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^{13}C Chemical Shifts and $^{13}C—^{15}N$ Coupling Constants of Some ^{15}N-Labelled Bridgehead Nitro Compounds

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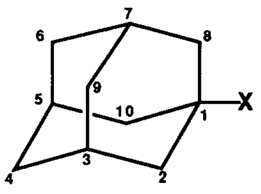
ABSTRACT

Measurement of the ^{13}C NMR spectra of the bridgehead nitro compounds **1a–5a** *has been performed. It is found that one-bond $^{13}C—^{15}N$ coupling is not necessarily a reflection of the degree of s character of the bridgehead carbon exocyclic bonding orbital. Although the magnitude of vicinal coupling to the bridgehead carbon increases, in accordance with the number of three-bond pathways available for transmission of spin information, coupling is actually reduced by opposing contributions from through-space intramolecular orbital interactions.*

INTRODUCTION

Nuclear magnetic resonance studies of nitrogenous compounds are relevant not only because of their intrinsic interest [1–4], but also because of the importance of nitrogen in biological systems. We recently reported [5] the synthesis and ^{13}C NMR spectra of adamantane and a series of bicyclic hydrocarbons containing the $^{15}NH_2$ and $^{15}NH_3^+$ substituents at the bridgehead with particular emphasis on the magnitude of the one-bond, $^1J(CN)$, and vicinal, $^3J(CN)$, coupling constants. For comparison, we have synthesized the corresponding nitro derivatives of the systems **1–5** in order to assess the impact of sp^3 vs. sp^2 nitrogen on these parameters. We now wish to report our observations.



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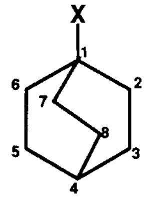

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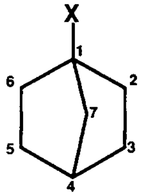

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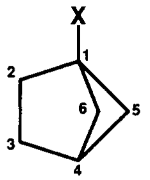

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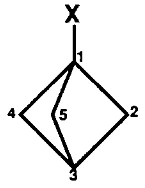

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a, X = $^{15}NO_2$; b, X = $^{15}NH_2$; c, X = $^{15}NH_3^+$; d, X = ^1H; e, X = ^{19}F

RESULTS AND DISCUSSION

The required nitro compounds **1a–5a** were synthesized readily and in good yield by *m*-chloroperbenzoic acid oxidation of the corresponding amine in hot 1,2-dichloroethane [6]. Table 1 contains the ^{13}C chemical shifts of the substrates as well as those of the parent hydrocarbons **1d–5d**. Predictably, the α-effect of the nitro group is seen to be paramagnetic and substantial, although the range of substituent-induced shifts is quite variable. Thus the magnitude

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Dedicated with affection to Ernest L. Eliel on the occasion of his seventieth birthday.

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TABLE 1 Carbon-13 Chemical Shifts[a,b] of the Nitro Compounds **1a–5a**

Compound					
	C1	C2, 8, 9	C3, 5, 7	C4, 6, 10	
1a	84.7	40.9	29.7	35.5	
	(28.8)	(38.2)	(28.8)	(38.2)	
	C1	C2, 6, 7	C3, 5, 8	C4	
2a	84.6	30.1	26.2	23.8	
	(24.0)	(26.0)	(26.0)	(24.0)	
	C1	C2, 6	C3, 5	C4	C7
3a	91.8	33.8	29.7	35.3	42.6
	(36.6)	(30.0)	(30.0)	(36.6)	(38.6)
	C1	C2	C3	C4	C5, 6
4a	83.8	29.5	27.8	31.0	43.6
	(39.5)	(26.3)	(26.3)	(39.5)	(39.0)
	C1	C2, 4, 5	C3		
5a	66.5	53.2	20.1		
	(33.6)	(50.8)	(33.6)		

[a] ±0.02 ppm. Shifts determined on **1a–5a** dissolved in $CDCl_3$.
[b] Values in parentheses refer to the chemical shifts in the parent hydrocarbons.

