1

# NUCLEAR MAGNETIC RESONANCE SPECTRA OF CARBANIONS

# IX*. CARBANIONS PRODUCED BY REACTIONS OF METHYL-SUBSTITUTED PYRIDINES WITH n-BUTYLLITHIUM

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## SUMMARY

Methyl-substituted pyridines were allowed to contact with n-butyllithium in n-hexane. The reaction products were dissolved with tetrahydrofuran (THF) or 1,2-dimethoxyethane (DME) and checked with PMR measurements. The metal–proton exchange reaction occurred at the α-methyl group. 2,4-Lutidine and 2,4,6-collidine in DME were metallated at the γ-methyl group. The metallated positions have been confirmed by chemical shift considerations. The extra charge in the prepared carbanions is largely delocalized into the aromatic ring. The methylene carbon atom in the carbanions is near $sp^2$-hybridized. The two methylene protons in the α-picolyl carbanions show magnetic nonequivalence in the lower-temperature measurements.

## INTRODUCTION

In a previous paper, we have observed the PMR spectra of α-picolyllithium prepared from α-picoline and phenyllithium[1]. This study has been extended to the carbanions prepared by the reactions between methyl-substituted pyridines and n-butyllithium. The carbanions prepared are numbered from (I) to (VII) as follows. (VIII) was presented for comparison.
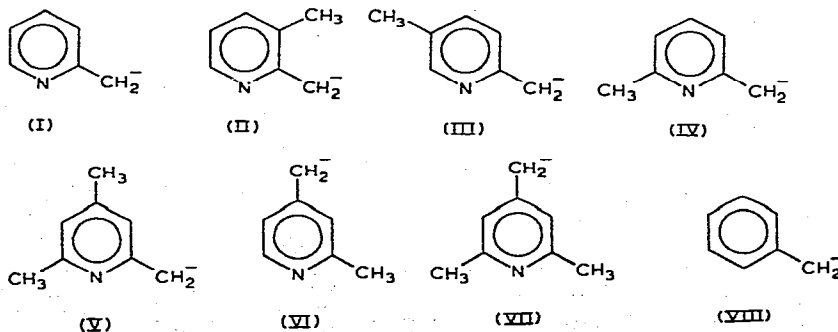


* For Part VIII, see ref. 1; and for a preliminary communication of a part of this work see ref. 2.

EXPERIMENTAL

The preparation of the carbanions was carried out in a high vacuum. About 1–2 mmoles of a starting material were made to react with an equimolar 1.5 mol/l solution of n-butyllithium in hexane or benzene at room temperature. After the completion of the reaction, all the volatile materials were trapped out and then a suitable polar solvent such as THF or DME was introduced into the system. In most cases, the reaction products were colored yellow before the introduction of the solvent. However, after the introduction of the solvent the solution became brown-red. The solution was then introduced into a 5 mm O.D. NMR sample tube. The solution was stable for at least one month at −20° as observed by NMR.

All the starting materials used in this study are commercially available. These materials were dried with $CaH_2$ and distilled *in vacuo*. The chemical shifts were referred to the upfield resonances of the solvents. The shifts were 1.79 ppm for THF and 3.28 ppm for DME with respect to TMS. The chemical shifts of carbanions varied slightly with concentrations but showed great sensitivity to different solvents.

TABLE 1

THE PROTON CHEMICAL SHIFTS OF THE CARBANIONS AND THE STARTING MATERIALS, IN ppm AT 60 MHz AND 35°[a]

