Rate Increase in Consecutive Nucleophilic Aromatic Substitution Reactions of Trichlorotrinitrobenzene: The Synthesis of 1-(Alkylamino)-3,5-dichloro-2,4,6-trinitrobenzenes†

J. Jens Wolff,* Andreas Zietsch, Thomas Oeser, and Ion Bolocan‡

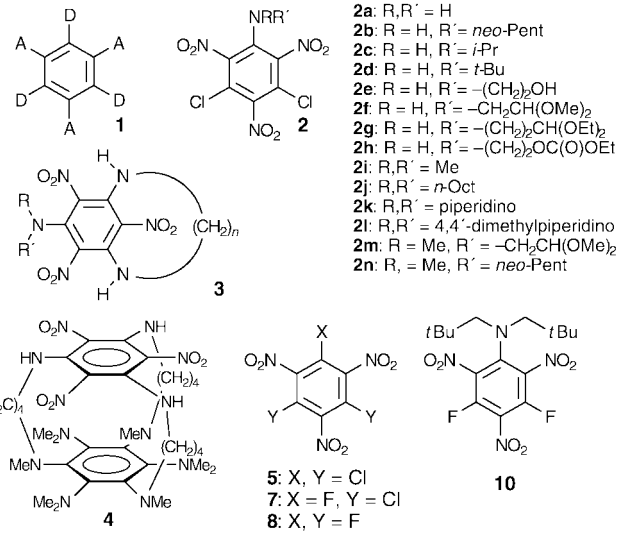
Organisch-Chemisches Institut der Universität Heidelberg, Im Neuenheimer Feld 270, D-69120 Heidelberg, Germany

Received February 27, 1998

The title compounds are formed by the nucleophilic aromatic substitution reaction between *sym*-trichlorotrinitrobenzene and amines. The yields and relative rates of formation depend critically on the degree of alkylation of the nucleophile. Contrary to the usual behavior, the introduction of a second and third donor is facilitated in the case of ammonia and monoalkylamines, while this is not the case for secondary amines. This behavior is rationalized on the basis of intramolecular hydrogen bonding and substantiated by an X-ray analysis of 3,5-dichloro-2,4,6-trinitroaniline.

Introduction

In the course of our work on 3-fold push−pull-substituted arenes (**1**) as a new class of nonlinear-optically active compounds,[1−4] the study of their geometric and electronic structures,[5,6] and their use as intermediates for the construction of electron-rich hexaaminobenzene derivatives for electron-transfer studies,[7,8] we needed an easy access to substituted 1-amino-3,5-dichloro-2,4,6-trinitrobenzenes (**2**). For example, their reaction with an α,ω-diamine provides an easy access to—otherwise strained—metacyclophanes (**3**) in unusually high yields without the need of high-dilution conditions.[7] It even proved possible to employ a similar, but 3-fold, cyclization as a key step to give **4**. Again, no high-dilution conditions were necessary. Both **3** and **4** serve as intermediates in the construction of bis-hexaaminobenzene cyclophanes, which are used to study electron-transfer reactions.[8] Compounds of type **2** are available from the reaction of trihalogenotrinitrobenzene and amines.[9] By inspection of the different behavior observed when **5** reacts with amines of different degrees of alkylation, we have noted an unusual increase in the consecutive S_NAr reactions. These observations allow us to rationalize our success in the syntheses of **3** and **4**.



Results and Discussion

If multiple nucleophilic aromatic substitution reactions[10−12] via Meisenheimer[13,14] complexes are possible with an electron-deficient arene, the rate of reaction is expected to decrease with the introduction of each donor substituent. For example, reaction of ammonia with 1,3-dinitro-2,4,6-trifluorobenzene[15] or tetrafluoro-1,3-dinitrobenzene[16] gives monosubstitution products in high yields, and the Meisenheimer complex with methoxide is 10 times more stable for 2,4-dinitroanisole than for 1,3-dimethoxy-2,4-dinitrobenzene.[17] We found that trinitrotrichlorobenzene (**5**) does react with amines to form the

† Dedicated to Prof. Dr. Hermann Irngartinger on the occasion of his 60th birthday.

‡ Permanent address: University of Ploieşti, Chemistry Department, Bd. Bucureşti, 39, RO-2000 Ploieşti, Romania.

(1) Wortmann, R.; Glania, C.; Krämer, P.; Matschiner, R.; Wolff, J. J.; Kraft, S.; Treptow, B.; Barbu, E.; Längle, D. *Chem. Eur. J.* **1997**, *3*, 1765−1773.

(2) Voigt-Martin, I. G.; Li, G.; Yakimanski, A.; Schulz, G.; Wolff, J. J. *J. Am. Chem. Soc.* **1996**, *118*, 12830−12381.

(3) Voigt-Martin, I. G.; Gao, L.; Yakimanski, A.; Gross, H.; Wolff, J. J. *J. Phys. Chem. A* **1997**, *101*, 7265−7276.

(4) Zyss, J.; Ledoux, I. *Chem. Rev.* **1994**, *94*, 77−105.

(5) Wolff, J. J.; Nelsen, S. F.; Powell, D. R. *J. Org. Chem.* **1991**, *56*, 5908−5911.

