UCRL-9995

UNIVERSITY OF CALIFORNIA
Lawrence Radiation Laboratory
Berkeley, California

Contract No. 7405-eng-48

THE NEUTRON-DEFICIENT YTTRIUM ISOTOPES Y^{82}, Y^{83}, AND Y^{84}

V. Maxia, W. H. Kelly, and D. J. Horen

December, 1961

THE NEUTRON-DEFICIENT YTTRIUM ISOTOPES Y^{82}, Y^{83}, AND Y^{84}

V. Maxia, W. H. Kelly, and D. J. Horen

Lawrence Radiation Laboratory
University of California
Berkeley, California

December, 1961

ABSTRACT

The neutron-deficient yttrium isotopes Y^{82}, Y^{83}, and Y^{84} have been produced by irradiations with the Berkeley heavy-ion linear accelerator. Where possible, identifications were made by establishing genetic relationships with known daughter or granddaughter activities. The half-life of Y^{84} determined by direct decay is 39±1 min. By a series of timed chemical separations, the following half-lives have been established: Y^{82}, 9±3 min; Y^{83}, 8±2 min. No information pertaining to the radiations emitted in the decay of these yttrium isotopes, other than Y^{84}, has been obtained. The gamma-ray spectra of Y^{84} and Sr^{83} are shown.

THE NEUTRON-DEFICIENT YTTRIUM ISOTOPES Y^{82}, Y^{83}, AND Y^{84} *

V. Maxia,† W. H. Kelly,‡ and D. J. Horen

Lawrence Radiation Laboratory
University of California
Berkeley, California

December, 1961

1. INTRODUCTION

Early attempts to study the decay of Y^{82} revealed that its half-life was much shorter than the 70 minutes previously reported by Caretto and Wiig.[1] These authors also reported the half-life of Y^{85} as 5 hours. From other work at this laboratory, in which Sr^{85m} was chemically separated from yttrium at regular intervals, it was found that Y^{85} has a 3-hr half-life.[2] The apparent disagreement in the half-life for Y^{85} as found by Caretto and Wiig[1] and Kim et al.[2] has been resolved by the discovery of a 5-hr isomeric state in Y^{85}.[3] The present work was undertaken in order to clarify the situation pertaining to the neutron-deficient yttrium isotopes with $A \leq 84$. In this paper we report on the identification of Y^{82}, Y^{83}, and Y^{84}.

---

1. A. A. Caretto, Jr., and E. O. Wiig, J. Am. Chem. Soc. 74, 5235 (1952).
2. Y. E. Kim, D. J. Horen, and J. M. Hollander, unpublished data.
3. D. J. Horen and W. H. Kelly, to be published.

---

† Permanent address: Laboratorio di Radiochimica, Università di Pavia, Pavia, Italy.

‡ On leave from the Department of Physics and Astronomy, Michigan State University, East Lansing, Michigan.

* Work done under the auspices of the U.S. Atomic Energy Commission.

/

2. EXPERIMENTAL METHOD

The Berkeley heavy-ion linear accelerator (Hilac) was used to produce neutron-deficient yttrium isotopes by the reactions $As^{75}(C^{12},xn)Y^{87-x}$ and $Ga^{69}(O^{16},xn)Y^{85-x}$. For convenience, most of the data were obtained from bombardments of thick targets of powdered arsenic metal with about 120-Mev carbon ions, while other reactions were mainly used for corroborative purposes. The irradiation times varied from 5 min to 2 hr, depending upon the particular activities being studied. The yttrium activities reported here were also produced by spallation of natural strontium with 240-Mev protons in the Berkeley 184-inch cyclotron. To aid in the identification of Y^{84}, a few milligrams of enriched Sr^{84}† were irradiated with 5- and 15-Mev deuterons in the Crocker 60-inch cyclotron.

The half-lives of Y^{82} and Y^{83} were determined by establishing their genetic relationships to known strontium and rubidium isotopes by means of timed chemical separations of daughter activities. Photon spectra were examined with a 7.62-cm x 7.62-cm NaI(Tl) crystal mounted on a Dumont 6363 photomultiplier coupled to a multichannel pulse-height analyzer. Positron spectra were measured with a 2.5-cm diam. x 1.25-cm plastic scintillator, and gross beta counting was done with an end-window, flowing-methane proportional counter.

---

† Obtained from separated Isotopes Division, Oak Ridge National Laboratory, Oak Ridge, Tennessee.

3. CHEMICAL PROCEDURES

After irradiation, the arsenic targets were dissolved in hot aqua regia and boiled to dryness. The residue was dissolved in 5 ml of 0.1 N HCl from which the yttrium was extracted into a 10-ml solution of 1.5 M di-2-ethyl-hexyl phosphoric acid (i.e., HDEHP) and toluene.[4] The organic phase, containing the yttrium activities, was washed several times with 0.1 N HCl, after which timed chemical separations (milks) of the daughter strontium and rubidium activities were conducted by washing with 0.1 N HCl. The "milk" intervals were varied from 5 to 17 min in different experiments.

