CCCCXXXIV.—*The Mercuration of Aromatic Substances. Part III.* p- *and* m-*Nitrotoluenes.*

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RECENT quantitative investigations on the mercuration of relatively simple benzenoid compounds, *e.g.*, nitrobenzene (Dimroth, *Annalen*, 1926, **446**, 148; Jürgens, *Rec. trav. chim.*, 1926, **45**, 61), toluene (Coffey, J., 1925, **127**, 1029), and *o*-nitrotoluene (Coffey, this vol., p. 637; Burton, Hammond, and Kenner, *ibid.*, p. 1802), have clearly proved that these reactions do not follow the usual laws of substitution (compare also Coffey, *Chem. Weekblad*, 1926, **23**, 194). The study of this type of substitution has now been extended to *p*- and *m*-nitrotoluenes. A third substituent enters the former compound as a rule exclusively in position 2, but the mercuration is "abnormal" in that a large quantity of the compound substituted in the 3-position is formed; in fact, this may constitute as much as 80% of the mono-substitution products isolated. Therefore, as with toluene and *o*-nitrotoluene, the mercuration of *p*-nitrotoluene appears to depend mainly on the nature of the entering group. Owing to the antagonistic orienting powers of the methyl and the nitro-group in *m*-nitrotoluene, substituents may enter the nucleus in positions 2, 4, 5, and 6 (compare Holleman, "Die direkte Einführung von Substituenten in den Benzolkern," Leipzig, 1910, pp. 310—314), and it is impossible to decide what the normal course of the reaction should be.

Reissert (*Ber.*, 1907, **40**, 4209) has obtained derivatives of *p*-nitrotoluene mercurated in the side chain, but no compounds have yet been described containing mercury directly attached to the aromatic nucleus. Such compounds are readily produced, however, by heating *p*-nitrotoluene with mercuric acetate at 140°.

The proportions of the 2- and 3-*acetoxymercuri*-4-*nitrotoluenes* obtained on mercuration were determined by converting the product through the chloromercuri-*p*-nitrotoluenes into a mixture of 2- and 3-bromonitrotoluenes and analysing this thermally. For comparison, 2- and 3-bromonitrotoluenes were prepared and the final melting points of the binary mixture determined. The two substances behaved normally, no compounds or solid solutions being formed.

Pure individual products could not be isolated from the mercuration mixture and therefore the two components were made synthetically.

2-*Chloromercuri*-4-*nitrotoluene* was prepared from the corresponding sulphinic acid (compare Peters, *Ber.*, 1905, **38**, 2567), obtained by warming the sulphonyl chloride with sodium sulphite (compare Blomstrand, *Ber.*, 1870, **3**, 965; Limpricht, *ibid.*, 1892, **25**, 75, 3477).

Derivatives of *p*-nitrotoluene containing a substituent in the 3-position are difficult to prepare.

3-*Chloromercuri*-4-*nitrotoluene* was synthesised by the following series of reactions: 4-Nitro-*o*-toluidine was sulphonated with chlorosulphonic acid, giving exclusively 4-*nitro*-o-*toluidine*-5-*sulphonic acid* (the constitution of which was proved by reducing it to 2 : 4-tolylenediamine-5-sulphonic acid; Foth, *Annalen*, 1885, **230**, 300). The diazonium derivative of this sulphonic acid was extremely stable and the elimination of the diazonium group was effected only by means of copper powder and formic acid. The 4-*nitrotoluene*-3-*sulphonic acid* thus obtained was converted into the corresponding *sulphinic acid*, and this into 3-chloromercuri-4-nitrotoluene.

