Charge-changing cross sections for $^{42-51}$Ca and effect of charged-particle evaporation induced by neutron removal reactions[†]

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The point-proton radius r_{p} of an atomic nucleus is generally determined by optical isotope shift and muonic X-ray measurements. However, these experimental methods are limited to certain elements. Alternatively, "alternative methods, particularly for unstable nuclei, have been proposed to overcome this limitation, such as electron scattering using SCRIT at RIBF."[1)] A charge-changing cross-section σ_{CC} is one of the possible quantities to extract the r_{p} of unstable nuclei. Recently, the σ_{CC} measurement has been utilized to extract the r_{p} of light-mass nuclei.[2,3)] However, some σ_{CC} data for medium-mass nuclides around Ca deviate from the Glauber-like models adopted in previous studies.[4)]

To clarify the relationship between σ_{CC} and r_{p}, σ_{CC} on ^{12}C for $^{42-51}$Ca at around 280 MeV/nucleon was measured at RIBF. The present data are shown in Fig. 1. For comparison, the Glauber-like calculation adopted in previous studies[2–4)] was performed using the existing r_{p} value[4)] as an input. The calculated values ($\tilde{\sigma}_{\mathrm{CC}}$: black dashed line), which reflect the trend of experimental r_{p},[5)] show a significant discrepancy from the experimental values of stable nuclei around ^{42}Ca.

This discrepancy was found to correlate with the proton separation energy. From this figure, the cross-section of the charged-particle evaporation induced by the neutron removal, σ_{evap}, was introduced based on the abrasion-ablation scheme in addition to $\tilde{\sigma}_{\mathrm{CC}}$. The calculated values of $\tilde{\sigma}_{\mathrm{CC}} + \sigma_{\mathrm{evap}}$ (solid red line) reproduced well in the experimental data. This calculation also systematically explained the existing σ_{CC} data for other isotopic chains from C to Fe with a standard deviation of 1.6%.

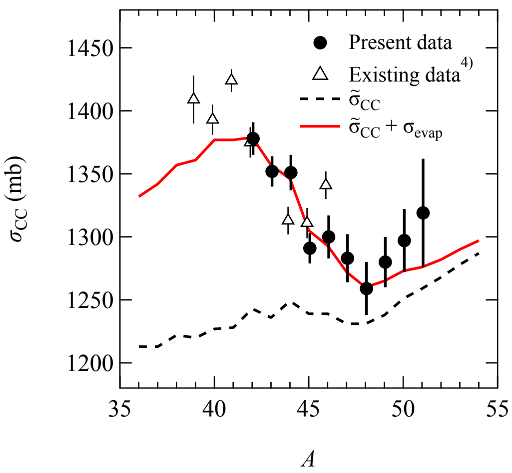

Fig. 1. Mass number (A) dependence of σ_{CC} for Ca isotopes on ^{12}C at 280 MeV/nucleon.

Figure 1 also shows that the effect of σ_{evap} becomes negligibly small in the neutron-rich region. It was found that a 1% accuracy of σ_{CC} has the potential to determine r_{p} with 0.9% accuracy in neutron-rich Ca isotopes ($A \geq 51$).

References
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