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A He-JET CHOPPER FOR MEASURING HALF-LIVES OF SHORT-LIVED NUCLEI*

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A He-jet chopper has been built to enable one to measure the half-lives of nuclear species from several seconds to as short as several tens of milliseconds. The chopper has been used to measure some of the mirror beta decays in the $f_{7/2}$ shell.

1. Introduction

The He-jet recoil transport system (HeJRTS) has become a routinely used tool for the study of nuclei far from stability[1,2]). One type of experiment is the simple measurement of a half-life, usually performed by collecting a spot of radioactivity from the HeJRTS, mechanically moving this spot in front of a detector, and watching it decay away. This method works quite well but does not permit one to measure half-lives as short as the HeJRTS is capable of handling, for it can transport activities in several tens of msec, while it takes about 1 s to move the spot to a well-shielded detector.

Clearly it would be preferable not to move the spot, but rather turn the HeJRTS on and off. Unfortunately, this is difficult to do. If one attempts to pulse the

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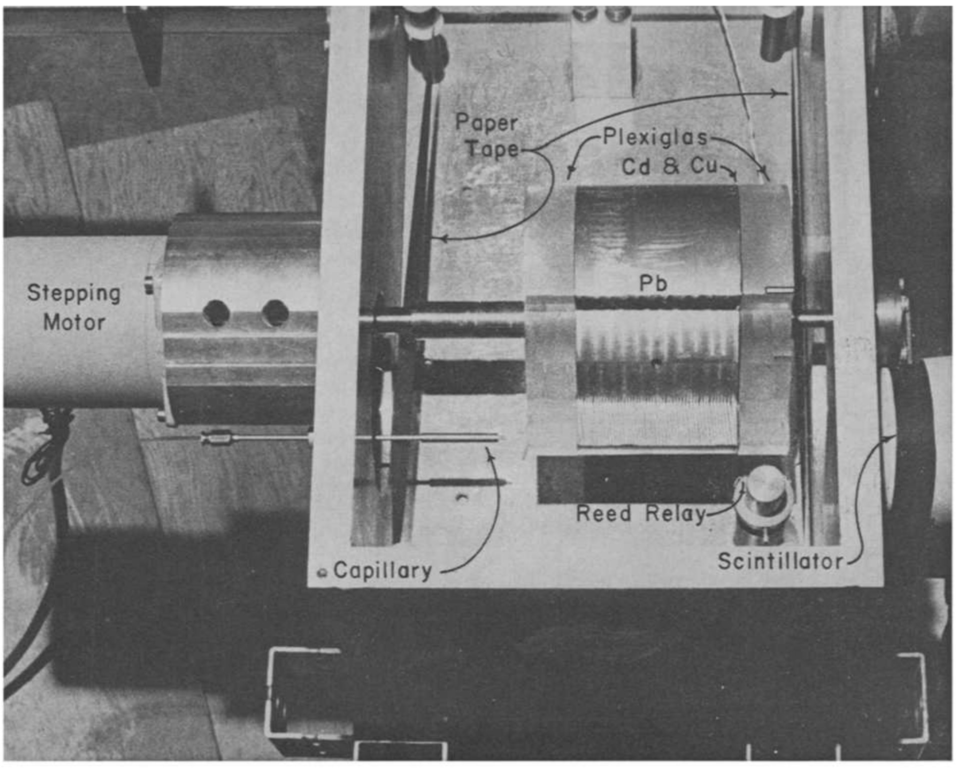

Fig. 1. Photograph of the Pb chopper in place ready for data to be taken.

HeJRTS by interrupting the gas supply, it takes several seconds for the transport to cease. Also, if one attempts to insert a valve in the capillary, it disrupts the laminar flow (cf. ref. 1) for a discussion of Reynolds numbers and the problems inherent in maintaining a laminar flow) and results in a very low transport efficiency. The best solution seems to be to chop the He-jet between the capillary exit and the detector. In this paper we describe such a system and give an example of its operation.

2. The chopper

When one decides to chop the He-jet effluent in the vicinity of the detector, the chopper not only must block the He-jet flow, but also must shield the detector from the radioactivity collected on the chopper while the He-jet is supposed to be off. If the radiation is primarily β-radiation, this requires only a chopping element of about 50 mm of plastic to block up to 10 MeV electrons. If, however, the radiation is γ-radiation, several cm of Pb needs to be used. The mass of the Pb prohibits one from using a chopper of oscillatory motion, so the simplest solution is circular motion.

Our chopper is a rotating disc with an aperture. The size of the aperture, the thickness of the disc, and the material of the disc can easily be changed to suit the experiment. For β-radiation we use plexiglas discs of 25–50 mm in thickness. For γ-radiation the disc (cylinder) is $\approx$15 cm of graded Pb with plexiglas on each end to help prevent X-rays and bremsstrahlung.

