On the Magnetic Moments of Xe^{129}, Bi^{209}, Sc^{45}, Sb^{121}, and Sb^{123}*

W. G. PROCTOR AND F. C. YU
Department of Physics, Stanford University, Stanford, California
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THE nuclear magnetic resonances of Xe^{129}, Bi^{209}, Sc^{45}, Sb^{121}, and Sb^{123} have been observed by use of the nuclear induction spectrometer described earlier.[1] The magnetic moments listed in column two of Table I have been computed directly from our measured frequency ratios and the value of the magnetic moment of the nucleus used as a standard. Diamagnetic corrections were not applied; they are listed separately in column three, and have been determined by linear interpolation from the values for specific atoms given by Lamb, using Hartree fields.[2] These corrections are to be applied in a direction such as to increase the magnitude of the listed magnetic moments.

As a monatomic gas, Xe presented certain difficulty with regard to a suitable mechanism for establishing thermal equilibrium. An admixture of O_2 could be used as paramagnetic catalyst,[3,4] but it would require rather excessive pressures to obtain the full signal magnitude. Instead, we followed a suggestion by Professor Bloch, filling a test tube packed with powdered Fe_2O_3 to a pressure of about 12 atmos. of xenon for a sample. The kinetic motion of the Xe atoms about the paramagnetic Fe_2O_3 particles successfully shortened the longitudinal relaxation time by providing time-varying magnetic fields at the Xe nuclei. Samples made without paramagnetic powders present, and samples using $CuCl_2$ or $K_3Fe(CN)_6$, gave no signals. The resonance was located near 7.7 Mc, using a magnetic field of 6600 gauss. Comparing this frequency with that from Na^{23}, we found

$$\nu(Xe^{129})/\nu(Na^{23}) = 1.0456 \pm 0.0001$$

leading to the magnetic moment listed in Table I. This is in good agreement with the spectroscopic[5] value, $\mu(Xe^{129}) = -0.9\mu_N$. The negative sign has been confirmed.

Using an aqueous solution of 0.69M $Bi(NO_3)_3$, the resonance of Bi^{209} was found in the neighborhood of 7.0 Mc, with a magnetic field near 10,000 gauss. Comparing the resonance frequency with that from D^2, we found

$$\nu(Bi^{209})/\nu(D^2) = 1.0468 \pm 0.0001.$$

The magnetic moment was found to be positive and it is in good agreement with the h.f.s. value[6] of $3.45\mu_N$.

The Sc^{45} resonance was observed with a magnetic field of 7400 gauss, near 7.6 Mc, using a sample of Sc_2O_3 in HNO_3. We found

$$\nu(Sc^{45})/\nu(Na^{23}) = 0.9183 \pm 0.0001$$

which leads to a value in excellent agreement with the h.f.s.[7] value $\mu(Sc^{45}) = 4.8\mu_N$. The positive sign was verified.

The antimony resonances were observed using a sample of $NaSbF_6$ in weak HF. The absorption lines of both the Sb^{121} and the Sb^{123} resonances manifested a structure inasmuch as they were each composed of five lines, approximately 2 gauss apart. The structure can be understood qualitatively, and will be reported upon in detail elsewhere. It appears most likely that it is due to the additional field, acting on the Sb nucleus, which originates from the magnetic moments of the six surrounding fluorine nuclei in the $(SbF_6)^-$ ion; the analysis shows that the central line suffers no displacement from this cause. Measurements then gave

$$\nu(Sb^{121})/\nu(Na^{23}) = 0.9048 \pm 0.0001,$$

$$\nu(Sb^{123})/\nu(D^2) = 0.8442 \pm 0.0001.$$

These frequency ratios lead to values of the magnetic moments which are in good agreement with the spectroscopic values $\mu(Sb^{121}) = 3.7\mu_N$, $\mu(Sb^{123}) = 2.8\mu_N$, and their ratio,[8] $\mu(Sb^{121})/\mu(Sb^{123}) = 1.32$.

No attempt was made to check spin values for the above nuclei, and the spectroscopically determined values have been used in computing the magnetic moments listed[9] in Table I. In view of the observed dependence of nuclear magnetic resonance frequencies on chemical compound,[10,11] we wish to emphasize that the moments listed in Table I are without corrections of any kind. At the time of this writing none of the nuclei reported upon here has been observed in compounds other than those given.

