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The S_NAr Reaction of 2,3,5,6-Tetrachloronitrobenzene with Diamines under High Pressure: Formation of Cyclization Products

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The reaction of 2,3,5,6-tetrachloronitrobenzene with ethylenediamine under high pressure gave mainly a 1 : 1-product and a bridged 2 : 1-product by the substitution of a nitro group and/or an *o*-chlorine atom. The ratio of the products varied depending upon the amount of amine used. Other diamines, such as 1,4-butanediamine *cis*-and *trans*-1,2-cyclohexanediamines, *m*-xylylenediamine, and *o*-phenylenediamine, gave similar results. On the other hand, *N*,*N*′-dimethylethylenediamine and *N*,*N*′-dimethyl-1,3-propanediamine gave cyclization products through successive substitutions of an ortho-chlorine atom and a nitro group by the two methylamino groups of a molecule of diamine. *N*-Methylethylenediamine afforded a 1 : 1-product through the substitution of a nitro group by a primary amino group together with a cyclic 1 : 1-product through substitutions of an *o*-chlorine atom and a nitro group by secondary and primary amino groups, respectively.

The acceleration of the S_NAr reaction of aromatic halides with primary and secondary amines under high pressure[1,2] has recently been studied by us as well as Matsumoto et al. from a synthetic view of aromatic amines. The reaction of 2,3,5,6-tetrachloronitrobenzene (**1**) with primary amines gave the products mainly through a nitro-group substitution in contrast to the reaction of the secondary amines, which gave *o*-chlorine atom-substitution products.[3] As a continuation of our previous work, we studied the reaction of **1** with primary and secondary diamines in order to obtain general information concerning the behavior of diamine in the S_NAr reaction with a polychloronitrobenzene, and to develope a new synthetic route of cyclic aromatic diamines.

The reaction of **1** with an equimolar amount of ethylenediamine (**2a**) under high pressure (0.60 GPa, 50 °C, 20 h, in THF) in the presence of 2 molar amounts of triethylamine gave products of 1 : 1-substitution, bridged 2 : 1-substitution, and cyclization in high total yields, as listed in Table 1 (Run 1). The 1 : 1-substitution products are *N*-(2,3,5,6-tetrachlorophenyl)ethylenediamine (**3a**) and *N*-(3,4,6-trichloro-2-nitrophenyl)ethylenediamine (**4a**), formed by the substitution of a nitro group and an *o*-chlorine atom, respectively (Scheme 1). No substitution product (**5a**) of an *m*-chlorine atom was obtained in this reaction.[4] The bridged 2 : 1-substitution products are *N*,*N*′-bis(2,3,5,6-tetrachlorophenyl)-ethylenediamine (**6a**) and *N*-(2,3,5,6-tetrachlorophenyl)-*N*′-(3,4,6-trichloro-2-nitrophenyl)ethylenediamine (**7a**), yielded by successive substitutions of two nitro groups, and by the substitution of a nitro group and an *o*-chlorine atom of each two molecules of **1** by two amino groups of **2a**, respectively. Neither the bridged 2 : 1-product **8a** by substitutions of a nitro group of **1** and an *m*-chlorine atom of another molecule of **1**[4] nor **9a** by substitutions of *o*-chlorine atoms of two molecules of **1** was obtained in this reaction. The cyclic 1 : 1-product was characterized as being 5,6,8-trichloro-1,2,3,4-tetrahydroquinoxaline (**10a**), which was formed by successive substitutions of an *o*-chlorine atom and a nitro group with two amino groups of a molecule of **2a**. The details concerning the pathway for the formation of **10** are discussed later.