3-Bromo-4-nitrotoluene was prepared from 4-nitroaceto-*m*-toluidide, which is produced to the extent of 10—15% by the usual method of nitrating aceto-*m*-toluidide (Cohen and Dakin, J., 1903,

83, 333; Cook and Brady, J., 1920, **117**, 1952). This method is slow and laborious on account of the great solubility and tendency to form supersaturated solutions of the nitroacetotoluidide. By using Menke's method (*Rec. trav. chim.*, 1925, **44**, 144) of nitration with copper nitrate and acetic anhydride, the yield of 4-nitroacetotoluidide has been increased from 10% to 50%, thus allowing of its isolation in quantity.

m-Nitrotoluene is more difficult to mercurate than the ortho-compound, but on heating with mercuric acetate for 12 hours it gave a mixture of acetoxymercuri-*m*-nitrotoluenes, which were converted into the corresponding chloromercuri-derivatives. 4- and 5-Chloromercuri-3-nitrotoluenes were isolated from this mixture and the occurrence of 6-chloromercuri-3-nitrotoluene was proved by the isolation of 6-bromo-*m*-toluidine from the mixture of amino-compounds obtained by reducing the corresponding mixture of bromonitrotoluenes.

EXPERIMENTAL.

Mercuration of p-*Nitrotoluene.*—*p*-Nitrotoluene (crystallised from petroleum) and mercuric acetate in various proportions were heated together at 140° for different lengths of time. In most cases, the product, if allowed to cool, solidified at about 100°. The hot mixture was therefore poured directly into ether (10 times the weight of nitrotoluene taken) and left over-night. The large precipitate (B) obtained consisted of unchanged mercuric acetate, mercurous acetate, and highly mercurated nitro-compounds, the proportions of which varied with the duration of heating.

The ether was distilled from the filtrate, excess of sodium chloride added, and the excess of *p*-nitrotoluene distilled in steam, the last traces being removed by boiling with water. The residue of crude monomercurichlorides (A) was dried and extracted with hot acetone, the solution boiled with animal charcoal, and the solvent removed.

The details of the experiments are :

Expt.	Nitrotoluene.	Mercuric acetate.	Time of heating.	B.	A.
I	150 g.	40 g.	4 hours	14 g.	—
II	450 ,,	120 ,,	4 ,,	70 ,,	35 g.
III	200 ,,	60 ,,	5 ,,	—	21 ,,
IV	270 ,,	70 ,,	13 ,,	44 ,,	27 ,,

In the last experiment scarcely any mercuric acetate remained unchanged.

As a rule, the crude monochloromercuri-*p*-nitrotoluene contained about 25% of matter insoluble in acetone. The purified products were colourless solids, readily soluble in hot acetone and fairly easily soluble in hot glacial acetic acid, from which they separated in feathery or woolly crystals. In all cases, however, they were ill-defined and obviously mixtures. They consisted of pure monochloromercuri-*p*-nitrotoluenes (Found: Hg, 53·2, 52·9; Cl, 9·9; N, 3·8. $C_7H_6O_2NClHg$ requires Hg, 53·9; Cl, 9·5; N, 3·8%), but could not be separated into their components by crystallisation.

Orientation of the Chloromercuri-4-*nitrotoluenes.*—The mixture was very readily converted by an equivalent quantity of bromine, dissolved in potassium bromide solution, into a pale yellow oil consisting of the corresponding bromo-*p*-nitrotoluenes. This was distilled in steam and solidified on cooling. Crystallisation from alcohol furnished pure 2-bromo-4-nitrotoluene, m. p. 76°, in small yields, but it proved impossible to isolate pure 3-bromo-4-nitrotoluene by crystallising the oils and buttery solids which remained.

Differential Action of Bromine in Carbon Tetrachloride.—The crude product (24 g. from an experiment identical with II), suspended in 104 c.c. of dry carbon tetrachloride containing 10·4 g. of bromine, was kept in the dark for 12 weeks; bromine and unchanged chloromercuri-*p*-nitrotoluene were then still present. The solution was filtered, the solvent evaporated, and the yellow, buttery residue crystallised from methyl alcohol, about 3 g. of pure 2-bromo-4-nitrotoluene being obtained. The mercuric bromide produced and the unchanged substance were treated with bromine in potassium bromide solution; a further quantity of mixed bromonitrotoluenes was then obtained as an oil. This was distilled in steam; it solidified (m. p. 30—35°) after several weeks and on crystallisation from methyl alcohol gave 3 g. of very pale yellow, prismatic needles of 3-bromo-4-nitrotoluene, m. p. 36°. Hence the original mixture of monochloromercuri-4-nitrotoluenes must have contained at least 25% of the unexpected 3-compound.

