Yield of iodine isotopes from interaction of 47 MeV/u ^{12}C with ^{133}Cs*

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Abstract The production cross sections of the iodine isotopes have been measured radiochemically for the interaction of 47 MeV/u ^{12}C with ^{133}Cs. The iodine isotopic yield distribution was deduced from these data and found to be a Gaussian shape. The Gaussian curve peaks in the vicinity of ^{124}I and has a FWHM of 5.5 mass units. The mass loss of the most probable product, $\Delta A_p = A_t - A_P$, is 9.2 mass units. The area of the yield curve is as high as 111 mb.

Keywords Isotopic distribution, Mass loss, Primary product, Independent yield

1 Introduction

In the past years heavy-ion reactions have been studied extensively. It is interesting to study how the reactions vary with incident projectile energy. Radiochemical measurements have provided an useful method for this purpose. A large amount of data on the isotopic yield distribution have been reported with high energy (hundreds of MeV/u or more) and low-energy projectiles.[1-3] There are a few published papers of radiochemical work[4,5] on this subject in the intermediate energy (10~100 MeV/u) region. It has been suggested that more experimental data are needed to better understand the reaction mechanism at these projectile energies.

We have reported the isotopic yield distribution of near-target product Hg[6] from the interaction of the 47 MeV/u ^{12}C with ^{209}Bi. The present experiment is only a part of the studies in such area where we focus our attention on the production mechanism of A >170 neutron -rich nuclei in the interactions of light intermediate energy ions (^{12}C, $^{16,18}O$, etc.) with heavy neutron-rich target nuclei. This paper deals with a description of the experimental method and some of the experimental results on the production cross sections of the iodine isotopes for the interaction of 47 MeV/u ^{12}C with ^{133}Cs.

2 Experimental

2.1 Irradiation and chemical separation

Irradiations were performed with Heavy Ion Research Facility of Lanzhou (HIRFL) at Institute of Modern Physics. A 564 MeV ^{12}C beam with an intensity of about 8~10 nA was delivered to the targets. The beam spot of 10 mm diameter was defined with an upstream collimator. The beam intensity was determined by the reaction $^{27}Al(^{12}C, xpyn)\ ^{24}Na$ or periodically recording the beam current entering the Faraday Cup with an electrometer. In the experiments the thick targets which are 520 mg/cm^2 CsCl(analytical reagent) or 560 mg/cm^2 $CsNO_3$ (spectroscopically pure) powder were used to get enough activities for some iodine isotopes with lower formation cross-sections. In the case the beam energy at the center of the target was degraded to 40 MeV/u. Bombardments for each experiment lasted 1~4 h.

The irradiated target powders were well-mixed and divided into three parts. One part of them was used for direct measurements of γ-ray spectra and the other two parts were separated chemically. The iodine was separated with a standard radiochemical procedure. An oxidation-reduction cycle was carried out to ensure complete exchange between radioiodine and carrier. In the final step, the sources were prepared as AgI precipitation for counting. No contaminant activities from the other reaction products were observed in the AgI sources. Based on the activity ratio between

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^{124}I(or ^{126}I) separated and unseparated chemically, the chemical yield was determined.

2.2 Gamma ray spectroscopic measurements and data treatment

Measurements of γ-activities were carried out with two HP Ge detectors having the energy resolution (FWHM)of 2.1 keV and 2.5 keV at the 1332 keV γ-ray of ^{60}Co, respectively. The efficiency calibrations of the detectors were made using a set of standard radionuclide sources. The decay of γ-ray spectra was followed as a function of time. Counting started approximately 20~30 min after the end of bombardment and extended 3~4 weeks. The activity of each isotope was determined by observing characteristic γ-rays for the sample sources.

The analysis procedure of γ-spectrum data was similar to that described previously.[6] Briefly, the photopeak intensities in the spectra were determined and the resulting decay curves were extrapolated to obtain the decay rate . Meanwhile taking into account the beam intensity variation during the irradiation, the production cross section for each nuclide was calculated from the detector efficiencies, the γ-ray abundances, the chemical yields and the decay rate.

The decay properties of iodine isotopes[7] used in the cross section calculation are listed in Table 1. The error of each cross-section stems from the extrapolated decay rate from the least-square decay curve analysis, the measurements of photopeak intensity, the efficiency calibration of the Ge detector and the chemical yield. The possible systematic error caused by the γ-ray abundance is not included.

