Identification of neutron-rich isotope ^{197}Os

YANG Wei-Fan, YUAN Shuang-Gui, XU Yan-Bing, XIAO Yong-Hou, ZHAO Li-Min, WANG Ping-Zhi, LI Heng-Yuan

(Institute of Modern Physics, the Chinese Academy of Sciences, Lanzhou 730000)

Abstract A new neutron-rich isotope ^{197}Os was produced in the ^{198}Pt(n, 2p) reaction by irradiating natural Pt targets with 14 MeV neutrons. The γ(X) singles spectrum and coincidence spectrum measurements were performed using two HPGe γ-ray detectors. Ten unknown γ-rays at 41.2, 50.7, 196.8, 199.6, 223.9, 233.1, 250.2, 342.1, 403.6, and 460.4 keV attributed to the decay of ^{197}Os were observed in the experiments. The half-life of ^{197}Os was found to be (2.8 ± 0.6) min. A partial decay scheme of ^{197}Os was proposed on the basis of decay and coincidence relations. The half-life was compared with the values expected by different theoretical models.

Keywords ^{197}Os, Half-life, Coincidence measurement, Decay scheme

CLC numbers O571.3, O571.42^{+}1

1 Introduction

In the last few decades, the medium energy proton facilities have played an important role in the discovery of new neutron-rich heavy isotopes.[1,2] Simultaneously, a great number of new neutron-rich heavy isotopes have also been synthesized in the reactions of neutron-rich heavy nuclei with fast neutrons.[3] Recently, we have reported [4-6] identification of a few of new neutron-rich heavy isotopes produced by the fast neutron reactions.

The activities of the impurities with high yields in the targets irradiated with neutrons would sometimes make identification of new nuclides very difficult. Thus, rather extensive chemistry and even isotope separation were often performed in order to identify the new isotopes and to study their decays.[2,4,5,7] However, the traditionally radiochemical separations are not suitable if the half-life of a new nuclide to be synthesized is very short and it is chemically similar to some of produced elements. It is impossible that the γ-rays from ^{197}Os decay are observed through γ single spectra if the separation of Os from the Pt targets is not carried out because of lower ^{197}Os yield and quite a large amount of impurities produced in the irradiation. Hence the coincidence of Ir *K*X-rays with γ-rays should be made so as to obtain γ rays of ^{197}Os. In this case, identification of ^{197}Os can be performed according to the energies and half-lives of γ-rays,[6] their coincidence relations as well as the production modes.

As a continuance of our earlier studies on identification of new nuclides with $A\geqslant 170$, in this paper we report the experimental details of the identification of a new neutron-rich isotope ^{197}Os produced by bombardments of natural Pt metal foils with 14 MeV neutrons.

2 Experimental procedure

2.1 Irradiation

The experiment was performed on the Cockcroft-Walton accelerator at the Institute of Modern Physics. The natural Pt metal foils (99.9% purity) of ~100 mg/cm^2 were bombarded with 14 MeV neutrons. ^{197}Os was produced through the ^{198}Pt(n, 2p) reaction. Irradiation period was 6 min. 120 runs were carried out in order to get enough counting statistics. Because it is predicted that ^{197}Os has a shorter half-life, after the end of irradiations, the irradiated Pt targets have been transferred fast to a lead shielded chamber by a pneumatic transport system.

Supported by the National Natural Science Foundation of China (No.10075063, 10175079), Major State Basic Research Development Program (No. G2000077400), and the Chinese Academy of Sciences.

Received date:2003-07-18

2.2 Measurements and data analysis

In all runs the Os element was not chemically separated from the irradiated Pt targets. The γ(X) singles and coincidence spectrum measurements were carried out using two HPGe detectors: a planar detector having a resolution of 580 eV at 122 keV and a clover detector consisting of four coaxial N-type Ge detectors, in which each has a 25% efficiency and a resolution of 2.1 keV at 1332 keV. They were equipped with MPA3 Multiparameter Data Acquisition System. About 20 s elapsed from the end of irradiation to the start of counting. The sources of known radioactivities were used to provide the energy and intensity calibrations. The γ and X spectra from 20 keV to 2 MeV and from 10 keV to 400 keV were measured as a function of time, respectively. The measured data were stored on a magnetic disk.

The cumulative data were analyzed by applying a set of MXA-099K program on the Pentium-2 computer. The least-squares fit was performed for the decay curve of γ-rays of interest. The final half-lives were obtained from a weighted average of results.

