A Measurement of the Deuteron Proton Magnetic-Moment Ratio[1]

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DURING a recent period of availability of the Massachusetts Institute of Technology cyclotron magnet, measurements were made of the ratio of the magnetic moment of the deuteron to that of the proton in liquid hydrogen and deuterium by means of nuclear-absorption experiments with circuits similar to those previously used.[2]

The resonances were presented simultaneously on an oscilloscope by means of an electronic switch. A sinusoidal sweep was used, so that with proper adjustment the observed patterns could be made symmetrical about the center-line of the oscilloscope. The shapes of the two resonance curves were rather different, and the most prominent maxima of the deuterium resonance were of the order of a half-line width from the hydrogen maxima when the desired symmetry conditions were established. This effect, though not understood in detail, is probably due to the rate of sweep through resonance.

Eleven observations were made, of which three were rejected because the photographs of the oscilloscope traces were found to be unsymmetrical. Half of the remaining eight observations were made with the Dewar containing the resonance coils rotated through 180° so that the effects of a field gradient in the magnet could be eliminated. All eight of these observations fell within the following limits:

$$\mu_D/\mu_H = 0.307021 \pm 0.000005.$$

[1] This work has been supported in part by the Signal Corps, the Air Materiel Command, and O.N.R.
[2] F. Bitter, N. L. Alpert, H. L. Poss, C. G. Lehr, and S. T. Lin, Phys. Rev. **71**, 738 (1947).

Multiple Nuclear Isomerism

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IN the course of an investigation of the activity induced in Sb by slow neutrons we noticed three previously unobserved short periods. An analysis of the decay curves obtained under various conditions of bombardment yields the following half-life periods: 1.3 min., 3.5 min., and 21 min. Though a short bombardment brings out these activities quite well relative to the long-lived known Sb^{122} (2.8 d) and Sb^{124} (60 d) activities, the saturation intensities as detected with either an end-window Geiger counter or an ionization chamber are only of the order of a few tenths of one percent of those of the long-lived activities. The new activities were observed with a number of samples of Sb of different origin, including C. P. Sb_2O_3 and Hilger's spectroscopically pure Sb metal. We could observe the activities with epicadmium neutrons as well as thermal neutrons and were able to show that all three activities induced by epicadmium neutrons are strongly

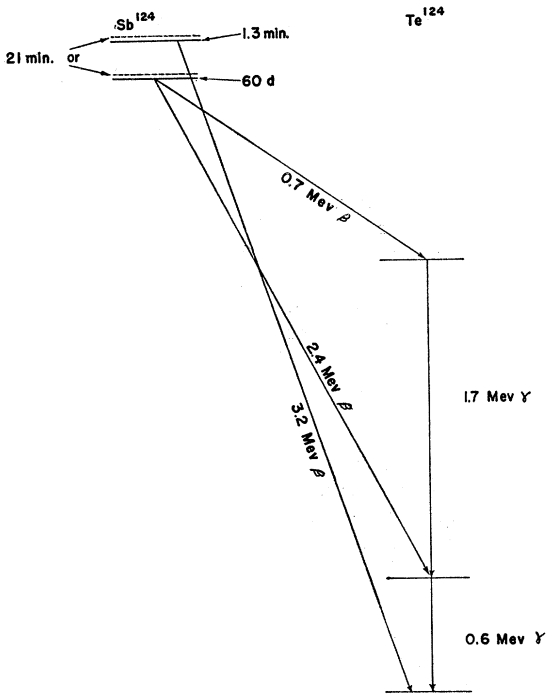

FIG. 1.

"self-absorbed" by Sb, which makes it unlikely that they are due to impurities. In addition, it was found that the short periods along with 2.8-d Sb plated out on Fe from an acid (HCl) solution of freshly bombarded Sb metal powder, whereas Sn, added as a carrier and plated out on Zn after the Sb was removed, proved inactive.

Using a sample of Sb enriched in Sb^{123} (96.3 percent Sb^{123}) we found that the 1.3- and 21-min. periods are due to isomers of Sb^{124} (60 d) and that the 3.5-min. period is due to an isomer of Sb^{122} (2.8 d). Characteristic K α-radiation of Sb was found to be associated with the 3.5-min. period, but not with the 1.3- and 21-min. periods. The 3.5- and 21-min. periods both show intense internal conversion electrons with half-value thicknesses in Al of 1.7 mg/cm²

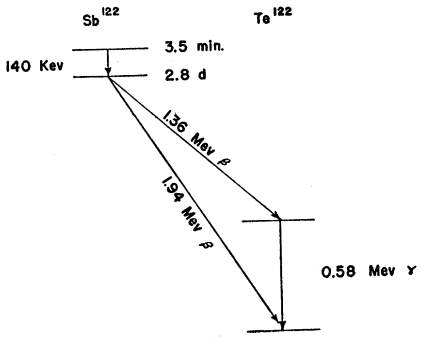

FIG. 2.

and 0.2 mg/cm², respectively, indicating approximate energies of 110 kev and 14 kev, respectively. It appears, therefore, that the energy of the isomeric transition of Sb^{124} (21 min.) is unusually low and smaller than the K work function of Sb (31 kev). If we assume that the 110-kev electrons are K electrons and the 14-kev electrons L electrons, we obtain for the energy of the isomeric transition of Sb^{122} (3.5 min.), approximately 140 kev and for that of Sb^{124} (21 min.) approximately 20 kev.

