689. *Syntheses of Polycylic Systems. Part II.* 8-Ketodibenzo*[c,mn]*acridine and* 8 : 16-*Diazadibenzo*[b,k]*perylene.*

By E. A. Braude and J. S. Fawcett.

The Diels–Alder reaction between *o*-nitrophenylbutadiene and 1 : 4-naphthaquinone is accompanied by dehydrogenation of the resulting tetrahydro-1-*o*-nitrophenylanthraquinone (I) to the dihydroanthraquinone (II) or the anthraquinone (III), depending on the conditions employed. On treatment with methanolic potassium hydroxide, the tetrahydroanthraquinone (I) undergoes an internal oxidation–reduction reaction and simultaneous dehydration to the anthrone (V), which is also obtained by reduction of the anthraquinone (III) with sodium dithionite (hydrosulphite).

The addition of *o*-nitrophenylbutadiene to 1 : 4-benzoquinone in nitrobenzene solution gives a mixture of 1 : 5-di-*o*-nitrophenylanthraquinone (VI) and the 1 : 8-isomer (VIII). The former undergoes reduction and dehydration to 8 : 16-diazadibenzo[*b,k*]perylene (VII); the latter undergoes reduction and cyclisation to (IX).

The work described in this paper illustrates the extension of the new phenanthridine synthesis described in Part I (preceding paper) to higher polycyclic derivatives.

o-Nitrophenylbutadiene readily reacts with 1 : 4-naphthaquinone in boiling benzene to give a mixture of the expected tetrahydro-1-*o*-nitrophenylanthraquinone (I) and the corresponding

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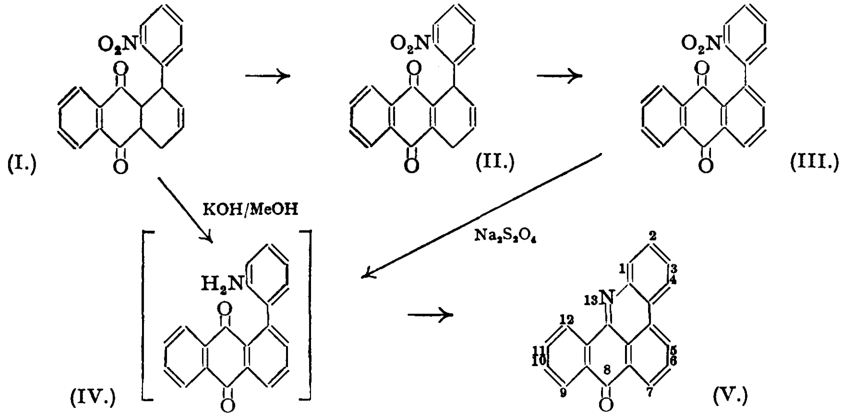
* Part I, preceding paper.

dihydroanthraquinone (II). The position of the two non-aromatic hydrogen atoms in (II) has not been proved, but is not in doubt since 1 : 4-dihydroquinones are invariably the first oxidation products of tetrahydro-anthra- or -naphtha-quinones (Diels and Alder, *Ber.*, 1929, **62**, 2337; Fieser, *J. Amer. Chem. Soc.*, 1948, **70**, 3165). Partial dehydrogenation accompanying Diels–Alder reactions has previously been observed in a number of cases, though usually under rather more drastic reaction conditions (cf. Clar, *Ber.*, 1936, **69**, 1686; Bergmann *et al.*, *J. Amer. Chem. Soc.*, 1938, **60**, 1331; 1942, **64**, 176; *J. Org. Chem.*, 1942, **7**, 303; Swain and Todd, *J.*, 1942, 626). The formation of the dihydroanthraquinone (II) under relatively mild conditions shows that the dehydrogenation is facilitated by the strongly electron-attracting *o*-nitrophenyl substituent; this effect is, of course, analogous to the enhanced reactivity of the methyl group in nitrotoluene as compared with toluene towards oxidising agents.



