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Accelerator mass spectrometry programme and related developments at the BARC–TIFR Pelletron accelerator

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ABSTRACT

The accelerator mass spectrometry programme and the related developments based on the BARC–TIFR Pelletron accelerator is described. A segmented gas detector and beam chopper control electronics have been developed for conducting ^{36}Cl measurements. Distinct energy loss characteristics of the gas detector and beam chopper performance are presented. Also presented are the initial results for the measurement of ^{36}Cl in standard and samples of unknown concentration.

1. Introduction

The accelerator mass spectrometry (AMS) is a versatile technique employed in multidisciplinary programmes [1–3]. The AMS programme at the BARC–TIFR 14UD Pelletron accelerator has been initiated with major emphasis on the determination of ^{36}Cl concentration in environment in general and water samples in particular. The system used for AMS measurement based on a 14 MV Tandem Accelerator including the operational performance of a low energy beam chopper is described in Section 2. Section 3 describes the detailed detector characteristics. Presented in Section 4 are the results of ^{36}Cl concentration measurement for various samples.

2. The AMS system

The Pelletron accelerator and the beam line components along with the detector system developed in-house are shown in Figs. 1 and 2.

2.1. Ion source and beam extraction system

The single cathode SNICS (Source of negative ions by Cesium Sputtering) was thoroughly cleaned and assembled before conducting the AMS measurements to minimize "source memory effects". Cl^- ions were sputtered from a AgCl cathode at 2 keV Cs^+ ion bombardment energy. The extracted Cl^- ions were pre-accelerated (pre-acceleration voltage of 150 kV) and mass selected before injecting into the accelerator. Typical analyzed intensities of Cl^- ions (sum of ^{35}Cl and ^{37}Cl ions) utilized in the current set of measurements were up to 10 μA or so.

2.2. Sample details

The blank and the standard samples obtained from Prime Lab, Purdue University, USA, have been used to assess the beam transmission efficiency through the accelerator and for initial quantitative measurement of ^{35}Cl/^{37}Cl and ^{36}Cl/Cl ratios (Cl stands for ^{35}Cl + ^{37}Cl). Additional measurements were also done using the AgCl samples, which were prepared from the ground water collected from different locations in South India.

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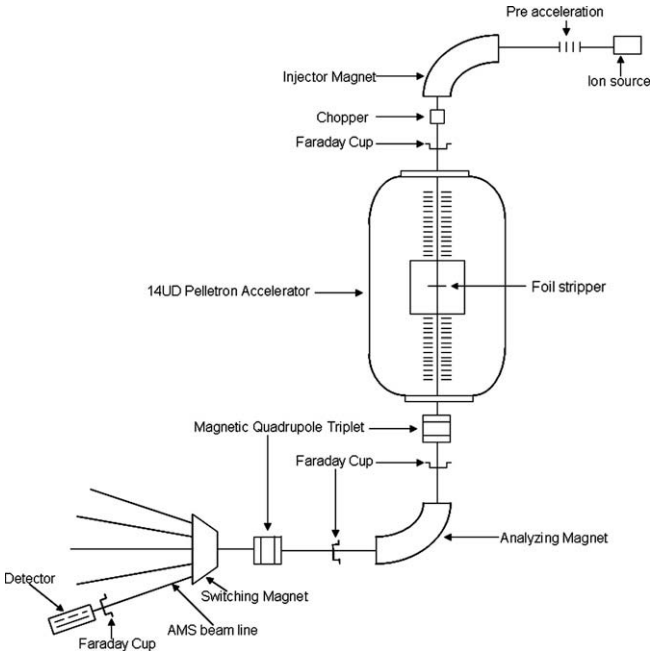

Fig. 1. Schematic layout of Pelletron tandem accelerator and AMS system.

