to 1 or not. The possibility was discussed in Ref. 4 that g_l could be determined from the g factor of the $(h_{9/2}i_{13/2})\ 11^-$ state of ^{210}Po, but a precise determination to elucidate this problem is yet to be done.

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THRESHOLD PHOTONEUTRON CROSS SECTION FOR Mg^{25} AND ISOBARIC ANALOGS OF Na^{25} †

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The photoneutron cross section for Mg^{25} has been measured from 30 to 2000 keV above threshold. The locations of the isobaric analogs of the ground and first excited states of Na^{25} have been assigned and lower limits for their neutron-decay widths have been determined.

In many nuclei, the region of excitation just above the photoneutron threshold contains the isobaric analogs of low-lying states in the nucleus whose ground-state isospin is one unit higher than that of the nucleus under study. In such cases, the threshold photoneutron technique[1,2] is a useful tool for (1) locating precisely the excitation energies of the analog states, (2) helping to identify their spins and parities, and (3) measuring their neutron or ground-state radiative transition widths. The first of these items results from the precise energy resolution of neutron time-of-flight spectroscopy; the second from use of the electromagnetic selection rules; and the third from the cross-section measurements themselves. When the width for neutron emission is large compared with the width for proton and gamma-ray decay, then the radiative width is determined, independent of the experimental resolution, from the area under the resonance. When it is not, then in general the level will not be resolved completely; in this case, a prior knowledge of the radiative width, together with the threshold photoneutron cross section, yields a lower limit for the neutron width. The excitation energies of the analog levels give a direct measure of the Coulomb-energy radius of the nucleus, and can be used, in the case of isospin quartets, to predict nuclear masses. The radiative transition widths can be compared with theoretical predictions of the radiation width computed from a knowledge of both the target and parent ground-state wave functions, and also can be used to deduce the beta-decay matrix elements of the parent states. The neutron widths can be compared with the corresponding neutron widths for ordinary states (states with the same isospin as the ground state) to give the isospin mixing, or isospin purity, of the analog states.

This paper reports a measurement of the threshold photoneutron cross section for Mg^{25}. The data presented here were taken at an angle of 135° between the neutron-flight tube and the incident-photon beam. The bremsstrahlung target was yttrium, and the incident electron-beam energy was 11.0 MeV. The sample consisted of

50 g of $Mg^{25}O$, enriched to 97.9% Mg^{25}, contained in a 7.6-cm-diam thin-walled aluminum can. Experimental runs also were performed at lower electron-beam energies, both above and below the (γ, n) threshold at 7.33 MeV, to measure backgrounds and to differentiate between ground- and excited-state transitions.

The results are shown in Fig. 1. The uncertainty in the absolute cross section is about 20%. The laboratory neutron energies of the most prominent resonances are 41.11, 74.89, 235.8, 438.5, 472.4, 514.8, 601.3, 791, 914, 1092, 1707, and 1764 keV. Peak energies that correspond to neutron emission to the first excited state of Mg^{24} (at 1.369 MeV, $J^{\pi} = 2^+$) occur at 45.1, 208.5, and probably 1236.2 keV.

From the point of view of observing transitions to isobaric analog states with the threshold photoneutron technique, the situation for Mg^{25} is nearly ideal. The proton channel is closed and the low-lying level structure of Na^{25} is well known: Its ground state has $J^{\pi} = \frac{5}{2}^+$, and there