When the unpurified tetrahydroanthraquinone (I) is treated with warm 2% methanolic potassium hydroxide solution, a rapid colour change takes place and the desired cyclisation product (V) is obtained in 65% yield. The direct conversion of (I) into (V) under these conditions is somewhat unexpected and presumably proceeds through 1-*o*-aminophenylanthraquinone (IV) which then undergoes spontaneous dehydration. Since 1-*o*-nitrophenylanthraquinone remains unchanged even in boiling methanolic potassium hydroxide (see below), the direct conversion of (I) into (V) must involve a hydrogen-transfer reaction in which the tetrahydroanthraquinone grouping is dehydrogenated, probably intramolecularly, by the *o*-nitro-substituent. A similar internal oxidation–reduction reaction, though under very much more drastic conditions, occurs in the conversion of 1 : 4 : 5 : 6-tetrahydro-2-*o*-nitrophenylbenzoic acid into phenanthridone when heated with selenium (Part I, *loc. cit.*).

When the condensation between *o*-nitrophenylbutadiene and naphthaquinone was carried out in nitrobenzene at 100° the main product isolated was the dihydroanthraquinone (II), and at 150° the only product obtained was 1-*o*-nitrophenyl-9 : 10-anthraquinone (III). Here, dehydrogenation is evidently effected intermolecularly, with the nitrobenzene solvent acting as oxidising agent (cf. Bergmann *et al.*, *loc. cit.*; Swain and Todd, *loc. cit.*). The dihydroanthraquinone (II) is oxidised to the anthraquinone (III) when warmed with methanolic potassium hydroxide. The fully oxidised anthraquinone (III) remains unchanged even in boiling methanolic potassium hydroxide, but undergoes simultaneous reduction and dehydration to the anthrone (V) on treatment with alkaline sodium dithionite, presumably *via* the aminoquinone (IV). 8-Ketodibenzo[*c, mn*]acridine (Ring Index 3307) has been synthesised by Koelsch (*J. Amer. Chem. Soc.*, 1936, **58**, 1325) by another route starting from *o*-aminodiphenyl. It does not form a picrate or 2 : 4-dinitrophenylhydrazone under the usual conditions. When warmed with zinc and hydrochloric acid, it is reduced to a dark blue dihydro-derivative, which is readily oxidised back to the anthrone on exposure to air.

The ultra-violet light absorption of (V) closely resembles that of the carbocyclic analogue (Fig. 1), in accordance with the general experience that the replacement of one C⁚C by a C⁚N group in cyclic systems does not appreciably alter the spectral characteristics in this region (cf. Braude, *Ann. Reports*, 1945, **42**, 108; Barany, Braude, and Pianka, *J.*, 1949, 1898; Albert, Brown, and Cheeseman, *J.*, 1951, 474; Clemo and Felton, *ibid.*, p. 671).

The reaction between *o*-nitrophenylbutadiene and benzoquinone in benzene or nitrobenzene gives partly dehydrogenated mono- and di-addition products which are difficult to separate. However, when the diene (2 moles) and benzoquinone (1 mole) are heated together in nitrobenzene at 100° for 12 hours, the fully dehydrogenated di-addition product, 1 : 5-bis-*o*-nitrophenylanthraquinone (VI) can be isolated in 20% yield, together with a smaller quantity of the 1 : 8-isomer (VIII). The structures of the two products follow from the cyclisation reactions described below. The formation of both possible di-adducts in the reaction between benzoquinone and unsymmetrically substituted dienes has been observed in other cases (cf. Diels and Alder, *Ber.*, 1929, **62**, 2337), but with phenylbutadiene only the 1 : 5-di-adduct appears to be formed (Bergmann *et al.*, *J.*, 1939, 391; *J. Org. Chem.*, 1942, **7**, 303).

On treatment with sodium dithionite in boiling aqueous ethanol, the anthraquinone (VI) is converted directly into the desired fully cyclised product (VII), whereas the anthraquinone (VIII) is converted into the anthrone (IX), which forms a picrate and exhibits ultra-violet light absorption properties very similar to those of the parent (V).

FIG. 1.

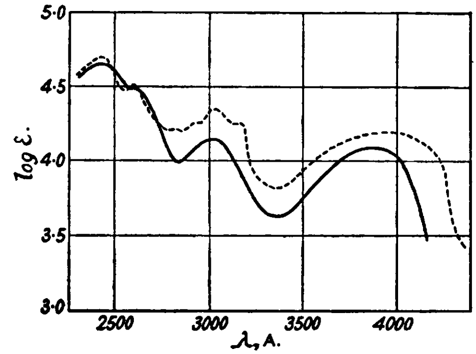


FIG. 2.

