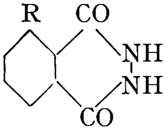
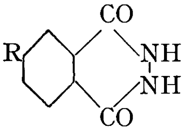
5. *Chemiluminescent Organic Compounds. Part II. The Effect of Substituents on the Closure of Phthalhydrazides to 5- and 6-Membered Rings.*

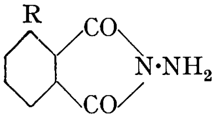
By H. D. K. Drew and F. H. Pearman.

The chemiluminescence of phthalaz-1 : 4-dione is modified on substitution of the phenyl group, but the effect is not predictable. Our objects were to investigate this point and revise the methods of preparation of phthalazdiones.

5-Nitrophthalaz-1 : 4-dione (I; R = NO_2) is best prepared from 3-nitrophthalic anhydride and just over 1 mol. of hydrazine in acetic acid, and 6-nitrophthalaz-1 : 4-dione (II; R = NO_2) by the action of aqueous hydrazine (1 mol.) on 4-nitrophthalimide.


(I.)


(II.)

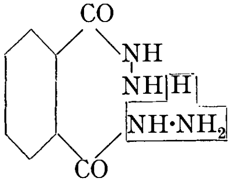

(III.)

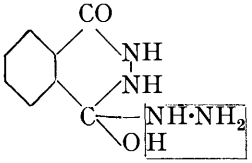
Reduction of 5- and 6-nitrophthalaz-1 : 4-diones to the more strongly luminescent amino-compounds (I and II; R = NH_2) gives impure products when ammonium sulphide or hydrazine is used as the reducing agent (compare Hoesch, *J. pr. Chem.*, 1907, **76**, 307; Radulescu and Alexa, *Bull. Soc. Chim. România*, 1930, **12**, 163; Huntress, *J. Amer. Chem. Soc.*, 1934, **56**, 241); but reduction with stannous chloride produces quantitative yields of colourless amines. The action of aqueous hydrazine on 3- or 4-aminophthalimide likewise gives the pure aminophthalazdione.

There is a significant distinction between the behaviour of 3-amino- and of 4-aminophthalimide with aqueous hydrazine: with 1 mol. of hydrazine the former gives N : 3-*diaminophthalimide* (III; R = NH_2) as practically the sole product, but with 2 mols. of hydrazine it gives only the 6-ring hydrazide (I; R = NH_2); whereas 4-aminophthalimide gives in either case only the 6-ring hydrazide (II; R = NH_2), the analogue of (III) not having been observed. Neither of these aminophthalimides reacts appreciably with hydrazine hydrate in glacial acetic acid, and reaction is slow in alcohol.

From this point of view, we have compared with these nitro- and amino-phthalimides the behaviour with hydrazine of four other substituted phthalimides. 3-Chlorophthalimide reacts with alcoholic hydrazine hydrate, giving 3-*chloro*-N-*aminophthalimide* (III; R = Cl) with 1 mol. of hydrazine, but 5-*chlorophthalaz*-1 : 4-*dione* (I; R = Cl) with 2 mols. of hydrazine; whereas 3-*hydroxyphthalimide* reacts with aqueous hydrazine to give only 5-*hydroxyphthalaz*-1 : 4-*dione* (I; R = OH), whether 1 mol. or 2 mols. of hydrazine are used. 3 : 6-Dichlorophthalimide, on the other hand, gives with either 1 mol. or 2 mols. of hydrazine hydrate in alcoholic solution only 3 : 6-*dichloro*-N-*aminophthalimide*, and under similar conditions 4 : 5-dichlorophthalimide gives only 6 : 7-*dichlorophthalaz*-1 : 4-*dione*.

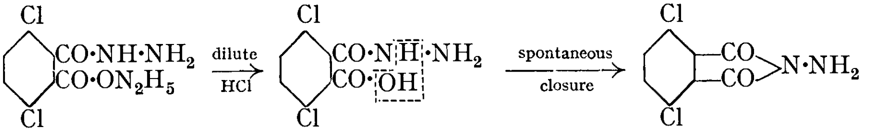
Further, a comparison was made of the behaviour of the substituted phthalic anhydrides with hydrazine. 3- and 4-Nitrophthalic anhydrides react with a slight excess over 1 mol. of hydrazine hydrate in acetic acid solution to give the 6-ring hydrazides as the end products. 3 : 6-Dichlorophthalic anhydride gives only 3 : 6-dichloro-*N*-aminophthalimide with 1 mol. of aqueous-alcoholic hydrazine, but with more than 2 mols. of hydrazine hydrate at 150° it gives only 5 : 8-*dichlorophthalaz*-1 : 4-*dione*; on the other hand, 4 : 5-dichlorophthalic anhydride reacts with 1 mol. of hydrazine hydrate in aqueous alcohol or in acetic acid to give 6 : 7-dichlorophthalaz-1 : 4-dione free from the 5-ring isomeride. It is notable that, parallel with these results, 3 : 6-dichlorophthalic acid forms its anhydride with unusual ease, whereas the 4 : 5-dichloro-acid does so reluctantly. So also 4 : 5-dichlorophthalimide is much less stable and more reactive than the 3 : 6-dichloro-isomeride. Tetrachlorophthalic acid or anhydride reacts with hydrazine hydrate at 150° to give only *tetrachloro*-N-*aminophthalimide* even when the hydrazine is in excess; the 6-ring hydrazide has not been prepared : the former compound has been mistaken for the latter by Phelps (*Amer. Chem. J.*, 1905, **33**, 586) and by Radulescu and Alexa (*loc. cit.*). A probable mechanism for the conversion of *N*-aminophthalimides into the corresponding phthalaz-1 : 4-diones by means of hydrazine is the opening of the phthalimide ring by addition of hydrazine, to form a dihydrazide, followed by closure in the new direction with extrusion of the added hydrazine; this can be regarded as a direct change (as shown below on the left) or as taking place through an intermediate 6-ring stage (on the right) :

