LA-UR- 96-4469

96-2???

CONF-960949--6

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Proc. 13th Int'l. Conference on Electromagnetic Isotope Separators and Techniques Related to their Applications, EMIS-13, Sept. 23-27, 1996, Bad Dürkheim, Germany

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A High-Intensity Thin Target He-Jet Production Source

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A thin-target He-jet system suited to the production and rapid transport of non-volatile radioactive species has been successfully operated with proton beam intensities of up to 700 μA. The system consists of a water-cooled, thin-target chamber, capillary gas transport system, moving tape/Ge detection system, and an aerosol generator/gas recirculator. The yields for a wide variety of uranium fission and deep spallation products have been measured and robust operation of the system demonstrated for several weeks. He-jet transport and collection efficiencies ranged between 15 and 25% with collection rates of 10^7 to 10^8 atoms/sec/isotope. The high-intensity, thin-target He-jet approach represents a robust production source for nonvolatile radioactive heavy ion beams.

Key words: He-jet, gas transport, radioactive beams
PACS: 29.25.Rm

1 Introduction

As the scientific community drives radioactive heavy ion beam facilities to ever higher beam intensities for a wider range of beams with improved beam qualities, one of the most crucial questions regards the ability to scale-up the target/ion source production region. Can the thick-target integrated ion source approach be operated reliably at the 100 μA level? And how might a much wider variety of beams be produced? Herein, we explore the use of a high-intensity, thin-target He-jet system [1,2] as an alternative and complementary production source to that of the standard thick-target approach. Relying on reaction products which recoil out of thin targets and are stopped and entrained in a surrounding gas volume that is rapidly swept away to a low radiation area, the He-jet approach is well suited to the production of non-volatile, refractory element species which are not readily released from thick targets. The loss in raw production rates resulting from the use of thin-targets can be partially offset by the use of multiple targets and higher primary beam intensities. This work highlights the development of a He-jet target that is capable of operating reliably at beam intensities of $\sim$ 700 μA of 800-MeV protons for months.

2 The High-Intensity He-jet Experiment

The high-intensity He-jet system, shown in Figure 1, consists of: (1) a water-cooled target chamber; (2) several differential pumped capillaries to rapidly transport the reaction products away from the target; (3) a tape collection and gamma-ray detection system; and (4) an aerosol generator / gas recirculation. The cylindrical target chamber consists of two thin-walled (0.7 mm) stainless steel coaxial tubes, which are aggressively cooled by high pressure water passed between the inner and outer tubes to keep target temperatures below 220^{o}C when heated by the 1-mA, 800 MeV proton beam ($\sim$5 kW deposited beam power) available at Los Alamos. The production target consists of a thin ($\sim 12mg/cm^2$) coating of $^{238}U_2O_3$ which is electroplated onto the inside surface of the inner tube. The entire target chamber is welded together for ruggedness. Fission and spallation products which recoil out of the target are stopped in the central volume of helium gas (typically pressurized to $\sim$ 2.5 atm) and attach themselves to aerosols suspended in the helium. Several differentially-pumped capillary tubes transport the reaction products to a collection tape transport system [3] located $\sim$33 m away. A high-purity Ge gamma-ray detection system measures the transported activities which are either continuously or sequential moved into the counting position by the tape drive. Because of the large amounts of transported activity (typically several Ci), the Ge detector was removed from the counting tape position by 1.6 m. Moreover, the Ge detector was well shielded and collimated to limit the detectors point of view to only the correct tape counting position. Gamma-ray spectra were recorded and analyzed off-line using an automated gamma-ray analysis code GAMANAL[5]. A closed-loop, gas recirculator system was constructed to reduce radioactive gas emissions to safe levels and enabled operation at high flow rates without excessive use of helium gas. This system consists of several pumps, purifying filters, and an evaporative, oven-type aerosol generator that can be remotely computer controlled. The system is designed to operate at target pressures of up to 6 atm and at flow rates of 1 std. liter/sec.

