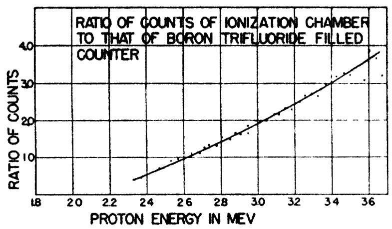


FIG. 2. The ratio of counts in an ionization chamber to those in a boron trifluoride counter covered with paraffin. The statistical deviations are ±6.4 percent at 2.8 Mev.

at 0° and 90° were taken with a flat energy response detector similar to the one described by A. O. Hanson and J. L. McKibben.[3]

The yield at 0° was measured with the counter 13¼ inches from the target. In this position it subtended a solid angle of 0.28 steradian. At 90° the counter was placed 31 inches from the target. Figure 1 shows the yield at 90° and 0° as measured with the flat energy response counter. The large solid angle at 0° distorts the first peak in the curve. The results agree fairly well with those of Taschek and Hemmindinger.[2] No evidence for additional resonances as reported by Hill and Shoupp[1] were found.

In an attempt to find more than one group of neutrons, a comparison was made of the yield at 20° as measured simultaneously with an ionization chamber and a boron trifluoride-filled counter surrounded with a two-inch layer of paraffin. The argon-filled ionization chamber with a thin paraffin radiator was designed to detect only fast neutrons of energy greater than 0.6 Mev. Since the ionization chamber efficiency increases with neutron energy and the boron counter decreases with neutron energy, it was felt that an excited state of $Be^7$ would result in a discontinuity in the ratio of counts in these two detectors at an incident proton energy just sufficient to produce this excited state. Figure 2 shows the ratio between the neutron counts in the ionization chamber and the boron trifluoride counter as a function of the proton energy. No anomalies were found. We conclude that to within the accuracy of our measurements there is only one group of neutrons emitted in this reaction up to a proton energy 3.66 Mev.

This research was done under the partial support of the ONR, Contract N5ori-147.

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[2] R. Taschek and A. Hemmindinger, Phys. Rev. **74**, 373 (1948).
[3] A. O. Hanson and J. L. McKibben, Phys. Rev. **72**, 673 (1947).

## Measurement of the Proton Moment in Absolute Units

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January 10, 1949

THE absolute value of the magnetic moment of the proton has been determined by measuring the magnetic field and frequency required for nuclear resonance absorption in a proton sample. The nuclear resonance technique is similar to that developed by Purcell[1] and his collaborators but has a modified circuit design. The sample is water with the relaxation time adjusted to an optimum value by the addition of ferric oxalate.

An electromagnet having auxiliary coils in addition to the main exciting windings was used to produce a field of about 5000 gauss in a 2-inch gap having approximately rectangular pole pieces 8½ inches by 12½ inches. The field distribution in the gap was obtained by using two nuclear resonance probes, one to plot the field and the other to regulate the field by means of a phase detector and power amplifier supplying the auxiliary coils. After shimming, field variations throughout the volume used did not exceed one part in 10,000 and they were accurately plotted. By means of a balance the value of the field at the center of the gap was measured from the force produced on straight conductors 10 cm long which carried a known current. These conductors form one side of a rectangular coil whose opposite side is 70 cm above the center of the gap. The stray field at the upper end of the coil was reduced to zero by a pair of large diameter Helmholtz coils. The accuracy of the measurement of the field by this means was limited principally by the uncertainty in the length of the conductors which was one part in 20,000.

During the measurement, the field was regulated to within 0.02 gauss by one resonance probe which had a local field bias such that the field at the center of the gap where the conductors were located was the exact value required for proton resonance. This could be checked before and after each field measurement by using the other probe. Both resonance probes were supplied from a 20-mc crystal oscillator, and the frequency was measured to a few parts per million by heterodyning the oscillator with the NBS standard frequency station WWV.

The values of field and frequency thus measured give a value for the gyromagnetic ratio of the proton of

$$\gamma_p = (2.6752 \pm 0.0002) \times 10^4.$$

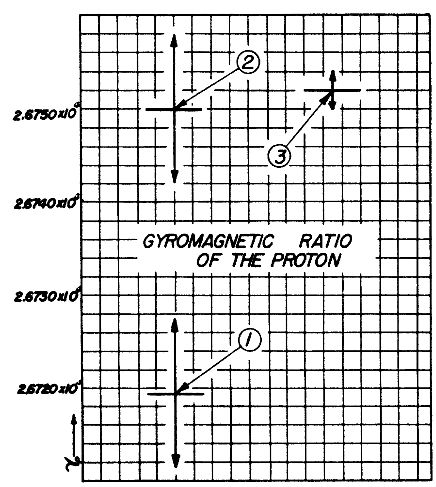


FIG. 1. (1) indicates the value of the gyromagnetic ratio of the proton reported by Millman and Kusch (reference 3). (The error does not include any uncertainty in the value of $m/M$); (2) shows the value of Millman and Kusch with the radiative correction to the electron moment (see references 4 and 5); (3) is the value reported here.

