charging have lesser effect. (Indeed, one is compelled toward these conditions because the charge 1 peak is so weak that it has to be compressed by pre-deflection acceleration into the transmission width of the instrument before it can be made to stand above background.) Figure 2 shows the charge 1 peak observed with 75 volts applied to the source volume. The peak appears at 9.8±0.2 ev on the recoil energy scale, but the recoil energy scale is itself uncertain within ±0.5 ev because of a small uncertainty in the present value of the calibration constant of the spectrometer.

In summary, the observations show that the recoil ions are of mass 37, have an energy spread that can be accounted for by thermal motion and recoil from Auger electron emission, and possess an energy of recoil within about 7 percent of that predicted from emission of a single neutrino with an energy of 816 kev.

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Isomerism in Al^{26}*

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It has been suggested that the 6.7-second state of Al^{26}, which exhibits a superallowed transition to Mg^{26}, might not be the ground state.[1] Perhaps the most direct evidence for this contention comes from comparison of the mass of Al^{26} (mass of Al^{26} − mass of Mg^{26} = 4.00 ±0.03 Mev) as determined from nuclear reaction Q-values[2] and the β-decay energy $E_\beta + 2m_0c^2 = 4.2 \pm 0.1$ Mev.[3] Also suggestive are the facts that the neutron yield of the reaction $Al^{27}(\gamma,n)Al^{26}$ is three times the positron yield,[3,4] and that the ratio of γ-ray yield to positron yield observed in $Mg^{25}(p,\gamma)$ varies with bombarding energy.[5] In the present work we have confirmed the latter observation and, by a new measurement of the β-decay energy and of γ-ray spectra, established the location of the 6.7-second state.

The yield of positrons and γ-rays from a 10-kev target[6] of Mg^{25} as a function of proton energy is shown in Fig. 1. To obtain these data an end-window β counter and a thick-walled γ counter were placed near the target and the beam was interrupted at a rate of 60 cps; the γ counter counted continuously but the β counter recorded only when the beam was off the target. If the γ counter had a linear efficiency-*vs*-energy response, its counting rate would be proportional to the capture cross section regardless of the mode of decay of the

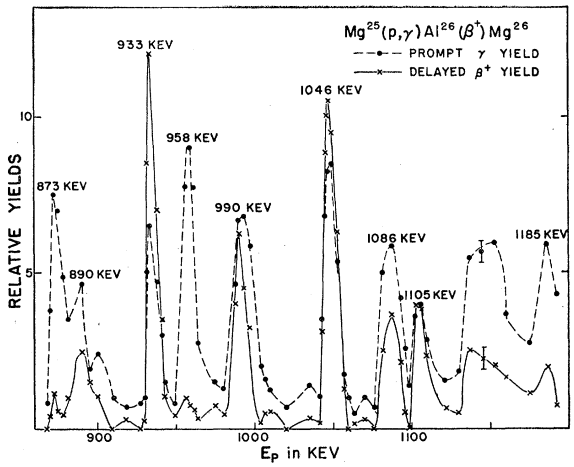

FIG. 1. Yield of prompt γ rays in a thick-walled counter compared to the yield of delayed positrons in an end-window counter, as a function of the energy of protons bombarding a 10-kev Mg^{25} target.

compound level. Since a thick-walled γ counter approximates this condition fairly well,[7] the γ yield of Fig. 1 can be taken to represent to a good approximation the capture cross section, while the positron yield is proportional to the number of captures which terminate in the 6.7-second state. The wide variation of the ratio of the two curves suggest that a varying fraction of the captures must terminate in a state of Al^{26} having a half-life much longer than 7 seconds. For example, at 958-kev proton energy, nearly all of the captures go to this state.

An 8-mg/cm² $Mg^{25}O$ target on 1-mil Al backing, placed with the MgO facing the proton beam from a 3-Mev electrostatic accelerator, was bombarded in a magnetic lens spectrometer to determine the positron spectrum. The beam was again interrupted at the 60-cps rate with positron detection permitted only while the beam was off the target. The Kurie plot of the resulting spectrum was straight down to 1.5 Mev and had an end-point energy of 3.20±0.05 Mev, including a 0.02-Mev correction for backing and target thickness. With a half-life of 6.68±0.11 seconds,[8] the ft-value is 3120± 290 seconds, in agreement with other measurements for 0→0 transitions: 3275±75 for[9] O^{14}, and 3220±200 for[10,11] Cl^{34}. From the difference between this end-point and Q-values from other work,[2] the excitation of the 6.7-second state in Al^{26} is calculated to be 0.22±0.06 Mev; a recent determination[12] of the threshold of the reaction $Mg^{26}(p,n)Al^{26}$, giving a preliminary Q-value of 4.886±0.010 Mev, leads to the value 0.12±0.06 Mev. This confirms that the positron-emitting state is not the ground state.

