Mailed: JAN 3 1 1961

M onthly
  E cumenical
    L etters from
      L aboratories
        O f
   N - M - R

          No. 28

December 23rd, 1960

Dr. A.A. Bothner-By,
Mellon Institute,
Pittsburgh, Pennsylvania.

Dear Dr. Bothner-By,

As you know I have been interested in the coupling constants of protons in substituted ethanes and in that connection I have examined some compounds containing rigid fused-ring systems. The results will be published in Can. J. Chem. and are briefly reported below.

The NMR spectra (60 Mc/sec) of the four camphane-2,3-diol (A, B, C and D) have been taken in pyridine solution containing

A

B

C

D
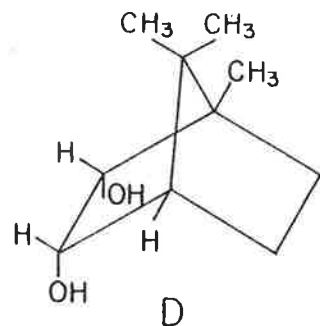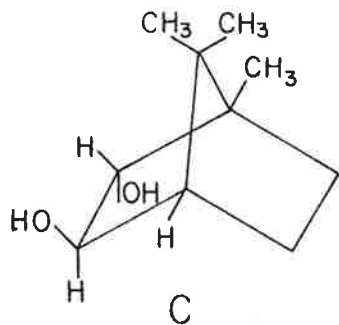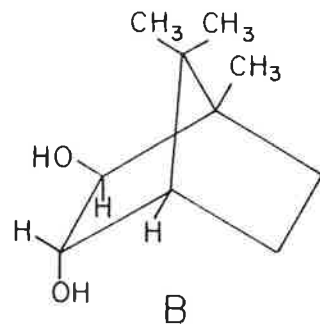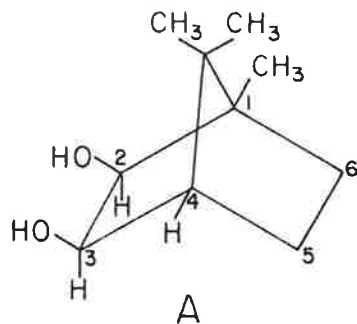
a small amount of deuterium oxide. From the spectra, coupling constants (J_{23} and J_{34}) were obtained for each isomer and are listed in Table I, together with the values expected from

TABLE I

OBSERVED AND CALCULATED COUPLING CONSTANTS

(In c.p.s.) FOR THE CAMPHANE-2,3-DIOLS

DIASTEREOISOMER	J_{23}		J_{34}		J_{26}	J_{35}
	Obs.	Calc.	Obs.	Calc.	Obs.	Obs.
2-exo,3-exo (A)	7.7	8.2	0	0	0	0
2-exo,3-endo (B)	2.3	2.1	ca 4.0	4.1	?	0
2-endo,3-exo (C)	2.2	2.1	0(?)	0	0	?
2-endo,3-endo (D)	8.9	8.2	4.4	4.1	1.4	1.0

Karplus' calculation (J. Chem. Phys. 30, 11 (1959)). The dihedral angles ($0°$, $44°$, $79°$, $120°$) were measured on Barton molecular models of [1,2,2]-bicycloheptane. The agreement for the compounds considered is very good.

It is also of interest that there appears to be appreciable coupling between exo-protons on C2 and C6 and also on C3 and C5. This is most clearly shown in the spectrum of the 2- and 3-protons of the 2-endo,3-endo-isomer (D) (Fig. 1). In contrast the spectrum

... 3

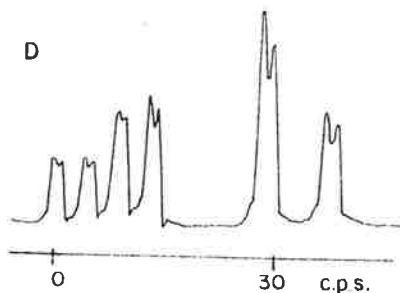of the 2-exo,3-exo-isomer (A) shows a simple AB quartet for these

Figure I.

protons.

Thanks are due to Dr. S.J. Angyal of the University of New South Wales, Australia, for providing samples of the diols.

Yours sincerely,

F.A.L. Anet.

