

# Dipole-stabilized carbanions in series of cyclic aldonitrones: Part 4. $^{13}\text{C}$ , $^{14}\text{N}$ and $^7\text{Li}$ NMR spectra of dipole-stabilized organolithiums derived from a cyclic aldonitrone

Maxim A. Voinov,\* Georgy E. Salnikov, Alexander M. Genaev, Victor I. Mamatyuk, Makhmut M. Shakirov and Igor A. Grigor'ev

Novosibirsk Institute of Organic Chemistry, Akad. Lavrent'ev Ave. 9, 630090 Novosibirsk, Russia

Received 30 November 2000; Revised 12 June 2001; Accepted 13 June 2001

$^{13}\text{C}$ ,  $^{14}\text{N}$  and  $^7\text{Li}$  NMR spectra of a lithiation product of the cyclic aldonitrone 1,2,2,5,5-pentamethyl-3-imidazoline 3-oxide were obtained. The  $^{13}\text{C}$  NMR spectrum of the lithiated particle exhibits the resonances of the C-4 and C-5 atoms ( $\delta$  213 ppm and 73 ppm, respectively) shifted to high frequency relative to the signals of the corresponding nuclei of the starting nitron ( $\delta$  C-4 132 ppm and  $\delta$  C-5 60 ppm). The  $^{14}\text{N}$  NMR spectrum of the particle shows the resonance of the N-3 atom ( $-115$  ppm) at lower frequency in comparison with  $-74$  ppm for the starting nitron. The calculated chemical shift changes are in good agreement with those observed experimentally. The electronic structure of the lithiated particle is discussed. Copyright © 2001 John Wiley & Sons, Ltd.

**KEYWORDS:** NMR;  $^7\text{Li}$  NMR;  $^{13}\text{C}$  NMR;  $^{14}\text{N}$  NMR; chemical shifts; aldonitrones; lithiation; dipole-stabilized carbanions; carbenoid

## INTRODUCTION

The lithiation of cyclic aldonitrones allows the generation of dipole-stabilized organolithium compounds, reactive towards different electrophiles.<sup>1,2</sup> The carbanionic character of such intermediates has been postulated,<sup>3,4</sup> but no experimental structural information has been reported until now. We report here the results of an NMR spectroscopic study aimed at obtaining data that could shed light on the structure of the lithiation products of aldonitrones.

## RESULTS AND DISCUSSION

The  $^{13}\text{C}$  NMR spectrum of the organolithium compound **2** (Scheme 1) showed a broadened signal at  $\delta$  213 ppm shifted to high frequency relative to C-4 of the starting nitron compound at  $\delta$  132 ppm ( $\Delta\delta = 81$  ppm, Table 1). The C-5 signal of the imidazoline ring was also shifted to high frequency ( $\delta$  60  $\rightarrow$  73 ppm,  $\Delta\delta \approx 13$  ppm), whereas the C-2 chemical shift was unchanged ( $\delta \sim 90$  ppm). The broad resonance lines are typical for the lithiated carbon atoms of organolithium compounds.<sup>5</sup> The C-4 carbon resonance line width ( $\Delta\nu_{1/2} \approx 70$  Hz) thus gives a convincing argument for C—Li bonding in the resulting particle. However, the

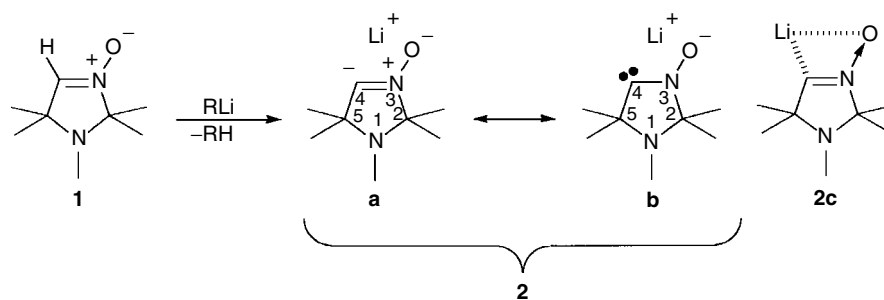
measured linewidth exceeds the cited value for lithium-coupled carbon ( $\Delta\nu_{1/2} > 48$  Hz)<sup>5b</sup> by a factor of 1.5. The additional broadening could arise from the quadrupole moment of the adjacent nitrogen nucleus.