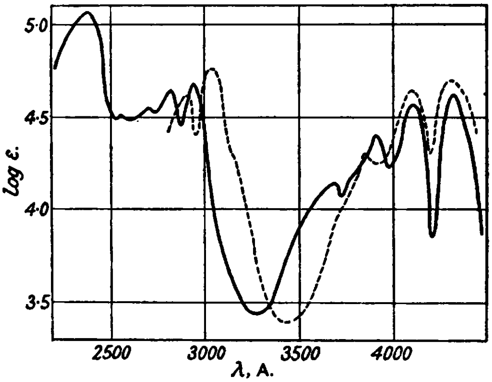


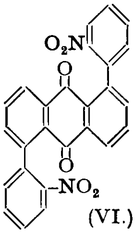
FIG. 1.

Light absorption of (V) (———) *and its carbocyclic analogue* (– – – – –) *in chloroform.*

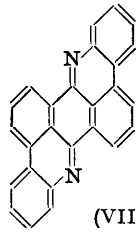
FIG. 2.

Light absorption of (VII) (———) *in dioxan and its carbocyclic analogue* (– – – – –; *from Clar,* loc. cit.) *in benzene.*

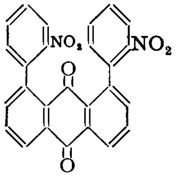
The heptacyclic compound (VII) is a light yellow solid which is almost insoluble in the usual solvents and does not melt below 360°, and is characterised by a picrate. Its light-absorption properties (Fig. 2) closely resemble those of the carbocyclic analogue (Clar, *Ber.*, 1932, **65**, 846; Zinke and Ziegler, *Ber.*, 1940, **73**, 115; Schauenstein and Bürgermeister, *Ber.*, 1943, **76**, 205) and, as would be expected, its solutions are highly fluorescent. An examination of some possible biological properties was kindly carried out by Professor A. Haddow, who reports that, at a dosage of 250 mg./kg., it appeared to be without effect on the growth of the Walker rat carcinoma 256.



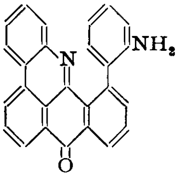
(VI.)



(VII.)



(VIII.)



(IX.)

EXPERIMENTAL.

(M.p.s are uncorrected.)

Reaction between 1-o-*Nitrophenylbutadiene and Naphthaquinone*.—(*a*) 1-*o*-Nitrophenylbutadiene (12 g.) (Part I, *loc. cit.*), naphthaquinone (8 g.), and benzene (50 ml.) were refluxed for 24 hours. Most of the solvent was removed by distillation and the residue (14 g.) solidified; it was a mixture of 1 : 4 : 11 : 12-tetrahydro- and 1 : 4-*dihydro*-1-o-*nitrophenylanthra*-9 : 10-*quinone*, from which the latter was isolated by crystallisation from ethyl acetate as yellow crystals, m. p. 188—190° (Found : C, 72·3; H, 4·0. $C_{20}H_{13}O_4N$ requires C, 72·5; H, 3·95%).

A suspension of the dihydro-compound (0·35 g.) in 2% methanolic potassium hydroxide solution (20 ml.) was boiled in a stream of oxygen for 30 minutes, and the mixture was cooled, diluted with water, and filtered, to give 1-o-*nitrophenylanthraquinone* (0·28 g.), which crystallised from ethyl acetate in yellow prisms, m. p. 213° (Found : C, 72·9; H, 3·3; N, 4·2. $C_{20}H_{11}O_4N$ requires C, 72·9; H, 3·4; N, 4·2%). Light absorption in chloroform : $\lambda_{max.}$ 2570 and 3380 A.; ε = 44,600 and 2300, respectively.

(*b*) 1-*o*-Nitrophenylbutadiene (2 g.), naphthaquinone (2 g.), and nitrobenzene (10 ml.) were heated together at 100° for 3 hours. On cooling and dilution with ethanol (50 ml.), a pale yellow solid separated (1·7 g.), which was crystallised from ethyl acetate to give 1 : 4-dihydro-1-*o*-nitrophenylanthraquinone, m. p. 186°, undepressed on admixture with the above sample.

