produced by electroplating under the direction of H. Ross of the Argonne Shop. The first attempts resulted only in about 50 percent polarization but use of longer neutron wave-lengths (to reduce the possibility of non-adiabatic transitions) and of higher magnetizing currents, made complete polarization (within statistical accuracy of about 1 percent) attainable. Two distinct advantages of the reflection method of polarization are (1) no intensity loss occurs as in the transmission method, and (2) polarization of long wave-length neutrons is possible, unlike the transmission method which is applicable only for $\lambda < 4.04$A (because iron becomes "transparent" to neutrons of longer wave-length).

The details of these and other mirror experiments will appear in a report now in preparation. Plans for the application of the mirror technique to other nuclear properties, such as the coherent hydrogen scattering amplitude are now being made. We wish to thank Dr. M. Hamermesh for his extremely helpful discussions during these experiments.

* Now at Brookhaven National Laboratory, Upton, Long Island, New York.

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New Low Mass Isotopes of Emanation (Element 86)

A. Ghiorso, W. W. Meinke, and G. T. Seaborg
Department of Chemistry and Radiation Laboratory, University of California, Berkeley, California

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AMONG the spallation products obtained from the 350-Mev proton bombardment of Th^{232} we have identified two gaseous alpha-emitters which apparently do not decay into any presently known alpha-decay chains. The half-lives observed for the decay of the alpha-activities are 23 minutes and 2.1 hours. These half-lives may be principally determined by an unknown amount of orbital electron capture. At least one alpha-emitting daughter (about 4 hours half-life) has been observed to grow from a gaseous parent, but it has not been determined whether it arises from alpha-decay or electron-capture.

Since these gaseous atoms emit alpha-particles it is assumed that they are isotopes of element 86 (emanation or radon) rather than a lighter rare gas. If they were heavy isotopes such as Em^{221} or Em^{223}, both unknown, they would decay into known alpha-decay series, the neptunium and actinium series, respectively, and so would grow known short-lived alpha-emitters which would have been detected. It thus appears reasonable that they must be lighter than the known emanation isotopes.

The lightest isotope of emanation observed prior to these experiments was Em^{216}, which arises from the U^{228} alpha-decay series[1] and which should have a half-life of approximately 10 microseconds as predicted by means of the new alpha-decay systematics.[2,3] The reappearance of longer half-lives, such as 23 minutes and 2.1 hours, with lower mass numbers is apparently due to the stable configuration of 126 neutrons. Thus these activities are to be assigned to the mass numbers 212 and lower (that is, Em^{212} and $Em^{<212}$). Therefore it appears that the plot of alpha-energy *versus* mass number for the isotopes of emanation goes through the same type of maximum and minimum as is observed for bismuth, polonium, and astatine.[2]

The method used to measure the emanation alpha-activities was very simple but designed to separate the emanation from tremendous amounts of other alpha-emitters, from bismuth to protactinium. The cyclotron target consisted of thin thorium metal strips sandwiched with thin aluminum foils to act as catchers for the transmuted atoms which were able to recoil out of the surface of the thorium. These aluminum foils were then heated at a very low temperature in a vacuum system. A slow stream of argon "carried" the emanation through two cold traps at $-50°$C and into a final trap at $-90°$C where the emanation should freeze out. From this storage trap it was possible to fill a cylindrical ion chamber in which alpha-pulses could be detected. In order to prove that a gas was involved it was shown that the activity could be quantitatively transferred back and forth many times by varying the temperature of the cold trap. After an emanation sample had been allowed to decay for some hours the gas was thoroughly pumped out of the chamber and the alpha-activity left behind (presumably due to the daughters) was followed for decay. It was not possible to measure alpha-energies in these first experiments and Geiger counter measurements were clouded by the probability of xenon and krypton fission product contaminants from which no careful separation had been made.

New equipment is now being built with which it should be possible to measure alpha-energies for these emanation isotopes and their daughters and to determine the proper mass assignments.

We wish to thank James Vale and the crew of the 184-inch cyclotron for their assistance in carrying out this work.

