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ON PROPERTIES OF THE ISOTOPE 102^{251}

Объединенный институт
ядерных исследований
БИБЛИОТЕКА

In experiments on the synthesis of element 102 performed in Stockholm in 1957, an alpha emitter with a half-life about 10 min. and 8.5 + 0.1 MeV alpha-particle energy was found/1/. A statement was made that these properties belonged to one of the isitopes of element 102. In these experiments the target of Cm isotope mixture (Cm^{244} -95%, Cm^{245}-1%, Cm^{246}-4%) was bombarded with C^{13} ions, the energy spectrum of bombarding particles being very wide (from 70 to 100 MeV) with the centre of gravity about 90 MeV. A complex isotopic composition of the target and a large uncertainty in the energy did not allow to speak definitely about the type of the reaction leading to this emitter formation, i.e. there was no possibility to identify mass number of the obtained isotope. However, there was a probability that one of the odd isotopes of element 102 with mass number 251, 253 or 255 was synthesized. Such a conclusion was made to explain the relatively long half-life of the emitter, as the isotopes with odd mass numbers only may have hindrance for alpha-decay as compared with their even-even neighbours. According to the authors estimates, unforbidden decay of the isotope of element 102 with E_α= 8.5 MeV corresponds to a half-life on the order of 10 sec. and the hindrance factor for the above isotopes must be about 60. However, recent experiments performed in Dubna/2-4/, showed that 102^{253} and 102^{255} isotopes are largely different from the emitter obtained in Stockholm. Half-lives and alpha-particle energies of these isotopes are equal to 1.5 min. and 3 min. , 8.01 MeV and 8.08 MeV, respectively.

In the present work an attempt was made to synthesize 102^{251} isotope which had been never studied before and to determine its radioactive properties.

For the synthesis of this isotope the following reactions were used:

$$U^{235}(Ne^{20},4n)102^{251},\ U^{233}(Ne^{22},4n)102^{251} \text{ and } Pu^{239}(O^{16},4n)102^{251}.$$

In these three target-particle combinations we chose the reaction with the evaportaion of four neutrons since the expected yield of 102^{251} was very small, and it was necessary to eliminate a possibility of appearance of 8.5 MeV alpha-particles from the decay of the neighbouring isotopes, especially 102^{252} with a half-life of 4.5 sec and 8.41 MeV alpha-particles /2/. There was no danger from the other lighter isotope 102^{250}, which may appear from the reaction with the evaporation of five neutrons, since its half-life must be very short (tenth of a second).

The experiments were performed with the heavy ion external beam of the 310-cm cyclotron at the Laboratory of Nuclear Reactions, JINR, by the recoil nuclei gas collection method described earlier in /3/.

In the first experiments U^{235} was bombarded with Ne^{20} ions. There were some groups of alpha-particles which involved the 8.4 MeV group with a half-life of 10-30 min. To enlarge the yield of this emitter we used Ne^{22} ions for getting more intense beam. The optimal trimming of the cyclotron corresponds to Ne^{22} ions. In connection with this we ought to prepare a U^{233} target which was bombarded with a more intense Ne^{22} beam. Then the yield of the isotope emitting 8.4. MeV alpha-particles suddenly increased (about 30 times) at the same ion beam. The most surprising thing was as follows: the cross section corresponding to the appearance of the studied isotope reached 10^{-30} cm^2. When we increased Ne^{22} energy by 10 MeV we observed a noticeable enlargement of this emitter yield (~ 2 times) which definitely showed the non-evaporating charachter of the nuclear reaction leading to the formation of the studied product. Fig. 1 shows the energy spectrum of alpha-particles detected in the reaction $U^{233} + Ne^{22}$. The analysis showed that the complicated alpha-spectrum appeared due to decay of the Th^{225} and Th^{226} isotopes with half-lives 8 min and 30 min, respectively. These isotopes are produced from the nucleon cluster pick-up reaction between the projectile and the

target nucleons (U^{233}). Actually, all alpha-lines in these spectra are connected to the decay of short lived elements of the radioactive rows whose parents were these Th isotopes.

