The NMR signals of $^{123}$Te and $^{125}$Te have been observed in solutions of K$_2$TeO$_3$ and Na$_2$TeO$_3$ in D$_2$O. In these solutions the ratios of Larmor frequencies $\nu(\text{^{125}Te})/\nu(\text{^{123}Te})$, $\nu(\text{^{125}Te})/\nu(\text{\textsuperscript{2}H})$ and $\nu(\text{^{125}Te})/\nu(\text{^{23}Na})$ have been determined with high accuracy. With the measured chemical shifts of $\text{\textsuperscript{2}H}$, $\text{^{23}Na}$, $\text{^{125}Te}$ relative to infinitely diluted solutions the ratios of the Larmor frequencies are extrapolated and values of the magnetic moments are given. The relaxation times $T_1$ and $T_2$ are very different for $\text{^{125}Te}$ in TeO$_3^{2-}$: a ratio $T_1/T_2$ of $8.2 \pm 0.4$ has been found. No nuclear Overhauser effect due to dipole-dipole interaction of $\text{^{125}Te}$ with the water protons has been detected.

### Results

**a) Ratio of the Larmor Frequencies $\nu(\text{^{125}Te})/\nu(\text{^{123}Te})$**

In a 4 molal solution of K$_2$TeO$_3$ in D$_2$O, the ratio of the Larmor frequencies of $^{125}$Te and $^{123}$Te was measured at different days using the HR-probe:

$$\nu(\text{^{125}Te})/\nu(\text{^{123}Te}) = 1.2055816(48) \times 10^6.$$
chemical shift is smaller than $1 \cdot 10^{-7}$ and therefore chemical shift data of $^{125}\text{Te}$ and $^{123}\text{Te}$ are equivalent.

b) Ratio of the Larmor Frequencies $\nu(\text{Te})/\nu(\text{H})$

In the 4 molal solution of K$_2\text{TeO}_3$ in D$_2$O, the ratio of the Larmor frequencies of $^{125}\text{Te}$ and $^2\text{H}$ was measured at different days with the HR-probe. For $^2\text{H}$ the centre band signal of the reference channel at 13.8145833 MHz was used. The result is:

$$\nu(\text{Te})/\nu(\text{H}) = 2.058 \pm 0.15(15).$$

In a further experiment, $^{23}\text{Na}$ was used as reference nucleus since its Larmor frequency is not far away from that one of $^{125}\text{Te}$. In a 3 molal solution of Na$_2\text{TeO}_3$ in D$_2$O the Larmor frequencies of $^{125}\text{Te}$ and $^{23}\text{Na}$ were measured with the HP-probe:

$$\nu(\text{Te})/\nu(\text{Na}) = 1.194 \pm 0.007(7).$$

The linewidth of the $^{23}\text{Na}$ signal is 34 Hz and decreases with decreasing concentration of the solutions.

c) Dependence of the Larmor Frequencies on Concentration

The Larmor frequencies of $^2\text{H}$, $^{23}\text{Na}$ and $^{125}\text{Te}$ depend on the concentration of the aqueous solution. In the given solutions the Larmor frequencies of all the nuclei decrease with decreasing concentration. The shifts are about $\delta(\text{H}) = 1$, $\delta(\text{Na}) = 2$ and $\delta(\text{Te}) = 2$ referred to infinite dilution. The dependence of the Larmor frequency has been measured and has been found to be nearly linear for these nuclei.

d) Larmor Frequencies at Vanishing Concentration and Magnetic Moments

From the chemical shift data and the ratios of the Larmor frequencies the following ratios for vanishing concentration in D$_2$O can be derived:

$$\nu(\text{Te})/\nu(\text{H}) \mid \text{extrapol.} = 2.058 \pm 0.15(15),$$

$$\nu(\text{Te})/\nu(\text{Na}) \mid \text{extrapol.} = 1.194 \pm 0.007(7).$$

The magnetic moments of $^{125}\text{Te}$ and $^{123}\text{Te}$ are derived for both ratios using

