ISSN 1066-3622. Radiochemistry, 2006, Vol. 48, No. 2, pp. 195–197. © Pleiades Publishing, Inc., 2006.
Original Russian Text © O.D. Maslov, A.V. Sabel'nikov, S.N. Dmitriev, 2006, published in Radiokhimiya, 2006, Vol. 48, No. 2, pp. 176–178.

Preparation of ^{225}Ac by ^{226}Ra(γ, n) Photonuclear Reaction on an Electron Accelerator, MT-25 Microtron

O. D. Maslov, A. V. Sabel'nikov, and S. N. Dmitriev

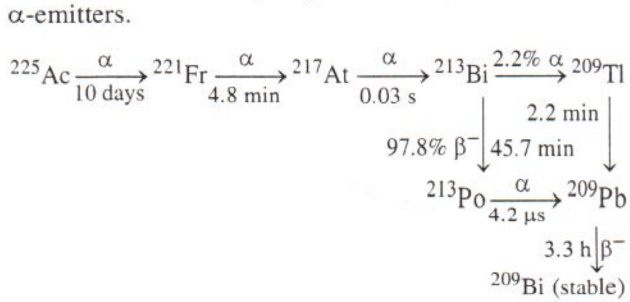
Flerov Laboratory of Nuclear Reactions, Joint Institute for Nuclear Research, Dubna, Moscow oblast, Russia

Received January 27, 2005; in final form, June 20, 2005

Abstract—^{225}Ac was prepared by the ^{226}Ra(γ, n) reaction on an electron accelerator (MT-25 microtron) at FLNR. The radiation yield of ^{225}Ac was 550 Bq/(μA h mg ^{226}Ra). ^{225}Ac was isolated from the target material and radioactive impurities by the ion-exchange procedure. The ^{225}Ac : ^{227}Ac : ^{226}Ra activity ratio in the preparation was $1 : \sim 2 \times 10^{-9} : \leq 6 \times 10^{-5}$.

PACS numbers: 25.20.-x
DOI: 10.1134/S1066362206020184

The use of new radioactive isotopes, in particular ^{225}Ac, for diagnostics and therapy of various diseases is one of the urgent trends in the modern nuclear medicine. Actinium-225 is a parent radionuclide for preparing ^{213}Bi [1] which is used for tumor therapy, especially for therapy of micrometastases. Nuclear physical properties of ^{225}Ac [2] allow its application for the same purposes. It is an α-emitter with a relatively short half-life (10 days), and its daughter products ^{221}Fr and ^{217}At (along with ^{213}Bi) are short-lived α-emitters.



Production of ^{225}Ac in amounts required for nuclear medicine is an urgent problem of nuclear physics. To optimize ^{225}Ac production, different preparation procedures of this isotope are developed.

Actinium-225 can be prepared by irradiation of a Ra target with neutrons [1], protons [3–8], and deuterons [6], of a Th target with neutrons [1] and protons [7, 8], and of a U target with protons [7, 8]. One of the most convenient ways to obtain ^{225}Ac is its isolation from ^{229}Th [1,7] formed by α-decay of ^{233}U produced for military and energy purposes.

The aim of this study was to examine the possibility of preparing ^{225}Ac by the $^{226}\text{Ra}(\gamma, n)^{225}\text{Ra} \xrightarrow{\beta^-}$ ^{225}Ac photonuclear reaction on an electron accelerator, MT-25 microtron (Flerov Laboratory of Nuclear Reactions, Joint Institute for Nuclear Research).

EXPERIMENTAL

To determine the ^{225}Ac yield, we prepared two thin targets containing 0.65 μg of ^{226}Ra each. One of these targets was a mixture of powdered barium sulfate and radium sulfate, and the other was radium nitrate on an aluminum support. Each target was placed in a cylindrical aluminum container 8 mm in diameter and 5 mm high. The container was closed with an aluminum lid 0.1 mm thick.

The container was fixed at the center of an aluminum holder open on one side. The open side of the holder was tightly sealed with 50-μm aluminum foil. The targets were irradiated on an MT-25 microtron for 30 and 20 h with photons having the maximal energy of 24 MeV at the electron current of 24 MeV. The irradiation was performed by the procedure described in our previous paper [9].

After the irradiation completion, the target was kept for 18 days to reach the maximal accumulation of ^{225}Ac (Fig. 1). The actinium activity was determined by the activity of its daughter products ^{221}Fr (E_γ = 217.6 keV, 12.5%, $T_{1/2}$ = 4.8 min) and ^{213}Bi (E_γ = 439.7 keV, 27.3%, $T_{1/2}$ = 45.6 min) [2].

