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**Abstract**

**Full Text**

## Physics

**Yu. A. Surkov**

# Experimental Studies of the Alpha Decay of Elements of Medium Atomic Weight

*(Presented by Academician A. P. Vinogradov, 7 March 1957)*

The question of the $\alpha$-decay of elements with $A < 209$ has already been considered in the literature ([1]), and it was shown that all elements with mass number approximately greater than 150 are unstable with respect to $\alpha$-decay. Elements of medium atomic weight ($N = 82 \div 126$) prove to be stable only because their decay energy is small, and their lifetime correspondingly large. Registration of such $\alpha$-activity is most often limited by the capabilities of the measurement methods presently available. However, in some cases careful investigations have nevertheless made it possible to detect a number of natural $\alpha$-emitters ([2–6]).

From the theory of $\alpha$-decay it follows that, with decreasing mass number of an isotope, the $\alpha$-decay energy increases. Thus, the lighter the isotopes, the less stable they are with respect to $\alpha$-decay. This circumstance makes it possible to use nuclear reactions occurring under the action of high-energy nucleons to obtain isotopes with a large neutron deficiency. But these isotopes also prove to be unstable with respect to $K$-capture and $\beta^+$-decay; moreover, in the region under consideration these transitions most often turn out to be the most probable, which to a considerable degree complicates the registration and study of $\alpha$-decay. However, for elements of medium atomic weight as well, in some cases $\alpha$-decay becomes predominant among other processes of radioactive transformation. Thus, for example, from energy considerations it is known that the isotopes at the beginning of the filling of a nucleon shell are the most unstable with respect to $\alpha$-decay. A number of such isotopes, having 84–85 neutrons, have been detected and studied in works ([7–10]). The jump in the binding energy of nucleons in the nucleus, determined by the shell $N = 82$, is so large that the decay of isotopes with $N < 84$ cannot be observed. In addition, for the heaviest elements of medium atomic weight, even with a small neutron deficiency, the isotopes already become unstable with respect to $\alpha$-decay, whereas $K$-capture or $\beta^+$-decay is still of low probability. This explains the $\alpha$-activity of the neutron-deficient isotopes Au, Hg, Bi, Po, At, and Rn.

A systematization of experimental data on the $\alpha$-decay of elements of medium atomic weight makes it possible to note the existence of the same regularities of $\alpha$-decay as those observed in the region of heavy elements ($A > 209$). This makes it possible to establish certain prerequisites for carrying out experimental

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Fig. 1. Chromatograms of products of bombardment of Er, Yb, and Hf with 660-MeV protons

Figure 1: Fig. 1. Chromatograms of products of bombardment of Er, Yb, and Hf with 660-MeV protons

studies of the $\alpha$-decay of elements of medium atomic weight.

On the basis of the foregoing, we have carried out experimental studies of $\alpha$-decay in the isotope region under consideration ($N = 82 \div 126$). The $\alpha$-active isotopes were obtained in nuclear reactions during irradiation of Er, Yb, and Hf on the synchrocyclotron of the Joint Institute for Nuclear Research with protons of energy from 70 to 660 MeV. For the study

To study short-lived $\alpha$-activity, the elements were irradiated in the accelerator for 2 hours. Long-lived $\alpha$-activity was studied in the products of nuclear reactions accumulated over a 3-month period of accelerator operation.

The elements formed in the course of the nuclear reactions were separated by a chromatographic method and identified according to the various types of radioactive decay published in the literature, and according to the chromatographic elution scale of activated elements obtained under the same conditions as in the chromatographic separation of nuclear-reaction products. For the study of $\alpha$-decay, in each of the experiments only definitely pure fractions of the elements formed (chromatographically separated down to background) were taken. In the experimental work carried out, one of the important points was to obtain sufficiently cleanly separated elements, to which special attention was paid.

**Fig. 1.** Chromatograms of the products of bombardment of Er, Yb, and Hf with protons of energy 660 MeV (separation was carried out with lactic acid on resin D = 50 (X-12); pH 3.4-3.6; $t = 85^\circ$, $V \approx 1$ drop/min.).

Figure 1 presents chromatograms of the products of nuclear reactions formed in the bombardment of Er, Yb, and Hf with protons of energy 660 MeV. The chromatograms were recorded simultaneously for $\beta$- and $\alpha$-activity. Solid lines correspond to the value of the $\beta$-activity, and dotted lines to the value of the $\alpha$-activity in counts per minute, counted by this counting device. The $\alpha$-activity registered only by photographic plates is not indicated on the chromatogram.

Table 1 lists all $\alpha$-active isotopes detected by us in the investigations carried out on products of bombardment of elements of medium atomic weight. Some of them were known from previously published work. For them, the most accurate data obtained in work (8) are given. The isotopes Dy($^{153}$) and Hf(?) are assumed to be new. Values

mass numbers were not determined by us. The numbers given in parentheses are the most probable values assigned to the given $\alpha$-activity on the basis of the systematics of $\alpha$-decay. The $\alpha$-activity of hafnium is not entirely reliable because of the imperfection of the chemical method. Measurement of the $\alpha$-activity of

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the elements listed in Table 1 was carried out several hours after irradiation of the target (the measurement time depended on the ordinal number of the irradiated and investigated element). Elements with $Z < 64$ were not studied by us.

**Table 1**

| Element | $A$ | $E_\alpha$, MeV | $T_\alpha$ | $E_\alpha$, MeV (according to other data) | $T_\alpha$ (according to other data) |
|---|---|---|---|---|---|
| Gd | 148 | $3.3 \pm 0.2$ | $\sim 10^2$ years, calc. | 3.27 | $> 35$ years |
| Tb | 149 | $4.06 \pm 0.05$ | $4.3 \pm 0.2$ h | 4.08 | 4.1 h |
| Dy | 152 | $3.66 \pm 0.08$ | $3.2 \pm 0.3$ h | 3.73 | 2.3 h |
| Dy | (153) | $3.3 \pm 0.2$ | $\sim 10$ years, calc. | – | – |
| Hf | – | $3.5 \pm 0.2$ | $\sim 10^4$ years, calc. | – | – |

For the isotopes $Tb^{149}$ and $Dy^{152}$ the energies were measured with an ionization chamber with a multichannel pulse-amplitude analyzer. The corresponding half-lives were measured on a scintillation $\alpha$-counter. For the isotopes $Gd^{148}$, $Dy^{(153)}$, and Hf(?), the energies were determined from the range in thin-layer (50 $\mu$) photographic plates. The $\alpha$-decay half-lives calculated for them are a rough estimate.

In addition to the apparatus and methods for recording $\alpha$-activity mentioned above, the following were used in the work to identify the products of nuclear reactions: a luminescence $\gamma$-spectrometer, standard installations with end-window Geiger counters, and a rough magnetic analyzer of $\beta$-particles.

In conclusion, I take the opportunity to express my gratitude to L. P. Moskaleva and A. A. Pozdnyakov for their assistance in carrying out this work.

Institute of Geochemistry and Analytical Chemistry
named after V. I. Vernadsky
Academy of Sciences of the USSR

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*Note: Figure translations are in progress. See original paper for figures.*

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