Evidence for p-process nucleosynthesis recorded at the solar system abundances

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The solar system abundances show some evidences for nucleosynthesis processes, for example, two abundance peaks at the neutron magic number for the s- and r-processes. The origin of the p-nuclei has long been discussed with many possible nuclear reactions. They are the rp-process in neutron stars [1], the proton-induced reactions by Galactic cosmic rays [2], the photodisintegration reactions in supernova (SN) explosions (p-process) [3,4], and the neutrino-induced reactions in SN explosions (ν-process) [5].
We ~~here~~ present an evidence for the origin of the p-nuclei at the solar system abundances [6]. There are twenty-two p-nuclei associated with almost pure s-nuclei that have two more neutrons than the p-nuclei. The pure s-nuclei are dominantly synthesized by the s-process. Taking the abundance ratios of the s-nucleus to the p-nucleus, N(s)/N(p), where N is each isotope abundance, we find a clear correlation between them. The ratios concentrate at a constant value of N(s)/N(p) $\approx$ 23 in a wide range of the atomic number. Furthermore, we find another scaling rule between two pure p-nuclei with the same atomic number. Nine nuclear species have two pure p-nuclei, in which the second p-nucleus is two neutron-deficient to the first p-nucleus. The ratios concentrate at a constant value of N(1st p)/N(2nd p) $\approx$ 1.
The first scaling shows a strong correlation between p- and s-nuclei with the same atomic number. This is consistent with the previous theoretical calculations that the p-nuclei are produced by the p-process in SN explosions. The pre-existing nuclei in massive stars are affected by the s-process before SN explosion. The p-nuclei are subsequently produced from the s-nuclei by photodisintegration reactions such as (γ,n) reactions in a huge photon bath at extremely high temperatures in SN explosions. The particle induced reactions in the other processes and the charged current interaction in the ν-process change the proton number of seed nuclei. Therefore, the first scaling is a piece of evidence that the p-process is the most promising origin of the p-nuclei.
We carry out nucleosynthesis calculations of the p-process in oxygen-neon layers in typical core-collapse SN explosion models. The calculated N(s)/N(p) and N(1st p)/N(2nd p) ratios are consistent with the observed scalings. The observed scalings and calculation results indicate a novel concept: the universality of the p-process that the two ratios are almost independent on astrophysical conditions such as the metallicity and progenitor mass of the massive stars.

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