Title
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A SYSTEM FOR STUDYING ACCELERATOR-PRODUCED SHORT-LIVED ALPHA EMITTERS+

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ABSTRACT

A target assembly and detection system is described which has applications for studying accelerator-produced short-lived alpha activities with good efficiency and excellent alpha particle resolution. The system is simple and fast and allows for the continuous recording of alpha particle spectra at the same time the activity is produced.

1. INTRODUCTION

A research program was recently undertaken to study the alpha decay systematics of nuclides near the 82-neutron shell and near the double closed shell of 82-protons and 126-neutrons. In order to study short-lived alpha emitters which were produced by heavy-ion induced compound nucleus reactions in these regions, a system was developed to observe these activities on a relatively fast time scale.

Elegant techniques for the production and identification of short-lived alpha emitters have been developed by Ghiorso and co-workers in their studies on the transplutonium elements[1,2,3]. Because of their need for extremely high sensitivity, they developed systems which were

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necessarily complex in order to attain the maximum efficiency for detecting very small levels of alpha activity. For our work, high sensitivity was not an essential requirement so that it was possible to develop a much simpler system by sacrificing some sensitivity for very low levels of activity. This system has proven to be useful for studying alpha activities with half-lives down to 0.03 sec and has given alpha particle spectra with 30 to 35 kev resolution in the presence of an intense beta-gamma background. Some features of this method are similar to a technique of recoil collection by gas entrainment recently described by Friedman and Mohr[4].

2. EXPERIMENTAL DETAILS AND RESULTS

2.1. Description

A schematic diagram of the target assembly and detection system is shown in Fig. 1. A collimated beam of heavy ions from the accelerator enters the target assembly through a thin nickel window (0.0025 mm thick), passes through an aluminum absorber wheel, which is used to degrade the beam energy a variable amount, and a second wheel which contains the target. Nuclear reactions which occur in the target produce a number of recoils whose forward momentum is sufficient to eject them from the target. The target is usually sufficiently thick (~ 2 mg/cm^2) that recoils with energies varying from near zero to a maximum value leave the target. The recoils are thermalized by helium at a pressure of 1 atm and are swept through a 0.5 mm diameter orifice into a second chamber which is under vacuum and adjacent to the target chamber. The orifice is located on the edge of a cylindrical hollow brass plug which fits into the wall separating the two chambers and extends into the target chamber. The stream of helium entering the vacuum chamber, carrying with it the thermalized recoils, impinges on the inner wall of the brass plug and a large fraction of the recoils adhere to the metal surface. The helium, which does not adhere, is pumped off. A solid state alpha particle detector of the gold-surface barrier type is used to record the alpha activity from the recoils collected. The orifice is aligned vertically with the beam axis and the outer edge of the beam, defined approximately by a 9 mm diameter collimator in the front part of the assembly, passes within 1 mm of the orifice and the front face of the brass plug. The orifice, which faces the target, is located 7 cm from the center of the target. In the vacuum chamber, the recoils travel 2.5 cm from the orifice before striking the metal surface where they are collected over an area of $\sim 4\ mm^2$. The angle of the orifice relative to the beam axis defines the position where the recoils are collected. Helium is pumped continuously from the vacuum chamber at the rate of 12 litres per second. The steady state pressure inside the vacuum chamber was measured to be $\sim$1000 u.

