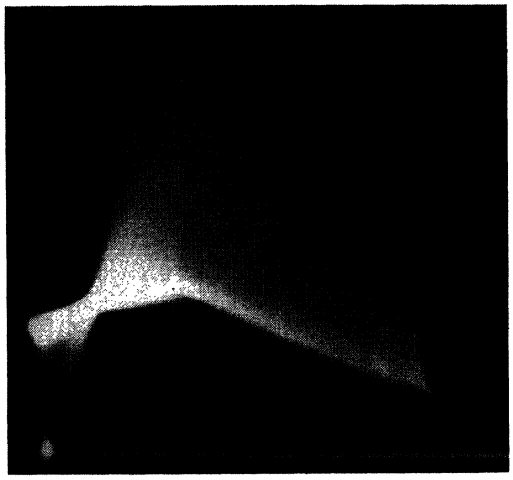

FIG. 2. Oscillogram of the spectrum excited by neutron capture in manganese.

to the escape from the crystal of both annihilation quanta, and the weaker line at 3.94 Mev is due to the occasional capture of one such quantum by the crystal. The line at 4.45 Mev is too faint to show up in the reproduction. The lower energy group has been shown to correspond to the photoelectron lines produced by a trace of radium impurity in the polonium source, and to the polonium gamma-ray at approximately 790 kev.

Figure 2 illustrates the spectrogram obtained with the manganese target in position. The oscillograph trigger level has been set fairly high to eliminate most of the intense low energy background pulses. It is apparent even from this reproduction that there are two intense bands, one at the end of the spectrum (consisting of three apparently associated pair lines), and the other at a somewhat lower energy (also consisting of three lines). Each of these bands has thus been identified with a homogeneous gamma-ray,

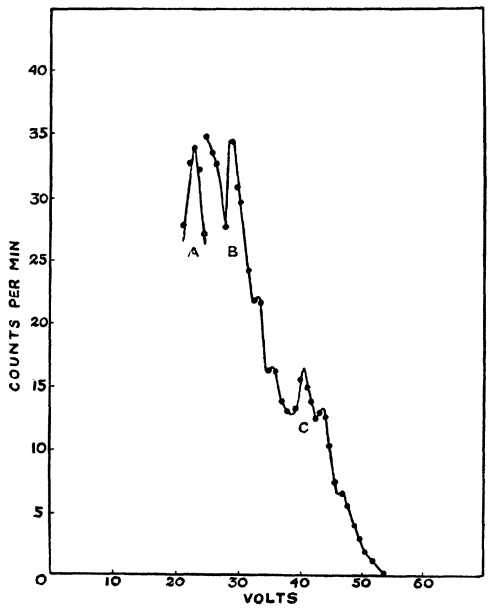

FIG. 3. Differential pulse height distribution for the spectrum excited by neutron capture in manganese. (A) Po-Be calibration line at 3.43 Mev. (B) Main pair line of manganese gamma-ray of 5.37 Mev. (C) Main pair line of manganese gamma-ray of 7.15 Mev.

the most prominent line in each group being the lowest energy pair line and corresponding to B and C in the differential discriminator distribution of Fig. 3. A is the Po-Be 3.43-Mev calibration line. The values of the two gamma-rays, as obtained from three photographs, are 5.27 Mev and 7.17 Mev, the corresponding differential discriminator values being 5.37 Mev and 7.15 Mev. We have, therefore, adopted values of 5.32 ± 0.05 Mev and 7.16 ± 0.05 Mev for the gamma-rays of neutron capture in Mn^{55}, thus concluding that the latter figure represents the binding energy of the last neutron in Mn^{56} and that there exists an excited level in the same nucleus of 1.84 Mev. The lower energy gamma-ray has not previously been reported, but recently Kinsey *et al.*,[6] using a magnetic coincidence pair spectrometer in conjunction with the Chalk River reactor, have reported a gamma-ray of 7.25 ± 0.03 Mev for manganese. However, manganese is classified by them as having a ground-state transition which predominates over that of all other radiation, a conclusion which does not follow from our own results which suggest a comparable intensity for the two radiations reported.