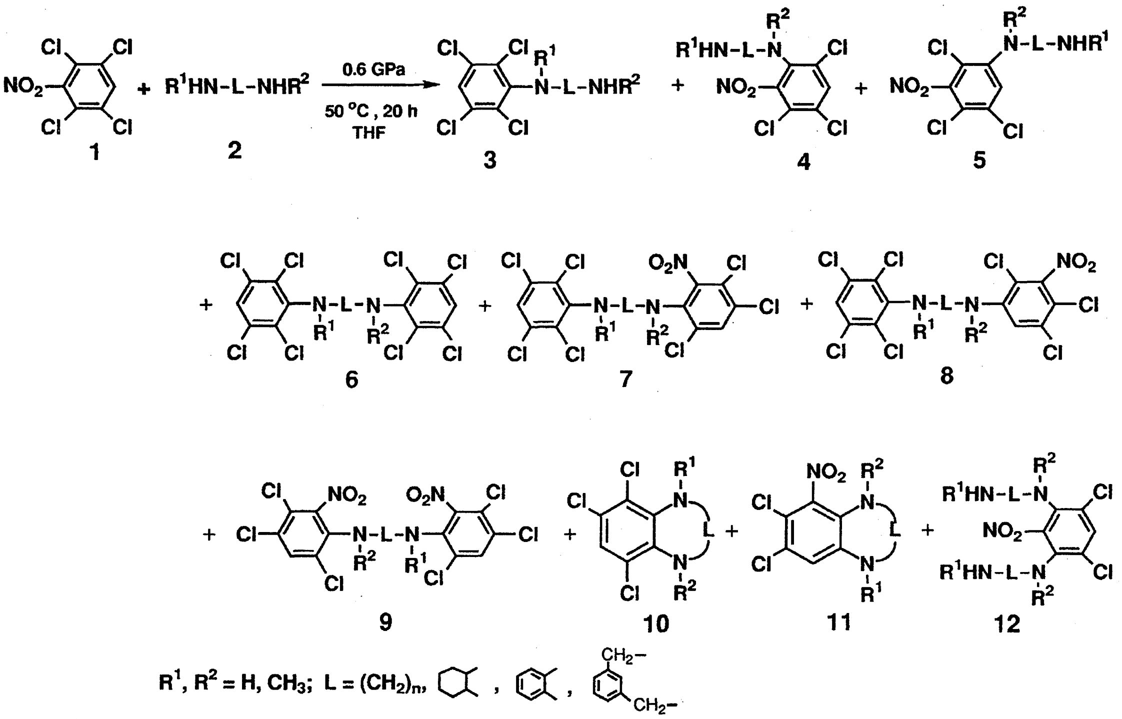
These results are different from those concerning the reaction of 3,4,5,6-tetrachloro-1,2-dinitrobenzene with **2a** at atmospheric pressure, reported by Heaton et al., who obtained only the 1 : 1-substitution product of the nitro group.[5] The fact that our main products are the nitro-group substitution products (**3a**, **6a**, **7a**, and **10a**) is coincident with the reactions of **1** with the primary amines reported before.[3]

When three molar amounts of **2a** were used, the yields of the 1 : 1-substitution products (**3a** and **4a**) increased predominantly without affording a 2 : 1-product and a cyclization product (Table 1, Run 2). On the other hand, the reaction with 0.5 molar amount of **2a** gave only the 2 : 1-substitution products (**6a** and **7a**) (Run 3). In Table 1, the molar yields are shown for the 2 : 1-substitution products (**6**, **7**, **8**, and **9**) based on the used **1**. These results indicate that the nucleophilicity of the primary amino group of the 1 : 1-substitution

Table 1. Reaction of 2,3,5,6-Tetrachloronitrobenzene with Diamines under High Pressure[a)]

Run	Diamine				Amount of **2**	Products (yield %)[b)]	Recovered
	2	R^1	R^2	L	mmol		**1** (%)
1	**2a**	H	H	(CH$_2$)$_2$	1[c)]	**3a** (39), **4a** (9.8), **6a** (17), **7a** (4.3), **10a** (3.6)	0
2[d)]	**2a**	H	H	(CH$_2$)$_2$	3	**3a** (90), **4a** (10)	0
3[d)]	**2a**	H	H	(CH$_2$)$_2$	0.5[c)]	**6a** (32), **7a** (18)	0
4	**2b**	H	H	(CH$_2$)$_4$	1[c)]	**3b** (4.5), **4b** (1.4), **6b** (34), **7b** (10), **9b** (0.7)	0
5	**2c**	CH$_3$	CH$_3$	(CH$_2$)$_2$	3	**10c** (75), **11c** (8.5)	0
6	**2d**	CH$_3$	CH$_3$	(CH$_2$)$_3$	3	**10d** (51), **11d** (7.2), **12d** (18)	0
7	**2e**	H	CH$_3$	(CH$_2$)$_2$	3	**3e** (70), **10e** (19)	0
8	**2f**	H	H	*cis*-1,2-Cyclohexylene	1[c)]	**3f** (45), **4f** (16), **5f** (4.4), **10f** (14)	14.4
9[d)]	**2f**	H	H	*cis*-1,2-Cyclohexylene	3	**3f** (79), **4f** (7.3), **10f** (13)	0
10	**2g**	H	H	*trans*-1,2-Cyclohexylene	1[c)]	**6g** (15), **7g** (7), **8g** (3.3), **10g** (20)	15.0
11	**2h**	H	H	*m*-Xylylene	1[c)]	**6h** (22), **7h** (8), **13h** (12)	0
12[e)]	**2i**	H	H	*o*-Phenylene	1[c)]	**4i** (2.7), **10i** (4.4)	85.2