Thus in the first two reactions we observed long-lived emitters with alpha-particle energy about 8.5 MeV, but they had nothing to do with 102^{251}.

The search for this isotope continued in a new target-particle combination - Pu^{239} and O^{16}. Just in the first experiments it was noticed that the yield of the undesirable Th isotopes fell down sharply (1000 times) and this permited us to search for 102^{251} isotopes.

The estimate of possible yield of the 102^{251} in the nuclear reaction $Pu^{239}(O^{16}, 4n)102^{251}$ was performed on the basis of data on cross section for the nuclear reactions

$$Pu^{242}(O^{16},4n)102^{254},\ Pu^{242}(O^{16},4n)102^{256},\ Pu^{239}(O^{16},4n)102^{253}$$

and calculated from the mean value of the ratio between neutron and fission widths $(\frac{\Gamma_n}{\Gamma_f})$ /5/. Since an order of magnitude of the ratio $(\frac{\Gamma_n}{\Gamma_f}) = 0.04$, we might expect the maximum cross section for the nuclear reaction would be about $2 \times 10^{-32} cm^2$.

Besides, we based on the data on nuclear reaction type $(I, \alpha 4n)$.

The ratio of the cross sections $\frac{\sigma(I,\alpha 4n)}{\sigma(I,4n)}$ studied in /6,7/ at energies corresponding to the maximum cross section for the reaction (I.4n). In our case the nuclear reaction $Pu^{239}(O^{16},4n)$ must lead to the formation of Fm^{247} whose properties are known /8/, with the cross section about $3 \times 10^{-32} cm^2$ and the energy of O^{16} ions near the maximum of the cross section $(O^{16}, 4n)$.

The bombardment of Pu^{239} was performed at two energies of O^{16}: 88 and 93 MeV. At the beginning of the experiment we chose the optimum regime of the work of the device for the observation Fm^{247} (80 sec - time of bombardment, and 80 sec - time of measurement). In this case we observed Fm^{247} (E_α = 7.88 MeV, $T_{1/2}$ = 36 sec) with a cross section about $3 \times 10^{-32} cm^2$ and $8 \times 10^{-32} cm^2$, respectively. Then the time conditions were changed to be optimum to search for the 10 min. isotope 102^{251}. The experiment continued for a rather long time so that the integral O^{16} beam was large enough to observe 10 alpha-particles with energy of

8.5 MeV if the cross section would be $2 \times 10^{-32} cm^2$. Still we did not manage to detect an alpha-particle in the energy intervals 8.3-8.7 MeV. The sensitivity of the device allowed to notice any product emitting 8.3-8.7 MeV alpha-particles, if its half-life was about 5-20 min, and the cross section is not less than $2 \times 10^{-33} cm^2$.

The aim of the next experiments was to search for 102^{251} taking into account that its half-life is shorter. The basis for this was the systematics of alpha-decay half-lives and the absence of the long-lived activity (We, at least, did not observe it). The difference between the half-lives of the even-odd isotopes of the heaviest elements (Cf , Fm , 102) and the smooth curves for the even-even isotopes is not very large; besides, for the lightest isotopes and heaviest elements, the hindrance factor became less. For 102^{255} this is 10 and for 102^{253} - 6. So we may expect the hindrance factor 102^{251} would be in the interval of 1-10. The measurements were performed in short time conditions (0.5 sec, 2.5 sec, 5 sec - bombardment and 0.5 sec , 2.5 sec, 5 sec - measurements). In all the experiments with bombardment time and time of measurement 0.5, 2.5 sec we observed 6 impulses of 8.6 MeV alpha-particles, but in the experiments 5/5 sec non alpha-particle was noticed. It is difficult to come to a conclusion on the exact half-life of 102^{251} and its alpha-decay energy, but we may assume that $T_{1/2}$ of it will be about 0.5-1sec and the alpha-particle energy about 8.6 MeV.

