

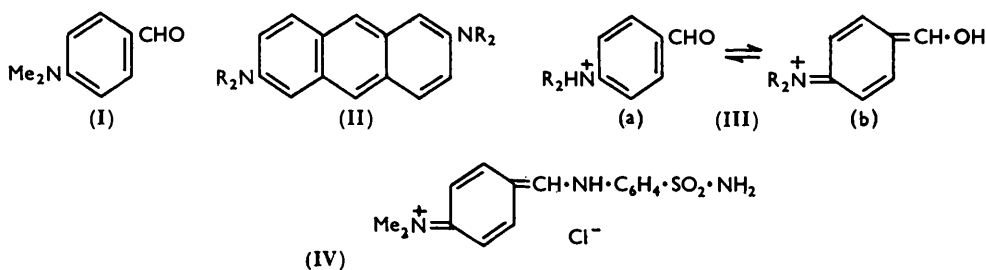
200. *The Action of Tin and Hydrochloric Acid on p-Dialkylamino-benzaldehydes. Part I. The Mechanism of the Reaction.*

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Treatment of *p*-dialkylaminobenzaldehydes with tin and hydrochloric acid produces 2:6-bisdialkylaminoanthracenes. The yield of anthracene and the velocity of the reaction depend on the nature of the dialkylamino-group. The mechanism of this reaction is discussed.

REDUCTION of an aromatic aldehyde usually gives one of three main classes of product depending on the reducing agent used, namely, (a) toluene derivatives as in the Clemmensen reaction, (b) benzyl alcohols, and (c) hydrobenzoin. In the case of *p*-dimethylaminobenzaldehyde (I) all three types of normal product have been observed under various conditions with different reagents.¹ An apparently novel mode of reduction has, however, been reported for this aldehyde by Albano² who found that with tin and hydrochloric acid at room temperature it gave 2:6-bisdimethylaminoanthracene (II; R = Me) in 25% yield. In view of the potential value of this reaction for the synthesis of new anthracene derivatives the mechanism has now been investigated.

Albano suggested that the reaction proceeded through the quinonoid cation (IIIb; R = Me), which is in equilibrium with the normal hydronium cation (IIIa; R = Me), the equilibrium in this case being much displaced in favour of the latter. In support, he



pointed out that reduction of the deeply coloured anil hydrochloride (IV), in which the quinonoid form analogous to (IIIb; R = Me) is more important,³ gave a higher yield of the anthracene (II; R = Me). The behaviour of compound (IV), however, is not strictly comparable with that of *p*-dimethylaminobenzaldehyde (I) in view of the probably considerable effect of differing rates of cleavage of carbon-nitrogen and carbon-oxygen

¹ Schwenk, Papa, Whitman, and Ginsberg, *J. Org. Chem.*, 1944, **9**, 1; Nystrom and Brown, *J. Amer. Chem. Soc.*, 1948, **70**, 3738; Chaikin and Brown, *ibid.*, 1949, **71**, 122; Allen, *J. Org. Chem.*, 1940, **15**, 435; Clemo and Smith, *J.*, 1928, 2423; Conant and Cutter, *J. Amer. Chem. Soc.*, 1926, **48**, 1016.

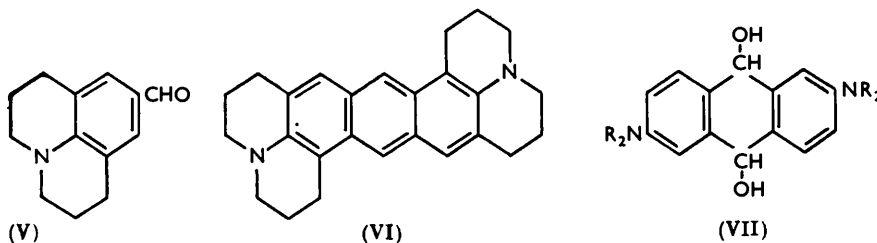
² Albano, *Anal. Asoc. Quim. Argentina*, 1946, **34**, 18.