The high-frequency resonance of the lithiated carbon being observed is in accordance with the general trends of carbon chemical shift changes upon formation of organolithium derivatives.<sup>6</sup> For some compounds having  $\text{sp}^2$  carbon–lithium bonds these changes reach considerable values [e.g. phenyllithiums,  $\delta$  186–193 ppm ( $\Delta\delta \approx 60$  ppm),<sup>7a,b</sup> vinylolithiums,  $\delta$  168–183 ppm ( $\Delta\delta \approx 60$  ppm)<sup>7b</sup>]. Thus, the  $^{13}\text{C}$  NMR spectrum of the particle **2** corresponds to the current notions concerning the structure of organolithiums.

As is now, well established the carbon chemical shift is dominated by the paramagnetic shielding term<sup>8</sup> ( $\sigma^{\text{para}}$  in the Saika and Slichter equation<sup>9</sup>). This term is considered to be responsible for the high-frequency shift of both the lithiated carbon and adjacent nuclei,<sup>10</sup> (e.g. C-4 and C-5, Table 1). Based on this assumption, one could expect the absorption of N-3 of the organolithium intermediate also to appear at higher frequency relative to **1**.<sup>10</sup>

The  $^{14}\text{N}$  NMR spectrum of starting imidazoline **1** exhibits the signal of the C=N group nitrogen at  $\delta$   $-74$  ppm (reference  $\text{CH}_3\text{NO}_2$ ), and a considerably broader signal for the tertiary amine at  $\delta$   $-322$  ppm (Table 1). The  $^{14}\text{N}$  NMR spectrum of the organolithium species reveals the amine signal at about the same position (N-1,  $\delta$   $-320$  ppm), and another signal centered at  $\delta$   $-115$  ppm (low-frequency shift,  $\Delta\delta = -41$  ppm, Table 1),

\*Correspondence to: M. A. Voinov, Novosibirsk Institute of Organic Chemistry, Akad. Lavrent'ev Ave. 9, 630090 Novosibirsk, Russia. E-mail: maxx@nioch.nsc.ru



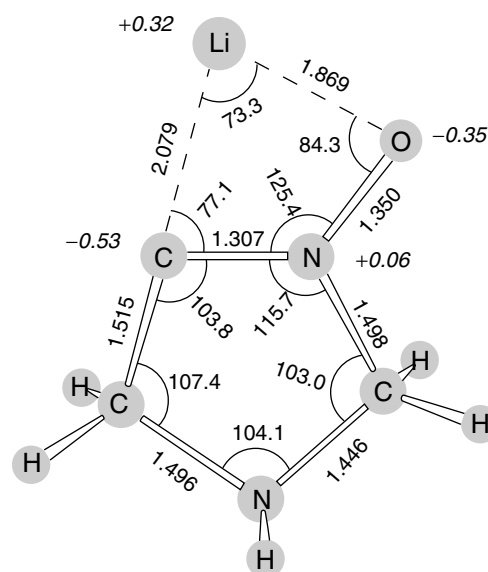
Scheme 1

significantly broadened in comparison with that of the parent nitron. Hence, in practice, the N-3 signal is shifted in the opposite direction as expected.

In terms of resonance, the low-frequency position of the N-3 signal could be attributed to the carbenoid mesomeric structure **2b** (Scheme 1) contributing to the resonance hybrid. This explanation finds support in the range of chemical shifts of carbene carbons (200–260 ppm)<sup>11,12</sup> and nitrogens (–161 to –234 ppm, reference CH<sub>3</sub>NO<sub>2</sub>)<sup>11b,c,12</sup> in diaminocarbenes. Obviously, the lithiation product of aldonitrone **1** could be represented by structure **2c**, intermediate between mesomeric structures **2a** and **2b** (Scheme 1). This assumption is buttressed by bond length calculations in the model organolithium derivative **4** (see Fig. 1). A contribution from the carbenoid form **2b** could be attributed to the ability of the electronegative oxygen of the N–O group effectively to localize the negative charge.

The broadening of the N-3 signal can arise from distortion of the charge distribution within the nitrogen nucleus in the lithiated particle. This affects the electric field gradient on the N-3 nucleus and causes an increase in the nuclear quadrupole relaxation rate.<sup>13</sup> On the other hand, lowering of the sample temperature is also known to result in an increase in quadrupole relaxation rates.<sup>13</sup>

