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Study on the Cross Sections of the Short-Lived Evaporation Residues in Reaction $^{12}C + ^{112}Sn$

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The cross sections of the evaporation residues from the bombardment of 52--71 MeV ^{12}C ion on ^{112}Sn have been measured by means of γ-ray detection. The residues have been transported from inside of the target chamber to the detection port by using a special device, and detected by a Ge(Li) detector. Only the relative cross sections have been obtained.

1. INTRODUCTION

The complete fusion reaction has an important place in the investigation of heavy ion nuclear reactions. Lots of results of the complete fusion excitation function were obtained from experimental measurements. To explain the experimental results and represent the complete fusion excitation function, a number of models with various restrictions on the complete fusion were proposed[1], in which the competitions between the complete fusion and other reaction mechanisms are described. The complete fusion excitation function in low energy region is successfully reproduced with barrier penetration model except in the very heavy reaction systems. Conversely, the interaction barrier parameters and the nuclear potential can be abstracted from the experimental excitation function with the help of the models.

Now more complete curves of the excitation function from the experimental results all belong to the light system because of the feasibility of the experiments. So far the experimental excitation function data of the complete fusion reaction for medium heavy system are still insufficient. The reason is that as far as the experimental technique is concerned, the recoil velocities of the evaporation residues in the medium heavy system are too low to be identified and detected by means of the ΔE-E telescope and time of flight which are usually very effective and rapid and are in

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common use in the experiments. Most of the residues are neutron deficient isotopes, so the main method for measuring them is the activation analysis. Of course, there are some difficulties in experiment and data analysis because of the difference between the life-times of the residues and the lack of decay information, especially for the residues having very short life-times.

In this work, the evaporation residues following the complete fusion of the reaction system $^{12}C + {}^{112}Sn$ have been measured by means of the off-line activation analysis for ^{12}C energy ranging from 52 to 71 MeV. Most of the nuclides in question have half-lives of about one minute. A simple tape transport system has been designed in order to perform the measurement of the half-life in this range. Using this transport system, the sample can be transferred from the irradiation area to the detection station in one second. Experimental excitation function result has been given in relative scale, because the calibration of the absolute efficiency of the system has not been done.

2. EXPERIMENT AND DATA ACQUISITION

The energy of the ^{12}C beam (72.5 MeV) from the 1.5 m Heavy Ion Accelerator at the Institute of Modern Physics (IMP) was reduced by changing the thickness of the aluminum degrader mounted in front of the collimator.

The target of 2.2 mg/cm^2 thickness was a rolled metal of ^{112}Sn riched to 78%. The effective thickness which the residue could pass through was estimated to be 760 μg/cm^2 by calculation.

In order to detect the γ-rays of the reaction products, Cs isotopes, a simple and convenient transport system was designed[2]. The products were collected on the tape of aluminum-plated mylar foil of 1.27 cm wide and 28 μm thick. The tape pulled by the step motor transferred the collected

