3.21 Projectile Dependency of Radioactivities of Spallation Products Induced in Copper

Hiroshi Yashima H. Sugita, T. Nakamura, T. Shiomi
Cyclotron and Radioisotope Center, Tohoku University, Aoba, Aramaki, Aobaku, Sendai 980-8578,Japan
e-mail:yashima@cyric.tohoku.ac.jp

Y. Uwamino
Institute of Physical and Chemical Research, Hirosawa, Wako, Saitama 351-01, Japan

A. Fukumura
National Institute of Radiological Sciences, 4-9-1, Anagawa, Inage-ku
Chiba-shi, Chiba, 263-8555, Japan

The reaction cross sections of spallation products in a Cu target by 230MeV/u C and Ne ions were obtained. Irradiation experiments were performed at HIMAC (Heavy Ion Medical Accelerator in Chiba), National Institute of Radiological Sciences. Gamma-ray spectra from activation samples were measured with a HPGe detector. From the gamma-ray spectra, we obtained the variation of reaction cross sections of Cl-38, Cr-49, Mn-55, Cu-60, Cu-61 and Co-62m in Cu sample with Cu target thickness, and compared it with the experimental data by Kim et al.. The results showed that the dependence of the cross sections to the projectile mass is very small for the same projectile energy per nucleon.

1. Introduction

Recently the high-energy and high-intensity accelerators have increasingly been used for nuclear physics, solid-state physics, radiotherapy, material damage study, and so on. Safety design consideration for the accelerator facilities requires reaction cross section data for high-energy ions to estimate the radioactivities induced in the accelerator components and in the shielding materials. We therefore irradiated 230MeV/nucleon C and Ne ions onto a Cu target, and investigated the projectile dependency of induced radioactivities of spallation products.

2. Experiment and Analysis

Irradiation experiments were performed at HIMAC (Heavy Ion Medical Accelerator in Chiba), National Institute of Radiological Sciences. A schematic view of the experimental set-up is shown in Fig.1. The Cu target was composed of a stack of 100mm×100mm×5mm Cu plates, and C, Al, Cr, Fe, Ni, Cu, Pb samples were inserted between the Cu plates. The thickness of Cu target is longer than the flight path of the projectile beam. The flight path of the projectile beam calculated by the SPAR code [1] is 10.5mm for 230MeV/u Ne and 17.4mm for 230MeV/u C. After irradiation, we measured the gamma-ray spectra from samples with a HPGe detector. Fig.2 shows a schematic view of the gamma-ray detection system. The reaction rates of radionuclides produced in samples which were identified from the gamma-ray spectra and the decay curves were estimated after being corrected for the peak efficiency of the HPGe detector and the coincidence-summing effect.

3. Results and Discussions

From the reaction rates, we obtained the reaction cross sections of Cl-38, Cr-49, Mn-56 Cu-60, Cu-61 and Co-62m in a Cu target by 230 MeV/u Ne and C ions. The results were compared with the data for 290, 400MeV/u C and 400MeV/u Ne ions by Kim [2].

Fig.3 shows the variation of reaction cross sections of Cl-38 produced in the Cu sample with Cu target thickness. In Fig.3, the reaction cross sections of Cl-38 are almost constant down to the beam flight path and rapidly decrease beyond it. The reaction cross sections of Cl-38 produced by 230MeV/u C and Ne ions are almost equal each other. Since the mass number difference between Cu and Cl-38 is large, Cl-38 is almost produced by a primary projectile beam. But, for 400MeV/u C and Ne ions, the cross sections by Ne ions are about 40% higher than those by C ions, which implies some contribution of secondary particles to the production of Cl-38.

Fig.4 shows the variation of reaction cross sections of Cr-49 produced in the Cu sample with Cu target thickness. In Fig.4, the reaction cross sections of Cr-49 increase down to the beam flight path and decrease beyond it. Since the mass number of Cr-49 becomes closer to Cu than that of Cl-38, the fraction of Cr-49 produced by secondary particles increases, but the projectile dependence of the reaction cross sections is very small for the same projectile energy per nucleon.

