Dependence of the cross sections for Ir isotopes on the values of Q_{gg} in the heavy ion collision*

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Abstract ^{197}Au were irradiated with 47 MeV/u ^{12}C ions. Iridium was produced via the multinucleon transfer reactions in bombardments of ^{197}Au with ^{12}C. and was separated radiochemically from Au and the mixture of the reaction products. The γ radioactivities of Ir isotopes were measured by using a HPGe detector. The production cross sections of Ir isotopes were determined from activities of Ir isotopes at the end of bombardment and the other relative data. It has been found that the cross sections for neutron-rich isotopes of iridium show an exponential dependence on the values of Q_{gg}. Our experimental results also demonstrate lack of correlation between the cross sections and Q_{gg} in the case of neutron-deficient isotopes of iridium. The fact can be explained from that neutron-rich isotopes of iridium were produced in the deep inelastic transfer reactions.

Key words iridium, ^{197}Au, Multinucleon transfer reaction, Q_{gg}

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1 Introduction

In several papers of the Dubna group[1—3], Q_{gg} systematics of the cross sections for the transfer reaction products have been proposed. Q_{gg} is the energy required to produce a given isotope in transfer reaction provided that the nuclei are produced in their ground states. $Q_{gg} = (M_1+M_2)-M_3+M_4)$, where M_1 and M_2 are the masses of the initial nuclei, M_3 and M_4 are the masses of the final nuclei, respectively.

The nucleon transfer was assumed to proceed as a two-body process. It implies that two large fragments are only formed in these reactions. So far, there is not such evidence that three fragments are formed in deep inelastic transfer reactions (DIT). The Q_{gg} systematics may be explanted by partial statistical equilibrium model in the system of two interacting nuclei.

It has been found that the isotopes produced mainly duo to DIT have similar angular distributions. Gatty et al.[4] indicated that the Q_{gg} systematics reflect the regularities of not only differential cross sections but also the total cross sections for the production of isotopes in DIT. The Q_{gg} systematics may not interpreted within the framework of the traditional mechanisms of direction reaction.

The results obtained earlier[5], as well as the data from some additional experiments show that the cross sections for DIT are large, when heavy elements are used as targets. The exponential dependence of the cross section on the Q_{gg} value observed in the case of nucleon-exchange reactions (projectile $-x$ protons $+y$ neutrons) is of great practical importance. Extrapolation of these relations may be used to estimate the yields for the reactions in which the unknown nuclides should be produced.

We report here some preliminary results on the dependence of the cross sections for Ir isotopes on the values of Q_{gg} in the reaction of 47 MeV/u ^{12}C with ^{197}Au.

2 Experimental

Irradiations were performed at the Heavy Ion

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Research Fasility at Lanzhou (HIRFL) in the Institute of Modern Physics (IMP). The gold foils with thickness 520 mg/cm^2 were bombarded with 47 MeV/u ^{12}C ions having an average intensity of about 10 enA.

The isotopes of iridium were produced via the multinucleon transfer reactions (^{197}Au-2p$\pm x$n) in the interactions of ^{197}Au with ^{12}C ions.

The iridium was separated 1.5 h after the end of irradiation from the reaction products by using the routine radiochemical procedures. In the final step, the γ solid sources of iridium were prepared for γ counting.

The γ-activities of each sample were measured using an HPGe detector with a pulse-height analyzer in a multispectrum mode. The detector has a resolution of 2.4 keV (FWHM) for 1332 keV gamma ray of ^{60}Co. The detector calibration was carried out with a standard ^{152}Eu source. Measurements for long-lived isotopes lasted about 5 months. The data were stored on the magnetic disks with a PC-CAMAC Multi-Parameter Data Acquisition System.

The measured γ-ray spectral data were analyzed employing a set of computer programs. The production cross sections were determined from the target thickness, the end-bombardment activities, variation on the beam intensity during the irradiation as well as the chemical yields and so on. The experimental details have been described in the Ref. [6].