a) The reactions were carried out using 1.0 mmol of **1**: at 0.6 GPa, 50 °C, 20 h, in THF. b) Yields are shown in molar yields of the products isolated by medium pressure column chromatography unless otherwise described. c) 2 mmol of NEt$_3$ was used to trap HCl generated in the reaction. d) The yields were determined by ^{1}H NMR spectroscopy as shown in Experimental. e) The reaction was carried out under the following reaction conditions: at 1.0 GPa, 50 °C, 50 h, in THF.



Scheme 1.

products (**3a** and **4a**) toward **1** is comparable with the nucleophilicity of **2a**, and that the intramolecular S$_N$Ar reactivity of **3a** and **4a** to give the cyclization product (**10a**) is not so high as their intermolecular S$_N$Ar reaction with the second molecule of **1**.

The reaction of an equimolar amount of 1,4-butanediamine (**2b**) with **1** gave results similar to that of **2a**, affording 1 : 1 (**3b** and **4b**) and 2 : 1-substitution products (**6b**, **7b**, and **9b**) without yielding **10b** by the intramolecular cyclization of **4b**, which is more difficult than in the case of **4a**, because of the seven-membered ring formation (Table 1, Run 4). The fact that the yield of **3b** decreased to 4.5% with an increase in the yield of **6b** (34%) is explained by the faster second substitution of **1** with **3b** than the first reaction of **1** with **2b** compared to the reaction of **1** with **3a**. This is attributed to the low reactivity of the primary amino group of the initial product **3a** in the second reaction with **1**, because the bulky aryl group locates near the reacting amino group in **3a**. The lower reactivity of **2b** than **3b** toward **1** may be attributed to the intramolecular hydrogen bonding between two amino groups of **2b**, which reduced the reactivity of **2b**. On the other hand, the steric hindrance of the aryl group in **3b** hindered the formation of hydrogen bonding without reducing the nucleophilicity of **3b**.

Two 1 : 1-products (**3** and **4**) are possible as the precursor of the second cyclization reaction to give **10**. To clarify the pathway to give **10**, control experiments were caried out using isolated **3a** and **4a** under high pressure. The treatment of **3a** under high pressure and forced reaction conditions (0.8 GPa, 50 °C, 60 h) recovered **3a** quantitatively. On the other hand, the treatment of **4a** under the same reaction conditions gave **10a** in high yield (see Experimental). These results indicate that the precursor of the cyclization product **10a** is not **3a**, but the ortho-chlorine-substitution product **4a**. Similar results were obtained by the treatment of **3e**, **3f**, and **4f**.

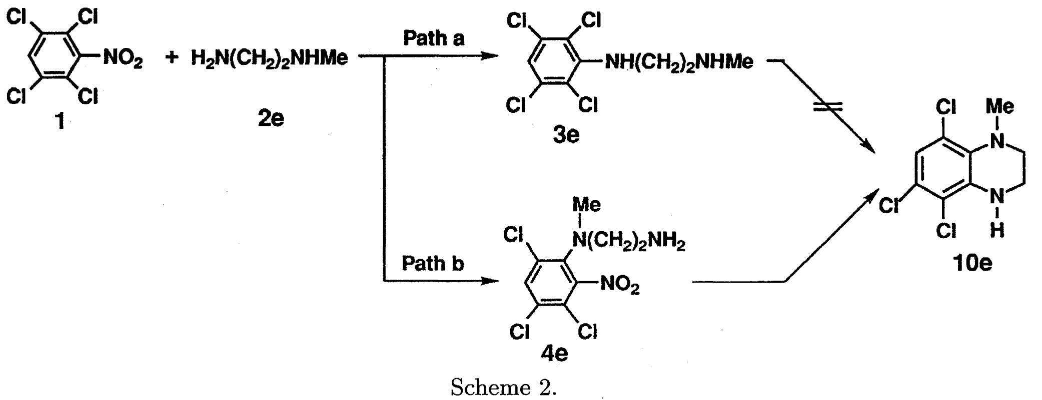
To compare the reactivity of the primary and secondary amines in this reaction system, *N*,*N*′-dimethylethylenediamine (**2c**) was reacted with **1** using three molar amounts of **2c** under similar reaction conditions. The obtained products were only the cyclization products: 1,4-dimethyl-5,6,8-trichloro-1,2,3,4-tetrahydroquinoxaline (**10c**: 75% yield) by substitution of a nitro group and an *o*-chlorine atom, and 1,4-dimethyl-6,7-dichloro-5-nitro-1,2,3,4-tetrahydroquinoxaline (**11c**: 8.5% yield) by the substitution of two chlorine atoms at the ortho and meta positions[4] (Table 1, Run 5). No linear 1 : 1 or 2 : 1-product was isolated, despite a detail inspection of the reaction mixture by medium-pressure column chromatography. Judging from the behavior of **3a**, the initial product **3c** is assumed to give no cyclization product. Therefore, the precursor of **10c** and **11c** is presumed to be **4c**. This indicates that **2c** substitutes only the *o*-chlorine atom of **1** to afford **4c** in the first step of the reaction, without affording **3c** by a substitution of the nitro group. This behavior of **2c** is quite similar to the reaction of **1** with the usual secondary amines,[3] which is coincident with the results of Heaton.[5] No isolation of **4c** in this reaction indicates that the cyclization of **4c** to give **10c** and/or **11c** is much faster than the formation of **4c** in the first step of the reaction.

