

CYCLODEXTRINS AS NMR SHIFT REAGENTS FOR HYDROCARBONS

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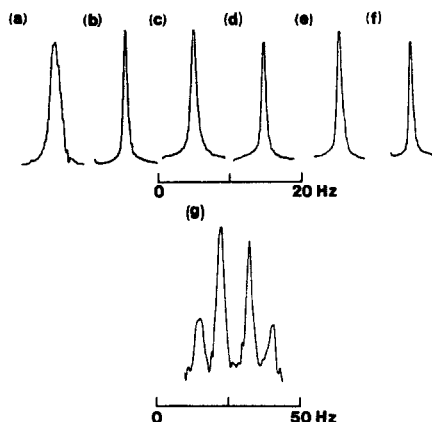
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Hydrocarbons, unlike many other classes of compound, are not in general amenable to the use of lanthanide shift reagents¹ or of aromatic solvents² to bring about changes in NMR spectra useful in structure determination.³ Seeking a method for producing shifts not requiring functionality we have measured the spectra of several hydrocarbons which may be accommodated in the voids of the α - and β -cyclodextrins⁴ (α - and β -CD), which are torus shaped molecules composed of respectively six and seven α -(1 \rightarrow 4) linked D-glucopyranose residues.

The study of the 100MHz ¹H n.m.r. spectrum of *p*-cymene, *p*-isopropyl-toluene, serves to illustrate the useful shifts which may be produced. The aromatic protons of this compound were found to give rise to only a single band in a wide range of solvents, see, for example, the upper portion of the Figure [(a)-(f)]. However, after heating the hydrocarbon with an excess⁵ of α -CD to allow complex formation to occur, one observes a marked splitting of the aromatic spectrum, as can be seen from spectrum (g) measured at 50°C. The chemical shift separation shows a marked temperature dependence, and is significantly greater at ambient temperature. This behaviour may reflect an increasing tendency for the guest to adopt a preferred orientation⁶ in a sterically restricted situation and/or reduced thermal motion within the cavity as the temperature is lowered. Accommodated in the relatively wide⁷ voids of β -CD, the aromatic protons of *p*-cymene show only a singlet.

Adamantane provides a further interesting case since this saturated, and approximately spherical hydrocarbon gives with α -CD in D₂O (measured at 80°C), a well resolved spectrum at 100 MHz: methine (4H), W_{1/2} ca 10 Hz; methylene (12H), triplet structure apparent: relative shift 0.19 p.p.m. In all other solvents tried, including CDCl₃, benzene, dioxane, and methanol, only a poorly resolved spectrum was observed. Although examination of space filling molecular models reveals that owing to the large diameter of this guest, inclusion in the cavity of a single α -CD host molecule cannot be nearly so complete as is possible for *p*-cymene, nevertheless a useful shift was still produced.



The 100 MHz ^1H n.m.r. spectra of the aromatic protons of p-cymene:

- (a) as neat liquid; (b) in CDCl_3 ; (c) in $\text{CDCl}_3/\text{Eu}(\text{fod})_3$;
 (d) in hexamethylphosphoramide; (e) in tetramethyl urea;
 (f) in MeOH; (g) in presence of α -CD in D_2O at 50°C .

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References.

1. For a recent review see: D.H. Williams, Pure and Applied Chemistry, 1974, **40**, 25.
2. P. Laszlo, Progr. N.M.R. Spectroscopy, 1967, **3**, 231; J. Ronayne and D.H. Williams, Ann. Rev. NMR Spectroscopy, 1969, **2**, 83.
3. For shift reagents for alkenes see: D.F. Evans, J.N. Tucker, and G.C. de Villardi, J.C.S. Chem. Comm., 1975, 205; see also, I. Morishima, K. Ishihara, K. Tomishima, T. Inubushi, and T. Yonezawa, J. Amer. Chem. Soc., 1975, **97**, 2749.
4. D. French, M.L. Levine, J.H. Pazur, and E. Norberg, J. Amer. Chem. Soc., 1949, **71**, 353.
For changes in the proton spectrum of the host β -CD with aromatic substrates see: P.V. Demarco and A.L. Thakkar, Chem. Comm., 1970, 2.
5. A host/guest ratio of 1:1 was assumed. In the presence of excess liquid hydrocarbon, an additional (unsplit) aromatic resonance displaced ca 0.7 p.p.m. (at 28°C) to high field is observed.
6. Cf. K. Harata and H. Uedaira, Nature, 1975, **253**, 191.
7. See, for example, D.W. Griffiths and M.L. Bender, Adv. in Catalysis, 1973, **23**, 209.