| Compound | Solvent | Assignment | | | | | |
|---|---|---|---|---|---|---|---|
| | | 3-H | 4-H | 5-H | 6-H | $CH_2$ | $CH_3$ |
| (I) | DME | 5.58 | 6.01 | 4.77 | 6.82 | 2.52<br>2.45[b], 2.56[b] | |
| | THF | 5.64₅ | 6.06 | 4.84 | 6.90 | 2.54 | |
| (II) | DME | | 6.07 | 4.95 | 6.90 | 2.57[c]<br>2.27[b], 2.78[b] | 1.57 |
| (III) | DME | 5.69 | 6.01 | | 6.71 | 2.43<br>2.37[b], 2.47[b] | 1.68 |
| (IV) | DME | 5.49 | 6.00 | 4.76 | | 2.54<br>2.47₅[b], 2.58[b] | 1.77 |
| | THF | 5.57 | 6.10 | 4.86 | | 2.44 | [d] |
| (V) | THF | 5.47 | | 4.83 | | 2.44 | [d] |
| (VI) | DME | 5.20 | | 5.17 | 6.43 | 2.61 | 1.65 |
| | THF | 5.21 | | 5.18 | 6.38 | 2.64 | [d] |
| (VII) | DME | 5.16 | | 5.16 | | 2.64 | 1.74₅ |
| (VIII)[e] | THF | 6.09 | 6.30 | 5.50 | 6.30 | 1.62[f] | |
| 2-Picoline | DME | 7.13 | 7.54 | 7.05 | 8.42₅ | | 2.48 |
| | THF | 7.16 | 7.57 | 7.07 | 8.46 | | 2.48₅ |
| 2,3-Lutidine | DME | | 7.35 | 6.93 | 8.23 | | 2.24, 2.45 |
| 2,5-Lutidine | DME | 6.98 | 7.34₅ | | 8.26 | | 2.23, 2.43 |
| 2,6-Lutidine | DME | 6.91 | 7.44 | 6.91 | | | 2.44 |
| | THF | 6.92 | 7.45 | 6.92 | | | 2.45 |
| 2,4,6,-Collidine | DME | 6.75 | | 6.75 | | | 2.24, 2.40 |
| | THF | 6.75 | | 6.75 | | | 2.24, 2.42 |
| 2,4-Lutidine | DME | 6.93 | | 6.90 | 8.28 | | 2.25, 2.44 |
| | THF | 6.95 | | 6.92 | 8.29 | | 2.27, 2.46 |

[a] Errors are estimated to be within ±0.03 ppm. [b] Measured at −25°. [c] Measured at 70°. [d] Chemical shifts are not available because of overlapping of the large solvent peak. [e] From the data in ref. 7. [f] From the data in ref. 14.

RESULTS AND DISCUSSION

The PMR data of the carbanions and the starting materials are given in Table 1. Almost all the results come from a first-order analysis. The values of (I) are slightly different from those reported previously[1]. This difference seems to originate in the contamination by benzene produced from phenyllithium. It was noticed that benzene induced downfield shifts for the aromatic protons of the carbanions in THF or DME. Similar observations have been reported before[3-6]. The value for the chemical shift of $H_3$ in α-picoline was erroneous in our previous paper[1]. The correct value is given in Table 1.

*Reactions between methyl-substituted pyridines and n-butyllithium*

α-Picoline reacted with n-butyllithium and gave an α-picolyl carbanion. This carbanion gave a PMR spectrum consistent with that reported before[1]. The PMR spectra of the products derived from β- or γ-picoline and n-butyllithium were complex. In these cases, the reaction products may consist of several components and need further study. All of the compounds having an α-methyl group reacted at the α-position except 2,4-lutidine. The sites of the reactions were confirmed by chemical shift considerations. For example, 2,6-lutidine gave a spectrum of an $AB_2$ type. However, the prepared carbanion (IV) showed a spectrum of an ABC type. This change is acceptable if metallation occurred at the α-position. On the other hand, in the case of 2,4-lutidine, it is apparent from chemical shift considerations that a metal–proton exchange reaction occurred at the γ-methyl group. When the carbanion was treated with $D_2O$, it was ascertained that one deuterium was attached to the 4-methyl carbon of recovered 2,4-lutidine. This result is consistent with the previous chemical shift considerations. The carbanion prepared from 2,4,6-collidine showed two non-equivalent $H_3$ and $H_5$ chemical shifts in THF but two equivalent $H_3$ and $H_5$ chemical shifts in DME. Several months after the preparation, the PMR peak intensities showed that carbanion (V) in THF partly changed to species (VII). Therefore, the more symmetric (VII) seems to be more stable than (V). We propose that the metal–proton exchange reaction between 2,4,6-collidine or 2,4-lutidine and n-butyllithium occurs most rapidly at the α-position, but the thermodynamically stable anion is the γ-ion, isomerization taking place from the α-ion to the γ-ion.

In the case of 2,6-lutidine, the metallation occurred only at one methyl group even when two equivalents of n-butyllithium were used. In some cases, the mono-metallation reaction seems not to be unique. Although the main reaction products are always the same in all the runs, the side products are not always the same. However, the conclusion reached in this work is not affected by these minor products. Some typical spectra of the reaction products are shown in Fig. 1. A peak due to minor products is seen at 1.65 ppm in Fig. 1a; this peak is ascribed to a methyl group. Further studies are needed for the assignment of the resonances of minor products.