The reaction of **1** with three molar amounts of *N*,*N*′-dimethyl-1,3-propanediamine (**2d**) also gave cyclization products (**10d**: 51% and **11d**: 7.2% yield) predominantly, together with a 1 : 2-product **12d** formed by the second substitution by **2d** at the *o*-chlorine atom of the initial product **4d**. The formation of **12d** in this reaction relates to a decrease in the yield of **10d**, which is attributed to the low reactivity of **4d** to cyclize to give a seven-membered ring. The similarity in the behavior of **2c** and **2d** is ascribed to the general reactivity of the secondary diamines.[3]

N-Methylethylenediamine (**2e**) yielded a 1 : 1-product (**3e**: 70% yield) through a substitution of the nitro group by the primary amino group of **2e** together with a cyclization product (**10e**: 19% yield) (Run 7). The structure of **10e** was tentatively determined by a comparison of its ^{13}C NMR data with those of **10a** and **10c**, as shown in Experimental (Table 2). To give a cyclic product (**10e**) (Scheme 2), there are two possible precursors (**3e** and **4e**) formed in the reaction of **1** with **2e** through the substitution of the nitro group of **1** by the primary amino group of **2e** (path a), and through the substitution of the *o*-chlorine atom of **1** by the secondary amino group of **2e** (path b), respectively.

Of the expected precursors formed in the initial paths of the reaction, the only product isolated was **3e** through path (a). To obtain information concerning the formation of cyclization product **10e**, **3e** was treated under forced reaction conditions (0.8 GPa, at 50 °C, for 65 h), which recovered **3e** quantitatively without affording **10e**. This indicates that the precursor of **10e** is not the **3e**, but the *N*-methyl-*N*-(2-nitro-3,4,6-trichlorophenyl)-ethylenediamine (**4e**) formed through path (b). The ratio between the yields of **3e** and **10e** (70 : 19) reflects the reactivity of paths (a) and (b) in the initial reaction.

In order to study the steric effect on the S$_\mathrm{N}$Ar reactivity of the diamines we studied the reactions of **1** with *cis*- and *trans*-1,2-cyclohexanediamines. The reaction of an equimolar amount of *cis*-1,2-cyclohexanediamine (**2f**) with **1** gave a cyclization product **10f** in 14% yield, besides the 1 : 1-substitution products **3f** (45%), **4f** (16%), and **5f** (4.4%)[4] along with the recovered **1** (14%) (Run 8). The reaction with 3 molar amounts of **2f** increased the yield of **3f** to 79% without recovering



Scheme 2.

Table 2. NMR Data of Reaction Products of 2,3,5,6-Tetrachloronitrobenzene (**1**) with Diamines under High Pressure