A variety of measurements were performed to characterize and optimize the performance of the He-jet system. These included the: (1) optimization of the

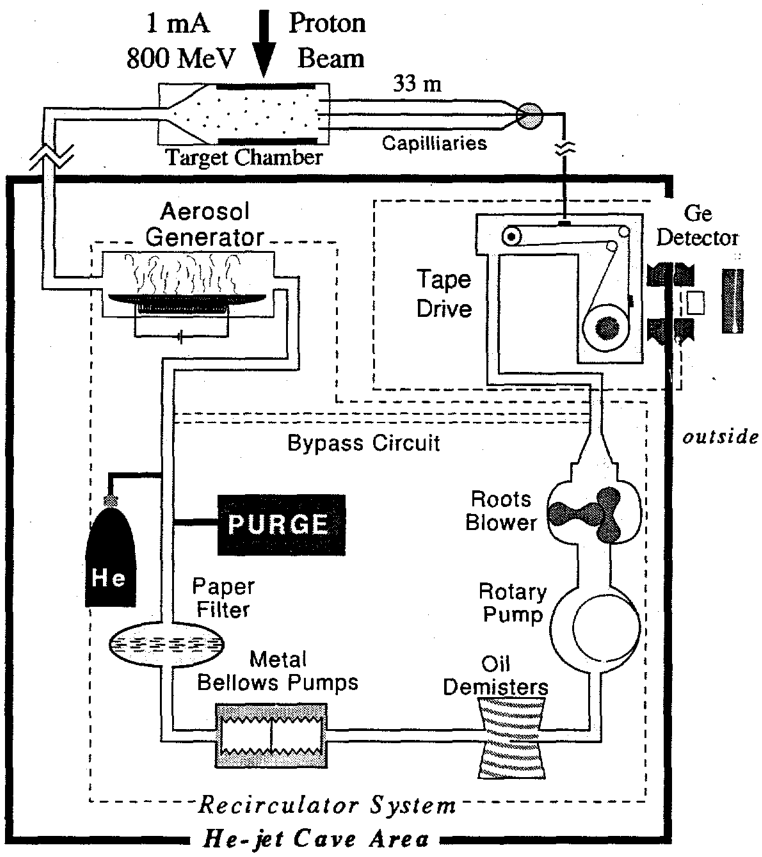

Fig. 1. Schematic layout of the high-intensity He-jet system.

aerosol conditions using either NaCl or KCl at different oven temperatures; (2) measurement of average transport times by pulsing the beam on and off; (3) investigation of recoil yields vs target pressure and capillary size; and (4) determination of recoil yields as a function of beam intensity from 10 to 700 μA. In brief (see [4] for details), we found that the He-jet system performed as expected. Optimized aerosol conditions were crucial in obtaining high transport efficiencies. As much as a factor of 20 reduction was noted when the oven was turned off. Average transport times were ~2 sec consistent with the combined sweep out time of the target chamber (~1.5 sec) and capillary transport time (~ 0.7 sec). (Increased speed could be obtained by using multiple capillaries.) Reaction product yields are found to increase with target pressure until the areal thickness of the gas become equal to stopping ranges of the recoils at which point the yields saturated. And all yields increased linearly with beam intensity showing no signs of beam heating turbulence effects up to 700 μA. Given stable aerosol conditions, the He-jet proved to work reliably. The He-jet efficiency is deduced from the measured collection rate, as determined from the gamma decay analysis, the calculated production rate using the known or empirical estimated [6] cross sections, and a calculation of the fraction of reaction products which recoil out of the target and are stopped in the He gas volume. The latter quantity was calculated using a Monte Carlo code utilizing average fission product recoil energies, a known range-energy relationships, and a uniform angular distribution for the reaction products. A sample of measured collection yields and He-jet efficiencies are given in table 1. Typical yields ranged from 10^7 to 10^8 atoms/sec/isotope with He-jet efficiencies of 15-25% for a variety of species. With the exception of noble gas and halide species, the efficiencies were found to be element independent.