³ Albano, *ibid.*, 1944, **32**, 43; Madelung, *J. prakt. Chem.*, 1926, **114**, 46.

bonds on the course of the reaction, since it is clear that such a cleavage must occur at some stage of the overall reaction. A more suitable compound for comparison with *p*-dimethylaminobenzaldehyde (I) is 8-formyljulolidine (V). In this the conjugative ability of the nitrogen atom is greater than in the dimethylamino-analogue as a result of the coplanarity enforced by the heterocyclic system,⁴ which will tend to enhance the stability of the quinonoid form analogous to (IIIb). When the aldehyde (V) was treated with tin and hydrochloric acid it reacted much more rapidly than *p*-dimethylaminobenzaldehyde under the same conditions and gave a 70–75% yield of benzo(1 : 2-7' : 8')(4 : 5-7'' : 8'')dijulolidine (VI).

The conjugative ability of the diethylamino-group is less than that of the dimethylamino-group owing to steric inhibition of resonance.⁵ Thus diethylaniline is a considerably stronger base (pK_a 6.56) than dimethylaniline (pK_a 5.06) owing to the suppression of base-weakening quinonoid structures in the former. This effect was reflected in the behaviour of *p*-diethylaminobenzaldehyde which reacted very slowly with tin and hydrochloric acid to yield a trace only of 2 : 6-bisdiethylaminoanthracene (II; R = Et). More or less intermediate behaviour was exhibited by *p*-ethylmethylaminobenzaldehyde which reacted more slowly than *p*-dimethylaminobenzaldehyde (I) with formation of 2 : 6-bisethylmethylaminoanthracene in 25% yield. These results indicate the importance for this reaction of mesomeric interaction between the dialkylamino- and formyl groups.

Although *p*-diethylaminobenzaldehyde gave very little 2 : 6-bisdiethylaminoanthracene (II; R = Et) a 20% yield of 2 : 6-bisdiethylamino-9 : 10-dihydro-9 : 10-dihydroxyanthracene (VII; R = Et) was isolated from the reaction mixture. This compound was smoothly converted into 2 : 6-bisdiethylaminoanthracene (II; R = Et) in warm stannous chloride solution. It seemed probable from this result that a diol of this type is an inter-



mediate in each of these reactions, and this view was supported by isolation of the corresponding diol (VII; R = Me) from a reaction with *p*-dimethylaminobenzaldehyde (I) stopped at a point when the anthracene (II; R = Me) was just beginning to separate as its sparingly soluble tin salt. Like its diethylamino-analogue the diol (VII; R = Me) readily yielded the corresponding anthracene (II; R = Me) with stannous chloride.

The formation of a 2 : 6-bisdialkylamino-9 : 10-dihydro-9 : 10-dihydroxyanthracene (VII) from a quinonoid cation (IIIb) does not involve an overall reduction, but represents a condensation of a relatively familiar type. It resembles the self condensation of 3 : 4-dimethoxybenzyl alcohol derivatives under acid conditions to give 9 : 10-dihydro-2 : 3 : 6 : 7-tetramethoxyanthracene (VIII).⁶ A similar reaction is the formation of 2 : 6-bisdimethylamino-9 : 10-dihydroanthracene (IX) from *p*-methoxymethyl-*NN*-dimethylaniline and phenylmagnesium bromide.⁷ These condensations can be considered as involving the incipient cations (X) and (XI), respectively, as intermediates.

It is noteworthy that the present condensation is not effected by hydrochloric acid alone, but requires the presence of metallic tin. The formation of the intermediate diol

⁴ Smith and Yu, *J. Org. Chem.*, 1952, 17, 1281.