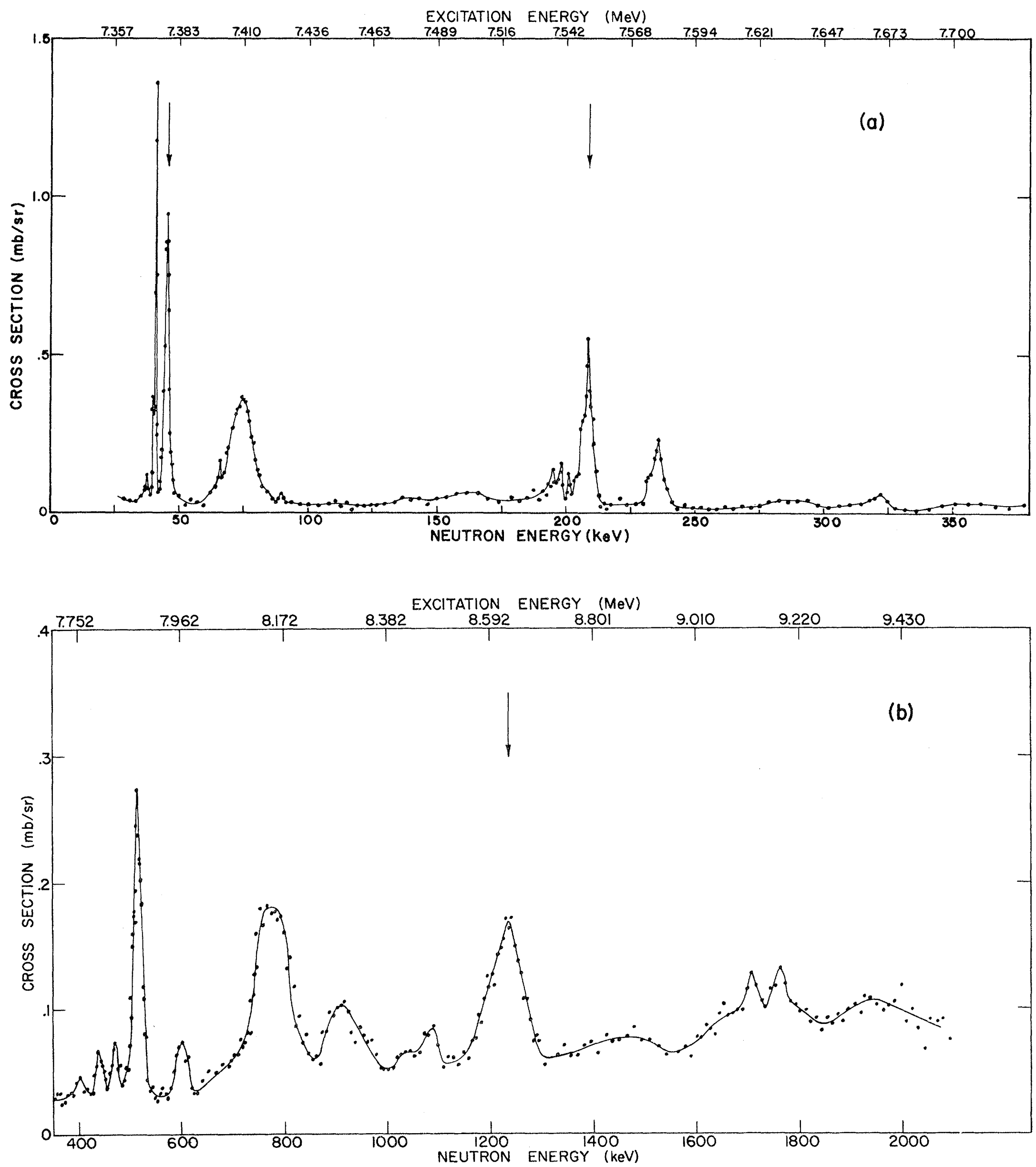

FIG. 1. Differential photoneutron cross section for Mg^{25} at 135° as a function of laboratory neutron energy (lower scale) and of excitation energy (upper scale). The arrows refer to peaks resulting from transitions to the first excited state of Mg^{24}. (a) Low-energy cross section; (b) high-energy cross section.

