Recent results in nuclear astrophysics using radioactive fluorine beams at the HRIBF*

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Nuclear reactions involving proton-rich radioactive isotopes of oxygen (^{14,15}O) and fluorine (^{17,18}F) are of crucial importance in stellar explosions such as novae and X-ray bursts. Despite numerous studies using stable beams (see for example [1,2] and references therein) and radioactive ion beams [3-5], substantial uncertainties have persisted in many key reaction rates. Measurements using beams of ^{17}F ($t_{1/2}$ = 64 s) and ^{18}F ($t_{1/2}$ = 1.8 h) at ORNL's Holifield Radioactive Ion Beam Facility (HRIBF) have resolved important uncertainties in several reactions and have put some crucial rates on firm experimental footing for the first time. These results will be presented, focusing on recent measurements that are important for understanding the ^{14}O(α,p)^{17}F and ^{18}F(p,α)^{15}O reaction rates.

Substantial quantities of the ^{14}O isotope ($t_{1/2}$ = 71 s) are accumulated in novae and X-ray bursts resulting from two successive proton captures on ^{12}C. Further hydrogen captures are inhibited because ^{15}F is proton unstable, and ^{14}O may be burned only by the ^{14}O(α,p)^{17}F reaction. We have studied the ^{1}H(^{17}F,α)^{14}O reaction, the time-inverse of the ^{14}O(α,p)^{17}F$_{g.s.}$ reaction, using a radioactive ^{17}F beam at the HRIBF. The ^{1}H(^{17}F,α)^{14}O reaction and ^{1}H(^{17}F,p)^{17}F elastic-scattering cross sections were measured over the energy range of interest for the ^{14}O(α,p)^{17}F reaction rate ($E^{\alpha}_{cm} = 1.0 - 2.6$ MeV). Properties of states in ^{18}Ne with energies $E_x = 6.0 - 7.7$ MeV were determined, and the direct reaction cross section was measured. These measurements allow the ^{14}O(α,p)^{17}F$_{g.s.}$ reaction rate to be determined with reasonable certainty for the first time.

A beam of ^{18}F has also been used at the HRIBF to measure the ^{1}H(^{18}F,p)^{18}F [6] and ^{1}H(^{18}F,α)^{15}O excitation functions. The decay of ^{18}F provides the most intense source of potentially observable gamma rays in novae, and the amount of ^{18}F which survives the nova explosion and the gamma-ray flux is largely determined by the rate of the ^{18}F(p,α)^{15}O reaction. A resonance corresponding to a state in ^{19}Ne near E_x = 7.07 MeV may dominate the ^{18}F(p,α)^{15}O reaction rate, but discrepancies between previous measurements have resulted in as much as a factor of 3 uncertainty in the reaction rate. We have precisely determined the excitation energy and total and partial widths of this important resonance from a combined analysis of the ^{1}H(^{18}F,p)^{18}F and ^{1}H(^{18}F,α)^{15}O excitation functions measured in coincidence with a thin target, resolving the discrepancy among previous measurements.

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