CXXXIV.—*Investigations in the Diphenyl Series. Part IX. Further Experiments with Sulphonamides.*

By Frank Bell.

Although the acetyl derivatives of 2-amino- and 4-amino-diphenyl can be nitrated only to dinitro-compounds (Scarborough and Waters, J., 1927, 89), it appeared probable that by the use of sulphonyl derivatives trinitro-compounds and hence trinitroamines would be obtainable (Bell, J., 1928, 2772). To avoid complications during the vigorous nitration, *m*-nitrobenzenesulphonyl derivatives were employed and in this way both 2-amino- and 4-amino-diphenyl were easily converted into trinitro-compounds.

The reaction of outstanding interest in the substitution of derivatives of 2-amino- and 4-amino-diphenyl is the bromination of 4-acetamidodiphenyl (Scarborough and Waters, J., 1926, 507; Kenyon and Robinson, *ibid.*, p. 3050), for in marked contrast with every other simple monosubstitution reaction of aminodiphenyls and their derivatives there is produced a considerable yield of a heteronuclear-substituted product, 4′-bromo-4-acetamidodiphenyl.

Since the above experiments showed that the arylsulphonamides readily undergo substitution, the bromination of 2- and 4-*p*-toluenesulphonamidodiphenyls was investigated. The latter is brominated

exclusively in the 3-position and is then dibrominated in the 4′-position, whereas 2-*p*-toluenesulphonamidodiphenyl is brominated in the 5-position and is then resistant to further substitution under the conditions employed.

These results show very clearly the marked difference which exists in the processes of nitration and bromination. Both 2- and 4-*p*-toluenesulphonamidodiphenyls are dinitrated with the utmost ease in the 3 : 5-positions and although the failure to brominate 3-bromo-4-*p*-toluenesulphonamidodiphenyl in the 5-position may be attributed to the competitive action of the bromo- and the *p*-toluenesulphonamido-group acting in the same nucleus, this explanation can scarcely be valid for the monobromination of 4-acetamidodiphenyl.

The comparison of the processes of nitration and bromination was extended to include 4-methoxydiphenyl. This substance on bromination gave a mixture of 3-*bromo-* and 4′-*bromo*-4-*methoxydiphenyls*, the yields being about 60% and 30% respectively. Both these monobromo-derivatives on further bromination gave 3 : 4′-*dibromo*-4-*methoxydiphenyl*. In this case, therefore, there is much less contrast between bromination and nitration (Bell and Kenyon, J., 1926, 3047).

It was intended to include 2-dimethylaminodiphenyl in this study, but 2-aminodiphenyl on methylation under the same conditions which readily produced 4-dimethylaminodiphenyl (Bell, J., 1926, 2709) gave only 2-methylaminodiphenyl.

During the course of this work it was noticed that certain of these sulphonamides readily reacted with a further molecule of sulphonyl chloride to give disulphonamides, and it was thought of interest to examine this reaction in greater detail. The following results were obtained :

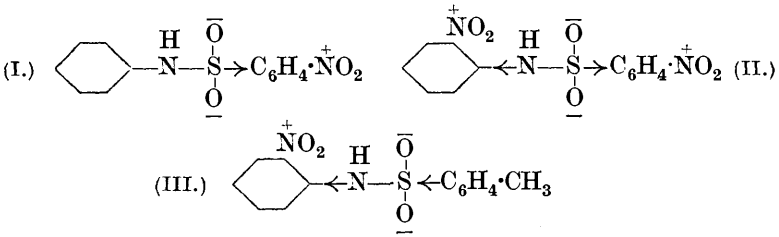
(*a*) 3 : 5-Dibromo-4-aminodiphenyl, 2-nitro-*p*-toluidine, and 6-nitro-*o*-toluidine reacted with the sulphonyl chloride (1 mol.) to give disulphonamides. The yield was not quantitative even when 2 mols. of sulphonyl chloride were employed, and therefore the velocity of disulphonamide formation must be high compared with that of monosulphonamide formation.

(*b*) *o*-Nitroaniline and 1 : 8-dinitro-β-naphthylamine with the sulphonyl chloride (1 mol.) gave mixtures of monosulphonamide and disulphonamide (Bell, J., 1929, 2787).

(*c*) Other amines gave monosulphonamides which were converted into disulphonamides with very different velocities.