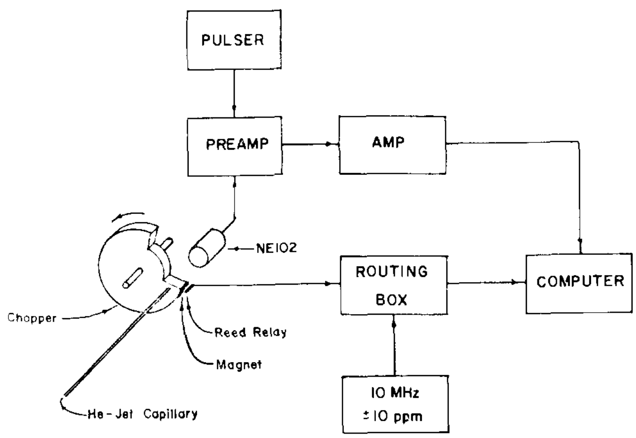

Fig. 2. Block diagram of the experimental set-up for measuring the ^{47}Cr half-life. The He-jet sprays activity onto a paper tape (not shown), which is positioned between the chopper and the NE102 scintillator. This tape is moved several inches at the end of each cycle to reduce long-lived background.

The Pb chopper is shown in fig. 1. It is rotated by a stepping motor which operates outside the vacuum box for simplicity and cooling. A stepping motor was chosen because it provides precise control of the speed; however, the stepping motor cannot be firmly connected to the Pb cylinder because the cylinder's inertia is too great to permit proper stepping. A clutch coupling remedies this situation and enables the 20 kg cylinder to be driven easily with a 0.6 N·m (85 oz·in.) motor. Maximum speed is about two revolutions per second. Proper aperture width makes this usable for measuring half-lives as short as about 10 ms. Since the stepping motor is more for proper speed than for positioning, the position of the chopper is sensed by a reed relay, which is activated by magnets on the chopper. When the chopper has blocked off the He-jet, the magnet closes the relay and thus resets a sequencer which routes the detector signals in the computer. The sequencer counts clock pulses and generates 16 distinct logic outputs, each of which can be set to go "high" at any desired clock count and return "low" at any desired clock count. The clock is a 10 MHz oscillator accurate and stable to within 10 ppm.

3. Example and conclusions

As an example of the chopper's utility we show the measurement of the half-life of ^{47}Cr. The ^{47}Cr was

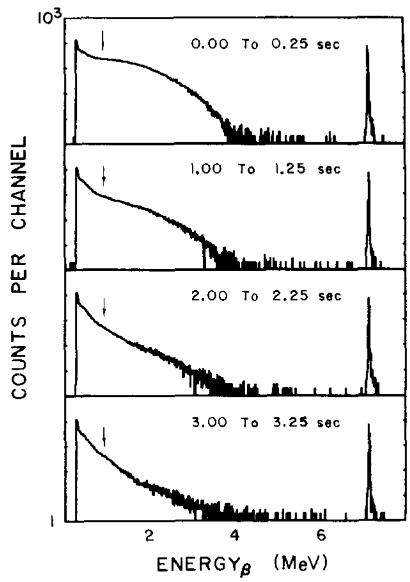

Fig. 3. β^+ spectra for measuring the Cr half-life. Shown are the 1st, 5th, 9th, and 13th of 13 time-routed spectra. The counts occurring at energies lower than that indicated by the arrow were ignored in the data analysis.

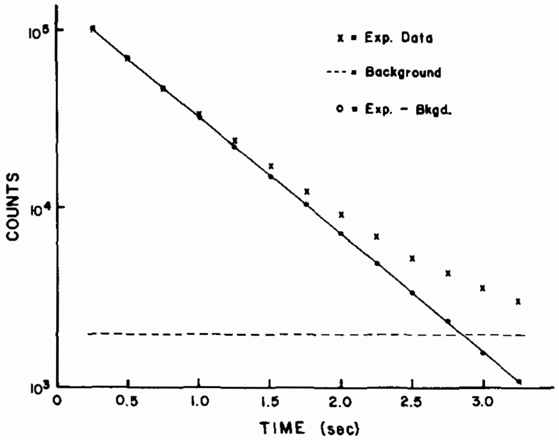

Fig. 4. ^{47}Cr half-life data and fit.

produced by the $^{46}Ti(\tau, 2n)^{47}Cr$ reaction and brought to the chopper with a 1.4 mm × 8 m capillary. The ^{47}Cr events were identified from the other counts, from nearby neighbors, by their high-energy positrons ($Q_\varepsilon = 7.3$ MeV) detected in an NE102 plastic scintillator[3]). The chopper was a 25 mm thick plexiglas disc which was operated to yield a He-jet on-period of 1 s and a He-jet off-period of 4 s. The chopper, in combination with the Al vacuum window, is capable of stopping 6 MeV positrons.

The schematic for the experiment is shown in fig. 2, and some of the data are shown in fig. 3. The counts per channel between about 1 MeV and 4 MeV were added to yield the counts per time interval. There is a background due to Compton events from high-energy γ-rays. However, the shortest-lived background is ^{47}V with a half-life of 32 min, and since 32 min is very large compared to a chopper cycle of 5 s, the background can be considered to be constant. The data and fit are shown in fig. 4. The half-life is calculated to be 460 ms $\pm$ 1.5 ms, which yields $\log ft = 3.63$.

The choppers described work quite well and are easily adapted to a wide range of particular experiments involving both β- and γ-activities. The system should easily enable one to measure half-lives as short as one can transport with the He-jet.

References

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