Nuclear Isomerism and Internal Conversion

According to Weizsäcker,[1] one may explain nuclear isomerism by assuming that the lowest excited state of the nucleus has an angular momentum differing by several units from that of the ground state. Selection rules may then be invoked to increase the lifetime of time of the excited level, against gamma-ray transitions to the ground state, to such a large value that the normally slower beta-processes may compete effectively in destroying the upper state. The γ-ray—β-ray branching ratio will depend on the relative lifetimes for the two modes of decay, but when the latter are of the same order of magnitude, the γ-ray transitions should be observable. Hebb and Uhlenbeck[2] have suggested that the failure of attempts to observe these gamma-rays is probably due to the high probability of internal conversion. (The internal conversion coefficient increases rapidly as the spin change increases, and as the energy difference decreases).[3]

We have therefore looked for a line spectrum of conversion electrons from one of the isomeric forms of Rh^{105}, formed from Rh by slow neutron capture. To decrease the absorption of slow electrons in the rhodium target as well as in the detector walls, the target was electrolytically deposited inside a Ni cylinder, and the counter walls were constructed of 0.005 mm Al. An absorption curve of the radiation from the 4.2 min. isomer showed the presence of two components; the harder one was identified through its absorption coefficient, with the well-known primary beta-rays of this period. The softer component, which accounted for about 30 percent of the total counts, had an energy of 35–60 kev. That this soft component was not instrumental could be demonstrated by the fact that no such soft group was observed to follow the 44 sec. Rh period under identical geometrical conditions.

From these data, we may draw the following conclusions regarding the 4.2 min. isomer:

(1) The radiation does not consist of *one* simple continuous beta-ray spectrum.

(2) The radiation does not consist of two simple beta-ray spectra superposed, since no hard γ-ray is observed. Also, the partial decay constant for the hypothetical soft beta-rays is too great for their energy.

(3) The soft component is therefore composed of conversion electrons from a γ-ray of about 80 kev. To prove that this gamma-ray transition precedes the beta-ray emission, it will be necessary to show that the characteristic x-rays which must follow the internal conversion are Rh $K\alpha$ and not Pd $K\alpha$. This will be attempted in the future. For the present, it should suffice to show that all the experimental results may be explained by assuming that *the soft radiation is an "electron line" emitted by internal conversion in the transition from the metastable state to the ground state of the* Rh^{105} *nucleus.*

On this assumption, the 44 sec. penetrating component arises in beta-transitions from the ground state of Rh^{105} to the ground state of Pd^{105}. This same transition gives the hard component of the longer period, but it proceeds at a slower rate, as the Rh^{105} ground state (44 sec.) is now formed by γ-ray decay from the 4.2 min. level. This assumption could be tested by examining the early part of the 4.2 minute decay curve, i.e., before the 44 sec. period was in equilibrium with the longer one. Unfortunately the high initial intensity of the 44 sec. period makes this test impossible. This simple picture requires that the beta-ray spectra of the two isomers be identical. The experimentally observed difference might be accounted for by assuming the existence of direct beta-transformations from the excited state of Rh^{105} to the ground state of Pd^{105}.

A detailed account of this work will appear in the *Journal de Physique.*

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[1] Weizsäcker, Naturwiss. **24**, 813 (1936).
[2] Hebb and Uhlenbeck, Physica **5**, 605 (1938).
[3] Pontecorvo, *Travaux du Congrès du Palais de la Decouverte* (Paris, 1937).

Preliminary Report on the Radioactivity Produced in Y, Zr, and Mo

A study of the radioactivity produced in Y, Zr, Cb and Mo started at the Radiation Laboratory, University of California, Berkeley, by one of the authors, has been continued by making chiefly neutron bombardments on these elements from the cyclotron in the Institute of Physical and Chemical Research, Tokyo. Both lithium and beryllium targets were bombarded by 20 to 100 μa of 5.5 to 7.6 Mev deuteron beam at Berkeley and 20 to 40 μa of about 3 Mev in Tokyo to produce fast and slow neutrons. The results obtained on yttrium are given in Table I.

A further careful chemical test and a study of β-rays must be done for the assignment of the shorter periods. The 2.3 hr. period is expected to be due to Dy contamination. The results obtained on zirconium are given in Table II.

The 34 d period might be due to Hf contamination. The 70 hr. period assigned to be Y^{92} here seems likely to

TABLE I. *Radioactivity induced in yttrium by neutron bombardment.*

Bombardments	Observed Periods			
Slow neutrons	—	2.3 hr.	66 hr.	—
Fast neutrons	60 min.	—	66 hr.	55 days
Sign	e^-	e^-	e^-	e^-
Chemical test	—	—	Y	Sr
Assignment	?	Dy^{165}?	Y^{90}	Sr^{89}
Upper limit derived from K–U plot	—	—	2.1±0.1 Mev	—

TABLE II. *Radioactivity induced in zirconium by neutron and deuteron bombardment.*

