Low energy Li+p,d reactions in liquid plasmas and the effect of liquefied Li$^+$ ions on the screening potential

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Low energy nuclear reactions play a most important role in nuclear synthesis in stellar environments. In a laboratory experiment at present, however, it is impossible to observe nuclear reactions directly in such high density ($\rho$) plasmas as $\rho > 10^{25}/\text{cm}^3$, where the environments affect the reaction rates strongly. To approach this problem, we have studied nuclear reactions at very low energies with target nuclei in liquid metal plasmas, for the first time, where much higher density ($\rho \sim 10^{22}/\text{cm}^3$) than laboratory gas plasmas can be realized.

In this work, we compare the Li+p and Li+d reactions in a liquid phase with those in a solid phase. In the solid phase, Li$^+$ ions are sitting periodically on the fixed sites and are surrounded by conduction electrons. In the liquid phase, on the other hand, the Li$^+$ ions can move almost freely in a sea of the conduction electrons. Thus, the reaction in the liquid metal can be regarded as the nuclear reaction in plasmas consisting of positive ions and conduction electrons.

The experiments were performed by using proton and deuteron beams obtained from a low-energy ion generator at Laboratory of Nuclear Science at Tohoku University. A technique to generate the liquid Li metal target has been developed. A lump of natural Li or enriched $^6\text{Li}$ metal was placed horizontally on a small saucer which can be heated up to 500 °C in a vacuum chamber. The temperature of the surface of the Li metal was monitored directly by a radiation thermometer. The melting point of the Li metal is about 180 °C; a phase change was easily known by watching the temperature. A beam was injected from the upper part of the chamber, with its angle of 30° with respect to the vertical line. Alpha particles emitted in the $^6\text{Li}(d,\alpha)^4\text{He}$ and $^7\text{Li}(p,\alpha)^4\text{He}$ reactions were measured with Si detectors.

Thick target yields of $\alpha$ particles were measured for the solid (T$\sim$60 °C) and the liquid (T$\sim$250 °C) Li as a function of bombarding energy. Observed excitation functions show clear difference for the liquid and the solid: reaction rates for the liquid Li are always larger than those for the solid. This suggests that the stopping power of hydrogen ion in the liquid Li metal might be much smaller than in the solid. Although the analyses are in a preliminary stage, the screening potentials of the Li+p and Li+d reactions are deduced. The deduced screening potential for the liquid Li is much larger than for the solid, at least by 200 eV. This suggests that the liquefied Li$^+$ ions contribute very much to reduce the Coulomb barrier between the Li nucleus and the projectile as well as bound and conduction electrons. The effect of the liquid plasmas on the screening potential will be discussed.