VII.—*The Nitration of Aromatic Thiocyanates.*

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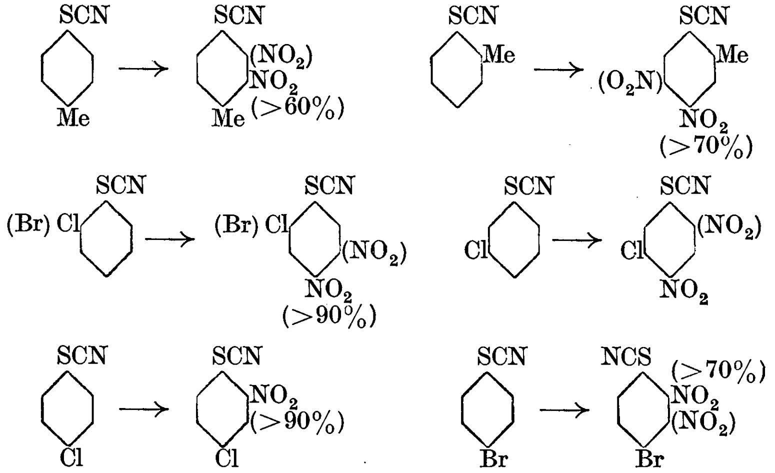
THE *o* : *p* ratio for the nitration of phenyl thiocyanate (Challenger and Collins, J., 1924, **125**, 1377) has been found to be 1 : 4. The ratio for phenyl selenocyanate (Challenger and Peters, J., 1928, 1368), which is being determined, may be expected to be greater, since rise in the atomic number of the halogens increases ortho-substitution (Lapworth and Robinson, *Mem. Manchester Lit. Phil. Soc.*, 1927–8, **72**, 49; *Ann. Rep.*, 1928, 141).

The preparation and nitration of o-*chloro*-, o-*bromo*-, and m-*chlorophenyl thiocyanates* are now described. The ortho-compounds yielded almost exclusively 2-*chloro*(or *bromo*)-4-*nitrophenyl thiocyanates*. About 0·1 g. of the 5-nitro-derivative was obtained from 5·4 g. of *o*-chlorophenyl thiocyanate and from 5 g. of the *o*-bromo-compound. The results obtained in this and earlier communications are summarised on p. 27 : the yield of mononitro-compound is recorded against the nitro-group, and the position of the nitro-group in the isomeride produced is shown by NO_2 in parentheses.

Both the thiocyano-group and the halogens, owing to their large number of unshared electrons, tend to transfer these to the carbon–sulphur or carbon–halogen linkage in phenyl thiocyanates or halogenobenzenes. A drift of electrons (conjugative effect) is thus set up which activates the *o*- and *p*-positions (Allan, Oxford, Robinson, and Smith, J., 1926, 409). The dissociation constants of thiocyanoacetic acid (Ostwald, *Z. physikal. Chem.*, 1889, **3**, 179) and of chloro- and bromo-acetic acids are $2{\cdot}65 \times 10^{-3}$, $1{\cdot}55 \times 10^{-3}$, and $1{\cdot}38 \times 10^{-3}$ respectively. Thiocyanogen is therefore analogous to chlorine in attracting electrons more strongly than hydrogen and imposing on the benzene nucleus a positive field (negative general effect) which opposes the *o* : *p*-orienting conjugative effect. It is well known, however, that no meta-substitution has been detected with the halogenobenzenes, nor have we observed it with phenyl thiocyanate.



The results obtained on nitration of *p*-tolyl thiocyanate may be regarded as in agreement with the much greater ortho-directing influence of methyl as compared with that of thiocyanogen; the *o* : *p* ratio for CH_3 is 58·8 : 36·8 and that of SCN is 20 : 80. Here in the major product the " general effects " of methyl (positive general effect) and of SCN support each other.

In *o*-tolyl thiocyanate, where the *p*-positions with respect to both substituents are unoccupied, the effect of SCN predominates. No vicinal derivatives such as $C_6H_3(NO_2)(SCN)(CH_3)[6:1:2]$ were isolated and the *o*-effects of SCN and CH_3 appear to play a subordinate part. The result appears to be largely determined by the conjugative effect of SCN at position 4. Some substitution occurs to a less extent at 5, the position activated by the methyl group and least inhibited by the general effect of SCN.