Table 1 Decay properties of iodine isotopes used in the calculation[7]

Isotopes	$T_{1/2}$	E_γ/keV	I_γ/%
^{121}I	2.12 h	212.2	85.0
^{123}I	13.2 h	159.0	83.3
^{124}I	4.18 d	602.7	61.0
^{126}I	13.02 d	388.6	32.2
^{128}I	25.0 min	442.9	16.0
^{130}I	12.36 h	536.1	99.0
^{130}I	12.36 h	668.5	96.1
^{131}I	8.02 d	364.5	81.2

3 Results and discussion

The cross-sections for iodine isotopes determined in the experiment are tabulated in Table 2, where yields of the iodine isotopes are all independent except ^{121}I, ^{123}I, and ^{131}I. The contribution of ^{131}Te to ^{131}I is negligible in the reaction. Therefore, the yield of ^{131}I can also be considered to be independent. ^{121}I and ^{123}I isotopes are all not the primary products of the reaction; but, partly formed by electron capture (EC) decay of their parent nuclei. Thus, the cross sections of the two isotopes given in Table 2 have been corrected for their parent decays.

Table 2 The measured iodine isotopic yields

Isotopes	^{121}I	^{123}I	^{124}I	^{126}I	^{128}I	^{130}I	^{131}I
Cross section/mb	10.3±2.6	13.9±2.8	17.0±2.0	11.7±1.30	4.40±1.30	1.20±0.30	0.67±0.20

A nonlinear least-square program was used to fit the measured cross sections with the following expression

$$\sigma_i(A) = \sigma_p \exp\left[-\frac{(A-A_p)^2}{2S^2}\right]$$

where A is isotopic mass, A_p the probable mass, $\sigma_i(A)$ independent yield of the i-th iodine isotope, σ_p the most probable yield, S the width parameter of isotopic yield distribution.

The resulting isotopic yield distribution curve is plotted in Fig.1 and the Gaussian parameters are summarized in Table 3. The most straight forward information can be obtained from the position of A_p, the most probable mass of the yield curve. FWHM of yield curve peaked in the vicinity of ^{124}I is about 5.5 mass units. The mass loss ($\Delta A_p = A_t - A_p$) for ^{133}Cs→I is 9.2±1.8 mass units. A_t is target nucleus mass. In a similar experiment[4] the reported mass loss for ^{209}Bi→Po is 4.8±0.6 mass units. The production cross section of ^{131}I isotope from -2Z transfer is 0.67±0.20 mb. Activity of ^{132}I isotope produced by (-2 p + n) transmutation was not observed in the experiment.

In summary we have presented here some preliminary results of isotopic distribution for targetlike products produced in intermediate

energy ^{12}C bombardment of ^{133}Cs. A further discussion of the data is beyond the scope of the present paper.

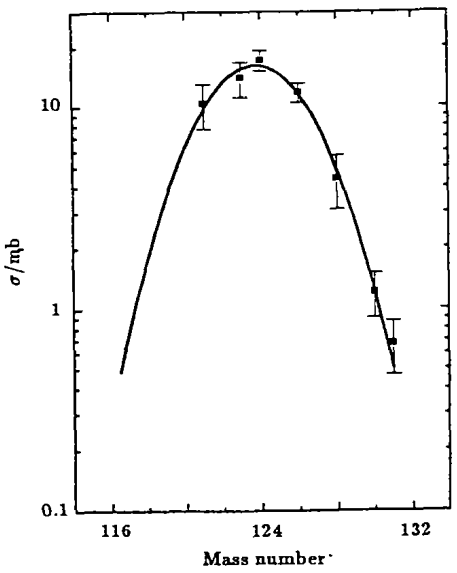

Fig.1 The iodine isotopic yield distribution for the interaction of 47 MeV/u ^{12}C with ^{133}Cs

Table 3 Gaussian parameters of iodine isotopic yield distributiom

σ_p/mb	15.99±0.70
A_p/mass unit	123.80±1.80
S/mass unit	2.76±0.19
σ_{tot}/mb	110.70±0.71

σ_{tot} is the area of the yield distribution curve

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