FALA/cg

INSTITUTE OF CHEMISTRY
UNIVERSITY OF UPPSALA
UPPSALA
SWEDEN

SG/km

December 23, 1960

Dr. Aksel A. Bothner-By
Mellon Institute
4400 Fifth Av.
Pittsburgh 13. P.A.
USA

Dear Dr. Bothner-By:

In answer to your letter of November 30 we can report on some work done in connection with the NMR-spectra of thiophenes (c.f. the list of reprints available). In this study we have been primarily concerned with evolving convenient methods of extracting on inspection the parameter values of the NMR-spectra; with the influence of substituent effects on the chemical shifts of the ring hydrogens of thiophenes; with the ranges of variations of the ring coupling constants and with the mechanisms of the side-chain couplings.

As you may know (c.f. MELLON MR 13) we have been interested in the connection between long-range methyl group couplings and hyperconjugation. The π-electron couplings in methyl olefins and acetylens calculated by Karplus (MELLON MR 22) agree well with the coupling constants observed by us in some compounds of these series (Acta Chem. Scand 13, 1487 (1959), Arkiv Kemi 16, 471 (1960)). The formulae derived by Karplus and also those derived by McConnell (J. Mol. Spectroscopy 1, 11 (1957) imply that the π-electron transmitted contact coupling of proton spins should remain constant in magnitude but change sign if a methyl group is substituted for a proton directly bound to an sp or sp^2 hybridized carbon. This "method of methyl substitution", may be used to determine the π-electron contact contribution to long-range coupling constants in various systems. We have thus demonstrated that

2

Gronowitz-Hoffman

the side-chain couplings (J_{SH-3} = 1.4 - 1.6 c/s) and
J_{SH-5} = 0.9-1.0 c/s) in 2-thiophenethiols are dominated by this
mechanism, since the two side-chains in 3-methyl-2-thiophene-
thiol and in 5-methyl-2-thiophenethiol display mutual
couplings equal to 1.3 c/s and 1.1 c/s respectively. In a
similar way we have found that J_{SH-2} in 3-thiophenethiol is
due to this mechanism whilst J_{CHO-5} in 2-thiophenealdehydes
is not.

We have tried to investigate the mechanism of J_{CH_3-3} in
2-methylthiophenes and J_{CH_3-2} in 3-methylthiophenes by
finding the value of J_{CH_3, CH_3} in 2,3-dimethylthiophene.
Unfortunately, the couplings of the side-chain and ring protons
preclude the possibility of resolving the fine structure in
the methyl bands. We have therefore prepared 4,5-dibromo-
2,3-dimethyl thiophene, the NMR-spectrum of which is shown in
figure 1. The splitting of the quartet components has the
value of 0.70 $\pm$ 0.10 c/s, which is insignificantly smaller
than J_{CH_3-2} in methyl thiophenes, demonstrating that the
largest side-chain couplings in methylthiophenes are due to
π-electron interactions.

We are continuing our studies of NMR-spectra of hetero-
aromatic compounds. We wish to take this opportunity of ex-
pressing our appreciation of your newsletter, which we receive
eagerly.

We send you our best wishes for the New Year, and for
the successful continuation of your NMR-work at Mellon.