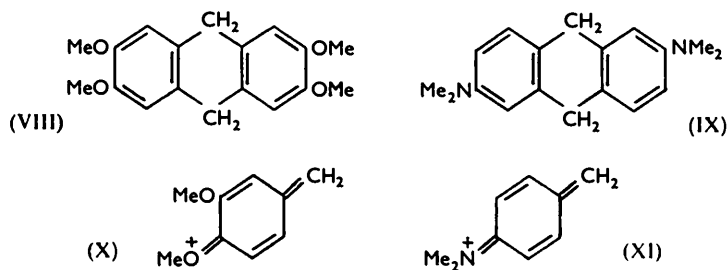
⁵ Brown, McDaniel, and Häfliger, "Determination of Organic Structures by Physical Methods," (Ed. Braude and Nachod) Academic Press, New York, 1955, p. 607.

⁶ Robinson, *J.*, 1915, 107, 287.

⁷ Mann and Stewart, *J.*, 1954, 4127.

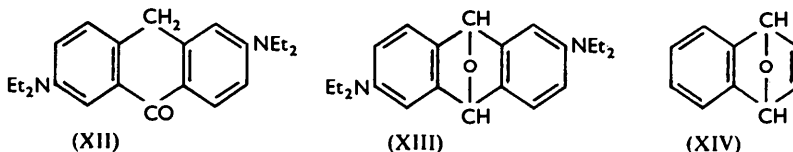
(VII) is possibly a heterogeneous reaction involving the quinonoid cation (IIIb) on the surface of the dissolving tin.

Heating 2:6-bisdiethylamino-9:10-dihydro-9:10-dihydroxyanthracene (VII; R = Et) with hydrochloric acid gave a rather complex mixture from which 2:6-bisdiethylaminoanthrone (XII) was isolated in 30% yield. Small amounts of 2:6-bisdiethylaminoanthracene (II; R = Et) and a white crystalline substance were also formed. The structure of the last material is uncertain; it has the empirical composition $C_{22}H_{28}ON_2$,



and its infrared spectrum indicates the absence of hydroxyl groups, but a strong peak at 1035 cm^{-1} , which is not found for the anthrone (XII) or 2:6-bisdiethylaminoanthracene (II; R = Et), is consistent with the presence of an ether linkage. A possible formulation of the substance as 2:6-bisdiethylamino-9:10-epoxy-9:10-dihydroanthracene (XIII) is scarcely in accord with its stability to boiling hydrochloric acid, since the analogous compound (XIV), prepared by Wittig and Pohmer,⁸ is converted into α -naphthol under these conditions.

An outstanding property of 2:6-bisdialkylaminoanthracenes is the production of a deep red colour when their dilute acid solutions are treated with various oxidising agents. This colour is irreversibly discharged by heat, but its thermal stability and its intensity are dependent to a marked degree on the particular anthracene used, being least for 2:6-bisdiethylaminoanthracene (II; R = Et) and greatest for benzo(1:2-7':8'')(4:5-7'':8'')dijulolidine (VI). From the latter compound, by using hydrogen peroxide in

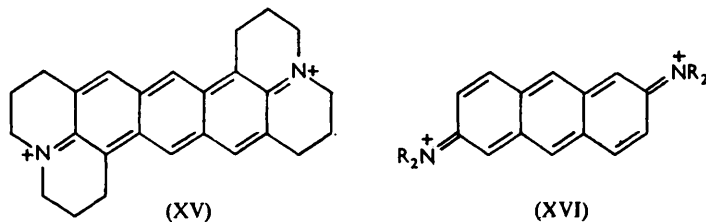


hydrochloric acid as the oxidising agent, it was possible to isolate the coloured product in crystalline form. This was a very soluble blue salt, readily reconverted into (VI) by titanous chloride, and analysing as the tetrahydrate of the dichloride of the di-imonium cation (XV). This structure was supported by the preparation of the corresponding picrate, perchlorate, and chloroplatinate in anhydrous form. The stability of a cation of this type will depend to a large extent on the conjugative ability of the nitrogen atoms. In the case of the cation (XV) the conjugation is probably near its maximum value owing to the enforced coplanarity of the molecule.⁴ With the corresponding diethylamino- and dimethylamino-cations (XVI; R = Et and Me) the conjugation of the nitrogen atoms will tend to be weakened, as mentioned earlier, by factors such as steric hindrance and rotation of the amino-groups due to thermal agitation.

