Radiations of Ra^{227}†

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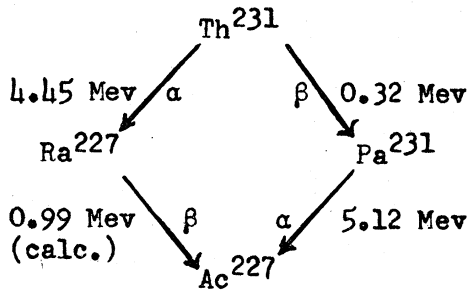
Ra^{227} has been prepared by the slow neutron irradiation of Ra^{226} in the NRX reactor. Ra^{227} is a β^- emitter with a half-life of 41.2±0.2 minutes and with a β^- end point of 1.31±0.02 Mev. Gamma rays of 291 and 498 kev were observed with a scintillation spectrometer. The cross section for the reaction $Ra^{226}(n,\gamma)Ra^{227}$ was found to be 23 barns.

INTRODUCTION

Ra^{227} has been previously prepared by Peterson[1] by the neutron irradiation of Ra^{226}; however, he did not isolate Ra^{227} but only its daughter Ac^{227}.

In order to determine whether it would be possible to isolate Ra^{227}, it was necessary to predict the nuclear properties of Ra^{227}. The β^- disintegration energy of Ra^{227} was calculated from the following closed decay cycle:



The β^- disintegration energy of Th^{231}(UY) was obtained from the data of Freedman *et al.*[2] The α disintegration of Th^{231} was estimated to be 4.45 Mev by extrapolating the appropriate line on an α-energy *vs* mass number curve.[3] In this manner, the β^- disintegration energy of Ra^{227} was calculated to be 0.99 Mev. The β^- decay of Ra^{227} was expected to be first-order forbidden and thus this energy would lead to a β^- decay half-life of about 30 minutes. Therefore it seemed possible that Ra^{227} could be observed by a short irradiation of Ra^{226} in a high-neutron flux in the NRX nuclear reactor followed by a rapid chemical separation of radium.

EXPERIMENTAL

The Ra^{226} used in these experiments was analyzed spectrographically and was shown to contain 0.2 percent barium, 0.2 percent calcium, 0.1 percent iron, and traces of magnesium and boron.

Before irradiating the Ra^{226}, it was freed from its decay products by boiling the solution of $RaCl_2$ for a few minutes. This removed the 3.85-day Em^{222}. The other decay products, Po^{218}, Pb^{214}, and Bi^{214}, which have short half-lives, were allowed to decay away. A sample of the Ra^{226} solution was then evaporated in a small silica tube and irradiated for 30 to 50 minutes in a thermal neutron flux of 4×10^{13} neutrons/cm² sec.

After the irradiation, the sample was returned to the laboratory through a pneumatic tube. With this arrangement, targets were received 20 seconds after the end of the bombardment. The silica tube was smashed and the radium chloride was dissolved in 0.2*N* hydrochloric acid containing barium, bismuth, and lead carriers. The sulfides of bismuth and lead were precipitated in order to free the radium from the decay products of Ra^{226} which had grown in during the irradiation. Iron sulfide was then precipitated to remove other undesirable impurities. The radium was further purified by precipitating it as the carbonate and then as the chloride, using barium as a carrier. The chemical separation of the radium was completed in about 15 minutes.

The β^- decay of the purified radium was observed with an end-window Geiger counter, using a 5.9-mg/cm² aluminum absorber to prevent α particles from Ra^{226} and its decay products from entering the counter. A half-life of 41.2±0.2 minutes was observed and attributed to Ra^{227}. A typical decay curve is shown in Fig. 1. By subtracting the counts due to Pb^{214} and Bi^{214} which grow in from Ra^{226} with a 3.8-day half-life, it was possible to follow the decay of Ra^{227} through eleven half-lives. In the decay of the sample of Ra^{227} no other components were observed.