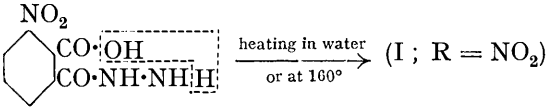




In other cases, where the presumed dihydrazides close to give *N*-aminophthalimides, analogous mechanisms are possible, the active hydrogen being here that of the imino- instead of the amino-group.

In two instances ring closure was observed of open-chain hydrazides whose structures were determined :

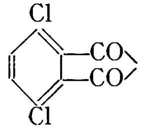
(1) 

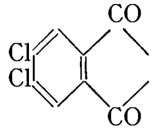
(2) 

These results, and others given in the experimental part, show that the type of ring-closure from open-chain compounds of this series, though it is not entirely unaffected by temperature, is mainly controlled by the nature of the substituents in the phenyl group, including those in the 1- and the 2-position. Thus, the other substituents being the same, the presence (in positions 1 : 2) of two $CO\cdot NH\cdot NH_2$ groups favours 6-ring formation, but that of one $CO\cdot NH\cdot NH_2$ and one $CO\cdot NH_2$ or CO_2H favours 5-ring formation; substitution of $CO\cdot NH\cdot NHPh$ for one $CO\cdot NH\cdot NH_2$ also has the latter tendency. Again, where the 1 : 2 substituents remain unaltered, the nature and position of the other substituents pronouncedly influence the course of the closure. The latter effects may be summarised as follows : closure to the 5-ring is favoured by 3-Cl, 3-NH_2, 3 : 6-Cl_2, and 3 : 4 : 5 : 6-Cl_4 (Type *A*); whereas closure to the 6-ring is favoured by 3-OH, 4-NH_2, 4 : 5-Cl_2, and probably also by both 3-NO_2 and 4-NO_2 (the effect of 4-NO_2 being the greater of the two) (Type *B*).

These effects may be accounted for by assuming that the positional substituents tend to orient the Kekulé double bonds of the benzene ring (compare Mills and Nixon, J., **1930**, 2510). Then, the applicability of Baeyer's strain theory to rings containing both carbon and nitrogen being assumed, it is suggested (1) that the substituents of type *B*, which favour the 6-ring formation, tend to fix a double bond in the position common to the two rings, since in that case the 6-ring, whether or not it occurs in a lactim form, will have a smaller strain than the 5-ring; and (2) that those of type *A*, which favour the 5-ring formation, tend to fix the double bonds out of the common position, since in that case the 5-ring (which cannot assume a lactim form in the *N*-aminophthalimides) will have a smaller strain than the lactim form of the 6-ring :

(A.)

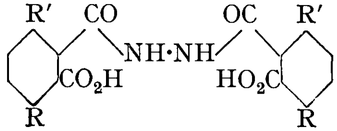


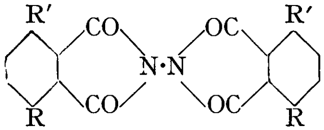


(B.)

s-*Bis*-(6-*nitro*-2-*carboxybenzoyl*)*hydrazine* (IV; R = H, R′ = NO_2) and s-*bis*-(3 : 6-*dichloro*-2-*carboxybenzoyl*)*hydrazine* (IV; R = R′ = Cl) have been prepared. Both compounds cyclise to the corresponding substituted *N*-phthalimidophthalimides (V),

(IV.)





(V.)

but from the nitro-compound a proportion of the phthalaz-1 : 4-dione also results. *Octachloro*-N-*phthalimidophthalimide*, which is free from hydrogen, also has been prepared.

EXPERIMENTAL.