It is recognized that an improvement in technique would probably be the use of a triple coincidence device to count only the main pair line for each gamma-ray, as discussed by Johanssen.[7] Such an arrangement would, however, require a much stronger neutron flux than was available. In conclusion we would emphasize that the photographic technique provides an excellent means for the rapid survey of neutron capture spectra, especially if microphotometer recording is available. A few homogeneous gamma-rays have been obtained with targets of Cd, Cl, Ni, and W, superimposed on continuous backgrounds of unresolved radiation.

* This project has been assisted by the National Research Council of Canada.

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Excitation Curve for the $H^3(p, \gamma)He^4$ Reaction*

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IT has been recently suggested by Argo *et al.*[1] and Jarvis *et al.*[2] that the compound He^4 nucleus might have an excited level near 23 Mev. In order to investigate the existence of this level, the excitation curve for the $H^3(p, \gamma)He^4$ reaction, which had been measured at Los Alamos up to 2.5-Mev proton energy, has been extended to 3.4 Mev.

The electrostatic generator of the Department of Terrestrial Magnetism of the Carnegie Institution was used to produce a monoenergetic proton beam. The target, which was made available through the courtesy of Dr. T. W. Bonner of the Rice Institute, consisted of tritium absorbed in a layer of zirconium 220 $\mu g/cm^2$ thick (energy loss for 2.5-Mev protons $\sim$50 kev) evaporated on a tungsten button.[3] The γ-ray yield was detected by a cylindrical NaI(Tl) crystal, 3.8 cm in diameter and 3.0 cm thick. The crystal was mounted on a magnetically shielded RCA 5819 photomultiplier and located 1.25" away from the center of the target, with its axis at 90° with respect to the direction of the proton beam. The pulses were fed into a cathode follower, fast amplifier, and scaler arrangement and were biased at the input of the scaler.

The response of the crystal to γ-rays of various energies was tested by using Co^{60}, $F^{19}(p, \gamma)Ne^{20}$, and $H^3(p, \gamma)He^4$ γ-rays. In

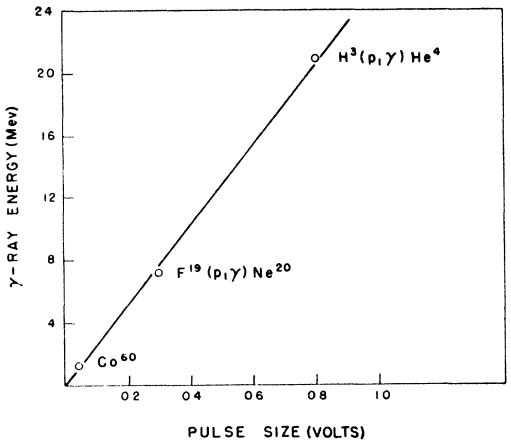

FIG. 1. Calibration curve for NaI(Tl) crystal used in this experiment. The γ-ray pulse heights are maximum heights measured from integral bias curves.

each case the maximum pulse height was determined by measuring the end points of the respective integral bias curves. Figure 1

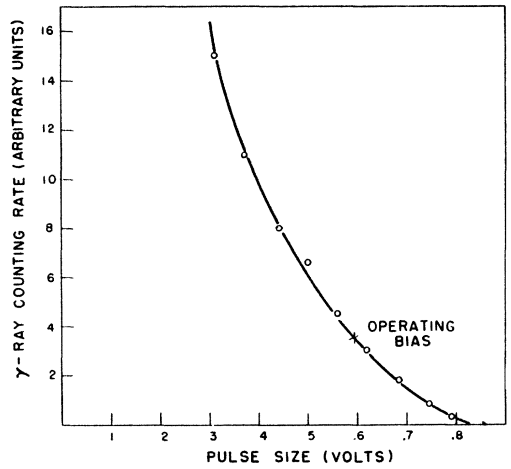

FIG. 2. Integral bias curve produced by γ-rays from a 50-kev target of Zr-H³ bombarded by 1.4-Mev protons and measured by a NaI(Tl) crystal (3.8-cm diameter, 3.0-cm height).

