## The Nuclear Spin of $He^3$

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THE nuclear $g$-factor of $He^3$ has been determined by Anderson and Novick[1] by means of the nuclear magnetic resonance method. Assuming a nuclear spin of $\frac{1}{2}$, they obtained for the nuclear magnetic moment the value 2.131 n.m. Even though the spin value $\frac{1}{2}$ appears most probable, to our knowledge no experimental determination of this quantity has yet been made. Since at least in one important case, that of $B^{10}$, a direct determination of the spin[2] has led to a value widely different from the one expected from theory, it appears to be of interest to determine the spin of $He^3$ unambiguously.

We have determined the spin of $He^3$ from the intensity alternation in the band spectrum of the $He_2^3$ molecule. An 88 percent sample of $He^3$ was excited by a slightly condensed discharge through a small Geissler tube. The spectrum was taken in the first order of a 21-foot grating and exhibited several $He_2$ bands. The band chosen for more detailed measurements is the one at 6400A representing a $^3\Sigma^+_\mu - {}^3\Pi_g$-transition. It involves only low lying states which are not likely to be perturbed or affected by $l$-uncoupling. The triplet spliting is negligible. Figure 1 reproduces the photometer curve of part of the $P$ branch showing clearly the intensity alternation. A relative intensity scale obtained by means of a rotating sector is indicated at the left. It can be seen from Fig. 1 that the intensity ratio of successive lines is approximately 3:1. Actual measurement of the original record (using several groups of three successive lines and determining the ratio of the mean of the two outer ones to the central line of each group) gives the intensity ratio 2.8:1. Semiquantitative evaluations of other bands also give ratios close to 3:1. The theoretical ratios for the spins $\frac{1}{2}$, 1, and $\frac{3}{2}$ are 3:1, 2:1, and 1.67:1 respectively. The nuclear spin of $He^3$ is therefore unequivocally established to be $\frac{1}{2}$, in agreement with theoretical predictions. The nuclear spin of $He^3$ is thus the same as that of $H^3$ recently determined from the hyperfine structure of the magnetic resonance spectrum by Nelson and Nafe[3] and from the intensity alternation in $H_2^3$ by Dieke and Tomkins.[4]

In the 6400A band of $He_2^4$ the lines with odd $K$ are missing in the $P$ and $R$ branch (since the nuclear spin is zero and since $He^4$ follows Bose statistics). In the corresponding $He_2^3$ band the lines with odd $K$ are the strong ones (see Fig. 1) showing that the $He^3$ nuclei follow *Fermi statistics*, in agreement with expectation for a nucleus consisting of an odd number of nucleons.

As shown by Fig. 1 the lines of $He^3He^4$ also appear in the spectrum. In agreement with expectation there is no intensity alternation in the $He^3He^4$ band.

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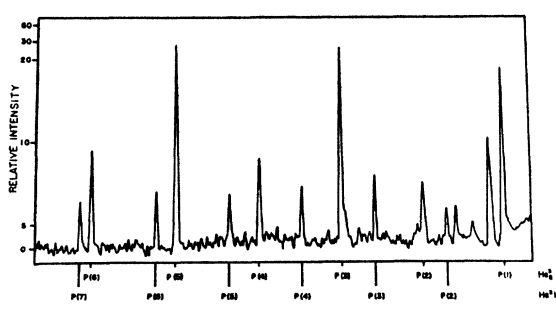


FIG. 1. Photometer curve of a portion of the $P$ branch of $He_2^3$ and $He^3He^4$.

[1] H. L. Anderson and A. Novick, Phys. Rev. **73**, 919 (1948).
[2] Gordy, Ring, and Burg, Phys. Rev. **74**, 1191 (1948).
[3] E. B. Nelson and J. E. Nafe, Phys. Rev. **75**, 1194 (1949).
[4] G. H. Dieke and F. S. Tomkins, Phys. Rev. **76**, 283 (1949).