These results suggest a possible mechanism for the final stage of the reaction of *p*-dialkylaminobenzaldehydes with tin and hydrochloric acid. The initially formed diol (VII) can be considered as the *pseudo*-base corresponding to the hypothetical hydroxide of the

⁸ Wittig and Pohmer, *Angew. Chem.*, 1955, **67**, 348.

di-imonium cation (XVI), and under strongly acid conditions will tend to form a salt of the latter. The resulting cation (XVI) will be rapidly reduced by the stannous chloride present, forming the corresponding anthracene by the uptake of two electrons. The observed appearance of a thermolabile red colour when either of the diols (VII; R = Et or Me) was treated with warm dilute sulphuric acid supports this explanation. The tendency of a diol (VII) to ionise to a cation (XVI) under the action of acids will depend on



the conjugative ability of the dialkylamino-groups in the manner discussed earlier, and must be considered as an important factor in determining the velocity of the overall reaction. It is possible that this factor may even be more decisive than the stability of Albano's quinonoid intermediate (IIIb).

The application of this reaction to the synthesis of other substituted anthracenes and, in particular, of heterocyclic derivatives such as (VI) is now being studied.

EXPERIMENTAL

Preparation of p-Dialkylaminobenzaldehydes.—The aldehydes used have been described in the literature. With the exception of *p*-dimethylaminobenzaldehyde, which was used as the "AnalaR" product, they were made by the *NN*-dimethylformamide-phosphorus oxychloride procedure of Campaigne and Archer⁹ which gave the following yields: 8-formyljulolidine⁴ (81%), *p*-diethylaminobenzaldehyde¹⁰ (72%), and *p*-ethylmethylaminobenzaldehyde¹⁰ (70%).

Reduction of p-Dialkylaminobenzaldehydes with Tin and Hydrochloric Acid.—In order to make the results comparable the following standard conditions were employed. The procedure is somewhat different from that described by Albano.²

The aldehyde (5.0 g.) was dissolved in concentrated hydrochloric acid (165 ml.) and water (135 ml.), and granulated tin (20 g.) was added. The mixture was kept at about 40° until the reaction was complete (1–16 days), and the precipitated tin salt filtered off and decomposed with 20% aqueous sodium hydroxide to liberate the crude anthracene, which was dried and extracted with hot benzene. After removal of the benzene the anthracene was recrystallised from a suitable solvent.

(a) After 7–8 days *p*-dimethylaminobenzaldehyde (I) gave 2:6-bisdimethylaminoanthracene (II; R = Me), yellow needles (from benzene), m. p. 253–254° (decomp.; rapid heating in sealed tube) (33%). Albano² gives m. p. 250° and 25% yield.

(b) After 1–2 days 8-formyljulolidine (V) gave *benzo*(1:2-7':8')(4:5-7'':8'')*dijulolidine* (VI), buff leaflets or yellow needles (from ethanol-benzene), m. p. 221–223° (decomp.) (70–75%) (Found: C, 84.55; H, 8.1; N, 7.7. C₂₆H₂₈N₂ requires C, 84.7; H, 7.7; N, 7.6%). Benzene solutions deposited a dark brown solid on exposure to air.

(c) After 16 days *p*-ethylmethylaminobenzaldehyde gave 2:6-bisethylmethylaminoanthracene, yellow crystals (from benzene-ethanol), m. p. 167–168° (25%) (Found: C, 81.9; H, 8.7; N, 9.4. C₂₀H₂₄N₂ requires C, 82.2; H, 8.3; N, 9.6%).

Dilute benzene solutions of these anthracenes exhibited a strong blue fluorescence.