shows the results, from which it can be seen that the response is linear with respect to energy. The integral bias curve produced

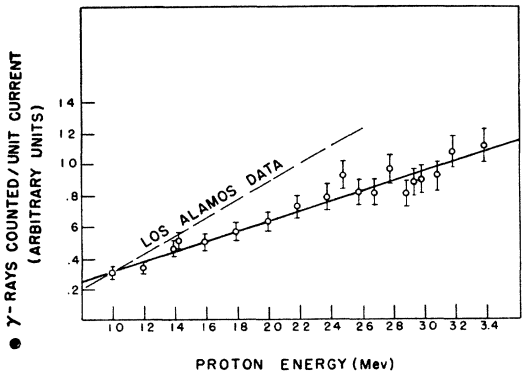

FIG. 3. Excitation curve for the $H^3(p, \gamma)He^4$ reaction.

by the $H^3(p, \gamma)He^4$ γ-rays was quite steep (Fig. 2), which agrees with the measurements of Good *et al.*[4] for a similar detector.

Only about 1 microampere of beam was used in order to prevent overheating of the target. Furthermore, all points were repeated during one run to make sure that tritium was not lost from the target.

The resulting excitation curve is shown in Fig. 3. The steepness of the pulse distribution of γ-rays made the constancy of the overall gain of the system very critical and limited the experiment to ±10 percent accuracy even though the counting statistics were about 3 percent. Nevertheless, it is quite evident that no large resonance exists up to 3.4-Mev proton energy. This is in agreement with the calculations of Flowers and Mandl.[5] The experiment, however, does not rule out a weak (up to 30 percent) broad resonance superposed on the rising cross section.

It should be noticed that the slope of this excitation curve is less than that measured by Argo *et al.*[1] This difference in slope can possibly be explained by the fact that the crystal used in this experiment subtended a half angle of about 25°, while that in the Los Alamos experiment subtended about 5°. Consequently, we detected a larger fraction of the angle-independent part of the $(A+B\sin^2\theta)$ γ-ray distribution, which appears to be a considerably slower function of energy than the $\sin^2\theta$ term.[1]

We should like to express our thanks to Dr. M. Tuve for making this collaboration possible, Dr. N. P. Heydenburg for his over-all aid, Dr. E. O. Salant for suggesting the experiment, and Dr. T. W. Bonner of the Rice Institute for the loan of the tritium target.

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† On leave from the Rice Institute, Houston, Texas.
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Fast Neutron Energies Determined by the Use of Resonant Scatterers*

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IN this note we wish to suggest and illustrate a method of measuring fast neutron energies which utilizes total neutron cross-section resonances. Essentially, the method consists of measuring scattering cross sections, using as a scatterer an element such as lithium, beryllium, or sulfur whose cross section is a known function of neutron energy,[1–3] and as a source neutrons of unknown energy produced by monoenergetic protons incident on thin targets of the nuclei of interest. The identification of resonances then allows one to deduce the energy of the neutrons and hence the Q-value of the reaction. The method has been used to determine (a) the Q-value for the reaction $Mn^{55}(p, n)Fe^{55}$, (b) the position of an excited state of Mn^{53} produced by the reaction $Cr^{53}(p, n)Mn^{53}$, and (c) an upper limit for the width of the ground state of the B^9 nucleus produced by the reaction $Be^9(p, n)B^9$.

The (p, n) thresholds for light elements are quite sharp and are convenient as voltage reference points. However, for heavier elements with low (p, n) thresholds, the higher coulomb barrier causes the yield near threshold to be very low and the measurement correspondingly more uncertain. Richards *et al.*[4] obtained a threshold value of 1.18±0.01 Mev for the $Mn^{55}(p, n)Fe^{55}$ reaction, while McCue and Preston[5] found a threshold value of 1.02±0.02 Mev. Therefore, we have employed the method mentioned above to determine the Q-value for this reaction.

The total neutron cross section of beryllium in the region of the