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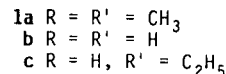
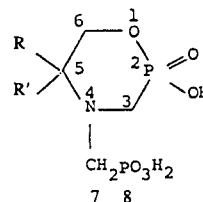
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The ^1H and ^{13}C nmr signals of the methylene groups directly linked to the phosphorus atoms, namely P(2)-C(3) H_2 and P(8)-C(7) H_2 in **1a** were assigned with the help of heteronuclear decoupling experiments and HETCOR spectrum.

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[(Tetrahydro-2-hydroxy-4*H*-1,4,2-oxazaphosphorin-4-yl)methyl]phosphonic acid *P*-oxides **1** are obtained by the reaction of 2-aminoalkanols with formaldehyde and phosphorous acid in the presence of hydrochloric acid [1-3]. The cyclic structure of compound **1b** has been confirmed by X-ray diffraction studies [4]. In compounds **1**, there are two methylene groups directly linked to phosphorus atoms, namely P(2)-C(3) H_2 and P(8)-C(7) H_2 . It was not possible to unambiguously assign the ^1H and ^{13}C nmr signals of these methylene groups from the ^1H and ^{13}C nmr spectra reported earlier [1]. We have now recorded the ^{31}P (Figure 1), ^1H (Figure 2) and ^{13}C nmr spectra of **1a** on a



In its ^{31}P nmr, **1a** exhibits two signals at 5.1 ppm and 8.7 ppm. The signal at 5.1 ppm was assigned to the ring phosphorus P(2) because in a proton-coupled spectrum, it split into an apparent quintet because of the coupling with C(3)- H_2 and C(6)- H_2 groups [3]. There is further fine splitting of each peak of the quintet into a triplet (see later for explanation). The signal at 8.7 ppm was assigned to the P(8) because in a proton-coupled spectrum, it split into a triplet.

In the ^1H nmr, **1a** exhibits the three methylene signals at 3.45 ppm (double doublet), 3.66 (doublet) and 4.22 (doublet). Based on the chemical shift, the signal at 4.22 ppm is assigned to the C(6)- H_2 group. In a heteronuclear decoupling experiment, the effect of irradiating various ^1H nmr signals on the ^{31}P nmr was studied. The most significant observation was that when the ^1H nmr signal at 3.45 ppm was irradiated, the ^{31}P signal at 8.7 ppm collapsed to a singlet suggesting that the CH_2 -group appearing at 3.45 ppm in the ^1H nmr was linked to P(8). The ^{31}P signal at 5.1 ppm collapsed to a triplet when either of the ^1H nmr signals at 3.66 ppm and 4.22 ppm was irradiated suggesting that the CH_2 -group appearing at 3.66 ppm was linked to P(2). These assignments were further confirmed by the observation of the ^1H nmr spectrum with selective and broad-band ^{31}P decoupling experiments [5,6]. The broad-band ^{31}P decoupling during ^1H observation showed that all couplings observed in the ^1H nmr spectrum were due to the coupling with the phosphorus groups and there were no H-H couplings observed. Selective irradiation of

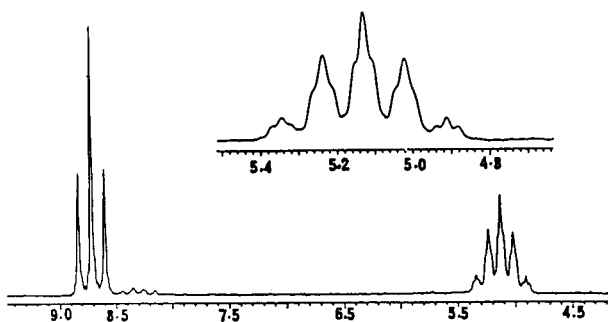


Figure 1. Proton-coupled ^{31}P nmr spectrum of **1a** in deuterium oxide at 121 MHz.

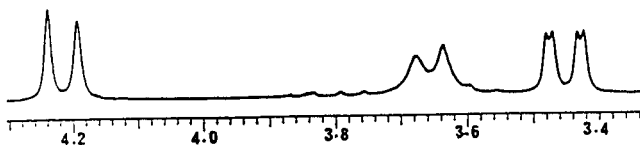


Figure 2. ^1H nmr spectrum of **1a** in deuterium oxide at 300 MHz showing the protons of the methylene groups directly linked to P atoms and the protons of the -OCH_2 group.

Varian Associates Gemini-300 broad band spectrometer and performed additional experiments (namely heteronuclear decoupling and HETCOR) to completely assign all the spectral signals for compound **1a**. Compound **1a** was chosen for this study because, as reported earlier [1], its ^1H nmr was well resolved.

phosphorus at 8.7 ppm collapsed the ^1H nmr signal at 3.45 ppm and selective irradiation of phosphorus at 5.1 ppm collapsed the ^1H nmr signals at 3.66 and 4.22 ppm.

Next an HETCOR experiment (Figure 3) was performed to assign the ^{13}C nmr signals to the methylene groups. The CH_2 -group giving rise to the signal at 3.45 ppm in the ^1H nmr is correlated with ^{13}C nmr signal at 51.6 ppm [therefore C(7)] (a doublet doublet, showing one bond P(8)-C(7) coupling of 136.8 Hz and a three bond P(2)-C(7) coupling of 8.5 Hz). The CH_2 -group giving rise to the signal at 3.66 ppm in the ^1H nmr is correlated with the ^{13}C signal at 50.2 [therefore C(3)] (a doublet with one bond P(2)-C(3) coupling of 128.8 Hz).

