Gamma decay of the lowly excited states of ^{189}Re*

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Abstract ^{189}W activities were produced via the ^{192}Os(n, α) reaction using irradiation of isotopically enriched ^{192}Os metallic powder of ∼100 mg/cm^2 with 14 MeV neutrons. The X-γ and γ-γ coincidence measurements were made so as to obtain γ rays from ^{189}W decay and its coincidence relations. A new simple decay scheme of ^{189}W including three γ rays of 210.2, 229.6 and 260.2 keV is proposed. Two new levels of ^{189}Re at 470.4 and 489.8 keV are assigned.

Key words ^{189}W, decay scheme, new level

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1 Introduction

^{189}W lies at the rotational region $A = 190$. The studies on its decay γ rays will do great help for the understanding of the structure systematics in this region. Also its decay scheme study is very important for determining the capture cross-section of ^{188}W, which is an emerging radioisotope for therapeutic radiopharmaceutical applications in nuclear medicine[1]. To our knowledge, There have been a few work concerning ^{189}W decay[2—5]. In 2003, S. C. Wu and H. Niu[6] gave a sample decay scheme including two γ rays of ^{189}W at 222.0 and 260.4 keV based on the γ-ray data of W. F. Yang et al.[5] and the reaction data of C. R. Hirning et al.[7, 8]. Until now, no precise coincidence measurement for ^{189}W γ rays was made. The present work is to check the coincidence relations inferred from previous work[3, 6].

2 Experimental

The present experiments were performed using 14 MeV neutrons from the 600 kV Cockcroft-Walton accelerator at the Institute of Modern Physics, Chinese Academy of Sciences. ^{189}W activities were produced via the ^{192}Os(n, α) reaction using irradiation of isotopically enriched ^{192}Os metallic powder of ∼100 mg/cm^2 with 14 MeV neutrons. Osmium targets each were irradiated for 30 min to fit the 10.7 min half-life of ^{189}W[6]. And then they were transported into a lead-shielded room by an improved rabbit system. The measurement started 20 s after the end of irradiation with a planar HPGe detector (for X-ray and low energy γ-ray measurement) and a clover detector which consists of four coaxial N-type Germanium detectors. The two detectors were placed face to face on both sides of the source in the lead-shielded room. The measurement lasted 30 min to fit the half-life of ^{189}W[6]. The procedure mentioned above was repeated many times to improve the counting statistics. γ(X)-ray singles events and three parameter coincidence γ(X)-γ-t were recorded with a Multi-Parameter Data Acquisition System, where t was the time of each event after the beginning of a counting period.

3 Results and discussion

During the irradiation, several radioactive isotopes of Os, Re and W were produced by (n,2n), (n,γ), (n,p) and (n,α) reactions, respectively. It was not possible to observe γ rays from ^{189}W decay through γ singles spectra because of the lower ^{189}W yield and the large backgrounds from other nuclides

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produced in the experiments. The X-γ coincidence measurement was made so as to obtain γ rays from ^{189}W decay. A part of the γ-ray spectrum in coincidence with 61.1 keV Re Kα_1 and 59.7 keV Re Kα_2 X rays is presented in Fig. 1.

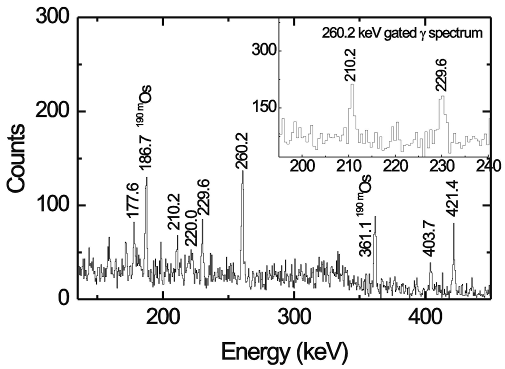

Fig. 1. Part of the γ-ray spectrum gated by Re Kα_1 and Kα_2 X rays. The inset shows the γ-ray spectrum gated by the 260.2 keV γ ray.

The 260.2±0.4 keV γ ray was carefully followed. The half-life of the 260.2 keV γ ray was determined to be 11.2±1.7 min. It is in agreement with the previous result[6]. So the 260.2 keV γ ray can be assigned to come from ^{189}W β decay through its transition energy and half-life[6]. In the γ-ray spectrum gated by the 260.2 keV γ ray (Fig. 1.), two γ rays with energies of 210.2±0.4 and 229.6±0.4 keV were observed. Their energies and half-lives are in agreement with the previous result[6]. The two γ rays can also be seen in the γ-ray spectrum gated by Re Kα_1 and Kα_2 X rays, so they can also be assigned to come from the β-decay of ^{189}W. Moreover the γ-ray spectrum gated by the 222.0 keV γ ray was carefully observed. Indeed the 260.2 keV γ ray was not found in the spectrum. And we noticed that there is no coincidence relation between the 210.2 and 229.6 keV γ rays. In addition, 177.6, 403.7 and 421.4 keV γ rays of ^{189}W[6] also appeared in Fig. 1. It should be pointed out that the γ-ray spectrum gated by the 260.2 keV γ ray was earnestly checked. There are no 177.6, 403.7 and 421.4 keV γ-ray peaks in the spectrum. Besides 210.2, 229.6 and 260.2 keV γ rays we analyzed all of the γ spectra gated by each γ ray, especially 421.4 keV one, in whole other γ rays of ^{189}W. As a consequence any available results were not obtained. Consequently a simple decay scheme of ^{189}W is proposed as shown in Fig. 2.

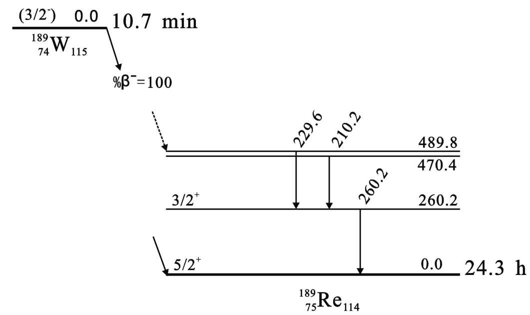

Fig. 2. Proposed simple decay scheme of ^{189}W.

Based on the following arguments, we conclude that the previous assignment of a 222 keV γ ray decaying from a level at 482.4 keV is incorrect, and that the 260.2 keV γ ray is in coincidence with 210.2 and 229.6 keV γ rays, and not the 222 keV γ ray.

In the work of P. Kauranen et al.[3], 210.2 and 229.6 keV γ rays could not be distinguished because of the poor energy resolution of NaI detectors. The two γ rays with energies of 210.2 and 229.6 keV were mistakenly assigned to be the 222 keV γ ray.

The decay scheme in reference[5] is given according to the measurement results from the γ singles spectra of ^{189}W and the level data of ^{189}Re. It is not reliable due to no coincidence measurement data.

The 260.2 keV γ ray was indicated to de-excite from a 260.2 keV $3/2^+$ state to the ground state ($5/2^+$). The two γ rays with energies of 210.2 and 229.6 keV can be inferred to de-excite from 470.4 and 489.8 keV states to the 260.2 keV state. These two levels of ^{189}Re were inferred from γ-ray decay for the first time. The result reveals that the amount of β-decay of ^{189}W feeding to 260.2 keV level is dominating source of 260.2 keV γ ray. In the work of R. Hirning et al.[7, 8], two α peaks which correspond to the levels at 470.4 and 489.8 keV, respectively may be masked by a strong α peak which corresponds to the 481 keV level because of the large peak widths.

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