Tetrahedron Letters No.47, pp. 4867-4870, 1968. Pergamon Press. Printed in Great Britain.

NUCLEOPHILIC AROMATIC SUBSTITUTION. V - Simple correlations in dipolar aprotic solvent. (*)

G. Bartoli and P.E. Todesco

Istituto di Chimica Organica, 70126 Bari, v.Amendola 173 (ITALY)

(Received in UK 5 August 1968; accepted for publication 16 August 1968)

It is known that the dipolar aprotic solvents strongly modify the aromatic and aliphatic nucleophilic reactivity (1). However, a general picture which quantitatively explains these modifications appears to be very complex (2-4) and it is a common opinion that simple correlations cannot account for the observed reactivity changes (5,6).

Since we have previously proposed (7) some simple correlations of type I

I) $\log k_1/k_2 = A + B.\log [R_{C-Halg}]_D$

which correlate the difference in reactivity between a polarizable reagent (N_1) and a scarcely polarizable one (N_2) to the polarizability of the leaving halogen (as measured by the value of refractivity constant of the C-halogen bond measured at the D line), (**) we aimed to check the validity of the relationship above in the case of a dipolar aprotic solvent. Relationship I was shown to be largely valid in protic solvents, since it is obeyed by several hundreds of experimental data.

(*) Work supported by a grant from the Consiglio Nazionale delle Ricerche, Roma. Part IV: G. Bartoli, L.Di Nunno and P.E. Todesco, Tetrahedron Letters, 2369 (1968).

(**) In our opinion the concept of "polarizability" is not fully adequate to represent the observed variations, which mainly depend on the repulsion between negative charge on the incoming nucleophile and the one on the leaving group as well as on the substrate. Varying the leaving halogen the changes on interaction areas are probably proportional to the variations observed in the polarizability parameters, as measured by the refractivity constants.

We have therefore measured the rate constants for some reactions of sodium phenoxide and thiophenoxide ions with p-nitrohalogeno-benzenes in dimethyl sulphoxide at 25°.

At variance with our previous works, we could not employ the methoxide ion as a scarcely polarizable nucleophile, since it is well known that in DMSO this reagent appreciably yields $CH_3SO-CH_2^-$ (8). However, the two nucleophiles employed in this investigation, namely phenoxide and thiophenoxide ions still differ in the atom involved in the nucleophilic attack (O,S) and their comparison should be valid.

The data obtained are reported in the table below and satisfactorily fit the correlation above, as shown by the related plot (line a); from this, one obtains the following parameters A=-0.07; B= 2.22.

This indicates that relationship I is still valid in a dipolar aprotic solvent; however, the high value of the parameter B observed, seems to indicate a relatively high sensitivity to the polarizability effects. (*) Such value can be compared, as a first approximation, with a similar value obtained for the reactants thiophenoxide/methoxide ions in methanol relatively to the same substrate [B= 2.80; value evaluated from the data in ref. (7)].

However, in comparing the data, we need to account for the fact that the phenoxide ion, given the presence of a benzene ring which can delocalize the negative charge on the oxygen atom, is much more polarizable than methylate ion. For this reason the B value for the reaction of the couple thiophenoxide/methoxide in DMSO are probably higher than the value of the couple thiophenoxide/phenoxide reported here.

This seems to indicate that a change from protic to dipolar aprotic solvents does not dramatically influence the polarizability factors involved in the reactions investigated.

(*) The significance of A values is not fully understood, since they depend upon the sensitivity to the polarizability factors of the substrate, on the different basicity of the nucleophiles, and are being related to the zero value of $[R_{C-Halg}]_D$ parameter.