In some experiments the strontium and rubidium fractions were separated by using the standard techniques of coprecipitation of $Sr(NO_3)_2$ with $Ba(NO_3)_2$ by the addition of fuming nitric acid and chilling.[5]

---

4. D. F. Peppard, G. W. Mason, and S. W. Moline, J. Inorg. and Nucl. Chem. 5, 141 (1957).

5. D. N. Sunderman and C. W. Townley, The Radiochemistry of Barium, Calcium, and Strontium, National Academy of Sciences - National Research Council, NAS-NS 3010 (January, 1960).

4. EXPERIMENTAL RESULTS

4.1 Yttrium-82

After an irradiation of powdered arsenic metal with 120-Mev carbon ions, the genetic relationship of Y^{82} to its daughter Sr^{82} was established by a series of timed chemical separations (milkings). In these experiments yttrium was extracted into a solution of toluene and HDEHP while strontium was back-extracted into 0.1 N HCl.

Several days after the milking experiments were performed, the strontium fractions were chemically isolated and measured with the scintillation spectrometer and proportional counter. From these measurements it was found that annihilation radiation, a weak 770-kev photon, and approximately 3-Mev positron branch decayed with about a 25-day half-life. These data are attributable to the decay of Sr^{82} - Rb^{82} - Kr^{82}, since it is known that 25-d Sr^{82} decays by electron capture to 1.3-min Rb^{82}, which in turn decays to Kr^{82} with the emission of 3.1-Mev and 2.3-Mev positron branches and a weak 777-kev photon.[6] By counting the positrons with energies between 2 and 3 Mev, the yield of Sr^{82} as a function of the time of the chemical separation of strontium from yttrium was obtained. Typical results are shown in Fig. 1. From a number of such experiments, the average value obtained for the half-life of Y^{82} is 9±3 min.

4.2 Yttrium-83

The gamma-ray spectra of the strontium fractions milked from yttrium contained prominent peaks at 38, 375, 511, 770, 1160, and 1520 kev which decayed with a 34-hr half life. This activity is assigned to Sr^{83}, since the latter is known to decay with a similar half-life with the emission of a

---

6. Nuclear Data Sheets, National Academy of Sciences - National Research Council, NRC 59-1-67 (National Research Council, Washington, D.C.)

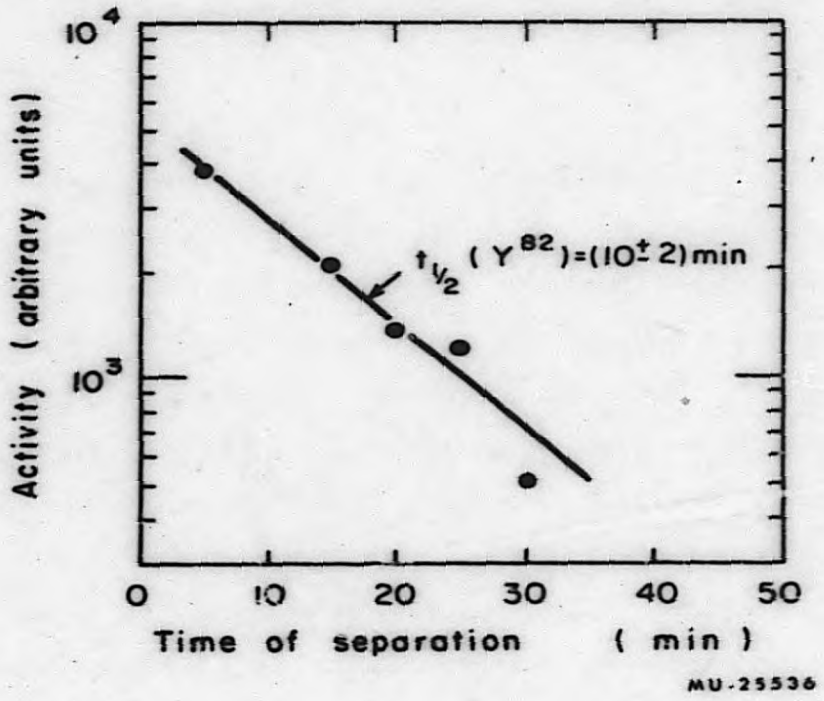

Fig. 1. Yields of 2.0- to 3.0-Mev positrons of Sr^{82}-Rb^{82} decay as a function of time of chemical separation of strontium from yttrium parent.