2-*Bromo*-4-*nitrotoluene.*—A solution of *p*-nitro-*o*-toluidine (25 g.) in hydrobromic acid was diazotised and added to a cooled solution of cuprous bromide and the product was distilled in steam (compare Blanksma, *Chem. Weekblad*, 1909, **6**, 899), practically pure 2-bromo-4-nitrotoluene passing over (yield, 90%). After crystallising twice from alcohol, it was obtained in almost colourless, glistening needles; the fused solid froze constantly at 75·8°. In the literature, the melting point is variously given as from 75° to 78° (compare Nevile and Winther, *Ber.*, 1881, **14**, 418; Scheufelen, *Annalen*, 1885, **231**, 171).

Nitration of Aceto-m-*toluidide and Preparation of* 3-*Bromo*-4-*nitrotoluene.*—A solution of *m*-toluidine (15 g.; 2 mols.) in 90 g. of acetic anhydride was cooled to 0° and shaken with trihydrated copper nitrate (16·4 g., recrystallised from hot concentrated nitric acid and carefully dried). The copper salt gradually dissolved with evolution of heat and the temperature was kept as low as possible by cooling in ice; copper acetate crystallised as the reaction proceeded. The main reaction was over in about 1½ hours and cooling was then unnecessary. After 12 hours, the mixture was poured into 3 litres of ice-water and stirred until the anhydride had disappeared. The washed yellow solid (21 g.; m. p. 58—68°), which was free from occluded copper salts, was crystallised from alcohol (good cooling was required to crystallise the 4-nitro-compound), 4-nitroaceto-*m*-toluidide separating in long sheaves of golden-yellow needles and 6-nitroaceto-*m*-toluidide in compact, crimson prisms. The two compounds were separated mechanically and each was recrystallised until pure.

4-Nitroaceto-*m*-toluidide, thus obtained in long, golden needles, m. p. 85·8°, was warmed on a water-bath with 2½ times its weight of hydrobromic acid (*d* 1·4) and the solution was added to 40 c.c. of hydrobromic acid and 30 c.c. of water and cooled below 0°. The theoretical quantity of sodium nitrite dissolved in ten times its weight of water was then added all at once with violent agitation, and the clear diazotised solution added to a cooled solution of cuprous bromide obtained by boiling 3·5 parts of copper oxide and 5·2 parts of copper in 70 parts of hydrobromic acid (*d* 1·4) and 8 parts of water. A violent action took place and when this had subsided the bromonitrotoluene was distilled in steam. The yield was nearly theoretical. The oil solidified readily and was then recrystallised from methyl alcohol until the freezing point was constant. 3-Bromo-4-nitrotoluene crystallises in pale yellow prisms or needles, m. p. 36·2°.

The System 2-*Bromo*-4-*nitrotoluene*–3-*Bromo*-4-*nitrotoluene.*

The final melting points of mixtures of these two substances were determined by cooling the molten mixture very slowly with constant vigorous agitation until solidification began and then remelting by gentle warming, the temperature at which a solid phase ceased to exist being observed to within 0·1°. No untoward difficulties were encountered and the results were as follows:

2-Bromo-4-nitrotoluene %.	M. p.	2-Bromo-4-nitrotoluene %.	M. p.	2-Bromo-4-nitrotoluene %.	M. p.	2-Bromo 4-nitrotoluene %.	M. p.
—	36·2°	24·4	25·4°	44·75	39·2°	70·65	59·6°
3·57	35·0	29·75	22·6	49·55	43·6	77·1	63·7
7·34	33·3	32·1	25·6	53·9	47·4	89·2	70·6
12·6	31·2	37·0	31·8	57·35	50·2	100·0	75·8
17·1	29·0	41·3	36·0	64·6	56·0		

Mixtures containing from 17·1 to 37% of 2-bromo-4-nitrotoluene, on being cooled continuously below the solidification point, solidified completely when the eutectic temperature, 22·2°, was reached.

