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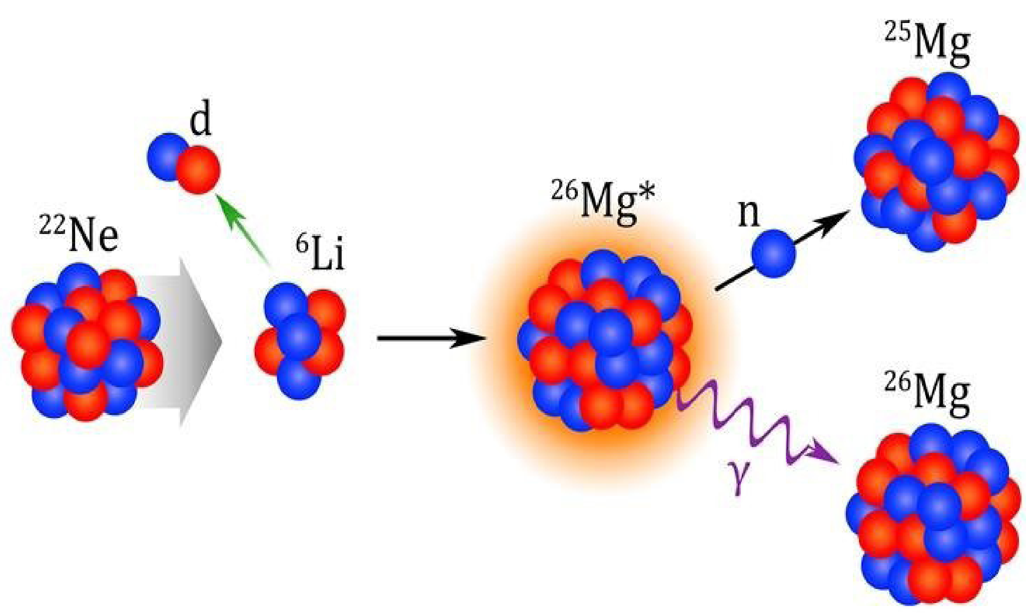
Scientists Further Their Investigation into the Origin of Elements in the Universe

New experimental data on a key nuclear reaction with a major role in producing nearly half the universe's chemical elements

THE SCIENCE
The slow neutron-capture process (the s-process) is one of the nucleosynthesis processes that occurs in stars. It results in about half of the elements heavier than iron in the universe. Two important reactions involved in the s-process are Neon-22 (alpha, gamma) and Neon-22 (alpha, neutron). In these reactions, neutron-rich Neon-22 captures alpha-particles. The capture produces Magnesium-26 in an excited state, meaning it has received extra energy. It then releases energy by emitting either a gamma ray, leading to Magnesium-26 in a normal state, or a neutron, leading to Magnesium-25. The rates of the Neon-22 (alpha, gamma) and Neon-22 (alpha, neutron) reactions have significant effects on the s-process, affecting abundances of elements like selenium, krypton, rubidium, strontium, and zirconium.

THE IMPACT
Scientists are trying to answer the question, what is the origin of elements in the universe? The answer is extremely complex, requiring a collaborative effort by researchers in many fields and an enormous amount of experimental data. One part of answering this question is understanding the specific processes that create elements heavier than iron. Some of these elements form through particular nuclear reactions inside stars involving neutron captures (s-process). Neutrons are unstable and need to be produced continuously to fuel this process. Determining the intensities of neutron source reactions is important to better understanding this nucleosynthesis scenario.

SUMMARY
Two reactions have a strong influence on the neutron flux during the s-process, ^{22}Ne(α,γ)^{26}Mg and ^{22}Ne(α,n)^{25}Mg. The probabilities of these reactions occurring are difficult to measure directly because these probabilities (called reaction cross sections) are extremely low at the energies relevant for stellar nucleosynthesis. A team of nuclear physicists used two indirect methods to determine the probabilities for both reactions. Both methods used a Neon-22 beam produced at the Texas A&M University Cyclotron Institute. In one study, the team measured the likelihood for the most relevant excited states in 26-Magnesium to decay by alpha-particles. The other experiment involved direct measurements of neutron/gamma branching ratios for the same excited states. Combining these studies led researchers to a consistent conclusion: that the actual probability of the ^{22}Ne(α, n)^{25}Mg reaction occurring is lower than the widely accepted probability by a factor of three. This finding significantly changes the final s-process abundances of some elements, including selenium, krypton, rubidium, strontium, and zirconium.



An isotope of Neon (^{22}Ne) captures an alpha-particle (α) to create Magnesium-26 (^{26}Mg) in an excited state. The excited Magnesium-26 then releases energy by emitting a gamma ray (γ), leading to Magnesium-26 or a neutron, leading to Magnesium-25 (^{25}Mg).

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PUBLICATIONS
Jayatissa, H., et al. "Constraining the ^{22}Ne(α,γ)^{26}Mg and ^{22}Ne(α,n)^{25}Mg reaction rates using sub-Coulomb α-transfer reactions," Physics Letters B 802, 135267 (2020).

Ota, S. et al. "Decay properties of ^{22}Ne + α resonances and their impact on s-process nucleosynthesis," Physics Letters B 802, 135256 (2020).

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ABOUT THE CYCLOTRON INSTITUTE: *Dedicated in 1967, the Cyclotron Institute serves as the core of Texas A&M University's accelerator-based nuclear science and technology program. Affiliated faculty members from the Department of Chemistry and the Department of Physics and Astronomy conduct nuclear physics- and chemistry-based research and radiation testing within a broad-based, globally recognized interdisciplinary platform supported by the United States Department of Energy (DOE) in conjunction with the State of Texas and the Welch Foundation. The facility is one of five DOE-designated Centers of Excellence and is home to one of only five K500 or larger superconducting cyclotrons worldwide.*