^{14}N Chemical Shifts in some Hydroxyquinolines

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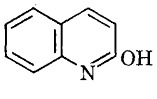
THE nuclear magnetic resonance signal strength from ^{14}N nuclei is lower by a factor of $1{\cdot}01 \times 10^{-3}$ than that from the same number of protons in the same magnetic field. For this reason, relatively little work has been done on the measurement of ^{14}N chemical shifts and virtually no use has been made so far of ^{14}N n.m.r. data as an aid in organic structural problems. Most of the available ^{14}N chemical shift values have been collected together by Herbison-Evans and Richards.[1] These values were obtained using spectrometers operating directly at the ^{14}N resonant frequency. However, for those nitrogen nuclei coupled to protons, ^{14}N chemical shift values can be obtained indirectly in many cases by observing the proton spectrum of a compound, whilst the sample is irradiated simultaneously at the ^{14}N resonance frequency. In organic compounds, nitrogen quadrupole relaxation effects normally cause a broadened singlet peak to be found for the coupled proton rather than the expected multiplet and the ^{14}N chemical shift can be derived from the critical ^{14}N irradiating frequency that removes this broadening. This method largely overcomes the sensitivity problem, but it can fail when the ^{14}N nuclear quadrupole relaxation rate, or alternatively the proton-exchange rate if a labile proton is involved, is fast enough to effectively decouple the nitrogen nucleus and the proton concerned.

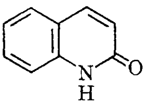
The double resonance method has been used to measure the ^{14}N chemical shifts in some 2- and 8-hydroxyquinolines. Full details of the apparatus and experimental procedure have been given already,[2] together with a more detailed discussion of the relative advantages and disadvantages of the direct and indirect methods of obtaining ^{14}N chemical shifts.

For 2-hydroxyquinolines, two tautomeric forms are possible, the hydroxy-form (I) and the oxo-form (II). For 8-hydroxyquinolines (III), no comparable oxo-form exists.

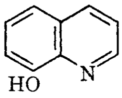
It should be possible to decide between the tautomers (I) and (II) using ^{14}N double-irradiation techniques, since only (II) will show a nitrogen–proton coupling. Also the ^{14}N chemical shift in (II) is expected to differ from that of normal quinolines due to the loss of aromatic character of the heterocyclic ring. In (III), a coupling between the nitrogen and the α-proton is expected and the ^{14}N chemical shift can be measured by eliminating the broadening of the α-proton resonance.



(I)



(II)



(III)

^{14}N Chemical shift values for some 2- and 8-hydroxy-quinolines are shown in the Table. The chemical shifts are quoted in p.p.m. relative to that of the nitrate nitrogen of 4·5M-ammonium nitrate in 3N-aqueous hydrochloric acid.[1] The values shown in parentheses are approximate ^{14}N chemical shifts obtained for three compounds where the proton signals are only very slightly broadened. The ^{14}N chemical shifts in normal aromatic heterocyclic compounds range from about 60—110 p.p.m., depending upon the substituents on the ring system,[1] and therefore values found for the 8-hydroxyquinolines of 90—95 p.p.m. are typical. For each of the 2-hydroxyquinolines, coupling was detected between the ^{14}N nucleus and a proton having a signal at low field. This indicates that the oxo-form (II) is present. The measured ^{14}N chemical shift values of ~235 p.p.m. show that the oxo-form (II) must exist almost exclusively and for comparison, the ^{14}N chemical shift of acetanilide is shown, since here the environment of the nitrogen nucleus will be very similar to that in (II).

Many methods have been used to investigate tautomerism in nitrogen heterocyclic compounds. These methods, which include basicity measurements, infrared and ultraviolet spectroscopy, *X*-ray crystallography, and dipole moment studies, have been reviewed in detail by Katritzky and Lagowski.[3] The general evidence now shows conclusively that for 2-hydroxyquinolines the oxo-form predominates, whereas the 8-hydroxyquinolines exist as such. However, few, if any, of the methods reviewed by Katritzky and Lagowski appear to provide such a clear-cut distinction of the tautomeric forms as that provided by the ^{14}N chemical shifts, which differ by about 140 p.p.m. Since tautomerism of the type discussed above for the hydroxyquinolines is one of the general features of organic nitrogen chemistry, ^{14}N n.m.r. spectroscopy appears to have great potential usefulness in such problems.

TABLE

^{14}N Chemical shifts in some hydroxyquinolines

Compound	Solvent	Chemical shift (p.p.m.)
Quinoline	ether	72 ± 2[a]
8-Hydroxyquinoline	acetone	95 ± 4
5-Chloro-8-hydroxyquinoline ..	acetone	93 ± 7
8-Hydroxy-7-methylquinoline ..	acetone	91 ± 4
8-Hydroxy-5-methylquinoline ..	acetone	90 ± 5
6-Chloro-8-hydroxyquinoline ..	acetone	(~90)
8-Hydroxy-6-nitroquinoline ..	acetone	(~90)
Acetanilide	$CDCl_3$	243·3 ∓ 2[b]
2-Hydroxyquinoline	$CDCl_3$	238 ± 3
2-Hydroxy-4-methylquinoline ..	$CDCl_3$	238 ± 4
2-Hydroxy-3-methoxyquinoline ..	acetone	229 ± 4
4-Chloro-2-hydroxyquinoline ..	$CDCl_3$	(~230)

(*a*) Ref. 1. (*b*) Ref. 2.

(*Received, February 27th,* 1967; *Com.* 183.)

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[1] D. Herbison-Evans and R. E. Richards, *Mol. Phys.*, 1964, 8, 19.

[2] P. Hampson and A. Mathias, *Mol. Phys.*, 1966, 11, 541.

[3] A. R. Katritzky and J. M. Lagowski, *Adv. Heterocyclic Chem.*, 1963, 1, 339–437.