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Abstract:

Some general improvements to the on-line mass separator RAMA have yielded a factor of five increase in yield for most elements. By placing the ion source region at the full accelerating potential of 20 kV, the effective skimmer-plasma distance has been reduced from 12 cm to <2 cm. Changes in the helium-jet chamber and large volume pumping arrangement necessitated by placing the ion source region at high voltage are also given. Finally, details for a new highly shielded detector station are presented.

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1. Introduction

The construction and initial operation of the on-line mass separator RAMA [1,2,3] represented one of the earliest successful attempts at coupling the helium-jet recoil transport method with isotope separation techniques. RAMA had achieved its initial design goal of separating the $A = 4n$, $T_z = -2$ series of strong beta-delayed proton emitters from the simultaneously and copiously produced $A = 4n + 1$, $T_z = -3/2$ series of beta-delayed proton emitters. These included [4] decay studies of ^{20}Mg , ^{24}Si and ^{36}Ca . Further chemical universality was demonstrated by beta decay studies of several In isotopes [5]. Nevertheless, the yield was insufficient for some studies of very proton rich nuclei because the cross sections for the production of these nuclei are $< 1 \mu\text{b}$. Therefore, improvements to RAMA became necessary. Three primary considerations for increasing the total yields and for improving the general system reliability were incorporated into the design plans. Initial redesigns included significantly reducing the volume of the helium-jet chamber, shortening of the skimmer-capillary distance, shortening of the source itself and changing the ion extractor. The last improvement to RAMA is the construction of a new shielded measuring station necessary because the general background in the focal plane region was far too high for most desired β - γ decay studies. The nature of these changes and some initial tests will be detailed.

2. Helium-Jet System

Although the prior helium-jet chamber [3] worked extremely well, a new significantly smaller volume chamber was needed to decrease the purging time, to easily change the effective recoil range and to decrease the capillary length (the capillary inside the chamber was 17 cm long) for studies of very short-lived nuclides utilizing only the helium-jet. The chamber depicted in fig. 1 has a volume of 0.7 l compared with 35 l for the previous chamber, thus reducing the purging time from ~10 m to ~10 s. The effective use of nitrogen-cooled entrance and exit windows has been retained while an internal cooling water passage has been added for more consistent operation. The slotted collection cylinder permits adjustment of the target-capillary distance for varying recoil ranges which change with each different nuclear reaction. Although the single capillary arrangement is shown in fig. 1, a multiple-capillary, multiple-target system is normally used. Normal operating parameters for this system remain as before [2,3], including the 200-300 ms transit time from the target to the ion source.

3. Ion Source Region

The main goal in redesigning the ion source region was to decrease the distance between the capillary exit and the ion source plasma. The primary limitation in the old set-up was the large potential difference between the skimmer and the ion source. Discharges in this high pressure region often caused a general high-voltage breakdown; thus reducing this distance while maintaining the 20 kV potential difference was impossible. The new ion source region depicted in fig. 2 lies at high-voltage, thus eliminating sparking

between the source and the skimmer. The capillary-plasma distance has been reduced from ~12 cm to <2 cm, which from geometric considerations alone should give a 30-50 fold increase in yield. Placing the skimmer at high voltage was made possible by a high-voltage stepdown unit, which is necessary to hold the potential difference between the skimmer region and the Roots pump. The operating pressure in this region is between 30 and 80 mTorr; therefore accelerated electrons would start an avalanche discharge if unquenched. As can be seen in fig. 3, this high-voltage stepdown unit utilizes a third reverse bias grid which causes the electrons to see an alternating accelerating and decelerating potential; thus an avalanche is prevented. The reverse bias voltage was determined empirically. This unit has been tested to 45 kV with helium as a transport gas under the conditions listed in fig. 3.

As can be seen in fig. 2, reduction of the skimmer plasma distance also required a redesign of the ion source. The previous [3] versions of the hollow-cathode ion source were generally limited by a boron nitride insulator maintained at a temperature >2000 C. Without changing any fundamental operating parameters, the hollow-cathode source shown in fig. 4 has been constructed. This ion source is now only 3 cm long. Additionally, all high temperature insulators have been eliminated. The anode-cathode distance is maintained by independently threaded pieces. Since the operational characteristics (e.g. plasma potential and density) have remained the same, this should give an increase in the yield of a factor of ~40, strictly due to the increased solid angle. Although this hollow-cathode ion source has inherently lower efficiencies than other sources such as the Nier-Bernas helium-jet coupled sources at Grenoble [6] and Chalk River [7], the inability

of RAMA to handle slit-extracted beams and the unproven reliability of other types of sources suitable for fast coupling to the helium-jet cause us to continue utilizing this very simple ion source.