Sincerely yours

Salo Gronowitz   *Ragnar A. Hoffman*

Salo Gronowitz   Ragnar A. Hoffman

6.5 c/s

H
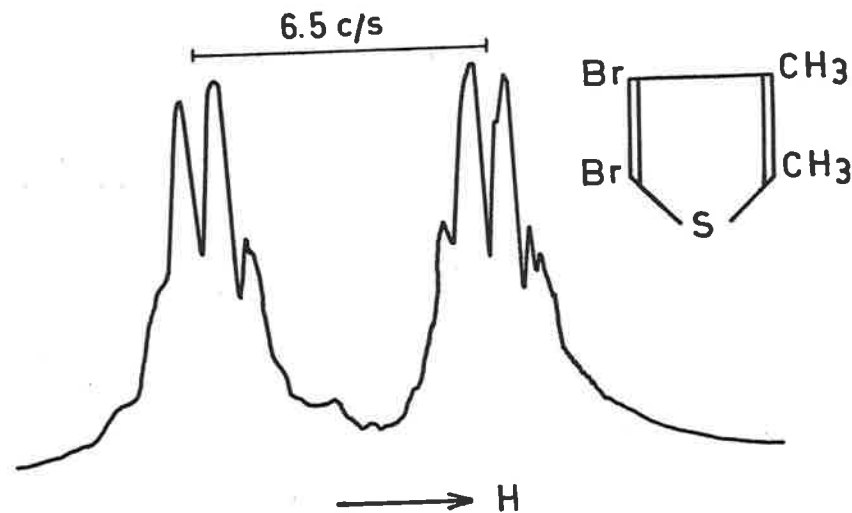
Gronowitz - Hoffman   Fig 1

THE SIGNS OF THE PROTON-PROTON SPIN-SPIN COUPLING

CONSTANTS IN N-BENZYLTHIENO[3,2-b]PYRROLE

A.L. Porte

Dept. of Chemistry, The University, Glasgow, W.2. Scotland

H.S. Gutowsky

Noyes Chemical Laboratory, The University of Illinois,

Urbana, Illinois

The high-resolution proton magnetic resonance spectrum of the
four protons attached to the heterocyclic rings of N-benzyl-
thieno[3,2-b]pyrrole (I) has been examined in detail at 16·2 Mc.
The spectrum is of the type ABCD perturbed by two nuclei X_2
which couple with A, and it involves three long-range proton-
-proton couplings, over five, six and six bonds respectively,
which can only be accounted for by invoking a mechanism
incorporating coupling via the pi-electronic system.   These
long-range couplings occur between nuclei attached to carbons
which are coupled in the pi-electronic system by the mesomeric
effect.   The relative signs of all the coupling constants
involved have been obtained from the observed spectrum.   These
signs are consistent with the absolute signs predicted by
theory.

I
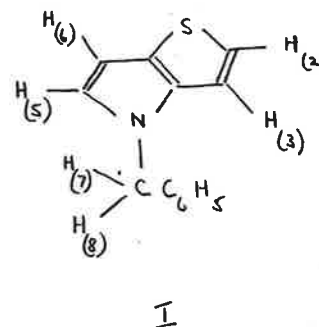
The chemical shifts (ϑ) and coupling constants (J) employed in
calculating the line spectrum shown in the figure are as follows,

$\vartheta_2 = 0$ $\vartheta_3 = 4·4$ $\vartheta_5 = 2·4$ $\vartheta_6 = 9·1$

$J_{23} = +4·9$ $J_{25} = +1·3$ $J_{26} = 0$ $J_{27} = +0·3$ $J_{28} = +0·3$

$J_{35} = 0$ $J_{36} = +0·5$ $J_{37} = 0$ $J_{38} = 0$

$J_{56} = +2·9$ $J_{57} = 0$ $J_{58} = 0$

$J_{67} = 0$ $J_{68} = 0$
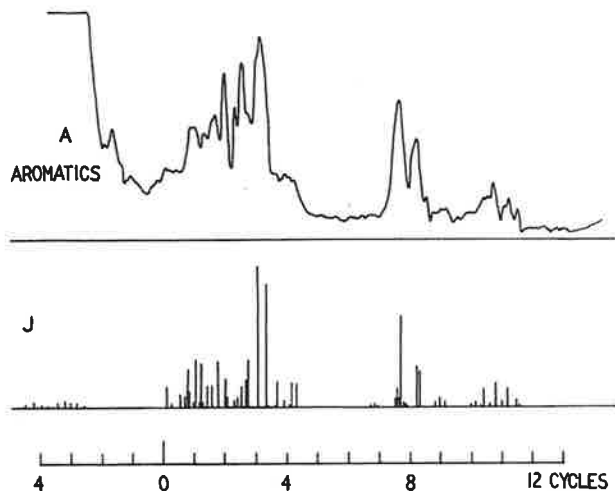
N-benzylthieno[3,2-b]pyrrole. Observed spectrum, A, and calculated line spectrum (J) due to the heterocyclic protons.

EMERYVILLE, CALIFORNIA

January 4, 1961

TELEPHONE OLYMPIC 3-2100

A DIVISION OF
SHELL OIL COMPANY

Dr. A. A. Bothner-By
Mellon Institute
4400 Fifth Avenue
Pittsburgh 13, Pennsylvania

Dear Aksel:

There are a couple of matters of notation that I would like to bring to the attention of other NMR spectroscopists via MELLONMR.