Quantitative Results obtained on mercurating p-*Nitrotoluene.*

The above melting points were used to determine the composition of the mixtures of monochloromercuri-4-nitrotoluenes obtained by mercurating *p*-nitrotoluene. The mixture was converted quantitatively into a mixture of the corresponding bromonitrotoluenes by treatment with bromine in potassium bromide solution and the bromonitrotoluenes were distilled in steam, filtered off while still warm and liquid through a wet filter, and dried. The melting points of these mixtures were then determined.

The mixture of chloromercuri-*p*-nitrotoluenes obtained in Expt. III gave a mixture of bromonitro-compounds melting completely at 22·8°; addition of a small quantity of pure 2-bromo-4-nitrotoluene raised the melting point. The mixture also solidified completely at the eutectic point—which was a clear proof of its being a mixture of the two bromonitrotoluenes. It therefore contained 30·5% only of the normal substitution product, namely, 2-bromo-4-nitrotoluene, and 69·5% of 3-bromo-4-nitrotoluene.

The mixture obtained in Expt. IV by heating for 13 hours gave a mixture melting at 26·4°, the solid phase being the 3-bromo-compound. This corresponds to 22·5% of the normal substitution product and 77·5% of the compound substituted in the 3-position.

Synthesis of 2-*Chloromercuri*-4-*nitrotoluene.*

4-Nitrotoluene-2-sulphonic acid was prepared by heating 50 g. of *p*-nitrotoluene and 110 g. of 20% oleum at 120° for 2 hours. The mixture was poured into 500 c.c. of saturated potassium chloride solution and the potassium salt was filtered off and recrystallised from water with the aid of charcoal (yield of anhydrous salt, 70%; compare Beilstein and Kuhlberg, *Annalen*, 1870, **155**, 8; Janssen, *ibid.*, 1874, **172**, 230).

4-*Nitrotoluene*-2-*sulphinic Acid.*—The molten sulphonyl chloride (10 g.; prepared from the potassium salt in the usual way) was shaken with a solution of 10·5 g. of sodium sulphite in 25 c.c. of water, the acidity that developed being corrected by the occasional addition of 50% caustic soda solution (total amount of caustic soda required, 3·3 g. or 2 mols.). Eventually the mixture reached a temperature of 65° and all the sulphonyl chloride disappeared; the whole mass then suddenly crystallised. The *sodium* salt was collected when cold and dried in a desiccator over-night (yield, 7 g.) (Found: Na, 9·1; H_2O, 13·9. $C_7H_6O_4NSNa,2H_2O$ requires Na, 8·9; H_2O, 13·9%).

4-Nitrotoluene-2-sulphinic acid, prepared by acidifying an aqueous solution of the sodium salt, slowly separated in shining, pale yellow plates, m. p. 127—128°. It was fairly stable in air but reduced permanganate (Found, by oxidation with permanganate: *M*, 199·2. Calc.: *M*, 201). The ferric salt was prepared (Found: Fe, 8·8. Calc.: Fe, 8·3%).

2-Chloromercuri-4-nitrotoluene was obtained as a white solid when the sulphinic acid was boiled with a 50% aqueous alcoholic solution of mercuric chloride. The solid was washed with 50% alcohol, dried, and extracted with acetone. From the extract, 2-chloromercuri-4-nitrotoluene separated in feathery needles, m. p. 230—231° (corr.).

Synthesis of 3-*Chloromercuri*-4-*nitrotoluene.*

Sulphonation of p-*Nitro*-o-*toluidine.*—The nitrotoluidine was mixed with chlorosulphonic acid (1½ mols.) and heated very cautiously to 150°. A fairly vigorous reaction took place, which was at an end in about an hour. (If the heating is not properly controlled, a vigorous reaction takes place with explosive violence and much charring.) The solid mass was dissolved in dilute boiling aqueous ammonia; the filtered solution, on cooling, deposited a mixture of four-sided plates and yellow needles. The latter (unchanged base) were removed by washing the mixture with ether, and the plates were then recrystallised from hot water, giving large, golden, striated, four-sided, anhydrous tablets of *ammonium* 4-*nitro*-2-*aminotoluene*-5-*sulphonate* (Found: NH_3, 6·8. $C_7H_{11}O_5N_3$ requires NH_3, 6·8%).

