Letters to the Editor

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On the Nuclear Moments of I^{127}, Ga^{69}, Ga^{71}, and P^{31}

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BY use of a recording radiofrequency spectrometer, measurements have been made of the relative frequencies and the widths of a number of previously unreported resonance lines caused by nuclear magnetic moments in a fixed magnetic field. The absorption line resulting from the I^{127} nucleus was first found using solid NaI as a sample. The ratio of the frequency of the line to that of Na^{23} in the same sample was found, by a method previously reported,[1] to be

$$\nu(I^{127})/\nu(Na^{23}) = 0.75664 \pm 0.0002.$$

When corrected for the diamagnetic effects of the electrons in the two ions,[2] using 2.217 ± 0.002 nuclear magnetons and 3/2 for the magnetic moment and spin of Na^{23},[3] and 5/2 for the spin of I^{127}, a value of

$$\mu(I^{127}) = 2.8122 \pm 0.0030 \text{ nuclear magnetons}$$

is found for the nuclear magnetic moment of I^{127}. This is in good agreement with the value of 2.8 previously reported from hyperfine structure measurements,[4] from which the sign of the moment is taken. Evidence in support of the value 5/2 for the spin is gained from the ratio of the integrated line intensities for the Na^{23} and I^{127} lines, which was about 1:3. Under the conditions of operation of the spectrometer, the line intensity ratio should be approximately the ratio of the values of $I(I+1)$ for the two nuclei, where I is the spin.

The iodine line was also observed with an aqueous solution of NaI as the sample. The line had a breadth between points of maximum slope of 14 kc/sec., which can be compared with the widths previously reported for the lines due to Br^{79} and B^{81} in solutions.[5] If one assumes the correlation time of the fluctuation of the grad **E** to be the same in the two cases, and that the grad **E** arises entirely from the dipolar fields of the water molecules, the spectral intensities of the components of grad **E** would be smaller for I^{127} than for Br by a factor of about 1.75, assuming the closest approach of the dipoles to be the sum of the molecular radii of the water molecules and the ionic radii. From this one is led to estimate the Br^{79} quadrupole moment as approximately 0.25×10^{-24} cm^2, since spectroscopic data[4,6] give -0.46×10^{-24} cm^2 for that of I^{127}. A check of the viscosities of the I^- and Br^- solutions showed them to be alike within 20 percent.

The lines caused by the two isotopes Ga^{69} and Ga^{71} have been observed with an aqueous solution of $GaCl_3$ as the sample. The ratio of the frequencies was

$$\nu(Ga^{71})/\nu(Ga^{69}) = 1.2701 \pm 0.0004,$$

in agreement with the ratio of the hyperfine structure $\Delta\nu$'s reported by Becker and Kusch.[7] The ratio of the frequency of the line due to Ga^{71} to that of Na^{23} was found to be

$$\nu(Ga^{71})/\nu(Ga^{69}) = 1.1529 \pm 0.0004.$$

Using this and the above values for the moment and the spin of Na^{23} and 3/2 for the spin of the gallium isotopes[8] gives

$$\mu(Ga^{69}) = 2.0165 \pm 0.0035 \text{ nuclear magnetons,}$$

and

$$\mu(Ga^{71}) = 2.5611 \pm 0.0030 \text{ nuclear magnetons.}$$

The Ga^{71} and Ga^{69} lines were about 3 and 7 kc/sec. in width, respectively, between points of maximum slope, in agreement with the ratio expected for line widths determined by a short relaxation time caused by the electric quadrupole coupling. The ratio of the squares of the quadrupole moments reported by Becker and Kusch is in good agreement with this. The broadening of the line makes the intensity observed with the modulation method proportional the fourth power of the quadrupole moment. Even though the Ga^{71} isotope is only $\frac{2}{3}$ as abundant as the Ga^{69} isotope, its line is about 4 times as intense. Comparison of the widths of these lines with those of the I^{127}, Br^{79}, and Br^{81} lines is not even so meaningful as the comparison between I^{127} and Br^{79} because the Ga^{+++} solution was rather viscous and was becoming hydrolized. The association of negative ions with water complexes is probably quite different from that of positive ions. The relative widths indicate greater similarity in the fluctuating tensors, grad **E**, than could be expected.