of the shift decreases as the s character of C1 in the substrate increases as illustrated by the α-shift of ca. 85 ppm in the essentially strain free adamantane derivative **1a** to only 33 ppm in 1-nitrobicyclo[1.1.1]pentane **5a**. β-Shifts are paramagnetic and modest in size ranging from 2–4 ppm. The remaining ^{13}C shifts are largely unexceptional except for the prodigious γ-upfield shifts of the bridgehead carbons in **4a** (−8.5 ppm) and **5a** (−13.5 ppm). This kind of behavior has been noted previously in connection with our work on the corresponding amines **4b** and **5b** and their hydrochlorides **4c** and **5c** [5] and the fluorides **4e** and **5e** [7]. In all these related substrates, the highly electronegative antiperiplanar substituent is found to induce large diamagnetic perturbations of the γ-bridgehead carbons, a phenomenon detected some years ago [8] in connection with other substrates. In the case of the bicyclo[*n*.1.1]alkyl systems **4a** and **5a**, we believe that the effect of the substituent is transmitted via intraannular interactions involving rear lobe overlap of the bridgehead carbon exocyclic bonding orbitals. This type of interaction is believed to be responsible for the enhanced four-bond coupling observed between bridgehead hydrogen [9] in **5d** and between bridgehead hydrogen and fluorine [7] in **5e**.

^{13}C—^{15}N coupling constants of the nitro compounds **1a–5a** are assembled in Table 2. One of the more noteworthy couplings is one involving the directly bonded ^{13}C and ^{15}N nuclei. These are found to be at least 50% larger than those in the amines **1b–5b** in agreement with corresponding values in aliphatic compounds such as nitromethane and methylamine [10] and aromatic analogues such as nitrobenzene and aniline [10]. The series of substrates **1a–5a** is arranged in order of increasing constraint at the bridgehead position, and the question arises as to how this affects the magnitude of $^1J(CN)$. In principle, the extent of coupling between directly bonded nuclei would normally be expected to be larger with enhanced s character, although Schulman and Venanzi [11], in a major contribution to the theory underlying one-bond carbon–nitrogen couplings, conclude that there is a complex interplay of the various contributors to $^1J(CN)$. It can be seen that the value of $^1J(CN)$ does indeed show a graded increase from 4.88–8.10 Hz in the first three members of the series. However there is a dramatic drop between **4a** (7.03 Hz) and **5a** (2.44 Hz).

A similar observation was made previously [5] in connection with the values of $^1J(CN)$ in the amines **1b–5b**. In fact, in the case of 1-aminobicyclo[1.1.1]pentane **5b**, one-bond coupling was not detectable. By contrast, $^1J(CN)$ in nitromethane is (−)10.5 Hz [10], and in nitrobenzene (−)14.5 Hz [12]. Clearly, in the case of the distorted ring systems **4a** and **5a** under study here, Fermi contact is not the dominating influence normally found. For

TABLE 2 ^{13}C—^{15}N Coupling Constants[a,b] in the Nitro Compounds **1a–5a**

Compound	^1J	^2J	^3J	^4J
1a	4.88	0.34	1.58	0.20
2a	6.20	0.19	1.76	0.24
3a	8.10	0.44 (C2)	1.95 (C3)	—
		0.50 (C7)	2.89 (C4)	
4a	7.03	1.03 (C2)	1.65 (C3)	—
		n.c.d. (C5)	4.96 (C4)	
5a	2.44	0.28	6.04	—

[a] In Hz, ±0.02 Hz.
[b] n.c.d. = no coupling detected (J ≤ 0.2 Hz).

these substrates the orbital and spin dipolar terms would appear to make a substantial contribution to the overall value of ^{1}J(CN) and in a direction that opposes that of the contact term.

