The Reaction Velocity of Some Substituted o- *and* p-*Chloronitrobenzenes with Piperidine.*

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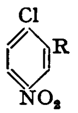
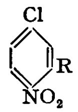
The velocity constants for the reactions of some monosubstituted (R = Me, OMe and OEt) *o*- and *p*-chloronitrobenzenes with piperidine in benzene at 100° have been determined. Possible reasons for the order of reactivity are given.

PREVIOUSLY (*Chem. and Ind.*, 1951, 971; *Anal. Asoc. Quim. Argentina*, 1951, **39**, 195) we recorded the velocity of the reaction of *o*- and *p*-chloro-, -bromo-, and -iodo-nitrobenzene with piperidine in benzene. We have now studied the changes in the reaction velocity at 100° when a methyl, methoxy-, or ethoxy-group is introduced into the benzene ring of *o*- and *p*-chloronitrobenzene.



(I)



(II)

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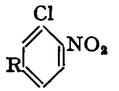

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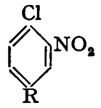

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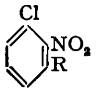


(VI)

The results for compounds of type (I—VI) are given in Table 1.

TABLE 1. *Reaction velocities of substituted* p- *and* o-*chloronitrobenzenes with piperidine at* 100° ± 0·1°. *Values of* 10^7k (l. mole^{-1} sec.$^{-1}$).

Halogenonitrobenzene		Me	OMe	OEt
p-Chloronitrobenzene	16·8	—	—	—
(I) 2-R-1-Chloro-4-nitrobenzene	—	0	7·0	4·16
(II) 2-R-4-Chloro-1-nitrobenzene	—	3·6	14·1	4·45
o-Chloronitrobenzene	779	—	—	—
(III) 1-R-2-Chloro-3-nitrobenzene	—	5·55	152	123
(IV) 4-R-2-Chloro-1-nitrobenzene	—	772	2630	1820
(V) 4-R-1-Chloro-2-nitrobenzene	—	152	35·9	30·2
(VI) 1-R-3-Chloro-2-nitrobenzene	—	12·1	23·3	9·73

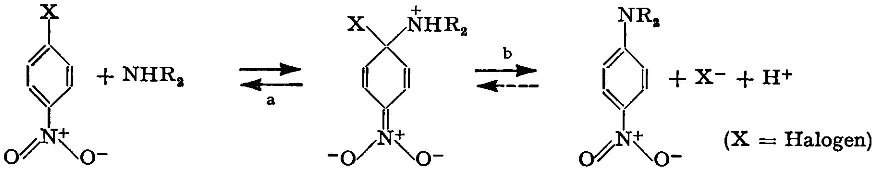
DISCUSSION

The mechanism of nucleophilic substitution of halogen in nitroaryl halides has been considered recently (Bevan, *J.*, 1951, 2340; Chapman and Parker, *J.*, 1951, 3301; Beckwith, Miller, and Leahy, *J.*, 1952, 3555; Berliner and Monack, *J. Amer. Chem. Soc.*, 1952, **74**, 1574). Substitution in *o*- and *p*-nitroarylhalides (VII) probably occurs through an intermediate complex of general type (VIII) (Bunnett and Zahler, *Chem. Reviews*, 1951, **49**, 293).

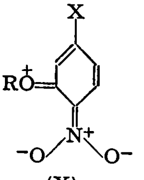
The overall effect of a substituent in various positions in (VII) on the velocity of halogen displacement appears to be mainly the resultant of the following factors.

Polar factors. (i) An electron-releasing substituent *ortho* to halogen will, by decreasing the positive character of the carbon atom to which the halogen is attached, reduce its susceptibility to nucleophilic attack.

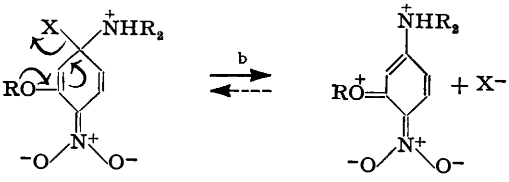
(ii) A substituent with a $+M$ effect *ortho* to the activating nitro-group may increase the energy of formation of (VIII) because of the necessary loss of resonance energy, in (VII) arising from the incidence of structures of type (X), which are impossible in (VIII). In this respect the first-order conjugation of an alkoxy-group will be greater than the first-order hyperconjugation of an alkyl group.



(VII) (VIII) (IX)



(X)



(XI*a*) (XI*b*)

(iii) In the intermediate complex (XI*a*), however, the presence of such $+M$ groups, which are also *meta* to the halogen, should increase the negative character of the halogen by incidence of structures of type (XI*b*) and thus facilitate the breakdown of (VIII) in the direction b by lowering the energy barrier over which the complex has to pass to give halogen displacement. Alkoxy-groups so placed might have a powerful accelerating action; *p*-quinonoid structures, being regarded as more stable, are more effective than *o*-quinonoid.