(*c*) 1-*o*-Nitrophenylbutadiene (2 g.), naphthaquinone (2 g.), and nitrobenzene (10 ml.) were heated together at 150° for 2 hours. On cooling and dilution with ethanol, a yellow product separated, which crystallised from ethyl acetate to give yellow prisms of 1-*o*-nitrophenylanthraquinone (1·4 g.), m. p. 213°, undepressed on admixture with the sample obtained above.

A suspension of 1-*o*-nitrophenylanthraquinone (0·55 g.) in 10% methanolic potassium hydroxide (40 ml.) was boiled for 30 minutes. On working up the product, unchanged 1-*o*-nitrophenylanthraquinone (0·5 g.) was obtained.

8-*Ketodibenzo*[c,mn]*acridine* (V).—(*a*) Crude tetrahydro-1-*o*-nitrophenylanthraquinone (4 g.) from (*a*) above, was boiled with 2% alcoholic potassium hydroxide solution (50 ml.) in the presence of oxygen. The suspension was diluted with water, filtered, washed with dilute acid and water, and then sublimed, to give the pentacyclic product (2·5 g.), which crystallised from ethyl acetate in yellow needles, m. p. 218°. Koelsch (*J. Amer. Chem. Soc.*, 1936, **58**, 1325) gives m. p. 221—223° from xylene (Found : C, 85·1; H, 3·9; N, 5·0. Calc. for $C_{20}H_{11}ON$: C, 85·4; H, 3·9; N, 5·0%). Light absorption in chloroform : $\lambda_{max.}$ 2420, 3030, and 3860 A.; ε = 42,000, 14,400, and 13,200, respectively.

(*b*) 1-*o*-Nitrophenylanthraquinone (0·75 g.), sodium dithionite (1·5 g.), methanol (15 ml.), and 10% sodium hydroxide solution (15 ml.) were heated under reflux for 1 hour in an atmosphere of nitrogen. The brown solid was filtered off, washed with water, and dried. On boiling with ethyl acetate (150 ml.) it gave a red solution which gradually changed to yellow, and on cooling gave yellow needles (0·45 g.), m. p. 218°, undepressed on admixture with the above material.

1 : 5-*Bis*-o-*nitrophenylanthra*-9 : 10-*quinone*.—1-*o*-Nitrophenylbuta-1 : 3-diene (32 g.), benzoquinone (8 g.), and nitrobenzene (30 ml.) were heated at 100° for 12 hours. Most of the solvent was removed by distillation at 2 mm. and the solid residue was extracted with hot pyridine. From the pyridine solution, the *quinone* (9 g.) separated and after repeated crystallisation from pyridine formed yellow plates, m. p. 311° (Found : C, 69·2; H, 3·1. $C_{26}H_{14}O_6N_2$ requires C, 69·3; H, 3·15%). Light absorption in chloroform : $\lambda_{max.}$ 2580 and 3300, inflection at 2510 A.; ε = 47,000, 7000, and 40,500, respectively. The pyridine-insoluble fraction (0·9 g.) was 1 : 8-*bis*-o-*nitrophenylanthraquinone*, which crystallised from nitrobenzene in yellow rods, m. p. 320° (decomp.) (Found : C, 69·1; H, 3·4; N, 6·1. $C_{26}H_{14}O_6N_2$ requires C, 69·3; H, 3·15; N, 6·2%). Light absorption in chloroform : $\lambda_{max.}$ 2580 and 3150 A.; inflection at 3300 A.; ε = 46,00, 8000, and 6300, respectively. Both products remained unchanged on treatment with hot 10% alcoholic potassium hydroxide solution.