## Inversion Spectrum of Ammonia

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THIRTY-SEVEN previously unreported ammonia absorption lines have been measured and identified. A Stark-modulation spectrograph with a one-foot absorption cell was used at room temperature with a modified 2K-33 tube[1] as the source. The assignments were made on the basis of the line intensities and a new empirical formula. The frequencies of the lines together with their assigned rotational quantum numbers are given in Tables I and II. The frequencies reported for the $N^{14}H_3$ lines are accurate to about $\pm 0.1$ mc/sec.; and those for $N^{15}H_3$ to about $\pm 0.5$ mc/sec. The experimental error of the $N^{15}H_3$ lines is determined by the fact that this isotope concentration is only 0.38 percent in unenriched ammonia as used in this study.

TABLE I. $N^{14}H_3$ absorption lines.

| Frequency (mc/sec.) $\pm 0.1$ | Assignment ($J$, $K$) |
|---|---|
| 16798.3 | 9, 5 |
| 16841.3 | 7, 1 |
| 17291.6 | 7, 2 |
| 17378.1 | 8, 4 |
| 18017.6 | 7, 3 |
| 18127.2 | 12, 9 |
| 18162.6 | 11, 8 |
| 18178.0 | 13, 10 |
| 18285.6 | 10, 7 |
| 18313.9 | 14, 11 |
| 18391.6 | 6, 1 |
| 18499.5 | 9, 6 |
| 18535.1 | 15, 12 |
| 18808.7 | 8, 5 |
| 18842.9 | 16, 13 |
| 18884.9 | 6, 2 |
| 19838.4 | 5, 1 |
| 21818.1 | 14, 11 |
| 23777.4 | 16, 14 |
| 24680.1 | 17, 15 |

TABLE II. $N^{15}H_3$ absorption lines.

| Frequency (mc/sec.) $\pm 0.5$ | Assignment ($J$, $K$) |
|---|---|
| 17097.2 | 7, 3 |
| 17548.4 | 9, 6 |
| 17855.3 | 8, 5 |
| 17943.4 | 6, 2 |
| 18258.8 | 7, 4 |
| 18788.2 | 6, 3 |
| 19387.5 | 5, 2 |
| 19702.1 | 8, 6 |
| 19708.2 | 9, 7 |
| 19793.4 | 7, 5 |
| 19810.8 | 10, 8 |
| 19984.6 | 6, 4 |
| 20009.9 | 11, 9 |
| 20131.6 | 4, 1 |
| 20272.3 | 5, 3 |
| 20683.0 | 4, 2 |
| 26243.0 | 9, 9 |

On the basis of the increased number of accurately measured lines now available, a new empirical formula

$$\begin{aligned}\nu(\text{mc/sec.}) = {} & 23785.8 - 151.450J(J+1) + 211.342K^2 \\ & + 0.503027J^2(J+1)^2 - 1.38538J(J+1)K^2 + 0.949155K^4 \\ & - 0.001259997J^3(J+1)^3 + 0.005182367J^2(J+1)^2K^2 \\ & - 0.007088534J(J+1)K^4 + 0.003210437K^6, \quad (1)\end{aligned}$$

given in Eq. (1), has been developed which includes sixth power terms in contrast to the older fourth power expressions. (See for example, references 2 and 3.) To gain some idea of the improvement in the prediction of new absorption frequencies, the positions of all the currently available assigned lines[2-4] were computed with the empirical expressions of references 2 and 3 as well as with the sixth power expression given here. The average deviation from experiment was found to be 45, 26, and 7 mc/sec., respectively, for the empirical equations of references 2, 3, and the present sixth power one.

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[1] See A. H. Sharbaugh and J. Mattern, Phys. Rev. **75**, 1102 (1949).
[2] Strandberg, Kyhl, Hillger, and Wentink, Phys. Rev. **71**, 326 (1947).
[3] J. W. Simmons and W. Gordy, Phys. Rev. **73**, 713 (1948).
[4] W. E. Good and D. K. Coles, Phys. Rev. **71**, 383 (1947).