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The Nuclear Excitation of Krypton and Rhodium

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Kr^{83*} has been produced by the direct x-ray bombardment of the element as well as from Kr^{82} by the $n-\gamma$ process. A study of the nuclear spectrum of Rh^{103} by x-ray excitation gave values of 1.26±, 0.03 Mev, 1.64, 2.02, 2.37, 2.71, and 3.05 for the higher nuclear states which combine with the metastable level. Measurements of the absorption of the conversion electrons in gas indicate that the energy of the metastable state is 40 Kev about the ground level. It was found that Rh^{103*} can also be produced by the direct bombardment of rhodium with electrons.

EXCITATION OF Kr^{83}

LANGSDORF and Segrè[1] observed a 113-minute period in krypton grown in the reaction

$$Se^{83} \xrightarrow{\beta} Br^{83} \xrightarrow{\beta} Kr^{83*} \xrightarrow{\gamma} Kr^{83},$$

while investigating the products of thorium and uranium fission.

The γ-rays emitted in the transition from

$$Kr^{83*} \xrightarrow{\gamma} Kr^{83}$$

have been found to be 0.029 and 0.046 Mev.[2]

Kr^{83*} was later produced[3,4] in the Se-α-n and Kr-d-p reactions.

Counters with brass cathodes of 2.5-cm diameter have been constructed and filled with a mixture of krypton gas to a pressure of 20 cm of Hg and ethyl ether to a pressure of 2 cm of Hg. These counters were found to react much like the usual argon-ether counters. After bombarding such a counter with intense x-rays of maximum energy 2.5 Mev, a moderate activity could be observed which decayed with a half-life of about 115 minutes. This activity was produced by the γ-rays and conversion electrons emitted in the decay of krypton.^{83*}

Material with this same half-life period was also produced by bombarding krypton gas with slow neutrons produced from the Be-γ-n process. The neutrons were slowed down by allowing them to pass through paraffin. Since neither the n-$2n$ nor the n-n process can take place at these low energies, the activity must have been produced by the reaction $Kr^{82}+n \rightarrow Kr^{83*}+\gamma$.

EXCITATION OF Rh^{103}

The presence of a metastable level in stable rhodium^{103} was first indicated by Flammersfeld[5] who induced an activity of half-life 48±5 minutes by bombarding this element with 3 Mev neutrons. The process was assumed to be a Rh-n-n reaction. Only very soft γ-rays were observed. Lead of thickness 0.3 g/cm² was found

[1] A. Langsdorf, Jr., and E. Segrè, Phys. Rev. **57**, 105 (1940).
[2] A. C. Helmholz, Phys. Rev. **60**, 415 (1941).
[3] E. P. Clancy, Phys. Rev. **58**, 88 (1940).
[4] E. P. Clancy, Phys. Rev. **60**, 87 (1941).
[5] A. Flammersfeld, Naturwiss. **32**, 36 (1944).

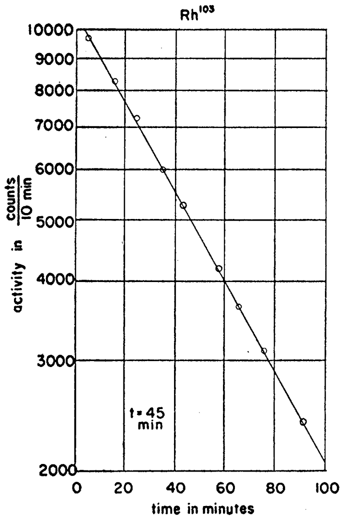

FIG. 1. Decay curve of Rh^{103*} to Rh^{103}. The half-life indicated is 45 ± 1 minute.

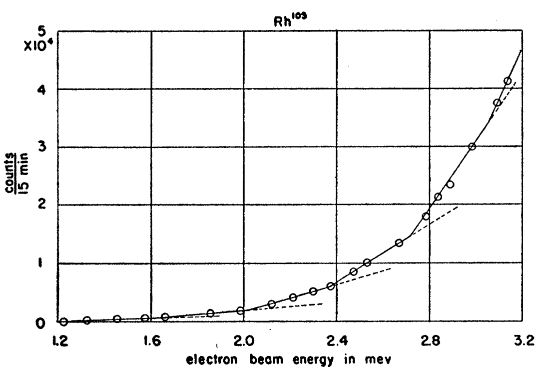

FIG. 2. X-ray excitation curve for Rh^{103}. The activity was produced by bombarding the samples for 10 minutes using an electron beam current of 100 microamperes.

to absorb all of the radiation while 0.85 g/cm^2 of graphite reduced the intensity to 60 percent.

