Neutron Capture in Tin Isotopes at Stellar Temperatures

THEORIES of stellar nucleosynthesis have emphasized the importance of neutron capture (*s*- and *r*-processes occurring in giant stars and supernovæ respectively) in producing the heavy elements[1,2]. For the *s*-process, cosmic isotopic abundances are predicted to show an inverse proportionality to the neutron capture cross-sections. While some nuclei can be produced by only one process or the other, the abundances can be most accurately measured for isotopes of a single element. Thus the many isotopes of tin provide the best opportunity to test the theories and to determine such parameters as the relative contribution of supernovæ to the material of the solar system. Tin-116 cannot be formed by the *r*-process, whereas tin-122 and tin-124 can only be so formed. In addition, the *r*-process is expected to be only a minor contributor[2] to the production of tin-117, -118, -119, and -120.

Stellar temperatures corresponding to neutron energies of 10–60 keV. have been suggested as typical for nucleogenesis. We have measured radiative capture cross-sections for seven of the tin isotopes by use of neutrons having an energy distribution of 18–46 keV. (mean energy, 30·4 keV.; full width at half maximum, 16 keV.), using the Oak Ridge National Laboratory 3-MV. pulsed Van de Graaff accelerator and the $^{7}Li(p,n)$ reaction near threshold[3]. We plan to extend the measurements to several energies from 10 to 60 keV. with better resolution, but as the neutron energy distribution in a star already covers many resonances in each isotope no significant change in the conclusions derived from the present results is anticipated.

The capture cross-sections were measured with a Moxon–Rae detector[4], using two *RCA*-7046 fourteen-stage photomultipliers and graphite converters 1 in. thick. The overall time resolution was 3–4 nanosec., permitting excellent neutron discrimination by time-of-flight, using an 8-cm. flight path to the isotope samples. Each sample weighed 30–35 gm. Corrections of a few per cent were made for resonance self-protection, average neutron path length in the sample, and isotopic impurities. The results are shown in Table 1.

The abundance attributed to giant-star nucleosynthesis, N_s, is found by subtracting an estimate of the supernovæ contribution, N_r (Table 1, col. 4), from the observed abundances N (Table 1, col. 3). The predicted inverse proportionality is shown by the approximate constancy of the product $N_s\sigma_c$ (Table 1, col. 5) for the *s*-process nuclei tin-116, -117, -118, -119, and -120. The increased relative importance of the *r*-process corresponding to these data is seen in comparing the ratio N_r/N_s (Table 1, col. 7) with the latest published estimates[2], which are shown in col. 8.

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Table 1. 30-KEV. NEUTRON CAPTURE CROSS-SECTIONS

(1) Nucleus	(2) σ_c (mb.)	(3) Isotopic abundance N*	(4) N_r†	(5) $N_s\sigma_c = (N - N_r)\sigma_c$	(6) $N_r\sigma_c$	(7) N_r/N_s†	(8) N_r/N_s‡
Sn 116	92 ± 19§	0·1424	0	13·1	—	0	0
117	390 ± 82§	0·0757	0·040	13·9	—	1·12	0·08
118	59 ± 12§	0·2401	0·045	11·5	—	0·23	0·02
119	243 ± 51§	0·0858	0·040	11·1	—	0·87	0·07
120	35 ± 7§	0·3297	0·045	10·0	—	0·16	0·03
122	23 ± 5	0·0471	0·0471	—	1·1	—	—
124	23 ± 4	0·0598	0·0598	—	0·8	—	—

Note: σ_c computed for natural tin from these results is 93 ± 20 mbarns (mb.).

* Strominger, D., Hollander, J. M., and Seaborg, G. T., *Revs. Mod. Phys.*, **30**, 585 (1958).

† Fowler, W. A. (private communication re-estimating the *r*-process contribution).

‡ See ref. 2.

§ This is the r.m.s. absolute error, the relative errors are estimated at ± 10 per cent.

METALLURGY

Some Factors influencing Dislocation Loop Size in Neutron-irradiated Metals

THE nature of radiation damage in metals has mainly been inferred from changes in physical properties resulting from irradiation. This evidence cannot generally be interpreted unambiguously. A more direct experimental approach has recently been made possible with the development of the technique of transmission electron microscopy which makes possible the direct observation of dislocations in metals. The damage resulting from neutron irradiation has been examined in a number of metals using this technique. In some metals dislocation loops were observed while in others no structural changes were found subsequent to irradiation. The reasons for these differences in behaviour are not yet understood.

Dislocation loops in metals result from the aggregation of point defects into disks on close packed planes. These disks afterwards collapse to form a circular area of stacking fault bounded by a dislocation loop. The radius at which collapse occurs will depend on the energy of the disk relative to that of the collapsed configuration. Since the stacking fault energies of metals may differ by more than an order of magnitude, it seems reasonable to expect that the stacking fault energy would be an important factor in determining whether or not dislocation loops are observed in a particular metal.

Transmission electron microscopy investigations have been carried out on six metals, including copper[1], gold[1], aluminium[1], nickel[1], iron[2] and molybdenum[3]. Irradiation conditions were similar in all cases and total integrated fluxes were in the same range. Dislocation loops were observed only in copper and gold, while the other metals investigated showed no