(6) Wolff, J. J.; Irngartinger, H.; Gredel, F.; Bolocan, I. *Chem. Ber.* **1993**, *126*, 2127−2131.

(7) Wolff, J. J.; Nelsen, S. F.; Powell, D. R.; Nuber, B. *Angew. Chem.* **1992**, *104*, 899−901; *Angew. Chem., Int. Ed. Engl.* **1992**, *31*, 882−884.

(8) Wolff, J. J.; Zietsch, A.; Irngartinger, H.; Oeser, T. *Angew. Chem.* **1997**, *108*, 637−639; *Angew. Chem., Int. Ed. Engl.* **1997**, *36*, 621−623.

(9) Koppes, W. M.; Lawrence, G. W.; Sitzmann, M. E.; Adolph, H. G. *J. Chem. Soc., Perkin Trans. 1* **1981**, 1815−1820.

(10) Bunnett, J. F.; Zahler, R. E. *Chem. Rev.* **1951**, *49*, 273−412.

(11) Miller, J. *Aromatic Nucleophilic Substitution*; Elsevier: Amsterdam, 1968; Vol. 8.

(12) Terrier, F. *Nucleophilic aromatic displacement: the influence of the nitro group*; VCH: New York, 1991.

(13) Terrier, F. *Chem. Rev.* **1982**, *82*, 77−152.

(14) Artamkina, G. A.; Egorov, M. P.; Beletskaya, I. P. *Chem. Rev.* **1982**, *82*, 427−459.

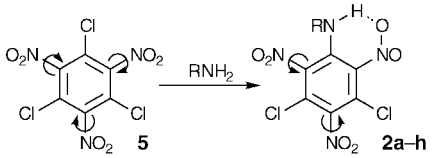
(15) Sitzmann, M. E. *J. Org. Chem.* **1978**, *43*, 1241−1243.

(16) Burdon, J.; Fischer, D.; Parsons, I. W.; Tatlow, J. C. *J. Fluorine Chem.* **1981**, *18*, 507−514.

(17) Crampton, M. R.; Ghariani, M. A. E.; Khan, H. A. *J. Chem. Soc., Perkin Trans. 2* **1972**, 1178−1182.

S0022-3263(98)00374-0 CCC: $15.00
Published on Web 06/27/1998

monosubstitution products **2**, with the exception of the very bulky dineopentylamine. However, the yields are



very different and depend on the degree of alkylation at nitrogen. The reaction of secondary amines (**6i**−**n**) is easily stopped at the monosubstitution stage and thus conforms to the expected behavior. Yields in the 60−80% range are achieved even if 2 equiv of base is employed. However, primary amines (**6b**−**g**) give only yields around 15−20% even with limiting amounts of nucleophile, regardless of whether an ancillary base like Hünig's base (*N*-ethyldiisopropylamine) or sodium bicarbonate is employed. Only in the reaction to give the *tert*-butyl derivative **2d** is the yield higher. With ammonia, the yield even drops to 2.6%; the bulk of the product consists of starting material and triaminotrinitrobenzene (**1a**).

We attempted to improve on these yields by use of the hitherto unkown 1,3-dichloro-5-fluorotrinitrobenzene (**7**) as substrate. Substrates with fluoride as a leaving group are in general more reactive in S_NAr reactions than those with chloride because the nucleophilic attack to give a Meisenheimer complex is rate limiting and facilitated by the more electron-withdrawing halogen.[10−12] For example, picryl fluoride reacts about 200 times faster with aniline than picryl chloride,[18] and trifluorotrinitrobenzene (**8**) is extremely sensitive to hydrolysis[19] in contrast to **5**. However, reactions of **7** were tried with little success. Already in the test reaction with dioctylamine, which gives high yields of monosubstitution products, a mixture of the possible two monosubstitution and two disubstitution products results. To judge from the relative amounts of reaction products, the acceleration effected by F over Cl is less than 3-fold in this substrate.

All of these unexpected observations are readily explained by the structure of the starting material **5** in the solid state:[20] the bulky chloro substituents cause the close to perpendicular orientation of the nitro substituents with respect to the benzene ring. Hence, there is little π conjugation of the nitro substituents with the ring. Introduction of dialkylamines does not change this situation because the steric strain is not relieved, possibly even increased. However, substituents that can hydrogen bond to the oxygen of a nitro group[21] will replace a repulsive interaction with an attractive one and thus—at least partially—restore a planar conformation.[22] Then, increased π conjugation should facilitate subsequent substitutions. This should be especially pronounced for ammonia, which is both the smallest amine nucleophile and can form two intramolecular hydrogen bonds.[23] Ammonia should therefore give the lowest yields of either mono- or disubstitution products, which is borne out by experiment. **2a** is thus much more expeditiously synthesized from **2d** by cleavage of the *tert*-butyl group with trifluoro acetic acid (cf. ref 9).

