Table II. Calculated values, with correction for correlation, of activation energy H and pre-exponential factor A for tracer diffusion in pure silver for various values of the parameter K.

Tracer	$K = 1$	$K = \frac{1}{2}$	$K = \frac{1}{4}$	$K = 0$
	Activation energy H (kcal/mole)			
Ag	44.09	44.09	44.09	44.09
Cd	41.2	40.5	39.8	38.4
In	40.1	38.8	37.0	16.6
Sn	38.9	37.5	35.2	a
Sb	38.1	36.6	34.2	a
	Pre-exponential factor A (cm^2/sec)			
Ag	0.48	0.48	0.48	0.48
Cd	0.57	0.45	0.35	0.21
In	0.55	0.37	0.19	2.2×10^{-5}
Sn	0.32	0.20	0.084	a
Sb	0.23	0.13	0.050	a

[a]Negative activation energy.

deviation of the correlation factor from a simple exponential dependence on the temperature will cause very little curvature in the $\log D$ vs $1/T$ plot unless ΔH is very large.

Whenever more than one energy for motion enters into the determination of the correlation factor, there will be a nonzero correction to the activation energy. This can occur when diffusion in alloys, diffusion in noncubic lattices, or diffusion of impurities in otherwise pure crystals takes place by means of a vacancy or interstitialcy mechanism.

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DETERMINATION OF THE HYPERFINE STRUCTURE OF ATOMIC NITROGEN BY OPTICAL ORIENTATION*

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The problems of producing a high degree of dissociation of molecular nitrogen and of detecting nitrogen atoms have prevented, so far, the determination of the hyperfine structure of atomic nitrogen by the method of atomic beams. In the method of optical orientation with spin exchange[1] these problems are simply and effectively solved: fractional dissociation of only about one part in 10^7 is required, and detection is effected with a photocell. In this note we report new precise values for the hyperfine intervals of the ground state of atomic nitrogen. The precision obtained in the present results (about 25 ppm) does not represent the limit of the optical method and it is expected that the N^{14} - N^{15} hyperfine structure anomaly can be determined with good precision. The only previous radio-frequency spectroscopy reported on atomic nitrogen is the work of Heald and Beringer[2] who used the method of paramagnetic resonance absorption. These workers obtained a value for the hyperfine interaction energy with an estimated uncertainty of two parts in one thousand.

The method of atomic orientation by optical pumping with spin exchange has been described previously in connection with the orientation of alkali and hydrogen atoms.[1,3-5] The present experiment is performed in a 500-cc flask filled with N_2 at a pressure of 3.0 cm Hg, He at 0.5 cm Hg, and Rb vapor at a temperature of 50°C. The rubidium atoms are optically oriented with circularly polarized and filtered rubidium resonance radiation. The orientation of the rubidium is monitored by the transmission method.[1] Nitrogen atoms are produced by a pulsed discharge between aluminum electrodes mounted along a diameter of the bulb. The electrodes have a diameter of 0.5 in. and are separated by 2.0 inches. Both rf and dc discharges have been used; the best signals are obtained with a 5-msec rf pulse. Zeeman modulation is used to facilitate observation of the resonances and the resonances in atomic nitrogen are observed by their effect on the optical transmission of the bulb.

The ground state of N^{14} consists of three hyper-

fine levels having total angular momentum values of $F=5/2$, $3/2$, and $1/2$. All of the Zeeman transitions ($\Delta F=0$, $\Delta m_F=\pm 1$) and all of the π hyperfine transitions ($\Delta F=\pm 1$, $\Delta m_F=\pm 1$) have been observed. Typical resonance curves are shown in Fig. 1. The resonances have a half-width of about 4 kc/sec. The identification of the various hyperfine transitions was facilitated by observation of their field dependence. In all cases the observed field dependence agreed within 1% with the theoretical values for the nitrogen resonances. The values obtained for the (5/2-3/2) and the (3/2-1/2) intervals are

