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RADIOACTIVE ISOTOPES OF THE RARE EARTH ELEMENTS

PART III. HOLMIUM ISOTOPES

Geoffrey Wilkinson and Harry G. Hicks

April 27, 1950

Berkeley, California

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RADIOACTIVE ISOTOPES OF THE RARE EARTHS ELEMENTS

PART III. HOLMIUM ISOTOPES

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April 27, 1950

ABSTRACT

A study has been made of neutron deficient radioactive isotopes of holmium produced by α-particle bombardments of terbium, and by proton and deuteron bombardments of dysprosium.

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RADIOACTIVE ISOTOPES OF THE RARE EARTH ELEMENTS

PART III. HOLMIUM ISOTOPES

Geoffrey Wilkinson and Harry G. Hicks

I. INTRODUCTION

In a previous paper,(1) the techniques of study of radioactive

(1) G. Wilkinson, H. G. Hicks, Phys. Rev. 75 1370 (1949).

isotopes of the rare earth elements have been described. Using the 60 inch Crocker Laboratory cyclotron, bombardments have been made of terbium with 38 Mev and lower energy α-particles, and of dysprosium with 10 Mev protons and 19 Mev deuterons. Separation of the rare earths was made by the ion exchange resin column procedure described previously.

With the exception of the 34 minute isotope, all the other activities studied decay with emission of electromagnetic radiations of half thicknesses 8.5 mg/cm^2 aluminum (6.8 Kev) and 70 mg/cm^2 lead (48 Kev), corresponding to dysprosium L and L x-radiation respectively, and indicating decay by orbital electron capture. Electron radiations of all the isotopes were checked for sign and energy on a simple beta ray spectrometer. In Table I, which summarizes the production and properties of the holmium activities, energies of electrons and γ rays are obtained from aluminum and lead absorption measurements; positron energies were obtained from the spectrometer.

Table I

Isotope	Type of Radiation	Half Life	Energy of Radiation in Mev Particles	γ Rays	Produced by
Ho^{160}	K, e^-, β^+(0.5%), γ	22.5 ± 0.5 mins.	0.17(e^-) ~1.3(β^+)	~1.2	Tb-α-3n
Ho^{161}	K, e^-, γ	4.6 ± 0.1 hours	~0.1(e^-)	1.1	Tb-α-2n Dy-p-n Dy-d-2n
Ho^{162}	K, β^-(~15%), e^-, γ	65 ± 0.5 days	~0.1(e^-) 0.8(β^-)	~1 (weak)	Tb-α-n Dy-p-n Dy-d-n, 2n
Ho^{163}	K, e^-, γ	5.2±0.05 days	0.4	0.4-0.5, 1.4	Dy-p-n Dy-d-n, 2n
Ho^{164}	β^-	34.0 ± 0.5 mins.	0.95		Dy-p-n

HOLMIUM ISOTOPES

In the bombardment of terbium with α-particles of various energies, radioactive isotopes of half lives 22.5 minutes, 4.6 hours and 65 days were observed. Short bombardments of dysprosium with 10 Mev protons allowed characterization of a 34 minute beta emitting isotope, together with the 4.6 hour and longer lived activities; in long bombardments of dysprosium with 10 Mev protons and 19 Mev deuterons, activities of 4.6 hours and 65 days half life, identical with those from Tb + α bombardments, were found together with an activity of 5.2 days half life.

The allocation of the 22.5 minute, 4.6 hour and 65 day holmium activities to masses 160, 161 and 162 respectively was made on the basis of yields in bombardments of terbium with 38, 30 and 19 Mev α-particles; the yields follow a pattern similar to that found for the production of thulium activities in α-particle bombardments of holmium.[1] The measured K x-radiation was taken as representing decay by orbital electron capture for the comparison of yields. The yields of the active isotopes formed in 10 Mev proton bombardments of dysprosium are approximately equal as would be expected from the similarity in abundance of the dysprosium isotopes of masses 161-4 inclusive. The 5.2 day activity is allocated to mass 163 since it was not observed in α particle bombardments of terbium, or in fast neutron bombardments of holmium, but was formed in yields approximately the same as the other isotopes in proton bombardments of dysprosium.

34.0 ± 0.5 minute Ho^{164}. An activity of 47 minutes half life produced by fast neutron bombardment of holmium has been reported in an early paper.[2]

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(2) Pool, M. L., Quill, L. L., Phys. Rev. 53, 437 (1938).

The 34 minute isotope here described was produced by short bombardments of pure dysprosium oxide with 10 Mev protons. Identification of the activity with holmium has not been proved by chemical separation but no activities due to known dysprosium isotopes have been observed, and longer lived activities from the same bombardment have been shown to follow holmium chemistry.

A half life of 34.0 ± 0.5 minutes was obtained through eight periods, after subtraction of the longer lived holmium activities, principally the 4.6 hour activity, from the decay curves. The resolved aluminum absorption curve of the 34 minute activity shows this to have a simple beta particle. The Feather range, 370 mg/cm^2 aluminum, (0.95 Mev), agrees with the maximum energy obtained for the negative beta particle on a simple beta ray spectrometer. An upper limit of 0.05 γ ray quanta per beta particle can be set; no γ radiation or conversion electrons attributable to the 34 minute activity were observed even in very active samples.

<u>5.20 ± 0.05 day Ho^{163}</u>. This activity whose decay was followed through six periods was found only in long bombardments of dysprosium with deuterons or protons. The ratio of the various radiations obtained from absorption measurements and corrected for counting efficiency, absorption in counter window, etc. are approximately, 0.4 Mev electron; L x-rays; K x-rays: ~0.5 Mev γ ray: 1.4 Mev γ ray, 0.04: 0.6: 1: ~ 0.1: ~ 0.25. The isotope thus appears to decay predominantly by orbital electron capture; the 0.04 Mev electron probably results from conversion of the weak 0.5 Mev γ ray.