The main result of this work consists of the following: the isotope 102^{251} has different properties as compared with the emitter observed in 1957 ($T_{1/2}$ = 10 min, $E_\alpha = 8.5 \pm 0.1$ MeV).

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References

1. P.R.Fields, A.M.Friedman, J.Milsted, H.Atterling, W.Forsling, L.M.Holm, B.Aström. Phys.Rev., 107, 1460 (1957); Arkiv für Fysik, 15 , 225 (1959).
2. В.Л. Михеев, В.И. Илющенко, М.Б. Миллер, С.М. Поликанов, Г.Н. Флеров, Ю.П. Харитонов. АЭ, 22, 90 (1967).

3. Г.Н. Акапьев, А.Г. Демин, В.А. Друин, Ю.В. Лобанов, Б.В. Фефилов, Г.Н. Флеров. Л.П. Челноков. АЭ, 22, 127 (1967).
4. Г.Н. Флеров, С.М. Поликанов, В.Л. Михеев, В.И. Илющенко, В.Ф. Кушнирук, М.Б. Миллер, А.М. Сухов, В.А. Щеголев. Препринт ОИЯИ Р7-3059, Дубна, 1966 г.
5. В.Л. Михеев,. Доклад на Конференции по физике тяжелых ионов, Дубна, октябрь, 1966 г.
6. Е.Д. Донец, В.А. Щеголев, В.А. Ермаков, АЭ, 18 , 195 (1964).
7. Е.Д. Донец, В.А. Щеголев, В.А. Ермаков, АЭ, 20, 233 (1966).
8. В.И. Илющенко, М. Б. Миллер, В.Л. Михеев, С.М. Поликанов, В.А. Щеголев. Препринт ОИЯИ Р7-3022, Дубна, 1966 г.

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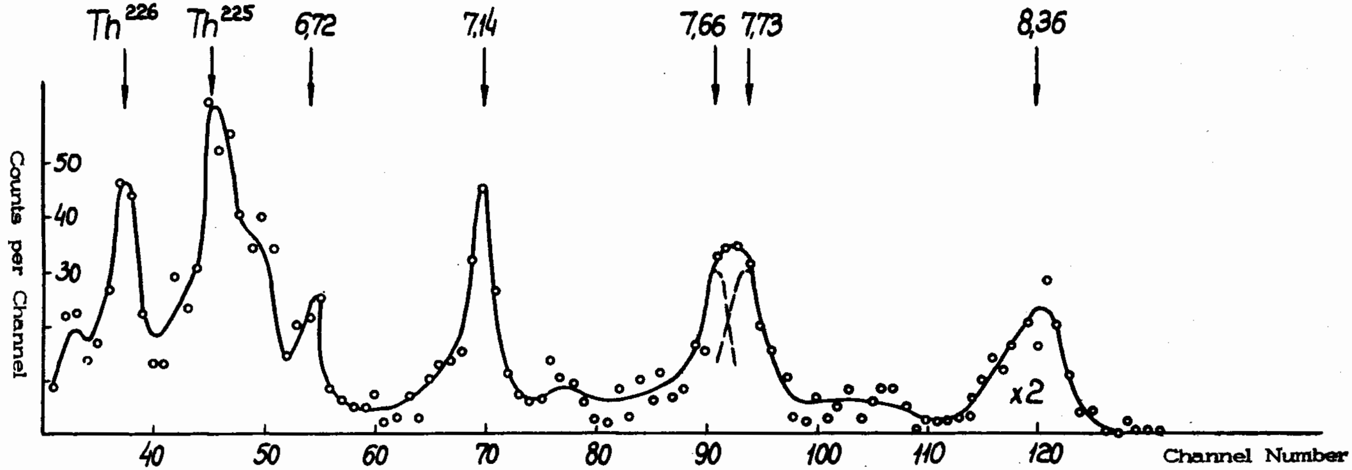

F i g. 1. Alpha-spectrum at irradiation of U^{233} with Ne^{22} ions.