Measurement of the ^{32}S(p,d)^{31}S Reaction and its Astrophysical Implications

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The ^{30}P(p,γ)^{31}S reaction plays a crucial role in the synthesis of heavier nuclear species, from Si to Ca, in nova outbursts on ONe White Dwarfs . However, its rate is very uncertain as a result of the lack of spectroscopic information on the levels above proton threshold in ^{31}S. The currently adopted rate of this reaction, based on statistical Hauser-Feshbach calculations , could have an uncertainty as much as a factor of 100 higher or lower under nova conditions.

To reduce these uncertainties, we have measured differential cross sections for the ^{32}S(p,d)^{31}S reaction and determined excitation energies for states in ^{31}S. A total of 26 states in ^{31}S were observed, including 17 above the proton threshold. Five new states were observed. Uncertainties in the excitation energies of states in the high energy region were significantly reduced. Spin and parity values were determined or constrained for 15 of the strongly populated levels through a distorted wave Born approximation (DWBA) analysis of the angular distributions, of which 6 were made for the first time.

A new ^{30}P(p,γ)^{31}S reaction rate was calculated utilizing the present experimental spectroscopic information. We confirmed the spin-parity assignment of $1/2^+$ for the state at 6263 keV which dominates the ^{30}P(p,γ)^{31}S reaction rate at lower temperatures in nova, while the state at 6544 keV dominates at temperatures above 0.2 GK. Our results indicate that the ^{30}P(p,γ)^{31}S rate based on our resonance calculations is reduced by up to a factor of 10 at nova temperatures compared to the previous rate.

Nova element synthesis calculations using the new ^{30}P(p,γ)^{31}S reaction rate were performed, and predictions of isotopic abundance patterns were obtained. Production of elements in the Si-Ca mass region are found to be altered by as much as 40% using the new rate. Important isotopic ratios such as ^{12}C/^{13}C, ^{14}N/^{15}N and ^{26}Al/^{27}Al are found to agree well with observations on presolar grains thought to have a nova origin . Of special interest are the close-to-solar ^{29}Si/^{28}Si ratio and large excess in ^{30}Si/^{28}Si found in our simulations, which are the most important features pointing to a nova origin of such grains.

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