The *potassium* salt was similar in appearance and general properties. The *sulphonic acid*, prepared from the ammonium salt, crystallised in colourless needles with no definite melting point. The ammonium salt was dissolved in hot hydrochloric acid and reduced with the calculated quantity of stannous chloride, 2 : 4-tolylenediamine-5-sulphonic acid being formed in almost theoretical yield. The properties of this acid and of its potassium and barium salts and hydrochloride agreed almost exactly with the descriptions given by Foth (*loc. cit.*).

4-*Nitrotoluene*-2-*diazonium*-5-*sulphonate.*—A fine suspension of ammonium 4-nitro-2-aminotoluene-5-sulphonate (16·5 g.) in water was treated in the cold with 10 g. of sodium nitrite (in water) followed by an excess of dilute sulphuric acid. The white, crystalline substance produced was collected after 12 hours, well washed, and dried in the air (yield, theoretical). The compound was very sparingly soluble and exploded on heating.

4-*Nitrotoluene*-3-*sulphonic Acid.*—The diazonium compound was suspended in six times its weight of formic acid (*d* 1·2), and 4 g. of copper powder were added. Nitrogen was evolved immediately and, on warming, a violent evolution of nitrogen and carbon dioxide (1·4 : 1·0) took place. A blue solution was produced—this and the low production of carbon dioxide point to the fact that the copper plays some part in the oxidation of the formic acid. Water was then added, the solution boiled and filtered, the formic acid distilled in steam, and the copper removed as sulphide. The acid solution was then neutralised with barium carbonate and evaporated. (The author is indebted to Dr. Brady for suggesting this method of removing the diazonium group.) The *barium* salt was extremely soluble and could only be obtained as a viscous syrup. The *potassium* salt, prepared from the barium salt, was obtained as a very soluble, pale yellow, anhydrous, crystalline powder (yield, 10 g. from 16 g. of the diazonium compound) (Found : K, 15·2. $C_7H_6O_5NSK$ requires K, 15·3%).

The sulphonyl chloride was obtained, by the action of phosphorus pentachloride on the above salt, as a pale brown oil which would not crystallise.

4-*Nitrotoluene*-3-*sulphinic Acid.*—The sulphonyl chloride was treated with sodium sulphite and caustic soda in the way previously described for the preparation of 4-nitrotoluene-2-sulphinic acid. The reaction was difficult to control satisfactorily. The dark brown solution was filtered from tar, diluted to 200 c.c., acidified, filtered hot through a wet filter, cooled, and treated with ferric chloride, and the sparingly soluble ferric salt was collected. This was converted into the ammonium salt, and the solution evaporated to small bulk and acidified; the sulphinic acid then separated as an oil, which formed colourless crystals, m. p. 112—113°, on scratching (yield, 1·5 g.) (Equiv. : found, 202; calc., 201).

3-*Chloromercuri*-4-*nitrotoluene.*—The sulphinic acid reacted readily with mercuric chloride in boiling 50% alcohol. The solid obtained was filtered off, washed, and extracted with hot acetone, almost all of it dissolving. The solution was boiled with charcoal and allowed to crystallise, 3-*chloromercuri*-4-*nitrotoluene* separating as a felty pad of very small, colourless needles, m. p. 226—227° (corr.). This compound does not crystallise so beautifully as its isomeride and is identical in appearance with the crude mercuration product. Crystallisation from acetic acid did not alter its melting point (Found : Hg, 54·4%). On treatment with bromine in potassium bromide solution this compound furnished pure 3-bromo-4-nitrotoluene, m. p. 36°.

