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EXPERIMENTS ON THE PRODUCTION OF THE 102nd ELEMENT

The present communication describes experiments on the production of a new element with atomic number 102, which were carried out at the Institute of Atomic Energy of the USSR Academy of Sciences in the autumn of 1957.

In the first half of 1957, experiments were carried out at the Nobel Institute in Sweden on the irradiation of Cm^{244} with carbon ions C^{13} ([1]). By a radiochemical method it was possible to isolate several tens of radioactive atoms that underwent α-decay with a half-life of 10 min and emitted α-particles with an energy of 8.5 ± 0.1 MeV. The authors of that work suggested that they had obtained one of the isotopes of the 102nd element with mass number 251 or 253.

In our experiments, isotopes of plutonium Pu^{239} and Pu^{241} were irradiated with accelerated oxygen ions. Quintuply charged oxygen ions, produced in a special ion source ([2]), were accelerated in a 150-cm cyclotron to an energy of 102 MeV. The inhomogeneity of the beam in energy did not exceed 3%; the ion current was 0.2–0.4 μa. In most of the experiments, ions with maximum energy were used, since preliminary experiments had shown that the formation cross section of the compound nucleus in the interaction of O^{16} ions with plutonium increases up to an energy of 102 MeV.

The targets consisted of layers of Pu^{239} and Pu^{241}, respectively 300 and 100 $\mu g/cm^2$ thick, deposited electrolytically on thin nickel foils (1.5 μ thick). In view of the high radioactivity of plutonium, serious requirements were imposed on the stability of the layers. A specially developed electrolysis procedure made it possible to obtain plutonium layers capable of withstanding prolonged bombardment by an intense beam of multiply charged ions. In addition, to prevent the shedding of the finest particles of plutonium, a protective copper film 50 $\mu g/cm^2$ thick was deposited on the layer by evaporation in vacuum. Irradiation of the targets was carried out in the internal beam of the cyclotron.

According to the regularities of α-decay, the isotopes of the 102nd element should have a short lifetime; therefore, in the experiments a technique was used that

Fig. 1

Figure 1: Fig. 1

made it possible to record α-decay occurring within several seconds. Figure 1 schematically shows the arrangement of the target and the recording device.

When an oxygen ion with an energy of ~ 100 MeV collides with a plutonium nucleus, the compound nucleus is given so large a momentum that its range exceeds the thickness of the plutonium layer and of the protective copper film. The range of such "recoil nuclei" was estimated on the basis of experiments to determine the range of products formed in the bombardment of gold with oxygen. In copper it was 200-300 $\mu g/cm^2$, and in plutonium 500-600 $\mu g/cm^2$. Thus, the nuclei arising from irradiation of plutonium with a beam of O^{16} freely left the target, struck the collector, and were stopped in it at a ne-

depth. The collector was periodically moved to a thick-layer photographic plate located at a distance of 2 m from the target and used to register α-particles from the radioactive decay of the isotopes formed. The holding time of the collector near the target and in front of the photographic plate could be varied over wide limits; the time required to move the collector was 4-5 sec.

Fig. 1. Arrangement of the target and recording device.
1—Ni foil, $1.5\,\mu$; 2—^{241}Pu, $100\,\mu g/cm^2$; 3—Cu, $50\,\mu g/cm^2$; 4—collector, $2\,\mu$ Al; 5—photographic plate.

In these experiments the NIKFI-T_1 photoemulsion was used; it has good discrimination between proton and α-particle tracks and low sensitivity to β- and γ-radiation. The energy of individual α-particles was determined with an accuracy of 0.3 MeV.

In irradiating ^{239}Pu the holding time was 20 sec, while in experiments with ^{241}Pu it was 20 sec and 1 hour. For each holding time, 10-12 three-hour irradiations were carried out. Figure 2 shows the energy spectra of α-particles observed at different collector holding times. In constructing the spectra, a correction was introduced to account for the loss of energy by the α-particles on leaving the collector. This correction, determined experimentally, was on the average 200 keV. As is seen from the figure, in the spectra obtained in irradiating ^{239}Pu and ^{241}Pu with a holding time of 20 sec, α-particles with energy > 8.5 MeV are observed. In experiments in which the holding time was 1 hour, only a single α-particle of such energy was registered.

