Tetrahedron Letters No. 35, pp 3063 - 3066, 1976. Pergamon Press. Printed in Great Britain.

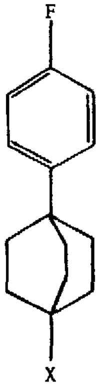
CONCERNING THE TRANSMISSION OF SUBSTITUENT EFFECTS IN UNCONJUGATED VERSUS CONJUGATED STRUCTURES BY ^{19}F NMR

W. Adcock* and T.C. Khor

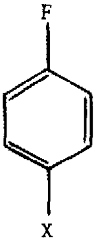
(School of Physical Sciences, The Flinders University of South Australia, Bedford Park, S.A. 5042, Australia)

(Received in UK 2 July 1976; accepted for publication 8 July 1976)

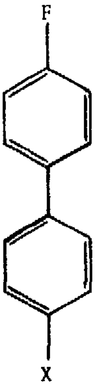
We present herein preliminary ^{19}F nmr data for a new model system (I; 1-substituted-4-p-fluorophenylbicyclo(2.2.2)octanes) which offer a definitive experimental estimate of the effects of remote polar groups on the ^{19}F chemical shifts of aryl fluorides in the absence of localized π electron interactions (π inductive and mesomeric effects). In this regard, the model is superior to the previously studied saturated bicyclic fluorides[1] for three main reasons: (i) substituent-induced structural changes are avoided[1]; (ii) the large number of bonds intervening between the fluorine probe and the substituent ensures that σ induction is inoperative[2]; and (iii) no critical and tenuous assumptions regarding the relative sensitivity of sp^2 - and sp^3 - bound fluorine nuclei to electronic influences[3] need be made when the data is compared with that from fully conjugated aryl fluorides.



I



II



III

An examination of the data listed in Table 1 leads to the following conclusions. Firstly, it is obvious that the ^{19}F SCS[4] are significantly dependent on substituent polarity (σ_I effect) which clearly must have a field origin. This point is formalised by the fact that the data are well fitted by the dual substituent parameter (DSP)[5,6] eq. 1 (benzene; n = 7; SD/RMS = 9.8%) and eq. 2 (DMF; n = 7; SD/RMS = 9.1%)

$$\text{SCS} = -1.82\ \sigma_I - 0.066\ \sigma_R^{o} \qquad (1)$$

$$\text{SCS} = -1.48\ \sigma_I - 0.024\ \sigma_R^{o} \qquad (2)$$

Note that ρ_R is virtually zero as demanded by the structural constraints of the model system (I). Hence this analysis offers further confirmation of the DSP equation to quantitatively separate polar and resonance effects[7]. The smaller ρ_I value in DMF relative to that in benzene confirms the origin of the σ_I effect, the electrostatic-field effect being attenuated as a result of a greater effective dielectric constant in the polar solvent (DMF) due to solvent intrusion into the transmissive cavity[8,9,10]

TABLE 1: ^{19}F SCS of 1-Substituted-4-p-Fluorophenylbicyclo(2.2.2)octanes (I).

Substituent[a]	SCS,ppm[b,c]	
	Benzene	DMF
F	-0.78	-0.66
Cl	-0.84	-0.70
Br	-0.85	-0.71
I	-0.81	-0.66
OH	-0.45	-0.24
$OCOCH_3$	-0.61	-0.55
OCH_3	-0.45	-0.38
NH_2	-0.30	-0.14
$NH.COCH_3$		-0.28
NH_3^+		-2.17[d]
CN	-0.98	-0.77

a. All compounds gave satisfactory analyses and their proton nmr spectra were in accordance with the assigned structures. b. The fluorine nmr spectra were measured with a Varian DP60 operating at 56.4 MHz using solutions containing 10% (W/W) of the fluorocompound, together with 5% (W/W) of 1, 1, 2, 2 - tetrachloro - 3, 3, 4, 4 - tetrafluorocyclobutane (TCTFB). c. Relative to p-fluorophenylbicyclo(2.2.2)octane (I; X=H). A negative sign implies deshielding. d. Solvent, (CF_3CO_2H).

