Production and Separation of Exotic Beams via Fragmentation Reactions Using MARS

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Introduction

Radioactive nuclei away from the valley of stability are important in the study of nuclear astrophysical reactions. Because such nuclei cannot be found in nature, they must be produced in the lab in order to be studied. The Momentum Achromat Recoil Spectrometer (MARS) [1] at Texas A&M University is able to produce beams of radioactive nuclei, which can then be separated from other nuclei based on their charge, mass, and energy. These nuclei are typically produced with low energy transfer and fusion-evaporation reactions. This is the first time that higher energy fragmentation reactions are being used at MARS.

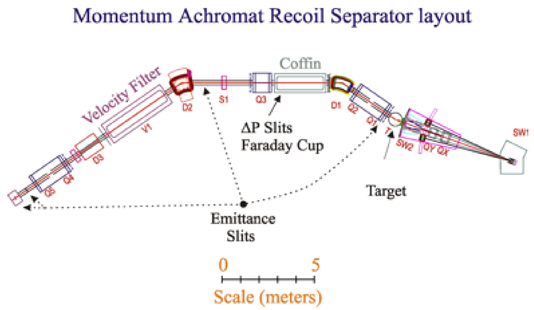

Figure 1. *The MARS setup with the beam entrance and target on the right, and the detectors on the far left.*

Purpose

LISE++ [2] is a mass spectrometer simulation tool which calculates cross sections for different reactions as well as production rates for nuclei after separation. LISE++ uses the EPAX [3] parameterization to calculate fragmentation cross sections, which is related to the production rate and other kinematic factors of a given reaction. Production rates have been collected for various nuclei for three different fragmentation reactions, and compared with corresponding LISE++ predictions to determine the accuracy and usefulness of these predictions.

Methods

Once the primary beam hits the target, the product nuclei continue through two dipole magnetic fields which separate the desired products from the remaining primary beam. The products then pass through a velocity selector consisting of perpendicular electric and magnetic fields, and go on to the detector. The detector used was a micron X1 PSD. Spectra of energy loss versus vertical position in the detector were obtained, where the individual nuclei could be identified. Production rates were then calculated using the number of counts in the spectra normalized to the total beam current.

Particle Identification

The three fragmentation reactions used were ^{36}Ar, ^{40}Ar, and ^{24}Mg at 45, 40, and 48 MeV per nucleon, respectively. All used a 306 μm ^{9}Be target. The reaction products were separated based on their charge to mass ratio. Then, in the spectra, the nuclei could be identified based on their energy loss in the detector and their vertical position in the detector.

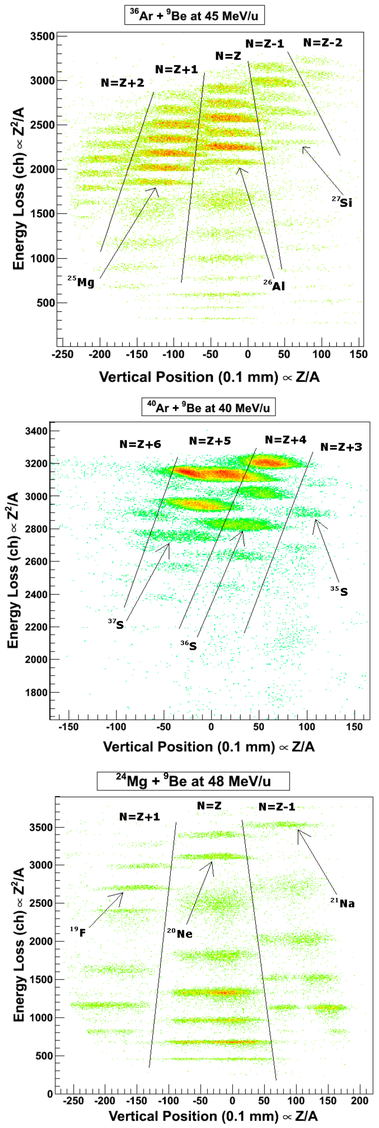

Figure 2. *Examples of the energy and position spectra for the ^{36}Ar, ^{40}Ar, and ^{24}Mg fragmentation reactions, showing the regions with varying numbers of neutrons.*

