New heavy element program at Texas A&M University

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A new program to study the heaviest elements has begun at the Texas A&M University Cyclotron Institute. The goals of this program are a better understanding of the production, decay, and chemical properties of the heavy actinide and transactinide elements. These elements are not naturally occurring and must be produced artificially using fusion reactions requiring high-intensity beams, long irradiation times, and efficient separation techniques. This combination of facilities is available at the Institute.

As part of a DOE-sponsored upgrade program, the idle K140 88-Inch Cyclotron is being recommissioned to provide intense, stable beams for experiments in fundamental interactions, rare isotope production, etc. [1]. The new heavy element program will focus on using medium-mass beams from the recommissioned K140 cyclotron for production of actinide and transactinide nuclei in complete fusion, neutron evaporation reactions. Due to the low recoil range of slow, heavy ions, target thicknesses in these experiments are limited to ≈500 μg/cm^2. Transactinide production cross sections are typically nanobarns or smaller (see Fig. 3 in [2]), so beam intensities of >200 pnA with energies of ≈5 MeV/u are required. Table I gives a sample of predicted intensities and energies for several beams from the K140 cyclotron. For those beams with listed energies greater than 5 MeV/u, the actual intensity is likely to be higher due to fewer losses during acceleration. Until the upgrade is complete, beams will be provided by the K500 superconducting cyclotron, which is capable of delivering beam intensities of ≈50 pnA.

Once the fusion reaction has taken place, it is critical to efficiently separate the evaporation residues from the unreacted beam, scattered nuclei, and transfer reaction products. The Momentum Achromat Recoil Separator (MARS) [3, 4] will be used for this purpose. It couples a pair of dipole magnets with achromatic focusing to a Wien velocity filter, followed by a final dipole magnet. The velocity of a typical heavy evaporation residue is ≈0.02*c* (energy ≈ 0.2 MeV/u) and generally a factor of 5 lower than the primary beam; therefore a velocity filter should provide excellent primary beam rejection. Table II shows a comparison of MARS to other separators in use in the heavy elements field. Currently, MARS is used primarily for experiments in nuclear astrophysics and radioactive beam production with primary beam energies of tens of MeV/u. Experiments are planned to characterize the performance of the separator for slow ions using sources of degraded *α* particles. These experiments will begin in Summer 2009.

TABLE I. Predicted intensities and energies of sample beam from the K140 cyclotron.

Beam	Energy (MeV/u)	Intensity (pnA)	Beam	Energy (MeV/u)	Intensity (pnA)
^{22}Ne	29	500	^{59}Co	11	900
^{40}Ar	17	1400	^{86}Kr	8.3	600

TABLE II. Comparison of MARS to other heavy element separators.

Separator	Solid Angle (msr)	$\Delta p/p$	Maximum $B\rho$ (T m)
MARS	9	4%	1.8
SHIP [5, 6]	4	10%	1.2
BGS [7]	45	9%	2.5

First beam experiments will focus on the production of lighter elements ($Z > 70$) to measure the transmission of MARS and compare it to simulations. The residue charge state distribution is the most important factor influencing the transmission, so the distribution will be measured in each case to augment the small amount of data available. Future experiments through 2010 will work to steadily push toward heavier elements, with the eventual goal of producing transactinides. Once this occurs, a broad-based program focused on the study of fusion reactions and chemical properties of these elements will begin.

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