Conversely, the nitro groups in symmetrical trifluorotrinitrobenzene **8** should suffer less from steric strain (no structural data are available). This may contribute to the known[9,19] higher overall reactivity for **8** vs **5**, as evidenced also by its successful reaction with bis-neopentylamine to give the monosubstitution product. More importantly, the higher reactivity of **8** should also be accompanied by a higher selectivity. Indeed, **8** reacts with 4 (!) equiv of ammonia under otherwise comparable conditions as **5** to give mono-, bis-, and tris-substitution products in 47, 11, and 21% yields, respectively.[9]

To lend further proof to this rationalization, we have performed an X-ray analysis of **2a**.[24] The ring is almost planar, and there is significant bond length alternation in the ring. The C−C bonds emanating from the C−NH_2 [average: 1.404(4) Å] are longer than the remaining four C−C [average: 1.378(4) Å] bonds in accordance with the general behavior of *o*-nitroanilines.[25,26] Although the molecule shows 3-fold disorder in all of the oxygen atoms,[27] it is clear that the twist with respect to the ring of the nitro groups in positions ortho to the amino group is reduced in comparison to the overall twist in **5**. While one of the three positions available to each of them is still quite twisted (by roughly 80°), the two remaining positions are twisted by about ±50−60°. We assume that the most likely conformation of **2a** has one of the *o*-nitro groups rotated to achieve better hydrogen bonding with the amino group and the other *o*-group is then twisted more to relieve steric strain. Since rotation can be either clockwise or counterclockwise, and on the left or right nitro group, four conformations are possible that are superimposed as a result of the X-ray analysis. In accordance with this hypothesis, hydrogen positions could not be located in contrast to the usual behavior in hydrogen bonding between nitro and amino groups in the ortho positions. The twist of substituents in **2a** had been estimated on the basis of its UV−vis spectrum.[28] On the basis of the X-ray structural data available then, the

(18) Parker, R. E.; Read, T. O. *J. Chem. Soc.* **1962**, 3149−3153.

(19) Shaw, G. C., III; Seaton, D. L. *J. Org. Chem.* **1961**, *26*, 5227−5228.

(20) Gerard, F.; Hardy, A.; Becuwe, A. *Acta Crystallogr., Sect. C* **1993**, *49*, 1215−1218. Computations at the HF 6-31G* level also find that nitrobenzene with the nitro group in the planar conformation is more susceptible to attack by nucleophiles than with the nitro group in the perpendicular conformation: Politzer, P.; Lane, P.; Jayasuriya, K.; Domelsmith, L. N. *J. Am. Chem. Soc.* **1987**, *109*, 1899−1901.

(21) NH···ON hydrogen bonds have been described as weaker as comparable OH···ON interactions. However, they are structure-determining even in intermolecular cases; see, for example: Panunto, T. W.; Urbànczyk-Lipkowska, Z.; Johnson, R.; Etter, M. C. *J. Am. Chem. Soc.* **1987**, *109*, 7786−7797. For semiempirical computations of their strength, see, for example: Vinson, L. K.; Dannenberg, J. J. *J. Am. Chem. Soc.* **1989**, *111*, 2777−2781.

(22) A planarizing effect of intramolecular hydrogen bonds has been noted in the comparison of the crystal structures of picramide and its *N*-methyl-, and *N*-ethyl-, and *N*,*N*-dimethyl derivatives: Butcher, R. J.; Gilardi, R.; Flippen-Anderson, J. L.; George, C. *New J. Chem.* **1992**, *16*, 679−692.

(23) Note, however, that the steric bulk of an NH_2 substituent as probed by *A* values is *higher* than that of a Cl substituent. *A* values read (in kcal·mol^{-1}): Cl, 0.53−0.64; NH_2, 1.23; NHMe, 1.29; NMe_2, 1.53; see: Eliel, E. L.; Wilen, S. H.; Mander, L. N. *Stereochemistry of Organic Compounds*; Wiley: New York, 1994; p 696f.

(24) See the Supporting Information. The authors have also deposited atomic coordinates for **2a** with the Cambridge Crystallographic Data Centre, 12 Union Road, Cambridge CB2 1EZ, UK.

(25) Holden, J. R.; Dickinson, C. *J. Phys. Chem.* **1977**, *81*, 1505−1514.

(26) Sadova, N. I.; Vilkov, L. V. *Russ. Chem. Rev.* **1982**, *51*, 87−105.

(27) Cf. the disorder of nitro groups in the dipotassium salt of trinitrophloroglucinol: Wolff, J. J.; Nelsen, S. F.; Powell, D. R.; Desper, J. M. *Chem. Ber.* **1991**, *124*, 1727−1731.

(28) Kamlet, M. J.; Minesinger, R. R.; Hoffsommer, J. C.; Dacons, J. C.; Adolph, H. G. *J. Chem. Soc. B* **1968**, 1147−1153.

Table 1. Yields and Chemical Shifts of NH Protons for 2

	2a	2b	2c[a]	2d	2e	2f	2g	2h	2i[a]	2j	2k	2l	2m	2n
% yield	2.6	19	14	43	13−28	18	15	*d*	46	77	63	58	45	36
δ_{NH}[b]	7.77[c]	5.73	4.97	3.94	7.26[c]	5.81	6.64	5.94						

[a] Reference 23. [b] In $CDCl_3$, unless noted otherwise. [c] DMSO-d_6. [d] By reaction of **2e** with ethyl chloroformate.

authors assumed a twist angle of 65−70° with respect to the plane through the benzene ring for the nitro group in the 4-position. They discussed several possibilities for the twist of the remaining substituents and arrived at a "best guess" of twist angles of 40−45° for the nitro groups in the 2,6 positions. Neither of these estimations seems to be confirmed for **2a** in the solid state, with the exception of the *p*-nitro group.