TABLE I. Magnetic moments and diamagnetic corrections.

Nucleus	Nuclear moment in nuclear magnetons	Diamagnetic correction in percent
Xe^{129}	-0.7726 ± 0.0001	0.56
Bi^{209}	$+4.0400 \pm 0.0005$	1.04
Sc^{45}	$+4.7497 \pm 0.0008$	0.15
Sb^{121}	$+3.3427 \pm 0.0005$	0.52
Sb^{123}	$+2.5341 \pm 0.0003$	0.52

The magnetic moment of Na^{23} has been computed by taking

$$\mu(H^1) = (2.7935 \pm 0.0003)\mu_N;^{12}$$

and

$$\nu(Na^{23})/\nu(H^1) = 0.26450 \pm 0.00003;^{13}$$

the magnetic moment of D^2 was similarly computed using $\mu(D^2)/\mu(H^1) = 0.307013$.[14]

We should like to express here our gratitude to Professor F. Bloch for many helpful consultations during the course of this work.

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Magnetic Suspension Balance*

J. W. BEAMS
University of Virginia, Charlottesville, Virginia
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MAGNETIC suspension balances, in which the material to be weighed is freely suspended, have been designed and operated successfully by Holmes[1] and by Clark,[2] but these balances lacked the sensitivity and stability necessary for some types of measurement. In a recent paper[3] a magnetic suspension for high speed rotors was described which also proved to be an excellent magnetic suspension balance. This magnetic balance has now been modified and improved to a point where its sensitivity is limited only by the natural fluctuations or "Brownian motion" of the system.

The material to be weighed is attached to a cylindrical ferromagnetic body (iron, steel, or Permalloy) which is supported freely by the vertical axial magnetic field of a solenoid. The ferromagnetic body is positioned in the edge of a horizontal light beam so that it scatters or reflects light into a photo-electron multiplier cell. The signal from the cell actuates an electronic circuit which in turn regulates the current in the solenoid in such a way as to maintain the suspended ferromagnetic body at the desired height. By proper adjustment of the circuits and of the vertical gradient of the light intensity, where the suspended body is positioned in the light beam, the apparatus can be made very sensitive to slight changes in vertical force on the suspended body. If the dimensions of the suspended ferromagnetic cylinder are small in comparison to its distance below the solenoid, the upward force F on the rotor is approximately MdH/dX where H is the magnetic field, X is a

distance along the axis of the field, and M is the magnetic moment induced in the ferromagnetic cyclinder by the field H. If M is roughly proportional to μH, where μ is the permeability of the cylinder, then $F \propto \mu H dH/dX$. Consequently, it is possible to adjust H and dH/dX so that F varies very slowly with height. This has been done by proper shaping of the field of the solenoid and by supporting the ferromagnetic cylinder well below the solenoid. Also in some experiments an additional solenoid with a constant current was used to support a portion of the weight of the suspended body.

When the apparatus is properly adjusted, the suspended body shows no motion, as viewed through a microscope focused on scratches on the suspended cylinder except when a vertical force is applied to the suspended cylinder. Consequently, the elevation of the suspended cylinder in the field of view of the microscope is a measure of the applied force. However, it is preferable in practice to measure the change in the current or voltage in the circuit as a function of the vertical force on the suspended cylinder. With a suspended steel cylinder 10 mils in diameter and 50 mils long, changes in force on the cylinder of the order of 10^{-9} gram weight could be observed. The balance was calibrated by suspending the cylinder in a glass chamber which could be evacuated and then determining the change in buoyancy of the air on the suspended body when the air pressure around the body was varied.

The above magnetic suspension balance may be used in almost any experiment where small changes in mass or force are to be determined. It is especially suited to experiments where the weighing must be carried out in an evacuated or enclosed chamber, under a transparent liquid, etc., where no mechanical connections to the outside are possible. Also the same apparatus may be used to support and weigh over a wide range of masses or forces.