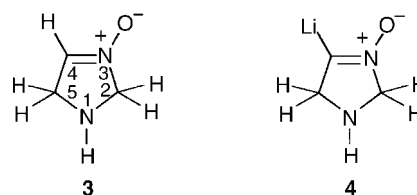
The <sup>7</sup>Li NMR spectrum of the organolithium species displays a single resonance line with a chemical shift  $\delta$ –0.69 ppm (reference dilute solution of LiClO<sub>4</sub> in acetone,  $\delta$  = 1.34 ppm<sup>14</sup>),  $\Delta\nu_{1/2}$  = 20.5 Hz.<sup>15</sup> The low-frequency <sup>7</sup>Li resonance of **2** in comparison with that of *s*-BuLi ( $\delta$  0.34 ppm) is evidence of more covalent character of the carbon–lithium bond in the former. When the temperature was increased from –80 to –60 °C, the <sup>7</sup>Li NMR spectra showed resonance lines shifted to high frequency (–70 °C,  $\delta$ –0.59 ppm;



**Figure 1.** Selected geometric parameters and Mulliken charges of the *ab initio* (MP2/6–31 + G\*) optimized structure of the model anion **4**. Bond lengths (Å), angles (degrees) and charges (italicized).

–60 °C,  $\delta$ –0.52 ppm), perhaps owing to changes in the solvation state of the lithium intermediate.

The experimentally observed trends in the chemical shift changes on formation of organolithium species **2** were compared with those predicted theoretically. The geometries of model **3** of starting nitron and **4** of the organolithium derivative optimized by an *ab initio* method were used in the chemical shift calculations (see Table 2).



The calculations predict the resonances of the C-4 and C-5 atoms of model organolithiums **4** to be at higher frequency than those of parent nitron **3**, in accordance with the experimentally observed results (Table 2). Interestingly, calculation

**Table 1.** <sup>13</sup>C (reference TMS) and <sup>14</sup>N (reference CH<sub>3</sub>NO<sub>2</sub>) chemical shifts for **1** and **2** ( $\delta$ , ppm;  $\Delta\delta = \delta_2 - \delta_1$ )

Compound	N-1	N-3	$\Delta$ N-3	C-2	C-5	$\Delta$ C-5	C-4	$\Delta$ C-4
<b>1</b> <sup>a</sup>	–322	–74		90.0	60.5		132.1	
<b>2</b> <sup>a</sup>	–320	–115	–41	89.8	72.0	11.5	213.1	81.0

<sup>a</sup> Other signals: **1**, 23.3 (5-CH<sub>3</sub>), 23.5 (2-CH<sub>3</sub>), 26.1 (NCH<sub>3</sub>); **2**, 23.2 (2-CH<sub>3</sub>), 25.6 (5-CH<sub>3</sub>), 26.7 (NCH<sub>3</sub>).

**Table 2.** Calculated  $^{13}\text{C}$  (reference TMS) and  $^{14}\text{N}$  (reference  $\text{CH}_3\text{NO}_2$ ) chemical shifts of models **3** and **4** ( $\delta$ , ppm;  $\Delta\delta = \delta_4 - \delta_3$ )

Compound	N-1	N-3	$\Delta\text{N-3}$	C-2	C-5	$\Delta\text{C-5}$	C-4	$\Delta\text{C-4}$
<b>3</b>	-347.2	6.0		73.0	44.2		144.6	
<b>4</b>	-346.7	-73.7	-79.7	68.9	58.8	14.6	243.2	98.6

predicts the low-frequency shift of the N-3 resonance upon lithiation. The calculated chemical shift differences between the parent and lithiated models are in good agreement with the differences obtained experimentally.

## CONCLUSION

The structure of the lithiation product of aldonitrone **1** of the 3-imidazoline-3-oxide series in solution was studied by  $^{13}\text{C}$ ,  $^{14}\text{N}$  and  $^7\text{Li}$  NMR spectroscopy. The  $^{13}\text{C}$  NMR chemical shift of C-4 matches the range characteristic for both anionic and carbenoid carbons. The  $^{14}\text{N}$  NMR data suggest that carbenoid **2b** is a significant contributor to the ground-state structure of the particle. As a result, the lithiation product of aldonitrone **1** could be depicted by hybrid structure **2c**.

## EXPERIMENTAL

$^{13}\text{C}$  and  $^{14}\text{N}$  NMR spectra were recorded at  $-80^\circ\text{C}$  on a Bruker AC-200 spectrometer at 50.323 and 14.458 MHz, respectively. The  $^7\text{Li}$  NMR spectrum was recorded at  $-80^\circ\text{C}$  on a Bruker AM-400 spectrometer at 155.508 MHz. A coaxial capillary with acetone- $d_6$ -TMS (1:1) mixture was used as external reference.  $^{14}\text{N}$  chemical shifts refer to  $\text{CH}_3\text{NO}_2$  as external reference and  $^7\text{Li}$  chemical shifts refer to a dilute solution of  $\text{LiClO}_4$  in acetone ( $\delta$  1.34 ppm), as external reference. Typical conditions for measurements were as follows:  $^{13}\text{C}$ , spectral width 16 000 Hz, 32K data points, delay 4.68 s, digital resolution 1 Hz per point and temperature  $-80^\circ\text{C}$ ;  $^{14}\text{N}$ , spectral width 7000 Hz, 16K data points, delay 0.00968 s and digital resolution 0.88 Hz per point;  $^7\text{Li}$ , spectral width 8000 Hz, 16K data points, delay 5.68 s and digital resolution 0.97 Hz per point.