Preparation of 2:6-Bisdialkylamino-9:10-dihydro-9:10-dihydroxyanthracenes.—(a) The reaction mixture from *p*-diethylaminobenzaldehyde (10 g.) with concentrated hydrochloric acid (330 ml.), water (270 ml.), and tin (40 g.) was set aside for 14 days, filtered, and diluted with water, and the tin was precipitated with hydrogen sulphide. The filtered solution was made

⁹ Campaigne and Archer, *J. Amer. Chem. Soc.*, 1953, **75**, 989.

¹⁰ Duff, *J.*, 1945, 276.

alkaline and extracted with benzene and ether. Evaporation of the dried extracts and treatment of the oily residue with light petroleum (b. p. 100—120°) gave 2 : 6-bisdiethylamino-9 : 10-dihydro-9 : 10-dihydroxyanthracene (VII; R = Et), which recrystallised from light petroleum (b. p. 100—120°) in needles, m. p. 118.5—120° (2.2 g., 22%) (Found : C, 74.2; H, 8.7; N, 8.05. $C_{22}H_{30}O_2N_2$ requires C, 74.5; H, 8.5; N, 7.9%).

The diol (VII; R = Et) (0.5 g.) was heated with a solution of tin (6 g.) in hydrochloric acid (90 ml.; 1 : 1 v/v) for 2 hr. on a steam-bath. The resultant clear solution was cooled in ice, whereupon a viscous oil separated. The supernatant liquid was decanted, the oil dissolved in hot water, and the solution basified. The yellow precipitate of 2 : 6-bisdiethylaminoanthracene (II; R = Et) was filtered off, dried and recrystallised from ethanol; it had m. p. 131.5—133.5° (0.25 g., 55%). For analysis the anthracene was recrystallised from ethanol containing a little benzene (lemon-yellow needles, m. p. 133.5—134.5°) (Found : C, 82.3; H, 9.0; N, 8.95. $C_{22}H_{28}N_2$ requires C, 82.5; H, 8.8; N, 8.75%). Solutions of the anthracene showed a strong blue fluorescence.

(b) The reaction mixture from *p*-dimethylaminobenzaldehyde (5.0 g.) was set aside for 2 days by which time an appreciable precipitate of the tin complex of 2 : 6-bisdimethylaminoanthracene (II; R = Me) had separated. The filtered solution was worked up as described for the diethylamino-analogue to yield 2 : 6-bisdimethylamino-9 : 10-dihydro-9 : 10-dihydroxyanthracene (VII; R = Me) as white needles (after several recrystallisations from benzene), m. p. 154—155° (decomp.) (0.8 g., 16%) (Found : C, 72.3; H, 7.3; N, 9.4. $C_{18}H_{22}O_2N_2$ requires C, 72.5; H, 7.4; N, 9.4%).

The diol (VII; R = Me) (0.1 g.), treated with a solution of tin (0.4 g.) in hydrochloric acid (6.0 ml.; 1 : 1 v/v) as described for the diethylamino-analogue (VII; R = Et), yielded 2 : 6-bisdimethylaminoanthracene (II; R = Me) which, recrystallised from benzene, had m. p. 253—254° (alone and mixed) (0.067 g., 76%).

Action of Hydrochloric Acid on 2 : 6-Bisdiethylamino-9 : 10-dihydro-9 : 10-dihydroxyanthracene.—A solution of the diol (VII; R = Et) (1.0 g.) in hydrochloric acid (16 ml., 1 : 1 v/v) was refluxed for 2 hr. On dilution with water a deep pink colour developed which disappeared later. The solution was basified and the precipitated yellow oil extracted with benzene and ether. The dried extracts were evaporated, and the residue was treated with a little warm ethanol, whereupon a small amount of a white crystalline solid separated. This substance, twice recrystallised from ethanolic benzene, had m. p. 243—244° (Found : C, 78.4; H, 8.7; N, 8.1. $C_{22}H_{28}ON_2$ requires C, 78.5; H, 8.4; N, 8.3%).