*The chemical shifts of the carbanions*

The ring proton peaks of the picolyl carbanions are present in a higher field than those of the corresponding methylpyridines. This upfield shift is ascribed to the delocalization of the extra negative charge into the aromatic ring as described earlier[7]. The extra charge distribution estimated from the chemical shift changes are given in

Table 2, using as constant one electron is equivalent to a 10 ppm shift upfield[8]. Although 10.7 is generally used[9], we preferred to use a round number of 10 ppm/ electron for simplicity. It must be noted that the estimated charge distribution is not self-consistent because of the lack of the data on the carbons having no proton. Carbon-13 shifts would be more useful to get the electron densities. Preliminary results on the carbon-13 shifts of the $\alpha$-picolyl carbanion (I) are given in Table 3, measured near to 15.085 MHz. The assignment of the $\alpha$-carbon is uncertain. If the
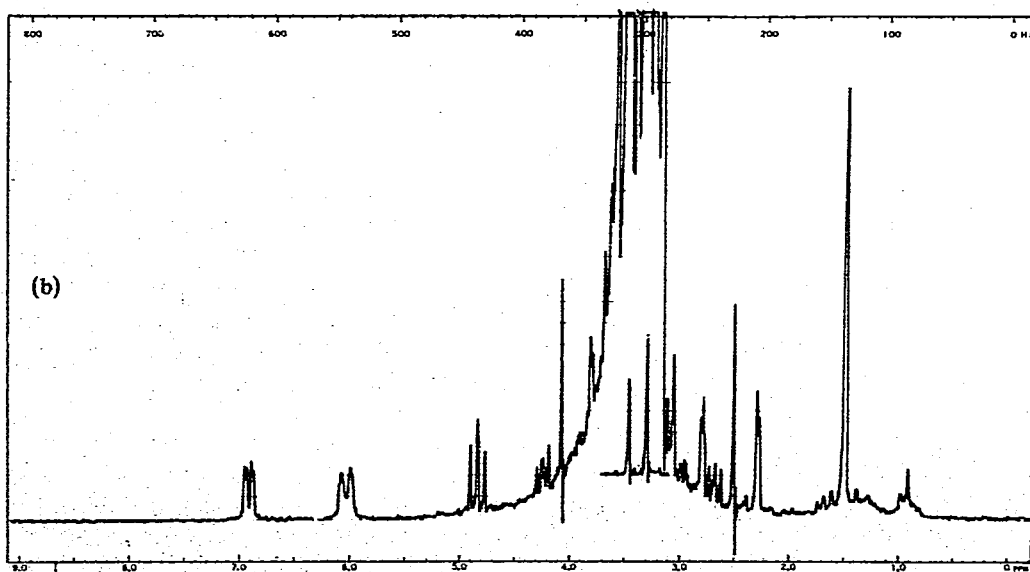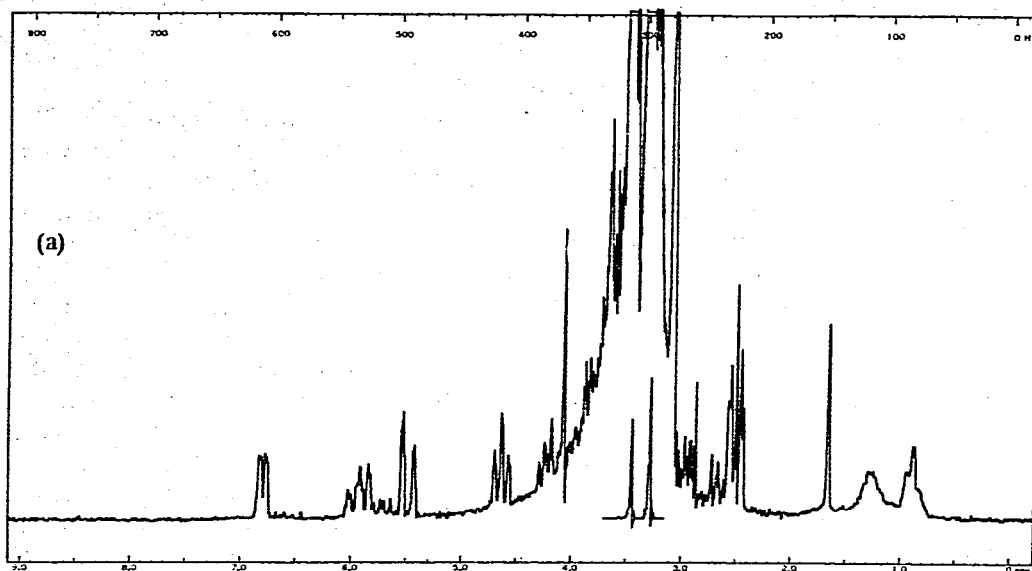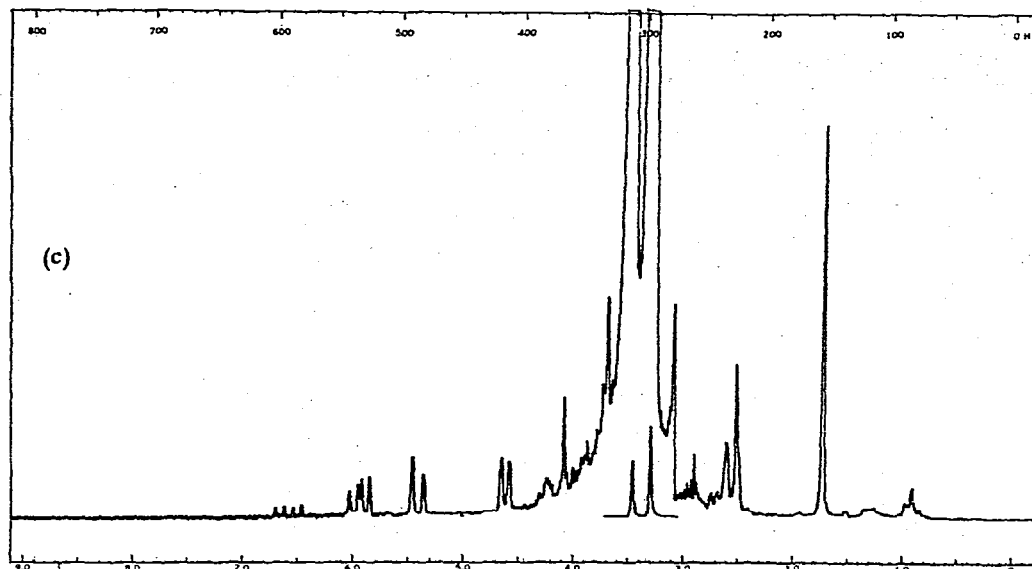
Fig. 1. PMR spectra of picolyl carbanions in DME at 90 MHz and −25°; (a) (I), (b) (II) and (c) (IV).