3- and 4-Nitrophthalic acids were prepared by nitrating phthalic anhydride (500 g.) in presence of sulphuric acid ("Organic Syntheses," VII, 70); the mixture of the two acids was washed on sintered glass with concentrated hydrochloric acid (Blicke and Smith, *J. Amer. Chem. Soc.*, 1929, **51**, 1868) and crystallised twice from water and then from glacial acetic acid, the 3-nitro-acid being obtained in white hexagonal tablets (185 g.), m. p. 216—218°. The aqueous filtrates from the crystallisations were evaporated on the water-bath, and the residue dried at 100° (it chars above this temperature). A solution of the resulting crude 4-nitro-acid in absolute alcohol (600 c.c.) was saturated with hydrogen chloride and refluxed for 1 hour (Blicke and Smith, *loc. cit.*, give 12 hours; but compare Hayashi and Kawasaki, *J. Soc. Chem. Ind. Japan*, 1933, suppl. vol., 121), the 4-nitro-acid thus being converted into its ethyl ester, and the 3-nitro-acid into the 1-ethyl hydrogen ester (Kahn, *Ber.*, 1902, **35**, 3857), which is very resistant to further esterification (an appreciable quantity of the ethyl ester is formed if refluxing is prolonged). The mixture of esters was isolated and dissolved in ether, and the ethyl hydrogen ester removed by extraction with 10% aqueous sodium carbonate. The required ethyl 4-nitrophthalate distilled at 233—234°/38 mm. and solidified in flat needles, m. p. 34°; it was boiled with concentrated hydrochloric acid (500 c.c.) and water (500 c.c.) for 12 hours (Hayashi and Kawasaki, *loc. cit.*), and the 4-nitro-acid crystallised from 15% hydrochloric acid, forming colourless rhombs (205 g.), m. p. 164—166°.

Ethyl 4-aminophthalate, obtained by reduction of the 4-nitro-ester with zinc and aqueous-alcoholic hydrogen chloride, formed colourless needles, m. p. 97°.

3- and 4-Nitrophthalic anhydrides were obtained by heating the acids with acetic anhydride (2 mols.) for 10 minutes (see *op. cit.*, VII, 74). The 3-nitro-anhydride formed pale yellow needles, m. p. 163—164°, and was stable to moist air for a long time. The 4-nitro-anhydride formed white rods, m. p. 119—120°; it readily passed into the acid in moist air and was even partly hydrolysed on crystallisation from glacial acetic acid.

3- and 4-Nitrophthalimides were best prepared by heating an intimate mixture of the acid or its anhydride and ammonium carbonate (1¼ mols.) at 220—230° with occasional stirring (½—1 hour); they were sufficiently pure for use. Crystallised from water, 3-nitrophthalimide formed cream-coloured hexagonal plates, m. p. 216—217°, and the 4-nitro-isomeride cream-coloured square plates, m. p. 201—202°.

3- and 4-Aminophthalimides were prepared from the nitrophthalimides by reduction with stannous chloride and hydrochloric acid, as described by Levy and Stephen (J., **1931**, 79) for 4-aminophthalimide. Reduction of the 3-nitro-compound commenced only at 40°. The resulting hydrochlorides were hydrolysed to the aminophthalimides by repeated washing with boiling water. 3-Aminophthalimide formed bright yellow, feathery needles from water, m. p. 263—264° (decomp.), showing a green fluorescence in water or acetic acid and a violet in benzene as described by Kauffmann and Beisswenger (*Ber.*, 1903, **36**, 2494). Its 3-acetyl derivative (obtained by warming with acetic anhydride) melted at 242°, and its 3-*benzoyl* derivative (by means of benzoyl chloride in pyridine) formed cream-coloured silky needles, m. p. 249°, from acetic acid (Found : N, 10·6. $C_{15}H_{10}O_3N_2$ requires N, 10·5%); these derivatives were weakly fluorescent (violet) in water or acetic acid but not in benzene. 4-Aminophthalimide formed long, yellow, acicular needles from water, m. p. 294° (decomp.), and was not fluorescent; its acetyl derivative, likewise non-fluorescent, melted at 334°.

5-Nitrophthalaz-1 : 4-dione (I; $R = NO_2$) was best prepared by dissolving 3-nitrophthalic anhydride (96·5 g.) in boiling glacial acetic acid (400 c.c.), allowing the solution to cool for a few minutes, and then slowly stirring in hydrazine hydrate (26 g.; a slight excess over 1 mol.); the reaction was completed by ½ hour's boiling under reflux. The precipitate was removed (filtrate A), washed with hot acetic acid, and dissolved in 5% aqueous sodium hydroxide; the filtered solution gave pure 5-nitrophthalaz-1 : 4-dione (94—98 g.) when acidified with acetic acid.