Products	^{13}C NMR δ/ppm		^{1}H NMR δ/ppm			
	Arom-C	NCH CH$_2$ or CH$_3$	Arom-H	NH	NCH	CH$_2$ or CH$_3$
3a	122.24 122.58 132.00 145.63	49.58	7.16(1H, s)	4.77(1H, brs)	3.41(2H, m)	
		42.15		1.38(2H, s)	2.92(2H, m)	
4a	120.95 122.45 124.05 130.88 137.04	45.20	7.47(1H, s)	5.40(1H, brs)	3.07(2H, m)	
	138.50	40.97		1.38(2H, s)	2.92(2H, m)	
6a	122.99 122.99 132.16 144.80	47.47	7.21(2H, s)	4.48(2H, brs)	3.60(4H, s)	
7a	122.03 122.61 124.11 124.17 124.28	46.42	7.50(1H, s)	5.03(1H, brt)	3.51(2H, brs)	
	130.98 132.13 136.31 144.37	44.25	7.28(1H, s)	4.10(1H, brs)	3.32(2H, m)	
10a	114.37 115.95 117.58 120.36 128.95	40.42	6.78(1H, s)	4.48(1H, brs)	3.50(2H, brs)	
	131.69	40.00		4.28(1H, brs)	3.48(2H, brs)	
3b	—		7.16(1H, s)	4.20(1H, brs.)	3.38(2H, t)	1.60(4H, m)
					2.77(2H, brs)	
4b	—		7.47(1H, s)	4.30(1H, brs)	3.08(2H, t)	1.60(4H, m)
					2.88(2H, brs)	
6b	122.47 122.53 132.04 145.22	47.19 28.13	7.18(2H, s)	4.20(2H, brs)	3.41(4H, brs)	1.66(4H, m)
7b	121.96 122.45 122.52 124.30 130.95	46.85 27.85	7.48(1H, s)	4.29(1H, brs)	3.39(2H, t)	1.65(4H, m)
	132.06 136.54 138.98 145.03	44.16 27.68	7.18(1H, s)	4.20(1H, brs)	3.10(2H, m)	
9b	122.28 122.68 124.36 131.05 136.48	44.16 27.57	7.50(2H, s)	4.28(2H, brt)	3.09(4H, m)	1.62(4H, m)
10c	124.00 124.47 125.84 126.19 138.30	45.54 43.78	7.15(1H, s)		3.02(4H, s)	2.86(3H, s)
	141.08	45.46 43.69				2.85(3H, s)
11c	109.98 111.65 126.39 128.07 140.32	49.06 43.50	6.68(1H, s)		3.29(2H, t)	2.96(3H, s)
	144.16	44.42 39.01			3.12(2H, t)	2.73(3H, s)
10d	124.50 126.67 127.43 128.73 144.46	50.51 39.84	7.10(1H, s)		3.19(4H, m)	2.91(3H, s)
	147.17	50.33 21.13			2.90(3H, s)	1.96(2H, s)
11d	113.69 118.39 128.83 134.34 149.49	54.65 42.19 40.53	6.90(1H, s)		3.07(4H, m)	2.89(3H, s)
	149.76	51.31 24.93			2.71(3H, s)	1.89(2H, m)
12d	127.18 131.76 132.61 132.72 133.23	52.45 40.08 35.45	7.42(s)	3.38(2H, brs)	3.20(t)	2.82(s)
	140.04 148.58 153.68	52.21 39.12 28.01	7.41		3.10(t)	2.74(s)
		49.17 35.76 27.49			2.65(m)	2.45(s)
		48.64			1.71(m)	2.43(s)
3e	121.92 122.32 131.73 145.46	50.96 35.15	7.14(1H, s)	4.93(1H, brs)	3.44(2H, m)	2.46(3H, s)
		45.63		1.95(1H, brs)	2.82(2H, t)	
10e	116.70 119.58 123.89 125.99 133.19	48.57 43.10	7.12(1H, s)	4.60(1H, brs)	3.40(2H, m)	2.77(3H, s)
	134.65	34.85			3.03(2H, t)	
3f	121.48 122.37 131.79 144.88	57.11 32.93 23.76	7.12(1H, s)	5.15(1H, d)	3.80(1H, m)	1.67—1.23(8H, m)
		49.80 27.91 19.78		1.40(2H, s)	3.12(1H, m)	
4f	121.01 123.85 124.03 131.14 136.81	55.92 32.90 23.53	7.48(1H, s)	5.46(1H, d)	3.16(1H, m)	1.67—1.25(8H, m)
	140.69	49.44 28.11 19.40		1.64(2H, s)	3.03(1H, m)	
5f	119.20 122.09 125.04 135.14 137.89	55.81 32.89 23.52	6.99(1H, s)	5.79(1H, d)	3.16(1H, m)	1.67—1.23(8H, m)
	139.14	49.45 28.17 19.40		1.64(2H, s)	3.04(1H, m)	
10f	113.92 115.51 117.26 119.92 128.04	49.53 30.50 21.87	6.75(1H, s)	4.32(1H, s)	3.53(2H, m)	1.67(4H, m)
	130.76	49.07 30.37	4.10(1H, s)			1.40(4H, m)
6g	122.31 122.49 132.03 143.99	60.24 33.40 24.43	7.17(2H, s)	4.43(2H, d)	3.89(2H, m)	1.96—1.26(8H, m)
7g	122.38 123.13 123.27 123.54 124.15	61.07 34.06 24.64	7.47(1H, s)	4.58(1H, d)	3.63(1H, m)	2.06(1H, d)
	131.21 132.08 136.21 139.92 144.00	59.12 33.55 24.30	7.21(1H, s)	4.06(1H, d)	3.13(1H, m)	1.89—1.25(7H, m)
8g	119.45 121.20 123.06 123.33 125.28	61.05 34.07 24.69	7.20(1H, s)	4.84(1H, d)	3.67(1H, m)	2.08(1H, d)
	132.11 135.28 137.00 138.54 143.94	59.35 33.59 24.31	7.00(1H, s)	4.03(1H, d)	3.10(1H, m)	1.92—1.25(7H, m)
10g	114.07 115.64 117.58 120.33 129.29	54.61 30.84 24.01	6.79(1H, s)	4.30(1H, s)	2.91(2H, m)	1.99(2H, d)
	131.99	54.24 30.79		4.11(1H, s)		1.83—1.30(6H, m)
6h	122.92 123.04 127.45 128.33 129.11	51.45	7.20(2H, s)		4.51(4H, s)	
	132.11 139.43 145.07		7.37—7.29(4H, m)			
7h	123.01 123.09 123.35 127.27 127.42	51.29	7.51(1H, s)		4.52(2H, s)	
	129.39 131.21 132.12 136.65 139.79	49.20	7.20(1H, s)		4.23(2H, d)	
	144.97		7.35—7.22(4H, s)			
13h	123.26 128.77 129.18 129.39 132.18	50.83	7.22(1H, s)		4.60(2H, s)	10.02(1H, s, CHO)
	133.76 136.85 140.74 144.74 191.90		7.91—7.49(4H, m)			
4i	116.39 118.90 121.67 122.66 124.62		7.18(1H, s)	5.91(2H, s)		
	125.60 125.95 127.85 135.87 137.99		7.08—6.67(4H, m)			
	138.49 142.28			3.92(1H, brs)		
10i	129.81 129.86 130.20 130.67 132.09		8.01(1H, s)			
	132.45 133.82 138.87 140.52 143.00		8.37(2H, m)			
	143.63		7.94(2H, m)			

