Rare Beam Estimates and Possibilities at Texas A&M

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At present, a major facility upgrade is planned at the Cyclotron Institute of Texas A&M University. Both, the generation of radioactive beams by projectile fragmentation and the implementation of IGISOL-type capabilities and reacceleration (involving the 88-inch Cyclotron) are being considered. In order to evaluate the various possibilities, among other issues, reliable estimates of production rates of rare isotope beams (RIBS) are necessary. We have performed rate calculations of RIBs for several possible situations as outlined in the following.

For configurations involving a "typical" achromatic fragment separator system, RIB estimates were performed using the codes LISE [1] and INTENSITY [2]. First, RIB rate estimates were obtained for the existing Beam Analysis System [3], (assuming some modifications -- see [4]) operated in an achromatic mode. However, the small angular and momentum acceptance ()Σ=0.2 msr,)p/p=0.6%) provided by the analysis line do not allow efficient collection of fragmentation products. Second, calculations were performed for a compact fragment separator device [4] with acceptances)Σ=1.6 msr,)p/p=6.0% that could accept beams from the K500 Cyclotron. For such a typical device, usable rates of relatively clean RIBs can be obtained using the beams and intensities that can be delivered by the K500 Cyclotron. Some RIB estimates along with the reaction parameters are summarized in Table 1.

Finally, the possibility of using a large bore superconducting solenoid as a fragment collector/separator was considered. For the calculations, the parameters of the Univ. of Michigan BIGSOL were used [5]. For rate and purity estimates, we developed a Monte Carlo/raytracing procedure that is outlined below. First, in order to simulate the fragment production, the approach described in [6] is applied in which a deep-inelastic transfer code followed by a statistical deexcitation code provide the fragment distributions after the target. The products are then raytraced through the solenoid magnet using the code RAYTRACE [7] and are collected at the focal plane in a 5mm-diameter apperture (or detector).

The results of these calculations indicate that the solenoid can act, as expected, as an efficient fragment collector, especially at energies around the Fermi energy, where the kinematic focusing of the fragments is not as strong as in higher energy fragmentation reactions. However, the inherently small dispersion of the solenoid results in rather poor "clean-up" of RIBs of interest. Below we mention two examples: first, the production of ^{38}S from the reaction of 100 pnA ^{40}Ar at 40 MeV/nucleon on a 10 mg/cm^2 ^{27}Al target: production cross section 0.4 mb, 35% transmission via the solenoid to the focal plane detector, 5% purity and rate of 1.7×10^4 pps. Second, the production of ^{66}Ni from the reaction of 100 pnA ^{68}Zn at 40 MeV/nucleon on a 10 mg/cm^2 ^{48}Ti target: production cross section 3.8 mb, 60% transmission via the solenoid to the focal plane detector, 20% purity and rate of 1.8×10^5 pps. From the calculations, we have observed that the final

RIB purities are strongly dependent upon the particular situation, but they are typically small in the few-percent range, whereas the collection efficiencies are escecially high at these energies and projectile-target combinations. TOF and)E tagging of the fragments will provide on-line characterization of the RIB mixture produced.

At present, for in-flight RIB capabilities at Texas A&M, we are examining two possibilities. First, a system of two superconducting solenoids (with a degrader at their intermediate image for beam clean-up). Second, a single superconducting solenoid as a preseparator/collector followed by a conventional achromatic fragment separator for RIB purification. In addition, a superconducting solenoid is considered as a pre-separator before an Ion Guide for the development of an IGISOL-type RIB concept at Texas A&M. The calculations for these configurations are currently underway.

References

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[3] D. H. Youngblood, J. D. Bronson, and G. Mouchaty, *Progress in Research*, Cyclotron Institute, Texas A&M University (1992-1993), p. 119.

[4] G. Kim, private communication.

[5] T. W. O'Donnell et al., Nucl. Instr. and Meth. **A422** (1999) 513.