If the usual assumption is made that the effective dielectric constant is much the same for different molecules[11], then based purely on a distance dependency law[12], various estimates for the electrostatic-field contribution to the ^{19}F SCS of para-substituted-fluorobenzenes (II) can be made. These values for several distance dependency functions that have been proposed, together with the polar effect contribution dissected by a DSP analysis[9] (benzene as solvent), are listed in Table 2. Although the calculated values based on an inverse third power law appear to be physically unrealistic, we believe the values for r^{-1} represent minimum contributions by the field effect to ^{19}F nmr polar substituent effects in system II.

Secondly, since the geometric relationship between the fluorine atom and the substituent for the model system (I) is similar to the relationship between these groups in 4'-substituted-4-fluorobiphenyls (III)[2], a comparison of the SCS between the two systems provides an assessment of the relative efficiency of conjugated and unconjugated structures for the propagation of polar effects important in determining aryl ^{19}F chemical shifts. The appropriate parameters from a DSP analysis of system (III) reported by Dayal and Taft[9] are $\rho_I = -3.35$ (benzene) and $\rho_I = -3.17$ (DMF). Thus the fully conjugated system is approximately twice as effective as the unconjugated analogue for transmitting the σ_I effect. Although this could be construed as definite evidence for an important contribution by the π inductive effect[13,14] to the ^{19}F nmr polar subsituent effect in system III, the fact that the π inductive effect is considered to vary with distance in approximately the same way as the mesomeric effect[15], together with the calculated field

TABLE 2: Calculated Polar Effect Contributions (ppm) to ^{19}F SCS of System 11.

Substituent	Distance Function[a]			DSP
	r^{-1}	r^{-2}	r^{-3}	$\rho_I \sigma_I$
F	-1.56	-3.12	-6.24	-4.09
Cl	-1.68	-3.36	-6.72	-3.76
Br	-1.70	-3.40	-6.80	-3.59
I	-1.62	-3.34	-6.68	-3.19
OCH_3	-0.90	-1.80	-3.60	-2.21
CN	-1.96	-3.92	-7.84	-4.58
NH_2	-0.60	-1.20	-2.40	-0.98
NH_3^+	-4.34[b]	-8.68[b]	-17.36[b]	-10.10[c,d]

a. The distance is taken between the mid-points of the CX(CC bond length) and CF bonds in I and II. b. Solvent, CF_3CO_2H. c. $\sigma_I(NH_3^+; CF_3CO_2H) = 1.08$ (calculated with ^{19}F SCS data from 6- and 7-substituted-2-fluoronaphalenes and the respective DSP correlation equations in DMF for these two dispositions[19b]). d. Calculated utilizing $\rho_I = -9.35$ (DMF; ref. 9).

effects for system II listed in Table 2, militates against such an interpretation as being the complete answer[16]. We raise the idea that much of the enhanced efficiency of III over I in propagating polar effects is probably a manifestation of the polarisation term of the field model i.e. variations in the effective dielectric constant for the two systems due to differing characteristics of the two molecular cavities[17,18,19c].

In summary, the main conclusion from this study is that data from a new model system unambiguously contradicts the majority viewpoint[1,20] that the field effect is relatively unimportant in determining the magnitude of aryl ^{19}F SCS. Thus, previous conclusions based on studies of other model systems[8,19] are placed on secure ground. Full details will appear in the main paper.

REFERENCES AND NOTES

1. G.L. Anderson and L.M. Stock, J.Am.Chem.Soc., 90, 212 (1968); 91, 6804 (1969) and references cited therein.
2. M.J.S. Dewar and A.P. Marchand, J.Am.Chem.Soc., 88, 3318 (1966) and references cited therein.
3. The ^{19}F SCS of aryl fluorides has been attributed to polarisation of the CF π bond: M.J.S. Dewar and T.G. Squires, J.Am.Chem.Soc., 90, 210 (1968); M.J.S. Dewar and J. Keleman, J.Chem.Phys., 49, 499 (1968).
4. ^{19}F substituent chemical shifts (SCS) are defined as the difference between the chemical shift of the unsubstituted fluoroaromatic and the substituted fluoroaromatic compound. A negative sign implies deshielding.
5. P.R. Wells, S. Ehrenson, and R.W. Taft, Progr.Phys.Org.Chem., 6, 147 (1968).
6. S. Ehrenson, R.T.C. Brownlee, and R.W. Taft, Progr.Phys.Org.Chem., 10, 1 (1973).
7. R.W. Taft and C.A. Grob, J.Am.Chem.Soc., 96, 1236 (1974) and references cited therein.
8. W. Adcock, M.J.S. Dewar, and B.D. Gupta, J.Am.Chem.Soc., 95, 7353 (1973) and references cited therein.
9. S.K. Dayal and R.W. Taft, J.Am.Chem.Soc., 95, 5595 (1973) and references cited therein.