With *o*-chloro- and *o*-bromo-phenyl thiocyanates examination shows no trace of vicinal derivatives in the nitration products. The conjugative effect of SCN and the general effect of halogen both tend to favour substitution at position 4, and only traces of the 5-nitro-compounds are formed. With *m*-chlorophenyl thiocyanate vicinal substitution is again absent and two products are formed by the reinforced conjugative effects of SCN and chlorine at positions 4 and 2 respectively, the 4-nitro-compound predominating.

The most interesting feature of these results is the relation of the effects induced by SCN to those induced by methyl and chlorine. It appears from the nitration of the tolyl thiocyanates that the speeds of substitution induced by the CH_3 and the SCN group are not very different, since in comparing ortho-effects (*p*-tolyl thiocyanate) methyl predominates, and in comparing para-directing effects (*o*-tolyl thiocyanate) SCN predominates. On the other hand, the results for halogenophenyl thiocyanates clearly show that the speeds of substitution *o*- or *p*- to SCN are incomparably greater than those *o*- or *p*- to chlorine or bromine in these molecules. In Holleman's series $OH > NH_2 > I > Cl > Br > CH_3$, chlorine is slightly more powerful than methyl (compare Challenger and Collins, *loc. cit.*). Further work is in progress and a study of the physical properties of certain thiocyanates will be made. Attempts to prevent elimination of iodine on nitration of *p*-iodophenyl thiocyanate were unsuccessful (compare Challenger and Collins, *loc. cit.*; Körner, *Gazzetta*, 1875, **4**, 385; Mayes and Turner, J., 1928, 691).

Ingold, Smith, and Vass (J., 1927, 1245) showed that the decomposition of substituted aryl iododichlorides to chloroiodobenzenes is an intermolecular reaction, the position entered by chlorine being determined not necessarily by the iodine, but by the strongest group present. Attempts to decompose the *dichloride* of p-*iodophenyl thiocyanate* so as to induce nuclear chlorination failed, loss of chlorine and regeneration of the iodothiocyanate usually occurring. In sunlight *pp'*-di-iododiphenyl disulphide was formed. This decomposition possibly proceeds by liberation of cyanogen chloride and formation of the *p*-iodophenyl thiolchloride $I{\cdot}C_6H_4{\cdot}SCl$. Thiolchlorides of this type yield disulphides with alcohol. It has therefore been impossible to compare the orienting effects of iodine and thiocyanogen.

Our results may be compared with those of Werner (J., 1907, **91**, 240, 529), who found that a nitro-group in the *o*- or *p*-position to ICl_2 prevents nuclear chlorination. With a halogen atom in the *p*-position, this effect is slightly less, some nuclear chlorination taking place.

EXPERIMENTAL.

o-*Chlorophenyl Thiocyanate.*—*o*-Chloroaniline was diazotised at 0°, added to an aqueous solution of ferric chloride and potassium thiocyanate, and left over-night. The *thiocyanate* was extracted twice with benzene, distilled in steam, and again extracted with benzene. After three fractionations in a vacuum it was almost colourless, boiled at 160—160·5°/42—47 mm., and solidified in ice. Yield, 18 g. (53% of the theoretical). It has an unpleasant odour and the vapour attacks the eyes and skin (Found: Cl, 20·7, 21·1; S, 19·1, 19·15. C_7H_4NClS requires Cl, 20·9; S, 18·9%).

The *o*-bromo-, *p*-iodo-, and *m*-chloro-derivatives of phenyl thiocyanate were similarly prepared (see table below). Extraction with benzene prior to steam distillation removes inorganic salts which may facilitate disulphide formation during treatment with steam.

The irritant effect of *m*-chlorophenyl thiocyanate is much more pronounced than that of the other halogen derivatives.

2-*Chloro*-4-*nitrophenyl Thiocyanate.*—2-Chloro-4-nitroaniline was obtained by the method of Chattaway, Orton, and Evans (*Ber.*, 1900, **33**, 3061), but hot dilute sulphuric acid was found to be most suitable for hydrolysis of the 2-chloro-4-nitroacetanilide, the free base separating on cooling.