The spectra do not indicate α-particles having ranges less than $35\,\mu$ ($E_\alpha <$ 7.0 MeV). Their appearance is due to the presence in the target of platinum deposited during the electrolysis of plutonium. When platinum is irradiated with ^{16}O ions, Rn isotopes are formed; however, they do not constitute a danger, since the energy of the α-particles from the decay of these isotopes and their products does not exceed 6.5 MeV. This was checked in control experiments.

Fig. 2

Figure 2: Fig. 2

According to the systematics of α-active nuclei, α-particles with energies greater than 8.5 MeV may be emitted by isotopes of the 102nd element: 102^{251}, 102^{252}, 102^{253}, formed in the reactions: ^{239}Pu (^{16}O, 4 n) 102^{251}, ^{241}Pu (^{16}O; 4-6 n) $102^{251-253}$.

Fig. 2. Energy spectra of α-particles emitted in the decay of the products of the reactions $^{239,241}\text{Pu} + {}^{16}\text{O}$. The amounts were ^{239}Pu, $300\,\mu\text{g/cm}^2$, and ^{241}Pu, $100\,\mu\text{g/cm}^2$. The total fluxes of ^{16}O ions in the three cases indicated were identical and amounted to $3.5\,\mu$A-h.
A–$^{241}\text{Pu} + {}^{16}\text{O}$, $\Delta t = 20$ sec; B–$^{241}\text{Pu} + {}^{16}\text{O}$, $\Delta t = 1$ hour; C–$^{239}\text{Pu} + {}^{16}\text{O}$, $\Delta t = 20$ sec.

The total number of registered α-particles with energy greater than 8.5 MeV in irradiating ^{241}Pu was 18, and in the case of ^{239}Pu, 8. The reaction cross sections calculated from these data proved to be, respectively, $\sim 2 \cdot 10^{-32}$ and $5 \cdot 10^{-33}\,\text{cm}^2$.

It is evident that, with such small effects, experiments to determine the background acquire particular importance. In our experiments the sources of background

could have been cosmic rays, reactions with emission of energetic α-particles induced by neutrons, and contamination of the photographic plates and probe parts by radioactive substances from the thorium family, among which there is ThC′ with α-particle energy of 8.78 MeV. However, the background due to these causes should not depend on the holding time of the collector near the target and near the photographic plate, and the absence of an effect upon irradiation with a holding time of 1 hour indicates the smallness of all components of this background.

An additional danger is presented by Bi and Pb impurities in the target. Among the products of reactions of oxygen ions with these elements there may be unknown isotopes emitting α-particles with energy > 8 MeV. Such isotopes have periods of 10^{-6}–10^{-8} sec; therefore only those of them that are in equilibrium with the parent elements undergoing K-capture with a sufficiently long period will be registered. An analysis of the radioactive properties of the elements in this region of the Mendeleev periodic system shows that the appearance of such isotopes is unlikely, but nevertheless cannot be entirely excluded. To clarify this question definitively, it is proposed to carry out special experiments.

In the interaction of accelerated O^{16} ions with plutonium, in addition to reactions with neutron emission, reactions of the type (O^{16}, pxn) are possible, which will lead to the formation of mendelevium ($Z = 101$). However, according to the existing systematics of α-active nuclei, only very light isotopes of mendele-

vium will emit α-particles with an energy of 9 MeV. For the formation of such isotopes, evaporation of 8–10 nucleons from the compound nucleus is necessary, which in our case is energetically impossible.

The results of the experiments carried out show that the method used in the present work can be employed for registering short-lived α-active reaction products with a very small yield (down to cross sections of 10^{-32}–10^{-33} cm^2).

On the basis of an analysis of possible causes of the background and of a number of control experiments, it seems to us that the α-particles with energy > 8.5 MeV observed upon irradiation of plutonium with oxygen ions are, in all probability, connected with the decay of isotopes of the 102nd element. Further control experiments are planned using a more refined method, which will make it possible to establish a genetic connection between the α-emitters by observing correlated tracks of α-particles on the photographic plate.

In conclusion, the authors consider it their duty to express gratitude to Acad. I. V. Kurchatov for his constant interest in and attention to the work. The authors are also grateful to the group of collaborators under the direction of Yu. M. Pustovoit, who ensured the uninterrupted operation of the cyclotron during the experiments.

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CITED LITERATURE

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