The reduced steric bulk of the unsubstituted amino group and its capability to form two hydrogen bonds should not only provide for a kinetic acceleration in S_N-Ar reactions but should also lead to a thermodynamic stabilization. Thus, in reversible S_NAr reactions, the electronically weaker donor ammonia should be capable of replacing the more strongly donating mono- and especially dialkylamines. Such cases have been noted before by us[29] and also (without explanation) in the reaction of tris[(3,5-dichloro-2,4,6-trinitrophenyl)amino]-1,3,5-triazine with ammonia to give *sym*-trinitrotriaminobenzene.[30] A related exchange for monoalkylamines occurs in 1-(dialkylamino)-2,4-dinitronaphthalenes.[31]

In turn, the attractive effect of hydrogen bonding should be annihilated if the steric bulk at the amino nitrogen is increased. Preparatively, this is reflected by the higher selectivity observed with *tert*-butylamine. Also, the chemical shift for the N*H* proton of **2** in $CDCl_3$ follows closely the size of the alkyl substituent; it is shifted considerably to higher field for the *t*-Bu derivative **2d**. Intramolecular hydrogen bonding is therefore weakest in **2d** (see Table 1).

Taken together, these observations allow us to explain the success in the crucial cyclization steps leading to **3** and **4**[7,8] because in both cases monoalkylamines are employed as the reacting species. Thus, a type of "zipper effect" is noted: as soon as the first amino site has reacted, the reaction of the second one will be facilitated. Therefore, the intramolecular cyclization becomes more favored with respect to the intermolecular oligomerization.

Experimental Section

Melting points: hotstage microscope, uncorrected. NMR spectra: 300.133 MHz for ^1H, 75.469 MHz for ^{13}C, unless noted otherwise. **CAUTION**: ***polynitro compounds may be explosive! We have not encountered any violent decomposition with the compounds reported here but advise the use of special care.*** Chemicals were obtained from commercial sources with the exception of the following: **1,3,5-trichloro-**[32,33] and **1,3,5-trifluoro-2,4,6-trinitrobenzene** (from nitration of 1,3,5-trifluorobenzene, ref 19), **1,3-dichloro-5-fluorobenzene**,[34,35] ***N*-methyl-neopentylamine (6n)**,[36] **dineopentylamine** (**6o**),[37] and **4,4-dimethylpiperidine**[38] (**6l**), which were synthesized according to known procedures (amines by $LiAlH_4$ reduction of the corresponding amides: trimethylacetamide, mp 151−153 °C from water; *N*-methyltrimethylacetamide, mp 92−94 °C; 4,4-dimethylglutarimide, colorless needles, mp 146−146.5 °C, first from 50% EtOH, then water). **2d** and **2i** were obtained as described previously.[29]

4,4-Dimethylpiperidine (6l): bp 140−142 °C, 76−78 °C (150 mbar); 60% yield; ^1H NMR ($CDCl_3$) δ 0.83 (s, 6 H), 1.20 (m, 4 H), 1.24 (br s, 1 H), 2.68 (m, 4 H); ^{13}C NMR ($CDCl_3$) δ 28.44, 28.87, 39.79, 42.72. **Methylneopentylamine (6n)**: bp 88−90 °C (lit.[36] bp 88−90 °C); 52% yield; ^1H NMR ($CDCl_3$) δ 0.69 (br s, 1 H), 0.79 (s, 9 H), 2.19 (s, 2 H), 2.31 (s, 3 H); ^{13}C NMR ($CDCl_3$) δ 27.65, 31.18, 37.49, 65.06. **Bis(2,2-dimethylpropyl)amine (dineopentylamine) (6o)**: bp 46−47 °C/22 Torr (lit. bp[37] 153−154 °C); 71.6% yield (molar scale); ^1H NMR ($CDCl_3$) δ 0.89 (br s, 1 H), 0.90 (s, 18 H), 2.33 (s, 4 H); ^{13}C NMR ($CDCl_3$) δ 27.82, 32.01, 63.61.

1,3-Dichloro-5-fluorobenzene.[34] Diazonium tetrafluoroborate (189 mmol) (fm. diazotation of 200 mmol of 3,5-dichloroaniline in aqueous HCl and subsequent precipitation) on thermal decomposition and distillation after workup as described gave 152 mmol (81.6% yield) of fluoro derivative: bp 54 °C/20 Torr; ^1H NMR ($CDCl_3$) δ 7.01 (dd, J = 1.7, 8.3 Hz, 2 H), 7.17 (dd, J = 1.1, 1.6 Hz, 1 H); ^{13}C NMR ($CDCl_3$) δ 114.96 (d, J = 24.6 Hz), 124.90 (d, J = 3.6 Hz), 135.73 (d, J = 11.5 Hz), 162.50 (d, J = 252.6 Hz).

