Role of β-Decays of $N=126$ Isotones in Supernova R-Process Nucleosynthesis

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The r-process is the promising nuclear process for the synthesis of about a half of heavy elements beyond iron [1,2]. Study of the r-process element synthesis has been done by considering neutrino-driven winds in supernova explosions [3] as well as ONeMg supernovae [4] and neutron-star meregers [5].

The evaluation of β-decay rates, particularly at the waiting point nuclei, is one of the important issues of the nucleosynthesis through the r-process. Investigations on the β-decays of isotones with neutron magic number of $N=82$ have been done by various methods including shell model [6], QRPA/FRDM [7] as well as CQRPA [8] etc., which lead to results consistent to one another.

For the β-decays at $N=126$ isotones, however, half-lives obtained by various calculations differ to one another [9]. First-forbidden (FF) transitions become important for these nuclei in addition to the Gamow-Teller (GT) transitions in contrast to the case of $N=82$. Beta decays of the isotones with $N=126$ are studied by shell model calculations taking into account both the Gamow- Teller (GT) and first-forbidden (FF) transitions. The FF transitions are found to be important to reduce the half-lives, by nearly twice to several times, from those by the GT contributions only as shown in Fig. 1 [1].

The present half-lives of the shell model calculations are shorter than those of the standard values of ref. [7] by 2.3 ~ 8.3 for even Z and by 1.4 ~ 2.0 for odd Z (except for $Z=71$), respectively. They increase monotonically as Z increases showing no odd-even staggering found in FRDM's. The present half-lives are longer than those of Ref. [8] by about 1.1 ~ 1.3 (1.5) for $Z=64$ ~ 67 (68) and by twice for $Z=69$ and 70, respectively.

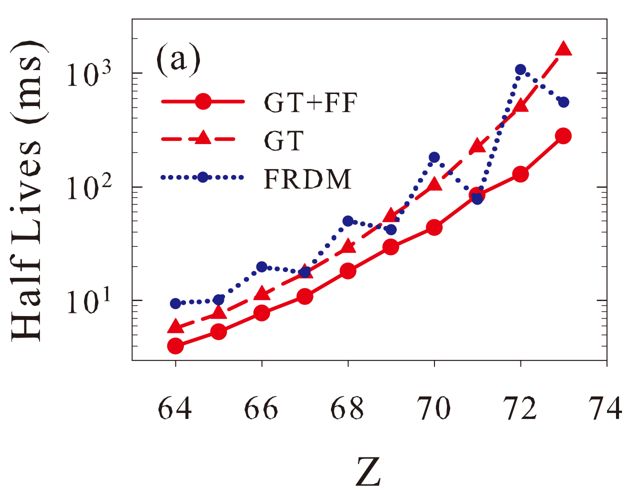

Figure 1: (a) Calculated half-lives for the $N=126$ isotones. Results of the present shell model calculations with GT and with GT+FF transitions are denoted by dashed and solid curves, respectively. Half-lives of Ref. [7] denoted as FRDM are shown by a dotted curve.

Possible implications of the short half-lives of the waiting point nuclei on the r-process nucleosynthesis during the supernova explosions are investigated. We use an analytic model for neutrino-driven winds [10] for the time evolution of thermal profiles. The third peak of the abundance of the elements in the r-process has been found to be shifted toward higher mass region as shown in Fig. 2. Although the magnitude of the shift is rather modest, it is found to be a robust effect independent of the present astrophysical conditions for the r-process as well as the quenching factors of g_A and g_V adopted in the shell model calculations [1].

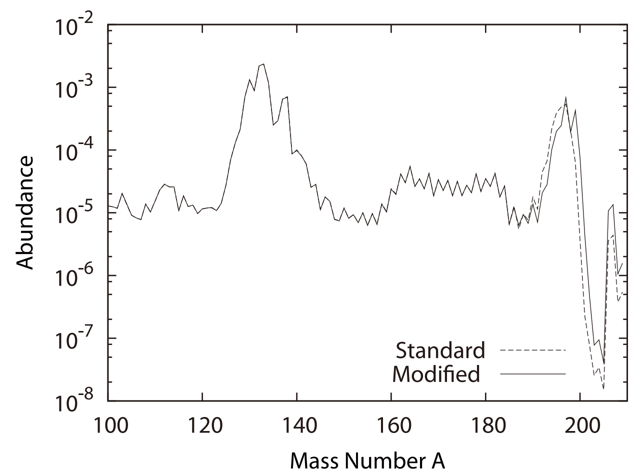

Figure 2: The abundances of elements in the r-process nucleosynthesis obtained by using the present β-decay half-lives for the $N=126$ isotones (denoted as 'modified') and standard half-lives of ref. [7] (denoted as 'standard').

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