Need for consistency in nuclear physics input data for astrophysics

B. Pfeiffer and K.-L. Kratz, Institut für Kernchemie, Universität Mainz, Germany, HGF VISTARS
The ESR-FSR Collaboration, GSI, Darmstadt, Germany

The influence of nuclear data input on r-process calculations can best be studied within the "waiting-point" concept. The main nuclear physics input data are 1) the β-decay properties half-lives $T_{1/2}$ and β-delayed neutron emission probabilities P_n and 2) neutron separation energies S_n, which enter into the nuclear Saha equation [1]. The r-process involves very neutron-rich nuclei, for most of them only scarce or no experimental data are available. Hence, data from global mass models have to be applied.

Fig. 1 displays a comparison of mass excesses (m.e.) and S_n derived from different mass models and experimental data for neutron-rich nuclei. The experimental values are either taken from the compilation of Audi et al. [2] or from the mass measurements at GSI [3]. The data display a considerable scatter. The influence on astrophysical calculations had been studied in Refs. [7, 8, 9]. Partly strong differences in calculated r-process abundances are observed, one example being the region A=93 and 94. For neutron densities around 10^{20} cm^{-3}, the r-process path at A=93 is determined by the S_n of ^{93}Br, which derives from the difference between the mass excesses of ^{93}Br and ^{92}Br, respectively. These values are displayed Fig. 2.

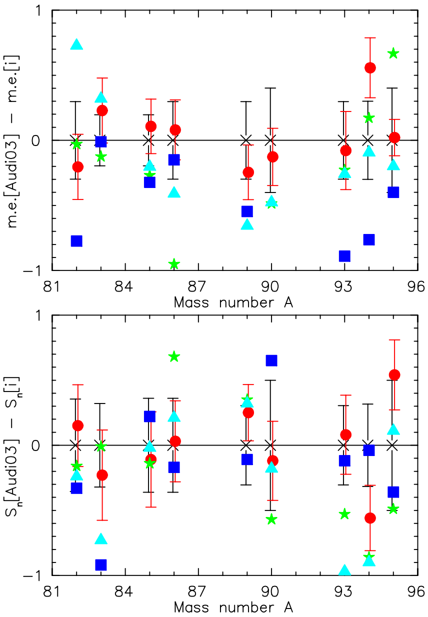

Figure 1: Experimental values from GSI [3] and predictions of mass models for mass excess (m.e.) and S_n of neutron-rich nuclei are compared to the evaluation of Audi et al. [2]. Crosses: [2], circles: [3], squares: ETFSI-Q [4], stars: FRDM [5], triangles: HFB-2 [6].

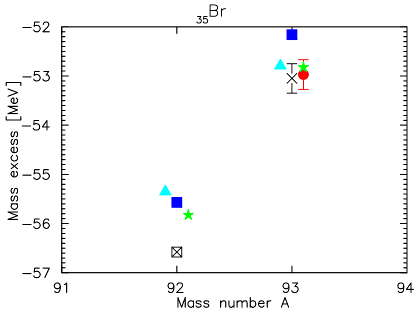

Figure 2: Measured and calculated mass excesses for ^{92}Br and ^{93}Br needed to calculate the S_n value of ^{93}Br. Same notation as for Fig. 1.

Measurements and predictions for both values scatter by about 2 MeV, resulting in quite considerable differences for $S_n(^{93}$Br). Closer inspection reveals that the experimental mass excess for ^{92}Br is reported with good accuracy [2]), but all theoretical values are higher by about 1 MeV. In the case of ^{93}Br, no experimental value existed prior to the measurement at GSI. This value confirms the extrapolated value of Audi et al. [2]). Also the theoretical predictions are with the exception of the value from the ETFSI-Q model in accord with the measured value.

Unfortunately, the nuclide ^{92}Br could not be remeasured simultaneously with ^{93}Br at GSI. As can be seen e.g. in Fig. 2 of [9], direct mass measurements can differ considerably from former results obtained from Q_β measurements. The discrepancy between the experimental and theoretical values for the mass excess of $^{92}Br_{57}$ might be explained by the proximity to the semi-magic neutron number N=56, which poses serious problems to all global mass models.

This is a striking example for the old request to apply only internally consistent data in astrophysical calculations [1]. The mix of data of different origin can introduce spurious results, especially when quantities have to be calculated from several primary data as is the case for Q_β or S_n.

References

[1] K.-L. Kratz et al., Ap. J. 403(1993) 216.

[2] G. Audi et al., Nucl. Phys. A729 (2003) 3.

[3] M. Matos, Ph.D. thesis, Giessen (2004).

[4] J.M. Pearson et al., Phys. Lett. B387 (1996) 455.

[5] P. Möller et al., ADNDT 66 (1997) 131.

[6] S. Goriely et al., ADNDT 77 (2001) 311.

[7] Scientific Report 2004, GSI, NUSTAR-E-27.

[8] H. Geissel et al., in Structure, Astrophysics and Reactions - "FINUSTAR", http://de.arxiv.org/abs/nucl-ex/0510009/

[9] B. Pfeiffer, GSI-Report, in preparation http://www.staff.uni-mainz.de/bpfeiffe/werk9t-d.pdf