Title
REACTION MECHANISMS AND PRODUCTION OF EXOTIC NUCLEI USING 200 MeV/n 40Ar

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Reaction Mechanisms and Production of
Exotic Nuclei Using 200 MeV/n ^{40}Ar*

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Recent experiments using the fragmentation of ^{40}Ar at 200 MeV/n have proved to be a powerful new tool for the investigation of both the dynamics of nuclear interactions at high energies and the limits of nuclear stability.[1,2] The study of ^{40}Ar-induced reactions at low energies (< 10 MeV/n) implies that the reaction proceeds by a diffusion mechanism leading to the emission of fragments from an equilibrated dinuclear system. Reactions induced by ^{16}O at much higher energies have been interpreted using both fast-abrasion models and models incorporation exciation followed by equilibration and decay.

In order to study the reaction mechanism, C and Th targets were bombarded by 213 MeV/n ^{40}Ar from the Bevalac. Energy spectra were measured at lab angles from 0° to 4° in a telescope consisting of eight 5-mm Si(Li) detectors capable of stopping fragments heavier than nitrogen. The particle indentification technique used the algorithm $(E+\Delta E)^n - E^n \propto TM^{n-1} Z^2$ where T is the thickness of the ΔE detector, M and Z are the mass and charge of the particle, and n is taken to be 1.78. This expression was modified for the case of an eight-element telescope to provide multiple identifications. The resulting mass spectra had a resolution varying from 0.2 to 0.5 amu. Isotope production cross sections were obtained by integrating the energy spectra and angular distributions.

The energy spectrum of ^{34}S fragments at 1.5° from the fragmentation of 213 MeV/n ^{40}Ar on a carbon target is given in Fig. 1a. The solid line corresponds to a fitted Gaussian momentum distribution. These widths σ of the distributions are given by

$$\sigma^2 = \sigma_0^2 A_f (A_p - A_f)/(A_p - 1) \qquad (1)$$

where A_f and A_p are the fragment and projectile masses and σ_0 is a constant. In Fig. 1a the values for σ_0 for all measured fragments in the mass range 16 to 37 are given. The average value, $\langle\sigma_0\rangle$, of 94±5 MeV/c can be interpreted in terms of the Fermi momentum of the projectile which gives the value p_f = 209±11 MeV/c which compares well with the measured value for ^{40}Ca of 251±5 MeV/c. Alternatively, $\langle\sigma_0\rangle$ can be related to a nuclear temperature if the emitting system is assumed to be in thermal equilibrium. This relation gives a temperature of 9.6± 1.1 MeV which is higher than the 8 MeV temperature seen in a wide range of ^{16}O-induced reactions.

The measured isotope production cross sections for the C target are given in Fig. 2. The absolute normalization is uncertain to within a factor of 2. Both thermal equilibrium and fast abrasion-ablation models have been used to describe these isotope distributions. In the model of decay of the excited projectile, the cross section is proportional to $\Sigma \exp(Q_f/T)$ where the sum extends over all fragmentation channels, Q_f is the corresponding separation energy, and T is an effective temperature. In Fig. 2, the predictions with T=9.6 MeV are compared for the elements with Z = 8,12, and 16 (thin, solid lines). The model does not reproduce the observed Gaussian distributions.

The isotope distributions can be rather well described within the framework of abrasion-ablation models. In these calculations the primary fragments mass distributions are determined from the geometry of the fireball model and the primary isotope distributions depends on the extent of proton-neutron correlations in nuclei. Two assumptions were made about the correlations: a) no correlations (NC), and b) correlation arising from the zero-point vibration of the Giant dipole resonance (GDR). The de-excitation of the primary fragments by particle emission was calculated using OVERLAID ALICE assuming the excitation energy was equal to the difference in surface energies of the abraded projectile and a spherical nucleus of the same mass. A second assumption was made that additional excitation was deposited in the primary fragment through absorption of nucleons from the interaction region (fireball). In Fig. 2, the results are shown for abrasion-ablation calculations, assuming NC, NC and additional excitation energy, and GDR correlations. The isotope distributions for the NC case are too wide whereas the GDR case and the NC plus additional excitation case both give rather good agreement. Thus one cannot distinguish whether ground state correlations are being observed or whether there are no correlations present with only additional excitation.

The yields of very neutron-rich nuclei resulting from the fragmentation of ^{40}Ar at 205 MeV/n have been measured using a magnetic spectrometer which is capable of mass resolution combined with the telescope described above. This system was capable of mass resolution of 0.2 amu for all observed fragments. The particular advantage of this method over heavy ion transfer