Gamma-ray spectra at a number of resonances have been examined with a crystal spectrometer, using 4 in.×4 in. and 1½ in.×1½ in. NaI crystals, with the following results. At the 958-kev resonance, where the positron yield is low, γ rays are observed having energies

0.416±0.004, 0.511 (weak), 1.67±0.02, 2.08±0.02, and 5.23±0.05 Mev, with no others of comparable intensity. The 0.416- and 1.67-Mev γ rays are in coincidence (within the resolving time of 4 μsec), while the 0.416- and 2.08-Mev γ rays are not. The 0.416- and 1.67-Mev γ ray intensities are about equal and twice that of the 2.08-Mev γ ray. These γ-ray energies fit well into the level scheme of Browne,[13] and the short half-life of the 0.416-Mev transition verifies his conclusion that the 0.418-Mev level is not the 6.7-second positron-emitting state. The 0.416-Mev γ ray was also observed in varying intensity ratio to the annihilation radiation, at 697-, 730-, 990-, 1046-, and 1086-kev bombarding energy.

At 730-kev proton energy, where the positron yield is relatively high, the 0.416-Mev and 0.511-Mev γ rays have about the same intensity. There also appear several new γ rays: three in prompt coincidence with energies 0.833± 0.006, 1.022±0.006, and 5.00±0.05 Mev, and two, not checked for coincidence, with energies 1.44±0.03 and 2.46±0.03 Mev. The last two may account for the fact that the 0.833-Mev γ ray is about 50 percent more intense than the 1.022-Mev γ ray. (For example, a level in Al^{26} at 3.51 Mev would be consistent with these and the considerations below.) The 0.833- and 1.022-Mev γ rays were also found with similar intensity ratios at proton energies of 730, 933, 990, 1046, and 1086 kev.

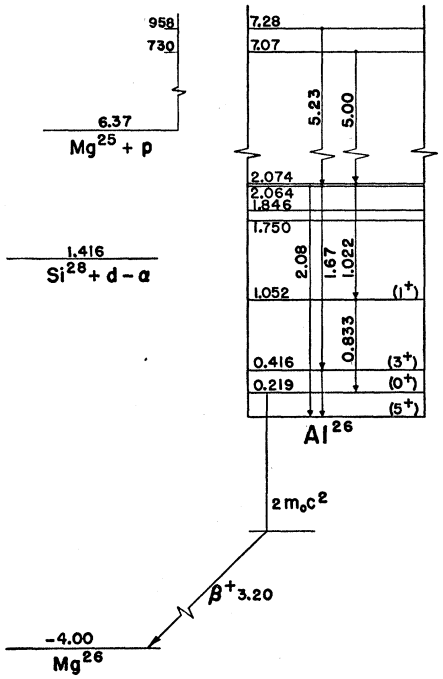

FIG. 2. Energy levels of Al^{26}. The spins indicated form a set consistent with the experimental data and the shell model. Levels below 2.1 Mev other than those at 0.219 and 2.074 Mev are those given in reference 13.

The 1185-kev resonance reveals only a 0.588±0.005-Mev γ ray, other γ rays having less than about one percent of its intensity: the resonance is therefore attributed to $Mg^{25}(p,p')$ terminating in the known first excited state[14] of Mg^{25}. The peak at 873 kev in Fig. 1 is attributed chiefly to F^{19} contamination.

The γ- and β-ray data suggest that the 1.67- and 2.08-Mev γ rays branch from the 2.064-Mev level previously reported[13] from the reaction $Si^{28}(d,\alpha)Al^{26}$, and that the 0.833- and 1.022-Mev γ rays originate from the reported 1.052-Mev level and a new level at 2.074 ±0.013 Mev, respectively. Regarding the latter as the second $T=1$ state with spin 2^+, which would not be expected to show up in the reaction $Si^{28}(d,\alpha)Al^{26}$, would not be inconsistent with the observed γ-ray data, and is suggested as the expected analogue of the 1.83-Mev level in Mg^{26}. The 0.833-Mev γ-ray assignment places the isomeric level at 0.219±0.013 Mev, in close agreement with the expected location of the analogue of the Mg^{26} ground state.

Assuming the shell model and jj-coupling for the odd $d^{5/2}$ neutron and proton requires that the states with $J=0$, 2, and 4 have isotopic spin $T=1$, and the states with $J=1$, 3, and 5 have $T=0$. An assignment of spins to the levels of Al^{26} (taking even parity) consistent with the observations is shown in Fig. 2. $J=5$ is taken for the ground state because of the absence of 1.83-Mev delayed γ-radiation in a thick $Mg^{25}O$ sample irradiated for three hours in a $\frac{3}{4}$-μa beam of 1.5-Mev protons.[15] If the ground state had $J=3$, an allowed 1.2-Mev positron transition to the first excited state of Mg^{26}, followed by a 1.83-Mev γ ray, would be expected, with a half-life of several minutes to several hours. A calculated half-life of about 5×10^4 years results for this transition if $J=5$ and log ft is taken to be 13.

