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THE NUCLEOPHILICITY OF 2,2,2-TRIFLUOROETHANOL

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The past two years have witnessed a great deal of interest in the unusual solvent 2,2,2-trifluoroethanol (TFE). Trahanovsky and Doyle[2] have found that 5-hexenyl p-nitrobenzenesulfonates undergo trifluoroethanolysis to give high yields of cyclization products, behavior reminiscent of the traditional ''limiting'' solvents such as formic acid. Shiner[3] has used precise kinetic isotope measurements to provide further evidence of the limiting nature of TFE in certain solvolysis reactions. Very recently, Streitwieser and Dafforn[4] studied the competition between 1,2-hydrogen migration and solvent displacement occurring in the trifluoroacetolysis, trifluoroethanolysis and acetolysis of n-propyl trifluoromethanesulfonate and were thus able to place the nucleophilicity of TFE between that of acetic acid and trifluoroacetic acid (TFA). Comparison of isotope effects for isopropyl tosylate (and β-d_6) in TFA and isopropyl brosylate (and β-d_6) in 97% aqueous TFE lent support to the comparison with TFA.

Some time ago, Dewar[5] employed a combination of theoretical calculations and kinetic measurements to evaluate nucleophilicity in solvolysis and other displacement reactions. A simple perturbational molecular orbital method was used to calculate π-energy differences between a series of alternant arylmethyl chlorides and the corresponding arylmethyl cations; correlations of those values with the logarithms of the corresponding solvolytic rate constants yielded straight lines whose slopes were shown to be directly related to solvent nucleophilicity. Streitwieser[6] has shown that better correlations can be obtained using linear free energy relationships between solvolysis rates of a series of arylmethyl systems (halides, tosylates, etc.) in various solvents and the solvolysis rates of arylmethyl chlorides in 80% EtOH at 50° C. The slopes may be interpreted as a measure of positive charge development in the transition states and hence a measure of solvent nucleophilicity. Dewar and Bentley[7] further demonstrated the utility of these "Streitwieser plots" in evaluating leaving group interactions in a given solvent. In the present study a linear free energy plot of trifluoroethanolysis rate data in the arylmethyl chloride system is presented as a quantitative evaluation of the nucleophilic characteristics of TFE.

The arylmethyl chlorides were prepared as previously described[5]; physical properties agreed with reported values. Trifluoroethanol (Halocarbon Products Co., Hackensack, N.J.) was distilled from P_2O_5, and conductivity water was added to prepare 97 wt. % TFE for consistency with Shiner[3] studies. Rates were measured by titration of the generated HCl using triethylamine in toluene with lacmoid indicator[5,6]. In the phenanthryl systems, rates were measured conductometrically using a YSI Model 31 A.C. bridge at 1 KHz. Agreement between the two methods was shown to be close in experiments with 1-naphthylmethyl chloride. Rate constants were calculated using L.S.G., a least squares program written by DeTar[8].

A summary of kinetic results are tabulated below.

TABLE 1. Rates of Trifluoroethanolysis of Arylmethyl Chlorides at 50.0° C.

Aryl.	k (sec^{-1})	k relative
Phenyl	$8.53 \pm 0.02 \times 10^{-7}$	1
2-Naphthyl	$2.4 \pm 0.1 \times 10^{-5}$	28
3-Phenanthryl	$2.23 \pm 0.05 \times 10^{-4}$	261
1-Naphthyl	$2.68 \pm 0.02 \times 10^{-4}$	314
9-Phenanthryl	$4.96 \pm 0.02 \times 10^{-4}$	581

The very large spread (581) when compared with corresponding spread of about 4.2 in the quite nucleophilic solvent 80% EtOH[5], clearly indicates the highly limiting character of these reactions in TFE.

In Figure 1 is shown a linear free energy plot of our data in TFE *vs.* that of Dewar[5] in formic acid.

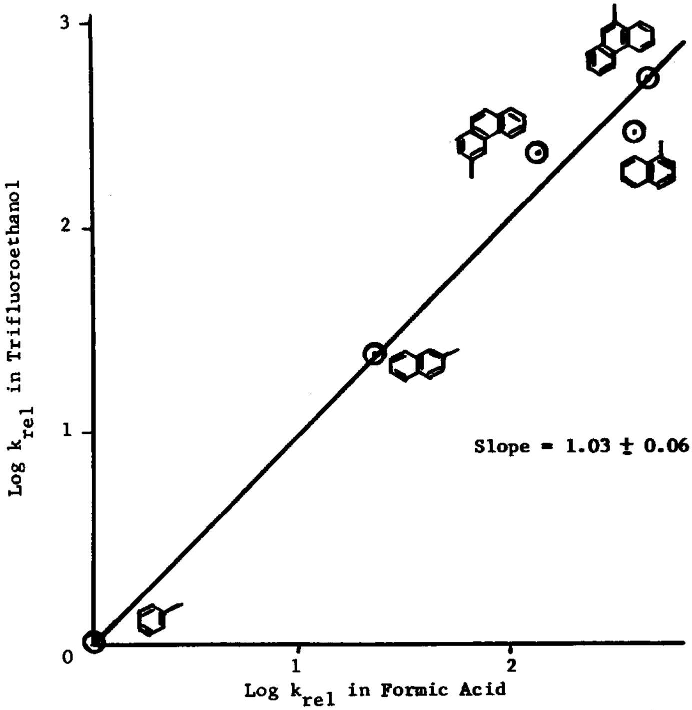

FIGURE I. Linear Free Energy Relationship for Solvolysis of Arylmethyl Chlorides in Formic Acid vs. Trifluoroethanol.

Within the standard deviation of the slope, formolysis and trifluoroethanolysis thus correspond to equivalent transition state charge development and hence involve very similar solvent nucleophilic assistance. The slope in Figure I corresponds to a "ρ" of 4.5 on a conventional Streitwieser plot (Compare to e.g. "ρ" = 0.9 for reaction of $ArCH_2Cl$ with I^- in acetone and 3.5 for acetolysis of arylmethyl tosylates[6].).

In addition to assigning TFE a position on the nucleophilicity scale, the present work also substantiates Shiner's[3] conclusions regarding the limiting nature of the trifluoroethanolysis of p-methylbenzyl chloride and thus provides support soundly based on molecular orbital theory for the application of α-isotope effects as a tool in evaluation of transition state charge characteristics in solvolysis reactions.

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