Radioactivity of Mo^{91} and Mo^{93} *

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THREE radioactive decay periods have been reported in the literature which might be assigned to either Mo^{91} or Mo^{93}. These have half-lives of 6.7 hours, approximately 17 minutes and 73 seconds.[1] Recent work of Kundu and Pool[2] indicates that the 17-minute period is probably Mo^{91}, but the mass asignments of the other two are still uncertain. We wish to report some of our observations on the properties of these isotopes as deduced from betatron experiments.

The irradiation of molybdenum with betatron x-rays produces the 17-minute period by a (γ,n) reaction, the threshold energy being 13.5 Mev.[3] This is higher than that calculated for either of the reactions $Mo^{94}(\gamma,n)$ or $Mo^{92}(\gamma,n)$ on the basis of Feenberg's nuclear energy surface. It is somewhat more reasonable for the latter however, since Mo^{92} contains the magic number 50 neutrons, a configuration which is especially stable.[4]

In order to establish the identity of these periods we have irradiated samples of molybdenum oxide enriched in Mo^{92} and Mo^{94} with 23-Mev betatron x-rays and examined the radioactive products.[5] The intensity of the 17-minute period has been found to be proportional to the Mo^{92} content of the irradiated samples, confirming its assignment to Mo^{91}. Our experiments gave a half-life of 15.5 minutes, in agreement with the determination of Wäffler and Hirzel.

The radiation characteristics are shown in Table I and Figs. 1 and 2. Positron emission was verified by following the decay with

TABLE I. Radiation characteristics.

Isotope	Made by	Half-life	Radiation
Mo^{91}	$Mo^{92}(\gamma, n)$	15.5±0.5 min.	β^+ 3.7±0.1 Mev no γ
Mo^{91}	$Mo^{92}(\gamma,n)$	75.0±5.0 sec.	β^+ 2.6±0.2 Mev γ 0.3 Mev

the source in the field of a permanent magnet with proper field orientation. The particle energy was estimated by a Feather analysis of the aluminum absorption curve of a sample of molybdenum metal using as a standard a P^{32} source mocked up to resemble the molybdenum in self-absorption.

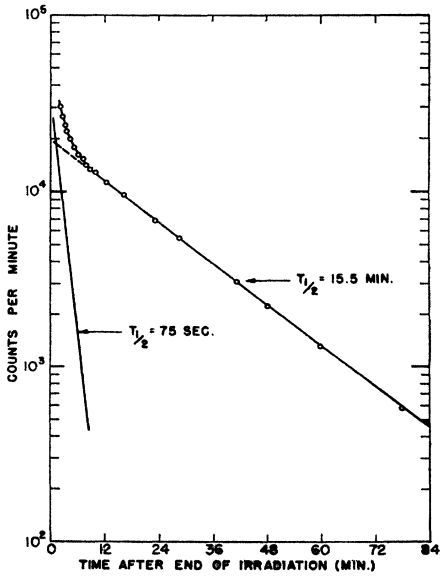

FIG. 1. Decay of Mo^{91} formed by 23 Mev x-rays on molybdenum containin 95.5 percent Mo^{92}.

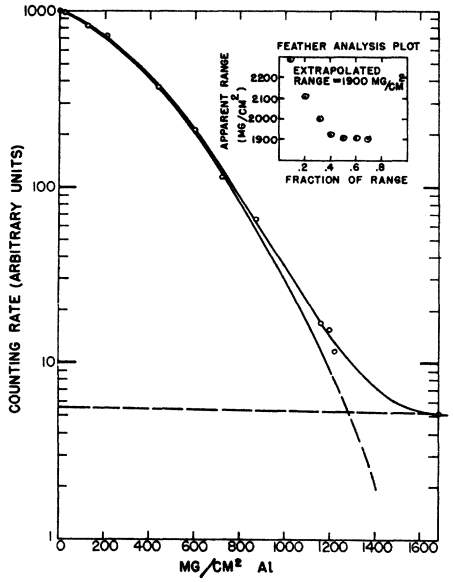

FIG. 2. Aluminum absorption curve of radiation from 15.5-minute Mo^{91}.