2-Chloro-4-nitroaniline was diazotised at −5° and treated as described above. The *product*, when crystallised from alcohol, acetone and finally from light petroleum, formed colourless needles, m. p. 85° (Found: N, 13·3. $C_7H_3O_2N_2ClS$ requires N, 13·05%).

The other halogenonitro-thiocyanates were prepared similarly (see table), cuprous thiocyanate being occasionally employed in place of ferric chloride.

2-Chloro-5-nitrophenyl thiocyanate melts at 107° (Found: C, 39·6; H, 1·3. $C_7H_3O_2N_2ClS$ requires C, 39·2; H, 1·4%).

Substituted aniline.	Wt. of base (g.).	H_2SO_4 (c.c.).	Water (c.c.).	$NaNO_2$ (g.).	KSCN (g.).	$Cu_2(SCN)_2$ (g.).	$FeCl_3$ (g.).	M. p. or b. p. of product.
2-Cl	25·5	40	160	18·7	38·8	—	30	B. p. 160°/ 42 mm.
2-Br	30	40	160	18·0	38·0	—	63·6	B. p. 161—165°/ 10—12 mm.
3-Cl	40	54	200	25·0	60·0	—	30·0	B. p. 135°/ 12·5 mm.
4-SCN	5	3·9	86	3·0	9 g. KI	—	—	M. p. 53°*
2-Cl-5-NO_2	10	60	120	5·0	12·0	—	10·0	,, 107°
2-Cl-4-NO_2	1·7	20	40	0·9	1·9	—	1·6	,, 85°
2-Br-5-NO_2	2·5	15	30	1·1	1·5	2·0	—	,, 124·5°
2-Br-4-NO_2	1·0	8	16	0·5	0·6	0·8	—	,, 93°
3-Cl-4-NO_2	6·0	100	100	3·0	6·2	—	5·3	,, 59°
3-Cl-6-NO_2	6·0	100	100	3·0	6·2	—	5·3	,, 104·5°

The product contained SCN in place of the NH_2 of the original base in every case except that marked *, where *p*-iodophenyl thiocyanate was formed.

Nitration of o-*Chlorophenyl Thiocyanate.*—The thiocyanate (5·4 g.) was slowly added to well-stirred nitric acid (*d* 1·5; 18 c.c.) at −6°, left for 4 hours at room temperature, and poured on ice. The crude product, m. p. 76—78°, weighed 6·6 g., *i.e.*, 96% of the amount required for a mononitro-derivative. Fractional crystallisation from alcohol and then from light petroleum gave a main product (A), m. p. 85°, and about 0·01 g. of (B), m. p. 107°.

A and B did not depress the m. p.'s of synthetic specimens of 2-*chloro*-4-*nitrophenyl thiocyanate* and of 2-*chloro*-5-*nitrophenyl thiocyanate* respectively (Found for A : Cl, 16·6 ; S, 14·7 ; N, 13·3. Found for B : N, 13·2. $C_7H_3O_2N_2ClS$ requires Cl, 16·5 ; S, 14·9 ; N, 13·05%).

A was boiled with animal charcoal in alcohol : the solution yielded a small quantity of white crystals (E), m. p. 165°, which were less soluble in alcohol and gave no thiocyanate reaction. Since (A) was previously pure, the formation of sulphide or disulphide was suspected and the behaviour of synthetic 2-chloro-4-nitrophenyl thiocyanate towards charcoal was studied. The production of E was confirmed and shown to be due to the charcoal and not to the alcohol. The charcoal gave an alkaline reaction in water. After being boiled with hydrochloric acid and washed, it was found not to affect the thiocyanate even when boiled for several hours in alcohol. When the thiocyanate was left with 10% sodium hydroxide solution for 7 days and recrystallised from acetone, the same product (E_1), m. p. 165, was obtained, as also on treatment with warm alcoholic ammonium sulphide (E_2). The m. p. of E was not depressed on admixture with E_1 or E_2. The method of formation of E_2 shows it to be a disulphide (compare Müller, *Z. farb. Text. Ind.*, 1906, **5**, 357), a conclusion confirmed by the formation of diphenyl disulphide, m. p. and mixed m. p. 60°, and of di-*o*-nitrophenyl disulphide from the corresponding thiocyanates and sodium hydroxide. *o*-Nitrophenyl thiocyanate also gave the disulphide when boiled with the contaminated charcoal in alcohol.