The (n,γ) cross section of Ra^{226} was determined in four irradiations. A value of 23 barns with a standard deviation of 1 barn was obtained after making the proper corrections for backscattering and counter window absorption. Since Ra^{226} could be used as a tracer for the Ra^{227}, it was not necessary to know either the initial amount of Ra^{226} irradiated or the chemical yield in order to calculate this cross section. The integrated flux was obtained by measuring the activity produced in a sample of gold which was irradiated

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[1] S. Peterson, *The Transuranium Elements: Research Papers* (McGraw-Hill Book Company, Inc., New York, 1949), Paper 19.9, p. 1393. National Nuclear Energy Series, Plutonium Project Record, Vol. 14B, Div. IV.
[2] Freedman, Wagner, Jaffey, and May, Argonne National Laboratory Report ANL-4613 (unpublished).
[3] Perlman, Ghiorso, and Seaborg, Phys. Rev. 77, 22 (1950).

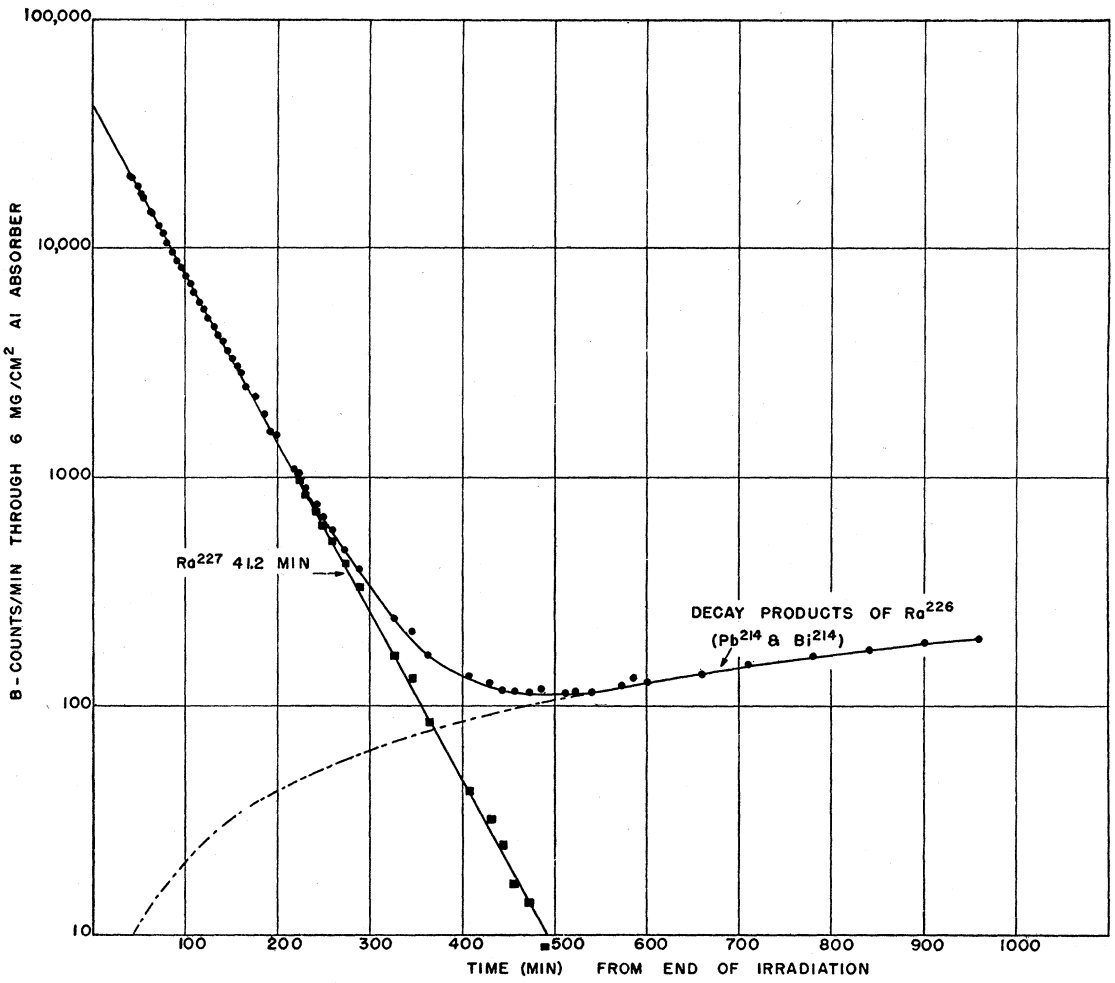

FIG. 1. Decay of Ra fraction from neutron-irradiated Ra^{226}.

simultaneously with the Ra^{226}. The gold cross section was taken as 98 barns.

An aluminum absorption curve of the radiations from Ra^{227} was taken using a sample mounted on a thin polystyrene film (1.5 mg/cm²) (Fig. 2). The absorption curve showed the presence of two components both of which decayed with a 41-minute half-life. The hard component C which was attributed to soft γ rays was subtracted from curve A to give curve B. From curve curve B the soft component, β^- radiation, was shown to have a range equal to 578 mg/cm² of aluminum. This range was obtained both visually and by carrying out a Feather-type analysis using P^{32} as a standard. Using the range-energy relationship,

