Long-Lived Isomer of Al^{26}†

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Long-lived Al^{26} has been chemically purified from aluminum targets used in the 86-in. cyclotron. The main decay observed is through a 1.30±0.15 Mev positron in coincidence with a 1.82-Mev gamma ray. In addition, gamma rays of 0.717 Mev and 2.91 Mev have been found.

INTRODUCTION

FROM experimental as well as theoretical considerations, it has been suggested [Kavanagh *et al.*[1] give an excellent summary of these data] that the 6-second β^+-emitting Al^{26} is not the ground state. Recently, Simanton, Rightmire, Long, and Kohman[2] have isolated a small amount of a long-lived aluminum activity from a target of magnesium bombarded with 15-Mev deuterons at the University of Pittsburgh cyclotron. From their very low intensity source, they were able to identify gamma peaks from the 0.51-Mev annihilation radiation, and evidence was found for a gamma ray at ~1.9 Mev. In addition, aluminum absorption data showed the presence of ~1-Mev electron. These data were consistent with the postulated positron decay from the 5^+ level in Al^{26} to the known 1.8-Mev excited level in Mg^{26}. The half-life of such isomer should then be 10^4–10^6 years.

At the Oak Ridge National Laboratory, there are available several old aluminum targets which have received many hours of proton irradiation. Al^{26} could be produced by the (p,pn) reaction or $(p,2n)$ to short-lived Si^{26} with decay to Al^{26}, and these targets should be a source of a considerable amount of Al^{26}. Several targets were obtained and were processed as described below.

PREPARATION OF THE SOURCE

These old aluminum test targets used in the ORNL 86-in. cyclotron had received an unrecorded number of hours bombardment with 22.4-Mev protons. The target of solid aluminum, 6 in.×10 in., which was cooled by circulating water and slightly concave, was flattened and placed in a tray with the face in contact with concentrated hydrochloric acid. Approximately 25 g of aluminum were removed from the face. Holdback carriers of suspected possible contaminants were added, i.e., Co, Fe, Mn, and Zn. Purification of the aluminum was accomplished by taking the hydrochloric acid solution of aluminum and saturating it with gaseous hydrochloric acid while cooling to a temperature of 15°C.[3] A volume of ether equal to the volume of the liquid was added and gaseous hydrochloric acid passed through until the solution was saturated; this was noted by a disappearance of the two layers. After standing approximately one hour, the supernate was discarded by decanting. The precipitate of $AlCl_3$ was washed with a solution composed of equal parts of hydrochloric acid and ether and saturated with hydrochloric acid gas at 15°C. The precipitate of $AlCl_3$ was dissolved in approximately 10*N* HCl, by warming, if necessary. Reprecipitation of $AlCl_3$ was repeated eight times. After a study of the gamma spectrum and coincidence measurements, the purification was repeated with eight additional $AlCl_3$ precipitations followed by an acid sulfide pre-

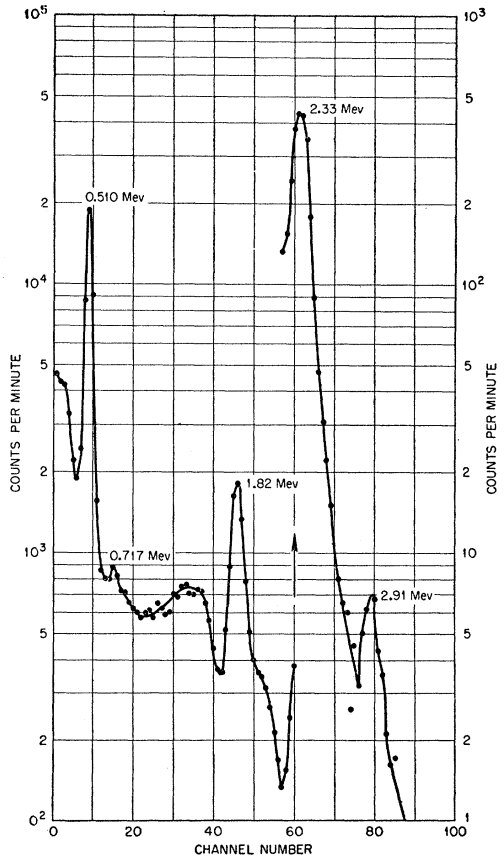

FIG. 1. Gamma-ray spectrum of Al^{26}.

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[1] Kavanagh, Mills, and Sherr, Phys. Rev. **97**, 248 (1955).

[2] Simanton, Rightmire, Long, and Kohman, Phys. Rev. **96**, 1711 (1954).