[6] See contribution: "Rare Beam Production around the Fermi Energy" of this Annual Report, by G. A. Souliotis *et al.*

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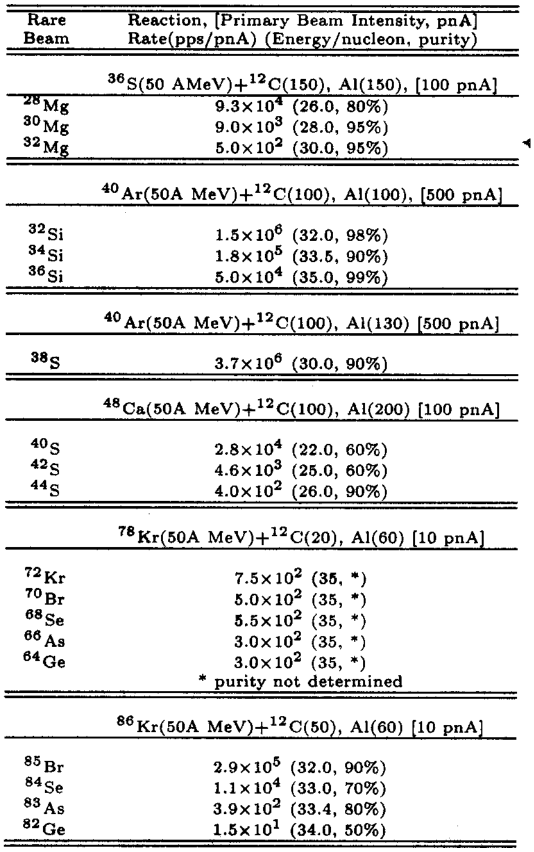
Table 1: Calculated Rare Beam Intensities (pps, primary beam intensity indicated) for the proposed projectile fragment separator. The reaction parameters are indicated. The target thickness (mg/cm^2 is given in parenthesis. The degrader material (thickness in parentheses) is given after the target. The energy (AMeV) and the purity (%) of the rare beams are given after the rate values.



Rare Beam	Reaction, [Primary Beam Intensity, pnA] Rate(pps/pnA) (Energy/nucleon, purity)
	^{36}S(50 AMeV)+^{12}C(150), Al(150), [100 pnA]
^{28}Mg	9.3×10^4 (26.0, 80%)
^{30}Mg	9.0×10^3 (28.0, 95%)
^{32}Mg	5.0×10^2 (30.0, 95%)
	^{40}Ar(50A MeV)+^{12}C(100), Al(100), [500 pnA]
^{32}Si	1.5×10^6 (32.0, 98%)
^{34}Si	1.8×10^5 (33.5, 90%)
^{36}Si	5.0×10^4 (35.0, 99%)
	^{40}Ar(50A MeV)+^{12}C(100), Al(130) [500 pnA]
^{38}S	3.7×10^6 (30.0, 90%)
	^{48}Ca(50A MeV)+^{12}C(100), Al(200) [100 pnA]
^{40}S	2.8×10^4 (22.0, 60%)
^{42}S	4.6×10^3 (25.0, 60%)
^{44}S	4.0×10^2 (26.0, 90%)
	^{78}Kr(50A MeV)+^{12}C(20), Al(60) [10 pnA]
^{72}Kr	7.5×10^2 (35, *)
^{70}Br	5.0×10^2 (35, *)
^{68}Se	5.5×10^2 (35, *)
^{66}As	3.0×10^2 (35, *)
^{64}Ge	3.0×10^2 (35, *)
	* purity not determined
	^{86}Kr(50A MeV)+^{12}C(50), Al(60) [10 pnA]
^{85}Br	2.9×10^5 (32.0, 90%)
^{84}Se	1.1×10^4 (33.0, 70%)
^{83}As	3.9×10^2 (33.4, 80%)
^{82}Ge	1.5×10^1 (34.0, 50%)