

Use of an Internal Reference in ^{13}C Chemical Shift Measurements

D. G. de Kowalewski¹

*Depto. de Física, Facultad de Ciencias Exactas y Naturales
Buenos Aires, 1428, Argentina*

C. de los Santos and E. Marceca

*Laboratorio de Fitoquímica, Facultad de Farmacia y Bioquímica
Buenos Aires, Argentina*

I. Introduction

Several inconsistencies have been noted during recent systematic studies of the validity of additivity relationships (1-6) in the ^{13}C chemical shifts of substituted pyridines. These showed that substantial errors could be introduced if care is not taken to use, for a given solvent, approximately the same concentration for all solutes; in our case this applied to monosubstituted and polysubstituted pyridines and benzenes.

Whereas for ^1H NMR spectra it is customary to "lock" the field using the signal of tetramethylsilane (TMS) for ^{13}C NMR spectra, on instruments such as the Varian FT-80, it is often customary to lock on to the signal of deuterium situated in a capillary concentric with the sample. The chemical shift of the solvent taken from tables or from previous measurements is then fed into the spectrometer program and the computer refers all data to the TMS scale (7-9).

Although this procedure eliminates the uncertainty due to the usually unknown magnetic susceptibility of the solution, it does not take into account the fact that with ternary solutions there is a significant solvent effect of the solutes on the solvent and even on the reference compound. This makes the use of this technique unsuitable.

On the other hand, the use of TMS as an internal standard for ^{13}C NMR has been found to be unsuitable for other reasons. Its very low boil-

ing point (26.5°C) and our high, local average room temperature make it almost impossible to measure its concentration correctly. To solve this problem we have used hexamethyldisiloxane (HM) as an internal standard (b.p. 101°C) at a concentration of 2% w/w.

The problem was then to make the data obtained with this standard comparable with those obtained with TMS. If no aromatic or complexing solvents are used, the main effects of the solvent are from the van der Waals forces. The effect of each solvent or solution can then be characterized by a factor g^2 (9,10) which is a simple function of the refractive index, n , of the solution. Using this property, a method has been devised to convert the measurements made with HM to those made with TMS.

II. Results

To estimate the effect of the van der Waals forces a plot (Fig. 1) of the ^{13}C chemical shifts of HM in different solvents measured against an external cyclohexane standard was made against the g^2 factor of the solution, where $g^2 = [(n^2-1)/(2n^2 + 1)^2]$ (9,10). A linear regression analysis of these data gives the equation

$$\delta_{\text{HM/CY}_{\text{ext}}} = [(0.64 \pm 0.06)g^2 \times 10^2] - (-27.8 \pm 0.2) \quad (1)$$

¹Research member of the Argentine National Research Council (CONICET)