[3] W. F. Hillebrand and G. E. F. Lundell, *Applied Inorganic Chemistry* (John Wiley and Sons, Inc., New York, 1929), p. 392.

TABLE I. Radiation from Al^{26*}.

Type	E (Mev)	Absolute γ intensity relative to total β^+	Remarks
Annihil. gamma	0.51	2	Coinc. with 1.82-Mev γ-ray
Gamma 1	0.717	0.01	
Gamma 2	1.82	1	
Gamma 3	2.91	0.004	
Beta	1.30±0.15	1	Coinc. with 1.82-Mev γ-ray

cipitation using Cu as a scavenger. The solution was then evaporated just to dryness and further studies made.

The supernate containing the impurities was collected and boiled just to dryness. A qualitative scheme separation of these impurities followed by a gamma-ray spectrum of the separated groups showed the presence of Na, Mn, Fe, Co, and Zn radioactivities. These activities were produced from impurities in the original aluminum target, or the target was contaminated with them during the various test runs. However, since a gamma spectrum of the final product did not show the presence of these impurities either before or after the final repurification, it is felt the final product is pure.

MEASUREMENTS AND DISCUSSION

The purified Al_2O_3 (~50 grams) was placed on top of a 3 in.×3 in. crystal NaI gamma-ray spectrometer and the gamma-ray spectrum obtained. The Al_2O_3 was dissolved, further purifications made, and the material re-examined using the 3 in.×3 in. NaI crystal gamma-ray spectrometer. The gamma spectrum was similar to that obtained previously indicating that the aluminum had been successfully decontaminated from other activities. Figure 1 is a plot of the gamma-ray spectrum of Al^{26*} obtained using the 3 in.×3 in. NaI crystal and a thirty-channel analyzer somewhat similar to that described by Porter and Borkowski.[4]

It is believed that the scattering of points from channel 20 to 38 (~0.86 Mev to ~1.5 Mev) is due to statistics. Besides the 0.51-Mev annihilation gamma, the spectrum shows the presence of 0.717-Mev, 1.82-Mev, and 2.91-Mev gamma rays. The peak at 2.33 Mev is believed to be mainly due to summing of the coincident positron and 1.82-Mev gamma ray. The peak at 2.91 Mev is believed to represent a real gamma ray of this energy and not a scattering pile up phenomena. A source of Na^{22} (β^+ and 1.28-Mev γ ray) of about twice the intensity of the Al^{26} was examined for a peak at (1.02+1.28) Mev; such a peak would result from a pile-up scattering also if the Al^{26} 2.91-Mev γ ray was produced in this manner. There was no peak observed in this region with the Na^{22} source. The approximate relative intensities of the gamma rays was obtained by dividing by the photopeak efficiency obtained from known standards in the usual manner. These data are shown in Table I.

Aluminum absorption data were obtained by using a source containing ~100 mg of the Al_2O_3 and an end-window Geiger-Muller counter as detector. Comparison of the slope of the activity *vs* absorber thickness plot with plots made of known energy beta emitters mounted in a similar manner indicated the positron energy to be 1.30±0.15 Mev.

Gamma-gamma coincidence measurements were made by using a 1 in.×1.5 in. NaI crystal spectrometer set to accept only 0.51-Mev photoelectrons from the annihilation gamma as one detector, and the 3 in.×3 in. NaI crystal set to accept only 1.82-Mev gamma-ray photoelectrons as the other detector. These data indicated the positron decay is to the 1.82-Mev level. No significant coincidence data were obtained between any of the other gamma rays.

From the approximate intensity measurements, it appears that the number of β^+ and 1.82-Mev gamma rays are about the same; this is confirmed by ion chamber measurements.

From the known energy difference, $Al^{26g}-Mg^{26g}=4.01\pm0.02$ Mev,[5] it appears that the positron energy must be $4.01-1.83-1.02=1.16$ Mev which agrees with the observed value noted above. The 1.83-Mev and 2.9-Mev levels in Mg^{26} are known,[6] but no level at 0.7 Mev has been reported; because of the exhaustive chemical treatment, however, it is felt that this level does occur in the decay of Al^{26*}.

The authors are indebted to F. M. Porter and C. J. Borkowski for permission to use the thirty-channel analyzer.

[4] F. M. Porter and C. J. Borkowski, Nucleonics **12**, No. 3, 53 (1952).

[5] C. P. Browne, Phys. Rev. **95**, 860 (1954).

[6] P. M. Endt and J. C. Kluyver, Revs. Modern Phys. **26**, 95 (1954).