$$\nu(\text{H})/\nu(\text{H}) = 1.03 \pm 0.06(6) \mid \text{of Nolle},$$

$$\nu(\text{Na})/\nu(\text{H}) = 1.72 \pm 0.04(4) \mid \text{of Lutz},$$

and the magnetic moment of the proton in water, $\mu_p = 2.792 \pm 0.04(11) \mu_N$ (Reference 9). The results are for tellurium in TeO$_3^{2-}$ at infinite dilution:

$$\mu(\text{Te}) = 0.88 \pm 0.04 \mu_N,$$

$$\mu(\text{Te}) = 0.882 \pm 0.04 \mu_N,$$

$$\mu(\text{Te}) = 0.73 \pm 0.04 \mu_N,$$

$$\mu(\text{Te}) = 0.732 \pm 0.04 \mu_N.$$

These results are not corrected for diamagnetism. Using the ratios $\nu(\text{Te})/\nu(\text{Na})$ and $\nu(\text{Te})/\nu(\text{H})$ of Weaver for a solution of TeO$_2$ in HCl one gets values of the magnetic moments, the amount of which is for both nuclei about 200 ppm smaller. This difference indicates a chemical shift of 200 ppm, as in both measurements no paramagnetic catalysts were used. The sign of the magnetic moments is negative.

e) Relaxation Times

Since both tellurium isotopes have the spin 1/2, long relaxation times are expected. Weaver estimated a ratio of the relaxation times of $T_1/T_2$ of 12 in a 3.1 molar solution of TeO$_2$ in HCl. This fact could be a limitation for further applications. Linewidths of about 2 Hz were observed (see Figure 1). For the 4 molal solution of K$_2\text{TeO}_3$ in D$_2$O the relaxation time $T_1$ of $^{125}\text{Te}$ has been measured by

![Fig. 1. Absorption signals of $^{123}\text{Te}$ at 23.592 MHz and of $^{125}\text{Te}$ at 28.442 MHz in a 4 molal solution of K$_2\text{TeO}_3$ in D$_2$O using 10 mm cylindrical sample tubes. The signals were observed with a high resolution probe working in the multi-nuclei mode (17 MHz—38 MHz) and an internal $^2\text{H}$-lock. $^{123}\text{Te}$: number of scans: 500; total measuring time: 25 min, linewidth: 2.0 Hz. $^{125}\text{Te}$: number of scans: 20; total measuring time: 1.5 min, linewidth: 2.7 Hz. The plotted spectrum width is for both signals 43 Hz. For each spectrum 400 data points were accumulated followed by 3696 points of zero filling before the Fourier transformation of 4 K points.](image-url)
the inversion recovery Fourier transform method: the result is: $T_1 = 2.50(10)$ s. Since the observed linewidths were somewhat broadened by the inhomogeneity of the magnetic field, $T_2$ was determined by measuring $T_1/T_2$ using the method of Kronenbitter and Schwenk. The result was $T_1/T_2 = 8.2 \pm 0.4$, which gives for the transversal relaxation time of $T_2 = 0.31(2)$ s. The difference between $T_1$ and $T_2$ is presumably due to exchange phenomena in the tellurite solutions. This fact is also supported by $^{17}$O NMR. In these solutions no separate signals for $\text{H}_2\text{O}$ and the tellurite oxyanion were observed even in a sample, which was enriched in $^{17}$O. Only a single 220 Hz broad $^{17}$O line was detected, which is much broader than the $^{17}$O signal in pure water.

Irradiation of the water proton frequency during the measurement of $^{125}$Te in a solution in $\text{H}_2\text{O}$ did not change the intensity of the tellurium signal (NOE = 0). Therefore only a very small contribution of dipole-dipole relaxation due to the water protons to the relaxation mechanisms of $^{125}$Te can be assumed.

**Conclusions**

For NMR investigations $^{125}$Te is a favourable spin-1/2-nucleus, which has a rather large receptivity, despite of the low natural abundance. The signals in aqueous solutions are narrow and the longitudinal relaxation times are in the range of seconds. Therefore the often occurring serious problems of waiting times are avoidable. All these properties indicate that the nuclear magnetic resonance method can be employed for investigations of tellurium in liquid and solid state physics and chemistry.

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2. H. E. Weaver, Jr., Phys. Rev. 89, 923 [1953].
7. A. Nolle, to be published.