Vicinal ^{13}C—^{15}N couplings in the nitro compounds **1a–5a** are somewhat larger than those in the related amines **1b–5b** and ammonium compounds **1c–5c**. Values of ^{3}J(CN) involving the nonbridgehead carbons (C3) in **2a–4a** fall within the narrow range 1.58–1.95 Hz. Interestingly, vicinal coupling in 1-nitrobicyclo[2.2.1]heptane **3a** is greatest, yet the N–C–C–C3 dihedral angle in this substrate (154°) is less than those (180°) in both **2a** and **4a**. The magnitude of ^{3}J(^{15}N—^{13}C4) is larger than ^{3}J(^{15}N—^{13}C3) in **3a**, presumably on the basis of the greater N–C–C–C4 dihedral angle (180°). We regard ^{3}J(^{15}N—^{13}C4) in **3a** (2.89 Hz) as an important "benchmark" because it is thought to be comprised of through-bond contributions via the σ-framework only with an essentially zero through-space contribution in view of the distance of separation of the bridgehead carbon atoms. Accordingly, through-bond coupling in the case of 1-nitrobicyclo[2.1.1]hexane **4a** may reasonably be expected to correspond to a value of ca. 5.8 Hz for ^{3}J(^{13}N—^{13}C4) since there are now two three-bond pathways available for transmission of coupling information. Extending this empirical analysis to the bicyclo[1.1.1]pentyl system would suggest a ^{3}J(CN) value of ca. 8.7 Hz. Experimentally, it is found that the values in these compounds are considerably less, viz., 4.96 and 6.04 Hz, respectively. We attribute the lower than expected values of ^{3}J(CN) in **4a** and **5a** to the effect of a contribution to coupling that is transmitted by overlap of the rear lobes of the exocyclic carbon bonding orbitals, a component that is thought to oppose that transmitted through the σ bond framework. Thus the nitro compounds behave much like the corresponding amines and ammonium salts investigated previously [5], whereas in the fluorides **4e** and **5e** [7] and the hydrocarbons **4d** and **5d** through-space and through-bond interactions reinforce each other.

EXPERIMENTAL SECTION

General NMR operating procedures for measuring chemical shifts and ^{13}C—^{15}N coupling constants described previously [5] were adopted. The natural and [^{15}N]-labelled amines available earlier were employed as precursors to the corresponding nitro compounds.

1-Nitroadamantane

1-Aminoadamantane (0.3 g, 2 mmol) in 1,2-dichloroethane (4 mL) was added to a suspension of 80% *m*-chloroperbenzoic acid (1.73 g, 8 mmol) in 1,2-dichloroethane (9 mL) and the mixture heated at reflux for 5 min. The cooled mixture was diluted with dichloromethane (12 mL) and then extracted with 4 M NaOH (5 mL) and 10% HCl (5 mL) before being dried ($MgSO_4$). Evaporation of the solvent and sublimation (95°C, 0.2 mm) of the residue furnished 1-nitroadamantane (0.3 g, 83%) mp 166°C (Ref. [13] mp 158.5–159.5°C); ^{1}H NMR (CCl_4) δ 2.2 (brs, 9H), 1.8 (brs, 6H); ^{13}C NMR ($CDCl_3$) δ 29.74 (C3), 35.54 (C4), 40.85 (C2), 84.73 (C1). 1-[^{15}N]-Nitroadamantane (**1a**) was prepared in a similar way from 1-[^{15}N]aminoadamantane and had physical properties in agreement with those of the unlabelled isomer.

1-Nitrobicyclo[2.2.2]octane

1-Aminobicyclo[2.2.2]octane (0.25 g, 2.0 mmol) was oxidized by *m*-chloroperbenzoic acid (4 eq) following the procedure described above. Workup yielded a solid that upon sublimation (80°C, 0.4 mm) gave 1-nitrobicyclo[2.2.2]octane (0.21 g, 70%) mp 75–76°C; ^{1}H NMR ($CDCl_3$) δ 1.58–2.27(m); ^{13}C NMR ($CDCl_3$) δ 23.84 (C4), 26.17 (C3), 30.07 (C2), 84.64 (C1). Anal calcd for $C_8H_{13}NO_2$: C, 61.9; H, 8.4. Found: C, 61.9; H, 8.2. 1-[^{15}N]Nitrobicyclo[2.2.2]octane (**2a**), prepared as outlined above from 1-[^{15}N]aminobicyclo[2.2.2]octane, had physical properties consistent with those of the unlabelled substance.