Results

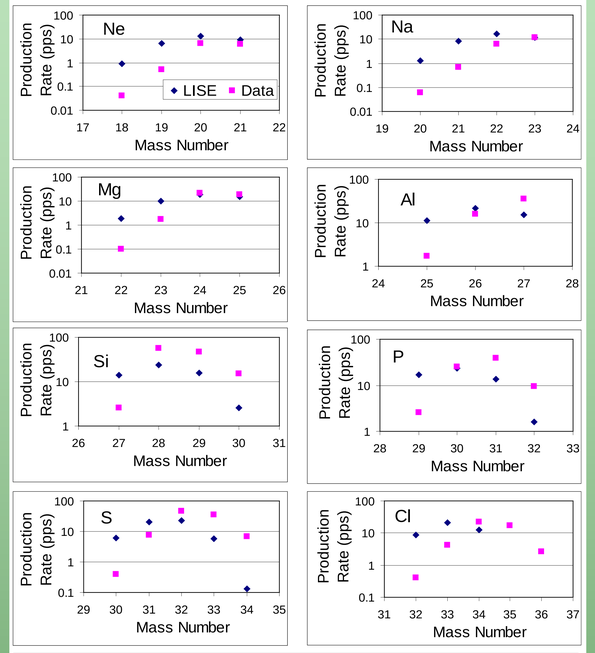

Figure 3. *Production rates for the ^{36}Ar + ^{9}Be reaction. The plots are organized by element, with the production rates plotted versus the mass number of each element. The final plot shows the numerical difference between the LISE++ predictions and actual data for each element, as a function of relative number of neutrons.*

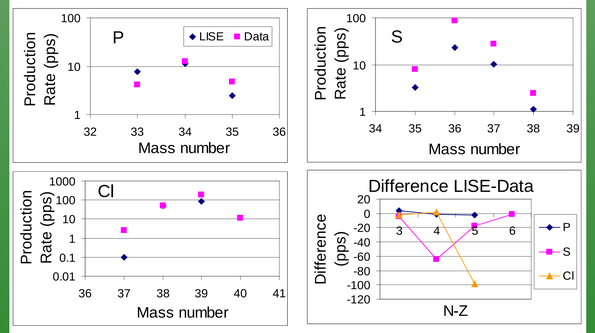

Figure 4. *Production rates for the ^{40}Ar + ^{9}Be reaction. The plots are organized by element, with the production rates plotted versus the mass number of each element. The final plot shows the numerical difference between the LISE++ predictions and actual data for each element, as a function of relative number of neutrons.*

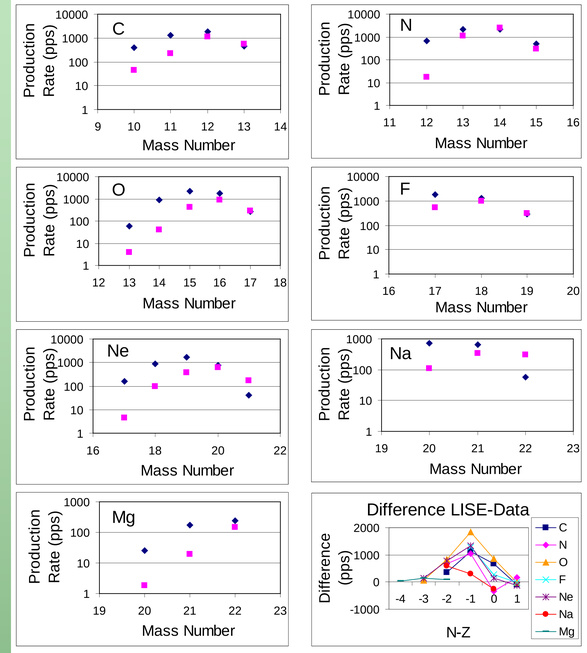

Figure 5. *Production rates for the ^{24}Mg + ^{9}Be reaction. The plots are organized by element, with the production rates plotted versus the mass number of each element. The final plot shows the numerical difference between the LISE++ predictions and actual data for each element, as a function of relative number of neutrons.*

Conclusions

Generally, the LISE++ predictions were within a factor of ~10 of the actual data obtained for the reactions. The predictions were most accurate for nuclei closer to stability, and had higher predictions for neutron-rich nuclei and lower predictions for proton-rich nuclei.

References

[1] R. E. Tribble, R. H. Burch, and C. A. Gagliardi, Nucl. Instrum. Meth. A **285**, 441 (1989).
[2] D. B. Tarasov and D. Bazin, Nucl. Instrum. Meth. B **266**, 4657 (2008).
[3] K. Sümmerer *et al*., Phys. Rev. C **42**, 2546 (1990).

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