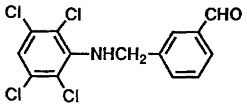
Table 3. IR Data of Reaction Products of TCNB with Diamines[a)]

Product	ν/cm^{-1}									
3a	3400	1640	1542	1392	1330	1110				
4a	3400	1640	1542	1461	1396	1330	1110	1080		
6a	3384	1540	1490	1420	1360	1302	1160	1110	1059	840
7a	3347	3335	2960	2940	1598	1530	1510	1408	1350	1101
10a[b)]	3410	2927	2866	1716	1590	1497	1358	1301	1222	996
6b	3366	2939	1650	1488	1408	1392	1355	1069		
7b	3397	2942	2875	1594	1542	1497	1473	1384	1362	1222
10c[b)]	2955	2880	1561	1529	1462	1430	1411	1383	2228	737
11c	2964	1598	1540	1538	1500	1360	1340	1201		
10d	2923	1472	1430	1405	1216	1008	950	728		
11d	2935	1581	1534	1490	1451	1436	1369	1198		
12d[b)]	3304	2943	1706	1540	1387	1313	1160	1040		
3e	3315	2925	2849	1548	1476	1412	1386	1081		
10e[b)]	3431	2933	2851	1578	1483	1464	1355	1029		
3f	3400	3267	2921	1540	1400					
4f[b)]	3386	3307	2927	1592	1531	1508	1460	1446	1360	
5f	3381	3283	2929	1566	1531	1482	1422	1362		
10f[b)]	3422	3388	2926	1600	1552	1482	1428	1363		
6g	3381	2945	1542	1483	1415	1401	1377			
8g	3377	2947	2930	1564	1458	1520	1498	1422	1350	1068
10g	3395	2931	1590	1560	1490	1460	1364	1292		
6h	3400	1547	1474	1412	1073					
7h	3394	1533	1491	1366						
13h	3391	1696	1546	1412	1152	1068				
4i	3419	3331	3211	1558	1528	1466	1414	1355	743	
10i	3443	1576	1462	1451	1125	991	763	753		

a) Measured in KBr Pellet unless otherwise described. b) Measured in neat liquid film.