Substitution of 3-nitrophthalic acid for the anhydride in the reaction gave a poor yield; but if, at the same time, alcohol was used as solvent, instead of acetic acid, acid hydrazine 3-nitrophthalate separated, and this, when heated alone at 150° in an air-stream (24 hours), gave 5-nitrophthalaz-1 : 4-dione in good yield (compare Bogert and Boroschek, *J. Amer. Chem. Soc.*, 1931, **53**, 745; Radulescu and Alexa, *Bull. Soc. Chim. România*, 1930, **12**, 140). This dione can also be prepared by heating 3-nitrophthalimide and aqueous hydrazine hydrate (1 mol. or 2 mols.) for 6 hours under reflux; much of it remains in the orange-red solution as a salt, but is precipitated by acetic acid (yield, nearly theoretical). When 3-nitrophthalimide is refluxed in alcoholic solution with hydrazine hydrate (1 mol.) for 1 hour, it is converted entirely into 5-nitrophthalaz-1 : 4-dione. This compound forms buff rhombic needles, m. p. 314° (decomp.), and is very sparingly soluble in water or acetic acid but more soluble in pyridine or nitrobenzene. There appear to be two isomeric monoacetyl derivatives. The first, prepared by heating the dione with acetic anhydride, has been described by Mihailescu and Protopopescu (*Bull. Soc. Chim. România*, 1930, **12**, 137), who give m. p. 230°; it was obtained as white fibrous needles, m. p. 221°, did not reduce Fehling's solution, and at once lost the acetyl group in presence of cold 5% sodium hydroxide solution. The second *monoacetyl* derivative was obtained from filtrate (A) above (particularly when the hydrazine was mixed first with the acetic acid) in buff hexagonal plates, m. p. 205° (Found : C, 48·4; H, 2·9; N, 16·8. $C_{10}H_7O_5N_3$ requires C, 48·2; H, 2·8; N, 16·9%), which reduced hot Fehling's solution and lost the acetyl group with 5% aqueous sodium hydroxide only on being boiled. The benzoyl derivative was obtained (by the use of benzoyl chloride and pyridine) in yellow needles, m. p. 228° (Mihailescu gives 200°); it was readily hydrolysed by cold 5% sodium hydroxide solution. 5-Nitrophthalaz-1 : 4-dione formed with hot 2*N*-aqueous ammonia lemon-yellow needles of an ammonium salt which was stable in air and could be recrystallised from water, and with hot 10% sodium carbonate solution orange hexagonal plates of a sodium salt.

3-*Nitro*-2-*carboxybenzhydrazide* was prepared from its 2-hydrazine salt (m. p. 157°), which was obtained by the method of Curtius and Semper (*Ber.*, 1913, **46**, 1162) from 1-ethyl hydrogen 3-nitrophthalate and hydrazine hydrate. The hydrazine salt was readily soluble in cold water, but when the solution was made just acid with dilute hydrochloric acid, white diamond-shaped needles of 3-nitro-2-carboxybenzhydrazide separated, m. p. 298—300° (decomp.) (Found : C, 42·9; H, 3·2. $C_8H_7O_5N_3$ requires C, 42·7; H, 3·1%). This substance reduced hot Fehling's solution, was only slightly soluble in water or alcohol, but soluble in alkalis, and when boiled with water for 2 hours or heated alone at 160° for 12 hours was converted into 5-nitrophthalaz-1 : 4-dione.

6-Nitrophthalaz-1 : 4-dione (II; $R = NO_2$) was best prepared from 4-nitrophthalimide (19·2 g.), suspended in water (125 c.c.), by adding hydrazine hydrate (5 g.; 1 mol.) in water (10 c.c.) and heating under reflux for 1 hour; most of it remained in the red solution as the ammonium salt and was precipitated by acetic acid (yield, 19·5 g.). It separated from 50%

acetic acid in small, pale yellow, hexagonal plates, m. p. 299—300° (decomp.), moderately easily soluble in water, alcohol, or pyridine. It was also prepared from the acid or anhydride as described for the 5-nitro-isomeride, than which it is more soluble, forms salts of deeper shade, and is more readily diacetylated; its ammonium salt forms orange needles.

5-*Aminophthalaz*-1 : 4-*dione* (I; R = NH_2).—(1) 3-Aminophthalimide (16·2 g.) was boiled with a solution of hydrazine hydrate (10 g.; 2 mols.) in water (100 c.c.) under reflux until evolution of ammonia ceased (1 hour); when the cooled solution was acidified with 10% acetic acid, the dione (17·7 g.) was precipitated. A solution of it in warm 5% aqueous sodium hydroxide was cooled to 0°, the sodium salt then crystallising in white hexagonal plates, easily decomposed by atmospheric carbon dioxide. The pure dione was precipitated from an aqueous solution of the sodium salt with dilute acetic acid.

(2) 5-Nitrophthalaz-1 : 4-dione (10 g.), dissolved in 5% aqueous sodium hydroxide (100 c.c.) at 50°, was added during 15 minutes to stannous chloride (45 g.) in concentrated hydrochloric acid (225 c.c.), with stirring, the temperature being kept at 50—60°. After cooling to 0°, 5-aminophthalaz-1 : 4-dione hydrochloride separated in needles; this was collected, washed, and freed from any tin salts by extraction in aqueous ammonia (10%) and filtration. Acidification of the filtrate with dilute acetic acid gave pure 5-aminophthalaz-1 : 4-dione (6·5 g.). A further amount was obtained from the filtrate by making it alkaline with sodium hydroxide, acidifying the solution with acetic acid, and purifying the precipitate as before (total yield, nearly theoretical).