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Magnetic Moment of La^{139} *

W. C. Dickinson
Research Laboratory of Electronics, Massachusetts Institute of Technology, Cambridge, Massachusetts

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THE ratio of the frequency of the nuclear magnetic resonance of La^{139} to that of the proton has been measured at 6700 gauss. Both resonances were observed in a single sample consisting of an aqueous solution of lanthanum chloride. A double-bridge magnetic resonance absorption method, similar to that used for the recent measurement of the Be^9-H^1 frequency ratio,[1] was employed so that further detail is not necessary here. However in this measurement, although the two frequencies correspond very closely to a 7:1 ratio as in the Be^9-H^1 measurement, advantage was not taken of the increased precision in frequency ratio measurement made possible by heterodyning the seventh harmonic of the one frequency with the fundamental of the other. For Be^9 the observed line width was $\sim\frac{1}{2}$ gauss and since it was possible to determine the center of this line to within 0.1 gauss in a field of 7000 gauss, a frequency ratio precision of at least 1 part in 70,000 could be utilized. However, the observed line width for La^{139} was ~ 3 gauss and since the true line center could be determined only to within $\frac{1}{2}$ gauss at best, the precision given by a Zenith BC-221-T frequency meter was sufficient.

A total of six determinations was made. From these the following value for the ratio of the resonant frequencies in the same magnetic field was obtained:

$$\frac{\nu(La^{139})}{\nu(H^1)} = 0.141251 \pm 0.000014.$$

The uncertainty given represents limit of error; all six values fall within the above limits. This result is in agreement with that of Chambers and Williams.[2]

The magnetic moment of La^{139} in units of the magnetic moment of the proton is hence:

$$\frac{\mu(La^{139})}{\mu(H^1)} = 0.98876 \pm 0.00010.$$

This expression is uncorrected for the slight diamagnetic field at the nucleus of the La^{139} due to the Larmor precession of its atomic electrons in the applied field. The best value for this correction can be obtained by using a Hartree atom model calculation for Cs and making a short extrapolation. This gives $(\Delta H/H)La = 0.60$ percent.

The broadness of the La^{139} resonance line may be ascribed to a nuclear quadrupole moment Q which, however, has never been measured. Similar broad lines have been observed for I^{127} and Cs^{133},[3] and also the two Br isotopes,[4] all of which are known to have quadrupole moments.

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Nuclear Quadrupole Moments and Nuclear Shell Structure

C. H. Townes
Brookhaven National Laboratory, Upton, New York*
AND
H. M. Foley and W. Low**
Physics Department, Columbia University, New York, New York
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Considerably before the recent revival of interest in nuclear shell structure, Schmidt[1] had found a systematic variation with Z of the deviation of nuclear charge distributions from a sphere (which he derived from nuclear quadrupole moments) and pointed out minima of the magnitudes of nuclear quadrupole moments near the "magic numbers" $Z=50$ and 82. Schmidt's plot has been extended with more recent data[2,3] and quadrupole moments correlated to some extent with nuclear shell structure.[3,4]

The following simple model, based on nuclear shell considerations, leads to the proper behavior of known nuclear quadrupole moments, although predictions of the magnitudes of some quadrupole moments are seriously in error.

1. Neutrons and protons fit into single particle levels in a scheme similar to those proposed for correlating spins, thus producing what may be called proton and neutron shells.

2. Proton and neutron shells tend to be oriented or polarized to allow maximum overlap between proton and neutron distributions.

This model leads to the conclusions:

A. For an odd-proton nucleus, the quadrupole moment is primarily dependent on the number of protons P and can be written $Q_{p\,\mathrm{odd}} = Q_p(P)$, where Q_p is always positive immediately before, and always negative immediately after a shell is filled.

B. For an odd-neutron nucleus, the magnitude of the quadrupole moment depends on the number of protons, but its sign is determined by the number of neutrons N, being given by $[Q_p(N)]/[|Q_n(N)|]$. $Q_n(N)$ is the electric quadrupole moment which would be produced by the neutrons if they were charged, and Q_n is very nearly the same function as Q_p.