A spin of $\frac{1}{2}$ has been assigned to phosphorous P^{31} from observations of band spectra,[9] but no experimental data on its magnetic moment have been reported previously. The line resulting from the magnetic moment of P^{31} was found after about five days search with the automatic spectrometer. The line was found in both solid red phosphorous and in a concentrated solution of P_2O_5 in water. The spectrometer covers the range from 2 to 4 Mc/sec. in three days, and the line was found after five days continuous search with the second setting of the magnetic field, at about 2000 gauss. The frequency ratio of this line to that of Na^{23} was

$$\nu(P^{31})/\nu(Na^{23}) = 1.5310 \pm 0.0003.$$

This, together with the value $\frac{1}{2}$ for the spin of P^{31}, yields

$$\mu(P^{31}) = \pm 1.1314 \pm 0.0013 \text{ nuclear magnetons.}$$

Unfortunately, the spectrometer has not been designed to give data on the sign of the moment, but of the nuclei containing an odd number of protons and an even number

of neutrons, 39 are reported to have positive moments and only two, Ag^{107} and Ag^{109}, to have negative. If the moment of P^{31} is positive, it falls near to a curve for this class of nuclei published by Latham.[10]

Finally, it is perhaps worth reporting the detection of absorption lines believed to be due to the copper nuclei in the wire of the coil of the r-f spectrometer. These show up on several runs, including ones with no sample. With a sample of solid NaBr the copper lines are identified by their positions relative to one another and relative to the much stronger Na^{23}, Br^{79}, and Br^{81} lines.[1,6] Using 4×10^{-3} cm as the skin depth, the interior of the copper wire of the coil contains about 3 percent of the stored magnetic energy. The relaxation time of the copper nuclei must be shorter than that of the Na and Br because the lines are relatively more intense than this. Therefore, it appears likely that the relaxation time of the nuclei in the metal is less than a second but greater than 10^{-4} sec. because a relaxation time shorter than this would broaden the lines, which were about 5 kc/sec. in width.

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Conductivity Induced in Diamond by Alpha-Particle Bombardment and Its Variation among Specimens

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IN our experiments on conductivity induced in diamond by alpha-particle bombardment we obtain some response from most of the diamonds.[1] However, the magnitude of this response varies by a large factor. Moreover, in some individual specimens a large variation in response is obtained when the surface is scanned with a beam of alpha-particles.

Friedman, Birks, and Gauvin[2] report experiments in which only a small percentage of diamonds respond to bombardment by gamma-rays. In general, they find that such "counting" diamonds are transparent in the ultraviolet region, whereas their non-counting diamonds are opaque in the ultraviolet region. Following the nomenclature of Robertson, Fox, and Martin,[3] they classify their counting diamonds as type II, which is relatively rare, and their non-counting ones as the more common type I diamond.

Early in our work with diamond we investigated the ultraviolet transmission of a few specimens, some in which conductivity pulses were observed under alpha-particle bombardment and others in which no response was observed. Conductivity pulses were observed in all of the opaque diamonds. Among the transparent diamonds, conductivity pulses were observed in some but not in others.

TABLE I.

Diamond	Ultraviolet cut off in A.U.	Transmission diamond type	Diamond type from x-ray diffraction	Response to alpha-particle bombardment positive	negative
2	2980	I		X	
2*E*	2900	I		X	
2*O*	2720			X	
1	2300	II	II		X
2*F*	2300	II		X	
2*H*	2250	II		X	
2*D*	2200	II			X
2M	2100	II			X
4*A*			I	X	
3*C*	2950	I	I	X	

A few diamonds were classified as to type by means of the x-ray diffraction technique of Lonsdale.[4] All specimens classified by this analysis as type I diamonds yielded conductivity pulses. The results of these ultraviolet transmission tests, x-ray diffraction tests, and alpha-particle bombardment tests are summarized in Table I.

Thus, in contrast to the gamma-ray experiments with diamond, we conclude that with alpha-particle bombardment conductivity pulses can be induced not only in diamonds that are transparent in the ultraviolet, but also in those which are opaque in the ultraviolet. There is the possibility that diamonds may be a mixture of the two types. A specimen which is a mixture could be opaque to the ultraviolet light, but the induced conductivity might be limited to the transparent parts of the diamond.

The fact that some diamonds give no response while others give a response which varies widely, not only among different specimens but also on different parts of a given specimen, might be associated with a mixture of diamond types in a given specimen. On the other hand, these variations may be associated with the degree of crystal imperfection and its variation among specimens. The trapping of electrons and positive holes that could occur at crystal imperfections is strongly indicated by the familiar space charge effects which are observed in crystal counters.

Bombarding diamond with 5-Mev alpha-particles from polonium, pulses up to 2700 microvolts have been observed with an input capacity of about 30 micromicrofarads. Friedman, Birks, and Gauvin[2] report pulses up to 50 microvolts from the few diamonds which respond to gamma-rays. Since they did not report the input capacitance of their circuit, a direct comparison of pulse magnitudes produced by alpha-particles and gamma-rays cannot be made from these data. However, the observation that more diamonds respond to alpha-particles than to gamma-rays may indicate that the alpha-particle is the more sensitive detector of the counting ability of diamond, as might be expected from energy absorption considerations.

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