10. This conclusion is strongly supported by the fact that a plot of the shifts in benzene against the shifts in DMF is linear (r = 0.99) provided OH and NH_2, which are well known to exhibit strong specific substituent-solvent interactions, are deleted from the correlation.

11. L.M. Stock, J.Chem.Educ., 49, 400 (1972) and references cited therein.

12. A major difficulty in quantitatively estimating the electric-field effect lies in the distance and effective dielectric constant terms: (a) r^{-1} (monopole) and r^{-2} (dipole) have been employed successfully for quantitatively estimating the effects of field phenomena on the ionisation of carboxylic acids (see ref. 11); (b) r^{-2} (see ref. 2) and r^{-3} (see ref. 12c) have been indicated for electric field nmr shifts; (c) J.G. Batchelor, J.H. Prestegard, R.J. Cushley, and S.R. Lipsky, J.Am.Chem.Soc., 95, 6358 (1973).

13. (a) M.J.S. Dewar and A.P. Marchand, J.Am.Chem.Soc., 88, 354 (1966) and references cited therein. (b) M.J.S. Dewar and Y. Takeuchi, J.Am.Chem.Soc., 89, 390 (1967) and references cited therein.

14. A.R. Katritzky and R.D. Topsom, J.Chem.Educ., 48, 427 (1971).

15. M.J.S. Dewar, "The Molecular Orbital Theory of Organic Chemistry", McGraw-Hill, New York, N.Y. 1969.

16. A reliable mesomeric transmission factor (7.06; benzene as solvent) for system II relative to III can be readily determined from the ρ_R values of the respective DSP equations (see ref. 9). Hence, if the difference between the SCS for I and the polar effect contribution ($\rho_I\sigma_I$) for III is attributed solely to the π inductive effect, then the predicted values for the polar effect in II are far too large. For example, on this basis the total calculated polar effect of CN in II [field effect (r^{-1} value; -1.96 ppm; Table 2) plus π inductive contribution (-6.35 ppm)] would be -8.31 ppm compared to the DSP value (ρ_I σ_I; Table 2) of -4.58 ppm!

17. It is important to note that this suggestion is not supported by the currently accepted model for quantitatively estimating the field effect of charged or dipolar substituents since no significant role is assigned to the nature of the intervening cavity[11] in this general theory. The accepted view, based largely on chemical reactivity studies of model systems[11], is that molecules in general are not very polarisable, so the average dielectric constants inside them are small (2-3) and are, moreover, much the same for different molecules. In contrast, CNDO/2 calculations[18] indicate an enhancement of the field effect of substituents when transmitted through a molecular framework as opposed to through a vacuum i.e. the effective dielectric constant is less than one. This result was shown to be in accord with calculations from a dielectric sphere model.[18]

18. R.B. Hermann, J.Am.Chem.Soc., 91, 3152 (1969) and references therein.

19. (a) W. Adcock and M.J.S. Dewar, J.Am.Chem.Soc., 89, 379 (1967); (b) W. Adcock, J. Alste, S.Q.A. Rizvi, and M. Aurangzeb, ibid., 98, 1701 (1976); (c) W. Adcock and B.D. Gupta, ibid, 97, 6871 (1975) and references cited therein.

20. (a) G.L. Anderson, R.C. Parish, and L.M. Stock, J.Am.Chem.Soc., 93, 6984 (1971).
(b) J. Fukunaga and R.W. Taft, J.Am.Chem.Soc., 97, 1612 (1975) and references cited therein.
(c) I.R. Ager, L. Phillips, T.J. Tewson, and V. Wray, J.C.S. Perkin Trans., 11, 1979 (1972).
(d) P.J. Mitchell and L. Phillips, J.C.S. Perkin Trans., 11, 109 (1974).