TABLE

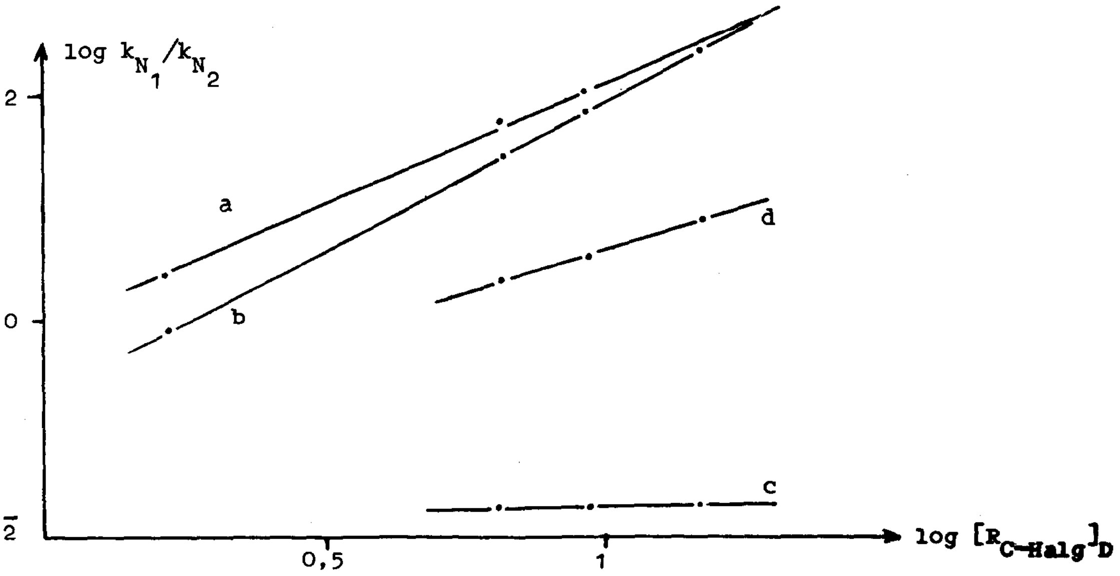
Experimental rate constants (10.k) for reactions of p.nitro-halogeno-benzenes at 25° with thiophenoxide (PhS^-) and phenoxide (PhO^-) ions, in dimethyl-sulphoxide.

halogen in p.nitro-halogeno-benzenes	PhO^-	PhS^-
F	5.2	13
Cl	0.020	1.6
Br	0.034	4.0
I	0.0095	2.6

(rate constants in $sec^{-1}mol^{-1}l$).

Fig.1 Plot of $\log k_{N_1}/k_{N_2}$ versus the polarizabilities of the leaving halogens (logarithms of the refractivity constants of C-halogen bond at the D line)

a: p.nitro-halogeno-benzenes in DMSO at 25°; $N_1 = PhS^-$; $N_2 = PhO^-$ see table
b: " in MeOH at 50°; $N_1 = PhS^-$; $N_2 = MeO^-$ see ref 7.
c: Methyl-halides in DMF at 0° ; $N_1 = SCN^-$; $N_2 = N_3^-$, see ref. 9
d: " in MeOH at 0° ; " " " " " " ".



On the contrary, in the case of the SN_2 reaction of methyl-halides with thiocyanide-ion and azide-ion in methanol and in dimethyl-formamide (9), which also obey correlation I, see fig. 1 (reaction in MeOH, A = -1,00; B= 1,68; reactions in DMF; A= 1,80; B= 0,12) we observed that the sensitivity to polarizability factors is strongly dependent upon the nature of the solvent.

This different behaviour, when related to the differential solvation effects of the leaving halogen group, can probably be ascribed to the different rules of bond breaking in the "rate determing step", which is important in a SN_2 process and usually not relevant in the commonly accepted SnAr two-step mechanism. (9)

If this rule could be confirmed, correlations of type I may be usefully employed in order to distinguish between the two kinds of mechanisms.

REFERENCES

1) For a Review, A.J. Parker in V. Gold, "Advances in Physical Organic Chemistry" Academic Press, London 1967, vol. 5°, pag. 173-232.
2) R. Alexander and A.J. Parker, J.Am.Chem.Soc., 89, 5549 (1967) and preceding papers.
3) D.L. Hill, K.C. Ho and J. Miller, J.Chem.Soc., (B), 299 (1966) and preceding papers.
4) U. Miotti, Gazz.Chim.Ital., 97, 254 (1967).
5) D. Cook, I.P. Evans, E.C.F. Ko and A.J. Parker, J.Chem.Soc.(B) 404 (1966).
6) R.G. Pearson, H. Sobel and J. Songstad, J.Am.Chem.Soc., 90, 319 (1968)
7) A. Ricci, P.E. Todesco and P. Vivarelli, Tetrahedron Letters, 3703 (1964).
8) C.D. Ritchie and R.E. Uschold, J.Am.Chem.Soc., 86, 4488 (1964); ibid. 89, 1730, 2960 (1967).
9) B.O. Coniglio, D.E. Giles, W.R. McDonald and A.J. Parker, J.Chem.Soc., (B), 152 (1966).