

Latest Results with Coulomb Dissociation Techniques

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Stellar nuclear-burning may involve short-lived nuclei, if capture reactions on certain nuclei become faster than their weak decays. Such situation occurs predominantly in “explosive” conditions where the temperature and density are high. Even in non-explosive situations as in the hydrogen burning in the sun, unstable nuclei are sometimes important. These capture processes are, however, difficult to study in laboratory experiments, especially when the nucleus is short-lived and is difficult to be served as a target. An alternate possibility is to use radioactive ion (RI) beams. Direct measurements of the reaction cross sections can be performed by using a low-energy beam of the nucleus of interest. Another possibility is to determine the cross sections indirectly by a nuclear reaction such as, the resonant scattering, transfer reaction, and Coulomb dissociation.

Recently, indirect methods using intermediate-energy beams of unstable nuclei have been developed. Compared with ordinary beams of stable particles, the quality of RI beams is generally very poor: i) The intensity is typically as low as 10^4 pps. ii) The beam emittance is large. Therefore, we have to develop new efficient tools: reactions with large cross sections and experimental setups with high efficiency. Efforts to overcome the poor quality of the beams should also be made to resolve the final states of the reaction.

The most successful indirect-method employs the Coulomb dissociation mechanism. A nucleus “X” disintegrates to its constituents “Y” and “a” in the strong Coulomb field formed during the collision with a high- Z target nucleus. This process is regarded as absorption of virtual photons created in the fast collision, and hence can be related to its inverse process $Y+a \rightarrow X+\gamma$. Its cross section is large at low a-Y relative energies, which are effective for nuclear burning in astrophysical sites.

The $^{13}\text{N}(p,\gamma)^{14}\text{O}$ reaction is the first example studied by the Coulomb dissociation method with RI beams. The reaction is the key to ignite the hot CNO cycle nuclear burning instead of the regular CNO cycle. The experiment was performed at RIKEN and GANIL, and the electromagnetic width Γ_γ of the 1^- resonance in ^{14}O , which dominates in the hot CNO burning, has been successfully extracted. The Coulomb dissociation method was then applied to the reaction $^7\text{Be}(p,\gamma)^8\text{B}$, which is the source of high-energy solar neutrino observed in terrestrial measurements. The results obtained at RIKEN, GSI and MSU are compared with direct measurements, and provide independent support to the cross section relevant to the solar-neutrino problem. More detailed studies on the reaction mechanism, however, is now desirable, because recent solar-neutrino measurements require more accurate determination of the $^7\text{Be}(p,\gamma)^8\text{B}$ cross sections at low energies.

Further applications of the method to explosive hydrogen burning processes have been made. Coulomb dissociation experiments with RI beams of ^9C , ^{12}N , ^{13}O , ^{23}Al , and ^{27}P have been performed to determine the relevant (p,γ) reaction rates. These reactions are involved in early-generation super-massive stars or novae. Neutron capture processes can also be studied by the Coulomb dissociation method. For example, the (n,γ) reactions on ^{14}C and ^{18}C have been studied.