are excited states at 0.090 ($\frac{3}{2}^+$), 1.068, and 2.204 MeV.[3] The excitation energy of the $T=\frac{3}{2}$ analog in Mg^{25} of the Na^{25} ground state has been given as 7.790 ± 0.015[4] and 7.812 ± 0.025 MeV [5] by previous charged-particle experiments; the present higher-resolution work [see Fig. 1(b)] locates this level at a neutron energy of 438.5 keV, corresponding to an excitation energy of 7.7926 $\pm$ 0.0040 MeV [including an uncertainty of 0.0022 MeV in the $Mg^{25}(\gamma, n)$ threshold]. The area under the resonance yields $g\Gamma_{\gamma 0}\Gamma_n/\Gamma = 0.053 \pm 0.011$ eV, where $\Gamma_{\gamma 0}$, Γ_n, and Γ are the ground-state radiative width, the neutron width, and the total width, respectively, and $g = (2J+1)/2(2I+1)$ is the statistical factor for photons. Information on $\Gamma_{\gamma 0}$ is acquired in two ways: (1) from a direct measurement of the same transition in the mirror nucleus Al^{25} by Morrison et al.,[6] who give $\Gamma_{\gamma 0}(Al^{25}) = 0.82$ eV, and (2) from the beta-decay lifetime measurement for Na^{25} by Gove et al.,[7] who give $\log ft = 5.3$, which yields $\Gamma_{\gamma 0}(Mg^{25}) = 0.88$ eV. Using the average value of 0.85 eV, then, together with $g = \frac{1}{2}$ for this state, we get $\Gamma_n/\Gamma = 0.125$. This in turn enables us to set a lower limit for Γ_n of 0.12 eV. An upper limit for Γ_n depends on an assumption for the gamma-ray decay rate of the analog state to states in Mg^{25} other than the ground state; but even if the sum of such decays is an order of magnitude more probable than the ground-state decay, the upper limit for Γ_n would be only 1.2 eV. Since d-wave neutron widths for $T=\frac{1}{2}$ states in this region should be of the order of 10 keV, this implies that the isospin impurity of this state is not likely to be greater than about 1%, but is at least as large as 0.3%.

The analog of the first excited state of Na^{25} occurs at a neutron energy of 514.8 keV [see Fig. 1(b)], which corresponds to an excitation energy of 7.8728 ± 0.0030 MeV, 80 keV higher than the ground-state analog. This value is midway between the 90-keV separation between the two parent states in Na^{25} and the 70-keV separation between the mirror analogs in Al^{27}.[6,8] The area under this resonance gives $g\Gamma_{\gamma 0}\Gamma_n/\Gamma = 0.46$ eV. Using the value for $\Gamma_{\gamma 0} = 5.8$ eV, an indirect result from the low-resolution electron-scattering work of Fagg et al.,[9] and $g = \frac{1}{3}$, this yields $\Gamma_n/\Gamma = 0.24$, so that the lower limit on Γ_n is 1.8 eV, implying somewhat more isospin mixing for this state ($\gtrsim 1.3\%$) than for the ground-state analog.

In the present work there is only weak evidence for the analog of the 1.068-MeV second excited state in Na^{25}, at about 1465 keV, or $E_{exc} = 8.87$ MeV, 1.07 MeV above the ground-state analog. The case of the third excited state (at 2.204 MeV in Na^{25}), however, is rather different. The analog of this state appears only weakly as a ground-state transition in our data, in an energy region where the resolution is poor and the background is high [above the range of Fig. 1(b)]; but there is a very prominent excited-state transition at a neutron energy of 1236.2 keV, which corresponds to a level in Mg^{25} at 9.999 MeV, 2.206 MeV above the ground-state analog, and might very well be the analog state in question. This behavior could result if the spin and parity of this state (e.g., $\frac{3}{2}^+$ or $\frac{5}{2}^+$) were such as to inhibit (d-wave) neutron emission to the 0^+ ground state of Mg^{24} in favor of (s-wave) emission to the 2^+ first excited state. Since this resonance is resolved completely in the present work, $\Gamma_n \gg \Gamma_\gamma$ and the area under the peak directly measures $g\Gamma_{\gamma 0}$ to be 1.34 eV.

One can compute the Coulomb displacement energy E_C from the measured excitation energy E_{exc} of an analog state by means of the relation

$$\Delta E_C = E_{exc} + \Delta(n,p) - m_e c^2 - Q_{\beta^-}, \tag{1}$$

where $\Delta(n,p)$ is the neutron-proton mass difference $= 1.294$ MeV, $m_e c^2$ is the rest energy of the electron $= 0.511$ MeV, and Q_{β^-} is the beta-decay end-point energy. This in turn allows one to deduce the radius parameter R_0 for the analog state under the assumption of a uniform charge distribution, from

$$\Delta E_C = \tfrac{3}{5}\left[Z_1(Z_1-1) - Z_2(Z_2-1)\right] e^2/R_0 A^{1/3}$$
$$= 0.295\left[Z_1(Z_1-1) - Z_2(Z_2-1)\right]/R_0 \tag{2}$$