Mercuration of m-*Nitrotoluene.*

m-Nitrotoluene (m. p. 15·5°; purified by freezing) (500 g.) was heated with mercuric acetate (125 g.), with occasional shaking, at 120—130° for 1 hour and then at 130—140° for 12 hours until a test portion of the mixture no longer gave a precipitate of mercuric oxide when treated with cold sodium hydroxide solution. When cold, the liquid was filtered from 9 g. of solid matter and poured into 6 litres of ether; about 10 g. of polymercurated nitrotoluenes then separated. The ether was distilled and the residual *m*-nitrotoluene solution was treated with brine and distilled in steam. When about half of the excess of nitrotoluene had been removed a large amount of solid (82 g.) separated and distillation became difficult. The remaining nitrotoluene was therefore decanted and again distilled in steam until the separation of more solid made distillation impossible. The combined solids were boiled with water until free from occluded nitrotoluene. The crude product (105 g.) was found by analysis to consist only of monochloromercurinitrotoluenes.

The aqueous solution in the distillation flask contained mercuric salts equivalent to 5 g. of mercuric acetate.

5-*Chloromercuri*-3-*nitrotoluene.*—The crude chloromercuri-*m*-nitrotoluenes were boiled with 300 c.c. of acetone for ½ hour, and the mixture filtered hot. The insoluble portion (20 g.) was extracted with hot acetone (three lots of 200 c.c. each). 5-*Chloromercuri*-3-*nitrotoluene* remained undissolved; it melted at 294° (corr.), even after recrystallisation from glacial acetic acid. It crystallised in colourless, feathery needles (Found: Hg, 53·3. $C_7H_6O_2NClHg$ requires Hg, 53·9%).

When treated with bromine in carbon tetrachloride or potassium bromide solution, the compound gave a theoretical yield of bromonitrotoluene, m. p. 80—81·5°, which crystallised from methyl alcohol in pale yellow needles, m. p. 83·5—84·5° (corr.). 5-Bromo-3-nitrotoluene, which has the highest melting point of all the known bromo-*m*-nitrotoluenes, melts at 81·4—81·8° (Nevile and Winther, *Ber.*, 1880, **13**, 969).

4-*Chloromercuri*-3-*nitrotoluene.*—The acetone extracts obtained above, on cooling, deposited a mixture containing small clusters of well-defined crystals. These were separated mechanically and crystallised from acetone until the m. p. remained constant. 4-*Chloromercuri*-3-*nitrotoluene* was thus obtained in clusters of pale yellow needles resembling mimosa flowers, m. p. 210° (corr.; sintering at 207°).

The substance obtained by treating this compound with bromine in potassium bromide solution (yield, quantitative) melted at 32—33° and on crystallisation from methyl alcohol furnished 4-bromo-3-nitrotoluene, m. p. 35°, identical with a specimen obtained from 3-nitro-*p*-toluidine (compare Beilstein and Kuhlberg, *Annalen*, 1871, **158**, 344; Nevile and Winther, *loc. cit.*; Claus, *J. pr. Chem.*, 1892, **46**, 25).

Presence of 6-*Chloromercuri*-3-*nitrotoluene.*—The remainder of the chloromercuri-*m*-nitrotoluenes was converted quantitatively into a mixture of bromonitrotoluenes by means of bromine in potassium bromide solution. This mixture was reduced to the corresponding amino-compounds by warming it on a water-bath with three times its weight of hydrated stannous chloride in concentrated hydrochloric acid for 2½ hours. The solution was then almost neutralised with sodium hydroxide solution, and an excess of sodium acetate added. The weakly acid solution on distillation with steam furnished a mixture of bromotoluidines which could not be crystallised. The residue in the distillation flask was made alkaline with sodium hydroxide and distilled with steam; the oil in the distillate rapidly solidified and after being dried on tile it crystallised from 50% alcohol in colourless plates, m. p. 79·5—80° (corr.). Since all the other known bromo-*m*-toluidines melt below 40°, the substance must be 6-bromo-*m*-toluidine (compare Scheufelen, *Annalen*, 1885, **231**, 180, who gives the m. p. as 78°). Thus 6-chloromercuri-3-nitrotoluene was present in the product of mercuration of *m*-nitrotoluene.

The remaining bromotoluidines were acetylated and the mixture obtained was recrystallised several times from alcohol, but only a small quantity of 4-bromoaceto-*m*-toluidide, m. p. 164°, could be isolated.

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