# Nitrogen 14 Nuclear Qnadrupole Resonance of Alloxan·$H_2O$

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**Synopsis.** The $^{14}N$ nuclear quadrupole resonance spectra of alloxan·$H_2O$ have been observed at room temperature. The predominant tautomer in a solid is concluded to be 5,5-dihydroxypyrimidine-2,4,6-trione. The NQR data were interpreted qualitatively by means of the Townes and Dailey theory.

Some nitrogen-containing heterocyclic compounds have been attracting pharmacological and biological interest because of thier pharmaceutical action, mainly attributable to the nitrogen atom's ability to make hydrogen bonds. For this reason, it seems important to obtain information about the electron density on the nitrogen nucleus, and, hence, about the chemical bonding of such heterocyclic compounds. Previously we have reported the $^{14}N$ NQR of sulfur-substituted uracils and analysed the valence-electron distribution around the nitrogen atom, using the Townes and Dailey theory.[1] In this paper we wish to report the first observation of the $^{14}N$ NQR of alloxan·$H_2O$. It is an analogue to barbituric acid and has been extensively studied in order to elucidate its ability to cause diabetes. For $^{14}N$ NQR, we can expect the three frequencies given in the following formulae,[2]

$$\nu_{\pm} = \frac{3}{4}e^2Qq/h\cdot\left(1\pm\frac{\eta}{3}\right)$$
$$\nu_0 = \nu_+ - \nu_- = \frac{1}{2}\eta\cdot e^2Qq/h \qquad (1)$$

where $e^2Qq/h$ is the quadrupole coupling constant and where $\eta$ is the asymmetry parameter, which is the measure of the deviation from the axially symmetry of the electric field gradient (e.f.g.). The NQR data of alloxan·$H_2O$ were interpreted qualitatively in terms of the Townes and Dailey theory.

## Experimental

The nuclear magnetic double resonance in the laboratory frame[3] was employed to detect the NQR transitions. Before performing the double-resonance experiment, the high-field (about 0.6 T) and zero-field spin lattice relaxation times for alloxan·$H_2O$ were measured in order to set the double-resonance time sequence, T-$\tau$ (cycle time and zero-field time respectively). NQR searching was carried out from 400 kHz to 4 MHz in 10 kHz steps, so the total experimental error may amount to about 10 kHz. The apparatus was a home-made one and has been described in detail in our previous paper.[4] The sample was a polycrystalline guaranteed-grade chemical obtained from the Tokyo Kasei Kogyo Co., Ltd. The sample volume was about 1 $cm^3$. All the experiments were performed at room temperature.

## Results and Discussion

The proton high-field spin-lattice relaxation time, $T_1$, of alloxan·$H_2O$ at room temperature was 25 s. In the zero field, the proton magnetization at first decreased quickly with the time constant, $T_{1D}$ (6 s), and later more slowly with the time constant, $T_{1N}$ (44 s). This slow decay of proton magnetization may be caused by the remagnetization of proton system by cross interaction with the $^{14}N$ system, which has a long spin-lattice relaxation time. From these data, the double-resonance cycle was set as $T$=60 s and $\tau$=2 s. The observed transition frequencies, the quadrupole coupling constants, $e^2Qq/h$, and the asymmetry parameters, $\eta$, of alloxan·$H_2O$ are given in Table 1, together with the data of its analogue, barbituric acid.[5] Figure 1 shows the NQR spectrum of alloxan·$H_2O$. Before analysing the charge densities, the correct tautomeric structure for alloxan·$H_2O$ must be settled. For alloxan·$H_2O$, Baeyer supposed the water molecule of alloxan·$H_2O$ to be incorporated into the alloxan molecule as the hydroxyl group.[6] His assigned configurational formula of alloxan·$H_2O$ is Illustration (A), shown below. For this formula, the keto or enol tautomeric forms through the migration of the hydrogen atoms may be possible; see Illustrations (B) and (C).

The nitrogens in (A) are both pyrrole-like, in (B) one is pyrrole-like and the other is pyridine-like, and in (C) both are pyridine-like. A simple criterion for distinguishing pyrrole-like and pyridine-like bond configurations is deduced when the nuclear quadrupole coupling constants of the pyridine-like and pyrrole-like nitrogens are compared, since the coupling constants of pyridine-like nitrogens are usually greater than 4

TABLE 1. NQR TRANSITION FREQUENCIES (kHz), QUADRUPOLE COUPLING CONSTANTS, $e^2Qq/h$ (kHz), AND ASYMMETRY PARAMETERS, $\eta$, OF alloxan·$H_2O$ AND ITS ANALOGUE, BARBITURIC ACID

| Compound | [$\nu_+$, | $\nu_-$, | $\nu_0$] | $e^2Qq/h$ | $\eta$ |
|---|---|---|---|---|---|
| Alloxan·$H_2O$ | [2670, | 2060, | 610] | 3150 | 0.39 |
| | [2600, | 1980, | 620] | 3050 | 0.41 |
| Barbituric acid | [2575, | 1895, | —] | 2980 | 0.46 |
| | [2480, | 1755, | —] | 2823 | 0.52 |

