Influence of thermally excited isomers on r-process abundances?

B. Pfeiffer[1,2] and K.-L. Kratz[1,2]

[1]Institut für Kernchemie, Universität Mainz, Germany; [2]HGF VISTARS

The influence of nuclear physics input as well as astrophysical parameters on the abundances of r-process nucleosynthesis can be studied systematically within the "waiting-point" concept [1]. Calculations applying theoretical nuclear masses and $T_{1/2}$ and P_n values from the FRDM or the ETFSI-Q mass models allow a satisfactory reproduction of the global isotopic abundances ($N_{r,\odot}$). Nevertheless, there still exist deviations in limited mass regions as the left wing of the A≃130 peak (see black line in Fig. 1). Even replacing the theoretical values with experimental ones (as far as available) does not solve the problem (see Ref. [3]).

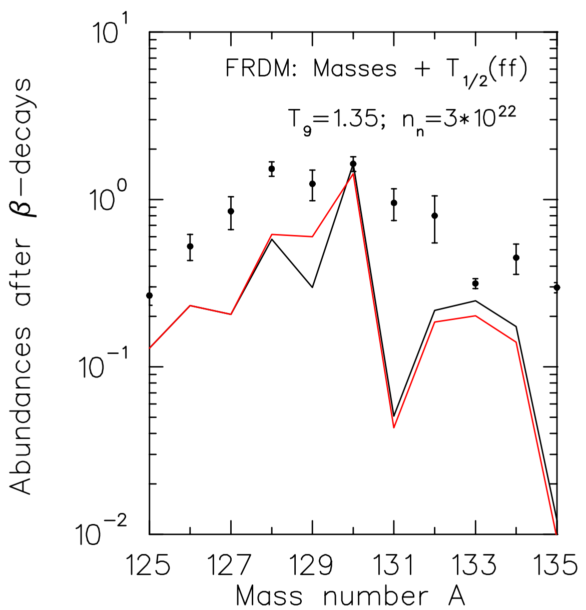

Figure 1: Solar r-process abundances calculated with masses and half-lives from the FRDM mass model [2]. The half-life of ^{129}Ag is either taken as the $\pi g_{9/2}$ g.-s. [black line] or as $T_{1/2}$=180 ms [red line] (see text).

As the abundances are proportional to the half-lives of the precursor nuclei in the r-process boulevard, longer half-lives for the N=82 nuclei with Z≤47 could be a solution. The r-process nucleosynthesis takes place in a heat bath with temperatures in access of 1 T_9. In the case of ^{129}Ag we have observed indications to the existence of an isomeric β-decaying $\pi p_{1/2}$ state with $T_{1/2}$=160 ms in addition to the $\pi g_{9/2}$ ground-state (g.-s.) decay with $T_{1/2}$=46 ms [4]. The excitation energy of the isomeric state is not known experimentally. QRPA calculations yield 500 keV. The stellar half-life of ^{129}Ag is shown in Fig. 2 as a function of the equilibrium temperature in units of 10^9 K (T_9). At the freeze-out temperature of 1.35 T_9, the stellar half-life is only marginally enhanced due to the high excitation energy, not influencing the abundance at A=129.

If one follows the γ-decay of unbound states populated in neutron capture on ^{128}Ag under non-equilibrium conditions, about one third of the rays populate the isomeric state [5]. From this a stellar half-life of about 80 ms can be deduced, much longer than in the case of the thermal excitation under equilibrium condition. The isotopic abundances obtained in replacing the short g.-s. half-life of ^{129}Ag with this longer value are displayed in Fig. 1 [red line]. The abundance for A=129 is now closer to the observed value.

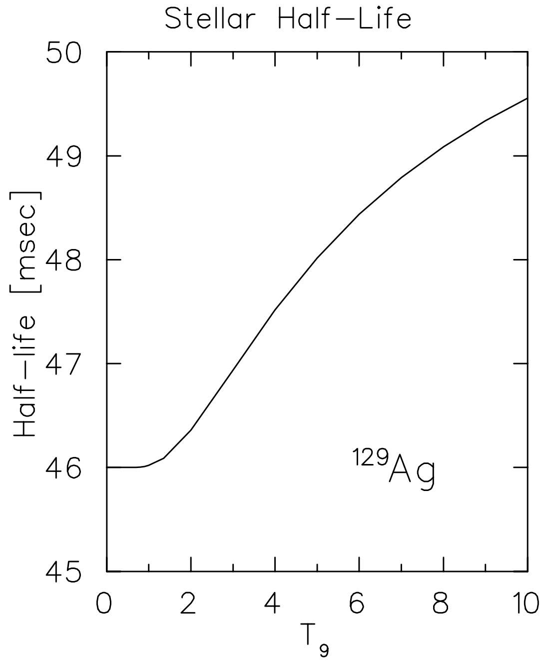

Figure 2: Stellar half-life of ^{129}Ag as a function of temperature. $T_{1/2}$ for the $\pi g_{9/2}$ g.-s. is 46 ms and 160 ms for the $\pi p_{1/2}$ β-isomeric state, respectively. The excitation energy of the isomeric state is assumed as 500 keV according to QRPA calculations.

The general solution for the calculated underabundances in the left wing of the A=130 peak has to be sought in nuclear structure different from the assumptions underlying the global mass models. Applying single-particle energies which reproduce the surprisingly high-lying 1^+ state in ^{130}Cd in Nilsson model calculations of β-decay half-lives of nuclides in the left wing, longer half-lives were obtained [3].

References

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