3 Summary

A high-intensity, thin-target He-jet system has been shown to work reliably with proton beam intensity of 700 μA for several weeks. Measured yields ranged from 10^7 to 10^8 atoms/sec/isotope (depending on production cross section) for a wide range of p+U reaction products with overall He-jet efficiencies of 15-25%. Given the much higher primary beam intensities used, our yields are approximately 100x larger than comparable He-jet systems. Especially noteworthy are the high yields of refractory species made available by this method. As such a high-intensity He-jet system represents an attractive and complimentary alternative to the standard thick target method for the production of ISOL-based radioactive beams.

References

[1] J. M. Wouters, W. L. Talbert, and D. J. Vieira, Proc. of the Workshop on the Production and Use of Intense Radioactive Beams at the IsoSpin Laboratory, J. D. Garret, ed., Oct. 1992, Oak Ridge Institute for Science and Education Report CONF-9110121, p. 309 (1993).

[2] D. J. Vieira, H. J. Kimerly, D. L. Grisham, D. Rosenauer, Y. Bai, W. L. Talbert, and J. M. Wouters, Proc. 3rd Int. Conf. on Radioactive Nuclear Beams, D. J. Morrissey, ed., May 1993, East Lansing, MI (Editions Frontiers, Gif-sur-Yvette, 1993) p. 115.

[3] R. L. Mlekodaj, E. F. Zganjar and J. D. Cole, Nucl. Instrum. Meth. **186**, 239 (1981).

[4] Y. Bai, (PhD thesis, Utah State University, unpublished, 1996).

[5] R. Gunnink and J. B. Niday, Lawrence Livermore Laboratory Report UCRL-51061, Vol. I (1972).

[6] W. L. Talbert, 6th Int. Conf. on Nuclei Far from Stability & 9th Int. Conf. on Atomic Masses and Fundamental Constants, Inst. Phys. Conf. **132**, 923 (1992).

Table 1
Collection rates and derived He-jet efficiencies for a sampling of isotopes measured with 685 μA beam intensity, 12.5 mg/cm^2 $^{238}U_2O_3$ target, 2.4 atm He gas pressure, and KCl aerosols. The cross sections in brackets are empirically estimated [6].

Isotope $^{A}Z(T_{1/2})$	Cross-section (mb)	Measured Yields (atoms/s)	Calc. % stopped in He	He-jet (%) Efficiency
^{84}Rb(32.9 d)	4.2 ± 0.9	(3.5 ± 0.2)x10^7	45	16 ± 4
^{89}Rb(15.2 min)	10 ± 1	(8.7 ± 0.2)x10^7	45	16 ± 2
^{91}Rb(58.4 sec)	9.0 ± 0.8	(1.0 ± 0.2)x10^8	45	21 ± 4
^{92}Rb(4.5 sec)	8.3 ± 0.8	(3.9 ± 0.1)x10^7	45	14 ± 2
^{94}Rb(2.7 sec)	2.5 ± 0.4	(1.2 ± 0.2)x10^7	45	15 ± 3
^{97}Zr(16.9 hr)	[13.3]	(1.5 ± 0.1)x10^8	43	[22]
^{99}Mo(65.9 hr)	32 ± 5	(2.8 ± 0.1)x10^8	44	17 ± 3
^{104}Tc(18.4 min)	[14]	(1.9 ± 0.1)x10^8	42	[27]
^{105}Tc(7.6 min)	[13.8]	(1.5 ± 0.3)x10^8	42	[23]
^{105}Ru(4.44 hr)	[15.2]	(2.2 ± 0.1)x10^8	42	[29]
^{107}Rh(21.7 min)	[15.4]	(2.3 ± 0.3)x10^8	41	[30]
^{129}Cs(32.1 hr)	4.2 ± 0.2	(3.0 ± 0.1)x10^7	31	20 ± 1
^{138}Cs(32.2 min)	4.8 ± 0.3	(3.8 ± 0.1)x10^7	34	22 ± 2
^{142}Cs(1.7 sec)	1.0 ± 0.2	(4.2 ± 0.1)x10^6	34	22 ± 4