2.2. Collection Efficiency and Collection Time

The overall collecting efficiency (number of recoils collected to number ejected from target) was measured to be 0.6. This was obtained by comparing the yield with that measured by an electrostatic collection technique whose collecting efficiency had previously been studied. The collection efficiency was found to be independent of bombarding energy and beam intensity from 50 mua to the maximum available current of 500 mu amperes. The approximate recoil collection time was deduced by results from various experiments where known alpha emitters with half-lives less than 0.1 sec were produced. It was possible to observe alpha activities with half-lives $\sim$ 0.06 sec long and obtain decay curves which did not show any effect of the collection time. However, nuclides such as Fr^{214} and Ra^{215}, with half-lives of 3.9 and 1.6 m sec, were not observed when reactions which produce these nuclides in good yield were studied. It is estimated from these observations that the average recoil collection time is on the order of 0.025 sec. This limit on the collection time is probably determined for the most part by the diffusion of the recoils in the helium before being swept through the orifice. This is supported by the fact that longer recoil collection times were observed when the distance between the orifice and the beam axis was increased. There was improvement in the collection time when the orifice was allowed to intercept the beam. However, with this arrangement there was some difficulty with erratic collection efficiency and increased radiation background which affected the detector. Other gases such as N_2, air and argon were tried at various pressures but none of these gave as good a collection efficiency and collection time as helium. The diameter of the orifice was also varied. The collection time decreased with increasing orifice size to a diameter of 0.5 mm. Above that size, no effect on the collection time was observed but the collecting efficiency decreased, probably because of increasing turbulent flow of the helium.

2.3. Results on Alpha Particle Spectra Measurements

With the detector and electronics system that was used, a standard alpha source in the absence of beam gave a resolution of 25 kev (full width at half maximum) at a steady state helium pressure of 1000 u in the vacuum chamber. Alpha particle spectra of recoils collected from the target by this gas sweeping technique gave resolutions of between 30 and 35 kev depending on the level of the accumulated beta-gamma background. For cross section measurements, alpha activities with half-lives up to 2 min were allowed to build up to an equilibrium level and alpha spectra were recorded continuously while the recoils were being produced and collected.

The beam of the heavy-ion accelerator used for these measurements is pulsed at 15 per second and the pulse width is 0.0025 sec. During the period that the beam is on, the radiation background affecting the detector is considerably higher than between beam bursts and the detection system is usually gated off for the duration of the beam burst. Examples of alpha spectra obtained by counting between beam bursts are shown in Fig. 2. The level of tailing on the low energy side of an essentially single alpha particle group (Fig. 2 D) corresponds to 1% of the peak height. Most of this tailing is due to the steady state pressure of helium in the vacuum chamber and to the collection of a small fraction of scattered recoils on the face of the detector.

2.4. Half-Life Measurements

For measurements of half-lives less than 1 min, an automatic cycling system was used to control the bombarding and counting time.

The following is a general description of the operation of this system. For normal operation of the heavy-ion accelerator, the ion source and extraction voltage are pulsed from a trigger signal synchronized with the RF pulse which accelerates the ions. To turn the heavy-ion beam on and off for a preset time, a timing circuit was used which controls the synchronization of the heavy-ion source trigger with the RF pulse. For "beam on" operation, a DC signal from the timing circuit is sent to the source trigger control resulting in a synchronization of the trigger pulse with the RF pulse. To turn the beam off, the DC voltage is removed which causes the source trigger to be delayed with respect to the RF pulse and an immediate loss of beam occurs. At the time that the DC signal is removed, a trigger pulse is formed by the timing circuit which is used to initiate the operation of a time-to-height converter whose input comprises alpha pulses selected by a single-channel analyzer and whose output yields pulses which are analyzed to give the decay curve for the particular alpha group being studied. At the end of the preset "beam off" period, the DC signal is then restored to the source trigger control allowing the source trigger pulse to be again synchronized with the RF pulse for "beam on" operation. With this system, beam can be sent to the target assembly for periods as long as desired and as short as 0.1 sec. The "beam off" periods can be similarly controlled. For half-lives on the order of 0.2 sec, up to 1000 cycles of 1 sec bombardments and 2 sec counting times have been used and excellent decay curves have been obtained. A block diagram of the system is shown in Fig. 3.

3. ACKNOWLEDGEMENTS

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5. FIGURE CAPTIONS

Fig. 1 Schematic diagram of target assembly and detection system.

Fig. 2 Alpha particle spectra of nuclides produced by $Nd^{142} + O^{16}$ bombardments at various incident energies. These spectra were obtained from samples of recoils which were being continuously replenished by recoils produced in the target assembly.

