RADIOPHARMACEUTICAL "THALLIUM-201-CHLORIDE" PRODUCTION USING THALLIUM-203 IRRADIATION BY HELIUM-3 IONS

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ABSTRACT

A method of radiopharmaceutical "thallium-201 chloride" production has been developed on the basis of experimental and calculated data on the excitation functions and nuclear reaction yields in thallium-203 targets irradiated by helium-3 ions. The calculated and experimental results allow us to determine the reaction channel priorities in thallium-203 (^{3}He,5n) bismuth-201 → lead-201 → thallium-201 formation.

1. INTRODUCTION

Thallium-201 radiopharmaceuticals are widely used in medical practice for early diagnosis of heart diseases. Thallium-201's main characteristics are radionuclide purity and low chemical contamination content and depend on the complex conditions of the radioactive isotope production.

At the Institute of Nuclear Physics of the Kazakhstan Academy of Sciences regular production of a "thallium-201 chloride" radiopharmaceutical using radiochemical treatment of a thallium-203 target irradiated by 29 MeV protons began in 1986. One of the possible ways of continuing this radiopharmaceutical production all the year round is to use not only protons but other ions also, especially after development of helium-3 ion acceleration using a high efficiency recovery system.[1)]

2. EXPERIMENTAL RESULTS

Irradiating thallium-203 by helium-3 ions, the radionuclide thallium-201 can be produced through the following reactions:

^{203}Tl(^{3}He,5n)^{201}Bi → ^{201}Pb → ^{201}Tl
^{203}Tl(^{3}He, p 4n)^{201}Pb → ^{201}Tl
^{205}Tl(^{3}He,7n)^{201}Bi → ^{201}Pb → ^{201}Tl
^{205}Tl(^{3}He, p 6n)^{201}Pb → ^{201}Tl

It was necessary to obtain experimental data on excitation functions of these nuclear reactions, and also on competitive ones in which contaminant radionuclides are formed, to choose the optimum irradiation conditions for the thallium-203 targets.

Unfortunately, the available experimental data on such excitation functions are not enough for solving this problem. So it was necessary to use model calculations.

Such calculations have been carried out using a statistical model of the compound nucleus decay with the program ALICE modified for helium-3 ions in the entry channel.[2)]

The nuclear masses, the binding energies and the energy effect of the reactions were calculated with the liquid drop model using Mayers-Swyatetckey parameters.[3)] Also the data from the tables of Ref.[4)] were used.

Figures 1 and 2 show the calculated excitation functions of the nuclear reactions of thallium-203 with helium-3 ions leading to the formation of Pb and Bi radionuclides with A=200-202. The curves obtained predict considerable cross sections for the formation of Bi

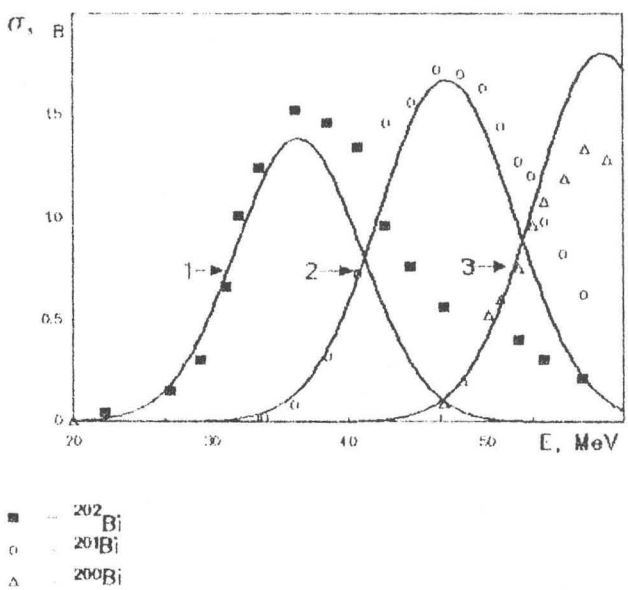

Fig. 1. The excitation functions of the reactions thallium-203 (helium-3,xn) with radionuclide formation. Continuous curves – the results of calculation, the points – experiment: 1 – bismuth-202, 2 – bismuth-201, 3 – bismuth-200.

radionuclides. At the same time experiments like the ones in Ref.[5] were performed.

