

ISOTOPIC YIELDS OF INTERMEDIATE-MASS FRAGMENTS EMITTED IN $E/A = 50 \text{ MeV } ^4\text{He} + ^{116,124}\text{Sn}$ REACTIONS

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In the present work we investigate the influence of the target N/Z ratio on the properties of intermediate-mass fragments (IMF's) formed in the reaction of $E/A \approx 50 \text{ MeV}$ ^4He ions with targets of ^{116}Sn ($N/Z = 1.32$) and ^{124}Sn ($N/Z = 1.48$). The experiment was performed with ^4He beams of 180 and 200 MeV incident energy. Self-supporting ^{116}Sn and ^{124}Sn targets were used, each with areal densities of 1.4 mg/cm^2 and isotopic purity of 95.6% and 96.7%, respectively.

Reaction products ($Z \geq 3$) were detected with two detector telescopes positioned on rotatable arms inside a 162-cm diameter scattering chamber. The first telescope, employed primarily at forward angles, consisted of an axial-field gas-ionization chamber followed by $90 \mu\text{m}$ and 1 mm silicon surface-barrier detectors (450 cm^2), and a 2-cm thick CsI(Tl) scintillator crystal operated with a photodiode. The first silicon element was placed 38 cm from the target and was also used for timing, with the beam rf signal as the time reference. Time-of-flight and ΔE - E measurements provided full isotope separation for $Z \leq 6$ fragments with a low energy threshold. The second telescope consisted of a gas-ionization chamber followed by a $500 \mu\text{m}$ passivated silicon detector (25 cm^2).¹ The gas-ionization chambers were operated at 20 Torr of CF_4 . Inclusive energy spectra of the intermediate-mass fragments were measured with the ΔE - E /TOF telescope at forward angles of 12° , 35° and 65° , and with the large solid-angle ΔE - E telescope at 160° . Backward-angle isotopic yields were obtained by complementary TOF/ ΔE - E measurements with the first telescope also. This measurement was performed at 154° and 180 MeV incident energy. For both systems the low energy thresholds were $E/A \simeq 0.4 \text{ MeV}$.

The data demonstrate the influence of target composition on both the charge and isotopic distributions of the fragments. Elemental cross sections from the $^{116}\text{Sn} + ^4\text{He}$ system are distinctly enhanced relative to $^{124}\text{Sn} + ^4\text{He}$ (Fig. 1). This effect is strongest for the equilibrium-like fragments (160°), where the yields are 2-3 times larger for ^{116}Sn compared to ^{124}Sn . For nonequilibrium emission (12°), both targets produce similar yields for light IMF's; however, the ratio of the elemental cross sections from ^{116}Sn to those from ^{124}Sn becomes larger as a function of increasing fragment charge. This result is understood in terms of the lower average neutron binding energies for the $^4\text{He} + ^{124}\text{Sn}$ system, thereby favoring decay via neutron emission at the expense of IMF probability.

For a given element the ratio of the cross section from the ^{116}Sn system to that from ^{124}Sn for any series of isotopes is found to decrease with increasing neutron number (Fig. 2). This behavior reflects the larger N/Z ratio of the composite system formed from ^{124}Sn and can be described in terms of a simple exponential function (slope= γ) related to neutron binding energy differences. This isotopic dependence on target N/Z is strongest for the

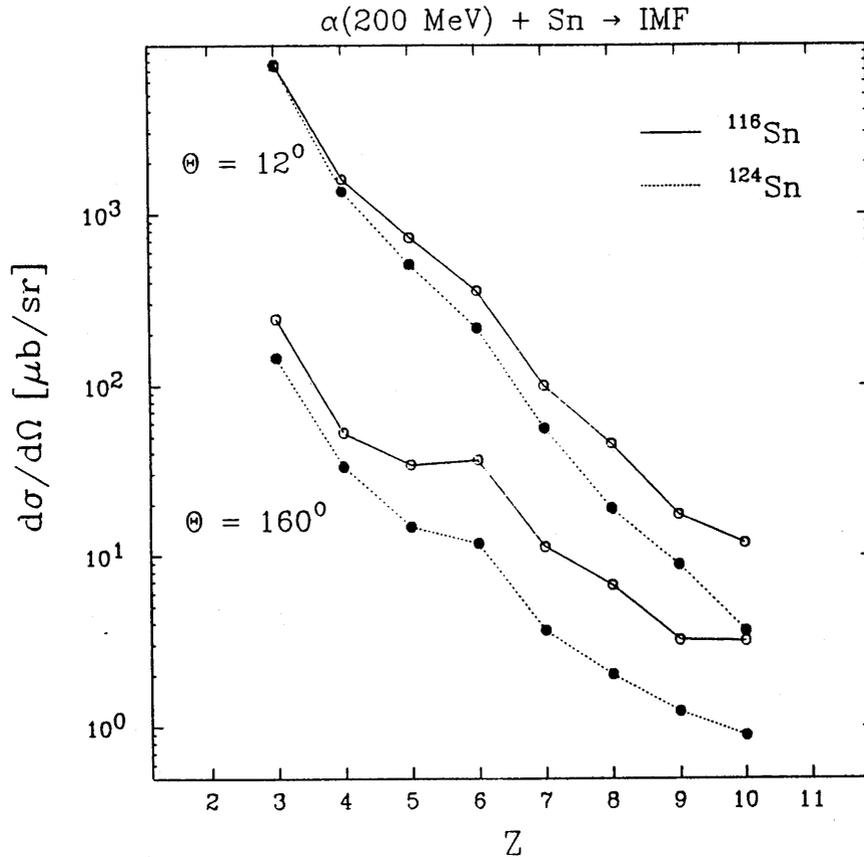


Figure 1. Charge distributions at 12° (upper set) and 160° (lower set) for IMF's emitted from ^{116}Sn (solid lines) and ^{124}Sn (dotted lines).

backward-angle component of the spectra, where the slope of the ratio $\sigma(^{116}\text{Sn})/\sigma(^{124}\text{Sn})$ is identical for Li, Be, B and C ejectiles. Such behavior is consistent with emission from an equilibrated system.

