Measurement of barrier distribution for ^{50}Ti,^{51}V+^{248}Cm, and ^{51}V+^{208}Pb reactions

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Barrier distribution[1–3)] in a heavy-ion induced fusion reaction yields information about the nucleus-nucleus interaction for the synthesis of heavy-nuclides, especially the capture process. Comprehensive studies on the barrier distribution, which is derived from taking the first derivative of the quasi elastic(QE) cross-section relative to the Rutherford scattering cross section, have always been performed for several heavier reactions.[4,5)] Toward future research for new super-heavy elements, in this work, the QE cross-section in reactions of ^{50}Ti, ^{51}V+^{248}Cm and ^{51}V+^{208}Pb were investigated to understand these fusion mechanisms.

The projectiles of ^{50}Ti with a charge state of 11^+ and ^{51}V charge state of 11^+ were supplied by the RILAC. These ions were extracted from the 18-GHz ECR ion source. A ^{248}Cm$_2$O$_3$ target with a thickness of 210 μg/cm^2 was prepared by electrodeposition onto a titanium backing foil of 0.9 mg/cm^2. A ^{208}Pb target of 400 μg/cm^2 was prepared by vacuum evaporation on a 60 μg/cm^2 carbon foil. The beam energies for the ^{50}Ti+^{248}Cm, ^{51}V+^{248}Cm and ^{51}V+^{208}Pb measurements were 193 to 241 MeV, 194 to 247 MeV, and 176 to 224 MeV, respectively. The energy loss of the beam in the target was about 1 MeV. The excitation functions were obtained for steps of 2 MeV in the center-of-mass energy. The beam dose was monitored by measuring the Rutherford scattered projectiles using a Si detector mounted at 45° with respect to the beam axis. Target nuclides, which were recoiled out of the target by the backward scattering (s-wave scattering), were separated in-flight from projectiles and other charged-particles using a gas-filled recoil ion separator GARIS and guided to a focal plane detection system.[6)] Then, the target nuclides were clearly identified by measuring the time-of-flight and kinetic energy of the recoils.

The normalized QE cross sections for the ^{51}V+^{208}Pb reaction were obtained by assuming the ratio of the differential cross section of the QE to the Rutherford scattering cross section ($(\mathrm{d}\sigma/\mathrm{d}\Omega)_{QE}/(\mathrm{d}\sigma/\mathrm{d}\Omega)_R$) to be one at sufficiently low energy, which is shown in Fig. 1(a). The barrier distribution obtained by differentiating with respect to energy is shown in Fig. 1(b). Comparison of the measured data with an optical potential calculation only (dashed lines) and a coupled channel calculation (solid lines) using CCFULL software[7)] are shown in both figures. It was found that the data points are well reproduced when the coupling effects of the first and second excited state of ^{208}Pb and the second excited state of ^{51}V are considered in the calculation, so excited states contributed to these reactions.

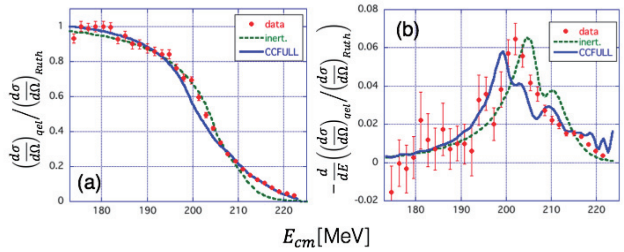

Fig. 1. Normalized quasi-elastic cross section and barrier distribution of the ^{51}V+^{208}Pb reaction.

The QE cross sections of the ^{50}Ti+^{248}Cm and ^{51}V+^{248}Cm reactions are shown in Figs. 2(a) and (b), respectively. Unfortunately, we could not measure the data in energy higher than 5.8 MeV/nucleon because of the lack of acceleration voltage of RILAC. In both figures, the calculations of the optical model and the coupled channel including the coupling effects of the excited state of the target and projectiles are also given as dashed and solid lines, respectively. However, we cannot yet discuss the channel effect as nuclear deformation and excitation. Data with higher beam energies are necessary for further discussion.

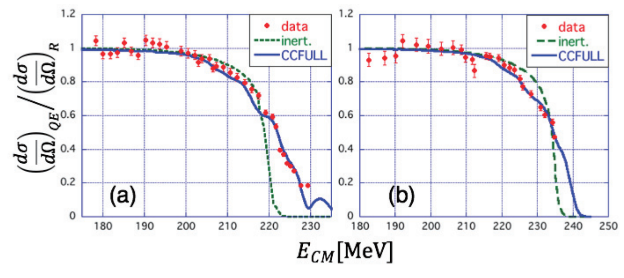

Fig. 2. Normalized quasi-elastic cross section of the ^{50}Ti+^{248}Cm (a) and ^{51}V+^{248}Cm (b) reactions.

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