1-Nitrobicyclo[2.2.1]heptane

A solution of bicyclo[2.2.1]heptane-1-carboxamide [5] (2.98 g, 22 mmol) in acetonitrile (220 mL) was added dropwise to a stirred slurry of hydroxytosyloxyiodobenzene (8.7 g, 22 mmol) in acetonitrile. After several minutes, a clear solution was obtained and this was heated under reflux for 3 h. The mixture was cooled to room temperature, concentrated to 40 mL and the precipitate collected and washed with ether. The crude 1-ammoniobicyclo[2.2.1]heptane tosylate (5.5 g) was dissolved in 2% sodium hydroxide (50 mL) and the mixture extracted with 1,2-dichloroethane (2 × 40 mL). The extract was dried (K_2CO_3) and then treated with 80% *m*-chloroperbenzoic acid (14 g) as described above. Workup afforded the crude product that upon sublimation (70°C, 0.1 mm) gave 1-nitrobicyclo[2.2.1]heptane (2.05 g, 80%) mp 80°C (Ref. [14] mp 63°C); ^{1}H NMR (CCl_4) δ 1.38–2.52 (m); ^{13}C NMR ($CDCl_3$) δ 29.74 (C3), 33.80 (C2), 35.27 (C4), 42.64 (C7), 91.83 (C1). Anal calcd for $C_7H_{11}NO_2$: C, 59.6; H, 7.9; N, 9.9. Found: C, 59.2; H, 7.8, N, 9.8. 1-[^{15}N]Nitrobicyclo[2.2.1]heptane (**3a**) was generated from the [^{15}N]-labelled amine under the conditions specified above and had the expected physical properties.

1-Nitrobicyclo[2.1.1]hexane

By following the above procedure, bicyclo[2.1.1]hexane-1-carboxamide [5] (0.9 g, 7.2 mmol) was converted into the corresponding amine and, by oxidation with *m*-chloroperbenzoic acid, into 1-nitrobicyclo[2.1.1]hexane (0.33 g, 36% overall) bp 70°C (0.2 mm), mp 23°C; ^{1}H NMR (CCl_4) δ 1.65–2.30 (m, 8 H), 2.40 (brs, 1 H); ^{13}C NMR ($CDCl_3$) δ 27.79 (C3), 29.47 (C2), 31.04 (C4), 43.61 (C5), 83.81 (C1). Anal calcd for $C_6H_9NO_2$: C, 56.6; H, 7.1; N, 11.0. Found: C, 56.5; H, 7.4; N, 11.1. 1-[^{15}N]Nitrobicyclo-[2.1.1]hexane **(4a)** was prepared in a similar manner from 1-[^{15}N]aminobicyclo[2.1.1]hexane and showed physical data in accord with those of the unlabelled isomer.

1-Nitrobicyclo[*1.1.1*]*pentane*

1-Aminobicyclo[1.1.1]pentane (0.3 g, 3.6 mmol) was treated with *m*-chloroperbenzoic acid (4 eq) in 1,2-dichloroethane as outlined above. Workup and distillation of the product yielded the title compound (0.09 g, 22%); ^{1}H NMR ($CDCl_3$) δ 2.37 (s, 6 H), 2.64 (s, 1 H); ^{13}C NMR ($CDCl_3$) δ 20.13 (C3), 53.20 (C2), 66.50 (C1). HRMS calculated for $C_5H_7NO_2$: 113.0477. Found: 113.0475. 1-[^{15}N]Nitrobicyclo[1.1.1]pentane **(5a)** was synthesized from the corresponding amine by the procedure described above and had physical data consistent with those of the unlabelled compound.

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