The first concerns the abbreviation for megacycles per second. In the usual jargon of the trade this unit is sloppily referred to in conversation as megacycles. However, there is no excuse for carrying this sloppiness over into our written communications and thus to the use of the corresponding abbreviation Mc (or even worse, mc). It seems to me that there are three acceptable abbreviations: Mcps, Mc/s or Mc/sec. Jackman, in his book, has used Mc/s, whereas Pople, Schneider and Bernstein have used Mc/sec. The latter would seem to be more consistent with U.S. practice and with the A.I.P. style manual. It is the one I personally prefer. This matter was brought rather sharply to my attention recently when the editorial office of the Journal of Chemical Physics, without first consulting me, changed the correct abbreviation Mc/sec wherever it occurred in a manuscript to Mc. The first I knew of the change was at the galley proof stage.

The other matter of notation is that of the unit for the spin-spin coupling constant. I have noted recent cases in the literature in which this constant is given "units" of sec^{-1}. The latter is not a unit but a dimension. The coupling constant may have the units e.g. of cycles per second or radians per second, the dimensions being the same (sec^{-1}) in each case. The author should specify clearly which unit is being used and not use sec^{-1}.

There, now I feel better!

Sincerely yours,

C. A. Reilly

CAR:jel

5

Dr. A.A. Bothner-By,

Mellon Institute,

4400 Fifth Avenue,

PITTSBURGH 13, Pennsylvania

U.S.A.

Dear Dr. Bothner-By,

During an investigation of the NMR spectra of proton com-
plexes of methyl-substituted benzenes* we found an interesting type
of proton exchange in which the exchanging proton remains on one
and the same ion, alternately occupying different positions of equal
proton affinity. An example is hexamethylbenzene. The spectrum of
the molecule consists of one single line of the six methyl groups.
The spectrum of the proton complex (dissolved in anhydrous hydrogen
fluoride saturated with BF_3) is temperature dependent: at room
temperature it consists of two sharp lines: a combined signal of the
six methyl groups and a peak of the captured proton. This is observed
in spite of the fact that the chemical shifts of the various protons
are strongly dependent on their position. In the spectrum at -75°C
these shifts are resolved: from low to high field we find: the signal
of the solvent (anhydrous HF), the captured ring-proton (quadruplet),
the methyl groups in para, ortho and meta position to the $C<^H_{CH_3}$ group
and at last the methyl group in the $C<^H_{CH_3}$ group. The latter is split
into a doublet by the "captured" proton. The temperature dependence
of the spectrum can be explained by the intramolecular proton exchange
reaction:
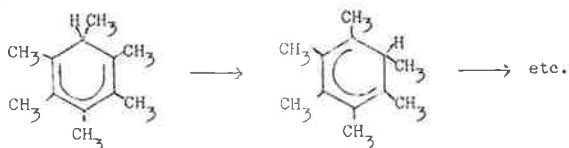
Similar reactions have been observed in other methyl-
substituted benzenes. The activation energy in mesitylene is about
10 kcal/mole with a frequency factor of 10^{11}.

----

* To be published in Journal of Chemical Physics; see also Mol.Phys. 1
(1958) 247

The charge distribution in this carbonium ion can, with a
high degree of confidence, be estimated from the chemical shifts
because one unit charge is distributed over only five carbon atoms
and these large excess charges cause considerable downfield shifts.
A calibration of the excess charge in terms of chemical shift can be
made in the following way.

There can be little doubt that, in the absence of excess
charges the chemical shifts should be equal to those of the same type
of proton near an olefinic carbon atom because the ring current is
interrupted. Taking this as a reference point, we obtain a total shift
of 550 c/s and 190 c/s for a ring proton and a substituted methyl group,
respectively, per unit positive charge.

The inferred charge distribution in the carbonium ion is:
para 0.24, ortho 0.17, and meta 0.21. This result is strongly at
variance with current molecular orbital calculations and this aspect will
be discussed in a paper which has been submitted for publication.