5-Aminophthalaz-1 : 4-dione is a white crystalline powder, m. p. 332—333° (decomp.), very sparingly soluble in the usual solvents; its solutions in water, acetic acid, dilute hydrochloric acid, alcohol, and acetone show a violet fluorescence, but not solutions in benzene, alkalis, or strong mineral acids. It dissolves in alkalis, forming salts decomposed by carbon dioxide, and in strong mineral acids, giving salts hydrolysed by hot water. The ammonium salt separates in colourless rods, hydrolysed by boiling water, and the hydrochloride in colourless needles, which lose hydrogen chloride when heated. The barium salt forms long cream-coloured needles. With acetic anhydride the amino-dione gives long white needles of 5-acetamidoacetylphthalaz-1 : 4-dione, m. p. 262° (from dry benzene) (Found : C, 55·3; H, 4·4; N, 16·3. Calc. for $C_{12}H_{11}O_4N_3$: C, 55·2; H, 4·2; N, 16·1%). When this substance is dissolved in dilute aqueous ammonia (10 mins.' boiling), and the solution acidified with acetic acid, white micro-crystals of 5-*acetamidophthalaz*-1 : 4-*dione* (I; R = NH·CO·CH_3), m. p. 325—326° (decomp.), separate (Found : N, 19·1, 19·25. $C_{10}H_9O_3N_3$ requires N, 19·2%), which forms a sodium salt with 5% aqueous sodium hydroxide. Its solutions are not fluorescent. The same substance was obtained by the action of (*a*) hydrazine hydrate (1 mol.) on 3-acetamidophthalimide in boiling alcohol and (*b*) hydrazine hydrate on 3-acetamidophthalic anhydride (Lawrence, *J. Amer. Chem. Soc.*, 1920, **42**, 1872). 5-*Benzamidophthalaz*-1 : 4-*dione* (I; R = NH·COPh) was obtained, by the action of an excess of alcoholic or aqueous hydrazine hydrate on 3-benzamidophthalimide, in small white needles (from nitrobenzene), m. p. 319° (decomp.) (Found : C, 64·1; H, 3·8; N, 14·9. $C_{15}H_{11}O_3N_3$ requires C, 64·1; H, 3·5; N, 14·9%). Treatment of the sodium salt of 5-aminophthalaz-1 : 4-dione in pyridine with benzoyl chloride gave silver-white hexagonal plates, m. p. 263°, of the *dibenzoyl* derivative (Found : C, 68·8; H, 4·0. $C_{22}H_{15}O_4N_3$ requires C, 68·6; H, 3·9%).

N : 3-*Diaminophthalimide* (III; R = NH_2) was practically the sole product when 3-aminophthalimide was treated with hydrazine (1 mol.) in water as in the preparation of the 5-aminodione (above). It crystallised from water in bright yellow, rhombic needles (Found : C, 54·4; H, 4·0. $C_8H_7O_2N_3$ requires C, 54·2; H, 3·95%), which melted at 252° and resolidified as 5-aminophthalaz-1 : 4-dione. The last compound is the by-product of the preparation and is removed by washing with cold 2% sodium hydroxide solution, in which *N* : 3-diaminophthalimide is insoluble. The latter is also much more readily soluble in water, alcohol, or acetic acid, and reduces hot Fehling's solution. It is converted into the sodium or hydrazine salt of the amino-dione by boiling (½ hour) with 5% aqueous sodium hydroxide or aqueous hydrazine hydrate (1 mol.), open-chain compounds being produced as intermediates.

3-*Acetamido*-N-*anilinophthalimide* was prepared by condensing 3-acetamidophthalic anhydride and phenylhydrazine in acetic acid solution; it formed pale buff needles, m. p. 179° (Found : N, 14·3. $C_{16}H_{13}O_3N_3$ requires N, 14·2%), insoluble in dilute alkali solution.

6-*Aminophthalaz*-1 : 4-*dione* (II; R = NH_2).—This could only be obtained satisfactorily (1) by the action of 1 mol. of hydrazine hydrate (5 g. in 200 c.c. of water) on 4-aminophthalimide (16·2 g.), the sodium salt being isolated in colourless needles, and (2) by reduction of 6-nitrophthalaz-1 : 4-dione, both methods being those described for the preparation of the 5-aminocompound. It forms small colourless needles, m. p. 339° (decomp.), and is more soluble than the 5-amino-isomeride; it is also less basic, showing little tendency to form salts with mineral acids. Its solutions are not fluorescent.

6-*Acetamidophthalaz*-1 : 4-*dione* (II; R = NH·CO·CH_3), prepared by refluxing 4-acetamidophthalimide with hydrazine hydrate, formed small white prisms from water, m. p. 341° (decomp.) (Found : N, 19·3. $C_{10}H_9O_3N_3$ requires N, 19·2%). It forms a sodium salt with 5% sodium hydroxide solution.