Fig. 3 Block diagram of system used to control bombarding and counting time for half-life measurements.

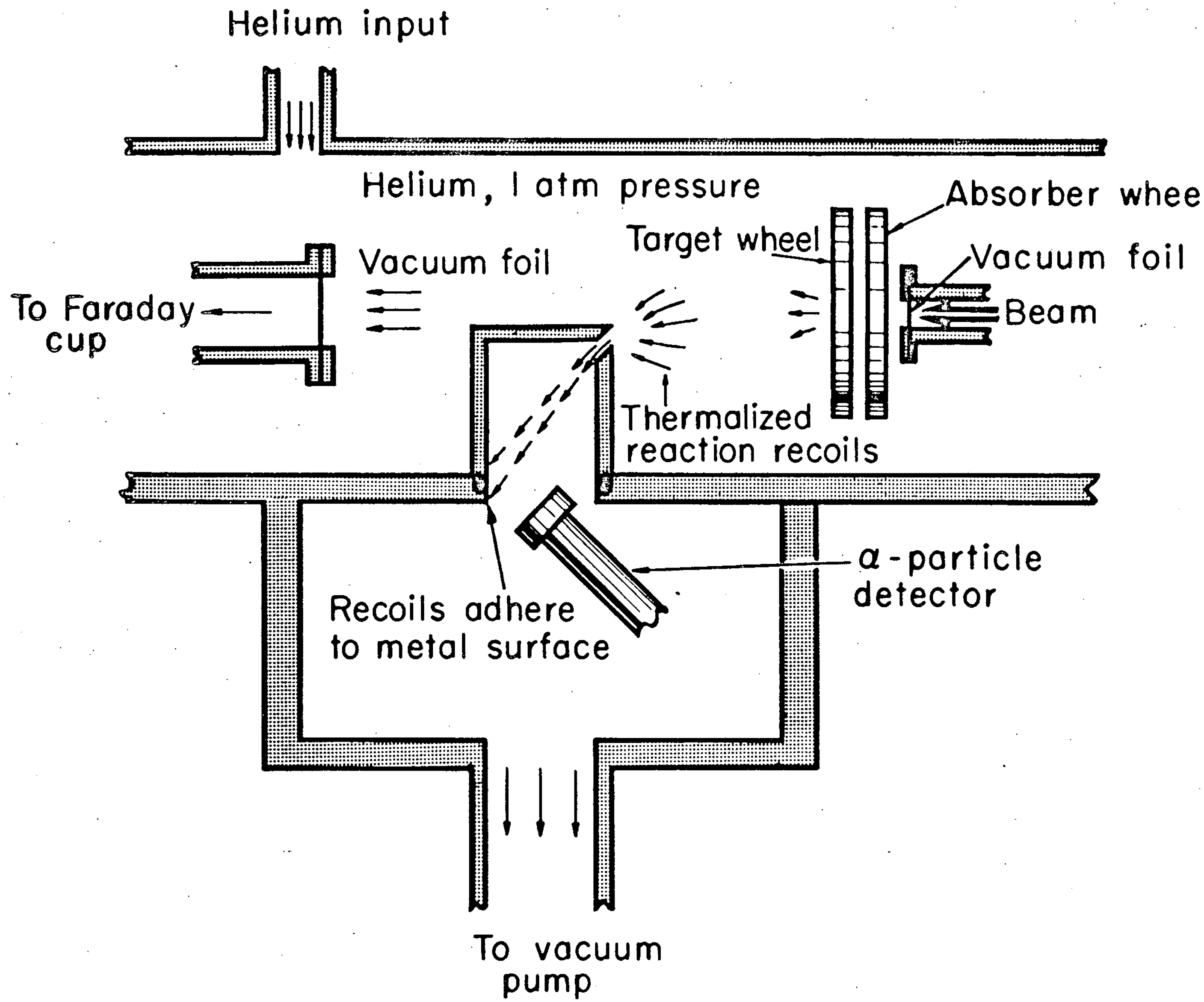

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Fig. 1.

