured into alcohol (Found: C, 78.0; H, 6.7. Calc. for $C_{14}H_{14}O_2$: C, 78.5; H, 6.7%).

Ethyl meso- and dl- $\alpha\alpha'$ -Di-(1-naphthyl)succinates.—A solution of sodium (3 g.) in absolute ethanol (50 c.c.) contained in a 3-necked flask was evaporated to dryness and finally heated to 100° under reduced pressure. When the colourless residue had been covered with ether (60 c.c.) containing ethyl 1-naphthylacetate (25 g.) and broken up by vigorous stirring, a solution of iodine (15 g.) in ether (80 c.c.) was slowly introduced (40—50 mins.) while the temperature was held at 0°. After several hours at room temperature, the product was shaken with aqueous thiosulphate, and the residual solid collected (yields varied from 5.5—9.5 g.). Crystallisation by concentrating a solution in boiling alcohol gave ethyl meso- $\alpha\alpha'$ -di-(1-naphthyl)succinate in colourless prisms, m. p. 176° after contracting at 159—160° (Found: C, 78.7; H, 6.1. $C_{28}H_{26}O_4$ requires C, 78.9; H, 6.1%).

When the ethereal solutions in which this ester had been prepared were evaporated, and the residues dissolved in the minimum amount of boiling alcohol, further small quantities of the meso-ester were obtained mixed with the racemic ester. The two products were separated by crystallisation from alcohol, and the more soluble dl-ester was finally obtained as colourless short prisms, m. p. 144° (Found: C, 79.0; H, 6.1%). Occasionally, evaporation of the reaction solvent gave only a dark red syrup yielding no further crystalline products. It contained much iodine, which was liberated on attempted high-vacuum distillation, even when the material had been refluxed in alcohol with amalgamated aluminium.

meso- $\alpha\alpha'$ -Di-(1-naphthyl)succinic Acid.—The meso-ester (2 g.) was heated with concentrated hydrochloric acid (10 c.c.) in a sealed tube at 190—200° for 6 hours. The greenish-white product (1.7 g.) was dissolved in warm aqueous bicarbonate, and the filtered solution acidified. The precipitated acid, almost insoluble in the usual solvents, crystallised from cyclohexanone or acetophenone diluted with light petroleum in microscopic, colourless needles, m. p. 260—261° (efferv.) (Found, after drying at 120°: C, 76.5, 76.4; H, 5.0, 5.2. $C_{24}H_{18}O_4$ requires C, 77.8; H, 4.8%. $C_{24}H_{18}O_4 \cdot \frac{1}{2}H_2O$ requires C, 76.0; H, 5.0%).

The dried acid (1 g.) was heated under reflux for 8 hours with ethyl alcohol (20 c.c.) previously saturated at 0° with hydrogen chloride. Water was then added, and the suspension made alkaline with sodium carbonate to remove unchanged dinaphthylsuccinic acid. Recrystallisation of the residue (0.4 g.) from alcohol gave the meso-ester, m. p. and mixed m. p. 176°.

dl- $\alpha\alpha'$ -Di-(1-naphthyl)succinic Acid.—The ethyl meso-dinaphthylsuccinate (2 g.) was refluxed with a solution of potassium hydroxide (1.1 g.) in water (2 c.c.) and alcohol (23 c.c.). Within 10 minutes the ester had dissolved and after 20 minutes the solution was diluted with water (25 c.c.), neutralised with concentrated hydrochloric acid (2.5 c.c.), and the alcohol evaporated at 100°. The solid (1.8 g.) collected next day was heated with glacial acetic acid to remove the sparingly soluble meso-acid (mixed m. p.), and the acetic acid solution diluted with hot water (30—40 c.c.). The dl-dinaphthylsuccinic acid separated in colourless needles, m. p., after recrystallisation from aqueous acetic acid, alcohol, or acetone, 247° (efferv.) (Found, after drying at 130°: C, 76.2, 76.4; H, 5.1, 5.1. $C_{24}H_{18}O_4 \cdot \frac{1}{2}H_2O$ requires C, 76.0; H, 5.0%).

The racemic acid was esterified essentially as for the meso-acid, and the purified ester formed colourless needles, m. p. 144° alone or mixed with the more soluble dl-dinaphthylsuccinate isolated from the naphthylacetic ester condensation.

meso- $\alpha\alpha'$ -Di-(1-naphthyl)succinic Anhydride.—The meso-acid (2 g.) was heated with acetyl chloride (15 g.) in a sealed tube at 100° for 10 hours. Evaporation of the excess reagents under reduced pressure left a gum which was treated with boiling benzene. Addition of light petroleum to the filtered liquid gave the meso-anhydride in colourless small needles, m. p. 171° (Found: C, 82.0; H, 4.6. $C_{24}H_{18}O_3$ requires C, 81.8; H, 4.5%).

dl- $\alpha\alpha'$ -Di-(1-naphthyl)succinic Anhydride.—The racemic acid (1 g.) was heated under reflux on a steam-bath with acetyl chloride and slowly passed into solution. The surplus acetyl chloride was evaporated in a desiccator, leaving a crystalline product. When recrystallised from benzene-petroleum, the racemic anhydride formed colourless needles, m. p. 160—161° (Found: C, 82.0; H, 4.6%).

Ring-closure Experiments.—The meso-ester dissolved in cold concentrated sulphuric acid, but was not precipitated by water. On the other hand, it was unattacked by the 75—80% acid during 1 hour at 100°. Warm phosphoryl chloride dissolved the ester without change, but heating to 100° for 15 minutes and pouring on ice gave a tarry product.

The dl-acid (2 g.) in boiling moist benzene (50 c.c.) was gradually treated with phosphoric anhydride (5 g.) (cf. Robinson and Koebner, J., 1938, 1994) and refluxed for 2 hours. After being poured on ice, the benzene solution was dried and evaporated, and gave the racemic anhydride, m. p. 161° (Found: C, 81.4; H, 4.7%). To a solution of the dl-acid (2 g.) in warm syrupy phosphoric acid, phosphoric anhydride (15 g.) was added. After stirring for 1 hour, addition of ice gave a benzene-insoluble product which crystallised from acetic acid and was identified as the original dinaphthylsuccinic acid. A mixture of the acid (2 g.), anhydrous stannic chloride (15 g.), and benzene (20 c.c.) was heated at 100° for an hour. Pouring on ice precipitated unchanged acid, and nothing was found in the benzene layer.

Thionyl chloride was without appreciable action on the meso-acid, but dl-di-(1-naphthyl)succinic acid (1 g.) dissolved in refluxing thionyl chloride (4 c.c.) in 25 minutes. The product remaining on evaporation was ground with water until the washings were chloride-free. Two crystallisations from acetic acid gave lemon-yellow tablets, m. p. 165—167° (Found: C, 79.9, 79.4; H, 4.2, 4.5%; Cl, a trace). The compound dissolved in boiling alcohol, but the colourless solid which separated on cooling appeared to be dl-dinaphthylsuccinic acid, m. p. ca. 235° (efferv.) (Found: C, 76.9; H, 5.4%).