

Highly Selective Nitrating Agents obtained by Complexation of Nitronium Tetrafluoroborate with Crown Ethers

Bernardo Masci

Centro di Studio sui Meccanismi di Reazione del Consiglio Nazionale della Ricerche, c/o Istituto di Chimica Organica, Università di Roma, 00185 Roma, Italy.

A well behaved electrophilic aromatic substitution with very high substrate and positional selectivity is observed in benzene and toluene nitration with NO_2BF_4 -crown ether complexes in CH_2Cl_2 .

The nitronium ion is known to be the electrophilic species in most aromatic nitrations,¹ but when these reactions are carried out with preformed nitronium salts an anomalous selectivity picture is obtained.² In many cases incomplete mixing of the reagents before such fast reactions occur can be held responsible^{3,4} for the observed very low substrate selectivity, compared with 'normal' regioselectivity. It has been reported⁵ that addition of simple ethers and alcohols to NO_2PF_6 in MeNO_2 changes the anomalous substrate selectivity observed in nitronium salt nitrations to that observed with commonly used nitrating agents.

In this communication evidence is presented that crown ethers interact with NO_2BF_4 in a manner quite different from that of simple ethers and give nitrating agents endowed with 'normal' to very high positional and substrate selectivity.

A concentrated homogeneous solution is readily obtained upon mixing equimolar amounts of NO_2BF_4 and 18-crown-6 (18C6) or 21-crown-7 (21C7) in CH_2Cl_2 : an excess (*ca.* 2.5 times the stoichiometric amount) of 15-crown-5 (15C5) or tetraglyme is needed to dissolve the salt. Equimolar amounts of NO_2BF_4 and 18C6 also give a homogeneous solution in MeNO_2 in spite of the fact that both the ether and the salt are scarcely soluble in this solvent.

The nitrating properties of the above solutions at various $[\text{crown ether}]/[\text{NO}_2\text{BF}_4]$ ratios have been tested on benzene and toluene. G.l.c. and ^1H n.m.r. analysis showed that the amount of the aromatic substrate that reacted could be

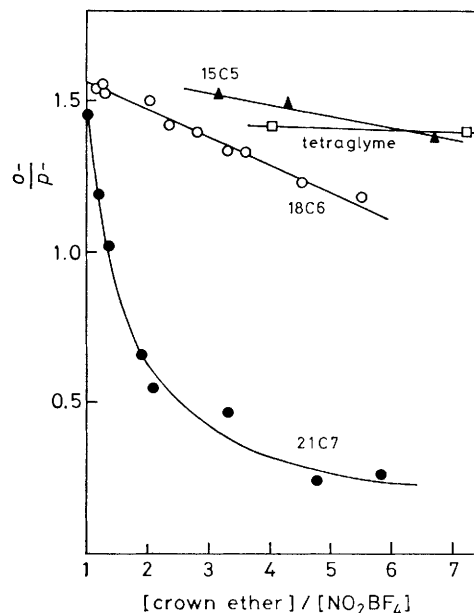


Figure 1. Effect of $[\text{crown ether}]/[\text{NO}_2\text{BF}_4]$ ratio on the regioselectivity of toluene nitration, as measured by the *ortho/para* ratio, in CH_2Cl_2 at 25 °C.

entirely accounted for by the formation of mononitro-derivatives.† The selectivity data obtained from benzene and toluene nitration in competitive kinetic experiments‡ at 25 °C indicate that chemical selectivity is no longer affected by mixing problems and suggest that the high reactivity of nitronium salts decreases on interaction with crown ethers. In CH₂Cl₂ the substrate and positional selectivities are unusually high and affected by the [crown ether]/[NO₂BF₄] ratio and by the nature of the crown ether. Figure 1 shows the marked effects of crown ethers on the *o*-/*p*- ratio for toluene nitration in CH₂Cl₂.§ The effects on selectivity decrease in the order 21C7 > 18C6 > 15C5 ≈ tetraglyme. On increasing the [21C7]/[NO₂BF₄] ratio from 1.2 to 5.9 the relative rate of nitration $k_{\text{toluene}}/k_{\text{benzene}}$ increases regularly from 61 to 77 and regular trends are observed in the partial rate factors, with f_p increasing from 163 to 361, f_m from 2.9 to 3.3, and f_o decreasing from 97 to 47.