TABLE 2

THE RELATIVE CHARGE DISTRIBUTION IN THE CARBANIONS IN UNITS OF THE
ABSOLUTE VALUE OF THE CHARGE OF AN ELECTRON

| Carbanion | Solvent | Position | | | |
|-----------|---------|------|------|------|------|
| | | 3-C | 4-C | 5-C | 6-C |
| (I) | DME | $-0.15_5$ | $-0.15_5$ | $-0.23$ | $-0.16$ |
| | THF | $-0.15$ | $-0.15$ | $-0.22_5$ | $-0.15_5$ |
| (II) | DME | | $-0.13$ | $-0.20$ | $-0.13_5$ |
| (III) | DME | $-0.13$ | $-0.13_5$ | | $-0.15_5$ |
| (IV) | DME | $-0.14$ | $-0.14_5$ | $-0.21_5$ | |
| | THF | $-0.13_5$ | $-0.13_5$ | $-0.20_5$ | |
| (V) | THF | $-0.13$ | | $-0.19$ | |
| (VI) | DME | $-0.17_5$ | | $-0.17_5$ | $-0.18_5$ |
| | THF | $-0.17_5$ | | $-0.17_5$ | $-0.19$ |
| (VII) | DME | $-0.16$ | | $-0.16$ | |
| (VIII)[a] | THF | $-0.10_5$ | $-0.08_5$ | $-0.16_5$ | $-0.08_5$ |

[a] Cited from Ref. 15.

proportionality constant of 160 ppm/electron is used[10], the charge densities estimated from the carbon-13 shift changes are completely different from those given in Table 2. In this sense, the proton shift is not an unfailing index of $\pi$-electron densities in the picolyl carbanions.

As is pointed out in our previous communication[1], the upfield shifts of the aromatic protons are much larger in the picolyl carbanions than those in the benzyl carbanion (VIII). This result implies that the picolyllithium compounds are much

TABLE 3

THE CARBON-13 CHEMICAL SHIFTS OF α-PICOLYLLITHIUM AND α-PICOLINE IN DME NEAR 15.085 MHz IN ppm[a]

| Compound | Assignment | | | | | |
|---|---|---|---|---|---|---|
| | 2-C | 3-C | 4-C | 5-C | 6-C | α-C |
| (I) | $29.7_5$ | $77.7_5$ | $62.1_5$ | 96.6 | 45.2 | 136.4 |
| α-Picoline | $34.9_5$ | 69.9 | $57.7_5$ | 72.9 | 44.2 | 169.4 |

[a] Referred to the external $CS_2$. Errors are estimated to be $\pm 0.3$ ppm.

more ionic than benzyllithium. All these picolyl anions are more stable than benzyllithium. These tendencies are attributable to the electronegativity of the nitrogen atom in the picolyl ring. The upfield shifts in the picolyl carbanions are the largest at the *para*-position ($H_5$) and are almost the same at other positions; that is, the difference between the *ortho-* and the *meta*-positions ($H_3$ and $H_4$, respectively) observed in (VIII) cannot be found in the picolyl carbanions.