A chemical separation was done to verify that the activity observed was really molybdenum and not columbium produced by $Mo(\gamma,p)$, or by growth from a short-lived molybdenum parent. The columbium was carried down by a ferric hydroxide precipitate from alkaline ammonium molybdate solution and the molybdenum then precipitated as ammonium phosphomolybdate from acid solution. Over 99 percent of the 15.5-minute activity was found in the molybdenum fraction. The 68-minute Cb^{97}, formed by $Mo^{98}(\gamma,p)$, was found quantitatively in the columbium fraction.

By similar techniques the 75-second positron emitter was found to be due to Mo^{91} made by $Mo^{92}(\gamma,n)$. Characteristics of its radiations are shown in Table I and Figs. 1 and 3. It is apparent that

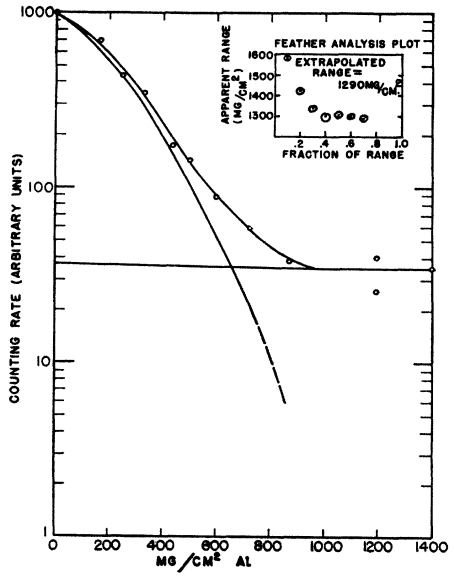

FIG. 3. Aluminum absorption curve of radiation from 75-second Mo^{91}.

this period did not grow from the 15.5-minute activity by isomeric transition, but we have not excluded the possibility that the 15.5-minute period was formed at least in part by decay of the 75-second period.

We have not observed the 6.7-hour activity to be formed by $Mo^{94}(\gamma,n)$ as can be seen from Fig. 4. If this reaction occurs to

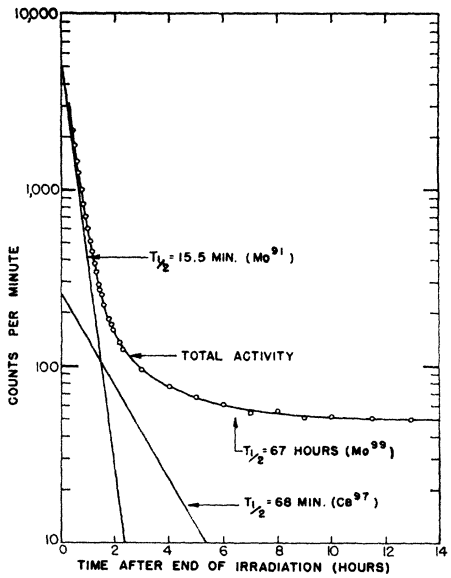

FIG. 4. Decay of total activity formed by 23 Mev x-rays on molybdenum containing 79.1 percent Mo^{94}

produce the 6.7-hour period, its cross section with 23 Mev x-rays must be less than 0.0005 that of the (γ,n) reactions for the other molybdenum isotopes. A further search for this activity was carried out on samples of enriched Mo^{92} and Mo^{94} which had been irradiated with slow neutrons in the pile at the Argonne National Laboratory. No evidence of decay with this half-life could be found.

It is interesting that the existence of the two isomers reported for Mo^{91} means that there are two well-established isomers for all the 49-neutron nuclei with even atomic number from 34 to 42. The prevalence of nuclear isomerism near the end of closed shells has been pointed out by Mrs. Mayer.[6]

* Assisted by the joint program of the ONR and the AEC.

[1] For a summary of previous work see G. T. Seaborg and I. Perlman, Rev. Mod. Phys. **20**, 585 (1948), also H. Wäffler and O. Hirzel, Helv. Phys. Acta **21**, 200 (1948).

[2] D. N. Kundu and M. L. Pool, Phys. Rev. **76**, 183 (1949).

