The impact of ^{17}O+α reaction rate uncertainties on the s-process in rotating massive stars

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Half of the elements heavier than iron were produced in the s-process. Neutrons are produced from source reactions, more importantly ^{13}C(α,n) and ^{22}Ne(α,n) and captured on seed nuclei. The neutron-capture rate is rather slower than the beta-decay rate and thus the nuclei produced during this process are close to the line of stability. In reality, "the" s-process is something of a misnomer since various different slow neutron-capture processes take place in different astrophysical locations caused by different reactions and with different characters.

A number of factors influence the elemental abundances of the elements created in the s-process. These include the amount of s-process neutron seed material (^{13}C and ^{22}Ne) available, the metallicity of the star, and the rates of various nuclear reactions both in producing the neutrons for the s-process and the capture rate for those neutrons. One important set of reactions are neutron sinks: ^{16}O captures neutrons to make ^{17}O. The ^{17}O(α,γ) reaction locks the captured neutron away, preventing additional nucleosynthesis. The ^{17}O(α,n) reaction recycles the neutrons causing additional neutron-capture reactions to take place. The ^{17}O+α reactions depend on the properties of excited states in the compound nucleus, ^{21}Ne. To investigate the spectroscopic properties of these states, we used the ^{20}Ne(d,p)^{21}Ne reaction with the TUNL Split-Pole (Enge) spectrograph. A focal-plane spectrum showing excited states in ^{21}Ne is shown in Fig. 1. Using this reaction, we measured excitation energies and assigned spins and parities, and neutron widths to excited states in ^{21}Ne and recomputed the ^{17}O+α reaction rates. We found that the neutron recycling of the ^{17}O+α reactions is stronger than predicted by previous rate estimates, and that the s-process in rotating metal-poor stars can potentially make elements up to at least barium (Z=56). This work has been published in Monthly Notices of the Royal Astronomical Society[1]. Another paper is in preparation reporting on states in ^{21}Ne below the α-particle threshold which may be interesting for nuclear structure.

[1] J. Frost-Schenk *et al.* MNRAS 514 2650 (2022)

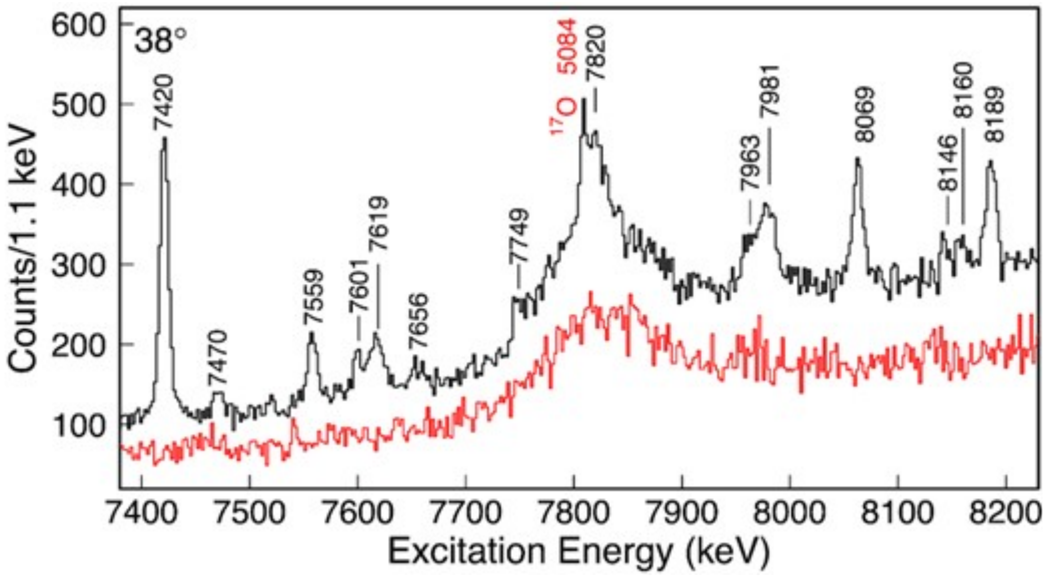

Fig. 1. The focal-plane excitation-energy spectrum for the ^{20}Ne(d,p)^{21}Ne reaction. The black spectrum shows the results from the neon-implanted carbon target and the red spectrum is that for only the carbon backing.

An additional experiment studying the ^{20}Ne(d,p) reaction using the HELIOS spectrometer at Argonne National Laboratory was performed in inverse kinematics. The resulting data will be published in another forthcoming paper.