Table 4. Melting Points and Results of Elemental Analysis of the Products

Product	Mp	Found/%			Calcd/%			Molecular
	θ_m/°C	C	H	N	C	H	N	formula
3a	49.7—52.0	HRMS:	271.9437			271.9442		$C_8H_8N_2Cl_4$
6a	165.0—165.7	34.50	1.76	5.85	34.47	1.75	5.74	$C_{14}H_8N_2Cl_8$
7a	108.3—108.9	33.87	1.75	8.43	33.74	1.62	8.43	$C_{14}H_8N_3O_2Cl_7$
10a	Oil	HRMS:	235.9681			235.9675		$C_8H_7N_2Cl_3$
6b	139.7—140.9	37.35	2.43	5.50	37.25	2.34	5.43	$C_{16}H_{12}N_2Cl_8$
7b	74.9—76.6	HRMS:	523.8843			523.8825		$C_{16}H_{12}N_3O_2Cl_7$
10c	Oil	45.20	4.17	10.45	45.23	4.17	10.55	$C_{10}H_{11}N_2Cl_3$
11c	97.9—99.7	43.59	4.06	15.15	43.49	3.99	15.22	$C_{10}H_{11}N_3O_2Cl_2$
10d	69.1—71.5	47.27	4.64	9.97	47.25	4.69	10.02	$C_{11}H_{13}N_3O_2Cl_2$
11d	90.9—91.7	45.68	4.49	14.53	45.54	4.52	14.48	$C_{11}H_{13}N_2Cl_3$
3e	74.2—77.4	HRMS:	286.9659			286.9676		$C_9H_{10}N_2Cl_4$
10e	Oil	HRMS:	249.9820			249.9831		$C_9H_9N_2Cl_3$
3f	65.2—66.8	44.18	4.30	8.59	43.91	4.30	8.54	$C_{12}H_{14}N_2Cl_4$
4f	Oil	43.11	4.28	12.17	42.56	4.17	12.41	$C_{12}H_{14}N_3O_2Cl_3$
5f	82.5—84.0	43.00	4.22	12.21	42.56	4.17	12.41	$C_{12}H_{14}N_3O_2Cl_3$
10f	Oil	HRMS:	290.0147			290.0145		$C_{12}H_{13}N_2Cl_3$
6g	193.4—195.5	40.00	2.61	5.38	39.89	2.60	5.17	$C_{18}H_{14}N_2Cl_8$
8g	169.0—172.1	HRMS:	548.8885			548.8906		$C_{18}H_{14}N_3O_2Cl_7$
10g	97.7—99.1	49.28	4.48	9.57	49.43	4.49	9.61	$C_{12}H_{13}N_2Cl_3$
6h	145.2—146.3	42.47	2.24	4.95	42.58	2.13	4.95	$C_{20}H_{12}N_2Cl_8$
7h	147.1—149.0	42.24	2.33	7.08	41.80	2.09	7.32	$C_{20}H_{12}N_3O_2Cl_7$
13h	112.8—114.2	48.41	2.72	4.25	48.17	2.58	4.01	$C_{14}H_9NO_2Cl_4$
4i	127.5—129.3	43.48	2.54	12.67	43.33	2.41	12.64	$C_{12}H_8N_3O_2Cl_3$
10i	169.2—172.3	50.80	2.07	9.90	50.46	2.45	9.81	$C_{12}H_7N_2Cl_3$



13h

Scheme 3.

1 (Run 9).

On the other hand, the reaction of an equimolar amount of *trans*-1,2-cyclohexanediamine (**2g**) gave predominantly 2:1-substitution products (**6g** (15%), **7g** (7%), and **8g** (3.3%)) together with cyclization product **10g** (20%) and recovered **1** (15%) (Run 10).

The reaction with an equimolar amount of *m*-xylylenediamine gave the benzaldehyde derivative **13h** in 12% yield (Scheme 3), besides the 2:1-products, **6h** (22%) and **7h** (8%). The formation of **13h** is explained by the reaction of **3g** with HNO_2 liberated as a by-product of the substitution of the nitro group.[5)] 1,2-Phenylenediamine (**2i**) gave only an *o*-chlorine atom substitution product **4i** and a cyclization product **10i** in low yields, because of its low reactivity (Run 12).[3)]

Experimental

General. The melting points were measured using a Yanagimoto melting point apparatus, and are not corrected. IR spectra were recorded on a Perkin–Elmer model 983. ^{1}H NMR and ^{13}C NMR spectra were measured on a JEOL EX-270 in a $CDCl_3$ solution using TMS as an internal standard. The mass spectra were measured with a JEOL JMS-DX303 spectrometer.