3 Results and discussion

An X-ray spectrum in coincidence with all of γ -rays is presented in Fig.1. The Ir $K_{\alpha1}$ and $K_{\beta2}$ X-rays

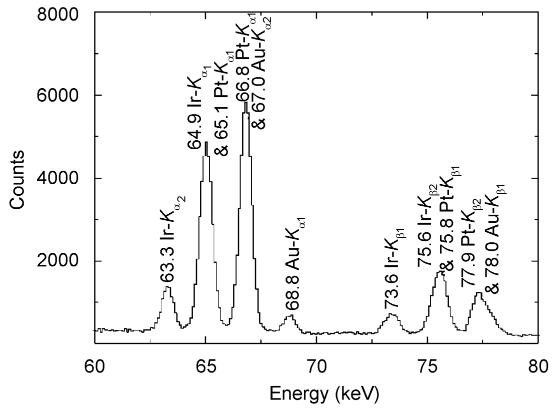

Fig.1 The accumulated X-ray spectrum obtained using a planar HPGe detector from natural Pt targets bombarded by 14 MeV neutrons in 120 runs.

were not considered in the data analysis owing to interference from Pt $K_{\alpha2}$ and $K_{\beta1}$ X-rays, respectively. Fig.2 shows a part of the γ-ray spectrum in coincidence with Ir $K_{\alpha2}$ and $K_{\beta1}$ X-rays. Three new γ-rays at 41.2, 342.1 and 403.6 keV can be clearly seen in Fig.2. Because of the quite low production rate of ^{197}Os in the ^{198}Pt(n, 2p) reaction, these γ-rays could be seen only in the coincidence spectra. Their decay curves were illustrated in Fig.3.

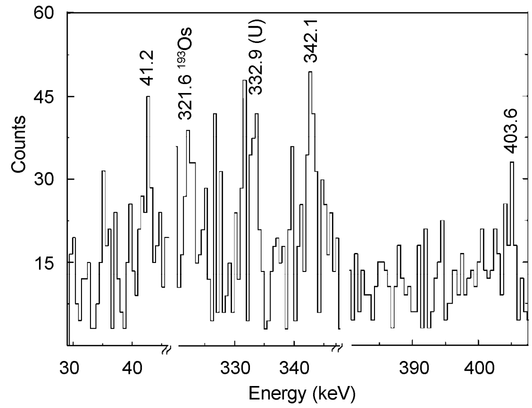

Fig.2 A part of the γ-ray spectrum measured in coincidence with Ir $K_{\alpha2}$ and $K_{\beta1}$ X-ray. The measuring time for every spectrum was 6 min and the measurements were started about 20 s after the end of the irradiation.

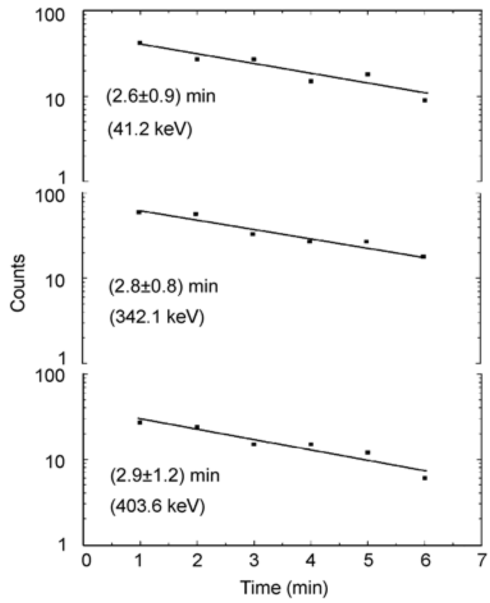

Fig.3 The decay curves of the γ-rays of 41.2, 342.1, and 403.6 keV.

Seven new γ-rays were observed again in coincidence with the three rays. It was found that any one of the ten γ-rays mentioned above could not be attributed to the decay of known nuclides.[8] The analysis of experimental data shows that all of them have the half-life of 2.8 min or so (Fig.3). Therefore, they should come from the same nuclide. The energy uncertainty for the ten γ-rays is ± 0.5 keV. Their coincidence relations are listed in Table 1.