8 : 16-*Diazadibenzo*[b,k]*perylene*.—1 : 5-Bis-*o*-nitrophenylanthraquinone (3 g.), sodium dithionite (10 g.), methanol (30 ml.), and 5% sodium hydroxide solution (60 ml.) were heated under reflux for 1 hour in an atmosphere of nitrogen. The dark green product (2·8 g.) was filtered off, washed with dilute acid and water, boiled with pyridine (10 ml.), filtered, and crystallised from nitrobenzene, to give orange-yellow needles of 8 : 16-*diazadibenzo*[b,k]*perylene*, cf. Ring Index 3833), m. p. >360° (Found : C, 87·8; H, 4·15; N, 7·8. $C_{26}H_{14}N_2$ requires C, 88·1; H, 3·95; N, 7·9%). Light absorption in dioxan : $\lambda_{max.}$ 2380, 2570, 2700, 2810, 2940, 3700, 3920, 4120, and 4350 A.; ε = 117,000, 31,800, 34,000, 40,500, 47,700, 13,200, 20,500, 37,000, and 40,500, respectively. The product is slightly soluble in chloroform and dioxan, forming yellow solutions with a blue fluorescence, and dissolves in concentrated sulphuric acid to give an orange solution. A solution in nitrobenzene when warmed with picric acid gave a *picrate*, which crystallised from nitrobenzene in fine red needles, m. p. 311° (Found : C, 66·2; H, 3·0; N, 11·65. $C_{32}H_{17}O_7N_5$ requires C, 65·9; H, 2·9; N, 12·0%).

12-o-*Aminophenyl*-8-*ketodibenzo*[c,mn]*acridine*.—1 : 8-Bis-*o*-nitrophenylanthraquinone (0·6 g.), sodium dithionite (3 g.), methanol (10 ml.), and 5% aqueous sodium hydroxide (20 ml.) were heated under reflux for 1 hour under nitrogen. After cooling, the solution was diluted with water (20 ml.) and the precipitated 12-o-*aminophenyl*-8-*ketodibenzo*[c,mn]*acridine* was filtered off, dissolved in benzene, chromatographed on an alumina column with benzene–chloroform (1 : 1) as eluent, and finally crystallised from chloroform–methanol as orange rods, m. p. 273—275° (Found : C, 83·4; H, 4·4; N, 7·5. $C_{26}H_{16}ON_2$ requires C, 83·4; H, 4·3; N, 7·5%). Light absorption in chloroform : $\lambda_{max.}$ 2450, 2940, 3030, and 3860, inflection 3200 A.; ε = 48,700, 14,400, 16,500, 13,100, and 7700, respectively. A solution of the anthrone and picric acid in benzene, after warming, deposited the *picrate*, which crystallised from ethyl acetate in orange-yellow prisms, m. p. 253° (decomp.) (Found : C, 64·8; H, 3·45; N, 12·0. $C_{32}H_{19}O_8N_5$ requires C, 64·0; H, 3·2; N, 16·65%).

1 : 4-*Naphthaquinone*.—The direct oxidation of naphthalene has been found a more convenient method for the preparation of this quinone than the conventional method starting from α-naphthol (Conant and Fieser, *J. Amer. Chem. Soc.*, 1924, **46**, 1862; Fieser and Fieser, *ibid.*, 1935, **57**, 491; Fieser, *Org. Synth.*, Coll. Vol. I, 1946, p. 383). The following procedure is adapted from Miller (*J. Russ. Phys. Chem. Soc.*, 1884, **16**, 414; cf. Japp and Miller, *J.*, 1881, **39**, 220). A solution of naphthalene (64 g.) in acetic acid (600 ml.) is gradually added to a well-stirred solution of chromium trioxide (150 g.) in acetic acid (120 ml.) and water (30 ml.) in a 2-l. flask surrounded by ice–salt. The temperature of the

mixture must not be allowed to rise above 0°. Stirring is continued overnight, during which time the reaction mixture gradually attains room temperature; it is essential to use a large volume of freezing-mixture and to replenish it in the evening. The dark green solution is then set aside for 3 days and occasionally stirred. Then the solution is poured into ice-cold water (6 l.) and the yellow precipitate is filtered off, washed with water (200 ml.), and dried in a desiccator. The product is crystallised once from light petroleum (b. p. 80—100°; 500 ml.), giving long yellow needles of 1 : 4-naphthaquinone (25—28 g., 32—35%), m. p. 124—125°.

Light-absorption Measurements.—These were carried out by the photographic method, a Hilger instrument being used (cf. Braude, *J.*, 1945, 490). The curve for the dibenzophenanthrene (Fig. 1) was determined on a sample, m. p. 232°, obtained by an unambiguous synthesis (Braude and Fawcett, forthcoming paper) and identical by mixed m. p. with the product prepared and kindly provided by Dr. E. Clar, but differs somewhat from the curve previously recorded (*Ber.*, 1943, **76**, 609).

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