At forward angles the nuclidic yields are found to be sensitive to both the N/Z of the target and the Z of the ejectile. Neutron-excess IMF's are favored with the ^{124}Sn target; however, the exponential slopes (γ) of the ratio $\sigma(^{116}\text{Sn})/\sigma(^{124}\text{Sn})$ for the isotopes of a given element evolve from a rather flat behavior for $Z = 3$ isotopes to one for $Z = 6$ that is virtually identical to that for equilibrium-like emission. Thus, nonequilibrium emission of light IMF's appears to be less sensitive to the target-projectile composition, indicating that only partial N/Z equilibration is achieved for these products. Another feature of the nonequilibrium spectra is that the isotope ratios depend on IMF kinetic energy. Near the Coulomb peak, the isotopic ratios at forward angles are similar to those at backward angles. However, for increasingly energetic IMF's, the yield of neutron deficient isotopes is enhanced with respect to the heavier isotopes. This effect is strongest for Li and Be isotopes.

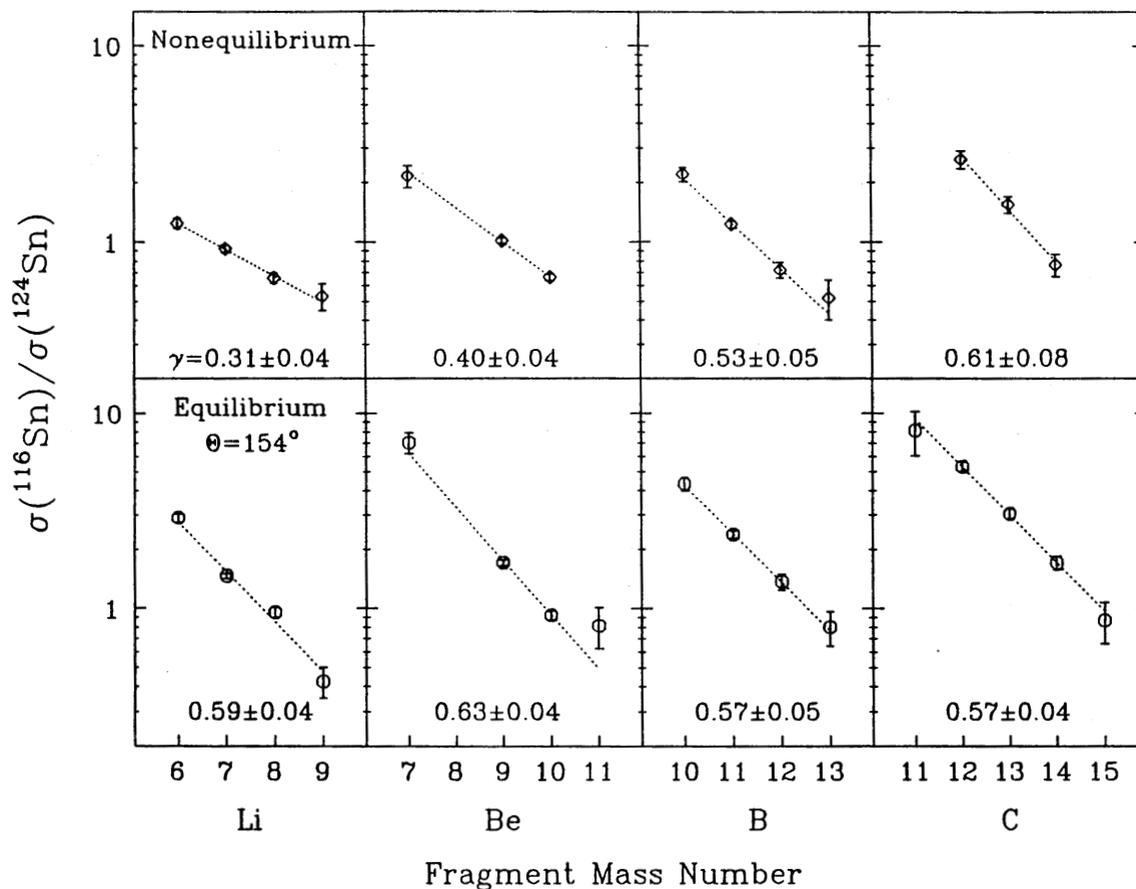


Figure 2. Ratio of yield for a given isotope from ^{116}Sn target to that from ^{124}Sn target as a function of mass number for Li, Be, B and C, as indicated on the figure. The upper set shows nonequilibrium data at forward angles; the lower set is for data obtained at 154° . The dotted line is a fit to the data of an exponential function, $\exp(-\gamma A)$; the value of γ is given in each frame.

When compared with the backward-angle data, a simple statistical model calculation which includes excited states of the fragments gives fair agreement. In general there is a tendency for the calculation to overpredict the yields of neutron-excess fragments. An accreting source calculation,¹ calibrated by the charge distributions, also provides a reasonable description of the nuclidic yield results for the entire data set. However, this calculation encounters difficulties in fitting spectral shapes at forward angles, as well as angular distributions.

1. W.A. Friedman and W.G. Lynch, Phys. Rev. C **28**, 16 (1983); **28**, 950 (1983).