Abstract. The very-metal-poor halo star CS 31082-001 was discovered to be very strongly r-process-enhanced during the course of a VLT+UVES high-resolution follow-up of metal-poor stars identified in the HK survey of Beers & colleagues. Both the strong n-capture element enhancement and the low carbon and nitrogen content of the star (reducing the CN molecular band contamination) led to the first $^{238}$U abundance measurement in a stellar spectrum (Cayrel et al. 2001), and the opportunity to use both radioactive species $^{238}$U and $^{232}$Th for dating the progenitor to this star. However, age computations all rely on the hypothesis that the r-process pattern is solar, as this was indeed observed in the other famous r-process-enhanced very metal poor stars CS 22892-052 (Sneden et al. 1996, 2000) and in HD 115444 (Westin et al. 2000). Here, we investigate whether this hypothesis is verified also for CS 31082-001, using a preliminary analysis of over 20 abundances of n-capture elements in the range Z=38 to Z=92.

Cayrel et al. (2001; this volume) discuss the discovery and importance of CS 31082-001, and here we report a summary of a preliminary abundance analysis for this star (Table 1).

The n-capture element abundances (relative to iron, [X/Fe]) of CS 31082-001 are compared in Fig. 1-a to those of CS 22892-052 and HD 115444, showing that the overabundance of the Z>56 n-capture elements in CS 31082-001 is almost identical to that of CS 22892-052, with a mean overabundance of [X/Fe]~+1.7dex. These two stars are therefore the most extreme cases of n-capture element enhancement in halo stars, far more extreme than HD 115444. Furthermore, the abundance pattern of the 56<Z<70 elements in CS 31082-001 are indistinguishable from that of CS 22892-052 or HD 115444. In contrast, the abundance pattern of Z>70 seems to be more abundant in CS 31082-001 than
in CS 22892-052 or HD 115444, including thorium, which is a factor four more abundant in CS 31082-001 than in CS 22892-052. Therefore the log $\epsilon$(Th/Eu) ratio, often used as an age indicator, is a factor 3 larger in CS 31082-001 than in CS 22892-052.

In Fig. 1-b, the abundance pattern of the n-capture elements of CS 31082-001 are compared to solar system r-process pattern (as of Burris et al. 2000) scaled to match the mean $56 \leq Z \leq 72$ n-capture elements abundance of CS 31082-001 log $\epsilon_{CS\,31082-001} - \log \epsilon_{SS} = -1.22 \pm 0.03$ ($\sigma = 0.10$ over 13 elements). Here again, whereas the $56 < Z < 70$ elements in CS 31082-001 are very well reproduced by a solar r-process, the $Z > 70$ elements are behaving in a somewhat more erratic way. While Os and Ir seem to be more abundant than the scaled solar r-process, Pb is notably underabundant (even the strongest line at 4057 Å was not detected).

This has the very interesting consequence that the [Th/Eu] ratio (Eu or any other $56 \leq Z \leq 70$ element) would predict an epoch of formation of the n-capture elements present in CS 31082-001 later than the epoch of formation of the n-capture elements which enriched the solar system! This conflicts with
Table 1. Neutron-capture elements abundances in CS 31082-001.

| El. | Z  | log₁₀σ | N_{lines} | El. | Z  | log₁₀σ | N_{lines} |
|-----|----|---------|-----------|-----|----|---------|-----------|
| Sr  | 38 | 0.68    | 0.09      | Tb  | 65 | -1.12   | 0.33      | 7         |
| Y   | 39 | -0.16   | 0.11      | Dy  | 66 | -0.20   | 0.16      | 7         |
| Zr  | 40 | 0.47    | 0.13      | Er  | 68 | -0.17   | 0.17      | 5         |
| Ba  | 56 | 0.30    | 0.13      | Tm  | 69 | -1.19   | 0.05      | 3         |
| La  | 57 | -0.56   | 0.08      | Hf  | 72 | -0.61   | 0.16      | 2         |
| Ce  | 58 | -0.27   | 0.10      | Os  | 76 | 0.49    | 0.20      | 3         |
| Pr  | 59 | -0.89   | 0.12      | Ir  | 77 | 0.37    | 0.2       | 1         |
| Nd  | 60 | -0.16   | 0.18      | Pb  | 82 | <-0.2:  |           | 1         |
| Sm  | 62 | -0.48   | 0.14      | Th  | 90 | -0.96   | 0.08      | 11        |
| Eu  | 63 | -0.70   | 0.09      | U   | 92 | -1.70   | 0.14      | 1         |
| Gd  | 64 | -0.21   | 0.18      |     |    |         |           | 7         |

$T_{eff} = 4825K \ log g = 1.5 \ \xi_{micro} = 1.8 \text{km s}^{-1} \ [\text{Fe/H}]=-2.9$

the observed U/Th ratios observed in CS 31082-001 and the solar system: $^{238}\text{U}$ has a half-life a factor 3 shorter than $^{232}\text{Th}$, so if the r-process elements of CS 31082-001 were produced after those of the solar system, the U/Th would be significantly smaller in CS 31082-001 than in the solar-system (dotted line), which is not observed. In fact, the age of CS 31082-001 predicted from the [Th/Eu] ratio conflicts with those from the [U/Th] [U/Os] or [U/Ir] ratios.

Beyond the issue of the age of this particular star, the fact that the Z>70 elements pattern does not seem to be well-matched by those of other similar stars (CS 22892-052, HD 115444) nor the solar-system r-process elements is worrisome concerning the used of Th/Eu (or U/Eu) ratios as age-tracers. The normalization of radioactive elements abundances to elements in the same mass-range becomes indispensable.

The reason for the discrepancy of the Z>70 elements could be a direct consequence of chemical inhomogeneities in the early Galaxy: the ISM giving birth to very metal poor stars has probably only been polluted by a very limited number of supernovae, and hence it is possible that we now see the various outcomes of single events. Only significant samples of such n-capture enhanced elements will give clues to this issue. Christlieb et al. (this volume) suggest one method for quickly achieving this goal.

References

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