1,3-Dichloro-5-fluoro-2,4,6-trinitrobenzene (7). The above fluorobenzene (8.38 g, 50.8 mmol) was nitrated in KNO_3 (40.4 g) and 30% oleum (266.5 g) in analogy to the synthesis of **5**.[33] The crude product after hydrolysis (12.93 g, mp 62−85 °C) was crystallized from CCl_4 to give needles, mp 101−103 °C (4.532 g). An analytical sample was recrstallized twice, mp 101−102 °C. Workup of the mother liquors by addition of pentane yielded a further crop: mp 98−101 °C (3.033 g, total yield 7.565 g, 25.22 mmol, 49.6%); ^1H NMR ($CDCl_3$) no signal; ^{13}C NMR ($CDCl_3$) δ 123.75 (d, J = 1.4 Hz), 138.12 (br d, J = 14.3 Hz), ca. 145.4 (br, obscured by following signal), 147.26 (d, J = 277.5 Hz). Anal. Calcd for $C_6Cl_2FN_3O_6$ (299.99): C, 24.02; N, 14.01; Cl, 23.64. Found: C, 24.16; N, 13.80; Cl, 23.55. Reaction with 1 equiv of Hünig's base and 1 equiv of dioctylamine (**6j**) in toluene at 0 °C gave (after chromatography; silica, 5% tolene in petroleum ether) 49.9% of **2j** and 18.8% of 1-chloro-3-fluoro-5-(dioctylamino)-2,4,6-trinitrobenzene, along with the disubstitution product **9** (4.7%) and a small amount of 1-fluoro-3,5-bis(dioctylamino-2,4,6-trinitrobenzene). The yield of **2j** was not improved when the reaction was conducted in dichloromethane at −85 to −10 °C.

1,3,5-Trifluoro-2,4,6-trinitrobenzene (8): mp 81.5−85.5 °C (CCl_4); ^{13}C NMR ($CDCl_3$) δ 127.57 (br m), 149.90 (dt, J = 282.5, 3.7 Hz).

3,5-Dichloro-2,4,6-trinitroaniline (2a). Method a. Precooled toluene solutions of **5** (2.919 g, 9.224 mmol, in 90 mL solvent) and ammonia (**6a**; 90 mL of a 0.205 M solution, 18.5 mmol) were mixed at −70 °C with stirring and then slowly warmed to room temperature. The crude product (2.274 g)

(29) Wolff, J. J.; Gredel, F.; Hillenbrand, D.; Irngartinger, H. *Liebigs Ann. Chem.* **1996**, 1175−1182.
(30) Coburn, M. D. *J. Heterocycl. Chem.* **1966**, *3*, 365−366.
(31) Sekiguchi, S.; Suzuki, T.; Hosokawa, M. *J. Chem. Soc., Perkin Trans. 2* **1989**, 1783−1788.
(32) Engelbertz, P. (Inv.), Chemische Fabrik Griesheim, D.R.P. 767510, 1936; *Chem. Abstr.* **1955**, *49*, 14803d.
(33) Hill, M. E.; Taylor, F., Jr. *J. Org. Chem.* **1960**, *25*, 1037−1038. Note: 266.5 g of oleum is required, not 266.5 mL, as written. The formation of 1,2,3,5-tetrachloro-4,6-dinitrobenzene is minimal under these conditions (ca. 2%; unpublished observations). For the kinetics of this nitration process, see: Moodie, R. B.; Payne, M. A.; Schofield, K. *J. Chem. Soc., Perkin Trans. 2* **1985**, 1457−1464.
(34) Pavlath, A.; Oláh, G. *Acta Chim. Acad. Sci. Hung.* **1956**, *10*, 227−232.
(35) Cannoni de Degiorgi, A.; Zappi, E. V. *Bull. Chim. Soc. Fr.* **1938**, *[5] 5*, 1441−1446.
(36) Pine, S. H.; Catto, B. A.; Yamaguchi, F. G. *J. Org. Chem.* **1970**, *35*, 3663−3666.
(37) Mosher, H. S.; Blanz, E. J., Jr. *J. Org. Chem.* **1957**, *22*, 445−446.
(38) Hoch, D.; Karrer, P. *Helv. Chim. Acta* **1954**, *37*, 397−402.

mainly consisted of poorly soluble trinitrotriaminobenzene and starting material. Chromatography (silica gel, chloroform) gave **2a** as a yellow powder (70 mg, 0.24 mmol, 2.6%) with characterization as below. **Method b.** A mixture of trifluoroactic acid (5 mL), **2d** (346 mg, 0.980 mmol), and dry dichloromethane (10 mL) was kept at room temperature for 14 h. The mixture was diluted with CH_2Cl_2, washed with water, saturated aqueous bicarbonate, and saturated brine, and dried (Na_2SO_4). The solvent was evaporated and the residue (290 mg, 0.976 mmol, 99%) recrystallized from *n*-heptane/toluene to give yellow prisms (215 mg): mp 208−209 °C; ^{1}H NMR (DMSO-d_6) δ 7.77 (br s); ^{13}C NMR (DMSO-d_6) δ 122.36, 134.94, 135.26, 136.94. Anal. Calcd for $C_6H_2Cl_2N_4O_6$ (297.01): C, 24.26; H, 0.68; N, 18.86, Cl, 23.87. Found: C, 24.35; H, 0.89; N, 19.00; Cl, 23.85.

