Radioactivity from Enriched Isotopes of Cadmium*

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By irradiating in the pile specimens of cadmium enriched in mass 108 and in mass 114, it is possible to interpret more positively the observed radioactivities and to evaluate the gamma-rays associated with each. Cadmium 109 produced by neutron capture in cadmium 108 decays with a half-life of approximately 250 days by *K*-capture to silver 109 in which a strong gamma-ray of 87.5 kev is emitted. Cadmium 115 is isomeric with half-lives of 54 hours and 42.6 days, both isomers decaying to indium 115 by beta-emission. The 54-hour activity yields many gamma-rays in indium whose energies are 335.5, 343.7, 348.9, 369.3, 423.7, 451.9, 525.4, 559.1, and 713.1 kev. These gamma-energies fit well a proposed nuclear level scheme in indium 115.

I. INTRODUCTION

PREVIOUS studies of activated cadmium with its normal array of isotopes have shown the presence of certain long-lived radioactivities. The assignment of an activity to a particular isotope of cadmium has previously been based on its production by various modes of bombardment. By irradiating in the pile a cadmium isotope enriched in mass 108 and another enriched in mass 114, it is now possible to affirm the assignments more positively. The normal abundance and relative percentages of isotopes in the two enriched specimens are shown in Fig. 1. It is apparent that while enriched 108 contains about one-third the normal content of mass 114, enriched 114 has present almost no cadmium of mass 108. It is thus possible by neutron capture in the pile to produce Cd^{115}, reported[1] as being isomeric with half-lives of 2.4 and 43 days, with no accompanying activity due to either masses 107 or 109. An activity in Cd^{109} due to *K*-capture with a half-life somewhere between 156 and 330 days had been reported

II. RESULTS

Since the enriched Cd^{108} still retains 10.3 percent of Cd^{114}, whose capture cross section is relatively large, the early decay curves for the two specimens are quite similar as shown by the superposition of the two curves

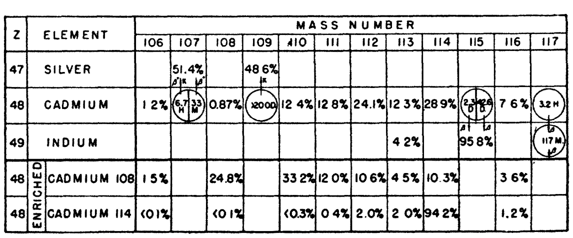


FIG. 1. The stable and radioactive isotopes of cadmium with relative abundance.

in Fig. 2. After three months, however, the Cd^{115} has a pure decay yielding half-lives of 42.6 days and 54 hours while the Cd^{109} curve begins to flatten out into its longer period. To choose between the widely divergent reported half-lives for Cd^{109}, observations must be extended over a much longer time, but indications are at present that the value is 255 days or longer.

Spectrometric photographic studies of the electron emission from the two specimens show many conversion electron lines as listed collectively in Table I, whose gamma-ray origin can be correctly assigned. One group of lines shown have *K–L–M* differences characteristic of silver and decay with a long half-life. They thus are associated with an 87.5 kev gamma-ray in Ag^{109} emitted following *K*-capture in Cd^{109}. A gamma-ray of approximately this energy emitted from a metastable state of Ag^{109} has been reported by Helmholtz.

TABLE I. Electron energies from irradiated cadmium.

Electron energy (kev)	Designation $Z=47$	Designation $Z=49$	Energy sum (kev)	Electron energy (kev)	Designation $Z=47$	Designation $Z=49$	Energy sum (kev)
62.0	K^1		87.5	338.9		L^3	343.1
83.6	L_1^1		87.4	341.4		K^6	369.3
83.9	L_2^1		87.4	344.5		L^4	348.7
86.6	M^1		87.4	395.8		K^7	423.7
307.6		K^2	335.5	424.0		K^8	451.9
315.8		K^3	343.7	497.6		K^9	525.5
321.2		K^4	349.1	521.0		L^9	525.2
331.2		L^2	335.3	531.2		K^{10}	559.1
334.6		M^2	335.4	685.2		K^{11}	713.1
		or K^5	362.5(?)				