The ethanol solution was evaporated *in vacuo*, and the residue taken up in benzene and chromatographed on an alumina column (1 × 10 cm.). Development with benzene produced a colourless region which fluoresced strongly in ultraviolet light, followed by a broad yellow band. The fluorescent region was washed through and the solvent removed to yield 2 : 6-bisdiethylaminoanthracene (II; R = Et); recrystallised from ethanol-benzene and sublimed, this had m. p. 130—131° (alone and mixed) (10 mg., 1.0%); it was accompanied by a trace of the above white substance, m. p. 240—242° (from ethanol-benzene).

The yellow region of the column was removed and eluted with ethanol. Evaporation of the solvent yielded 2 : 6-bisdiethylaminoanthrone (XII) which was purified by recrystallisation from light petroleum (b. p. 60—80°) containing a little ethanol, then having m. p. 95.5—96.5° (0.31 g., 30%). For analysis it was recrystallised several times from the same solvent mixture (m. p. 97.5—98.5°) (Found : C, 78.15; H, 8.6; N, 8.3. $C_{22}H_{28}ON_2$ requires C, 78.5; H, 8.4; N, 8.3%).

The anthrone-containing band was followed by a pinkish region which gave a yellow oil on elution with ethanol and evaporation. The oil, which failed to crystallise, rapidly became green in air.

Action of Oxidising Agents on 2 : 6-Bisdialkylaminoanthracenes.—Dilute acidic solutions of the anthracenes became deep red when treated with bromine water, sodium hypochlorite, potassium ferricyanide, ferric chloride, potassium dichromate, or warm hydrogen peroxide. The last reagent was found to be most convenient for studying the effect. The following simple test procedure was adopted for comparison of the behaviour of the different anthracenes. To each of the anthracenes to be compared (0.5—1.0 mg.), contained in separate test tubes, hydrochloric acid (1.0 ml., 1 : 1 v/v) and hydrogen peroxide (0.5 ml.; 0.3%) were added. The tubes were then placed in boiling water and the colour reactions observed. Under these conditions the colour from 2 : 6-bisdimethylamino- (II; R = Me) and 2 : 6-bisdiethylamino-anthracene (II;

R = Et) was discharged in 1—2 min., the colour from the latter being much less intense. Benzo(1 : 2-7' : 8')-(4 : 5-7'' : 8'')dijulolidine (VI) gave an extremely intense colour which was not completely discharged after 60 min. at 100°.

In each case the permanence of the colour was enhanced by dilution and by increased acid concentration.

Oxidation of Benzo(1 : 2-7' : 8')(4 : 5-7'' : 8'')dijulolidine (VI).—The compound (VI) (0.2 g.) was triturated with concentrated hydrochloric acid (0.5 ml.) and water (1.5 ml.). 30% Hydrogen peroxide (0.35 ml.) was added and the mixture warmed gently with vigorous stirring. The *dichloride* of the cation (XV) separated as blue needles of the tetrahydrate, which were filtered off and dried for 2—3 hr. over potassium hydroxide *in vacuo* and then at atmospheric pressure over silica gel (yield 0.23 g., 85%) (Found: C, 60.8; H, 6.85. $C_{26}H_{28}N_2Cl_2 \cdot 4H_2O$ requires C, 61.0; H, 7.0%).

The chloride was very soluble in water giving an intensely red solution having an absorption maximum at 516 m μ . It was decomposed on exposure to light or on prolonged storage *in vacuo*. An aqueous solution of the chloride (0.1 g.) was decolorised immediately on addition of alkali with deposition of an oil which yielded the anthracene derivative (VI), m. p. 226—228° (decomp.) (from ethanol-benzene) (0.07 g., 42%).