Work of a somewhat allied type has been carried out on the
proton complexes of other weak bases, such as water, ethyl alcohol and
acetone. Well-defined NMR spectra of the H_3O^+, $C_2H_5OH_2^+$ and $(OH_3)_2OH^+$-ions
could be obtained if all proton exchange reactions had been suppressed
by using a strong acid ($HF + BF_3$) and lowering the temperature. Lifetime-
limiting processes, which impede the detection of the spin-spin splitting
in the HF molecule, can in favourable cases be suppressed. The coupling
constant has been found to amount to 530 c/s. More details of this work
will be published shortly.

Yours sincerely,

Dr. C. MacLean

C. Mac Lean

Dr. E.L. Mackor

E.L. Mackor

IMPROVING BASE-LINE STABILITY OF V-4300-2 SPECTROMETER

Charles M. Huggins
General Electric Research Laboratory, Schenectady, New York

The base-line drift of our Varian V-4300-2 NMR Spectrometer (equipped with V-4310C 40mc transceiver) made conventional operation at high gain difficult and electronic integration well-nigh impossible. It was shown that the major part of the DC drift was introduced by fluctuations in the DC filament supply to the rf preamps (see Figure 1). Substitution of a 12-volt battery resulted in obvious improvement. According to recommendations of Varian personnel, the DC supply was rebuilt from the transformer out with only slight improvement.

The continual use of storage batteries is troublesome, so the use of regulated DC power supplies was investigated. A Lambda Model LT-2095 M (0-30 volts, 0-2 amps) power supply proved quite satisfactory, except for overload difficulties on initial start-up where the filaments draw about 5 amps compared to 1.8 amps when hot. A considerably cheaper and, ultimately, simpler solution was found in the use of Zener diodes in conjunction with the existing power supply (V-4360B). A Zener diode is merely a solid-state equivalent of the old VR (voltage-regulator) tube and has also the advantage of being available in a large range of voltages and power dissipations. Figure 2 shows typical usage for voltage regulation against fluctuations in input voltage, E in, and current consumption, I_L. The value of the current-limiting resistor, R, is determined by the current and voltage ratings of the power supply as well as the Zener voltage and allowable power dissipation. For example, the analysis for our spectrometer is as follows:

$$I(total) = I (load) + I (Zener)$$
$$E(in) = I (total) \times R + E (Zener)$$

E (Zener) is, of course, determined by the diode and must equal about 12.6 volts; I (Zener) is selected at an optimum point on the E vs. I plot of the diode. By changing the primary tap on the filament transformer, E(in) was raised to 14.2 volts at 2.3 amps load. Using the appropriate voltage and current requirements, R should be 0.7-0.8 ohms, which is close to the DC resistance of the choke already present. The addition of two International Rectifier Corp. diodes (10Z5.6V01 and 10Z6.8V01) wired in

series (see Figure 1) then supplies 1.8 amperes at 12.4 volts with a dynamic impedance of 0.3 ohms. Under these conditions, the diodes (series connected) conduct 0.5 amps, well within their allowable power dissipation of 10 watts each. Stability is further improved by mounting the diodes on massive heat sinks (commercially available).

Comparative results on base-line stability are shown in Figure 3. In each trace, receiver and recorder gains were at maximum while other adjustments were held constant in normal operating ranges. The spectrometer had been operating at least 24 hours in a thermostatted room prior to each trace, since all methods give some unidirectional dirft on initial start-up. This procedure is highly recommended, with the provision that the user takes care to follow the analysis given above to prevent overloading the power supply or diodes; and, at the same time, provides for operating at optimum current on the diode characteristic.
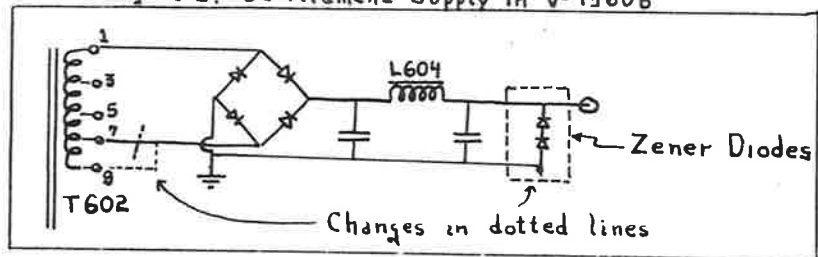
Figure 1. DC Filament Supply in V-4360B