Steric factors. (iv) Primary steric effects and (v) secondary steric effects both as defined by Ingold ("Structure and Mechanism in Organic Chemistry," G. Bell and Sons Ltd., London, 1953, pp. 402, 803). Although a *p*-nitroaryl halide has been used in illustration the same features will apply to the *o*-nitro-compounds. Estimation of the relative magnitudes and importance of the various factors is difficult and only a qualitative assessment of the resultant effect for any particular substituent is possible. It will be noticed that, with three exceptions, alkyl and alkoxy-substituents diminish the reaction velocity in both *o*- and *p*-chloronitrobenzene.

In compounds of type (IV) and (V) the effect of substituents is free from steric factors and, of these, only compounds of type (V) have been studied in detail (cf. Berliner and Monack, *loc. cit.*; Miller, *J.*, 1952, 3550). In compounds of type (IV) factors (ii) and (iii) are operative while in those of type (V) the effect of the substituent should be mainly attributed to (i). The ratio $k_{(\mathrm{V};\ \mathrm{R})}/k_{(o\text{-}\mathrm{NO}_2)}$ gives the relative effect of the *p*-substituent at a certain temperature under established experimental conditions. Our values for this ratio are: Me, 0·196; OMe, 0·046; OEt, 0·039. The fact that methyl substitution in 2-chloro-4-methyl-1-nitrobenzene has no retarding or accelerating effect but similarly placed alkoxy-groups in 2-chloro-4-methoxy- and -4-ethoxy-1-nitrobenzene produce a very marked acceleration suggests that such acceleration is due mainly to a very powerful effect (iii) by these substituents, the smaller (hyperconjugative) effect of the similarly placed methyl group being sufficient only to counteract its other retarding influences. The results suggest that for the alkoxy-groups the effect (ii) has no great influence on the rate of reaction in spite of the opposite mesomeric character of the alkoxy- and the nitro-group situated *para* each other (cf. Robinson, *J.*, 1947, 1288; Dewar, *J.*, 1949, 468).

The overall effect of R in compounds of type (I, II, III, and VI) is not free from steric influences and in some cases they are important.

The complete lack of measurable activity in 1-chloro-2-methyl-4-nitrobenzene is in broad agreement with Spitzer and Wheland's results (*J. Amer. Chem. Soc.*, 1940, **62**, 2995) for methyl-substituted *p*-bromonitrobenzenes. A strong deactivating effect of the methyl group when *ortho* to two nitro-groups and *meta* to the halogen atom has been described by Lindemann and Pabst (*Annalen*, 1928, **462**, 24) who found that 3-halogeno-2 : 6-dinitrotoluenes do not react with aniline under the conditions of their experiments.

Miller and Williams (*J.*, 1953, 1476) compared the reaction rate of some substituted chloronitro- and chlorodinitro-benzenes with sodium methoxide in methanol and concluded that in the *ortho*-effect of methyl groups geometrical hindrance is unimportant.

The ratio $k_{\text{V}}/k_{\text{III}}$ which is similar but not equivalent to the " steric index " defined by them measures the *ortho*-effect of R in the monosubstituted chloronitrobenzenes (Me, 27·4; OMe, 0·236; OEt, 0·246). The high value of this ratio for the methyl group suggests that the low reactivity of 2-chloro-3-nitrotoluene must be mainly due to primary steric retardation (iv) since, according to the figures quoted by Ingold (*op. cit.*, p. 259) for the rates of attack on the individual positions of toluene and *tert.*-butylbenzene in nitration, the transfer of charge by the methyl group to the *ortho*- and *para*-positions can be interpreted as fairly constant. The difference between the ratios $k_{(o\text{-NO}_2)}/k_{(\text{V; Me})}$ and $k_{(\text{V; Me})}/k_{(\text{III; Me})}$ is large enough to support our view. The same considerations apply to 2-chloro-5-nitrotoluene where factors (i) and (iv) also operate.

The reactivity of the 1-alkoxy-2-chloro-3-nitrobenzenes and of 2-alkoxy-1-chloro-4-nitrobenzenes cannot be interpreted unambiguously. The low value of $k_{(\text{V; OR})}/k_{(o\text{-NO}_2)}$ suggests an accelerative contribution of the alkoxy-group *ortho* to the chlorine but as quinonoid structures are probably more important for transfering charges to the *para*- than to the *ortho*-position (de la Mare, *J.*, 1949, 2871) the relative importance of factors (i) and (iv) cannot be assessed. The interpretation of the data for compounds of types (II) and (VI) is complicated but it can be observed that factor (iii) if operative does not compensate for retarding factors.

The sequence of our results with the different chloronitrotoluenes derived from *o*-chloronitrobenzene agrees with that obtained by Campbell, Anderson, and Gilmore (*J.*, 1940, 446) for some bromonitrotoluenes with piperidine as reagent and solvent. From their figures of the percentage removal of bromine at 45° during 1 hr., the ratios of reactivities, *o*-bromonitrobenzene/4-bromo-3-nitrotoluene and 4-bromo-3-nitrotoluene/2-bromo-3-nitrotoluene, 4 and 13 respectively, show that the overall effect of the methyl group *ortho* to the halogen is mainly steric. As their experiments and ours differ widely in experimental conditions, temperature, solvent, and halogen substituent, the structure of the compounds and the reagent being common, this conclusion seems well established.