It would appear that the velocity of disulphonamide formation is determined by the tendency of the sulphonamide-hydrogen atom to undergo ionisation. For instance, the *m*-nitrobenzenesulphonyl derivatives of the nitroanilines (II) react readily with a molecule of a

sulphonyl chloride, whereas that of aniline (I) reacts very slowly. This accords with the electron-absorbing character of the nitro-group, which is most easily satisfied if the hydrogen of the amino-group



separates with a positive charge (gives up its electron and separates as a hydrogen ion). Similarly the mobility of this hydrogen atom is influenced by the substituents present in the benzenesulphonyl group. It would be expected that *p*-toluenesulphonamides (III) should be less reactive than *m*-nitrobenzenesulphonamides, and this is actually the case. For example, under the same experimental conditions, *m*-nitrobenzenesulphon-*m'*-nitroanilide reacts quantitatively with *p*-toluenesulphonyl chloride, whereas *p*-toluenesulphon-*m'*-nitroanilide gives only a 50% yield of the same compound when treated with *m*-nitrobenzenesulphonyl chloride.

Sulphonamides capable of giving rise to disulphonamides will also undergo acetylation. For instance, *p*-toluenesulphon-*m'*-nitroanilide is easily converted into *p*-toluenesulphon-*m'*-nitroacetanilide. On the other hand, the acetyl derivatives of *o*- and *m*-nitroanilines did not react with either *m*-nitrobenzenesulphonyl chloride or *p*-toluenesulphonyl chloride in pyridine solution. This is comparable with the well-known fact that secondary amines, such as methylaniline, are readily acetylated, whereas acetylated primary amines cannot be methylated by shaking with methyl sulphate.

The diminution in directing power which takes place when the sulphonamido- is converted into the disulphonamido-group (J., 1929, 2877) is further illustrated by the fact that 5-nitro-2-di-*m*-nitrobenzenesulphonamidodiphenyl can only be converted into a dinitro-derivative, whereas the sulphonamido-derivative is easily trinitrated. Also *m*-nitrobenzenesulphon-*m'*-nitroanilide is very vigorously attacked by fuming nitric acid, whereas di-*m*-nitrobenzenesulphon-*m*-nitroanilide can be recovered unchanged from this reagent.

EXPERIMENTAL.

Unless otherwise stated, sulphonamides and disulphonamides were prepared by interaction of the appropriate amine, or sulphonamide,

and sulphonyl chloride in pyridine solution and were recrystallised from acetic acid.

4-m-*Nitrobenzenesulphonamidodiphenyl* formed colourless needles, m. p. 149° (Found: C, 61·3; H, 4·0. $C_{18}H_{14}O_4N_2S$ requires C, 61·0; H, 4·0%).

To this compound (15 g.) in acetic acid (150 c.c.) was added nitric acid (*d* 1·5, 15 c.c.) in acetic acid (15 c.c.). The solution rapidly deposited crystals which, after recrystallisation from acetic acid, gave pure 3-*nitro*-4-m-*nitrobenzenesulphonamidodiphenyl* in yellow prisms, m. p. 170° (Found: C, 54·2; H, 3·3. $C_{18}H_{13}O_6N_3S$ requires C, 54·1; H, 3·3%). This compound (5 g.) was added in small portions to nitric acid (*d* 1·5, 12 c.c.) and after $\frac{1}{4}$ hour the resultant solution was diluted with acetic acid; the 3 : 5 : 4′-*trinitro*-4-m-*nitrobenzenesulphonamidodiphenyl* thus precipitated, after crystallisation from acetic acid, formed needles, m. p. 199° (Found: C, 44·2; H, 2·3. $C_{18}H_{11}O_{10}N_5S$ requires C, 44·2; H, 2·3%). 3 G. were dissolved in sulphuric acid (6 c.c.) and after $\frac{1}{4}$ hour the solution was poured into water. The resulting precipitate after crystallisation from pyridine gave 3 : 5 : 4′-*trinitro*-4-*aminodiphenyl* as long yellow needles, m. p. 282° (Found: C, 46·9; H, 2·6. $C_{12}H_8O_6N_4$ requires C, 47·4; H, 2·6%).