A wide range of selectivity is spanned on changing the conditions, namely the selectivity factor⁶ $S_f = \log(f_p/f_m)$ is 1.36 with [18C6]/[NO₂BF₄] = 1 in MeNO₂ and as high as 2.04 with [21C7]/[NO₂BF₄] = 5.9 in CH₂Cl₂, but in all cases the selectivity data are consistent with a well behaved electrophilic aromatic substitution, as indicated by their close fit to the Brown's selectivity relationship.⁶

As for simple ethers, it must be noted that tetrahydrofuran and diethyl ether also dissolve NO₂BF₄ in MeNO₂ and CH₂Cl₂ (2.5:1 or higher molar ratios have been used) but these solutions gave only trace amounts of the nitro-derivatives when allowed to react with benzene and toluene.¶ G.l.c. and ¹H n.m.r. analysis showed that after interaction

with NO₂BF₄ the amount of simple ethers decreases, whilst the amount of 18C6 added remains unchanged. On adding 21C7 to a solution of 18C6–NO₂BF₄ the very high selectivity expected for the 21C7–NO₂BF₄ interaction has been observed. Moreover, on adding Et₂O to an 18C6–NO₂BF₄ solution and waiting 4 h before adding aromatics, mononitro-derivatives in 53% yield and in the relative ratios expected for nitration with 18C6–NO₂BF₄ were obtained. On the other hand, addition of 18C6 to the solution obtained by interaction of Et₂O with NO₂BF₄ did not give a nitrating mixture.

The conclusion may be drawn that a strong and reversible interaction takes place between crown ethers and NO₂BF₄, and an irreversible one between simple ethers and the salt: the interaction with the crown ether seems to inhibit the irreversible reaction with Et₂O.

The observed behaviour strongly suggests the occurrence of complexes of the host–guest type.⁷ The linear nitronium ion is likely to be inserted into the cavity of at least 18C6 and 21C7, with the positive charge favourably placed to interact with several of the oxygen atoms. Similarly 'threaded' structures have been reported for the association of the linear arenediazonium ions with crown ethers.^{7–9} Interestingly the effect on selectivity of complexes with NO₂BF₄ increases in the same order, 21C7 > 18C6 > 15C5, as that found for the complexation strength of ArN₂⁺.⁹

As selectivity varies with the nature and the concentration of the crown ether, the nitrating species cannot be the same under all the conditions. The opposing trends of f_p and f_o suggest electrophilic species of increasing bulkiness and selectivity are produced on increasing the concentration of 21C7.

I thank Professors G. Illuminati and L. Mandolini for helpful discussions and critical reading of the manuscript.

Received, 26th July 1982; Com. 876

References

- 1 K. Schofield, 'Aromatic Nitration,' Cambridge University Press, Cambridge, 1980.
- 2 G. A. Olah, S. J. Kuhn, and S. H. Flood, *J. Am. Chem. Soc.*, 1961, **83**, 4571.
- 3 J. H. Ridd, *Acc. Chem. Res.*, 1971, **4**, 248.
- 4 P. Rys, *Pure Appl. Chem.*, 1981, **53**, 209.
- 5 G. A. Olah, H. C. Lin, J. A. Olah, and S. C. Narang, *Proc. Natl. Acad. Sci. USA*, 1978, **75**, 1045.
- 6 L. M. Stock and H. C. Brown, *Adv. Phys. Org. Chem.*, 1963, **1**, 1.
- 7 D. J. Cram and J. M. Cram, *Acc. Chem. Res.*, 1978, **11**, 8.
- 8 R. A. Bartsch in 'Progress in Macrocyclic Chemistry,' eds. R. M. Izatt and J. J. Christensen, Wiley, New York, 1981, vol. 2.
- 9 P. Groth, *Acta Chem. Scand., Ser. A*, 1981, **35**, 541.

† Mononitro-derivatives were obtained in 50 to 80% yield (not optimised) as based on the weighed amount of NO₂BF₄. The usual precautions to avoid moisture were taken in manipulating small quantities of NO₂BF₄ (Aldrich, used as received or purified by washing with MeNO₂).

‡ These were run by quickly adding 0.5 ml of an equimolar solution of benzene and toluene *via* a syringe into a septum-capped vessel containing 1.5 ml of a stirred solution of NO₂BF₄ (0.13–0.3 mmol) and crown ether (up to 1.3 mmol) in CH₂Cl₂ or MeNO₂. Only slight differences in selectivity were noted when the salt–crown ether solution was added dropwise to the solution of the aromatic substrates. The relative rates and the isomeric distribution of the nitrotoluenes were obtained by g.l.c.

§ For comparison with literature values see refs. 1 and 5. Typical selectivity data for nitration with HNO₃ solutions are as follows: $k_{\text{toluene}}/k_{\text{benzene}} = 27$, %*o*- 62, %*m*- 3, %*p*- 35; $f_o = 50$, $f_m = 2.4$, $f_p = 57$.

¶ These reactions were carried out under the same conditions as those with crown ethers. Yields of products in ref. 5 were not reported.