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HIGH-RESOLUTION NEUTRON CAPTURE AND TRANSMISSION MEASUREMENTS AND THE STELLAR NEUTRON CAPTURE CROSS SECTIONS OF ^{116,120}Sn

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1 Introduction

Improved astrophysical reaction rates for ^{116,120}Sn(n,γ) are of interest because nucleosynthesis models have not been able to reproduce the observed abundances in this mass region. For example, previous *s*-process calculations have consistently underproduced the *s*-only isotope ^{116}Sn [1,2]. Also, these studies have resulted in residual *r*-process abundances for the tin isotopes which are systematically larger than predicted by *r*-process calculations [3]. It has been suggested [1,2] that these problems could be solved by reducing the solar tin abundance by 10-20%, but there is no experimental evidence to justify this renormalization. Instead, it is possible that the problem lies in the (n,γ) cross sections used in the reaction network calculations or in the *s*-process models. One reason to suspect the (n,γ) data is that previous measurements [1,2,4-8] did not extend to low enough energies to determine accurately the Maxwellian-averaged capture cross sections at the low temperatures (kT=6-8 keV) favored by the most recent stellar models of the *s* process [9]. Also, the two most recent high-precision measurements of the ^{120}Sn(n,γ) cross section [1,7] are in serious disagreement. Because of its small size, this cross section could affect (via the *s*-process branching at ^{121}Sn) the relative abundances of the three *s*-only isotopes of Te.

2 Experimental Procedures and Results

We have made high-resolution ^{116,120}Sn(n,γ) and ^{116}Sn-transmission measurements on isotopically enriched samples at the Oak Ridge Electron Linear Accelerator (ORELA) in the energy range from 100 eV to 500 keV using techniques described in Ref. [10]. We used the multilevel R-matrix code SAMMY [11] to obtain parameters for 211 resonances in ^{116}Sn and 99 resonances in ^{120}Sn between 100 eV and 30 keV. We have used these data to determine the astrophysical reaction rates in the temperature range kT=5-100 keV.

From our measurements we have determined that resonances below the 3-keV cutoff of the most recent previous measurement [1] account for 10-20% of

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the ^{116,120}Sn(n,γ) reaction rates at kT=6-8 keV. Furthermore, we found that a previous attempt [1] to estimate the contribution of these resonances to the reaction rate at 10 keV (the lowest temperature given) was significantly in error. Furthermore, the errors in these previous extrapolations were in opposite directions for the two isotopes so that the ratio of reaction rates (which is often most important in *s*-process calculations) is in error by even more than either of the individual rates. Similar problems with previous extrapolations were also revealed in our recent results for ^{134,136}Ba [10]. We also note that our transmission measurements reveal that there are small but significant systematic errors in the ^{116}Sn(n,γ) cross sections determined in a recent resonance analysis [4] due to the use of incorrect neutron widths.

Despite these differences, our (n,γ) data are in relatively good agreement with the most recent measurements [1] below $E_n \approx 20$ keV. However, for $E_n \approx 20$-120 keV for the (n,γ) data, and at all but the highest energy (of Ref. [1]) in the transmission data, there are substantial differences between our results and Ref. [1]. On the other hand, our results are in relatively good agreement with older measurements [5,8]. For example, in Fig. 1 it can be seen that our results for the total cross section for ^{116}Sn, averaged over the coarse energy bins used in previous work, are in good agreement with the older measurement of Ref. [5] whereas the most recent data of Ref. [1] appear to be 10-15% too high. Similarly, in Fig. 2 it can be seen that our ^{116}Sn(n,γ) data are in better agreement with the older data of Refs. [5,8] than with the most recent measurement [1] in the energy range from ≈20-120 keV. Similar results were obtained for ^{120}Sn(n,γ).

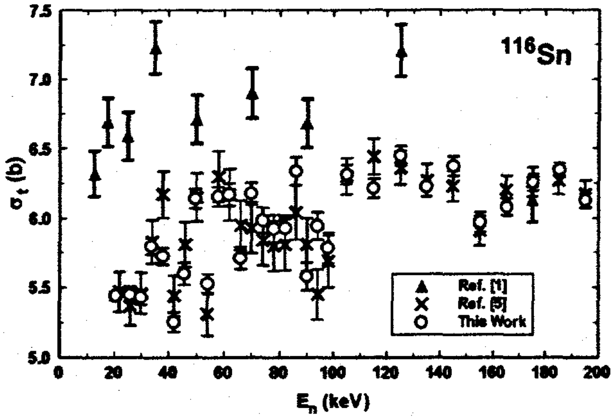

Fig. 1. Total cross sections for ^{116}Sn.