3 Results and discussion

The production cross sections of iridium isotopes (independent) obtained in the experiment are listed in Table 1. The dependence of the cross sections for iridium isotopes on the values of $Q_{\rm gg}$ was shown in Fig. 1. As it has been shown in one of the preceding papers[4], the cross sections for projectile-like, isotope chain products of a given element in typical DIT processes depend exponentially on the values of $Q_{\rm gg}$. The experimental results on mass distribution in the reaction of 240 MeV ^{12}C with ^{197}Au show that the isomeric ratio (σ_m/σ_g) of ^{197m}Hg and ^{197g}Hg is 9.2. The isomeric ratio of ^{196m}Tl and ^{196g}Tl is unexpectedly higher than 15.6. Therefore, the cross sections of ^{195m}Ir and ^{196m}It obtained in the experiment may be considered nearly equal to their total cross section, respectively.

The cross section of ^{194g}Ir was only obtained in present experiment. The cross section value of ^{I94g}Ir should be much lower than that of $^{194(m+g)}$Ir. Therefore, the cross section for ^{194g}Ir deviates obviously from the line.

Table 1. The cross sections of the iridium isotopes produced in the interaction of 47 MeV/u ^{12}C with ^{197}Au.

Isotopes	Half-life	Principal γ ray/keV	Abundance (%)	Independent yield/mb
^{184}Ir	3.09 h	264.0	67.5	8.7±0.7
^{185}Ir	14.4 h	254.2	13.3	12.1±1.0
^{186}Ir	16.6 h	269.6	64.0	10.4±0.4
^{187}Ir	10.5 h	427.0	4.23	13.0±2.5
^{189}Ir	13.2 d	245.1	6.0	17.5±3.1
^{190}Ir	11.78 d	186.7	52.4	14.1±0.8
^{192}Ir	73.8 d	468.1	48.1	10.2±2.2
^{194g}Ir	19.15 h	328.4	13.1	2.0±0.6
^{195m}Ir	3.8 h	432.9	9.4	1.68±0.27
^{196m}Ir	1.40 h	393.5	97.0	0.34±0.08

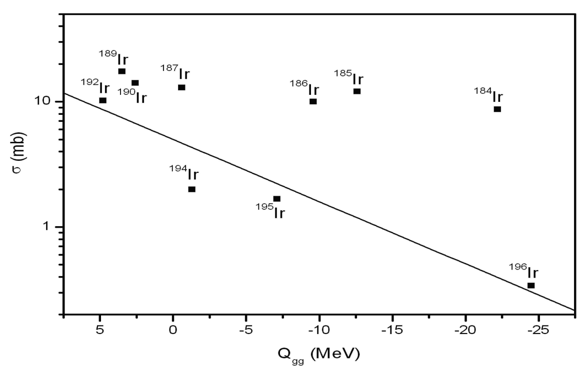

Fig. 1. The dependence of the cross sections for Ir isotopes in the reaction ^{12}C+^{197}Au on $Q_{\rm gg}$ value.

It can be seen from Fig. 1 that the dependence of the production cross sections on values of $Q_{\rm gg}$ shows considerable difference in the case of neutron-deficient and neutron-rich isotopes of iridium. The independent cross sections shown in Fig. 1 may be divided into two groups: the lower part of the data (cross sections of neutron-rich isotopes of iridium) and the other part, the higher data (those of neutron-deficient isotopes of iridium). The production cross sections for neutron-rich isotopes of iridium (^{195m}Ir, ^{196m}It and ^{192}Ir), except for ^{194}Ir depended almost linearly on $Q_{\rm gg}$, and the DIT processes may be considered the main reaction mechanism leading the production of neutron-rich Ir isotopes. But the cross sections for neutron-deficient isotopes of iridium deviate from this linear dependence, it may be attributed to an increasing contribution from quasielstic processes or explained by the secondary processes such as α- particle and neutron evaporation. Zhang li et al.[7] also reported the dependence of the thick-target-average production cross sections fro Hg isotopes on Q_{gg} values in the $^{18}O+^{nat}Pb$ reaction. It seems that the cross sections of neutron-rich heavy residues obtained with the light projectiles below ^{40}Ar show a Q_{gg} dependence.

We can conclude, from above mentioned facts that the production cross sections for neutron-rich isotopes of iridium depended almost linearly on Q_{gg} values. But the cross sections for neutron-deficient isotopes of iridium deviate from the linear dependence. It seems that the thick-target-average production cross sections of the neutron-rich heavy residues also follow an exponential dependence on Q_{gg} in the case of bombardment of the heavy targets with medium energy light projectiles below ^{40}Ar.

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