

A New Method of Nucleophilic Substitution in the Benzenoid Series

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THE classical method of nucleophilic displacement in the benzenoid series entails substitution by a nucleophile of an atom or group, *e.g.*, halogen or alkoxy, on a nucleus containing an appropriately situated substituent, such as NO₂ or SO₂R.¹ This communication deals with a similar over-all transformation involving the benzene nucleus which, however, bears no activating group in the usual sense. In fact, the reaction proceeds with aromatic compounds considered to be deactivated in the context of the familiar nucleophilic substitution procedure.

This novel transformation takes place when a suitable aromatic substrate is treated with trichloramine in the presence of aluminium chloride. According to our method, halogen and methoxyl are replaced by the amino-group. It is significant that the displacement is accompanied by introduction of a chlorine *ortho* or *para* to the amine functionality. In addition, *σ*-substitution occurs to varying degrees as a competing reaction.^{2,3} The investigations were carried out in ethylene dichloride or *o*-dichlorobenzene at temperatures in the range -5 — $+30^{\circ}$ with the indicated molar

¹ J. F. Bunnett and R. E. Zahler, *Chem. Rev.*, 1951, **49**, 273; J. F. Bunnett, *Quart. Rev.*, 1958, **12**, 1.

² P. Kovacic, C. T. Goralski, J. J. Hiller, Jr., J. A. Levisky, and R. M. Lange, *J. Amer. Chem. Soc.*, 1965, **87**, 1262.

³ P. Kovacic and J. A. Levisky, Abstracts of Papers, 150th National Meeting of the American Chemical Society, 1965, p. 77S.

ratio, aromatic reactant : trichloramine : aluminium chloride : solvent = 10 : 1 : 2 : 25. Products were characterized by comparison with authentic materials. The results from interaction of trichloramine-aluminium chloride with halogenobenzenes and anisole are summarized.

The σ -substitution mechanism (addition-elimination) is treated elsewhere in greater detail.^{2,3} Since the nitrogen-containing nucleophile which actually participates is unknown, the amide ion is used for the sake of simplicity.⁴ If the hypothesis proves valid, nucleophilic σ -substitution would

TABLE

Halogenobenzenes and anisole with trichloramine-aluminium chloride^a

C_6H_5X , X =	Basic Product, %		
	<i>p</i> -H ₂ NC ₆ H ₄ Cl	<i>o</i> -H ₂ NC ₆ H ₄ Cl	<i>m</i> -H ₂ NC ₆ H ₄ X
F ^b	13.5	1.4	19.4
Cl ^b	0.1	0.7	32.5
Br ^b	<0.1	0.4	32.7
OMe ^c	7.0	1.2	1.8

^a 25 ± 5°, 2 hr.

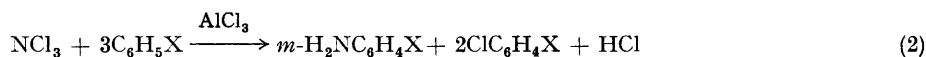
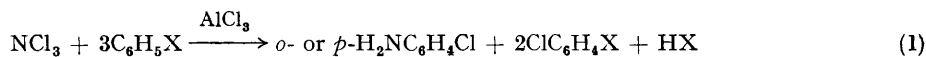
^b In ethylene dichloride.

^c In *o*-dichlorobenzene, 0°.

Yields are based on an equimolar relationship between trichloramine and amine product. Equations 1 and 2 are chosen somewhat arbitrarily to indicate a possible stoichiometry for each category. Of the basic product formed in the case of anisole, 82% was derived from

constitute a convenient designation for this type of substituent displacement.

Support for our theoretical approach is provided by the decrease in nucleophilic σ -substitution with the halogenobenzenes in the order: F >> Cl > Br. The same arrangement was observed in halogen

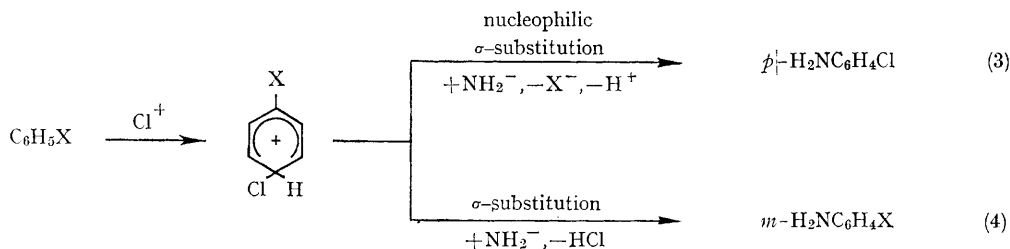


substituent displacement and 18% from σ -substitution, whereas with fluorobenzene, the ratio was 43 : 57.

The two types of amine products are believed to arise by routes which have certain characteristics in common. In both instances the chlorarenonium ion is apparently a crucial intermediate.

replacement by methoxide ion in the 1-halogeno-2,4-dinitrobenzene series.⁵

Nucleophilic σ -substitution can be enhanced at the expense of σ -substitution by the presence of a substituent *meta* to the leaving group. The indicated ratios for nucleophilic σ -substitution : σ -substitution were observed, 95 : 5 (13% yield, in *c*-dichlorobenzene at 0°) for *m*-methylanisole and



⁴ For a more detailed discussion of this aspect, see P. Kovacic, J. A. Levisky, and C. T. Goralski, *J. Amer. Chem. Soc.*, in the press.

⁵ J. F. Bunnett and W. D. Merritt, Jr., *J. Amer. Chem. Soc.*, 1957, **79**, 5967; A. L. Beckwith, J. Miller, and G. D. Leahy, *J. Chem. Soc.*, 1952, 3552; C. W. L. Bevan and G. C. Bye, *ibid.*, 1954, 3091.

87:13 (41% yield, in ethylene dichloride at 0°) for *m*-methylfluorobenzene, which constitute increases in comparison with the figures for the corresponding monosubstituted aromatics. Obviously, presence of the *meta*-substituent decreases the statistical probability of σ -substitution. The influence of the inductive and hyperconjugative

effects of the methyl group on the competing processes is not well understood.

One can visualize potentially wide generality for nucleophilic σ -substitution on the basis of variation in the electrophile, nucleophile, and leaving group.

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