1,3-Dichloro-5-[(2,2-dimethylpropyl)amino]-2,4,6-trinitrobenzene (2b) was obtained at room temperature from a solution of **5** (7.12 g, 22.5 mmol) in toluene (60 mL) and a solution of 2,2-dimethylpropylamine (**6b**; 1.92 g, 22.5 mmol) in the same solvent (120 mL). Chromatography (silica, PE/toluene = 7/3) and recrystallization from isooctane gave bright yellow needles (1.51 g, 4.11 mmol, 18.3%): mp 178−179 °C; ^{1}H NMR ($CDCl_3$) δ 0.93 (s, 9 H), 2.82 (d, J = 5.0 Hz, 2 H), 5.73 (br t, $J \cong 5$ Hz, 1 H); ^{13}C NMR ($CDCl_3$) δ 26.82, 31.88, 55.21, 124.35, 136.52, 137.02, 138.47. Anal. Calcd for $C_{11}H_{12}Cl_2N_4O_6$ (367.14): C, 35.99; H, 3.29; N, 15.26; Cl, 19.31. Found: C, 35.92; H, 3.37; N, 15.09; Cl, 19.25.

1,3-Dichloro-5-[(1,1-dimethylethyl)amino]-2,4,6-trinitrobenzene (2d) was obtained at −10 °C from a solution of **5** (7.00 g, 22.1 mmol) in toluene (300 mL) and a solution of *tert*-butylamine (**6d**; 3.23 g, 44.2 mmol) in the same solvent (100 mL). Filtration and chromatography (silica, PE/toluene = 7/3), followed by recrystallization from isooctane, gave pale yellow sheets (3.38 g, 9.57 mmol, 43.3%): mp 126−127 °C; ^{1}H NMR ($CDCl_3$) δ 1.18 (s, 9 H), 3.94 (s, 1 H); ^{13}C NMR ($CDCl_3$) δ 30.62, 50.58, 122.08, 135.95, 143.43, 145.86. Anal. Calcd for $C_{10}H_9Cl_2N_4O_6$ (353.11): C, 34.01; H, 2.85; N, 15.87; Cl, 20.08. Found: C, 34.12; H, 2.89; N, 15.76; Cl, 20.10.

1,3-Dichloro-5-[(2-hydroxyethyl)amino]-2,4,6-trinitrobenzene (2e) was obtained at room temperature from a solution of **5** (18.4 g, 58.2 mmol) in dichloromethane (100 mL) at room temperature and a solution of ethanolamine (**6e**; 4.50 g, 73.8 mmol) in the same solvent (50 mL). Filtration after 30 min and chromatography (silica, CH_2Cl_2) gave a light yellow powder (2.57 g, 7.54 mmol, 28% of starting material consumed) and recovered **5** (10.02 g, 31.67 mmol): ^{1}H NMR (DMSO-d_6) δ 3.00 (p, J = 5.5 Hz, 2 H), 3.47 (t, J = 5.7 Hz, 2 H), 4.64 (br s, 1 H), 7.26 (br t, J = 5.3 Hz, 1 H); ^{13}C NMR (DMSO-d_6) δ 46.14, 59.17, 122.81, 136.26, 136.54, 137.04. Anal. Calcd for $C_8H_6Cl_2N_4O_7$ (341.07): C, 28.17; H, 1.77; N, 16.43; Cl, 20.79. Found: C, 28.18; H, 1.79; N, 16.45; Cl, 20.72.

1,3-Dichloro-5-[[2-[(ethoxycarbonyl)oxy]ethyl]amino]-2,4,6-trinitrobenzene (2h). Reaction of **2e** with 1.9 equiv of ethyl chloroformate and 2.3 equiv of pyridine in dichloromethane, chromatography (silica, CH_2Cl_2), followed by crystallization from cyclohexane gave fine yellow needles of **2h**: mp 90−92 °C; 90% yield; ^{1}H NMR ($CDCl_3$) δ 1.29 (t, J = 7.2 Hz, 3 H), 3.36 (br m, 2H), 4.20 (q, J = 7.2 Hz, 2 H), 4.27 (br t, J = 4.8 Hz, 2 H), 5.92 (br t, J = 4.6 Hz, 1 H); ^{13}C NMR ($CDCl_3$) δ 14.11, 43.83, 65.06, 65.10, 123.76, 135.85, 137.11, 138.98, 155.58. Anal. Calcd for $C_{11}H_{10}N_4O_9Cl_2$ (413.13): C, 31.98; H, 2.44; N, 13.56; Cl, 17.16. Found: C, 31.96; H, 2.46; N, 13.52; Cl, 17.07.