The 1.3-min. isomer decays with the emission of beta-rays with an absorption coefficient in Al of ~310 mg/cm², corresponding to 3.2+0.2-Mev maximum energy. Softer beta-rays, as well as gamma-rays, are also present. The partial isotopic cross section for the formation of this isomer by thermal neutrons is found to be $\sim 0.03 \times 10^{-24}$ cm².

The decay schemes proposed for Sb^{124} and Sb^{122} are shown in Figs. 1 and 2. The decay scheme of Sb^{124} (60 d) adopted here is that proposed by Meyerhof and Scharff-Goldhaber.[1] Our experiments so far do not decide the question whether the 21-min. transition leads to the 60-d or 1.3-min. level. Besides internal conversion electrons the 21-min. period also shows a beta-transition which is being studied further. The decay scheme for Sb^{122} (2.8 d) is based on the work of Mitchell, Langer, and McDaniel,[2] Miller and Curtiss,[3] and Rall and Wilkinson.[4]

On current theoretical views there would seem to be two possibilities to account for the existence of two metastable states in a nucleus of even mass number: Either there is a spin difference of at least three units between any two of the three states of Sb^{124} (1.3 min., 21 min., and 60 d), or one of the states has a spin ≥ 3 and the other two have each a spin 0 and opposite parity.

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[1] W. E. Meyerhof and G. Scharff-Goldhaber, Phys. Rev. **72**, 273 (1947).
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[4] W. Rall and R. G. Wilkinson, Phys. Rev. **71**, 321 (1947).

Relative Yields of (γ, n) Reactions

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A NUMBER of elements throughout the periodic system have been irradiated with x-rays generated by the 100-Mev betatron at Schenectady. The amount of product resulting from loss of a single neutron by one of the target isotopes was determined by measurement of its beta-activity, which was distinguished from that of other beta-active isotopes by analysis of the decay curve. Irradiations were made at 50-Mev and 100-Mev maximum x-ray energies.

TABLE I. $(\gamma - n)$ yields relative to $N^{14}(\gamma, n)N^{13}$ yield as unity.

Parent isotope	Relative yield at maximum x-ray energy of 100 Mev	50 Mev
$_6C^{12}$	2.23	2.21
$_7N^{14}$	1.00	1.00
$_8O^{16}$	2.14	2.25
$_9F^{19}$	2.66	2.71
$_{15}P^{31}$	6.95	6.74
$_{17}Cl^{35}$	2.28	2.28
$_{19}K^{39}$	2.55	2.43
$_{28}Ni^{58}$	6.10	5.66
$_{29}Cu^{63}$	32.3	33.8
$_{31}Ga^{69}$	40.5	42.4
$_{31}Ga^{71}$	42.0	42.0
$_{46}Pd^{110}$	32.3	37.3
$_{47}Ag^{109}$	39.8	44.2
$_{51}Sb^{121}$	40.4	44.0
$_{75}Re^{187}$	82.5	82.0

The cases studied were chosen so as to eliminate or minimize the following possibilities: the product might have resulted from x-ray induced reactions on other isotopes present in the target material; an isotope of nearly the same half-life as that of the product sought might have been made; the quantitative result might be in error because of the unknown decay scheme of the product. Measurements were made which showed that $(n, 2n)$ reactions can account only for about one percent of the yields observed in this work.

Irradiations were monitored by measurement of the C^{11} or F^{18} activity induced in a standard piece of polystyrene or lithium fluoride which was bombarded together with each target. For product half-lives of less than one hour polystyrene monitors were used; for all other half-lives the monitors were lithium fluoride. All bombardments and measurements were carried out in standard geometries. Activities were calculated to saturation and were corrected for self-absorption, for absorption in counter windows, and for relative counter efficiencies. Yields were calculated to correspond to one milligram-atom of parent isotope in the target and, in the table below, they are normalized to the yield of the reaction $N^{14}(\gamma, n)N^{13}$, which is arbitrarily taken as unity at each x-ray energy. It is estimated that values in Table I are not in error by more than approximately ±15 percent.

The fact that the relative yields at 50 Mev and at 100 Mev are the same within experimental error suggests either that the cross sections of all the reactions investigated vary with energy in the same way or that the (γ, n) cross section is very small above 50 Mev. The latter conclusion is substantiated by unpublished data of G. C. Baldwin on the reactions $C^{12}(\gamma, n)C^{11}$ and $Cu^{63}(\gamma, n)Cu^{62}$.

Relative yields investigated fall roughly into three groups. The light elements as far as Ni^{58} have (γ, n) yields from 1 to 7. From Ni^{58} to Cu^{63} there is an abrupt and unexpected rise. Cases between Cu^{63} and Sb^{121} have values between 30 and 45. The only case studied above Sb^{121} is Re^{187} with a yield of 82. Additional cases of the (γ, n) reaction are being studied; a similar investigation of (γ, p) reactions is in progress.

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