Zener Diodes

T602 — Changes in dotted lines
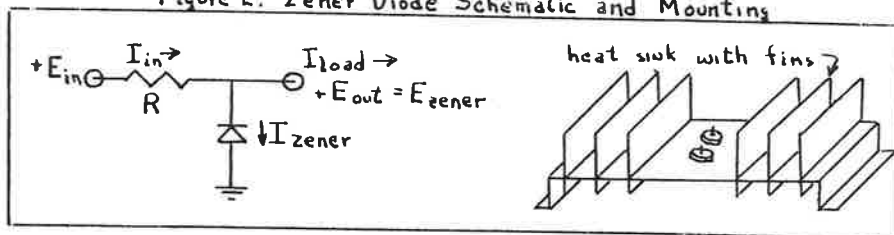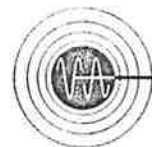
Figure 2. Zener Diode Schematic and Mounting

$+E_{in}$ $I_{in} \rightarrow$ R $I_{load} \rightarrow$ $+E_{out} = E_{zener}$ $\downarrow I_{zener}$

heat sink with fins

Figure 3. Comparative Recorder Traces

|← 1 min →|

a) Before conversion

b) Lambda

c) Zener diodes

d) Zener diodes on heat sink
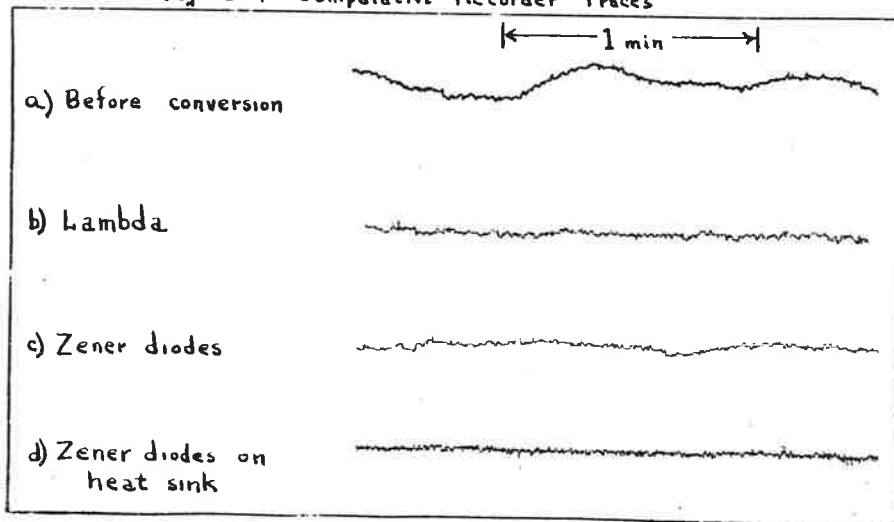
January 11, 1961

Dr. Aksel Bothner-by
Mellon Institute
4400 Fifth Avenue
Pittsburgh 13, Pennsylvania

Dear Aksel,

Upon receipt of your recent reminder we had the following almost ready to mail but you beat us to the punch. We hope that MELLONMR readers will find it of interest.

Some time ago Tiers and Bovey[1] reported on the narrowing of proton resonances from protons attached to amido-nitrogen by using trifluoroacetic acid as the solvent. The effect was attributed to a change in the molecular electric field gradient at the nitrogen nucleus induced by the highly polar surroundings. Observation of spin coupling between the NH proton and neighboring CH protons was cited as excluding proton exchange.

The spin coupling patterns observed by Tiers and Bovey also show that the CF_3COOH had <u>not</u> protonated the nitrogen atom under consideration, although the spectra published by them show that primary amino groups in the same molecules had become protonated. Since the amide group is not changed structurally, the observed effects would appear to be due to environmental changes, probably involving association with the solvent. It is difficult to distinguish between two possibilities:

1. That the electric field gradient at the nucleus is somehow increased in the presence of neighboring CF_3COOH molecules, or

2. That the gradient is inherently large enough to average out coupling with the N^{14} spins and the breadth observed in solutions other than CF_3COOH is due to some random interruption rate of the NH precession frequency, perhaps due to the breaking and reforming of hydrogen bonds.