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Preparation of Transplutonium Isotopes by Neutron Irradiation

A. Ghiorso, R. A. James,* L. O. Morgan,† and G. T. Seaborg
Radiation Laboratory and Department of Chemistry, University of California, Berkeley, California
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THE first production of isotopes of the transplutonium elements americium (atomic number 95) and curium (atomic number 96) was reported[1] by the present authors in a preliminary way in 1945 and more recently[2] in a more complete fashion. In these communications it was pointed out that a number of americium isotopes can be formed in cyclotron bombardments with various charged particles, and in particular that the ~500-yr. Am^{241} can be produced with approximately 40-Mev helium ions according to the reactions $U^{238}(\alpha,n)Pu^{241} \xrightarrow{\beta^-\ (10\ \text{yr.})} Am^{241}$. It was also reported that a number of curium isotopes can be formed by cyclotron bombardments with charged particles and in particular that the ~150-day Cm^{242} can be prepared by the 40-Mev helium ion bombardment of Pu^{239} according to the reaction $Pu^{239}(\alpha,n)Cm^{242}$. In addition it was stated that Cm^{242} can be formed by neutron irradiation of Am^{241} according to the reactions $Am^{241}(n,\gamma)Am^{242} \xrightarrow{\beta^-} Cm^{242}$ where Am^{242} exists in two isomeric states with half-lives for beta-emission given as 17 hr. and some 10^2 to 10^3 yr.

The purpose of the present note is to point out that the isotope Am^{241} can also be formed by neutron irradiation, according to the following reactions $Pu^{239}(n,\gamma)Pu^{240}(n,\gamma)Pu^{241} \xrightarrow{\beta^-\ (10\ \text{yr.})} Am^{241}$. This method of production was first observed by the authors late in 1944, and the use of the chain reacting piles as a source of neutrons makes it the best for the production of weighable amounts of Am^{241}. (The first evidence for the reaction $Pu^{239}(n,\gamma)Pu^{240}$ was that of Chamberlain, Farwell, and Segrè.[3]) In fact, the intense irradiation of large quantities of plutonium leads to the production of *milligram amounts* of Am^{241}. The cross section of Am^{241} for the n,γ-reaction is such that it is possible with long irradiations at high neutron fluxes to transmute a substantial fraction of it to Cm^{242}.

The fact that the elements americium and curium, as represented by their isotopes Am^{241} and Cm^{242}, can be prepared in substantial quantity in this manner by pile neutron irradiations makes it possible to investigate rather completely the chemical properties of these elements by use of weighable amounts. The existence of these reactions makes it quite likely that even higher mass isotopes can be prepared by n,γ-reactions, and in fact further work at this laboratory, to be published soon, indicates that this is indeed the case.

This work was performed at the wartime Metallurgical Laboratory, University of Chicago, Chicago, Illinois (now the Argonne National Laboratory) under the auspices of the Manhattan District, and at the Radiation Laboratory and Department of Chemistry, University of California, Berkeley, under the auspices of the Manhattan District and the AEC.

* Now at the Department of Chemistry, University of California at Los Angeles.
† Now at the Department of Chemistry, University of Texas, Austin, Texas.

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The Elastic and Photoelastic Constants of Fused Quartz

K. Vedam
Department of Physics, Indian Institute of Science, Bangalore, India
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EVEN though numerous investigations have been carried out on the various physical properties of fused quartz, the only known work on its photoelastic properties is that of Heymans and Williams,[1] who have determined the value of $(p-q)$ from bending experiments on a bar of fused silica, p and q being Neumann's strain-optical constants. In the present investigation the absolute values of p and q have been determined, and the results obtained are given below. The details of the method adopted will be published elsewhere.[2] The specimen studied was obtained from the Thermal Syndicate Ltd., England, and was in the form of a rectangular block of dimensions $2.7 \times 1.6 \times 0.85$ cm.

The elastic constants of fused quartz were determined by Hiedemann's method;[3] i.e., by observing the diffraction patterns produced by standing ultrasonic waves in the medium itself. Mueller[4] has shown that this method, with slight modifications, can be used to determine the value of p/q for isotropic substances. Using incident light polarized at 45° to the sound wave front, the light diffracted by the longitudinal waves is viewed through an analyzer. Then the analyzer is rotated through an angle θ, from the initial crossed position, to get the extinction of the first-order longitudinal pattern. By plotting the angle θ against the sound amplitude and extrapolating, it is possible to obtain "θ_{max}" corresponding to zero amplitude, which is given by the relation [Eq. (25) of reference 4]

$$\tan(\theta_{max}+45°) = p/q.$$

By this method the value of p/q for fused quartz was determined by the author and was found to be 2.85.