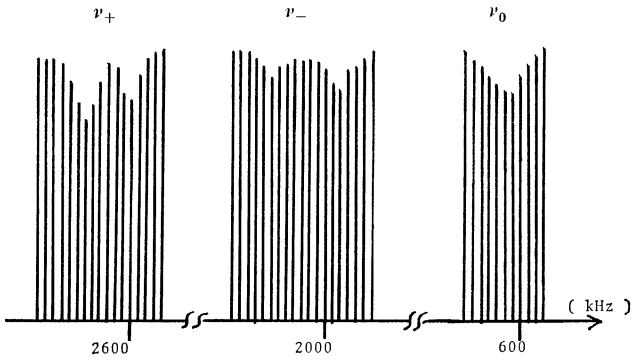
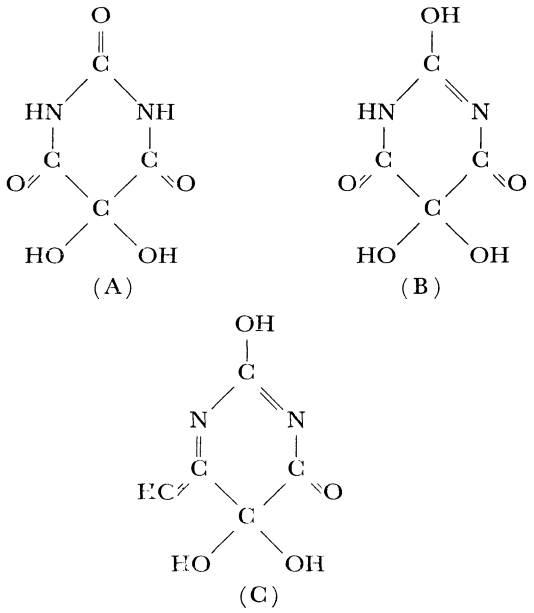



Fig. 1. $^{14}N$ NQR spectrum of alloxan·$H_2O$.




MHz. Additional insight can be obtained from the NQR spectrum shown in Fig. 1. In proton-nitrogen double-resonance experiments, nitrogen not directly bonded to hydrogen atoms gives weak absorption lines, and usually the $\nu_-$ lines are smeared out. From these considerations, we can decide that alloxan·$H_2O$ exists predominantly in the triketo configuration (A) in its ground state; this decision agrees with the previous X-ray diffraction study.[7]

As the NC bond lengths and CNC angle for each nitrogen in alloxan·$H_2O$ are quite similar, we can expect that the NQR coupling constants of two nitrogens of alloxan·$H_2O$ are not very different. However the difference of coupling constants is 100 kHz, as may be seen in Table 1. This large difference can be explained by the difference in the intermolecular hydrogen bonds at each nitrogen atom. The two hydrogen bond lengths, N(1)–H(1)–O and N(3)–H(3)–O, differ by 0.164 Å.[7] This large difference would cause a large change in the coupling constants of the nitrogens. It would be possible tentatively to assign one set of observed lines to one particular site by considering the two different intermolecular hydrogen bonds at each nitrogen site and the NQR data experimentally obtained. However, any definitive assignment seems very difficult; therefore, we do not make any such assignment here.

With the Townes and Dailey theory, expressions relating the NQR data to the charge densities are derived as follows;

$$\pi - \sigma_{NC} = \frac{4}{3}\nu_+/(e^2Qq_0/h)$$
$$\sigma_{NH} - \sigma_{NC} = \frac{4}{3}\nu_0/(e^2Qq_0/h)\cdot[1/1-\cot^2\gamma] \quad (2)$$

Table 2. Values of $\pi$ and $\sigma_{NH}$ populations for alloxan·$H_2O$ and barbituric acid. $\pi$ and $\sigma_{NH}$ are calculated assuming $e^2Qq_0/h=9.1$ MHz, and $\sigma_{NC}=1.200$

| Compound | $\pi$ | $\sigma_{NH}$ | $[\gamma]$[a] |
|---|---|---|---|
| Alloxan·$H_2O$ | 1.590 | 1.320 | [0.39] |
| | 1.581 | 1.322 | [0.41] |
| Barbituric acid | 1.577 | 1.334 | [0.46] |
| | 1.563 | 1.342 | [0.52] |

a) The asymmetry parameters are used to distinguish the two nitrogen sites in each molecule.

where $\pi$ is the pi population, $\sigma_{NH}$ is the NH sigma population, $\sigma_{NC}$ is the averaged NC sigma population, $2\gamma$ is the CNC angle, and $q_0$ is the electric-field gradient caused by a 2p electron of the nitrogen atom. In order to estimate these charge densities, $e^2Qq_0/h$, $\sigma_{NC}$, and 2 $\gamma$ are set at 9.1 MHz,[8] 1.200, and 126°, the averaged values of the CNC angles for each nitrogen in alloxan·$H_2O$ and barbituric acid.[7] The estimated values of the $\pi$ and $\sigma_{NH}$ populations are shown in Table 2. The great $\pi$ populations and the small sigma populations of alloxan·$H_2O$ compared with those of barbituric acid can easily be understood, since the hydroxyl group is known to be $\pi$-electron-donating and $\sigma$-electron-withdrawing.

## Conclusion

In this paper, the following two conclusions were obtained;

1. Alloxan·$H_2O$ exists predominantly in the 2,4,6-triketo-5,5-dihydroxy structure in a solid; this determination agreed with the results of the X-ray diffraction study.
2. The difference in coupling constants for nitrogens in alloxan·$H_2O$ is attributable to the difference in intermolecular hydrogen bonds for each nitrogen.

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