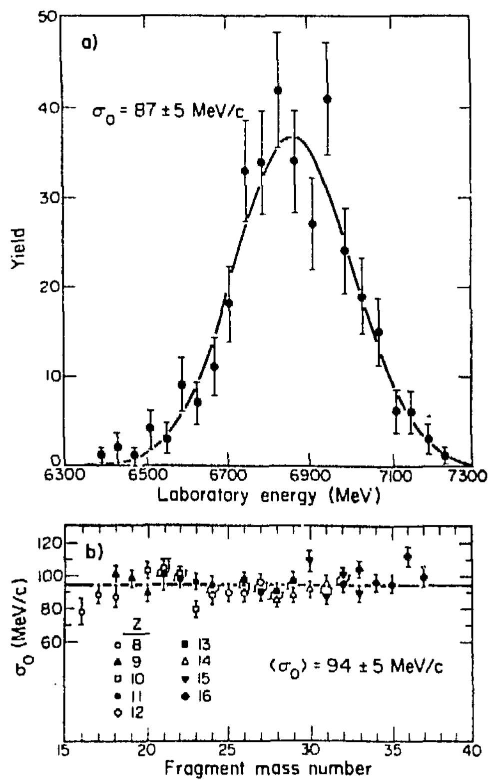

Fig. 1

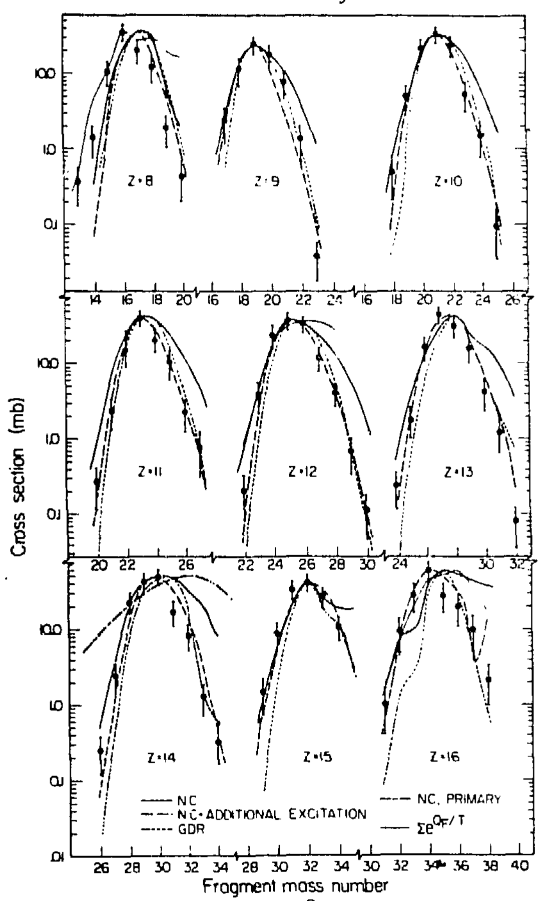

Fig. 2

reactions and spallation of heavy nuclei is that the products move at nearly beam velocity, close to 0^o in the laboratory. The exotic products are much easier to identify than in previous experiments where they emerge at low velocities in the lab. Since the method also allows the use of thick targets and enables a large fraction cross section to be collected, the resultant gain in efficiency over a typical low energy experiment can be as much as 10^6. It now is feasible to check the predictions of theoretical formulas close to the limit of stability.

Projected mass spectra with a gate of ± 0.2 units about charges 10, 11, 12, and 13 are shown in Fig. 3. ^{28}Ne and ^{35}Al are positively identified as particle-stable isotopes with more than 10 counts in each case. There is also evidence for the stability of ^{27}Ne, ^{31}Mg, ^{32}Mg, ^{34}Al, ^{30}Na, ^{31}Na, each of which has only been observed directly using a single technique. All three new nuclides are predicted to be particle stable, although in the case of ^{33}Mg, only by 480 keV, a value that is close to the uncertainty in the theoretical predictions. It will be of particular interest to extend the present experiment since ^{29}Ne and ^{25}O are predicted to be just bound and unbound, respectively. In cases such as these, even the observation of the isotope provides an important test of the mass formula used.

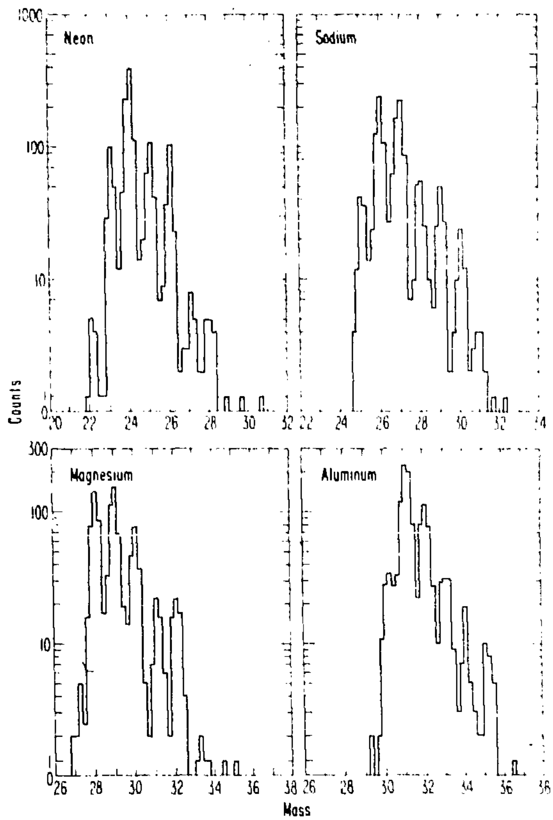

Fig. 3

Footnotes and References

†Work presented here was taken from Reference 1 and 2 and was done in collaboration with these authors.

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2. T. J. M. Symons, Y. P. Viyogi, G. D. Westfall, P. Doll, D. E. Greiner, H. Faraggi, P. J. Lindstrom, D. K. Scott, H. J. Crawford, and C. McParland, Phys. Rev. Lett. 42, 40 (1979), and references therein.