The methyl protons in the carbanions also show upfield shifts, but their magnitudes are about 0.6 ppm and do not depend on the positions of the methyl group. The methylene proton peaks in the picolyl carbanions are slightly deshielding with respect to the methyl proton peaks of the starting materials. However, those of (VIII) show a shift towards higher shielding than the methyl protons in toluene. As we pointed out previously for the 1,1-diphenylethylene dimer dianion, the deshielding of the methylene protons can be ascribed partly to the hybridization change of the α-carbon atom[11]. If this interpretation is correct, an embarassing fact is that the direction of the effect of hybridization change on the chemical shifts is opposite to that of the effect of the negative charge localization. Therefore, the extent of the negative charge localization cannot be estimated from the net observed chemical shifts for the methylene protons. For this reason, a conclusive comparison cannot be made for the methylene groups in the picolyl and benzyl carbanions. Nevertheless, it is interesting that the extent of the deshielding of the methylene protons in γ-picolyl carbanions [(VI) and (VII)] is greater than that in the α-picolyl carbanions.

*Nonequivalence of the two methylene protons in the α-picolyl carbanions*
The broad resonance of the methylene protons of (I) was discussed previously in the measurement at 35°[1]. Three possible interpretations were presented in our previous report. The cause of this broadness has been made clear in this study. The two methylene protons in the α-picolyl carbanions show magnetic nonequivalence at low temperatures. Typical spectra are shown in Fig. 1. The nonequivalent chemical shifts are included in Table 1. The nonequivalence can be ascribed to the rotational barrier between the ring and the methylene carbon. The coupling constant between two methylene protons is about 2 Hz. The magnitude of the coupling constant is very similar to that of the geminal coupling constants of vinyl compounds[12], and is different from those of the methane derivatives[13]. This result leads to the conclusion that the methylene carbon in such carbanions has a configuration similar to that of vinyl comcounds; that is, the carbon atom is nearly $sp^2$-hybridized. A typical expanded spec-
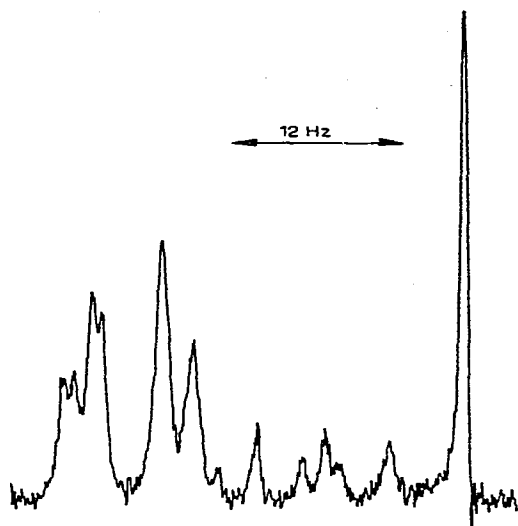
Fig. 2. An expanded spectrum of the methylene proton region of (I) in DME at 60 MHz and $-17.5°$. The peaks in the right half are due to the $^{13}C$ satellite signals of DME.

trum of the methylene peaks is shown in Fig. 2. The AB quartet pattern shows a further splitting in the less shielded peaks. Decoupling experiments show that $H_4$ is coupled to one of the methylene protons in (I) with a coupling constant of 0.7 Hz. The path of this long-range coupling is likely to be in a straight zig-zag path, as shown in the following formula.
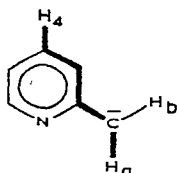


If this assignment is correct, $H_a$ is less shielded than $H_b$. As shown in several typical spectra in Fig. 1, this kind of long-range coupling between aromatic protons and less-shielded methylene protons has been observed for (I), (II), (III) and (IV). The coalescence temperature of the two methylene proton peaks is about $10°$ in carbanionic species (I) and about $40°$ in (II). Analysis of the variable-temperature spectra is in progress.

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