Bombardments	Observed Periods					
Slow neutrons	—	—	17 hr.	—	—	—	63 d
Fast neutrons	—	3 weak hr.	—	70 hr.	70 hr.	—	63 d
Deuterons (8 Mev)	90 min.	2.5 hr.	—	—	3 d	weak 34 d	63 d
Sign	e^-	e^-	e^-	e^+	e^-	e^-	e^-
Chemical test	—	—	Zr	Zr	Y	Cb	Zr
Assignment	—	Y^{94}?	Zr^{95}	Zr^{89}	Y^{92}	Cb^{95}?	Zr^{93}
Upper limit derived from K–U plot	—	—	1.25 ±0.1 Mev	1.03 ±0.1 Mev	1.3 ±0.1 Mev	—	0.25 ±0.3 Mev

TABLE III. *Radioactivity induced in molybdenum by neutron bombardment.*

BOMBARDMENTS	OBSERVED PERIODS			
Slow neutrons	—	24 min.	64 hr.	—
Fast neutrons	17 min.	—	64 hr.	several days
Sign	e^+	e^-	e^-	—
Chemical test	Mo	Mo	Mo	—
Assignment	Mo^{91}	Mo^{101}	Mo^{99}	?
Upper limit derived from K–U plot	1.8 ±0.4 Mev	1.3 ±0.1 Mev	1.0 ±0.1 Mev	—

belong to Y^{90}, but the discrepancy between the upper limits obtained is far beyond the experimental error. With fast neutrons one more short period of about 30 min. has been observed. The results obtained so far on columbium are still too ambiguous for publication, because the activity is usually very weak and moreover the chemistry of it is very difficult.

The results obtained when molybdenum samples were bombarded by neutrons are given in Table III.

No trace of the 36 hr. period reported by Fermi and his collaborators was found.

It is a pleasure to express our thanks to Professor E. O. Lawrence for the privilege of using his cyclotron. Thanks are also due to Dr. Y. Nishina and Professor K. Kimura for their valuable help and encouragement. We wish to acknowledge the assistance given to us by Mr. K. Shinma, Mr. F. Yamasaki and Mr. N. Mori. The experiment has been aided by grants from the Research Corporation, the Chemical Foundation, the Josiah Macy, Jr., Foundation, the Japan Society for the Promotion of Scientific Research, the Oji Paper Manufacturing Company, Mitsui Ho-Onkwai Foundation, Tokyo Electric Light Company and the Japan Wireless Telegraph Company.

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Internal Conversion of γ-Rays in Element 43

Radioactive element 43 has been examined in a magnetic spectrograph, and is found to have three internally converted γ-rays. Segrè and Seaborg,[1] in studying the radioactivity of element 43, discovered a new six-hour period, and noticed that the electrons emitted by it gave an absorption curve characteristic of a single energy group rather than of a continuous distribution as in a normal β-ray spectrum. They kindly prepared a sample of this material for the magnetic spectrograph and the accompanying photograph was obtained (Fig. 1). The two lines are due to internal conversion in the K and L shells of element 43 and have the proper separation for an element in this neighborhood. (The fine scratch is a fiducial mark.) The γ-ray energy is 129 kev. This isotope is formed by the β-decay of radioactive molybdenum.

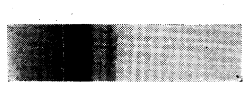

FIG. 1. Magnetic spectrogram of electrons emitted by radioactive element 43.

The long-lived isotopes of element 43 formed directly by deuteron bombardment of Mo were also tried in the spectrograph and gave lines corresponding to γ-rays of 87 kev and 184 kev. They are chemically element 43, but it is not yet known with what periods they are associated.

Other cases of internal conversion which have been reported are Ga[2] and Cd[3]. Ga has been photographed in the spectrograph, but Cd has not yet been tried. The author has also found internal conversion of a 230 kev γ-ray in a new 30-hour Ba isotope by absorption measurements, but at present, the activity is too weak to photograph. The electrons, x-rays and γ-rays have all been observed for this Ba, and there are no natural β-rays associated with it. A theoretical discussion of internal conversion has been given by Dancoff and Morrison.[4]

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[1] Complete explanation to appear soon in *The Physical Review*.
[2] L. Alvarez, Phys. Rev. **53**, 606 (1938).
[3] Ridenour, Delsasso, White, and Sherr, Phys. Rev. **53**, 770 (1938).
[4] S. M. Dancoff and P. Morrison, Phys. Rev. **54**, 149 (1938).

Location of Resonances in Boron Plus Proton Reactions

Gentner[1] has found the gamma-ray resonance in the reaction

$$_5B^{11}+{}_1H^1\rightarrow{}_6C^{12}+\gamma$$

to be at 180 kev. Allen, Haxby and Williams[2] place the alpha-particle resonance in the reaction

$$_5B^{11}+{}_1H^1\rightarrow{}_4Be^8+{}_2He^4$$

at 159 kev and the gamma-ray resonance at about the same voltage. A recent paper by Oppenheimer and Serber[3] has prompted new measurements of these resonances.

The alpha-particle and gamma-ray yields from the above reactions have been measured simultaneously with protons of energies up to 200 kev and thick boron targets. These measurements show that the two resonances coincide to within 1 kev and occur at 165±4 kev.

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[1] Gentner, Zeits. f. Physik **107**, 354 (1937).
[2] Allen, Haxby and Williams, Phys. Rev. **53**, 325 (1938).
[3] Oppenheimer and Serber, Phys. Rev. **53**, 636 (1938).