C. For odd-odd nuclei, estimation of quadrupole moments is more complex and depends on the way in which the mechanical moments of the odd neutron and odd proton add. If these moments are essentially parallel, the quadrupole moment should be of the same sign and approximately the same magnitude as for a similar odd-proton nucleus, if the neutron and proton mechanical moments are not essentially parallel, the quadrupole moment magnitude should be considerably reduced.

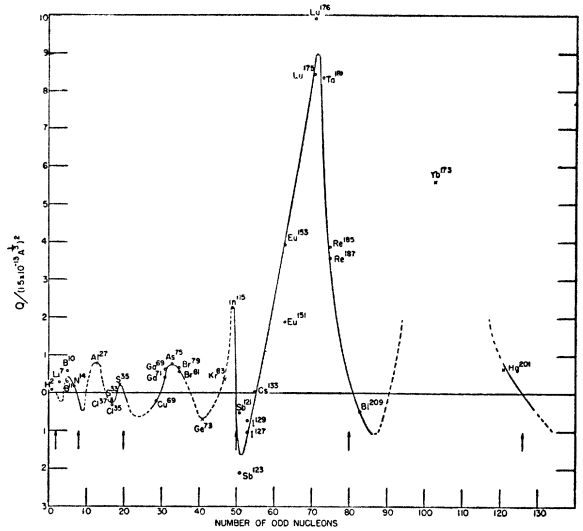

Fig. 1. Nuclear quadrupole moments divided by the square of the nuclear radius $(1.5\times10^{-13}A^{1/3})^2$. Known moments of odd-proton nuclei and odd-proton odd-neutron nuclei (excepting Li^6 and Cl^{36}) are plotted as circles against number of protons, moments of odd-neutron nuclei as crosses against number of neutrons. Arrows indicate closing of major nucleon shells. Solid curve represents regions where quadrupole moment behavior seems established, dashed curve more doubtful regions.

Known quadrupole moments appear to fit these expectations. Figure 1 shows nuclear quadrupole moments[5] as a function of number of nucleons.

The sign of Q near the closing of major shells is that expected in all cases except for Li^7. In view of uncertainties in the charge distributions in the molecules from which Q for Li^7 was derived, perhaps present indications that Q is positive should not be regarded as conclusive. The negative quadrupole moment of S^{33} and the reversal of sign to a positive moment for S^{35} is a striking illustration of the above rules since S^{35} has 19 neutrons, or one less than the filled shell of 20. This model would similarly predict that the quadrupole moments of K^{39} and K^{41} are positive, that of Sc^{45} and Zr^{91} negative.

Se^{77} seems from microwave measurements to have a quadrupole moment less than 0.001×10^{-24} cm^2, yet atomic spectra indicate a spin for this nucleus greater than 3/2. Both experiments may be correct, and the Se^{77} moment very small because of the spherical distribution of protons in this nucleus due to completion of the $4f$ sub-shell. Ca^{43} is a similar case which should have a complete proton shell and small quadrupole moment.

The negative quadrupole moment of Ge^{73} with 41 neutrons suggests that a completed sub-shell occurs at 40 neutrons (pointed out as a possibility by Nordheim) corresponding to filling the $3p$ levels in Nordheim's and Mayer's schemes.[6] If the neutron and proton shells fill in the same manner, the Cb^{93} quadrupole moment should also be negative and the Zr^{91} quadrupole moment small.

The odd-odd nuclei with known quadrupole moments consist of Li^6, B^{10}, N^{14}, Cl^{36}, and Lu^{176}. Their moments correspond to expectations from the model described above, and those cases for which the moments of neutron and proton shells are parallel (B^{10}, N^{14}, Lu^{176}) are plotted in Fig. 1.

Gordy's statement[3] that completion of a neutron shell tends to make quadrupole moments more negative does not follow from the above considerations. This is perhaps not serious because the evidence for this empirical observation is questionable. A number of quadrupole moments plotted by Gordy are values he predicts on the basis of an empirical relation between nuclear electric quadrupole moments and magnetic dipole moments. The most