Figs.5 to 8 show the variation of reaction cross sections of Mn-56,Cu-60,Cu-61,Co-62m produced in the Cu sample with Cu target thickness, respectively. In these figures, the reaction cross sections of these nuclides show the similar tendency as that of Cr-49 although the cross section increase with the target thickness is much higher for lighter mass products .

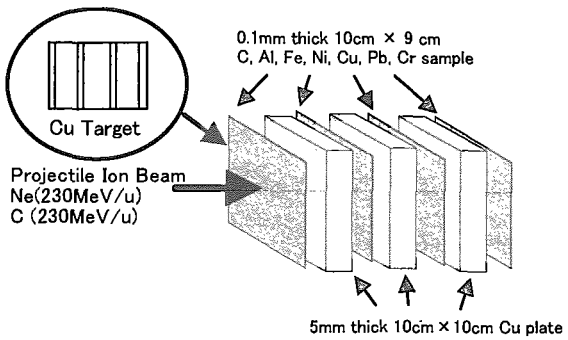

Fig.1 Schematic view of the experimental geometry.

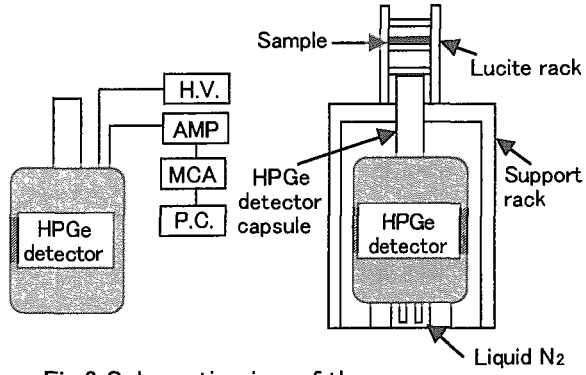

Fig.2 Schematic view of the gamma-ray detection system

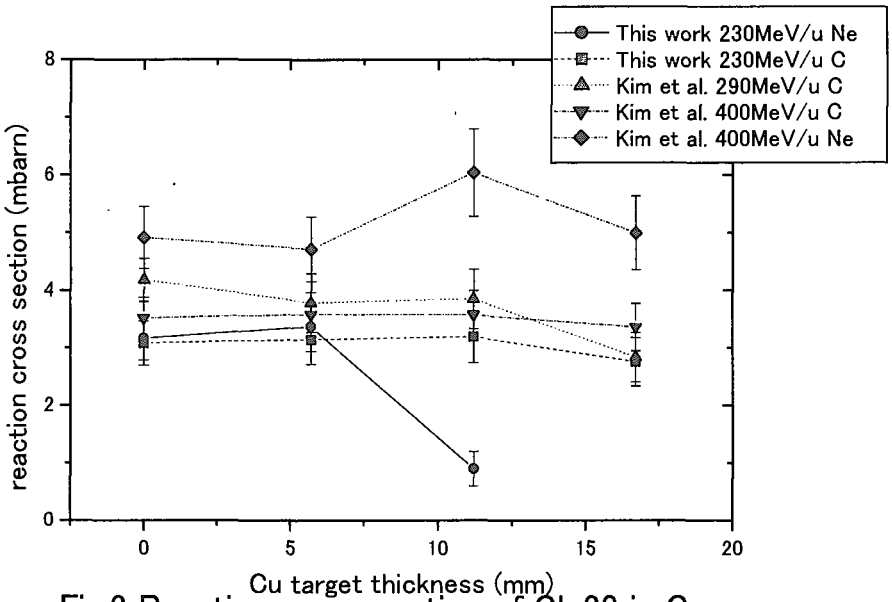