Preparation and Nitration of o-*Bromophenyl Thiocyanate*.—(*a*) The preparative details are given on p. 29. The *product* formed white needles, m. p. about 24° (Found : S, 14·9, 14·8 ; Br, 37·65. C_7H_4NBrS requires S, 14·95 ; Br, 37·3%). (*b*) The thiocyanate (5 g.) was added during 45 minutes to nitric acid (*d* 1·5 ; 18 c.c.) at —5° to —6°, left at room temperature for 15 minutes, and poured on ice. The yield of crude product, m. p. about 83°, was 5·8 g. (97% of the amount required for a mononitro-derivative). Fractional crystallisation from alcohol and from light petroleum gave a main product (C), m. p. 93°, and a trace of (D), m. p. 126°. These did not depress the m.p.'s of synthetic specimens of the 4-*nitro*- and 5-*nitro*-2-*bromophenyl thiocyanates* respectively (Found for C : N, 11·0 ; Br, 31·0, 30·9. Found for D : N, 11·0. $C_7H_3O_2N_2BrS$ requires N, 10·8 ; Br, 30·9%).

2-*Bromo*-4-*nitrophenyl Thiocyanate.*—2-Bromo-4-nitroaniline was prepared from *o*-bromoacetanilide and nitric acid (*d* 1·5) at —5° to —10°. Having been kept for 30 minutes in the freezing mixture and for 1½ hours at room temperature, the reaction mixture was treated with ice. The solid obtained, m. p. 120°, was fractionally crystallised : the less soluble portion, m. p. 130° (Chattaway, Orton, and Evans, *loc. cit.*, give 129° as the m. p. of 2-bromo-4-nitroacetanilide), was treated for 1¼ hours with sulphuric acid at 100° and poured into water, giving the yellow base, m. p. 105° (Hübner, *Ber.*, 1877, **10**, 1709, gives m. p. 104·5°). The preparation by this method has not been described.

The *thiocyanate* was prepared as usual (see p. 29). It formed pale yellow crystals, m. p. 93°, from light petroleum and gave the thiocyanate reaction (Found: N, 10·9. $C_7H_3O_2N_2BrS$ requires N, 10·8%).

2-*Bromo*-5-*nitrophenyl Thiocyanate.*—The corresponding amine was prepared by the method used by Chattaway, Orton, and Evans (*loc. cit.*) for the chloro-derivative, the application of which to the bromo-compound does not appear to be described. The pale yellow *thiocyanate* (see p. 29), after crystallising from alcohol and finally from light petroleum, melted at 126° (Found : C, 32·6; H, 1·5. $C_7H_3O_2N_2BrS$ requires C, 32·4; H, 1·16%).

Preparation and Nitration of m-*Chlorophenyl Thiocyanate.*—(*a*) See p. 29 for preparative details. Shortly after the addition of the *m*-chlorobenzenediazonium chloride to the ferric thiocyanate there was a violent reaction and the temperature rose considerably. This was also observed in a second experiment when the mixture was standing in ice. The pure *thiocyanate* boiled at 135°/12·5 mm. (Found : N, 8·6. C_7H_4NClS requires N, 8·3%).

(*b*) The thiocyanate (5 g.) was slowly added to well-stirred nitric acid (*d* 1·5; 15 c.c.) at —10°. After an hour the liquor was left at room temperature for 2 hours and poured on ice. Fractional crystallisation of the washed and dried crude product (5·9 g., m. p. 44—48°) from ethyl alcohol and then from methyl alcohol yielded (F), m. p. 48—51°, and (G), m. p. 104°. Crystallisation of F did not alter the m. p. Distillation with steam failed to purify it, since the product ceased to give the thiocyanate reaction (Challenger and Peters, J., 1928, 1368) and melted at 130—135°. Repetition of the nitration and further crystallisation from light petroleum finally gave a large fraction (H), m. p. 59°, and a very small one (K), m. p. 104—105°. There was no evidence of any other isomeride. H and K did not depress the m.p.'s of the thiocyanates of the same melting points prepared from 3-chloro-4-nitroaniline and 3-chloro-6-nitroaniline, respectively (Found for H and K : N, 13·2 and 13·1 respectively. $C_7H_3O_2N_2ClS$ requires N, 13·05%).