1.2-Mev positron branch.[7] A typical gamma-ray spectrum of Sr^{83} is shown in Fig. 2. Figure 3 shows the yield of the 375-kev peak as a function of the time of the chemical separation of strontium from yttrium. Consideration of the data from several experiments utilizing different production modes of yttrium and different milk times leads to an average value of 8±2 min for the half-life of Y^{83}.

4.3 Yttrium-84

When the yttrium fraction obtained from the bombardment of arsenic with C^{12} ions was chemically repurified approximately 2 hours after the irradiation, most of the gamma-ray spectrum decayed with 39±2 min, except for a relatively weak peak at 230 kev which grew in and then decayed with a 3.0-h half life. By leaving the activity in a separatory funnel containing the toluene solution of HDEHP and 0.1 N HCl, periodically shaking to wash the daughter activities into the aqueous phase, and observing only the organic phase containing the yttrium with a scintillation counter, we found that the entire spectrum (see Fig. 4) decayed with 39 minutes. Strontium fractions chemically separated from the yttrium activity at fixed time intervals (40 min) contained only 150- and 235-kev photons arising from the decay of Sr^{85m} and a very weak 513-kev photon from the decay of Sr^{85}. The half-life of Y^{85} determined in this way is 3.0±0.2 hr, in good agreement with the results of Kim et al.[2] The 39-min yttrium activity was also produced by irradiating strontium enriched in Sr^{84} with 15-Mev deuterons, but not with 5-Mev deuterons. These data are consistent only with the assignment of the 39-min activity to Y^{84}. This half-life is in good agreement with that obtained by Yamazaki et al.[8]

---

7. S. V. Castner and D. H. Templeton, Phys. Rev. 88, 126 (1952).
8. T. Yamazaki, H. Ikegami, M. Sakai, K. Saito, Y. Hashimoto, M. Fujioka, H. Ohnuma, E. Takekoshi, J. Matsumoto, and A. Hashizume, unpublished data; and private communication from M. Sakai (1961).

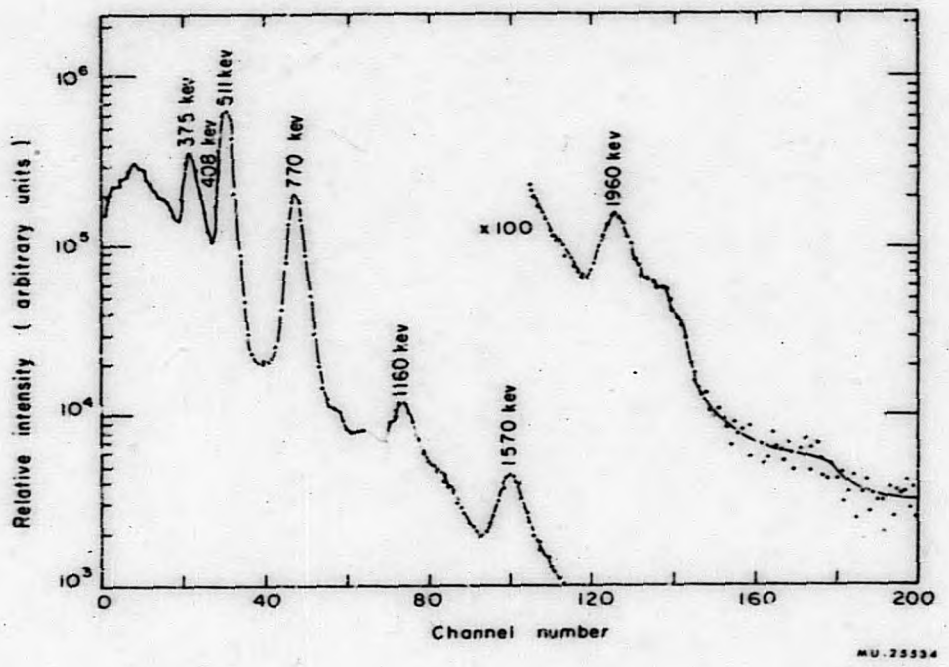

Fig. 2. Gamma-ray spectrum of 34-h Sr^{83} taken with a 7.6-cm x 7.6-cm NaI(Tl) crystal. A 0.75-cm carbon absorber was placed between the source and crystal to reduce bremmstrahlung and annihilation-in-flight photons caused by the positrons.