The magnetic moment of the proton is known less accurately than this because of the greater uncertainty in the value of $h$. Using a value[2] of

$$h=(6.6234\pm0.0011)\times10^{-27}\text{ erg sec.},$$

the magnetic moment of the proton is

$$\mu_p=(1.4100\pm0.0003)\times10^{-23}\text{ gauss cm}^3.$$

The figure shows the value of $\gamma_p$ from this measurement compared with a value given by Millman and Kusch[3] which was obtained by determining the magnetic field from radiofrequency spectra of the alkali atoms and thus depends on the electron moment. If the radiative correction[4,5] for the electron moment is applied to their value, excellent agreement, well within the experimental error, is noted.

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## Coincidence Measurement of Neutron Energy

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January 10, 1949

A TECHNIQUE for measurement of neutron energy has been developed in which use is made of a coincidence-absorption arrangement. Protons which originate as recoils from the incident neutrons in a hydrogen-filled proportional counter pass through a variable amount of absorption into a second proportional counter. Coincidences between the two counters are registered on the output of a medium resolution coincidence circuit and are normalized to the counting rate in the first counter. A plot of coincidence rate as a function of absorption gives the extrapolated range and energy of the scattered protons, hence of the neutrons.

Figure 1 gives an idea of the physical setup used for gas-target bombardment. The proportional counters have a grounded cathode of one-inch inner diameter, the center wire being maintained at a positive (above ground) potential. The associated preamplifiers are of the type standard to this laboratory,[1] modified to allow for the positive center-wire voltage by means of a high voltage blocking condenser. The video amplifiers[2] and resolution circuit[3] are of conventional type. The first counter (where recoils originate) is at low bias and the second counter is "peaked." When peaking is great enough, separate neutron groups may be seen.

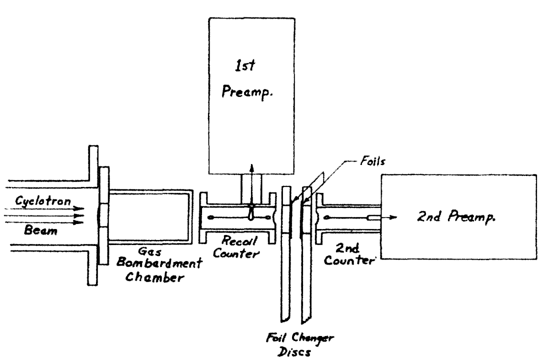


FIG. 1. Sketch of arrangement used. The foil changer disks are remotely operated by synchros, with provision on the disk for infinite absorption.

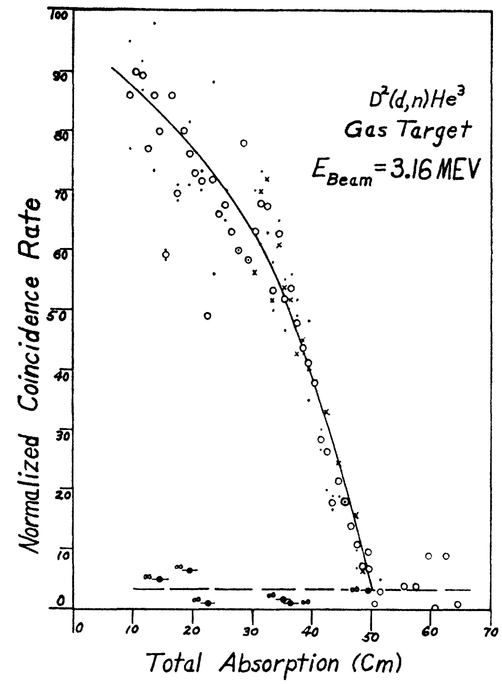


FIG. 2. Composite plot of several runs. The filled-in circles are infinite absorption points and represent the background yield.

A first test of the method is seen in the $H^2(dn)He^3$ reaction tried which was chosen for its homogeneous neutron yield. A composite plot of results is shown in Fig. 2. The $Q$-value determined by the extrapolated range is $Q=3.08\pm0.18$ Mev, with most of the uncertainty connected with the energy of the cyclotron beam after passing through a gold foil into the bombardment chamber.

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** Assisted by the joint program of the ONR and the AEC.
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## A Cosmic-Ray Particle of Charge Two or Greater*

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January 17, 1949

A CLOUD-CHAMBER photograph has been obtained at an altitude of 93,000 feet*** which shows a heavily ionized track penetrating a 1.25-cm lead plate. Stereoscopic views are given in Fig. 1. The track appears to have