We have previously reported[6] the production of Rh^{103*} by both x-ray and electron bombardment of elementary rhodium.

Although rhodium has been used in these laboratories for some time as a neutron detector in the presence of strong x-rays, it was not until the rhodium samples were placed directly in the active counting region that this x-ray induced activity could be observed.

A decay curve, Fig. 1, has been obtained by following the activity induced in a rhodium cathode counter through 100 minutes. This curve indicates that the half-life period is 45 ± 1 minutes which is in good agreement with the data of Flammersfeld.

The energy of the conversion electrons produced in the transition from Rh^{103*} to the ground state has been measured by absorption in argon gas. This value plus the binding energy of the K electrons in rhodium yields a value of 0.040 Mev for the energy of the metastable level.

An x-ray excitation curve has been obtained in a manner described elsewhere.[7,8] This is shown in Fig. 2. The breaks in the curve, indicating the positions of the higher nuclear energy levels which combine with the metastable state, were found at $1.26\pm$, 0.03 Mev, 1.64, 2.02, 2.37, 2.71, and 3.05 Mev.

TABLE I. Collection of combining nuclear levels.

Element	Half-Life	Energy (Mev)	ΔE (Mev)
Rh^{103}	45 min.	0.04 (metastable)	
		1.26 (threshold)	(1.22)
		1.64	0.38
		2.02	0.38
		2.37	0.35
		2.71	0.34
		3.05	0.34
		Average	0.36
$Ag^{107 \text{ or } 109}$	40.4 sec.	0.093 (metastable)	
		1.18 (threshold)	(1.09)
		1.59	0.41
		1.95	0.36
		2.32	0.37
		2.76	0.44
		3.13	0.37
		Average	0.39
Cd	48.8 min.	0.20 (metastable)	
		1.25 (threshold)	(1.05)
		1.68	0.43
		2.08	0.40
		2.56	0.48
		Average	0.44
In^{115}	4.42 hours	0.338 (metastable)	
		1.12 (threshold)	(0.78)
		1.55	0.43
		2.13	0.58
		2.63	0.50
		Average	0.50
Au^{197}	7.5 sec.	0.25 (metastable)	
		1.22 (threshold)	(0.97)
		1.68	0.46
		2.15	0.47
		2.56	0.41
		2.97	0.41
		Average	0.44

[6] M. L. Wiedenbeck, Phys. Rev. **67**, 267 (1945).

[7] M. L. Wiedenbeck, Phys. Rev. **67**, 92 (1945).

[8] M. L. Wiedenbeck, Phys. Rev. **68**, 1 (1945).

From these data a nuclear energy level diagram can be drawn, Fig. 3, showing the various nuclear transitions which occur.

DISCUSSION

A summary of the nuclear energy levels of stable nuclei which have been studied by x-ray excitation is given in Table I.

The error incurred in determining the intersection of the straight line portions of the thick target x-ray excitation curve does not exceed ± 0.03 Mev. Such lines are determined from numerous points obtained under identical geometrical conditions. In any given bombardment, the energy of the electron beam can be held constant to a value of ± 0.02 Mev and the current does not vary by more than 1 percent. The maximum error in the difference between two adjacent levels is therefore ± 0.06 Mev. It may be noted that with few exceptions the levels in any given element thus far studied fall within this limit. The average spacing varies, however, and increases regularly for rhodium, silver, cadmium, and indium.[9]

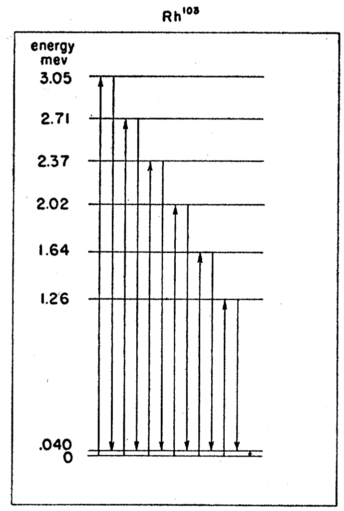

FIG. 3. Nuclear energy level diagram for Rh^{103} showing transitions which occur.

[9] B. Waldman and M. L. Wiedenbeck, Bull. Am. Phys. Soc. **17**, No. 5 (1942).