Preparation of the 6- *and the* 4-*Nitro-derivative of* m-*Chloropheny Thiocyanate.*—The corresponding amines were prepared by the method of Mayes and Turner (J., 1928, 693). The 6-*nitro-thiocyanate*, after crystallising from ethyl alcohol and twice from methyl alcohol, melted at 104—105° (Found : Cl, 16·2, 16·7; N, 13·3; S, 14·6). The 4-*nitro-compound*, m. p. 59°, was crystallised first from alcohol and then from light petroleum (Found : N, 13·3, 13·2. $C_7H_3O_2N_2ClS$ requires N, 13·05; Cl, 16·5; S, 14·9%).

Preparation and Attempted Nitration of p-*Iodophenyl Thiocyanate.*—This substance was obtained by Challenger and Collins (*loc. cit.*), but was not analysed. It melts at 53° (Found : I, 48·3; S, 11·9. C_7H_4NIS requires I, 48·5; S, 12·3%).

p-Iodophenyl thiocyanate was attacked neither by nitric acid (*d* 1·41) at —10° or at 15°, nor, in acetic anhydride solution, by nitric acid (*d* 1·5) at 0°. On slow addition of the thiocyanate (1 g.) to a mixture of sulphuric acid (10 c.c.) and nitric acid (*d* 1·41; 10 c.c.) at —14°, most of it dissolved, forming a pale brown solution, but iodine did not appear to be liberated. After remaining for 3 hours at —10° to —5°, the mixture was poured on ice; a black solid then separated, becoming paler in air and giving only *p*-nitrophenyl thiocyanate, m. p. and mixed m. p. 133°, on fractional crystallisation. The acid liquor contained free iodine. Similar results were obtained with nitric acid (*d* 1·5) at —16°. With equal volumes of nitric acid (*d* 1·5) and (*d* 1·41) at —12°, reaction was very slow, but on addition of more acid (*d* 1·5) a black solid separated. The *p*-nitro-derivative was isolated as before.

Preparation of p-*Dichloroiodophenyl Thiocyanate.*—The iodothiocyanate in three times its weight of chloroform was cooled in ice and treated with chlorine for about 30 minutes and the pale yellow needles were washed with light petroleum; m. p. 111°. The substance was analysed by Willgerodt's method (" Die Organischen Verbindungen mit mehrwertigem Jod," 1914, p. 22) using potassium iodide and sodium thiosulphate (Found : Cl, 21·4, 21·3. $C_7H_4NCl_2IS$ requires Cl, 21·4%).

When heated in an open vessel to 100°, the *iododichloride* evolved chlorine. The solidified residue, m. p. 49°, had m. p. 51° after recrystallisation and did not depress the m. p. of *p*-iodophenyl thiocyanate (52—53°). The thiocyanate was also formed in (*a*) boiling carbon tetrachloride and (*b*) light petroleum (b. p. 40—50°); addition of iron filings to (*a*) did not affect the result. After remaining for 24 hours in ultra-violet light, the iododichloride was completely converted into the thiocyanate. The iododichloride (3 g.), exposed to sunlight in a closed bottle, liquefied after 2 weeks but became solid a few days later. Much pressure developed, hydrogen chloride was present, and a very pungent odour which may have been that of cyanogen chloride. The yellow solid produced melted at 53°; after recrystallisation from alcohol, it became colourless, melted at 126°, and did not depress the m. p. (126°) of *pp'*-di-iododiphenyl disulphide.