Materials. Commercial 2,3,5,6-tetrachloronitrobenzene was used after purification by recrystallization. THF was purified by distillation after reflux over $LiAlH_4$, and stored with molecular-sieves type 4A under a nitrogen atmosphere. Amines were purified by distillation under a nitrogen atmosphere after an appropriate drying procedure.

Typical Procedure of the Reaction of 1 with Diamine (2). A THF solution (5 cm^3) of **1** (1.0 mmol) and diamine (1.0—3.0 mmol) with triethylamine (0—2.0 mmol) was treated at high pressure in a Teflon® capsule using a Hikari Kouatsu high-pressure apparatus under the reaction conditions cited in Table 1. The precipitates were removed by filtration from the reaction mixture, and washed with 30 ml of toluene. From the combined solution the solvents were evaporated under reduced pressure. The residue was separated by medium-pressure short-column chromatography (5 cm long silica gel column containing 6% of H_2O) using eluents of hexane–ethyl acetate (3:1 vol. %) and methanol. 2:1-Products (**6**, **7**, **8**, and **9**) and 1:1-cyclic products (**10** and **11**) contained in the first fraction were separated by further column chromatography using a long column of silica gel (20 cm). The second fraction usually contained linear 1:1-products (**3**, **4**, and **5**). After separation by further column chromatography these products were purified by recrystallization and characterized by ^{1}H NMR, ^{13}C NMR (Table 2), IR (Table 3), and elemental analysis or HRMS (Table 4).

Measurements of Product Ratio by ^{1}H NMR. From the reaction mixture a precipitate was removed by filtration, then rinsed with a small amount of toluene. After evaporation of THF and toluene to dryness under reduced pressure, the residue was weighed. The molar ratio of the products was calculated by integrating the ^{1}H NMR signals of their singlet signals of aromatic-H, which appear in the region of 6.50—7.74 ppm, as shown in Table 2. The amount of each product was calculated based on the molar ratio and total weight of the products.

Control Experiments. Control experiments to clarify the pathway to give the cyclization products **10** were performed under the following typical procedure using the 1:1 products (**3a**, **3e**, **3f**, **4a**, and **4f**). A THF solution of **4a** (14 mg, 0.05 mmol) was treated under high-pressure reaction conditions (0.80 GPa, at 50 °C, 65 h). The product separated by silica-gel column chromatography was characterized as **10a** by comparing the IR and NMR spectra with authentic samples obtained in the usual high-pressure S_NAr reactions of **1** with **2a**. The reactions of **3e** and **3f** under the cited reaction conditions recovered the starting material quantitatively without affording the corresponding cyclization products. Because of the difficult separation, a mixture of **3a** (89%) and **4a** (11%) was treated under the same reaction conditions, and obtained **10a** (8%) with the decreasing of **4a** (3%) with no change in the per cent of **3a**.

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3) T. Ibata, X. -Z. Zou, and T. Demura, *Tetrahedron Lett.*, **34**, 5613 (1993); *Bull. Chem. Soc. Jpn.*, **67**, 196 (1994).

4) The reactions of primary and secondary amines with mono-,[1a)] di-,[1b)] tri-,[1b)] and pentachloronitrobenzenes[1c)] scarcely gave *m*-chlorine atom substitution product. On the other hand, the reaction of tetrachloronitrobenzene (**1**) with amines gave moderate amounts of *m*-chlorine atom substitution products.[3)] To explain these results we are now studying the reactions of polychlorobenzenes with amines.

5) A. Heaton, M. G. Hill, and M. H. Hunt, *J. Chem. Soc., Perkin Trans. 1*, **1989**, 401.

6) The structure of **3e**, formed by the path (a), was supported by the facts that only four signals of aromatic carbon were observed in its ^{13}C NMR spectrum and that two signals of NH were observed at δ=4.93 (1H, br s) and 1.95 (1H, br s) in its ^{1}H NMR spectrum.

7) ^{13}C NMR data of **10e**: ($CDCl_3$) δ=34.85 (t, C_3), 42.10 (q, CH_3), 48.57 (t, C_2), 116.70 (t, $^2J_{CH}$ and $^3J_{CH}$=3.66 Hz, C_8), 119.58 (d, $^2J_{CH}$=4.2 Hz, C_6), 123.89 (d, J_{CH}=170.28 Hz, C_7), 125.99 (d, $^3J_{CH}$=9.16 Hz, C_8), 133.19 (br m, C_{10}), 134.65 and (bf d, ^3J=7.33 Hz, C_9).