3-*Nitro*-N-*anilinophthalimide*.—3-Nitrophthalic anhydride (3·8 g.) in glacial acetic acid (10 c.c.) was mixed with a saturated aqueous solution of phenylhydrazine hydrochloride (2·2 g.) and sodium acetate (3 g.) and refluxed for ½ hour. The precipitate was washed with water and with 2% sodium hydroxide solution and crystallised from glacial acetic acid, forming pale yellowish-brown plates, m. p. 188° (Found : N, 14·7. $C_{14}H_9O_4N_3$ requires N, 14·8%), only slightly soluble in water and insoluble in cold alkali. A small proportion of the dione also was produced.

s-*Bis*-(6-*nitro*-2-*carboxybenzoyl*)*hydrazine* (IV; R = H, R′ = NO_2. The orientation of the carboxyl groups, though probable, has not been proved).—Powdered 3-nitrophthalic anhydride (2·8 g.) was suspended in glacial acetic acid (20 c.c.), and hydrazine hydrate (0·7 g.; 1 mol.) in acetic acid (20 c.c.) rapidly added with stirring. The mixture of the required *substance* and its hydrazine salt deposited from the colourless solution after 1 hour was collected and dissolved in just sufficient cold 5% aqueous sodium hydroxide; when the solution was acidified with dilute hydrochloric acid, long cream-coloured needles, m. p. about 318° (decomp.) (depending on the rate of heating), separated (Found : C, 46·0; H, 2·7; N, 13·3. $C_{16}H_{10}O_{10}N_4$ requires C, 45·9; H, 2·4; N, 13·4%). Recrystallisation was impossible. The substance formed an acid solution in water and reduced Fehling's solution.

3-*Chloro*-N-*aminophthalimide* (III; R = Cl).—3-Chlorophthalimide (m. p. 236°; prepared from diazotised 3-aminophthalimide by the Sandmeyer process) was refluxed for 1 hour with hydrazine hydrate (1 mol.) in alcohol (96%), ammonia being evolved. The *product* was washed with dilute aqueous ammonia and recrystallised from water, forming cream-coloured needles, m. p. 194—195° (Found : C, 48·6; H, 2·7. $C_8H_5O_2N_2Cl$ requires C, 48·8; H, 2·5%). It reduced Fehling's solution and was insoluble in cold 5% sodium hydroxide solution. In the above reaction only a little of the following compound was produced.

5-*Chlorophthalaz*-1 : 4-*dione* (I; R = Cl).—(*a*) A mixture of 3-chlorophthalimide and hydrazine hydrate (2 mols.) in alcohol (96%) was refluxed for 1 hour, and the resulting yellow solution acidified with dilute acetic acid. (*b*) 5-Aminophthalaz-1 : 4-dione (2 g.), dissolved in concentrated sulphuric acid (12 c.c.), was treated at 0° with sodium nitrite (1 g.) in concentrated sulphuric acid (10 c.c.), with vigorous stirring; phosphoric acid (60 c.c.; *d* 1·7) at 0° was then slowly added (see Schoutissen, *J. Amer. Chem. Soc.*, 1933, **55**, 4531). After 1 hour at 0° the mixture was treated with urea (2 g.), poured on ice, rapidly run into a solution of cuprous chloride (from 2 g. of copper sulphate) in hydrochloric acid, stirred for 1 hour, and then heated on a water-bath. The precipitate was removed, dissolved in dilute sodium hydroxide solution, and reprecipitated with acetic acid.

5-*Chlorophthalaz*-1 : 4-*dione* formed cream-coloured micro-needles, m. p. 338° (decomp.) from nitrobenzene or much water (Found : C, 48·7; H, 2·7; N, 14·3. $C_8H_5O_2N_2Cl$ requires C, 48·8; H, 2·5; N, 14·2%). It did not reduce Fehling's solution and was completely soluble in dilute aqueous alkali. The above diazo-solution coupled with alkaline β-naphthol, giving scarlet needles (from alcohol) of the *azo-compound* (Found : N, 17·1. $C_{18}H_{12}O_3N_4$ requires N, 16·9%).

3 : 6-*Dichloro*-N-*aminophthalimide*.—(1) Hydrazine hydrate (5 g.; 1 mol.) in water (10 c.c.) was added to a solution of 3 : 6-dichlorophthalic anhydride (21·5 g.) (ethyl hydrogen 3 : 6-dichlorophthalate can be used) in hot 96% alcohol (50 c.c.) and heated under reflux (1 hour); needles (15 g.; 5 g. more can be obtained from the filtrate) separated on cooling, and addition of water (120 c.c.). (2) 3 : 6-Dichlorophthalimide and hydrazine hydrate (1 mol.) were refluxed (1 hour) in alcohol, and water added. When 2 mols. of hydrazine hydrate were used in the latter reaction, the hydrazine salt of the acid hydrazide, and not the dione, was produced.