Preparation of Phenyl Thiocyanate and Quantitative Study of its Nitration.—Challenger and Collins (*loc. cit.*) prepared phenyl thiocyanate by Gattermann's method (*Ber.*, 1890, **23**, 738), using potassium and cuprous thiocyanates. A better yield is obtained with ferric chloride and potassium thiocyanate (Korczyński, *Bull. Soc. chim.*, 1922, **31**, 1179), although in this and other cases (see p. 31) the evolution of nitrogen tends to lag and then suddenly to become violent. The steam-distilled product was carefully fractionated; b. p. 143—145°/64 mm. (Found: S, 23·4, 23·3. Calc.: S, 23·7%. Phenyl mercaptan and phenyl disulphide, which are possible impurities, contain 29·1 and 29·3% of sulphur respectively).

The *o*-, *m*-, and *p*-nitro-thiocyanates required for thermal analysis were prepared by the diazo-reaction (Müller, *Z. farb. Text. Ind.*, 1906, **5**, 357) by means of copper salts. Steam distillation was impracticable and the thiocyanates were purified by extraction of the solid product with alcohol and decoloration with carefully purified charcoal.

Nitration of phenyl thiocyanate. The thiocyanate (10 g.) was slowly added to nitric acid (*d* 1·41; 24 c.c.) and sulphuric acid (27 c.c.) at 0—5°. After 5 g. had been added, a solid separated. After remaining for 5 hours at 0°, the mixture rose to room temperature, but, as the odour of phenyl thiocyanate was still perceptible, another 6 c.c. of each acid were added. After 4 hours, the mixture was poured on ice, thiocyanate odour being absent. The oil-free solid was washed, triturated with cold water, shaken with water for several hours, dried at about 90°, and left in a desiccator. Yield, 12·5 g. (94% of the theoretical yield for a mononitro-derivative). The washings and spent acid were extracted with benzene, but yielded only a small amount of oil with an odour of phenyl thiocyanate. The nitration product was examined for compounds other than *o*- and *p*-nitrophenyl thiocyanates. When fused, it had a very slight odour of phenyl thiocyanate. The smell of this substance is very powerful and only minute traces could have been present. Repeated fractionation failed to detect any *o*- or *p*- or dinitro-derivative of phenyl disulphide which might have been produced by oxidation of the nitrothiocyanates. These substances are difficultly soluble. A test was made for the presence of 2 : 4-dinitrophenyl thiocyanate. Addition of *o*- or *p*-nitrophenyl thiocyanate to a mixture of acetone and sodium hydroxide gives an orange colour to the acetone layer, the alkali being coloured pale yellow. A trace of the dinitro-compound colours the mixture almost black and the alkali red. With the nitration mixture the colour was orange-yellow, indicating the absence of the dinitro-derivative.

Thermal analysis of the nitration mixture. The setting point (S.P.) of the well-washed and dried nitration mixture was 121·9°, results differing by not more than 0·1° being obtained on remelting. A second nitration of phenyl thiocyanate gave a product of S.P. 121·7°. The eutectic point was difficult to observe but appeared to be about 95°. The S.P. of various mixtures of *o*- and *p*-nitrophenyl thiocyanates were then determined by adding increasing quantities of the *o*-derivative to the *p*-compound of S.P. 131·0°.

% Ortho-	1	2	4	6	10	15	20	21	30
S.P.	130·3°	129·5°	128·5°	127·6°	126·1°	124·0°	121·9°	121·5°	114·5°

From these figures the nitration product would appear to contain 20% of *o*-nitrophenyl thiocyanate. The eutectic point of one of the synthetic mixtures was found to be about 96·5°, in fairly good agreement with that of the nitration product.

The nitration product being assumed to consist solely of 80% of para- and 20% of ortho-thiocyanate, sufficient *o*-nitrophenyl thiocyanate was added to form a 30% mixture. The S.P. was 114·9°, and that of a synthetic mixture is 114·5° (see table), the results being therefore in agreement. Further evidence was afforded by examination of mixtures containing *m*-nitrophenyl thiocyanate. A synthetic mixture containing 76·2% of para-, 19·0% of ortho-, and 4·8% of meta- had S.P. 118·6°. On addition of 0·2094 g. of *m*-nitrophenyl thiocyanate to 4·1870 g. of the nitration product, the resulting mixture should contain 4·8% of meta-. The observed S.P. was 118·9°.

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