The extractor has also been completely redesigned (see fig. 3) as an accel-decel unit for ion optical reasons; it has a thin ring construction to permit better vacuum pumping, thus reducing the scattering of the accelerated ions with the residual gas. Figure 5 shows a photograph of the new extractor.

4. Shielded Detector Station

The relatively close proximity of the cyclotron beam to the focal plane position often created high background problems. Thus, β - γ experiments on most very low yield activities were not possible. The background consisted of neutron-induced long-lived gamma emitters such as ^{60}Co , ^{40}K and ^{24}Na and short-lived activities induced by high neutron fluxes associated with light-ion bombardments. To overcome this problem we are moving the target-faraday cup assembly ~4 m downstream and we are extending the RAMA beam line to a highly shielded measuring position 7 m downstream from the focal plane. Figures 6 and 7 show different views of the new measuring station. As can be seen in these figures, there is a thick borated water shielding to suppress neutrons coming from the cyclotron and transport beam lines and a lead wall to suppress the general γ background. This new measuring station will be initially operated in two modes: with a differentially pumped tape drive system and with a fast deflector system. The tape drive system is illustrated in fig. 6 and has been described in more detail elsewhere [3]. The 1 m/sec tape speed and the 30 cm distance between detector stations limit

the nuclides which can be studied to those with half-lives greater than a few seconds. Additionally, the tape drive system can only effectively observe $\sim 1/4$ of the desired activity. To increase this last ratio to one, we are constructing measuring stations on both 0° and 3° beam lines depicted in fig. 7. The angle of 3° has been chosen so that the deflector plates can operate at ~ 1 kV. This voltage can switch the beam from one position to the other in $<1 \mu\text{s}$. This permits us to measure half-lives of very short-lived nuclei (<100 ms) with essentially no collection-observation period losses. The only initial limitation will be a buildup of long-lived daughter activities which can be eliminated by the addition of miniature tape drives used solely to remove daughter activities. Such a system will eventually supplant the tape drive system.

5. Initial Results and Conclusions

Many off- and on-line tests have been performed with the RAMA separator. Although ethylene glycol was always the helium-jet additive of choice [1] because of the $<2^\circ$ aerosol opening angle, recent tests have demonstrated that the very large temperature gradient associated with this new geometrical configuration causes the activity bearing aerosols to explode before they reach the plasma region of the ion source. Additional tests with unfiltered NaCl ($12-15^\circ$ opening angle, $T_M = 801^\circ\text{C}$), KCl ($8-10^\circ$ opening angle, $T_M = 776^\circ\text{C}$) and PbCl_2 ($7-8^\circ$ opening angle, $T_M = 501^\circ\text{C}$) aerosols have verified this hypothesis. Although the utilization of filtered aerosols will soon commence, the best current results have been obtained with KCl. We will also cool the entrance to the ion source to reduce the loss of activity.

$^{152,153}\text{Er}$ alpha radioactivity produced in the $^{142}\text{Nd} (^{16}\text{O}, \text{xn})$ reaction have been used in most of these measurements. The ^{153}Er spectrum in fig. 8 was acquired in a few minutes after optimizing many parameters. The rate of ~ 40 atoms/s corresponds to an absolute efficiency of 0.05 percent. This represents an increase of only a factor of 5 [2]. However, we believe the simple changes mentioned above should permit the realization of our geometric increase utilizing the same ion source technology. Use of different types of ion sources suitable for coupling to the helium-jet should also provide an increase in absolute efficiency.

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Figure Captions

- Fig. 1 Schematic diagram of the new helium-jet chamber.
- Fig. 2 New ion source region schematic.
- Fig. 3 RAMA high-voltage step-down unit.
- Fig. 4 Cross sectional depiction of the hollow-cathode ion source.
- Fig. 5 Photograph of the ion extractor.
- Fig. 6 Complete shielded detector station (top view) showing the tape drive unit in its assembled position.
- Fig. 7 Side view of the shielded detector station showing the fast deflector assembly.
- Fig. 8 Alpha particle spectrum arising from the $^{16}\text{O} + ^{142}\text{Nd}$ reaction collected at the mass 153 position on the RAMA focal plane.

Fig. 1

XBL 868-11650

XBL 868-11655

Fig. 2

$$R_1 = 320 \text{ M}\Omega, R_2 = 4.7 \text{ M}\Omega$$

Primary grid spacing = 7 mm

Secondary grid spacing = 3 mm

He breakdown voltage > 45 kV

RAMA Voltage Stepdown Unit

Fig. 3

XBL 868-11654

- ⊗ Tungsten
- ▨ Graphite
- ▤ Tantalum
- ▩ Boron Nitride

XBL 868-11653

Fig. 4

Fig. 5

CBB 868-6128

RAMA Shielded Detector Station: Tape Drive System

Fig. 6

RAMA Shielded Detector Station: Fast Deflection System

Fig. 7

XBL 868-11652

Fig. 8

XBL 868-11656

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