The irradiated $Ra(NO_3)_2$ target was dissolved in 9 M HCl. The solution was evaporated to wet salts which were dissolved in 0.1 M HCl. The reaction products were separated by the ion-exchange procedure described in [10]: (1) 0.5 ml of the initial solu-

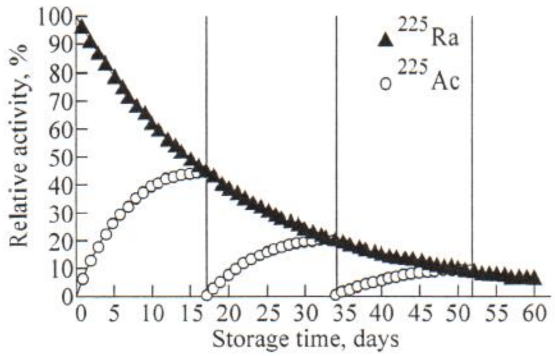


Fig. 3. Stepwise isolation of ^{225}Ac from the irradiated target. Separation steps are shown by vertical lines.

materials of the target unit is accompanied by generation of neutrons. Therefore, the minimal ^{227}Ac : ^{225}Ac ratio will be determined by the amount of ^{227}Ac formed by the $^{226}Ra(n,\gamma)^{227}Ra \xrightarrow{\beta^-} {}^{227}Ac$ reaction. The ^{227}Ac yield in this reaction depends on the experimental conditions.

In our experiments, the thermal neutron flux measured using the $^{197}Au(n,\gamma)^{198}Au$ reaction was $10^5\ n\ cm^{-2}\ s^{-1}$. The cross section of thermal neutron capture by ^{226}Ra is 12.8 b [11]. Hence, the minimal ^{227}Ac : ^{225}Ac activity ratio under all the irradiation conditions presented in the table is about 1.8×10^{-9}.

Our experimental results show that the purity of ^{225}Ac prepared by the $^{226}Ra(n,\gamma)$ reaction depends on the purity on the initial ^{226}Ra and the integral photon flux.

The model experiments with lead chloride show that the specific yield of the target product decreases by no more than 20% in going from a thin target to a thick 2-g target. Thus, 1.4×10^7 Bq (1.4×10^9 Bq) of ^{225}Ac can be prepared by irradiation of a 10-mg (1-g) ^{226}Ra target on an MT-25 microtron for 100 h at a 25 μA electron current. Irradiation of 1 g of ^{226}Ra on linear electron accelerators for a period shorter than 150 h at an electron current of 500 μA and more and the maximal γ-quantum energy reaching 50 MeV can yield more than 1 Ci of ^{225}Ac.

Stepwise isolation of ^{225}Ac from the irradiated target increases its yield by a factor of 1.5 (Fig. 3).

Thus, we developed a procedure for preparing ^{225}Ac by the $^{226}Ra(\gamma,n)^{225}Ra$ reaction. The ^{225}Ac yield is 550 Bq/(μA h mg ^{226}Ra). The ^{225}Ac : ^{227}Ac : ^{226}Ra activity ratio in the ^{225}Ac preparation is $1 : \sim 2 \times 10^{-9} : 6 \times 10^{-5}$.

ACKNOWLEDGMENTS

The authors are grateful to A.G. Belov for performing the irradiation experiments on the microtron.

REFERENCES

1. Koch, L. *et al.*, *Czech. J. Phys.*, 1999, vol. 49, suppl. 1, part II, pp. 817–822.
2. Sowby, F.D., *Radionuclide Transformations: Energy and Intensity of Emissions: ICRP Publication 38*, Pergamon, 1983. Translated under the title *Skhemy raspada radionuklidov. Energiya i intensivnost' izlucheniya: Rekomendatsii MKRZ. Publikatsiya 38-ya*, Moscow: Energoatomizdat, 1987, part 2, book 2, pp. 1–479.
3. Bonetty, R., Chiesa, C., and Guglielmetti, A., *Nucl. Phys.*, 1993, vol. 562, p. 32.
4. Beyer, G.J., Hermann, E., and Molnar, F., *Radiochem. Radioanal. Lett.*, 1972, vol. 12, p. 259.
5. Moellenbeck, J. and Schweickert, H., *Nachricht., Forschungszentr. Karlsruhe*, 2000, vol. 32, nos. 1–2, pp. 87–90.
6. Chaudhri, M.A., Abstracts of Papers, *The Fifth Int. Conf. "Modern Probelms of Nuclear Physics,"* Samarkand (Uzbekistan), August 12–15, 2003, p. 236.
7. Khalkin, V.A., Tsupko-Sitnikov, V.V., and Zaitseva, N.G., *Radiokhimiya*, 1997, vol. 39, no. 6, pp. 481–490.
8. Molinet, R. *et al.*, in *Proc. 4th Int. Conf. on Nuclear and Radiochemistry*, Saint-Malo (France), September 8–13, 1996, Orsay, 1996, report H-P2.
9. Dmitriev, S.N. *et al.*, *Radiokhimiya*, 1998, vol. 40, no. 6, pp. 533–537.
10. Guseva, L.I. and Tikhomirova, G.S., *Radiokhimiya*, 1994, vol. 36, no. 1, pp. 51–56.
11. Mughabghab, S.F., Divadeenam, M., and Holden, N.E., http://isotopes.lbl.gov/ngdata/sig.htm.