The *dipicrate*, prepared in aqueous solution, was a sparingly soluble, dark brown powder (Found: C, 55.3; H, 4.3. $C_{38}H_{32}O_{14}N_8$ requires C, 55.3; H, 3.9%). The *chloroplatinate* was an insoluble brown powder (Found: C, 40.1; H, 3.75; residue, 22. $C_{26}H_{28}N_2Cl_6Pt$ requires C, 40.2; H, 3.65; Pt, 25.0%). The *perchlorate* was a moderately soluble brown-black powder which exploded when heated (Found: C, 55.4; H, 5.3. $C_{26}H_{28}O_8N_2Cl_2$ requires C, 55.0; H, 5.0%).

An aqueous solution of the chloride (0.15 g.) was treated dropwise with 30% titanous

Infrared absorption bands (cm.⁻¹) of anthracene derivatives.

(a) 2 : 6-Bisdimethylamino- (II; R = Me), (b) 2 : 6-bisdiethylamino- (II; R = Et), (c) 2 : 6-bisethylmethylamino-anthracene, (d) benzo(1 : 2-7' : 8')(4 : 5-7'' : 8'')dijulolidine (VI), (e) 2 : 6-bisdiethylaminoanthrone (XII), (f) substance $C_{22}H_{18}ON_2$, (g) 2 : 6-bisdiethylamino-9 : 10-dihydro-9 : 10-dihydroxyanthracene (VII; R = Et), (h) 2 : 6-bisdimethylamino-9 : 10-dihydro-9 : 10-dihydroxyanthracene (VII; R = Me).

(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)
818 s	812 s	820 s	—	823 m	804 s	805 s	809 s
—	—	—	866 w	851 w	858 w	—	—
—	—	895 w	892 w	—	—	—	—
—	—	—	—	929 w	920 w	—	—
950 m	—	945 w	953 s	—	—	—	941 m
964 m	961 m	965 m	—	—	—	—	—
—	—	986 m	—	985 m	—	—	—
1005 w	1008 w	1006 w	—	1013 m	1007 m	1005 m	1010 m
1021 w	1019 w	—	1034 w	—	1036 s	1022 s	1037 s
—	—	—	1054 w	—	—	1049 m	1061 m
1070 m	1081 m	1084 m	1078 m	1080 m	1080 m	1078 m	—
—	1095 w	1110 m	—	1096 m	1098 w	1100 w	—
—	—	—	—	1131 w	—	1125 w	1137 s
1171 m	1158 m	1161 s	1161 s	1161 s	1160 m	1152 s	1170 s
1189 s	1191 s	1190 s	1189 s	1190 s	1196 m	1186 s	1188 m
—	1205 m	1215 m	1211 m	1201 m	1203 m	1203 m	1209 m
1229 m	1230 w	—	—	—	—	—	—
1241 w	—	—	1245 w	1250 s	—	—	—
1283 w	1280 s	1274 s	—	1278 s	1270 s	1270 s	1280 w
—	—	—	1311 s	—	—	—	—
—	—	1320 w	—	1338 m	1324 w	—	1325 s
1364 s	1360 s	1350 s	1345 m	1362 s	1359 s	1351 s	—
—	1405 m	—	—	1408 s	1406 m	1398 m	—
1525 s	1530 s	1522 s	1500 s	1529 s	1530 s	1520 s	1524 s
1557 w	1558 w	1560 w	—	1556 m	1567 w	1567 w	1575 w
—	—	—	—	1597 s	—	—	—
1608 s	1610 s	1606 s	1603 m	1615 s	1615 s	1609 s	1615 s
—	—	—	—	1670 s	—	—	—
—	—	—	—	—	—	—	3340 b
—	—	—	—	—	—	3450 b	—
—	—	—	—	—	—	3505b	—

s = strong; m = medium; w = weak; b = broad.

chloride solution until the colour was completely discharged. The precipitated crude hydrochloride of (VI) was filtered off, and the anthracene liberated by alkali. Recrystallised from ethanolic benzene, it had m. p. 224—226° (alone and mixed) (0.03 g., 30%).

Infrared Spectra.—The spectra were determined in Nujol. The Table records the more important bands of the various 2 : 6-bisdialkylaminoanthracene derivatives prepared.

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