Table 1 Energies, relative intensities and coincidence relations of γ-rays following the decay of ^{197}Os

E_γ (keV)	I_γ (relative intensity)	Coincidences
41.2	43(6)	223.9, 342.1
50.7	63(9)	196.8, 199.6, 403.6, 406.3
196.8	49(8)	50.7, 223.9, 233.1, 406.4
199.6	33(5)	50.7, 403.6
223.9	100	41.2, 196.8,233.1, 342.1
233.1	34(6)	196.8, 223.9
250.2	21(6)	403.6
342.1	66(8)	41.2, 223.9
403.6	42(7)	50.7, 199.6, 250.2
406.4	29(5)	50.7, 196.8

The activities with 2.8 min half-life may be assigned to ^{197}Os decay and its partial decay scheme (Fig.4) was proposed on the basis of the following evidences:

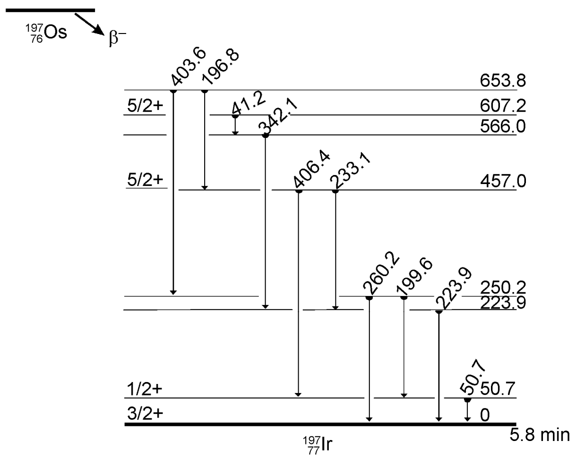

Fig.4 The proposed partial decay scheme of ^{197}Os.

(1) The ^{197}Os isotope can be produced through the ^{198}Pt(n, 2p) reaction in bombardments of Pt targets with 14 MeV neutrons.

(2) The three unknown γ-rays at 41.2, 342.1 and 403.6 keV are coincident with the Ir $K_{\alpha 2}$ and $K_{\beta 1}$ X-rays.

(3) Seven new γ-rays were observed in coincidence with the three γ-rays.

(4) At the same time, all ten new γ-rays show the same half-life of 2.8 min.

(5) Furthermore, the half-life of 2.8 min is quite different from that of any one of the known radioactive isotopes produced in fast neutron irradiations of the natural Pt.

(6) The levels proposed in Fig.4 agree reasonably with some of the excited states of ^{197}Ir observed in a ^{198}Pt (polarized t, α) reaction study.[9,10]

Therefore, a new neutron-rich isotope, ^{197}Os, has been identified. Its half-life was determined to be (2.8 ± 0.6) min.

A comparison of ^{197}Os half-life measured in experiments with those calculated by different theoretical models [11,12] is given in Table 2. It can be seen from Table 2 that half-life of the 2.8 min is very close to the values of 3.30 and 3.10 min calculated by using the proton-neutron quasi-particle random-phase approximation (QRPA) with a Gamow-Teller residual interaction determined from the mass formula of Hilf et al as well as Möller and Nix in second-generation microscopic predictions of beta-decay half-lives of neutron-rich nuclei.[11]

Table 2 A comparison of the half-life of ^{197}Os measured in experiments with the beta-decay half-lives of ^{197}Os predicted by different theoretical models

The present work	QRPA [11]			Gross theory[12]
	Möller and Nix	Hilf et al	Groote et al	
(2.8 ± 0.6) min	3.10 min	3.30 min	5.03 min	1.49 min

References

1 Ward T E, Chu Y Y, Cumming J B. Phys Rev **C**, 1973, **8**: 340-346

2 Orth C J, Daniels W R, Dropesky B J. Phys Rev **C**, 1973, **8**: 2364-2371

3 Franz E M, Katcoff S, Smith H A. Phys Rev **C**, 1975, **12**: 616-618

4 Yuan S, Zhang T, Xu S. Z Phys **A**, 1993, **344**: 355-356

5 Yuan S, Zhang T, Pan Q. Z Phys **A**, 1993, **346**: 187-188

6 Zhang Xueqian, Yuan Shuanggui, Yang Weifan *et al*. Z Phys **A**, 1996, **353**: 353-354

7 Haustein P E, Franz E M, Katcoff S *et al*. Phys Rev **C**, 1976, **14**: 645-649

8 Reus U, Westmeier W. Atom Data Nucl Data Tables, 1983, **29**: 194-406

9 Zhou C. Nucl Data Sheets, 1995, **76**: 399-456

10 Cizewski J A, Burke D G, Flynn E R *et al*. Phys Rev **C**, 1983, **27**: 1040-1059

11 Staudt A, Bender E, Muto K *et al*. Atom Data Nucl Data Tables, 1990, **44**: 79-132

12 Horiguchi T, Tachibana T, Katakura J I. Chart of the Nuclides (1996)