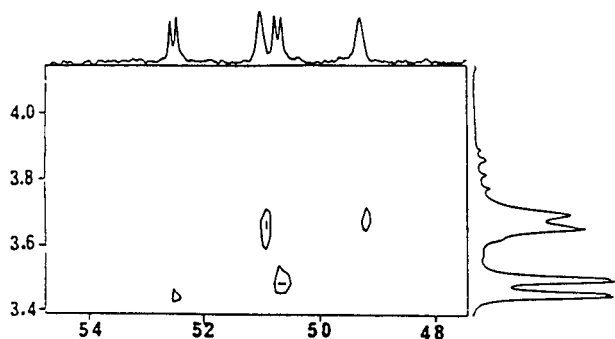


Figure 3. HETCOR spectrum of **1a** in deuterium oxide at observation frequencies of 300.07/75.46 MHz for ^1H and ^{13}C , respectively. The protons and carbons of the methylene groups directly linked to P atoms are shown.

In the ^1H nmr, the C(7)- H_2 group appears as a doublet of a doublet showing two bond P(8)-H coupling of 14.3 Hz and a four bond P(2)-H coupling of 3.0 Hz. In the ^{31}P nmr, each peak of the quintet appearing at 5.1 ppm [P(2)] is split into a triplet because of this four bond coupling with the protons of the C(7)- H_2 group.

Table 1
Spectral Data for **1a**

^{31}P nmr ppm	5.13 [13.2 Hz, 13.2 Hz, 3.0 Hz, P(2)] 8.72 [14.2 Hz, P(8)]
^1H nmr ppm	1.45 (s, 6H, CH_3), 3.45 (dd, 14.3 Hz, 3.0 Hz, 2H, P(8)-C(7) H_2), 3.66 (d, 12.3 Hz, 2H, P(2)-C(3) H_2), 4.22 (d, 13.7 Hz, 2H, OCH_2)
^{13}C nmr ppm	20.4 (CH_3), 50.2 (d, 128.8 Hz, P(2)-C(3)), 51.6 (dd, 136.8 Hz, 8.5 Hz, P(8)-C(7)), 67.8 (dd, 7.4 Hz, 3.0 Hz, $\text{C}(\text{CH}_3)_2$), 73.5 (d, 4.8 Hz, OCH_2)

EXPERIMENTAL

All nmr spectra except broad band and selective ^{31}P decoupling experiments [5,6] were acquired on a Varian Associates Gemini-300 broadband spectrometer operating at a frequency of 300.075 MHz for protons, 75.462 MHz for carbon and 121.47 MHz for phosphorus. Samples were dissolved in deuterium oxide to obtain a saturated solution at room temperature.

All spectra were acquired at 25°. Chemical shifts are reported in ppm relative to internal 3-(trimethylsilyl)propionic-2,2,3,3- d_4 acid, sodium salt for carbon and proton spectra. The phosphorus chemical shift data is referenced to an external capillary of 85% orthophosphoric acid.

Proton spectra were obtained using a 10 μs (52°) pulse width with no delay between transients and a sweep width of 1818.4 Hz. Carbon spectra were collected with a 10 μs (68°) pulse with a 1 second delay between transients. Phosphorus spectra were accumulated using a 10 μs (60°) pulse with a 1 second delay between repetitions. Waltz-16 modulated decoupling was employed for proton decoupled spectra.

A one-dimensional carbon spectrum was acquired with a spectral width of 5518.8 Hz. 256 increments of 128 transients each were collected to encode the proton-carbon correlation information. A coupling constant of 140 Hz was used to suppress long range proton carbon interactions. Standard Gemini software was used to acquire, process and output the data from the HETCOR experiment.

The collection of single frequency proton decoupled phosphorus data was facilitated by collecting a series of spectra under computer control in which the decoupler offset was augmented in 5 Hz increments through the spectral region of interest.

REFERENCES AND NOTES

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- [4] B. I. Makaranets, T. N. Polynova, M. A. Porai-Koshits and S. A. Il'ichev, *Izv. Akad. Nauk, SSSR, Ser. Khim.*, 2649 (1984).
- [5] We thank Dr. D. André d' Avignon of Washington University, St. Louis, for the broadband and selective ^{31}P decoupling experiments at the high resolution nmr facility of Washington University.
- [6] Broad band and selective ^{31}P decoupling experiments were carried out during ^1H observation on a Varian VXR-500 multinuclear pulsed-fourier transform instrument. Sample was dissolved in deuterium oxide. These experiments were done at 11.4 Tesla at a ^1H observation frequency of 499.843 MHz. The following collection conditions were used: temperature = 25°, ^1H pulse length = 3 μsec (40° flip angle), ^1H spectral width = 3638 Hz, acquisition time = 1.9 sec, 8 transient, preacquisition delay = 1 sec. The ^{31}P decoupling field was centered between two ^{31}P resonances for broad band waltz decoupling over a width of 3400 Hz and centered on individual ^{31}P resonances for selective decoupling with a field strength sufficient to collapse the H-P coupling.