We have recently observed a case in which it is likely that the molecular electric field gradient is inherently large enough to effect extreme narrowing of the NH resonance. This is observed for aniline (Fig. 1-b), both as the pure liquid and as a dilute solution in CCl_4. We feel that sufficiently rapid proton exchange to account for the observed results is unlikely, while a rather

---

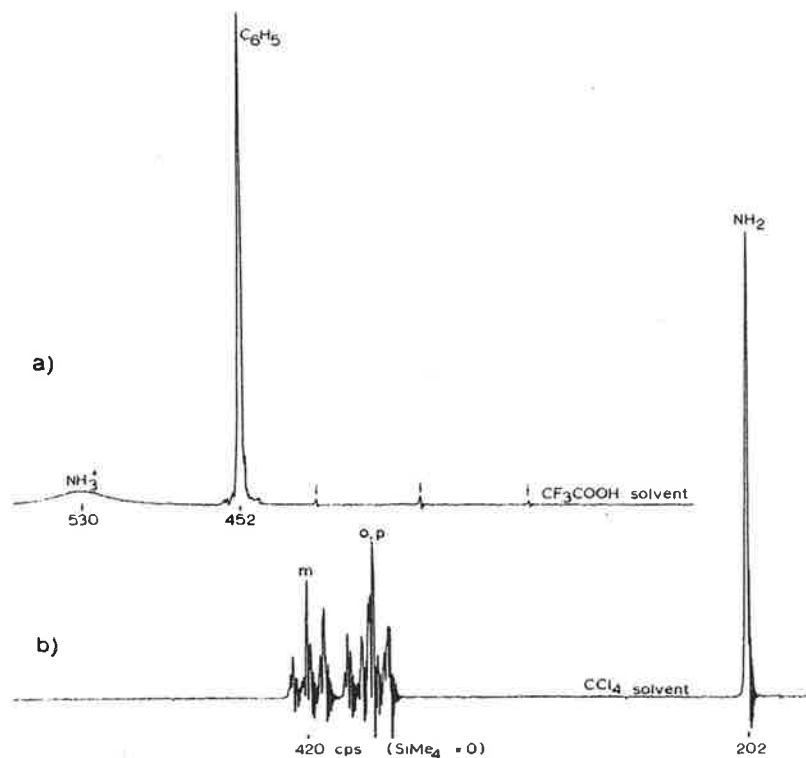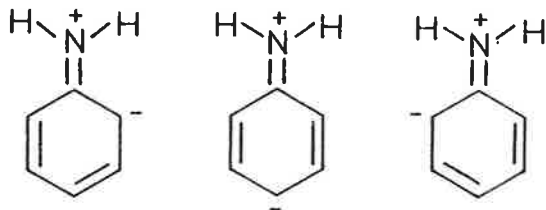[1] G.V.D. Tiers and F.A. Bovey, J. Phys. Chem., 63, 302 (1959)

Fig. 1 (a) Proton NMR spectrum of aniline in CF_3COOH, 60 mc. Peaks labelled i arise from CF_2HCOOH impurity in solvent.
(b) Aniline in CCl_4

large electric field gradient is to be expected due to the strong contribution from resonance structures such as:

In fact, if the recent proposals of Fraenkel et al[2] are applicable to aniline i.e., that a unit change of charge density on a carbon atom shifts the signal from the proton on that atom downfield by 10 ppm, the total charge transferred to the ring from the nitrogen comes out to be about 1/3 of an electron.

The spectrum of aniline in CF_3COOH (Fig. 1-a) corresponds to anilinium ion, since the ratio of integrated intensities of the NH_3^+ peak at 530 cps to the ring protons is exactly 3:5. The charge due to the resonance structures shown above is withdrawn from the ring, resulting in a shift of the ring protons to 452 cps (neglecting solvent effects), and a disappearance of the chemical shift differences between the o-, m- and p- positions. This is to be expected since anilinium ion cannot form a double bond to the ring.

Chemical exchange of the protons in the NH_3^+ group is unlikely in such a strongly acid medium. The breadth of the NH_3^+ resonance is accordingly attributed to the reduction of N^{14} quadrupole relaxation due to protonation in CF_3COOH, the symmetry of the resulting tetrahedrally coordinated nitrogen being insufficient to permit observation of the individual spin-coupling components.

