Chemical Suppression of Long Range ^{13}C-^{1}H Coupling in ^{13}C N.m.r. Spectra

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Summary Carbon-13 n.m.r. spectra of large, rigid molecules recorded in 0·1M solution of Fe(acac)$_3$ exhibit pronounced line-broadening. The resonances of the quaternary carbon atoms can be specifically defined due to chemical elimination of long range couplings.

RECENTLY Sadler[1] proposed a method for the selective enhancement of ^{13}C n.m.r. signals from quaternary carbon atoms relative to the signals of hydrogen-bearing carbons, in which decreased power for broad band proton decoupling is utilized. We now wish to report that a similar effect can be obtained by employing a paramagnetic relaxation reagent.

The addition of a shiftless paramagnetic relaxation reagent such as Cr(acac)$_3$ or Fe(acac)$_3$[2] is a well-known procedure in quantitative ^{13}C n.m.r. studies.[3] These reagents are usually added at concentrations up to 0·1M which is sufficient to shorten the appropriate relaxation times with minimum line-broadening. During an extensive study of the antibiotic hedamycin ($C_{41}H_{50}O_{11}N_2$)[4] it was discovered that the addition of relaxation reagent eliminates long range couplings of quaternary carbon atoms in non proton decoupled ^{13}C n.m.r. spectra. A spectrum recorded in this way shows the quaternary carbon atoms as the sharpest lines; all other resonances are sufficiently broadened to be indistinguishable from the background. It should be emphasized that, although similar spectra are obtained upon low power noise irradiation and chemical decoupling, the physico-chemical processes involved in the two cases are different. In the 'low power' technique weak irradiation causes further splitting of the signals[5] so that each of the partial lines obtained has less intensity than the parent signal and is therefore not easily detected against the background.

Addition of a paramagnetic relaxation reagent, however, produces the same effect as chemical exchange - line broadening and, if the exchange rate is fast enough, coalescence to a singlet.[6] In both techniques small coupling constants are more easily eliminated than large ones. Chemical spin decoupling using paramagnetic reagents has been reported previously. Phosphorus was decoupled from protons in phosphate, phosphite and phosphonate complexes of Co^{2+} and Ni^{2+};[7] the boron–hydrogen coupling in boranes was eliminated using Fe^{3+}, Cr^{3+} or Mn^{2+}.[8] Recently specific proton decoupling was achieved by Faller and LaMar with Gd(fod)$_3$.[6]

Using cholesterol and quinine as model compounds, a series of spectra were run under various conditions using Fe(acac)$_3$ as the relaxation reagent. Best results were obtained with 0·5—1M solutions of the model substrates which were 0·1M in Fe(acac)$_3$. When the concentration of the relaxation reagent was 0·05M the effect was not so pronounced, and at 0·01M no effect at all could be detected. The substances tested included hedamycin, cholesterol, quinine, brucine and DL-α-tocopheryl acetate all of which gave satisfactory results. We illustrate the technique

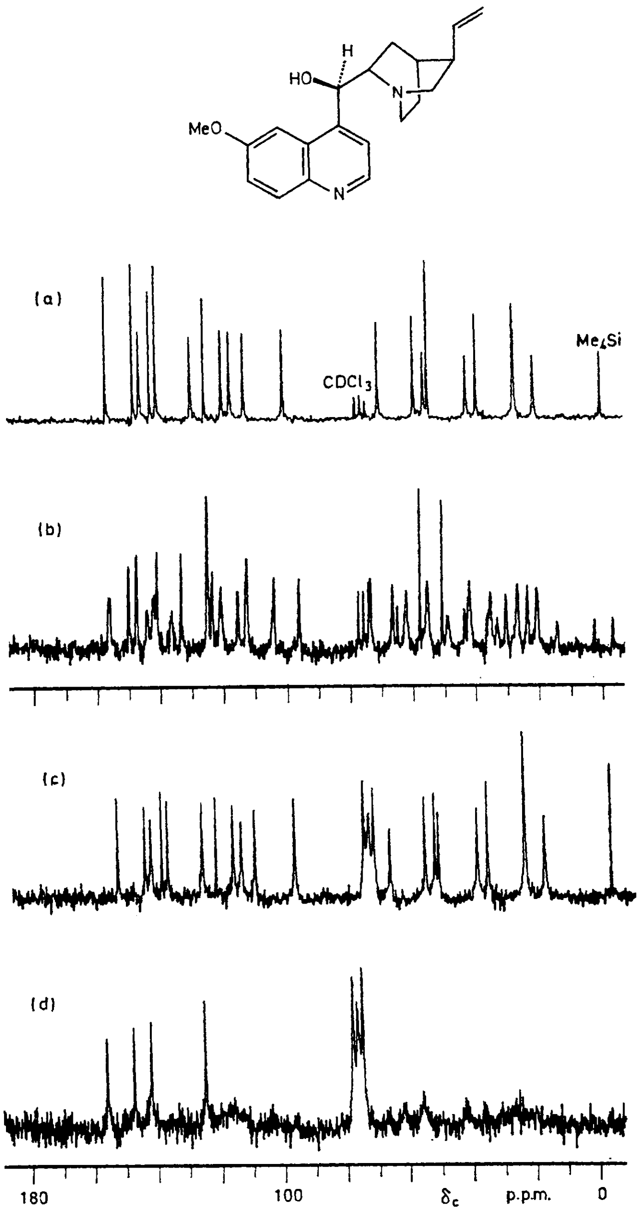

FIGURE. ^{13}C n.m.r. spectra of quinine, 1·0M in CDCl$_3$ containing about 5% Me$_4$Si as internal standard. Recorded on a Varian CFT-20 (20 MHz) at ambient temperature; 8 mm sample tubes; deuterium field/frequency lock; 4k data points in the time domain; flip angle 45° (9 μs); pulse repetition rate 1·512 s; 2000 pulses were accumulated; proton decoupler bandwidth 2 kHz centred at δ = 4·9 p.p.m.; time constant of the weighting function 0·5 s. (a) proton noise decoupled spectrum; (b) fully proton coupled spectrum, decoupler was switched on during pulse delay to get NOE; (c) proton noise decoupled spectrum in the presence of Fe(acac)$_3$, 0·1M; (d) fully proton coupled spectrum in the presence of Fe(acac)$_3$, 0·1 M, decoupler was turned off during acquisition time and pulse delay.

using quinine as an example in the Figure. Only the signals from the quaternary carbons can be discerned[9] in spectrum (d).

In the spectrum of the acyclic molecule squalene, only the methyl signals were effectively broadened.† Here the limits of the method become obvious. In the examples tested so far, large, unsymmetrical and rather rigid molecules appear to give the most satisfactory results. However, it is in the case of complex molecules that a firm identification of the resonances arising from quaternary carbon atoms is of great importance in making assignments; in smaller or more symmetrical molecules (*e.g.* squalene) an off resonance decoupled or fully proton coupled spectrum is usually sufficient to make unambiguous assignment.

We thank Professor J. W. Faller for helpful discussions. One of us (U.S.) acknowledges the receipt of a Reichstein Postdoctoral Fellowship 1973—1974.

(*Received*, 12*th September* 1974; *Com.* 1157.)

† Application of Sadler's method to squalene resulted in a spectrum in which strong methylene resonances were observed.

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