The experimental results are shown on Fig. 1 as points. The experimental excitation functions of the evaporation reactions agree satisfactorily with calculated ones.

Some excess of the experimental values over the theoretical ones in the high energy "tails" of the excitation functions is explained by insufficient account being taken of pre-equilibrium processes. The part played by such processes for high-energy bombarding particles is essential and it leads to higher cross section values in comparison with calculated ones.

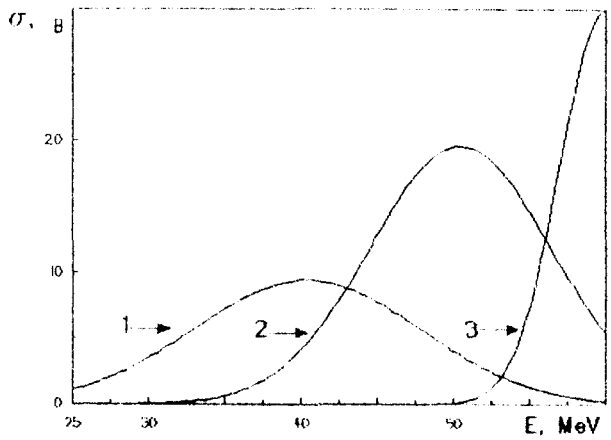

Fig. 2. Calculated excitation functions of the reactions thallium-203 (helium-3,p xn) with radionuclide formation.

The systematic overestimate of the calculated excitation function for bismuth-200 can be explained by the fact that the gamma-lines are not known with enough accuracy.[6–8]

The physical yield of Bi radionuclide as a function of the energy of the helium-3 ions was calculated by numerical integration of the experimental excitation functions for a flux of 3.12×10^6 part/sec for irradiation per hour by the formula

$$Y = 3.12 \cdot 10^6 \cdot n \cdot \lambda \int_o^{x_s} \sigma(x)dx$$

where Y – physical yield, MBr/μAh; n – number of nuclei in one milligram of target substance; x – distance travelled by the particle in the target.

For estimation of the reliability of the obtained results irradiation of "thick" thallium targets has been carried out over two energy ranges 43–33 MeV and 44.5–33 MeV. After one hour's irradiation with 1 mA of beam current each target was dissolved in nitric acid and then the gamma-radiation spectra of these samples were measured from the solution obtained.

The measurement was carried out in 2 and 35 hours. The accumulated thallium radionuclide activities after 2 hours' exposure were subtracted from the corresponding ones after 35 hours' exposure, taking into account the nuclides' decay. Such an approach gives the possibility of realizing the thallium-201 production method on condition of keeping the technology of the radiochemical treatment. The results are presented in Table 1.

Table 1. The experimental functions and the yields of bismuth and lead isotopes in bombarding thallium-203 with helium-3 ions.

N	E_{in} MeV	E_{out} MeV	Yield ^{201}Tl MB/μAh	Contaminant, % ^{200}Tl	^{202}Tl
1	47.0	33	11.9*	8.0	<0.1
	47.0	33	12.4**	7.0	<0.1
2	44.5	33	8.6*	1.9	<0.1
	44.5	33	9.13**	1.5	<0.1
3	43.1	33	4.5***	0.5	<0.1
4	45.0	33	3.0***	3.0	0.2

* – physical yield,
** – calculated data,
*** – yield after radiochemical treatment.

3. CONCLUSION

On the basis of the results obtained it can be concluded that the bismuth radionuclide yield is the main fraction for thallium-201 production from the "thick" targets (enriched with thallium-203) and that for the required isotope purity an accurate energy range must be kept. Thus, the method developed for production of the radiopharmaceutical "thallium-201 chloride" by irradiating a thallium-203 target with helium-3 ions is suitable for practical use, although it gives less yield in comparison with proton irradiation.[9]

4. REFERENCES

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