$$E=(R+0.133)/0.542,$$

given by Glendenin and Coryell,[4] the maximum energy of the β^- particle was calculated to be 1.31 ± 0.2 Mev. This value is 0.3 Mev greater than the predicted value which was calculated from the closed decay cycle.

The γ rays occurring in the β^- decay of Ra^{227} were studied with sodium iodide (thalliated) scintillation spectrometer. The pulses from the R.A.C. 5819 photomultiplier tube were fed into a linear amplifier, then into a cut amplifier and from thence into a twenty-four channel pulse analyzer. The scintillation spectrometer had been calibrated with the 60-kev line of Am^{241}, 364-kev line of I^{131}, 411-kev line of Au^{198}, and 662-kev line of Cs^{137}. From the observed γ spectrum of Ra^{227} plus Ra^{226}, the γ spectrum of Ra^{226} was subtracted. The resulting spectrum decayed with a 41-minute half-life and showed three γ rays with energies of 92, 291, and 498 kev. The numbers of quanta per 100 β^- disintegrations were 3.1, 4.0, and 0.6, respectively. The 92-kev line is most probably a mixture of K_α and K_β x-rays of actinum. These K x-rays presumably arise from the internal conversion of 291- and 498-kev γ rays.

[4] L. E. Glendenin and C. D. Coryell, *Radiochemical Studies, The Fission Products* (McGraw-Hill Book Company, Inc., New York, 1946), Paper 2.12, National Nuclear Energy Series, Plutonium Project Record, Vol. 9B, Div. IV.