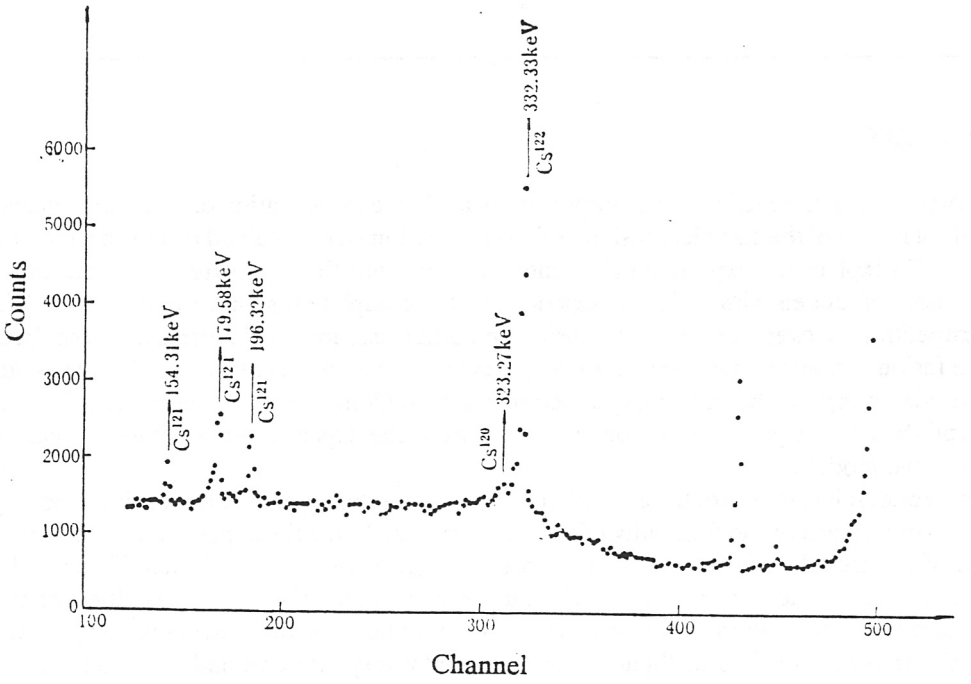

FIG.1 The γ-ray spectrum of products for reaction $^{12}C + {}^{112}Sn$.

sample from inside of the scattering chamber to a shielded Ge(Li) detector outside and there the sample was measured in one second. The step motor was powered by a time sequence autocontroller made by the Electronic Department of IMP.

The efficiency of the Ge(Li) detector calibrated by the standard Υ-ray sources of ^{153}Eu and ^{22}Na was 7.27×10^{-2} at 200 keV and 1.61×10^{-2} at 1000 keV. The energy signals from the Ge(Li) detector were recorded by a Multi-20 system, and for the same sample three spectra were recorded on magnetic tape sequentially in a period of 20 s within one minute. Then three experimental points in the decay curve were obtained.

3. DATA TREATMENT

The time at which the sample is removed (i.e. at that time when the irradiation stops) is defined as a zero point of the time for the series measurements of the Υ-spectra of the reaction products recorded by the Multi-20 acquisition system. The energy spectra measured at the same time and the same beam energy have been added together to obtain a Υ-ray spectrum with better statistics(Fig.1). It can be seen in Fig.1 that the Υ-ray peaks for ^{120}Cs, ^{121}Cs and ^{122}Cs are very obvious. Especially for ^{121}Cs, there are three adjacent peaks with higher intensity. Three peaks at 323.27 keV (^{120}Cs), 179.26 keV (^{121}Cs) and 332.33 keV (^{122}Cs) with 100% relative intensities have been treated to obtain the half-lives and relative cross sections of these three isotopes.

By integrating the area of each peak for ^{120}Cs, ^{121}Cs and ^{122}Cs, their decay curves can be drawn in half natural logarithm coordinate. Although the half-lives of ^{120}Ba, ^{121}Ba and ^{122}Ba and those of the corresponding daughter nuclei ^{120}Cs, ^{121}Cs and ^{122}Cs can be separated theoretically, only the mixed half-lives of ^{120}Ba and ^{120}Cs, ^{121}Ba and ^{121}Cs, ^{122}Ba and ^{122}Cs are obtained, respectively. Because there are only three experimental points in each decay curve, therefore such separation could not be done.

The nuclei of ^{120}Cs, ^{121}Cs and ^{122}Cs detected in this work could be either direct products of the reaction or the decay products of the Ba isotopes, that is

$$^{12}C + {}^{112}Sn \xrightarrow{\beta \text{ decay after evaporation of neutrons}} {}^{124}Ba^* \xrightarrow{\lambda_1} Cs \xrightarrow{\lambda_2} \quad (1)$$

$$^{12}C + {}^{112}Sn \xrightarrow{pxn} Cs \xrightarrow{\lambda_2} \quad (2)$$

Assuming that the count $N_1(t)$ of nucleus Cs comes from path(1) and $N_2(t)$ comes from path(2) at the time t, it can be obtained from the decay rule of the activation:

$$N_1(t) = \frac{\lambda_1}{\lambda_2 - \lambda_1} N_1(0)(e^{-\lambda_1 t} - e^{-\lambda_2 t})$$

$$N_2(t) = N_2(0)e^{-\lambda_2 t}$$

where

$$\left.\begin{aligned} N_1(0) &= \sigma_1 \phi(t')n \\ N_2(0) &= \sigma_2 \phi(t')n \end{aligned}\right\}$$

$N_1(0) = \sigma_1\phi(t')n$ and $N_2(0) = \sigma_2\phi(t')n$ are the numbers of the nuclei Ba and Cs at the zero time respectively, σ_1 and σ_2 are the cross sections of the produced Ba and Cs, respectively. n is the number of target nucleus per square centimeter. $\phi(t')$ is the effective beam flux with the decay of the products during the irradiation being taken into account. That is to say, $\phi(t')$ is the effective beam