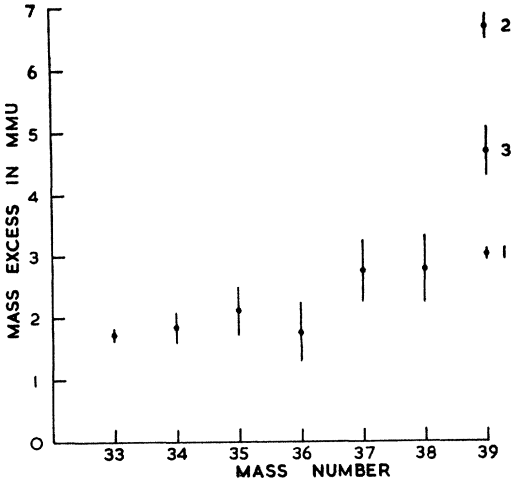

FIG. 1. The mass excess of chlorine isotopes over the semi-empirical formula: (1) present Cl^{39} mass; (2) betatron value; (3) K^{39} and decay chain value.

dance of only 0.3 percent and A^{38} of 0.06 percent. The tail in the photoproton distribution above group A is due partly to straggling effects, though the fairly sharp cut-off above 10 Mev may indicate a small contribution of alpha-particles from the reaction $A^{40}(\gamma, \alpha)S^{36}$. The maximum energy expected from this reaction is 9.8 Mev (using the S^{36} mass of Low and Townes[2] modified to suit the recent S^{32} mass of Motz[3]).

If we use the recent value of Nier[4] $A^{40}=39.97524\pm3$, and if our assignment of group A is correct, $Cl^{39}=38.97871\pm10$.

The only other direct determination of this mass comes from Haslam, Katz, Moody and Skarsgard[5] whose value of 14.2 ± 0.2 Mev for the threshold of the reaction $A^{40}(\gamma, p)Cl^{39}$, obtained with betatron x-rays, disagrees with our own 10.8 ± 0.1 Mev. The difference may be explained by their neglect of the effect of the potential barrier in analyzing the shape of the excitation curve. Their result is $Cl^{39}=38.98236\pm20$.

If we attempt to arrive at a mass for Cl^{39} from other nuclei, there is again some discrepancy with our own figure. Low and Townes[2] have given $K^{39}=38.97613\pm30$. Haslam *et al.*[5] find $Cl^{39}-A^{39}=3.56$ mMU, while Brosi, Zeldes, and Ketelle[6] find $A^{39}-K^{39}=0.61$ mMU. This gives $Cl^{39}=38.98038\pm40$ (using the newer value[4] for A^{40}).

Some support for our value comes from a consideration of the masses of other chlorine isotopes. Low and Townes[2] have given the masses of Cl^{33} through Cl^{38} and compared them with the predictions of a semi-empirical formula of the Bohr-Wheeler type. In Fig. 1 we show the excess mMU of the actual mass over the semi-empirical mass for these isotopes; the actual masses are based on the newer value of Motz[3] for S^{32}. At the position of Cl^{39} we show our own value labeled (1), that of Haslam *et al.*[5] labeled (2), and that based on K^{39} and the decay chain as (3).

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Scintillation Spectroscopy of the Gamma-Rays from Slow Neutron Capture in Manganese*

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THE development of the scintillation gamma-ray spectrometer has made possible many new investigations.[1] In particular, we have recently employed this technique to study the energies

FIG. 1. Oscillogram of the Po-Be calibration spectrum, showing also photoelectron lines due to Po and a trace of Ra impurity.

of the gamma-rays excited by slow neutron capture in a number of nuclear species, using only the relatively feeble neutron flux which is obtained from a 50-mC Ra-Be source. We wish to illustrate the method by presenting results for manganese, and hence show that an interesting and important field of investigation is now available to workers not fortunate enough to have a reactor at their disposal.

The scintillation spectrometer comprised an E.M.I. 5311 photomultiplier which was operated at 600 volts, a $\frac{3}{4}$-in. cube NaI-Tl crystal, a linear amplifier, a single-channel differential discriminator,[2] a Tetronix Model 511A oscilloscope, and highly stabilized power supplies for these units. The neutrons from the source were thermalized with the aid of a paraffin wax slow neutron howitzer, the crystal and photocell combination being protected as much as possible from the effects of Ra gamma-rays and slow neutrons by means of a 5-in. lead absorber and a thin boron shield (which produces only low energy capture radiation). The target consisted of 40 g of metallic manganese arranged to subtend the largest possible solid angle at the crystal. The pulse height distribution is first measured without the target in position, two simultaneous analyses being made with the single-channel discriminator and a photographic recording technique involving the oscillograph; and the whole procedure is repeated with the target in position. For the photographic recording a medium fast ortho film was found satisfactory at f:4.5, and exposure times ranging up to 2 or 3 hours gave an integrated blackening on the film of suitable density with only small statistical fluctuations. The latter method appears to give a resolution (measured in terms of the full width of a pair line at half-height) of 3 percent at 4 to 5 Mev, although the differential discriminator gives a value of 6 or 7 percent in the same energy range, indicating that the electronic pulse height sorting technique employed can cause a considerable apparent loss of resolution. Attempts are being made to minimize this effect, and a five-channel kicksorter will soon replace the existing discriminator.