We wish to extend once again our congratulations to you for the great contribution you are making to the NMR field with MELLONMR.

[2] G. Fraenkel, R.E. Carter, A. McLachlan, and J. H. Richards, J.A.C.S. 82, 5846 (1960)

Sincerely yours,

James N. Shoolery

James N. Shoolery

L. F. Johnson

L. F. Johnson

JNS/LFJ:jll

IN REPLY REFER TO:

CMLRD-CR-R(PR)2

19 JAN 1961

Dr. B. L. Shapiro
M.E.L.L.O.N.M.R. News Letter
Mellon Institute
4400 Fifth Avenue
Pittsburgh 13, Pa.

Dear Dr. Shapiro:

At the meeting of NMR spectroscopists held at SOHIO on 24 June, there was an interesting informal discussion concerning the calibration of NMR spectra by means of an audio frequency modulation signal. It was observed by several investigators that when the modulating field was imposed upon the radio-frequency field, a considerable error in calibration sometimes occurred. This was attributed to the fact that the modulating field tends to drive the crystal in the r-f oscillator off from its natural frequency. It has been found that it is more desirable to calibrate high resolution spectra by imposing a weak sinusoidally varying magnetic field on the primary magnetic field of the spectrometer, which causes side peaks to appear on either side of the main resonance peak. There was a question as to exactly how these side peaks are produced.

A brief literature search revealed a paper by W. A. Anderson (Phys. Rev., 102, 151, 1956) in which is discussed a technique for measuring the strength of the r-f field in an NMR spectrometer making use of modulating fields.

Anderson found the resonance conditions for the appearance of the first sidebands to be:

$$(\omega')^2 = (\omega_A - \omega_1)^2 + (\gamma H_1)^2$$

where ω' is the frequency of the modulation signal, ω_A is the resonant frequency of the nuclei in the sample being studied, and ω_1 and H_1 are respectively the frequency and magnitude of the r-f field. In actual practice ω_1, H_1, and ω' are fixed and the primary magnetic field (and

---

CMLRD-CR-R(PR)2
Dr. B. L. Shapiro

19 JAN 1961

consequently, ω_A) is linearly swept through the resonance region. Thus if one plots $(\omega_A - \omega_1)^2$, the square of the distance from a side peak to the main peak, as a function of $(\omega')^2$, a straight line should be obtained whose intercept indirectly gives the magnitude H_1 of the r-f field. These relations hold regardless of whether it is the r-f field or the primary magnetic field that is modulated. Measurements of the magnitude of H_1 using these techniques were carried out by Anderson and reported in the paper cited above.

Now if this expression for the resonance condition is examined with respect to the use of modulation techniques for the calibration of NMR spectra, certain problems immediately appear. Setting $\omega_A = \gamma H_z$ where H_z is the primary magnetic field and solving for H_z in the above expression, one obtains for the positions of the sidebands:

$$H_z = \frac{\omega_1}{\gamma} \pm \sqrt{\frac{(\omega')^2}{(\gamma)^2} - H_1^2}$$

In the calibration of spectra it apparently has been assumed that if one applies a modulating signal of frequency ω', sidebands will appear at intervals of $\frac{\omega'}{\gamma}$ above and below the main resonance peak. However, the above expression indicates that each interval is not $\frac{\omega'}{\gamma}$, but rather is $\sqrt{(\frac{\omega'}{\gamma})^2 - H_1^2}$. If these conclusions are valid, then the accuracy of the calibration depends on the relative magnitudes of ω' and H_1. If one takes a value of one milligauss for H_1, which is the approximate magnitude of the r.f. field in the NMR spectrometer, the error for a 25 cps modulating field ($\omega' = 157$ rad./sec.) on protons will be approximately 1%. The error rapidly becomes significant as the frequency of the modulating field is decreased below this value.

In light of the above argument, it would appear that there are limitations on the situations where modulating techniques can be used with accuracy. We have not been aware of any discussions of this topic in the literature and are posing the problem with the hope of clarifying a situation which we find to be somewhat disturbing.

Yours truly,

John F. Cotton

JOHN F. COTTON

Harold Klapper

HAROLD KLAPPER

2