The different conclusion drawn by Miller and Williams can be related to the reagent employed but in our view the simplification made by these authors of comparing compounds related to different reference compounds is not justified, as in this way the basic requirement of keeping the activating system unchanged is not fulfilled.

EXPERIMENTAL

Materials.—Commercial *o*- and *p*-chloronitrobenzene were purified by recrystallisation and had m. p. 32·5° and 84° respectively. The substituted chloronitrobenzenes were prepared by methods described in the literature. 4-Chloro-2-methoxy- and -2-ethoxynitrobenzene were made from *m*-chloronitrobenzene in two stages, the first according to Laubenheimer (*Ber.*, 1876, **9**, 760) and the second to Blanksma (*Rec. Trav. chim.*, 1902, **21**, 332). The intermediate 4-chloro-1 : 2-dinitrobenzene had m. p. 40° (methanol) (lit., 37°). For all the other chloronitro-compounds the last stage was a Sandmeyer reaction with the corresponding nitro-amine by Hodgson and Walker's method (*J.*, 1933, 1620). The chloro-compounds were distilled *in vacuo* or crystallised to constant m. p. shortly before use and had the following m. p.s or b. p.s: 2-chloro-5-nitrotoluene, m. p. 43—43·5°; 5-chloro-2-nitrotoluene, m. p. 25°; 2-chloro-3-nitrotoluene, b. p. 147°/25 mm.; 3-chloro-4-nitrotoluene, b. p. 145°/43 mm.; 4-chloro-3-nitrotoluene, m. p. 7°, b. p. 141°/25 mm.; 3-chloro-2-nitrotoluene, b. p. 127°/24 mm.; 2-chloro-

5-nitroanisole, m. p. 83°; 5-chloro-2-nitroanisole, m. p. 73°; 2-chloro-3-nitroanisole, m. p. 94—95°; 3-chloro-4-nitroanisole, m. p. 32°; 4-chloro-3-nitroanisole, m. p. 44—45°; 3-chloro-2-nitroanisole, m. p. 55°; 2-chloro-5-nitrophenetole, m. p. 64·5—65·5°; 5-chloro-2-nitrophenetole, m. p. 63°; 2-chloro-3-nitrophenetole, m. p. 50—51°; 3-chloro-4-nitrophenetole, m. p. 40—41°; 4-chloro-3-nitrophenetole, m. p. 49—50°; 3-chloro-2-nitrophenetole, m. p. 52°. Piperidine was dried over potassium hydroxide and distilled through an efficient column. The fraction of b. p. 106—107·5°/760 mm. was collected. Benzene was purified according to Haller and Michael (*Bull. Soc. chim.*, 1896, **15**, 1065).

Method.—For each compound, four or five glass tubes, each containing 20 c.c. of a benzene solution about 1M with respect to piperidine and 0·1M to the chloro-compound were sealed and placed simultaneously in the thermostat controlled to 100° ± 0·1° and when the temperature inside, taken as that shown by a thermometer in a sealed tube containing benzene, reached 100° one of the tubes was removed and cooled in ice-water. The contents were extracted with 20 c.c. of 10% nitric acid, and the halide ion was determined potentiometrically. The other tubes were removed at convenient times and treated in the same way.

The rate constants were calculated by the equation, $k = \{2{\cdot}303/[t(b - 2a)]\} \log_{10} \{a(b - 2x)/[b(a - x)]\}$ for the overall reaction

$$NO_2{\cdot}C_6H_3R{\cdot}Cl + 2C_5H_{10}NH \longrightarrow NO_2{\cdot}C_6H_3R{\cdot}NC_5H_{10} + C_5H_{10}NH{\cdot}ClH$$

where a and b are the initial concentrations of halogenonitrobenzene and piperidine, and x is the halide concentration at time t.

The following are two typical runs for 2-chloro-3-nitrophenetole,

a (mole/l.)	b (mole/l.)	x (mole/l.)	t (sec.)	10^7k (l. mole^{-1} sec.$^{-1}$)	a (mole/l.)	b (mole/l.)	x (mole/l.)	t (sec.)	10^7k (l. mole^{-1} sec.$^{-1}$)
0·0973	0·9658	0·0003	—	—	0·0973	1·0087	0·0002	—	—
		0·0139	12,600	125·9			0·0091	7,680	125·2
		0·0173	16,200	125·0			0·0157	14,450	121·2
		0·0580	84,000	119·1			0·0576	77,400	122·4
			Mean	123·3				Mean	122·9

The mean deviation of the mean for the reaction rates lies in the range 2—3%. Figures in Table 1 are the mean values of at least two independent runs.

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