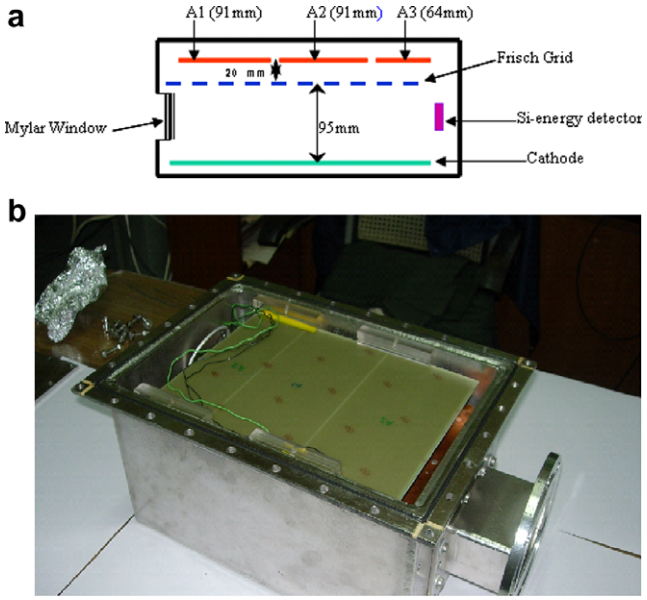

Fig. 3. (a) Schematic diagram of segmented gas detector. The size of the mylar window is 30 mm (width) × 25 mm (height). (b) Photograph of segmented gas detector.

2.3. The low energy beam chopper

It is not possible to inject more than a few μA of Cl^- ions into the accelerator without beam loading effects. Therefore, the stable chlorine beam has to be attenuated before injecting into the accelerator if the maximum yield from the ion source is to be utilized. This is achieved by a beam chopper located just after the injector magnet. An electronic circuitry was developed to control the chopper voltage and the time characteristics to obtain the chopping fraction with respect to the AMS requirements. This chopper maintains a potential difference of 300 V between two 12.5 cm long plates separated by 3.8 cm. The control voltage pulse width values for chopper ON and OFF periods are 950 μs and 50 μs, respectively, to ensure that the chopper transmits 1/20th yield of the stable beam. The control electronics for the chopper is based on an astable multivibrator which generates 1 kHz pulse to drive a transistor in switching mode. The chopper ON and OFF time are much higher than the transit time (estimated to be 138 ns) of Cl-isotopes of energy 150 keV through the chopper length so that the chopping is very efficient.

2.4. The accelerator and beam transport

The negative chlorine ions were mass selected by the injector magnet and accelerated up to the accelerator terminal where they were stripped by a ~5 μg/cm^2 thick carbon foil. After the second stage of acceleration the ions of required energy and charge state were bent by 90° using the analyzing magnet. The switching magnet deflects the beam into the ionization chamber detection system connected to the AMS beam line.

The ^{35}Cl and ^{37}Cl ions from a natural sample (AgCl) were transported through the accelerator and the ratio of ^{35}Cl yield to that of ^{37}Cl was found to be close to natural abundance after the injector magnet, the analyzing magnet and at the Faraday Cup located just before the detector. This ensures optimum transmission for ^{35}Cl and ^{37}Cl. The accelerator was operated in generating volt meter (GVM) mode to attain the requisite terminal voltage stability. To achieve this, a new terminal potential stabilizer (TPS) was procured from NEC, USA, especially for this programme. The two isotopes ^{35}Cl and ^{37}Cl were injected alternatively into the accelerator, and the terminal voltage was varied while keeping magnetic rigidity (Bρ) of analyzing magnet, magnetic quadrupoles and magnetic

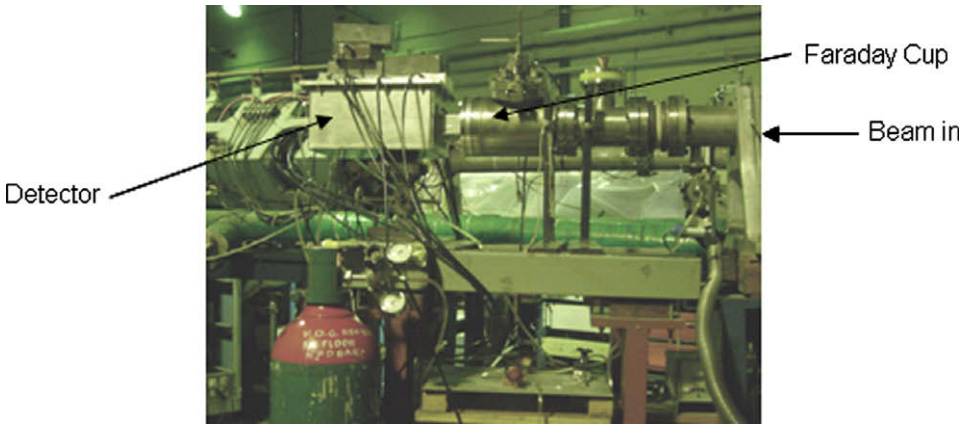

Fig. 2. Photograph of AMS measurement set up.