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One neutron transfer reaction in the ^{9}Be+^{89}Y system

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Abstract. One neutron transfer cross sections from the interaction of ^{9}Be with ^{89}Y have been measured at energies greater than the fusion barrier. The present measured 1n-transfer cross sections saturate at well above energies in comparison with the available experimental data at lower energies. Results of Coupled Reaction Channels Calculations (CRC) show very good agreement with the present measured cross sections.

1 Introduction

In recent years great effort has been made to understand the reaction mechanisms with weakly bound projectiles, which are important in the understandings of the astrophysical reactions and the production of nuclei near drip line [1–3]. This research can be performed with radioactive ion beams (RIBs), some of which exhibit unusual features like large breakup probabilities. Usually the beam intensity of the RIBs is low, and this lead to poor statistics. In contrast, good quality data can be obtained by using high-intensity beams of weakly bound stable nuclei, such as ^{6,7}Li and ^{9}Be which have significant breakup probabilities. In the breakup studies of weakly bound nuclei, the complete fusion (CF) of the projectile with the target, incomplete fusion (ICF) where one or more fragments are captured by the target, and the extracted complete fusion suppression factor are mostly discussed [3–5]. However, the one neutron transfer reaction, which was point to be important in the fusion of heavy nuclei [6, 7], was rarely considered. The present paper focuses on the presentation of new experimental results of one neutron transfer cross section for the ^{9}Be+^{89}Y system and compare with the theoretical model.

2 Experimental details

The experiment was performed using a ^{9}Be beam in the energy range of 44-51 MeV, in steps of $\sim$ 1.5 MeV, at the Heavy Ion Research Facility in Lanzhou (HIRFL). Fig. 1 presents the schematic illustration of the online experimental setup. Five ^{89}Y targets with thickness of $\sim$ 1.0 mg/cm^2 were bombarded. Each target was prepared by electrodeposition on a Gold backing, which is used to stop the recoiling nuclei. Beam energies were corrected for the loss at half thickness of the target and used in the further analysis. The beam flux was monitored by the total charge collected in the Faraday cup placed behind the targets using a high-precision current integrator device. In addition, an Au film was placed in front of the targets, and 5 monitor detectors were used to detect the scattered beam particles and deduce the total beam dose. To monitor current variations during the irradiation, a MPA-3 Data Acquisition System [8] was utilized online, which can easily extract the integrated current in intervals of 1 second. The offline γ counting method was employed for the measurement using HPGe (high-purity germanium) detectors. Energy and absolute efficiency calibrations of each detector were made using a set of calibrated radioactive sources (^{152}Eu, ^{133}Ba, and ^{60}Co), placed at the same geometry as the target. Typical energy resolution for the detectors was about 2.0-2.4 keV at FWHM for the 1332.5-keV ray of ^{60}Co. Absolute detection efficiency for each detector was about 1.5% for the 356.0-keV ray of ^{133}Ba. Offline data were acquired and stored in an event-by-event mode using VME based MIDAS [9] data acquisition system for further analysis.

3 Discussion

3.1 Data reduction

For the ^{9}Be+^{89}Y system the dominant channels in the measured energy range include three to five neutron evaporations of the compound nucleus ^{98}Tc, resulting in the formation of $^{93-95}$Tc. Other products observed are ^{92}Nb (α2n-CF/1n-αICF) and ^{90}Y (1n transfer). The typical spectrum for the off-line measurement is given in Fig. 2. The γ lines from the products following complete fusion and 1n transfer processes are denoted in the spectrum. To

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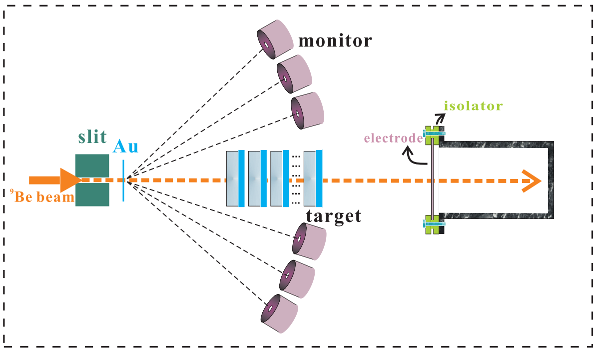

Figure 1. Schematic drawing of the online experimental setup for the measurement of the ^{9}Be+^{89}Y system

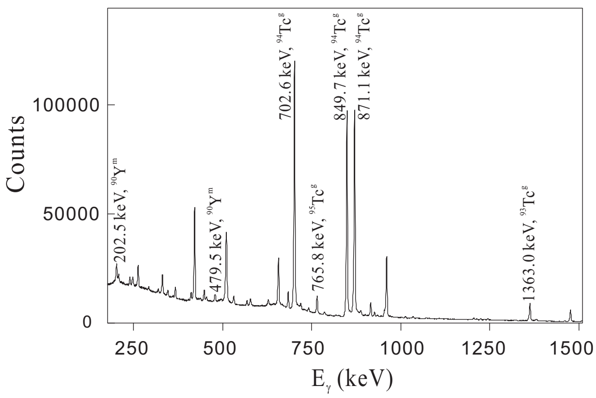

Figure 2. Typical γ-ray spectrum showing γ lines of different evaporation residues populated for the ^{9}Be+^{89}Y system at the projectile energy of 48.7 MeV.