1,3-Dichloro-5-[(2,2-dimethoxyethyl)amino]-2,4,6-trinitrobenzene (2f). A solution of aminoacetaldehyde dimethyl acetal (**6f**; 1.79 g, 17.0 mmol) and Hünig's base (2.20 g, 17.0 mmol) in dry toluene (60 mL) was added dropwise within 90 min to a stirred solution of **5** (5.00 g, 15.8 mmol) in the same solvent (140 mL) at −15 °C. The yellow mixture was left in the bath without further cooling and stirred overnight. The hydrochloride was filtered, the solvent evaporated, and the yellow residue chromatographed (silica, cyclohexane/ethyl acetate = 5/1) to give light yellow prisms: mp 105−106 °C (1.10 g, 2.86 mmol, 18%); ^{1}H NMR ($CDCl_3$) δ 3.15 (t, J = 4.9 Hz, 2 H), 3.37 (s, 6 H), 4.40 (t, J = 4.7 Hz, 1 H), 5.81 (br t, J = 4.4 Hz, 1 H); ^{13}C NMR ($CDCl_3$) δ 45.20, 54.76, 101.46, 123.84, 136.65, 137.28, 138.88. Anal. Calcd for $C_{10}H_{10}Cl_2N_4O_8$ (385.12): C, 31.19; H, 2.62; N, 14.55; Cl, 18.41. Found: C, 31.37; H, 2.67; N, 14.36; Cl, 18.28.

1,3-Dichloro-5-[(3,3-diethoxypropyl)amino]-2,4,6-trinitrobenzene (2 g) was obtained from **5** and 2 equiv of 3-aminopropanal diethyl acetal (**6g**) in toluene first at −10 °C and then at rt. Chromatography (silica, petroleum ether/ethyl acetate = 5/1) gave a yellow powder: mp 108−110 °C; ^{1}H NMR ($CDCl_3$) δ 1.22 (t, J = 7.1 Hz, 6 H), 1.87 (m, 2 H), 3.22 (m, 2 H), 3.50 (dq, J = 9.4, 7.0 Hz), 2 H), 3.68 (dq, J = 9.4, 7.1 Hz, 2 H), 4.59 (t, J = 4.2 Hz, 1 H), 6.64 (br t, J = 4.1 Hz, 1 H); ^{13}C NMR ($CDCl_3$) δ 15.04, 32.46, 39.40, 63.28, 102.29, 123.36, 136.04, 136.26, 137.38. Anal. Calcd for $C_{13}H_{16}Cl_2N_4O_8$ (427.20): C, 36.55; H, 3.78; N, 13.12; Cl, 16.60. Found: C, 36.73; H, 3.80; N, 13.04; Cl, 16.54.

1,3-Dichloro-5-(dioctylamino)-2,4,6-trinitrobenzene (2j). Solutions of **5** (1.869 g, 5.906 mmol) and dioctylamine (**6j**; 2.852 g, 11.81 mmol) in CH_2Cl_2 (50 + 50 mL) were combined at −70 °C, and the bath was slowly warmed; the reaction began at −40 °C. The mixture was kept at −10 °C for 2 h and then worked up as before. Chromatography (silica, PE/toluene = 95/5) gave a yellow-orange oil (2.369 g, 4.543 mmol, 76.9%). The disubstitution product (yellow-orange oil, 326 mg, 0.421 mmol, 7.1%) was also isolated and characterized (see below): ^{1}H NMR ($CDCl_3$) δ 0.88 (pseudo-t, J = 6.7 Hz, 6 H), 1.26 (m, 20 H), 1.48 (pseudo-p, J = 6.9 Hz, 4 H), 2.98 (m, 4 H); ^{13}C NMR ($CDCl_3$) δ 14.00, 22.58, 26.65, 28.03, 29.11, 29.13, 31.70, 52.72, 122.24, 140.01, 142.98, 146.68. Anal. Calcd for $C_{22}H_{34}Cl_2N_4O_6$ (521.44): C, 50.68; H, 6.57; N, 10.74; Cl, 13.60. Found: C, 50.82; H, 6.33; N, 10.65; Cl, 13.74.

1-Chloro-3,5-bis(dioctylamino)-2,4,6-trinitrobenzene (9): ^{1}H NMR ($CDCl_3$) δ 0.87 (pseudo-t, J = 6.7 Hz, 12 H), 1.26 (m, 40 H), 1.42 (pseudo-p, J = 6.9 Hz, 8 H), 2.91 (m, 8 H); ^{13}C NMR ($CDCl_3$) δ 14.03, 22.60, 26.78, 28.36,29.17, 29.22, 31.75, 53.35, 121.53, 139.97, 144.82, 148.94. Anal. Calcd for $C_{38}H_{68}ClN_5O_6$ (726.45): C, 62.83; H, 9.44; N, 9.64. Found: C, 63.13; H, 9.51; N, 9.65.

1,3-Dichloro-5-piperidino-2,4,6-trinitrobenzene (2k) was obtained at −10 °C from a solution of **5** (14.0 g, 44.2 mmol) in toluene (110 mL) and a solution of piperidine (**6k**; 10.0 g, 88.3 mmol) in the same solvent (110 mL). Filtration and then crystallization from isooctane gave yellow flakes (10.15 g, 27.80 mmol, 62.9%): mp 194−195 °C; ^{1}H NMR (270 MHz, $CDCl_3$) δ 1.58 (br m, 6 H), 3.06 (br m, 4 H); ^{13}C NMR (68 MHz, $CDCl_3$) δ 23.16, 25.80, 52.10, 122.19, 140.58, 142.89, 145.93. Anal. Calcd for $C_{11}H_{10}Cl_2N_4O_6$ (365.13): C, 36.18; H, 2.76; N, 15.34; Cl, 19.42. Found: C, 36.36; H, 2.82; N, 15.24; Cl, 19.67.