<u>65 ± 0.5 day Ho^{162}</u>. This activity, the decay of which has been followed for eight periods, is produced both in <u>Tb + α</u> and <u>Dy + p</u> bombardments and is identical in both cases. The Feather range of 300 mg/cm^2 (0.8 Mev)

for the hard electron corresponds well with the maximum energy of 0.8 Mev obtained from the spectrometer. The ratios of the radiations are 0.1 Mev e^-: 0.8 Mev β^-: L x-rays: K x-rays: 1.0 Mev γ ray = $\sim 0.1 : \sim 0.15 : \sim 1 : 1 : < 0.1$. The isotope thus appears to decay predominantly by orbital electron capture with ~15% branching decay by negative beta particle emission. The shape of the aluminum absorption curve (Fig. I) of the 0.8 Mev particle and also its distribution on the magnetic spectrometer is that of a negative beta particle.

<u>4.6 ± 0.1 hour Ho^{161}</u>. This activity was observed with identical radiation characteristics in both <u>Tb + α</u> and <u>Dy + p</u> bombardments. The decay of both electron and electromagnetic was followed through seven half lives. The approximate ratios of the various radiations obtained are ~ 0.1 Mev e^- L x-rays : K x-rays : 1.1 Mev γ ray $\approx \sim 0.1 : \sim 1 : 1 : \sim 1$.

<u>22.5 ± 0.5 minute Ho^{160}</u>. This activity was observed only in short 38 Mev α-particle bombardments of terbium together with the 4.6 hour and 65 day activities. The decay was followed through six periods. The approximate ratios of the radiation are: 0.17 e^- : β^+ : L x-rays : K x-rays : γ ray $\approx 0.1 : \sim 0.005 : \sim 0.4 : 1 : \sim 1$. Assuming that one K x-ray quantum represents one disintegration by orbital electron capture, branching decay by positron emission is about 0.5%.

ACKNOWLEDGMENTS

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Figure 1

Aluminum Absorption of Radiations of 65 Day Ho^{162}; A is the measured curve with D, the electromagnetic radiation contribution obtained after removal of electronsin beryllium. B and C are respectively the negative beta particle of 0.8 Mev maximum energy and the 0.1 Mev electron.

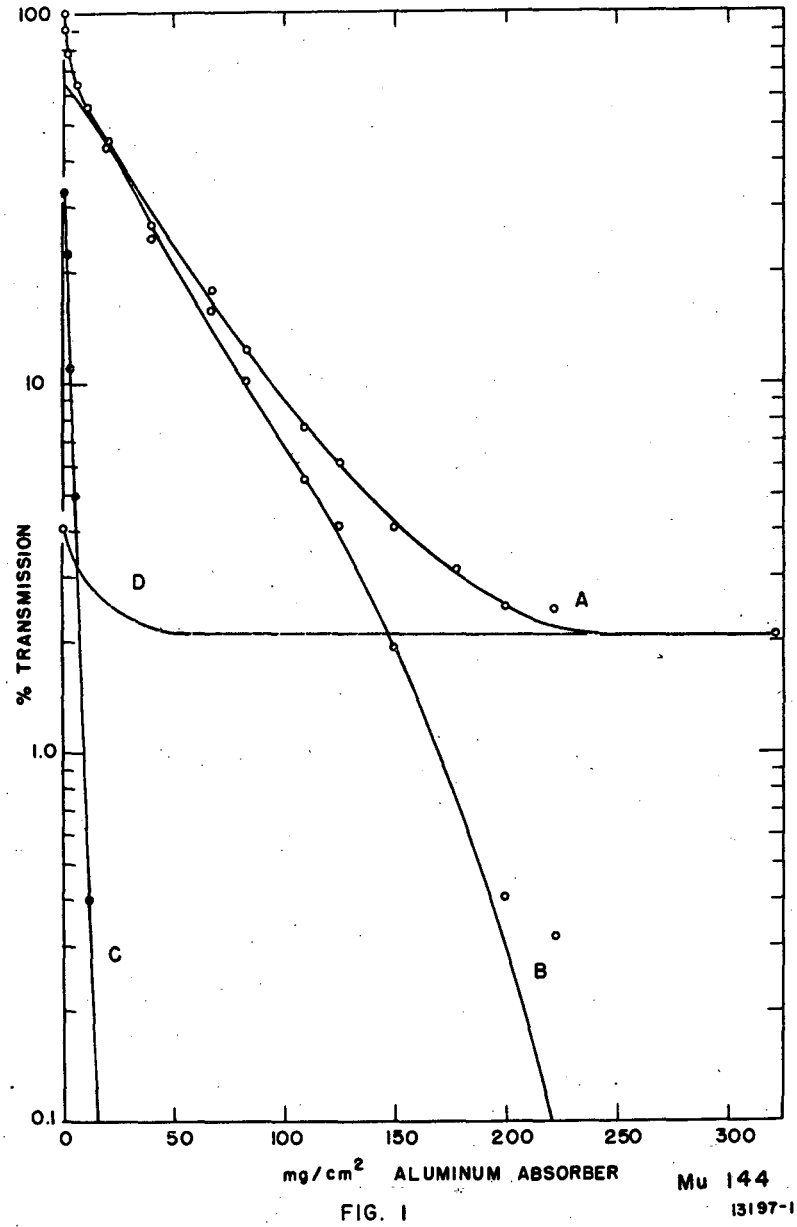
100
10
1.0
0.1
% TRANSMISSION
0
50
100
150
200
250
300
mg/cm² ALUMINUM ABSORBER
A
B
C
D
Mu 144
13197-1

FIG. 1