TABLE II. Gamma-rays from irradiated cadmium.

Arbitrary designation	Ag^{109} (∼255 days)	In^{115} (54 hr.)
γ^1	87.5 kev	
γ^2		335.5 kev
γ^3		343.7
γ^4		348.9
γ^5		362.5(?)
γ^6		369.3
γ^7		423.7
γ^8		451.9
γ^9		525.4
γ^{10}		559.1
γ^{11}		713.1

* This investigation was made possible by the joint support of the AEC and the ONR.

[1] J. Cork and J. Lawson, Phys. Rev. **56**, 291 (1939); Bradt, Gugelot, Huber, Medicus, Preiswerk, Scherrer, and Steffen, Helv. Phys. Acta **18**, 256 (1945); **19**, 218 (1946); A. C. Helmholtz, Phys. Rev. **60**, 160 (1941); **70**, 982 (1946); Seren, Engelkemeir, Strum, Friedlander, and Turkel, Phys. Rev. **71**, 409 (1947).

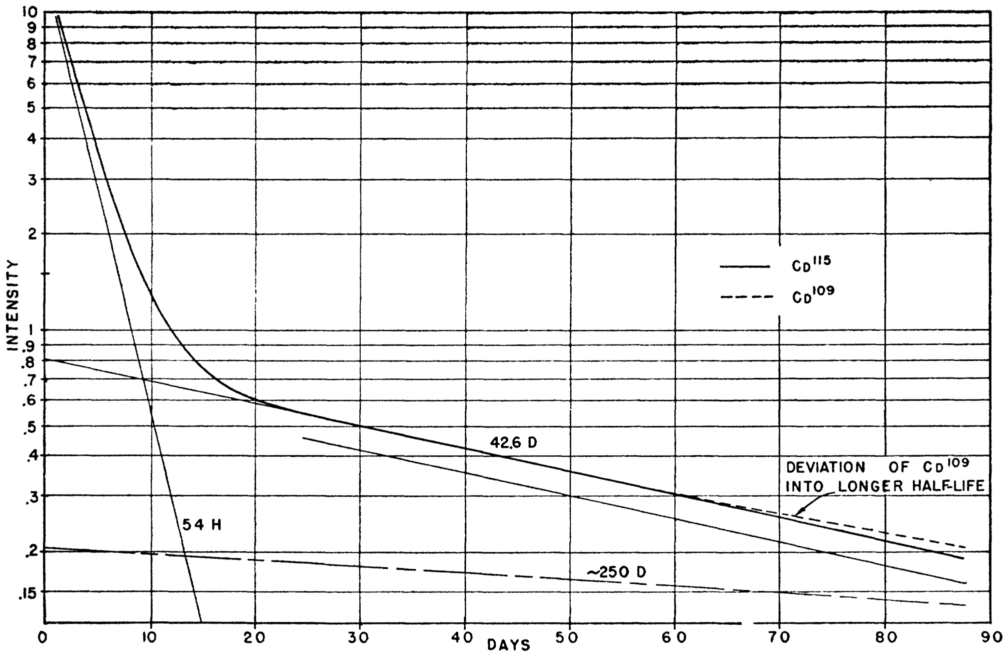


FIG. 2. Superimposed decay curves of cadmium 109 and cadmium 115.

The electron lines from Cd^{114} appear to be short-lived (54 hours) and have *K–L–M* differences characteristic of indium, and are thus associated with gamma-rays in In^{115} following beta-emission from Cd^{115}. These gamma-rays with arbitrarily assigned numbers are shown collectively in Table II in the order of increasing energy. No electron lines were found to be characteristic of the 42.6-day half-life, although it had at first been assumed that the gamma-ray of energy 525 kev was so related.