3-*Nitro*-4-*di*-m-*nitrobenzenesulphonamidodiphenyl* formed prisms, m. p. 187° (Found: C, 48·8; H, 2·8. $C_{24}H_{16}O_{10}N_4S_2$ requires C, 49·3; H, 2·7%), and 2-m-*nitrobenzenesulphonamidodiphenyl* colourless needles, m. p. 128° (Found: C, 61·0; H, 4·1. $C_{18}H_{14}O_4N_2S$ requires C, 61·0; H, 4·0%).

Nitration of 2-m-*Nitrobenzenesulphonamidodiphenyl.*—(*a*) 3 G. were warmed on a water-bath for 15 hours with a mixture of water (20 c.c.) and nitric acid (4 c.c.). The product, crystallised from alcohol, gave 5-*nitro*-2-m-*nitrobenzenesulphonamidodiphenyl* in platelets, m. p. 150° (Found: C, 54·3; H, 3·5. $C_{18}H_{13}O_6N_3S$ requires C, 54·1; H, 3·3%).

(*b*) To 4 g., dissolved in acetic acid (40 c.c.) at 70°, was added nitric acid (*d* 1·5; 3 c.c.) in acetic acid (3 c.c.) and the whole was maintained at 70° for $\frac{1}{4}$ hour. On cooling, the liquid filled with pale yellow leaflets, m. p. *ca.* 145°, containing acetic acid of crystallisation. Recrystallised from alcohol, this product furnished pure 3 : 5-*dinitro*-2-m-*nitrobenzenesulphonamidodiphenyl* in needles, m. p. 148° (Found: C, 48·2; H, 2·9. $C_{18}H_{12}O_8N_4S$ requires C, 48·7; H, 2·7%). This constitution was proved by hydrolysis: a solution of the compound (1 g.) in sulphuric acid (2 c.c.) was after $\frac{1}{2}$ hour poured into water and neutralised with ammonia; the precipitated 3 : 5-dinitro-2-aminodiphenyl crystallised from alcohol in yellow plates, m. p. 182° (Bell, J., 1928, 2774).

(*c*) 3 : 5-Dinitro-2-*m*-nitrobenzenesulphonamidodiphenyl (2 g.) was added slowly to nitric acid (*d* 1·5; 6 c.c.), and the solution poured into water. The resulting gum was filtered off, dried, and crystallised from benzene. After benzene had been expelled by heating at 120° for several hours, impure 3 : 5 : 4′-*trinitro*-2-m-*nitrobenzenesulphonamidodiphenyl* was obtained as a pale yellow powder, m. p. 170—175° (Found : C, 44·9; H, 2·6. $C_{18}H_{11}O_{10}N_3S$ requires C, 44·2; H, 2·3%). Hydrolysis of this gave 3 : 5 : 4′-trinitro-2-aminodiphenyl as prisms, m. p. 239° after recrystallisation from pyridine (Bell, J., 1928, 2775).

5-*Nitro*-2-*di*-m-*nitrobenzenesulphonamidodiphenyl* was obtained as a white powder, m. p. 222° (Found : C, 49·5; H, 2·9. $C_{24}H_{16}O_{10}N_4S_2$ requires C, 49·3; H, 2·7%).

This compound (2 g.) was added to nitric acid (*d* 1·5; 5 c.c.); after ¼ hour the solution was diluted with acetic acid, and the resulting precipitate collected and extracted with hot acetic acid; 5 : 4′(?)-*dinitro*-2-*di*-m-*nitrobenzenesulphonamidodiphenyl*, m. p. 240°, was left undissolved (Found : C, 45·4; H, 2·7. $C_{24}H_{15}O_{12}N_5S_2$ requires C, 45·8; H, 2·4%). Attempts to hydrolyse this compound were unsuccessful.

Bromination of 4-*Methoxydiphenyl.*—To 4-methoxydiphenyl (8 g.) in chloroform (25 c.c.) was added bromine (7 g.) in chloroform (10 c.c.). The solution was evaporated, and the residue fractionally crystallised from petroleum; it then separated into 4′-*bromo*-4-*methoxydiphenyl*, plates, m. p. 144° (Found : C, 59·2; H, 4·0. $C_{13}H_{11}OBr$ requires C, 59·3; H, 4·2%), and the more soluble 3-*bromo*-4-*methoxydiphenyl*, large prismatic needles, m. p. 79° (Found : C, 59·6; H, 4·4%). Both compounds were identified by comparison with the products obtained by the methylation of the corresponding bromo-4-hydroxydiphenyls.