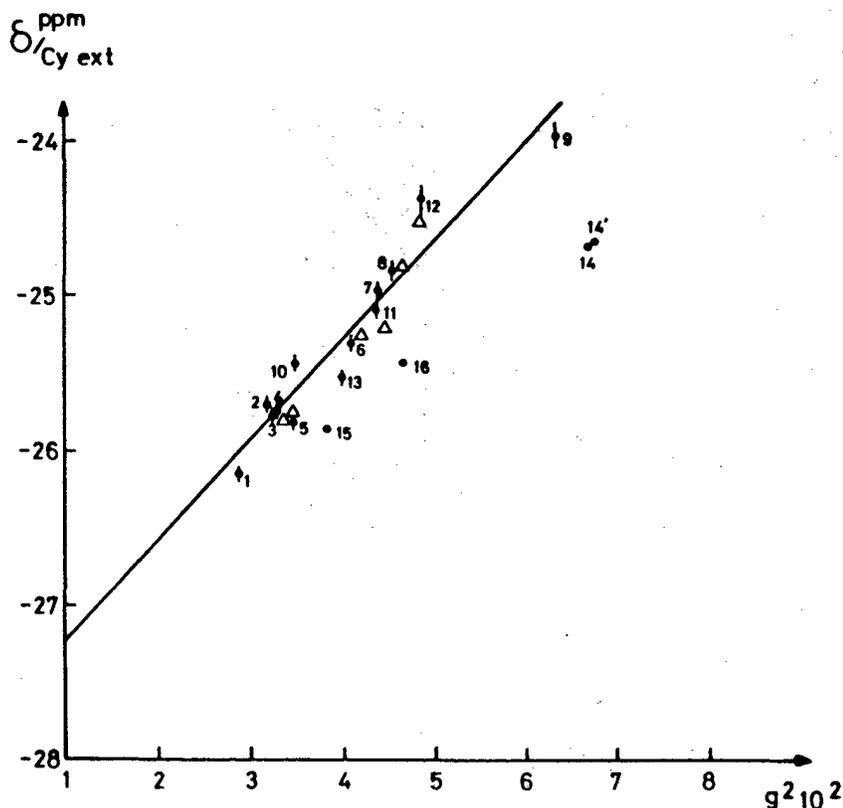


Figure 1.

with a standard deviation $\sigma = 0.18$ and a correlation coefficient $r = 0.95$.

Data for carbon disulphide, decalin and tetrahydrofuran were not included in this analysis, since they diverged too much from the straight line.

Since we are interested to know whether the above relationship holds for substituted pyridines, the refractive indices of which are usually now known, a series of similar measurements were made for several solutions of 3-methylpyridine, the refractive index of which is known ($n=1.50$) at a concentration of 10% w/w, but in a smaller number of solvents owing to solubility problems. These results are shown in Fig. 1 (Δ). It is evident that all these data fall within the error limits of the straight line given by Eqn. 1.

The few data available on the refractive index of pyridines show a spread between 1.49 and 1.56, which implies a very small variation of g^2 . The g^2 range for cyclohexane is from 4.211 to 4.435 and that from DMS is from 4.884 to 4.987. These values correspond, according to Eqn. 3 to HM chemical shift values of 2.05-2.03; 1.96-1.95 respectively, which agree fairly well with the experimental values of 1.99-0.04 and 1.94 ± 0.03 , measured for several solutions of pyridines in cyclohexane and DMS, re-

spectively. Incidentally, in some of these solutions it was possible to dissolve and detect the signals of both HM and TMS.

From Eqn. 1 and a similar expression from TMS (11):

$$\delta_{TMS/CY_{ext}} = [(0.78 \pm 0.04)g^2 \times 10^2] + (-30.4 \pm 0.2) \quad (2)$$

we can obtain the difference:

$$(\delta_{HM_i} - \delta_{TMS_i})_{ext} = [(-0.13 \pm 0.08)g^2 \times 10^2] + (2.6 \pm 0.3) \quad (3)$$

The lines representing Eqns. 1 and 2 are shown in Fig. 2, i.e. δ_{HM}/CY_{ext} and δ_{TMS}/CY_{ext} as a function of g^2 . If we assume that point A corresponds to a δ_{C_i} pyridine with a given g^2 factor, then the distance AB represents the measured chemical shift with respect to internal HM, δ_{C_i}/HM_i and BC is the difference between the two standards for that particular value of g^2 .

On the basis of our previous results with pyridines in solution with HM, we can now confidently assume that Eqn. 2 is also valid for substituted pyridine solutions with TMS, at least within the standard error of both curves. Then, given the