[3] G. C. Baldwin and H. W. Koch, Phys. Rev. **67**, 1 (1945).

[4] M. G. Mayer, Phys. Rev. **74**, 235 (1948).

[5] The Mo^{92} and Mo^{94} samples used in this investigation were supplied by Carbide and Carbon Chemicals Corporation, Y-12 Plant, Oak Ridge, Tennessee, and obtained on allocation from the Isotopes Division of the AEC.

[6] M. G. Mayer, Phys. Rev. **76**, 185 (1949).

Beta-Decay of In^{115*} ‡

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A SCINTILLATION spectrometer and a magnetic lens spectrometer have been used to investigate the decay of In^{115*}. This substance decays mostly by isomeric transition to In^{115} ground state but a beta-spectrum has also been observed.

A sample of cadmium metal was bombarded in the pile for some hours and allowed to decay for 24 hours to remove the 4-hour cadmium activity. Cadmium and indium were then separated chemically after the addition of indium carrier. The indium fraction was discarded and indium activity allowed to grow from the 2.3-day cadmium parent. After 16 hours a few milligrams of indium carrier were added and the indium fraction separated. The indium as hydroxide was mounted on 0.5 mg/cm² polyethylene and measured in the anthracene scintillation spectrometer.

A plot of pulse counting rate in a small height interval against pulse height is shown as curve *A* in Fig. 1.

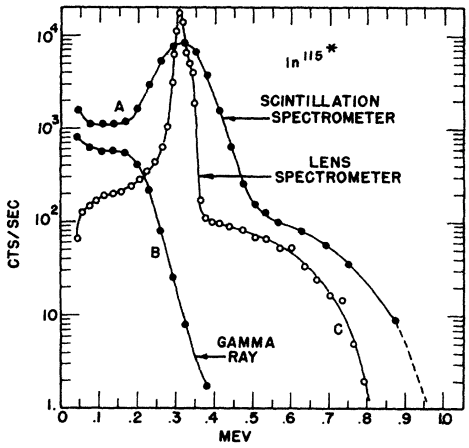

FIG. 1. Pulse counting rate as a function of pulse height.

The scale of pulse height was calibrated in Mev by using the 630-kev conversion line of Cs^{137}. The conversion line at 312 kev can be seen and also a beta-ray group containing about 1/10 as many electrons. Curve *B* is the Compton electron distribution produced by the gamma-ray when the electrons are cut off by an absorber. The curve shows evidence of only one strong gamma-ray group. All parts of curves *A* and *B* decay with the same 4.5-hour half-life. In order to make sure that the "β-ray" was not a defect in the scintillation spectrometer, a large sample was prepared and run in a magnetic lens spectrometer. The results, converted to a distribution as a function of energy rather than of momentum, are shown as curve *C* on Fig. 1. The β-ray is still seen and has about the same intensity (0.13) relative to the conversion line.

A Kurie plot of the lens spectrometer data above the conversion line is shown in Fig. 2. The plot is fairly straight and the endpoint

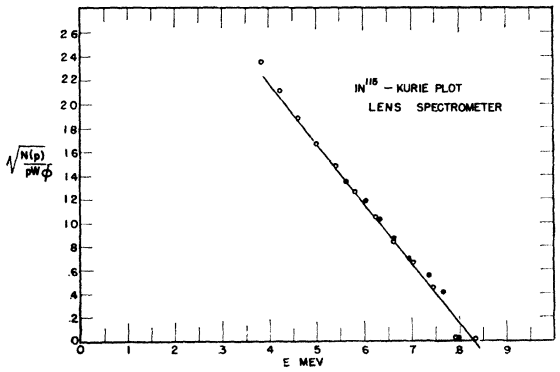

FIG. 2. Kurie plot of the lens spectrometer data.

seems to be 830±20 kev. If the 338-kev gamma-ray transition goes to the ground state of In^{115} and the 830-kev β-ray transition goes to the ground state of Sn^{115}, the energy difference between the two ground states would be 490 kev with In^{115} as the unstable member of the pair.

‡ This document is based on work performed under Contract No. W-7405, eng. 26 for the Atomic Energy Project at Oak Ridge National Laboratory.