3 : 6-*Dichloro*-N-*aminophthalimide* crystallised from water in almost white, flat needles (Found : C, 41·7; H, 1·8; N, 12·3. $C_8H_4O_2N_2Cl_2$ requires C, 41·6; H, 1·7; N, 12·1%); it melted at 210°, resolidified in a few minutes, and did not melt again below 350°. It was soluble in water (solution neutral), alcohol, or acetic acid (hot solutions are deep yellow), but insoluble in cold alkalis, although it dissolved on warming. In alcoholic solution it at once reacted with hydrazine hydrate to give acicular needles of the *hydrazine* salt of 3 : 6-dichloro-2-carboxy-

benzhydrazide (Found for a sample dried over phosphoric oxide: C, 34·2; H, 3·5. $C_8H_6O_3N_2Cl_2,N_2H_4$ requires C, 34·2; H, 3·5%), which on dehydration gave 3 : 6-*dichlorophthalodihydrazide* (Found for the substance dehydrated at 100°: C, 36·7; H, 3·1; N, 21·3. $C_8H_8O_2N_4Cl_2$ requires C, 36·5; H, 3·0; N, 21·3%). The former substance (hydrazine salt) reduced Fehling's solution in the cold. It dissolved in cold water and the solution soon deposited 3 : 6-dichloro-*N*-aminophthalimide; boiling water or a drop of dilute hydrochloric acid effected the change at once. 3 : 6-Dichloro-*N*-aminophthalimide reduced warm Fehling's solution, formed a *benzylidene* derivative in aqueous alcoholic solution (10 mins.' boiling), consisting of blunt needles, m. p. 224° (Found: N, 8·9. $C_{15}H_8O_2N_2Cl_2$ requires N, 8·8%), and was converted by sodium nitrite in warm acetic acid solution into 3 : 6-dichlorophthalimide and by 3 : 6-dichlorophthalic anhydride in acetic acid (5 mins.' boiling) into 3 : 6 : 3′ : 6′-tetrachloro-*N*-phthalimidophthalimide.

3 : 6 : 3′ : 6′-*Tetrachloro*-N-*phthalimidophthalimide* (V; R = R′ = Cl) separated in white needles (2 g.) when 3 : 6-dichlorophthalic anhydride (2·1 g.) and hydrazine hydrate (0·25 g.; ½ mol.) were refluxed in glacial acetic acid (20 c.c.) for ½ hour; and was also formed when 3 : 6-dichloro-*N*-aminophthalimide was kept at its m. p. for ½ hour, hydrazine being evolved. It crystallised from nitrobenzene in diamond-shaped crystals, m. p. above 350° (Found: C, 44·8; H, 1·2; N, 6·6. $C_{16}H_4O_4N_2Cl_4$ requires C, 44·6; H, 0·9; N, 6·5%). It was insoluble in water, acetic acid, or cold alkali, but hot 5% sodium hydroxide solution hydrolysed it to 3 : 6-dichloro-*N*-aminophthalimide and 3 : 6-dichlorophthalic acid.

5 : 8-*Dichlorophthalaz*-1 : 4-*dione*.—When 3 : 6-dichlorophthalic anhydride (4 g.) was mixed with hydrazine hydrate (3 g.; more than 3 mols.), heat was evolved and the anhydride dissolved. After 1 hour's heating at 120—130° the residue was dissolved in warm 2½% aqueous sodium hydroxide, and the filtered solution acidified with dilute acetic acid; this process was repeated. The *dione* (3·6 g.) formed small cream-white needles from nitrobenzene, m. p. above 350° (Found: C, 41·6; H, 1·9; N, 12·0. $C_8H_4O_2N_2Cl_2$ requires C, 41·6; H, 1·7; N, 12·1%), and had the expected properties. Its sodium salt (cream-coloured rhombic plates) and ammonium salt (needles) were sparingly soluble and their aqueous solutions were yellow. The dione was also formed when (1) hydrazine 3 : 6-dichlorophthalate was heated at 165° for 6 hours, and (2) 3 : 6-dichloro-*N*-aminophthalimide was heated with hydrazine hydrate (1 mol.) at 160°, or with hydrazine hydrate (2 mols.) at 120—130°, for 1 hour.

s-*Bis*-(3 : 6-*dichloro*-2-*carboxybenzoyl*)*hydrazine* (IV; R = R′ = Cl).—3 : 6-Dichlorophthalic anhydride (2·1 g.) was suspended in glacial acetic acid (20 c.c.), and hydrazine hydrate (0·5 g.) in acetic acid (20 c.c.) rapidly added with stirring. The precipitated hydrazine salt was collected after 1 hour and dissolved in water, and the *acid* precipitated by means of dilute hydrochloric acid in colourless needles, m. p. above 350° (Found: C, 41·4; H, 1·6. $C_{16}H_8O_6N_2Cl_4$ requires C, 41·2; H, 1·7%). It reduced hot Fehling's solution and was at once soluble in dilute alkali solution. It was only slightly soluble in the ordinary solvents and could not be recrystallised without decomposition. Boiling with glacial acetic acid caused ring closure to 3 : 6 : 3′ : 6′-tetrachloro-*N*-phthalimidophthalimide.

Hydrazine 3 : 6-*dichlorophthalate* was obtained, from hydrazine and the acid in alcohol, in colourless hexagonal plates, m. p. 206° (resolidification), soluble in cold water (Found: C, 31·9; H, 4·2. $C_8H_4O_4Cl_2,2N_2H_4$ requires C, 32·1; H, 4·0%).