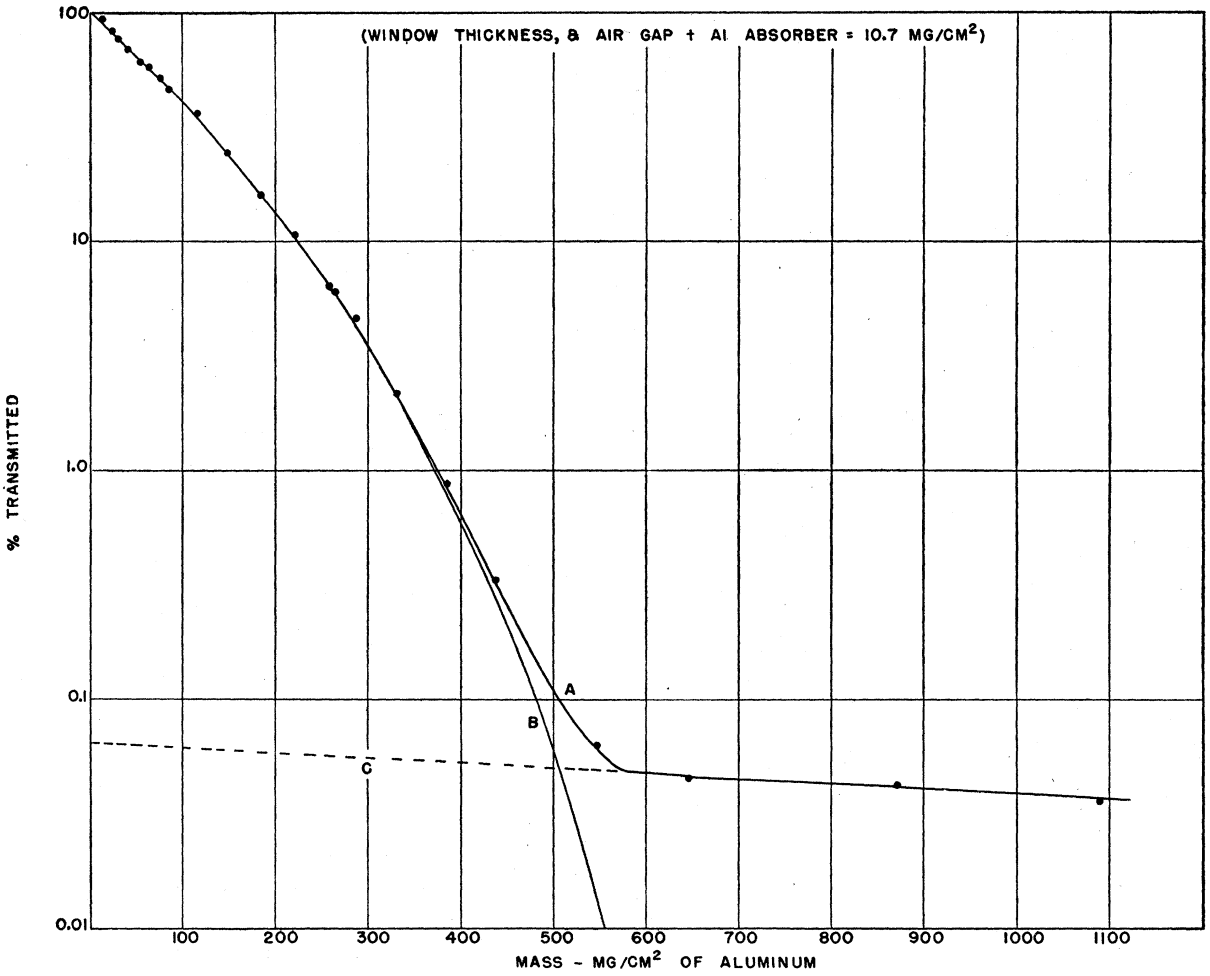

FIG. 2. Absorption curve of Ra^{227}.

DISCUSSION

Since the number of quanta of electromagnetic radiation in the decay of Ra^{227} is small, the 1.31-Mev β^- transition very probably goes to the ground state of Ac^{227}. Thus the β^- disintegration energy of Ra^{227} is 1.31 Mev. This value introduces a discrepancy of about 0.3 Mev in the decay cycle (see above). The decay of both Pa^{231} and Th^{231} (UY) has been studied by several investigators[5,2,6] and it is extremely unlikely that either the α disintegration energy of Pa^{231} or the β^- disintegration of Th^{231} are in error by this amount. Thus, the extrapolated value for the α disintegration of Th^{231} is the only logical decay to account for this discrepancy. The results of this experiment therefore indicate that the α disintegration of Th^{231} is 4.13 Mev. This value is only slightly greater than the α disintegration of Th^{232}.

ACKNOWLEDGMENT

We wish to thank Mr. P. B. Aitken for his design of the pneumatic tube which was used to carry out these experiments.

[5] Rosenblum, Cotton, and Bouissières, Compt. rend. **229**, 825 (1949).

[6] G. B. Knight and R. L. Macklin, Phys. Rev. **75**, 34 (1949).