1,3-Dichloro-5-(4,4-dimethylpiperidino)-2,4,6-trinitrobenzene (2l) was obtained at −10 °C from a solution of **5** (14.0 g, 44.2 mmol) in toluene (110 mL) and a solution of 4,4-dimethylpiperidine (**6l**; 10.0 g, 88.3 mmol) in the same solvent (110 mL). Filtration and then chromatography (silica gel, ethyl acetate/PE = 1/8) gave yellow prisms (10.15 g, 25.8 mmol, 58.4%): mp 160−162 °C; ^{1}H NMR ($CDCl_3$) δ 0.94 (s, 6 H), 1.38 (m, 4 H), 3.05 (m, 4 H); ^{13}C NMR ($CDCl_3$) δ 27.61, 28.18, 38.42, 47.76, 122.22, 140.60, 142.97, 146.06. Anal. Calcd for $C_{13}H_{14}Cl_2N_4O_6$ (393.19): C, 39.71; H, 3.59; N, 14.25; Cl, 18.03. Found: C, 39.89; H, 3.59; N, 13.99; Cl, 18.00.

1,3-Dichloro-5-[(2,2-dimethoxyethyl)-*N*-methylamino]-2,4,6-trinitrobenzene (2m) was obtained in analogy to the synthesis of **2f** from **5** (7.00 g, 22.1 mmol), (*N*-methylamino)-acetaldehyde dimethyl acetal (**6m**; 2.91 g, 22.5 mmol) and Hünig's base (3.17 g, 10.0 mmol): yellow prisms; mp 68−69 °C (9.92 mmol, 45%; based on recovered starting material, 82%); starting material was also recovered (3.17 g, 10.0 mmol); ^{1}H NMR ($CDCl_3$) δ 2.89 (s, 3 H), 3.01 (d, J = 5.2 Hz, 2 H), 3.31 (s, 6 H), 4.34 (t, J = 5.3 Hz, 1 H); ^{13}C NMR ($CDCl_3$) δ 42.17, 54.30, 56.26, 102.67, 122.27, 140.63, 143.63, 146.73. Anal. Calcd for $C_{11}H_{12}Cl_2N_4O_8$ (399.15): C, 33.10; H, 3.03; N, 14.04; Cl, 17.76. Found: C, 33.18; H, 3.15; N, 13.97; Cl, 17.79.

1,3-Dichloro-5-[*N*-methyl(2,2-dimethylpropyl)amino]-2,4,6-trinitrobenzene (2n) was obtained at room temperature from a solution of **5** (5.11 g, 16.1 mmol) in toluene (100

mL) and a solution of (2,2-dimethylpropyl)methylamine (**6n**; 3.26 g, 32.3 mmol) in the same solvent (120 mL). Repeated crystallizaton from isooctane gave yellow needles (2.22 g, 5.82 mmol, 36.2%), mp 114−116 °C. More material was contained in the mother liquors: ^{1}H NMR ($CDCl_3$) δ 0.87 (s, 9 H), 2.71 (s, 2 H), 2.99 (s, 3 H); ^{13}C NMR ($CDCl_3$) δ 27.64, 34.83, 46.50, 66.86, 122.55, 142.29, 143.41 (br), 146.66 (br). Anal. Calcd for $C_{12}H_{14}Cl_2N_4O_6$ (381.17): C, 37.81; H, 3.70; N, 14.70; Cl, 18.60. Found: C, 37.88; H, 3.71; N, 14.63; Cl, 18.72.

1-Bis[(2,2-dimethylpropyl)amino]-3,5-difluoro-2,4,6-trinitrobenzene (10) was obtained from bis(neopentyl)amine (**6o**; 1.553 g, 9.873 mmol) and trifluorotrinitrobenzene (1.318 g, 4.935 mmol) in dry THF; 9 days at room temperature. Rapid filtration over neutral alumina and recrystallization from isooctane gave dull-orange plates: mp 209−210.5 °C (920 mg, 2.28 mmol, 46.1%); ^{1}H NMR ($CDCl_3$) δ 0.91 (s, 18 H), 3.03 (s, 4 H); ^{13}C NMR ($CDCl_3$) δ 27.24, 36.99, 66.66, 131.38 (br d, J = 15.8 Hz), 141.19 (t, J = 3.4 Hz), 150.93 (dd, J = 4.9, 275.7 Hz). The expected triplet for *C*-NO_2 could not be detected, probably because of the excessive broadening known for this type of resonance (and also detected in other members of **2** here). Anal. Calcd for $C_{16}H_{22}F_2N_4O_6$ (404.37): C, 47.52; H, 5.48; N, 13.86. Found: C, 47.67; H, 5.71; N, 14.03.

Acknowledgment. This work was supported by Deutsche Forschungsgemeinschaft and Fonds der Chemischen Industrie.

Supporting Information Available: X-ray structure determination summary for **2a** and lists of coordinates, anisotropic displacement factors, bond lengths, bond angles, and torsional angles (6 pages). This material is contained in libraries on microfiche, immediately follows this article in the microfilm version of the journal, and can be ordered from the ACS; see any current masthead page for ordering information.

JO980374Z