3 : 4′-*Dibromo*-4-*methoxydiphenyl.*—(*a*) To a warm solution of 4′-bromo-4-methoxydiphenyl in chloroform was added bromine (1 mol.) in chloroform. The mixed solution was evaporated to small bulk and diluted with petroleum; 3 : 4′-*dibromo*-4-*methoxydiphenyl*, m. p. 134°, then separated.

(*b*) 3-Bromo-4-methoxydiphenyl treated as under (*a*) gave a product from which a 60% yield of purified 3 : 4′-dibromo-4-methoxydiphenyl was obtained (Found : C, 45·8; H, 2·9. $C_{13}H_{10}OBr_2$ requires C, 45·5; H, 2·9%).

3 : 5-*Dibromo*-4-*methoxydiphenyl*, prepared by methylation of the corresponding phenol, crystallised from petroleum in needles, m. p. 87° (Found : C, 45·2; H, 2·7%).

3 : 5 : 4′-*Tribromo*-4-*methoxydiphenyl*, prepared by methylation of the corresponding phenol, crystallised from benzene in needles, m. p.

115° (Found: C, 36·7; H, 2·2. $C_{13}H_{19}OBr_3$ requires C, 36·9; H, 2·1%).

Dibromination of 4-p-*Toluenesulphonamidodiphenyl.*—To 7 g. in warm chloroform (20 c.c.) was added bromine (7·5 g.) in chloroform (3 c.c.). The reaction was completed on the water-bath and after cooling the solution was filtered from the hydrobromide of 3 : 5 : 4′-tribromo-4-aminodiphenyl (free base, m. p. 149°; acetyl derivative, m. p. 256°). The filtrate on concentration deposited large prismatic needles containing chloroform of crystallisation (loss in weight on drying at 100° = 15·3%), which on recrystallisation from alcohol furnished pure 3 : 4′-*dibromo*-4-p-*toluenesulphonamidodiphenyl* in prisms, m. p. 130° (Found: C, 47·1; H, 3·1. $C_{19}H_{13}O_2NBr_2S$ requires C, 47·4; H, 3·1%).

Bromination of 4′-*Bromo*-4-p-*toluenesulphonamidodiphenyl.*—To 5 g. in warm chloroform (20 c.c.) was added bromine (2 g.) in chloroform (3 c.c.). Treated as above, this gave a small amount of 3 : 5 : 4′-tribromo-4-aminodiphenyl hydrobromide, the remainder being almost pure 3 : 4′-dibromo-4-*p*-toluenesulphonamidodiphenyl.

3 : 4′-*Dibromo*-4-*di*-p-*toluenesulphonamidodiphenyl* formed needles, m. p. 238° (Found: C, 49·1; H, 3·3. $C_{26}H_{21}O_4NBr_2S_2$ requires C, 49·1; H, 3·3%).

3 : 5-*Dibromo*-4-*di*-p-*toluenesulphonamidodiphenyl*, the only product which could be isolated from the interaction of 3 : 5-dibromo-4-*p*-toluenesulphonamidodiphenyl and *p*-toluenesulphonyl chloride (1 mol.) in pyridine solution, crystallised from pyridine in needles, m. p. 291° (Found: C, 49·5; H, 3·3%).

Bromination of 2-p-*Toluenesulphonamidodiphenyl.*—To 10 g. in chloroform (30 c.c.) was added bromine (5 g.) in chloroform (5 c.c.). After completion of the reaction the solution was evaporated to small bulk and diluted with light petroleum; 5-*bromo*-2-p-*toluenesulphonamidodiphenyl* then separated in almost theoretical yield. It was recrystallised from alcohol, forming stout needles, m. p. 115° (Found: C, 56·9; H, 4·0. $C_{19}H_{16}O_2NBrS$ requires C, 56·7; H, 4·0%), and was identical with the compound obtained by the interaction of 5-bromo-2-aminodiphenyl (Scarborough and Waters, J., 1927, 94) and *p*-toluenesulphonyl chloride in pyridine solution.

Attempts to dibrominate 2-*p*-toluenesulphonamidodiphenyl resulted in the production of gummy masses containing 3 : 5-dibromo-2-aminodiphenyl (compare Scarborough and Waters, *loc. cit.*, p. 95).