The dipole-stabilized organolithium compound was generated by lithiation of 1,2,2,5,5-pentamethyl-3-imidazoline 3-oxide (**1**) as follows: a THF solution of **1** (0.3 g,  $1.9 \times 10^{-3}$  mol in 3 ml) was slowly added under argon at  $-80^\circ\text{C}$  to s-BuLi in hexane (2 ml,  $2 \times 10^{-3}$  mol) with

vigorous stirring. The resulting slightly yellowish mixture was transferred through a dry ice-cooled adapter into a 10 mm NMR tube, already filled with argon and cooled with dry-ice.

The geometries of model structures **3** and **4** were optimized with the GAMESS program<sup>16</sup> in the MP2/6-31 + G\* basis set and used in the chemical shift calculations with the IGLO program<sup>17</sup> in the basis set II.

## REFERENCES

- Voinov MA, Grigor'ev IA, Volodarsky LB. *Heterocycl. Commun.* 1998; **4**: 261.
- Voinov MA, Grigor'ev IA, Volodarsky LB. *Tetrahedron* 2000; **56**: 4071.
- Brown RFC, Clark VM, Lamchen M, Todd A. *J. Chem. Soc.* 1959; 2116.
- Boocock DGB, Darcy R, Ullman EF. *J. Am. Chem. Soc.* 1968; **90**: 5945.
- (a) Bauer W, Winchester WR, Schleyer PvR. *Organometallics* 1987; **6**: 2371; (b) Reich HJ, Holladay JE. *J. Am. Chem. Soc.* 1995; **117**: 8470.
- (a) Levy GC, Nelson GL. *Carbon-13 Nuclear Magnetic Resonance for Organic Chemists*. Wiley-Interscience: New York, 1972; chapt. 6, 141–142; (b) Kalinowsky HO, Berger S, Braun S. *Carbon-13 NMR Spectroscopy*. John Wiley & Sons: Chichester, 1988; chapt. 3, 250–258.
- (a) Reich HJ, Sikorski WH, Gudmundsson BÖ, Dykstra RR. *J. Am. Chem. Soc.* 1998; **120**: 4035; (b) van Dongen JPCM, van Dijkman HWD, de Bie MJA. *Recl. Trav. Chim. Pays-Bas* 1974; **93**: 29.
- Karplus M, Pople JA. *J. Chem. Phys.* 1963; **38**: 2803.
- Saika A, Slichter CP. *J. Chem. Phys.* 1954; **22**: 26.
- Jones AJ, Grant DM, Russell JG, Fraenkel G. *J. Phys. Chem.* 1969; **73**: 1624.
- (a) Alder RW, Butts CP, Orpen AG. *J. Am. Chem. Soc.* 1998; **120**: 11526; (b) Arduengo AJ III, Dias HVR, Harlow RL, Kline M. *J. Am. Chem. Soc.* 1992; **114**: 5530; (c) Arduengo AJ III, Goerlich JR, Marshall WJ. *J. Am. Chem. Soc.* 1995; **117**: 11027.
- Arduengo AJ III, Harlow RL, Kline M. *J. Am. Chem. Soc.* 1991; **113**: 361.
- Akitt JW. *NMR and Chemistry. An Introduction to the Fourier Transform-Multinuclear Era*. Chapman & Hall: London, 1983; chapt. 4, 61–101.
- Lindman B, Forsen S. In *NMR and the Periodic Table*, Harris, RK, Mann BE. (eds). Academic Press: London, 1978; 129–181.
- McKeeven LD, Waack R. *J. Chem. Soc., Chem. Commun.* 1969; 750.
- Schmidt MW, Baldrige KK, Boatz JA, Elbert ST, Gordon MS, Jensen JH, Koseki S, Matsunaga N, Nguyen KA, Su SJ, Windus TL, Dupuis M, Montgomery JA. *J. Comput. Chem.* 1993; **14**: 1347.
- Kutzelnigg W, Fleischer U, Schingler M. In *NMR Basic Principles and Progress*, vol. 23, Diehl P, Fluck E, Günther H, Kosfeld R, Seelig J. (eds). Springer: Berlin, 1991; 165–262.