Neutron Capture Cross Sections for ^{86}Sr and ^{87}Sr at Stellar Temperatures*

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1. Introduction

Recent work on s-process nucleosynthesis has focused attention on the investigation of capture cross sections for nuclei in the mass region near the N=50 closed neutron shell.[1-3] Of special astrophysical interest are (i) the analysis of the s-process branching through ^{85}Kr as a monitor of stellar neutron density and temperature and (ii) the investigation of the possible chronometric pair ^{87}Rb-^{87}Sr as an independent measure of the age of the galaxy. For both problems the capture cross sections of the two pure s-process nuclei ^{86}Sr and ^{87}Sr have to be known to an accuracy of 5% or better. The current investigation of the neutron capture cross sections for ^{86}Sr and ^{87}Sr was undertaken to extend recent measurements by Walter and Beer[2] to energies below 3.5 keV, where strong resonances are known to exist, and to explore the discrepancy in the results of the Maxwellian averaged capture cross section of ^{87}Sr at kT = 30 keV as reported by previous investigators.[2,4,5]

2. Experiment and Analysis

The neutron capture cross sections for $^{86,87}Sr$ have been measured from 100 eV to 1 MeV at the Livermore Electron Linear Accelerator. Neutrons with a continuous energy distribution were produced in a tantalum target bombarded by 100-MeV electrons. The capture events and their flight times were recorded by detecting the prompt gamma-ray cascade with two C_6D_6 scintillators located 11 m from the neutron source. A ^{6}Li-glass scintillator was used to monitor the neutron flux. The background was determined experimentally utilizing the "black resonance" technique. Details of the experimental setup have been presented in previous reports.[6-7] We applied a weighting function to our data such that the resultant efficiency of the capture gamma-ray detectors is independent of the gamma-ray spectrum. Corrections have also been applied for neutron multiple scattering and self-shielding, and for gamma-ray attenuation. The strontium

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cross sections have been normalized to a standard gold cross section revised to agree with the latest measurements by Macklin, et al.[8] Figure 1 gives an example of our cross section results for ^{86}Sr.

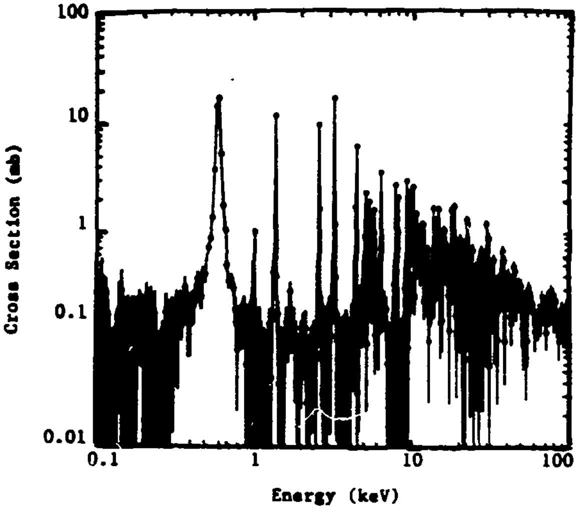

Fig. 1

Measured capture cross sections of ^{86}Sr, displaying strong resonances at 0.588, 1.370, 2.592, 3.247 and 4.496 keV, and an approximate 1/v decrease above 20 keV

3. Results

The Maxwellian averaged neutron capture cross sections have been calculated for stellar temperatures ranging from kT = 10 to 100 keV. Our cross sections at 20, 30, 40 and 50 keV are found to be in excellent agreement with those reported by Walter and Beer.[2] At kT = 30 keV we obtain 70 $\pm$ 4 mb for ^{86}Sr, and 97 $\pm$ 5 mb for ^{87}Sr. Combining our results with those reported previously,[2,4,5] we recommend Maxwellian averaged capture cross sections at kT = 30 keV of 70 $\pm$ 3 mb for ^{86}Sr, and 93 $\pm$ 4 mb for ^{87}Sr. These latter values have been used to analyze the branching in the s-process flow at the unstable nucleus ^{85}Kr. This branching can be used as a possible measure of the neutron density during the s-process by comparing the $\sigma \cdot N$ values for ^{86}Sr and ^{87}Sr with the corresponding value for ^{88}Sr. There exists also the additional possibility to use the ^{87}Rb-^{87}Sr isobaric doublet as a chronometric pair based on the long half-life of ^{87}Rb. Utilizing analyses of the capture flow based on an exponential distribution of neutron exposures including the temperature dependence of all beta decays and neutron captures, we find a good fit to the branching through ^{85}Kr can be obtained for all temperatures. The optimum conditions correspond to a mean neutron exposure of $\tau_0 = 0.40(\pm 0.06)\ (kT/30)^{1/2}\ mb^{-1}$ (where kT is in keV), and an average neutron density of roughly $n_n = 4.7(\pm 0.7) \times 10^7\ (kT/30)\ cm^{-3}$. It appears that this branch requires a slightly larger exposure and a lower-density neutron source than the heavier s-process nuclei. This might be attributed to production in low-mass AGB stars.[9]

The data are still too uncertain to be used for a reliable evaluation of the ^{87}Rb-^{87}Sr chronometric pair. However, we can infer from these data an upper limit (95% confidence) to the age of the universe of $\leq 14 \times 10^9$ years (for a constant rate of nucleosynthesis) which is consistent with other chronometers.

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