6 : 7-*Dichlorophthalaz*-1 : 4-*dione*.—(1) A solution of 4 : 5-dichlorophthalic anhydride (21·5 g.) in glacial acetic acid (120 c.c.) was refluxed with hydrazine hydrate (5 g.; more than 1 mol.) for ½ hour (yield, 19·8 g.). The reaction proceeds in the same manner in aqueous alcohol. (2) An alcoholic solution of 4 : 5-dichlorophthalimide containing hydrazine hydrate (1 mol.) was boiled for a few minutes. The *product* was completely soluble in alkali, giving yellow solutions. It formed white diamond-shaped prisms, m. p. above 350° (Found: C, 41·5; H, 1·8. $C_8H_4O_2N_2Cl_2$ requires C, 41·6; H, 1·7%), insoluble in the ordinary solvents. The sodium and the ammonium salt formed cream-coloured needles and were sparingly soluble in water.

3 : 4 : 5 : 6-*Tetrachloro*-N-*aminophthalimide*.—(1) Tetrachlorophthalic acid in alcoholic solution was treated with hydrazine hydrate (1 mol.) and the white precipitate which separated was heated on an oil-bath for 12 hours at 140—150°; the yellow residue was powdered, extracted with warm water, and crystallised from glacial acetic acid (compare Radulescu and Alexa, *loc. cit.*). (2) Tetrachlorophthalic anhydride (5 g.) was dissolved in alcohol (25 c.c.) and mixed with hydrazine hydrate (0·9 g.; 1 mol.) in water (25 c.c.); the mixture was refluxed for 1 hour. The colourless plates (4·5 g.) which separated were washed with water and crystallised from glacial acetic acid. *Tetrachloro*-N-*aminophthalimide* formed colourless, flat, rhombic needles, m. p. 288° (decomp.) (Found: N, 9·3. $C_8H_2O_2N_2Cl_4$ requires N, 9·3%), almost insoluble in water

or alcohol. It gave deep yellow solutions in glacial acetic acid or nitrobenzene. It was insoluble in cold aqueous caustic alkali or carbonate, but slowly dissolved in hot alkali and slowly separated when the solution was made acid. In hot acetic acid it was converted into tetrachlorophthalimide, m. p. 335°, by sodium nitrite. It reduced hot Fehling's solution. When boiled for 5 minutes with benzaldehyde in acetic acid it gave a *benzylidene* derivative, which formed pale yellow plates from alcohol, m. p. 232° (Found: N, 7·4. $C_{15}H_6O_2N_2Cl_4$ requires N, 7·2%).

*Octachloro-*N*-phthalimidophthalimide* (as V) was obtained by heating tetrachlorophthalic anhydride with 3 : 4 : 5 : 6-tetrachloro-*N*-aminophthalimide in glacial acetic acid for 10 minutes; the deep yellow colour of the solution disappeared, and long, white, acicular needles, m. p. above 350°, separated on cooling (Found: N, 4·9. $C_{16}O_4N_2Cl_8$ requires N, 4·9%).

3-*Hydroxyphthalimide*.—The use of hydrochloric acid in the following diazotisation leads to contamination of the product with 3-chlorophthalimide. 3-Aminophthalimide (4·8 g.) was dissolved in concentrated sulphuric acid (10 c.c.) at room temperature, cooled, and diluted to 30 c.c. with dry ice. The suspension of sulphate formed was diazotised at 0·5° with sodium nitrite (2·2 g. in 5 c.c. of water); the filtered diazo-solution (orange) was decomposed on the water-bath (2 hours), and the buff precipitate dried, sublimed at its m. p., and crystallised from water, yielding 3-*hydroxyphthalimide* in colourless needles (2·9 g.), m. p. 255—256°, soluble in cold alkali to a deep yellow solution with a strong green fluorescence, from which it was reprecipitated by acetic acid. It was soluble also in hot water or alcohol to green fluorescent solutions, and gave a deep red colour with ferric chloride (Found: C, 59·3; H, 3·2. $C_8H_5O_3N$ requires C, 59·0; H, 3·1%).

5-*Hydroxyphthalaz*-1 : 4-*dione* (I; R = OH).—This could not be obtained free from coloured impurities when prepared by diazotisation of 5-aminophthalaz-1 : 4-dione, but was obtained pure as follows. 3-Hydroxyphthalimide (1·6 g.) and hydrazine hydrate (1·0 g.; 2 mols.) were refluxed together for 1 hour, in water (20 c.c.); the pale yellow solution was then made acid with dilute acetic acid, and the white precipitate crystallised from a large volume of hot water. The *hydroxy-dione* formed white hexagonal rods, m. p. 330° (decomp.), readily soluble in alkalis to colourless solutions. It gave a deep brown coloration with ferric chloride (Found: C, 54·0; H, 3·6. $C_8H_6O_3N_2$ requires C, 53·9; H, 3·4%). The *mono-sodium* salt was prepared in long white needles (Found: Na, 11·2. $C_8H_5O_3N_2Na$ requires Na, 11·5%).

We thank the Department of Scientific and Industrial Research and the Chemical Society for grants.

Queen Mary College (University of London), E. 1. [*Received, October 9th*, 1936.]