Nuclear data study for the development of transmutation technology

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Nuclear transmutation is a promising technology for the disposal of nuclear waste with high-level radioactivity. High-level radioactive waste includes the minor actinides (MA), with $Z > 89$, and long-lived fission products (LLFP). For the reduction of MA, the accelerator-driven system (ADS) has been studied globally, e.g. J-PARC[1)] plans to establish an ADS test facility. However, an effective procedure to reduce LLFP has not been found yet. A major hurdle to development is the lack of reaction data for LLFP, especially for reactions induced by a charged particle. The demands for this data is high, although experiments with a LLFP target have difficulties related to the high radioactivity and chemical instability.

Recent progress at the radioisotope beam facility allows us to utilize LLFP nuclei as the beam. Experiments for the LLFP reaction data with inverse kinematics are performed.[2)] Activities of our data centre for the transmutation study are to accumulate related data, to distribute them to the public, and to estimate the physical quantities, through the followings:

- Developing a new data format
- Thick-target yield (TTY) for the transmutation
- Excitation function of the interaction cross section

The new data format is represented in XML which is both human- and machine-readable.[3)] We are confirming its availabilities to store and to search data, including previous one. The labelling of data is key for an effective data format. Figure 1 shows the format under development. The outline of the format is almost

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Fig. 1. The parts of data labelled in the Bibliography.

completed, although there are practical problems, e.g. the expression of the reaction formula for inverse kinematics. The detailed rules will be determined in the near future.

The TTY strongly depends on the matter properties, but might be useful data for nuclear engineering, although the cross section is the most fundamental information. To avoid an experiment with the radioactive target directly, we have suggested a conversion method between the TTYs of the original reaction system and the inverse kinematics system.[4)] The method is based on the common cross section between these systems and the energy dissipations of the projectile which can be described by the stopping power due to the target matter properties. The conversion coefficient depends on the incident energy of the projectile, but we found that it can be replaced by a constant value in a high energy region. The method is applied to more specific systems considering the kinds of projectile and energy, using the PHITS[5)] simulation.

The excitation function of the cross section has significance for nuclear structure (e.g. radius) and for the quantity reflected with matter properties (e.g. TTY). To measure the excitation function, we propose a simple method, which is the thick-target transmission (T3) method.[6)] The basic concept of the method is the extension of the ordinary transmission method to that with a thick target. In the T3 method, the target has also the role of beam moderator and its thickness corresponds to the energy of the incident particle. While adding a thin target Δx to the target, we count the number $I(x)$ of projectile passed through the target at each thickness x, and can calculate the interaction cross section, $\sigma_{\mathrm{Int.}}(x)$, from the beam attenuation;

$$\sigma_{\mathrm{Int.}}(x) \propto -\frac{1}{\Delta x}\ln\frac{I(x+\Delta x)}{I(x)}. \tag{1}$$

If the LLFP beams can be chosen in the T3 method, the $\sigma_{\mathrm{Int.}}(x)$ corresponds to the cross section of transmutation. The availability of the T3 method might be decided from the competition between efforts to change the thickness and beam energy.

We report the activities for the nuclear data study of transmutation, and will carry out them with the cooperation among nuclear data, theorists and experimentalists.

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References

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