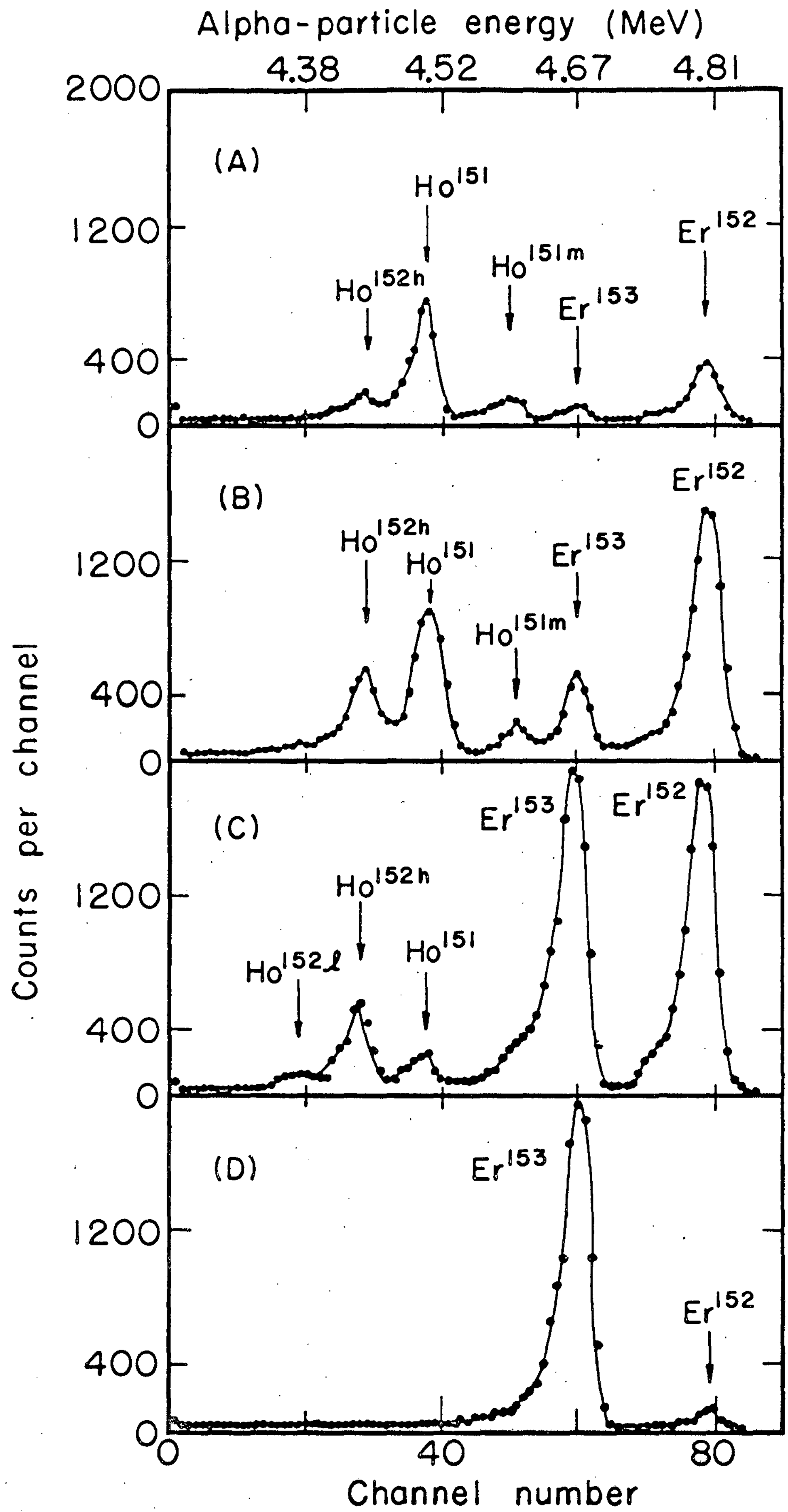

Fig. 2. MU-29383

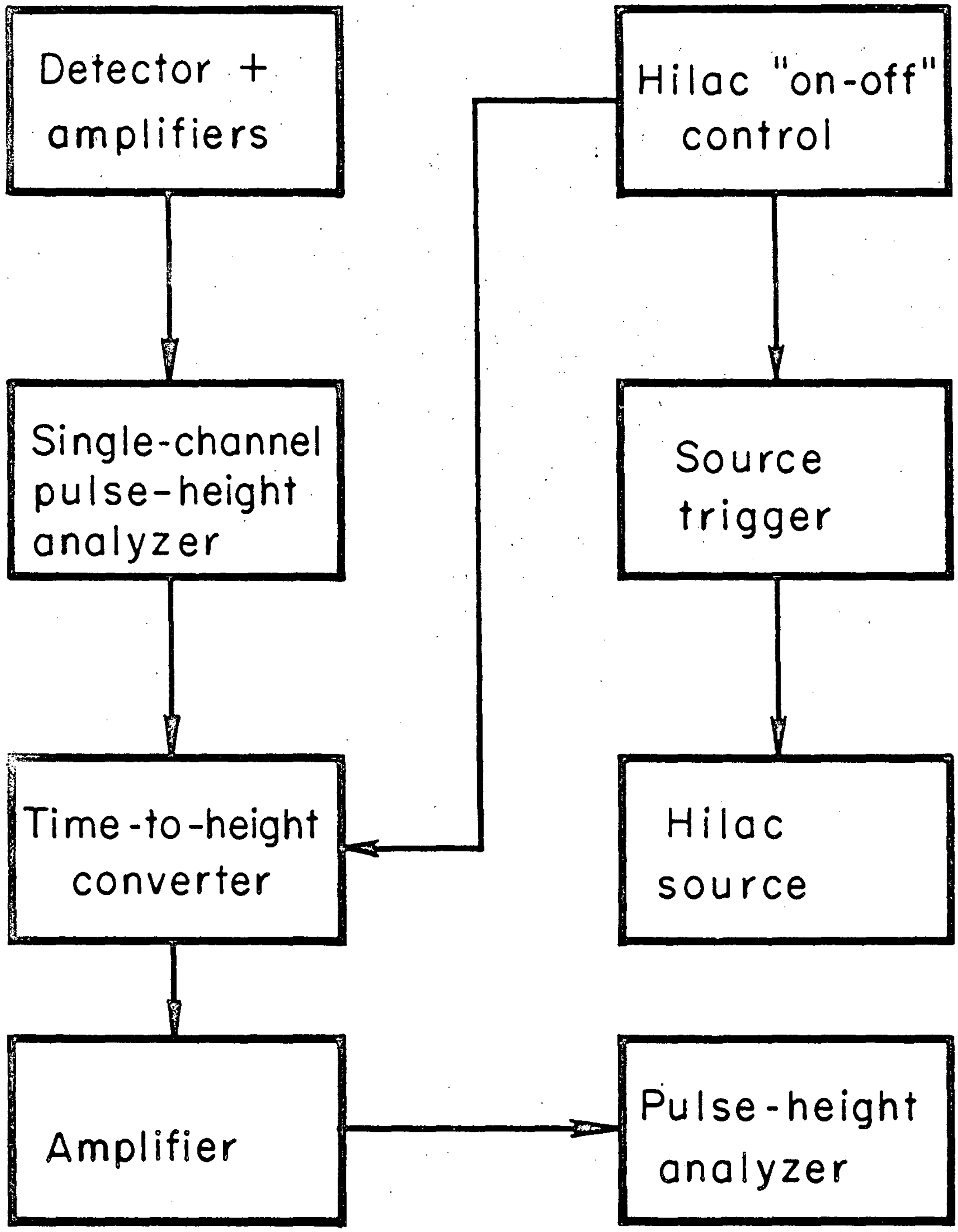

Fig. 3.

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