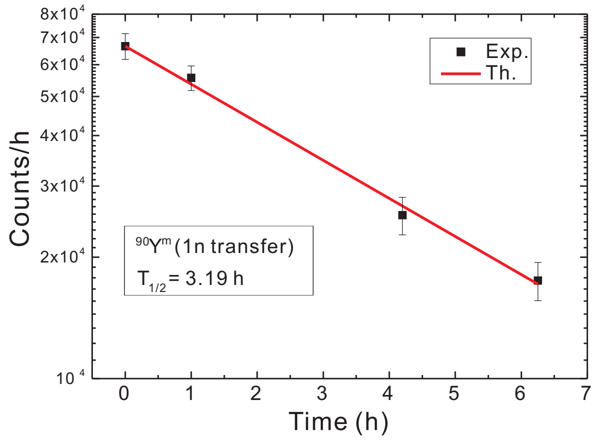

Figure 3. Decay curve for the ^{90}Y^{m} with Eγ = 202.5 keV at E_{beam} = 48.7 MeV.

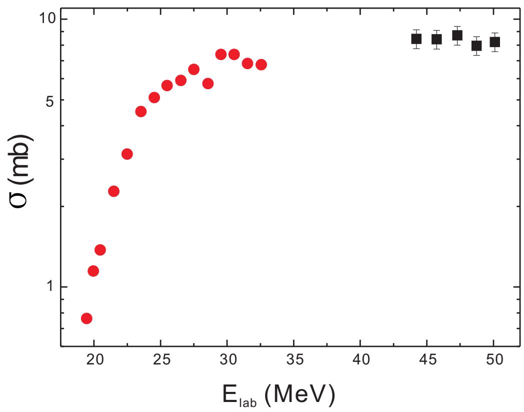

Figure 4. 1n transfer cross section as a function of projectile laboratory energy obtained in the ^{9}Be+^{89}Y system. The low energy data (red circle) were taken from Ref. [13].

confirm that the γ lines observed are coming from the nuclei of interest, the half-life for each nucleus has been followed. The data for the 1n transfer product ^{90}Y^{m} is shown in Fig. 3. The solid line is decay curve fits to the experimental data points using the half-life value from literature [10]. The experimental ^{90}Y^{m} cross sections were extracted using the half-life, prominent γ-ray energy of decay, and intensity [10] as well as method described in the Ref. [11]. In the measured energy range, ^{90}Y^{m} cross section was about 1.35% compared to the CF cross section. We consider this as a lower limit of the 1n transfer cross section, since when the reaction give the ^{90}Y products, ^{90}Y^{g} will also be populated. This could not be measured by offline counting method, because it decays directly to the ground state of the stable daughter nucleus. The total systematic errors of the extracted cross sections, arising from the uncertainties in target thickness, beam intensity, and detect efficiency is about 8%. This is combined with the statistical uncertainty in N_γ to get the total error using propagation of uncertainty.

3.2 CRC calculation and Discussion

Fig. 4 shows the measured 1n-transfer cross sections, with data at near barrier energies taken from Ref. [12]. It suggests that at energies well above the Coulomb barrier, 1n-transfer cross sections saturates.

Coupled Reaction Channels (CRC) calculations, for single neutron transfer cross sections, were also carried out for the ^{9}Be+^{89}Y reaction at 44.2, 45.7, 47.3, 48.7 and 50.1 MeV bombarding energies using the code Fresco [13]. In these calculations, coupling of ^{90}Y excited states up to 2 MeV are included to obtain the transfer cross sections. Also, the target inelastic coupling is included up to 1.75 MeV. The binding potential parameters for n+^{89}Y and n+^{8}Be and spectroscopic factors were taken from Ref. [14] and the required potentials are given in table 1. Shown in Fig. 5 are the 1n-transfer cross sections obtained from CRC calculations along with the corresponding experimental data. In this energy range, it can be observed that experimental and theoretical values for 1n-stripping reaction channel are in very good agreement.

Table 1. Optical model potentials used in the CRC calculations

System	V_0 (MeV)	R_0 (fm)	a (fm)	W_0 (MeV)	R_0 (fm)	a (fm)	V_s (MeV)	R_0 (fm)	a (fm)
^{8}Be+^{89}Y	30.79	1.22	0.64	30.54	1.22	0.65	-	-	-
n+^{8}Be	42.03	1.15	0.57	-	-	-	5.5	1.15	0.57
n+^{89}Y	51.47	1.25	0.65	-	-	-	6	1.25	0.65

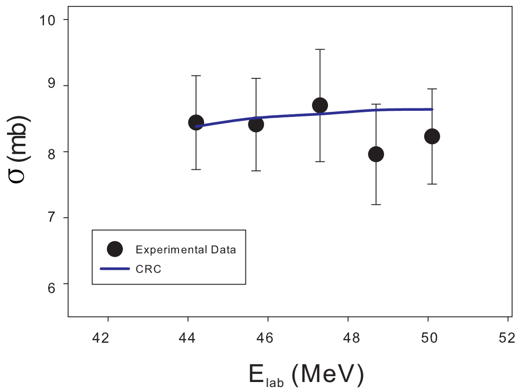

Figure 5. Comparison of experimental results of 1n transfer reaction with CRC calculations for ^{9}Be+^{89}Y system.

4 Summary

In the present work the excitation function of 1n transfer reaction have been measured for the ^{9}Be+^{89}Y system at energies 44.2, 45.7, 47.3, 48.7, and 50.1 MeV using the activation technique and HPGe γ-ray counting spectroscopy. To the best of our knowledge, the present experimental cross section of 1n transfer in the above energy region has been measured for the first time, as earlier measurements were carried out up to 32.6 MeV. Measured experimental results were compared with CRC calculations using FRESCO code. The present experimental results are in very good agreement with the theoretical values within the limits of the uncertainties in the measurements.

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