Fig.3 Reaction cross section of Cl-38 in Copper

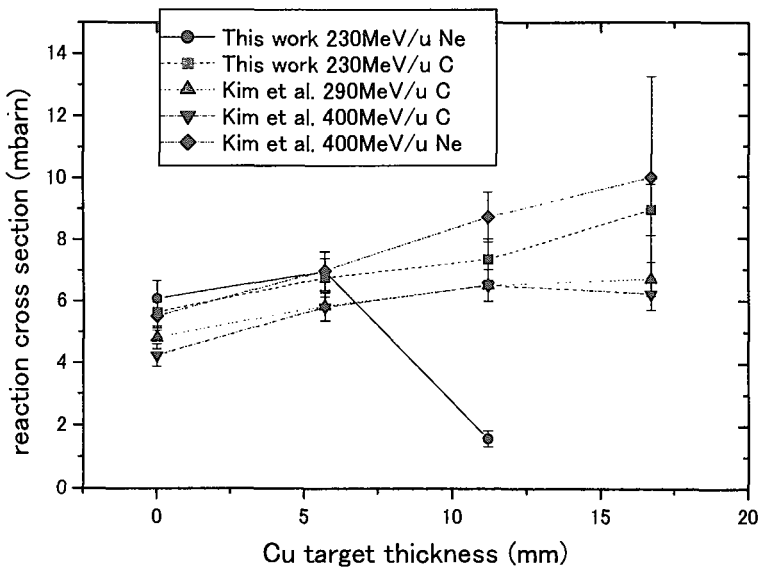

Fig.4 Reaction cross section of Cr-49 in Copper

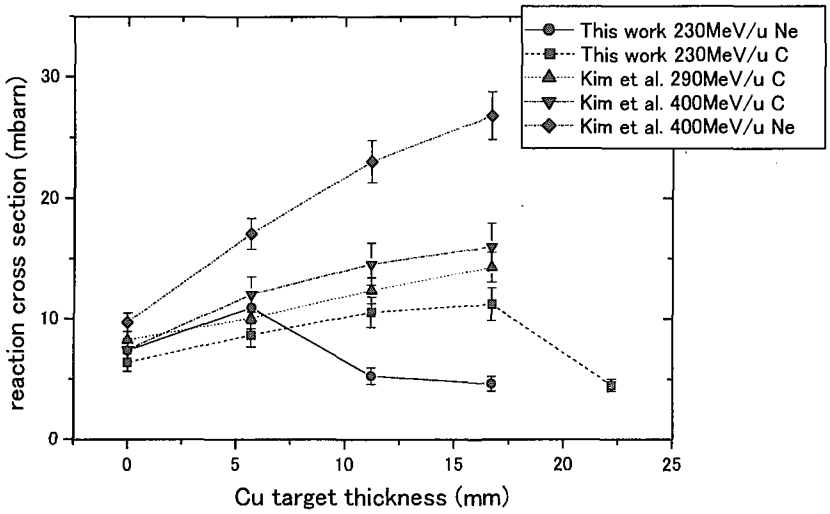

Fig.5 Reaction cross section of Mn-56 in Copper

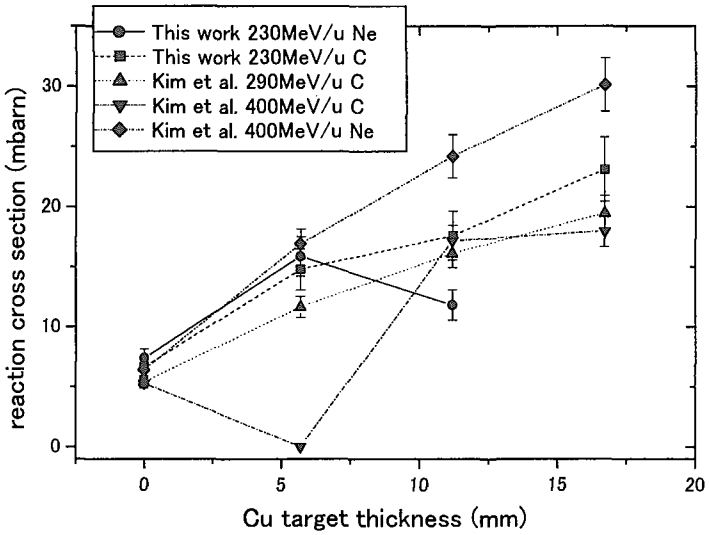

Fig.6 Reaction cross section of Cu-60 in Copper

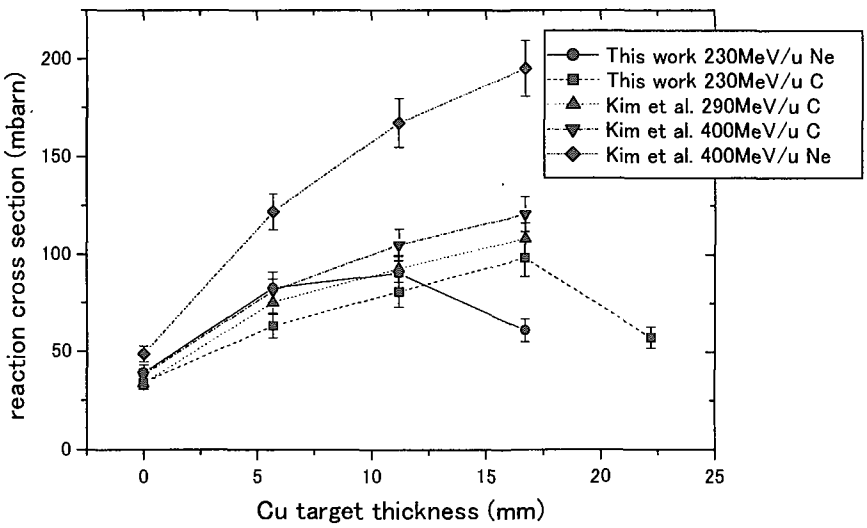

Fig.7 Reaction cross section of Cu-61 in Copper

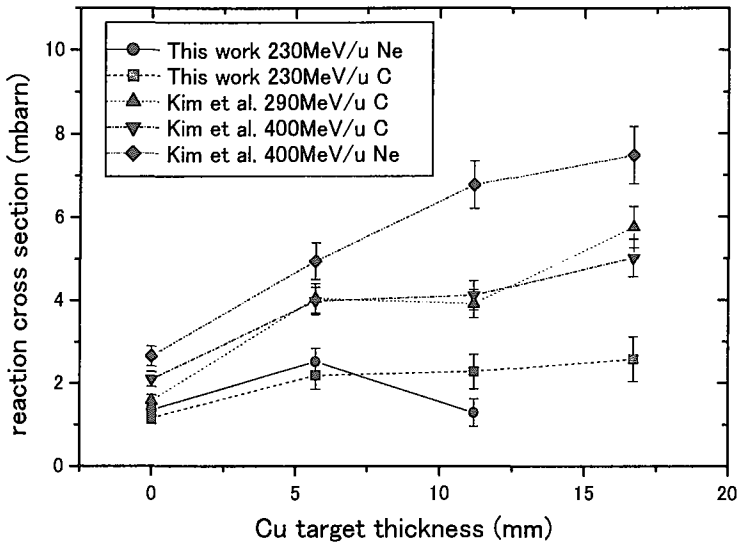

Fig.8 Reaction cross section of Co-62m in Copper

4.Conclusion

We performed the irradiation experiments by 230MeV/u Ne and C ions, and obtained the variation of reaction cross sections of nuclides produced in Cu sample with Cu target thickness. It was found that these cross sections have little dependence to the projectile mass having the same energy per nucleon. We are now analyzing the induced radioactivities produced in other samples.

Acknowledgments

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References

[1] T. Nakane, Nucl. Phys., A491, 130 (1989).

[2] E. Kim, Doctor Thesis, Tohoku University, Faculty of Engineering, Department of Quantum Science and Energy Engineering, March, 1999 (in Japanese)