Methylation of 2-*Aminodiphenyl.*—2-Aminodiphenyl was shaken with a considerable excess of methyl sulphate and sodium hydroxide, and the resultant oil extracted with ether. The ethereal extract was dried with sodium sulphate, evaporated, and the residue distilled in a vacuum. The distillate, b. p. 155°/10 mm., appeared to be a mixture

of substances, as it would not set solid. It was therefore dissolved in dilute hydrochloric acid and treated with a slight excess of sodium nitrite. The liquid was extracted with ether, the extract dried and evaporated, and the residue crystallised from alcohol. It gave stout prismatic needles of 2-*nitrosomethylaminodiphenyl*, m. p. 70° (Found: C, 73·7; H, 5·8. $C_{13}H_{12}ON_2$ requires C, 73·6; H, 5·7%). From the aqueous layer left after the ether extraction, no substance corresponding in properties with a nitroso-tertiary base could be isolated.

Acetylation of p-*Toluenesulphon*-m′-*nitroanilide*.—This substance was dissolved in warm acetic anhydride and two drops of sulphuric acid were added. On cooling, p-*toluenesulphon*-m′-*nitroacetanilide* separated; it formed a white powder, m. p. 165°, after recrystallisation from acetic acid (Found: C, 54·2; H, 4·3. $C_{15}H_{14}O_5N_2S$ requires C, 53·9; H, 4·2%).

By the same method *m*-nitrobenzenesulphon-*p*′-nitroanilide was converted into m-*nitrobenzenesulphon*-p′-*nitroacetanilide*, m. p. 214° (Found: C, 45·8; H, 3·4. $C_{14}H_{11}O_7N_3S$ requires C, 46·0; H, 3·0%).

m-*Nitrobenzenesulphon*-m′-*nitroanilide*, prisms, m. p. 151° (Found: C, 44·9; H, 2·9. $C_{12}H_9O_6N_3S$ requires C, 44·6; H, 2·8%), underwent vigorous nitration on dissolving in fuming nitric acid to give a mixture of polynitro-compounds.

Di-m-*nitrobenzenesulphon*-m′-*nitroanilide*, white powder, m. p. 235° (Found: C, 42·2; H, 2·6. $C_{18}H_{12}O_{10}N_4S_2$ requires C, 42·5; H, 2·4%), was recovered unchanged after solution in fuming nitric acid.

m-*Nitrobenzenesulphon*-p-*toluenesulphon*-m′-*nitroanilide*, prepared by interaction of *m*-nitrobenzenesulphonyl chloride and *p*-toluenesulphon-*m*′-nitroanilide or of *p*-toluenesulphonyl chloride with *m*-nitrobenzenesulphon-*m*′-nitroanilide, formed small needles, m. p. 207° (Found: C, 47·4; H, 3·4. $C_{19}H_{15}O_8N_3S_2$ requires C, 47·8; H, 3·1%).

Di-p-*toluenesulphon*-m′-*nitroanilide*, plates, m. p. 180° (Found: C, 54·1; H, 4·1. $C_{20}H_{18}O_6N_2S_2$ requires C, 53·9; H, 4·0%).

m-*Nitrobenzenesulphon*-p′-*nitro*-o′-*toluidide*, prisms, m. p. 189° (Found: C, 46·0; H, 3·6. $C_{13}H_{11}O_6N_3S$ requires C, 46·3; H, 3·3%).

Di-m-*nitrobenzenesulphon*-p′-*nitro*-o′-*toluidide*, m. p. 201° (Found: C, 43·2; H, 2·7. $C_{19}H_{14}O_{10}N_4S_2$ requires C, 43·7; H, 2·7%).

Di-m-*nitrobenzenesulphon*-o′-*nitro*-p′-*toluidide*, prisms, m. p. 215° (Found: C, 43·8; H, 2·7%).

Di-m-*nitrobenzenesulphon*-o′-*nitro*-o′-*toluidide*, pale yellow needles, m. p. 193° (Found: C, 43·4; H, 2·6%).

Di-p-*toluenesulphonanilide*, large prismatic needles, m. p. 183° (Found: C, 59·7; H, 4·6. $C_{20}H_{19}O_4NS_2$ requires C, 59·8; H, 4·7%).

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