Some attention had to be given to the use of a convenient gamma-ray line to use for calibration purposes in the high energy range. In this range one is concerned primarily with "pair lines."[1] The excited level in C^{12}, produced in the alpha-bombardment of Be, has been the subject of several investigations, some of the latest estimates for this level being 4.40 Mev,[3] 4.44 or 4.46 Mev,[4] 4.44 Mev,[5] and 4.45 Mev, according to our most recent comparisons with the Co^{60} gamma-rays. We have, therefore, adopted the value 4.45 ± 0.02 Mev for the gamma-ray from a Po-Be source (see Fig. 1). The main pair line appears at 3.43 Mev corresponding

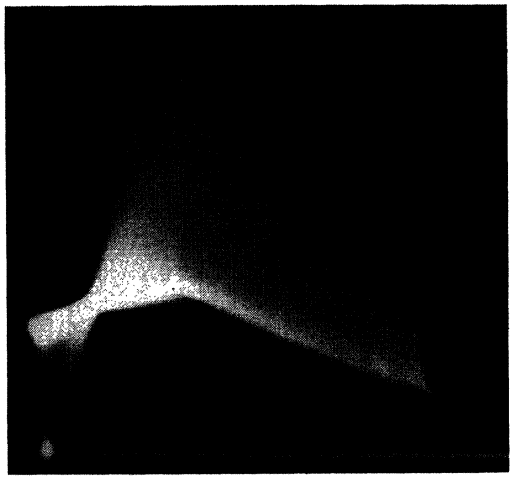

FIG. 2. Oscillogram of the spectrum excited by neutron capture in manganese.

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,

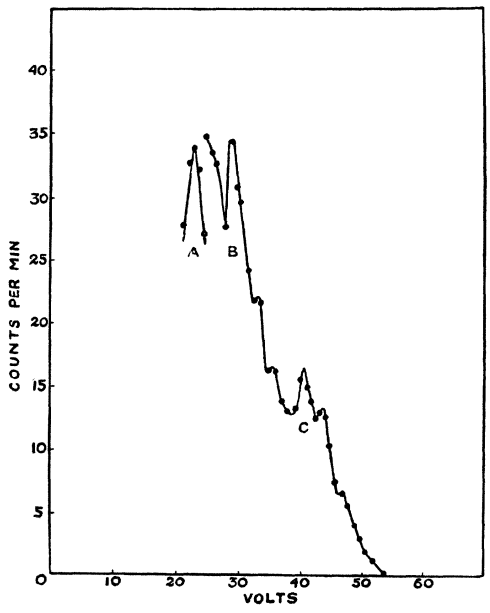

FIG. 3. Differential pulse height distribution for the spectrum excited by neutron capture in manganese. (A) Po-Be calibration line at 3.43 Mev. (B) Main pair line of manganese gamma-ray of 5.37 Mev. (C) Main pair line of manganese gamma-ray of 7.15 Mev.

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

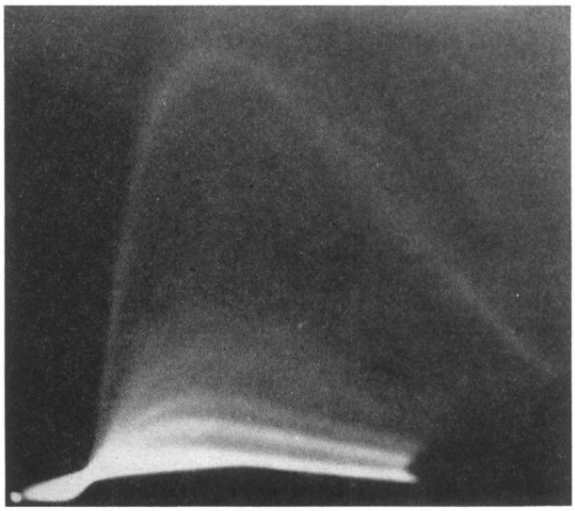

FIG. 1. Oscillogram of the Po-Be calibration spectrum, showing also photoelectron lines due to Po and a trace of Ra impurity.

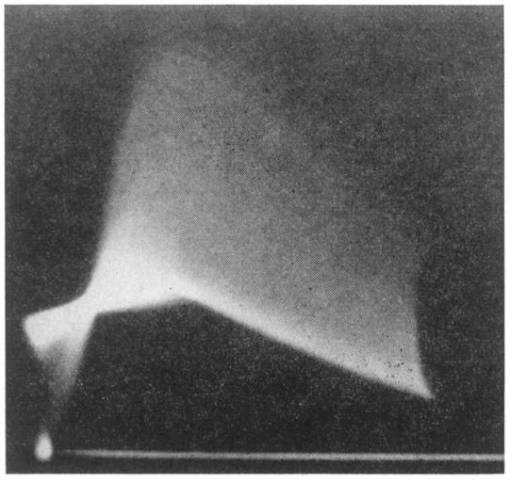

FIG. 2. Oscillogram of the spectrum excited by neutron capture in manganese.