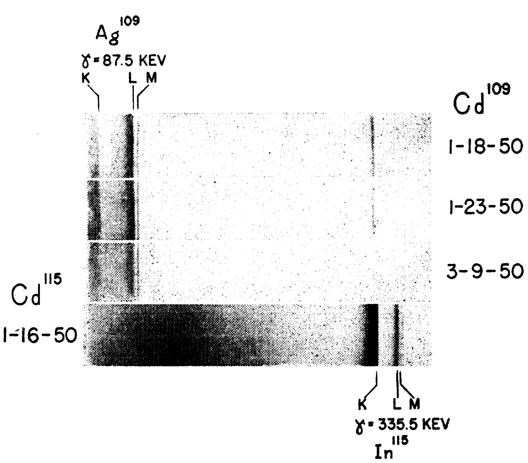


FIG. 3. Low energy electron spectra of cadmium isotopes enriched in 109 and 115.

Further evidence supporting the isomeric character of the 54-hour and the 42.6-day activity is seen in the similarity of the ratio of the initial intensities of the two activities in both enriched isotopes. This would indicate isomeric states of the same isotope rather than separate isotopic activities.

Figure 3 is a time sequence of exposures of the low energy spectrum of enriched Cd^{109}, showing the persistence of the *K–L–M* electron lines due to the 87.5-kev gamma-ray in Ag^{109}, together with the complete disappearance of the electron lines characteristic of the short-lived 335.5-kev gamma-ray in In^{115}, due to the existence of Cd^{115} in the enriched sample of Cd^{109}. Also shown is the same energy range of the spectrum for enriched Cd^{115}, yielding only the 335.5-kev gamma-ray. The greater intensity of the *K–L–M* electron lines characteristic of indium in the latter specimen is to be expected on account of the greater abundance of the parent Cd^{115} isotope.

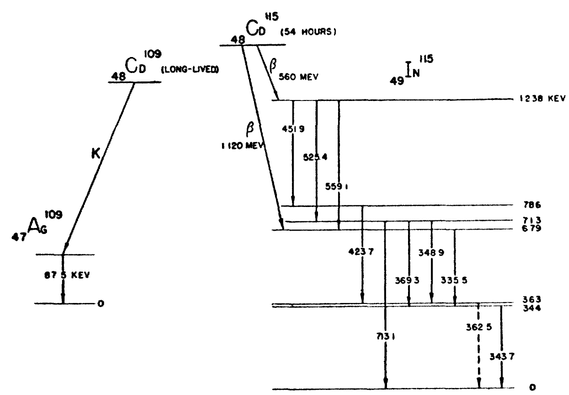
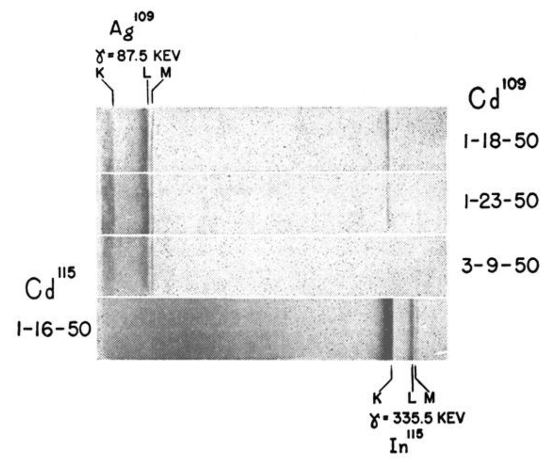


FIG. 4. Level schemes for silver 109 and indium 115.

The beta-upper limit of the 42.6-day activity in Cd^{115} appears by absorption in aluminum to be 1.46 Mev. The beta-spectrum of the 54-hour activity is complex with maximum energies at about 0.56 and 1.12 Mev.

It is possible to propose a level scheme as shown in Fig. 4 which explains quite satisfactorily the many gamma-rays associated with the In^{115} nucleus, together with the observed beta-energies. The *K*-capture decay in Cd^{109} is also shown.



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