R-process chronometers - I

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R-process calculations require nuclear-physics input data of unstable nuclei, which are in general not available from experiment. Hence, far reaching theoretical extrapolations are needed, which affect the calculated initial production ratios for r-process chronometric nuclei. Recent observations of the main third-peak platinum-group elements (Os, Ir, Pt) as well as U allow to replace the Th/Eu chronometer pair by abundance ratios of elements with smaller difference in atomic number. This is particularly true for the radioactive Th/U pair, where, in addition, a quite sensitive consistency check for the calculated "initial" abundances of these actinides can be given by a successful reproduction of the observed Pb and Bi r-abundances, which originate to more than 80% from α-decay of the Th and U isotopes.

We have performed r-abundance calculations assuming two different seed compositions,

- (i) the classical Fe-seed, and
- (ii) an A≅90 seed beyond N=50 (here denoted "Zr-seed").

The latter simulates the possible r-process seed composition after the α-rich freeze-out of the high-entropy wind scenario of a core-collapse SNII [4]. Table 1 compares the Solar System r-process "residuals" ($N_{r,\odot} \cong N_{\odot} - N_{s,\odot}$) [1,2] for the Pb and Bi isotopes with our theoretical predictions [5]. It is clear from this table, that - at least within our present r-process model parameterization - we consistently obtain Pb and Bi abundances, which are lower than the old recommended solar values (used e.g. in [1]), but agree better with the recent evaluations of Beer et al. [2] and Gallino [3]. Further progress in the understanding of r-process chronometry of Th/U may soon be obtained from the determination of Pb abundances in UMP Halo stars with the Hubble Space Telescope.

References:

[1] J.J. Cowan et al., ApJ 521 (1999) 194
[2] H. Beer et al., *Hadrons, Nuclei, and Applications*, World Scintific (2001) 372
[3] R. Gallino, private communication
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Table 1: Comparison of $(N_{\odot}-N_s) \simeq N_{r,\odot}$ "residuals" [1, 2, 3] of $^{206-208}$Pb and ^{209}Bi with our calculated r-abundances.

Isotope	Pb-206	Pb-207	Pb-208	Bi-209	ΣPb	ΣPb,Bi
$N_{\odot}$(s+r)	0.593	0.644	1.828	0.146	3.065	3.211
$N_{r,\odot}$						
Ref. [1]	0.240	0.254	0.158	0.144	0.652	0.766
Ref. [2]	0.178	0.171	0.133	0.101	0.482	0.583
Ref. [3]	0.178	0.116	0.091	0.118	0.385	0.503
$N_{r,calc.}$						
Ref. [1]	0.158	0.146	0.135	0.103	0.439	0.542
Fe-seed	0.163	0.151	0.138	0.111	0.452	0.564
Zr-seed	0.213	0.163	0.142	0.132	0.518	0.650