As a result of these differences, the shapes of our reaction rates (Fig. 3) are significantly different from those of Ref. [1]. One result is that a classical s-process calculation using our ^{116}Sn(n,γ) rate would result in an even larger overproduction of this s-only isotope. Curiously, our experimentally determined reaction rates for kT=6-8 keV appear to be close to what would be obtained if the results of Ref. [1] were extrapolated below their 10-keV cutoff. As a result, our low-temperature rates should be fairly close to those used in recent stellar *s*-process calculations [12] in which the main s-process component (including *s*-only ^{116}Sn) could be reproduced without renormalizing the solar tin abundance. Hence, it appears that the Sn isotopes are providing additional evidence in favor of the new stellar models of the *s* process.

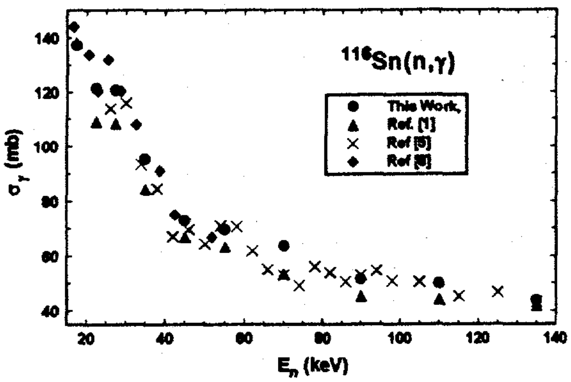

Fig. 2. Comparison of ^{116}Sn(n,γ) data.

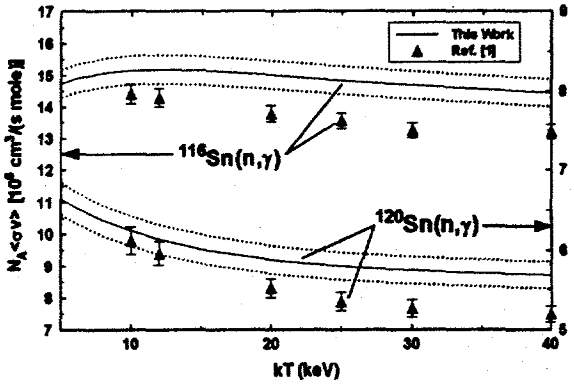

Fig. 3. ^{116,120}Sn(n,γ) reaction rates.

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References

[1] K. Wisshak, F. Voss, Ch. Theis, F. Käppeler, K. Guber, L. Kazakov, N. Kornilov, and G. Reffo, Phys. Rev. C **54**, 1451 (1996).

[2] H. Beer, G. Walter, and F. Käppeler, Astron. Astrophys. **211**, 245 (1989).

[3] K.L. Kratz, in *Nuclei in the Cosmos III*, edited by M. Busso, R. Gallino, and C.M. Raiteri, (American Institute of Physics, New York, 1989), p. 113.

[4] K. Wisshak, F. Voss, and F. Käppeler, Forschungszentrum Karlsruhe report FZKA 5755 (1996).

[5] V.M. Timokhov, M.V. Bokhovko, A.G. Isakov, L.E. Kazakov, V.N. Kononov, G.N. Manturov, E.D. Poletaev, and V.G. Pronyaev, Sov. J. Nucl. Phys. **50**, 375 (1989).

[6] R. Macklin and J. Gibbons, Rev. Mod. Phys. **37**, 166 (1965).

[7] F. Käppeler, W. Schanz, K. Wisshak, and G. Reffo, Astrophys. J. **410**, 370 (1993).

[8] R. Macklin, T. Inada, and J. Gibbons, Nature **194**, 1272 (1962).

[9] O. Straniero, R. Gallino, M. Busso, A. Chieffi, C. Raiteri, M. Limongi, and M. Salaris, Astrophys. J. **40**, L85 (1995).

[10] P.E. Koehler, R.R. Spencer, R.R. Winter, K.H. Guber, J.A. Harvey, N.W. Hill, and M.S. Smith, Phys. Rev. C **54**, 1463 (1996).

[11] N. Larson, Technical Report No. ORNL/TM-9179/R2, Oak Ridge National Laboratory, 1989.

[12] R. Gallino and M. Busso, to appear in the proceedings of the Presolar Grain Conference.