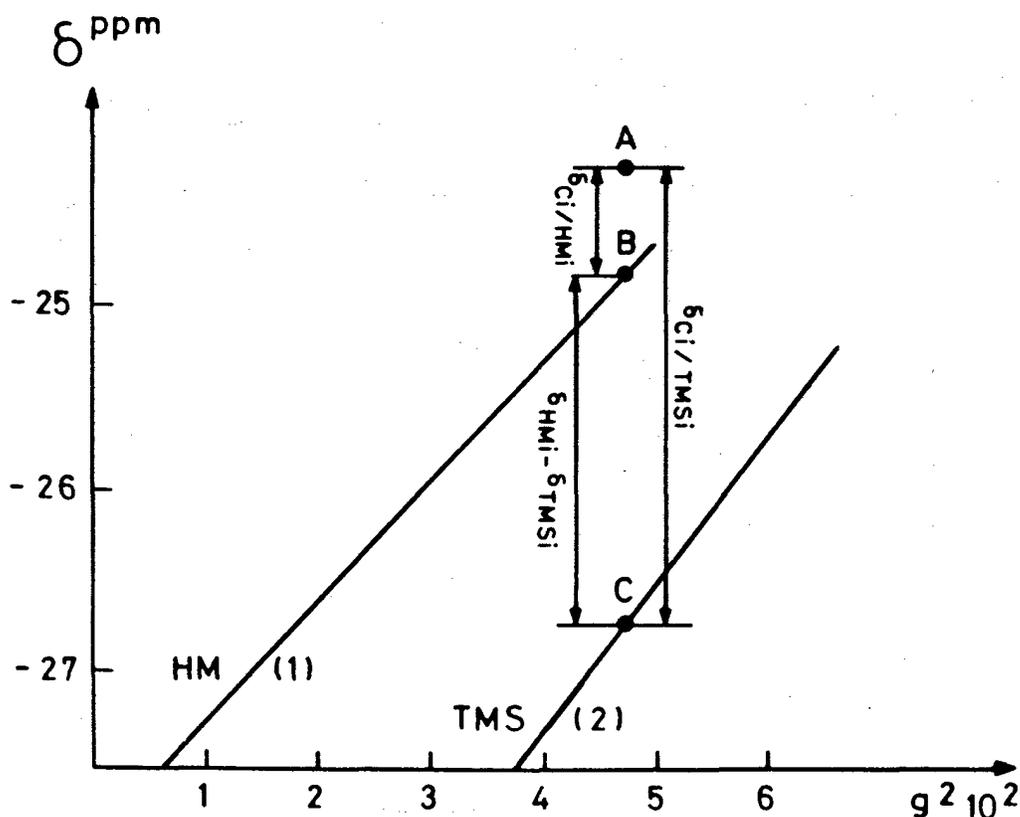


Fig. 2.

g^2 factor of a solution and using Fig. 2, we can convert our chemical shift data measured with respect to HM, to data with respect to TMS using the expression

$$\delta_{Ci/TMS_i} = \delta_{Ci/HM_i} + (\delta_{HM_i} - \delta_{TMS_i})_{ext}$$

III. References

¹B. Mechin, J.C. Richer and S. Odier, *Org. Magn. Reson.* **14**, 79 (1980).

²D.K. Dalling, K.H. Ladner, D.M. Grant and W.R. Woolfenden, *J. Am. Chem. Soc.* **99**, 142 (1977).

³O. Sudmeijer, A.E. Wilson, and G.R. Hays, *Org. Magn. Reson.* **22**, 459 (1984).

⁴J. Guilleme, E. Diez, L. Garrigos and A.L. Esteban, *Org. Magn. Reson.* **22**, 140 (1984).

⁵C.H. O'Connor, D.C. McLennon, D.J. Calvert, T.D. Lomax, A.J. Porter and D.A. Rodgers, *Aust. J. Chem.* **37**, 497 (1984).

⁶J. Bromilow, R.J.C. Browvelee, D.J. Craik, and M. Sadek, *Magn. Reson. Chem.* **24**, 864 (1986).

⁷A.E. Sopchik and C.A. Kingsbury, *J. Chem. Soc. Perkin II* **1058** (1978).

⁸K. Jackowski, *Org. Magn. Reson.* **22**, 263 (1983).

⁹F.H.A. Rummens, *Chem. Phys. Lett.* **31**, 596 (1975).

¹⁰B. Tiffon and J.P. Doucet, *Can. J. Chem.* **54**, 2045 (1976).

¹¹M.C. Moreau-Descoigns, G. Goethals, J.P. Seguin and J.P. Doucet, *Spectrochimica Acta* **43A**, 17 (1987).