$$\nu_{5/2,\,3/2} = 26.1275 \pm 0.0005 \text{ Mc/sec},$$

$$\nu_{3/2,\,1/2} = 15.6772 \pm 0.0005 \text{ Mc/sec}.$$

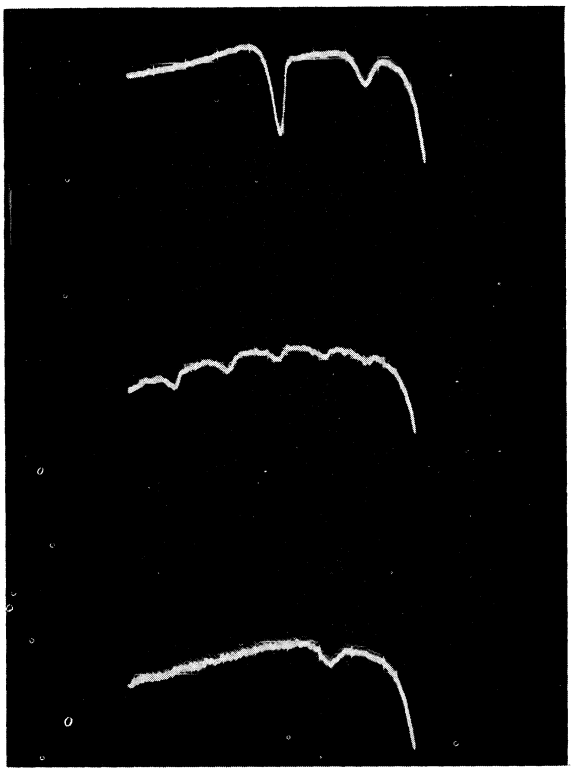

FIG. 1. Resonances observed in atomic nitrogen. The spike at the right-hand end of all of the traces is caused by the rf discharge used to dissociate the N_2 molecules. The duration of each of the traces is 1 sec.

Upper trace, Zeeman resonances in the $F = 5/2$ and $F = 3/2$ states as observed in a field of 0.1 gauss.

Middle trace, splitting of the $F = 5/2$ Zeeman resonance into its five components in a field of 1.0 gauss.

Bottom trace, hyperfine transition between the (3/2, -1/2) and (1/2, 1/2) states.

These values include a small correction for Zeeman curvature (typically 1 kc/sec). A search was made for a possible pressure shift by observing one of the hyperfine transitions as the pressure was reduced by a factor of two. It was established that if a pressure shift exists, it is less than 1 kc/sec over the range of pressures studied. The quoted uncertainties are about three times the probable error and are intended to allow for the possibility of a small pressure shift.

The value of the hyperfine interaction constant (a) obtained from the (5/2-3/2) transition is 10.4510 ± 0.0002 Mc/sec while that obtained from the (3/2-1/2) transition is 10.4515 ± 0.0003 Mc/sec. Both of these results are in excellent agreement with Heald and Beringer's[2] value of 10.45 ± 0.02 Mc/sec. The apparent discrepancy of the values of the interaction constant obtained from the two transitions may result from configuration mixing or interaction with the close-lying ^2P and ^2D states.

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MICROWAVE SPIN ECHOES FROM DONOR ELECTRONS IN SILICON

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With the introduction of the spin-echo technique by Hahn,[1] it became possible to observe and measure directly transverse relaxation times T_2 in substances where the resonance lines involved were inhomogeneously broadened by local field variations. The spin-echo technique has been applied in the radio-frequency region both to nuclear spin resonances,[2] and more recently

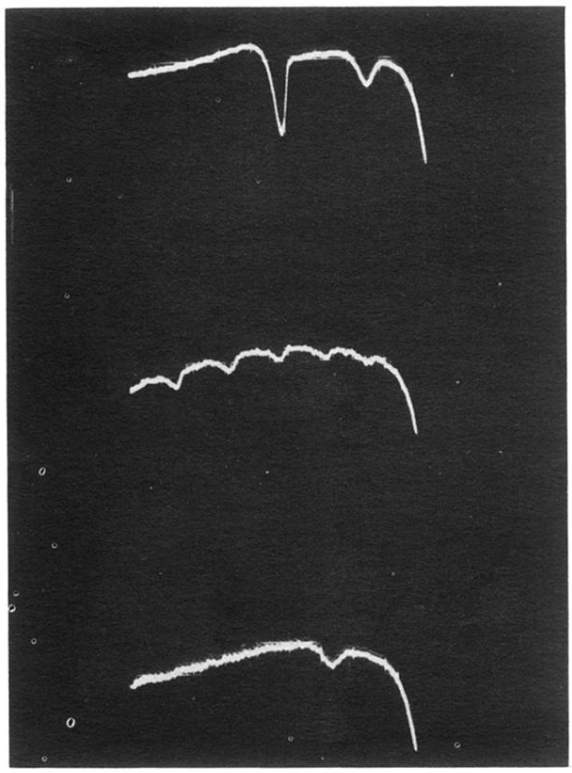

FIG. 1. Resonances observed in atomic nitrogen. The spike at the right-hand end of all of the traces is caused by the rf discharge used to dissociate the N_2 molecules. The duration of each of the traces is 1 sec.

Upper trace, Zeeman resonances in the $F = 5/2$ and $F = 3/2$ states as observed in a field of 0.1 gauss.

Middle trace, splitting of the $F = 5/2$ Zeeman resonance into its five components in a field of 1.0 gauss.

Bottom trace, hyperfine transition between the (3/2, -1/2) and (1/2, 1/2) states.