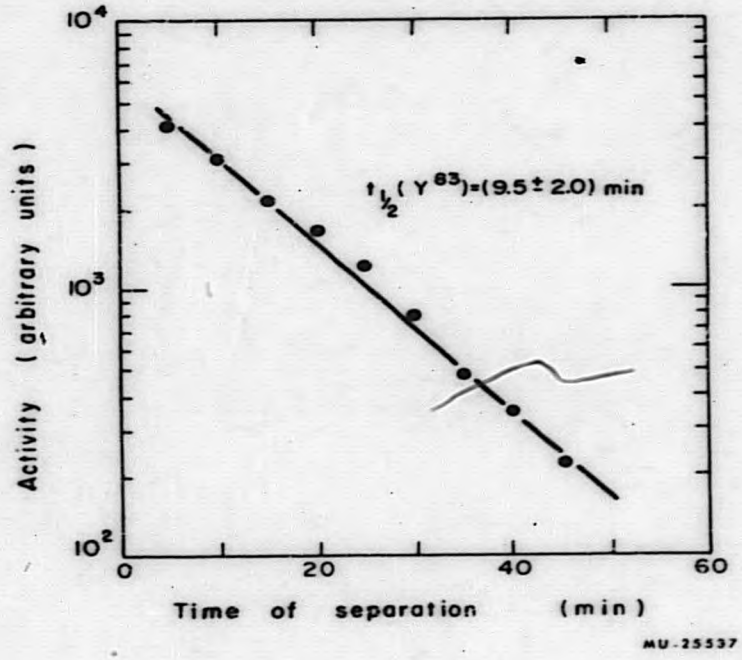

Fig. 3. Yields of the 375-kev gamma ray of Sr^{83} as a function of time of chemical separation of strontium from the parent yttrium.

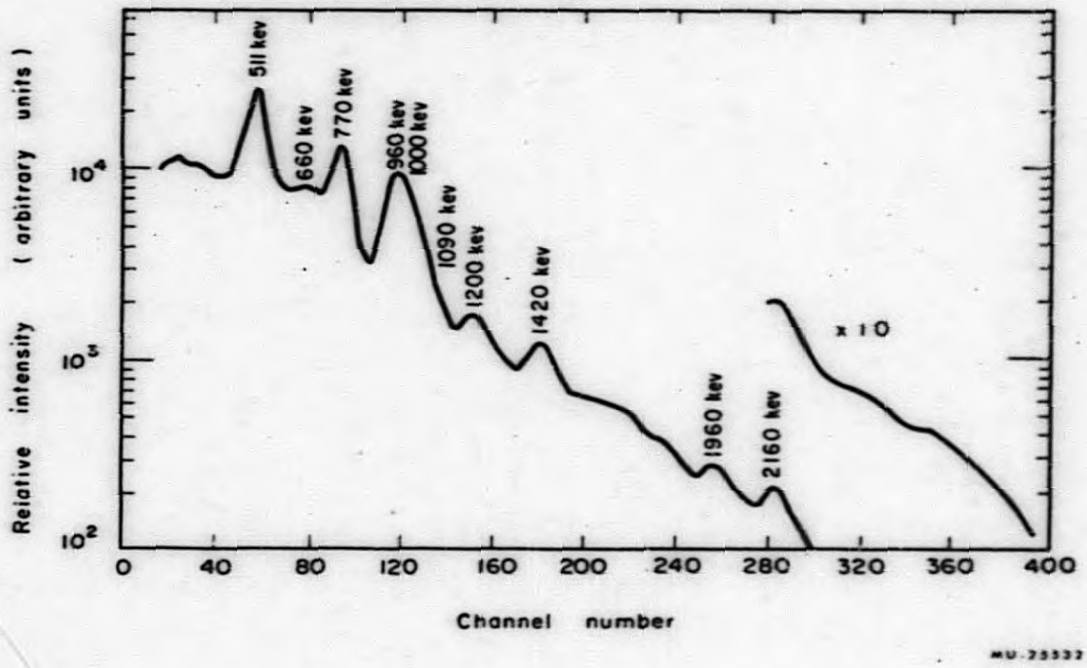

Fig. 4. Collimated photon singles spectrum of 39-min Y^{84} taken with a 7.6-cm x 7.6-cm NaI(Tl) crystal.

DISCUSSION

In this work, the neutron-deficient yttrium isotopes with mass numbers 82, 83, and 84 have been synthesized and their half-lives found to be considerably shorter than those previously reported. Owing to lack of time, no information has been obtained concerning the radiations emitted in the decay of these isotopes, with the exception of Y^{84}.

ACKNOWLEDGMENTS

One of us (VM) wishes to acknowledge the Conference Board of Associated Research Councils, Washington D. C., for a fellowship, and to thank Professor I. Perlman for the hospitality accorded her while a guest at the Lawrence Radiation Laboratory. We wish to thank Drs. S. S. Markowitz, R. M. Diamond, and J. M. Hollander for many helpful discussions. We wish also to thank Mr. J. A. Harris for his assistance in one of the chemical separations, and the operating crews of the Hilac and the 60-inch and 184-inch cyclotrons for providing the irradiations.

END