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Slowing Down of Polarized Protons*

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SEVERAL mechanisms for depolarization of protons as they are slowed down in matter have been discussed by Wolfenstein,[1] who concludes that these are ineffective. Furthermore the additional depolarizing processes which we have been able to think of do not promise to be larger. Nevertheless an experimental knowledge of depolarization effects is necessary in the interpretation of many experiments. To this end we have degraded the energy of a polarized proton beam in several different substances.

A 425-Mev 54 percent polarized proton beam was used, produced by scattering the 435-Mev average energy circulating protons elastically at 14° from a Be target in the cyclotron. The polarization of the external proton beam so produced was determined by measuring the asymmetry of elastic scattering from Be at the same angle. In addition, the asymmetries of elastic scattering at 20° and at 30° were measured in a geometry subsequently used to measure asymmetries for the beam degraded in energy.

Next the beam was degraded to E' in paraffin, in C, in Cu, and in Pb. The asymmetry of elastic scattering of the degraded beam by beryllium was again measured at 20° and at 30°. The geometry was such that no protons scattered by more than 2.2° in the slowing down material could reach the Be. In passing through the 2-inch thick Be scatterer, the mean energy of the beam was still further reduced from E' to E. The emergent energy E was determined by range measurement in Cu.

TABLE I. Proton polarization *versus* energy attenuation.

Average energy of degraded beam Mev	Attenuating material	Percent asymmetry of elastic scattering (thickness of Cu filter given in parentheses) 20°		30°	
425[a]	None	63.2±9.3 48.7±3.7	(5.25 in.) (5 in.)	6.7±9.5	(5.25 in.)
240	15.25 in. CH_2	50.0±1.6	(2.25 in.)	13.0± 4.3	(2.25 in.)
	10 in. C	50.0±1.8		11.2± 5.2	
	2.311 in. Cu	46.5±2.2		−4.8± 5.4	
	2.378 in. Pb	46.8±2.6		−7.0± 8.5	
	10 in. C	57.0±2.8	(2.75 in.)	21.9±13.0	(2.75 in.)
186	12 in. CH_2 + 10 in. C	64 ±8	(1 in.)	33 ± 5	(1 in.)
~115	12 in. CH_2 + 14 in. C	35.8±3.6	(½ in.)	23.3±10.3	(½ in.)

[a] Initial polarization of 425-Mev beam = 53.6±1.3 percent.

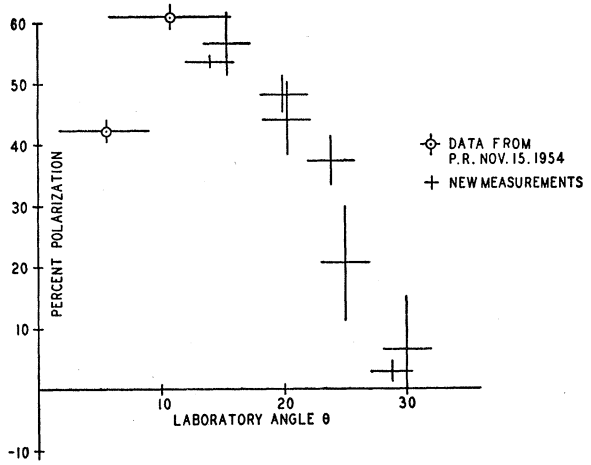

FIG. 1. Polarization of 425-Mev protons effected by elastic scattering on Be plotted as a function of laboratory angle of scattering.

The counter telescopes which measured the scattered protons were provided with copper filters such that quasi-nucleon-scattered protons could not produce a coincidence count. For the filter, that thickness of copper was chosen for which the range curve had dropped to about two thirds of the distance down from the "knee." In Table I are given the effective energy E, the thicknesses of the various attenuators, and the corresponding asymmetries of elastic scattering measured at the two laboratory angles.

In addition we have measured, with considerably better statistical accuracy and angular definition than previously,[2] the polarization of 425-Mev protons scattered elastically from Be and find the dependence shown in Fig. 1. It is similar to that known for Be,[2] C,[3] and He[3] at 310 Mev.

The asymmetries are practically unaffected by degradation of proton energy from 430 to 150 Mev regardless of Z and of nuclear spin of the attenuator. The slight increase in asymmetry with decreasing proton energy we ascribe to the fact that the elastic diffraction pattern is wider at lower energy and therefore the polarization curves (corresponding to Fig. 1) are wider.

In principle the polarization of the protons degraded from 425 to 240 Mev can be computed from the asymmetry measured at 240 Mev shown in Table I, together with the polarization by elastic scattering for Be at 20° and 240 Mev. Instead we use (50±10) percent measured[2] at 310 Mev and 20° for C, and compute for the polarization of protons degraded from 425 to 240 Mev, $P=\frac{1}{2}(50\pm2)/(50\pm10)=50\pm10$ percent. This number we compare with the polarization of 53.6±1.3 percent measured for the 425-Mev beam. One sees that within the error no depolarization has occurred.