for $A = 25$, where Z_1 and Z_2 are the atomic numbers of the analog and parent states, respectively. For the present case, $E_{exc} = 7.793$ MeV, $Z_1 = 12$, $Z_2 = 11$, and $Q_{\beta^-} = 3.834$ MeV[3]; Eqs. (1) and (2) yield $\Delta E_C(Mg^{25} - Na^{25}) = 4.742$ MeV and R_0(Mg^{25} analog state) = 1.369 F. One also can make use of the known value for $E_{exc} = 7.916$ MeV[6,8] in Al^{25} for the $T=\frac{3}{2}$ analog of the ground state of Na^{25} to compute the same quantities for this state, from

$$\Delta E_C = E_{exc}(Al^{25}) - E_{exc}(Mg^{25}) + \Delta(n,p) - m_e c^2 + Q_{\beta^+}, \tag{3}$$

where $Q_{\beta^+} = 4.259$ MeV[3] and from Eq. (2) with $Z_1 = 13$ and $Z_2 = 12$. This results in $\Delta E_C(Al^{25} - Mg^{25}) = 5.165$ MeV and R_0(Al^{25} analog state) = 1.371 F. Similar calculations using the excitation energies for the first-excited-state analogs yield

$$\Delta E_C(\text{Mg}^{25}-\text{Na}^{25}) = 4.732 \text{ MeV},$$

$$R_0(\text{Mg}^{25} \text{ analog state}) = 1.372 \text{ F},$$

$$\Delta E_C(\text{Al}^{25}-\text{Mg}^{25}) = 5.165 \text{ MeV},$$

$$\text{and } R_0(\text{Al}^{25} \text{ analog state}) = 1.373 \text{ F};$$

averaging these results then yields $\Delta E_C(\text{Mg}^{25}-\text{Na}^{25}) = 4.737 \pm 0.007$ MeV, $\Delta E_C(\text{Al}^{25}-\text{Mg}^{25}) = 5.160 \pm 0.006$ MeV, and $R_0 = 1.371 \pm 0.002$ F.

Finally, one can predict the mass of the fourth member of this isobaric-spin quartet, namely Si^{25}, from the relation

$$M = a + bT_z + cT_z^2, \qquad (4)$$

where $T_z = -\frac{3}{2}$, whence the mass excess for Si^{25} is 3793 ± 32 keV.

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SELECTIVE ORBITAL ANGULAR MOMENTUM TRANSFER IN (^{3}He, t) REACTIONS*

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Angular distributions previously found to be characteristic of the spin change for (^{3}He, t) transitions in even-mass $f_{7/2}$-shell nuclei are found to characterize transitions for a number of even- and odd-mass nuclei in the s-d shell. It appears that this may be due to certain strong selectivities in the orbital angular momentum transfer.

Recent studies[1-5] of the (^{3}He, t) reaction on even-mass $f_{7/2}$-shell nuclei have shown that there is a striking similarity in the shape of the angular distributions of tritons leading to states of the same J^π and that the transitions proceed primarily via the highest allowed orbital angular momentum transfer[6] L. It is important to determine whether these effects are general features of the reaction, i.e., whether they are present in transitions involving other shell-model orbitals and involving odd-mass as well as even-mass nuclei. Such general characteristics would make the (^{3}He, t) reaction a most valuable spectroscopic tool. The present study indicates that the strong similarities in angular distributions are, indeed, quite characteristic of the (^{3}He, t) reaction over the mass range 19 to 54. On the other hand, the preference for transitions to proceed via the highest allowed L is found to be limited to even-mass nuclei.

The (^{3}He, t) reaction on ^{19}F, ^{27}Al, and ^{26}Mg has been studied at incident energies of 24 and 26 MeV using Stanford University's Model FN tandem Van de Graaff. Emergent tritons were identified in an E-ΔE counter telescope over the angular range 10°-60° in 5° intervals with an energy resolution of 60 keV. Angular distributions were extracted for all well-resolved and statistically significant transitions. A number of typical angular distributions for each nucleus are presented in Fig. 1 as well as a number of angular distributions reported previously[2,3,5] in studies of the (^{3}He, t) reaction on ^{42,48}Ca and ^{54}Fe (also at an incident energy of 26 MeV). All angular distributions presented in Fig. 1 involve transitions to states of known spin and parity.

Transitions to even-J positive-parity states in even-mass nuclei proceed via a unique L while