MEASUREMENT OF ^{10}Be AND ^{26}Al WITH A TANDETRON ACCELERATOR MASS SPECTROMETER FACILITY

FRANÇOISE YIOU, GRANT RAISBECK, DIDIER BOURLES, JACQUES LESTRINGUEZ and DOMINIQUE DEBOFFLE

Laboratoire René Bernas, 91406 ORSAY, France

ABSTRACT. A description is given of the use of a Tandetron accelerator mass spectrometer system for measuring the isotopes ^{10}Be and ^{26}Al.

INTRODUCTION

At the third symposium on accelerator mass spectrometry at Zurich, we discussed a procedure for measuring ^{10}Be with a Tandetron accelerator mass spectrometer. During the past year we have used this procedure to measure cosmogenic ^{10}Be in over 430 natural samples, principally polar ice, marine and lacrustine sediments, but also cosmic spherules, rainwater, coral, fossil organic deposits and ocean particulate matter. We briefly review here the present status of our measurement technique, including background levels, efficiency and reproducibility. During the past few months we have also developed a procedure for measuring the isotope ^{26}Al with the Tandetron operating at a nominal terminal voltage of 1.75 MV. The details of this procedure, which has an efficiency and background levels comparable to higher energy machines, are presented below.

^{10}Be

A schematic diagram of the Tandetron operation for ^{10}Be analysis is shown in Figure 1. A detailed description of the procedure used is given in Raisbeck *et al* (1984). Although the technique used during the past year has changed little since our earlier description, the much larger experience obtained since that time allows us a significantly improved appreciation of our capabilities. These are summarized below.

Reproducibility

For most of our measurements we continue to include a 7% instrumental uncertainty in the reported results. This is approximately the observed long term (months) variability observed in the measured ^{10}Be/^{9}Be ratio of our ^{10}Be standard. However, since we usually measure the standard 2 or 3 times during the day, and normalize our results to them, it is likely that the actual instrumental error is usually less than this. For example, in a recent series of sediment measurements, we measured 18 different samples two or more times, on different days. The average variability of these duplicates was 2.7%. In the same series, there was one section of fairly homogeneous sediment in which we processed 8 different samples. The standard deviation of these 8 measurements was 3.1%. Thus, for a homogeneous series of samples, which are not limited by statistics, and when the machine is stable, it is probable that the precision is of the order of 3% or so.

Although the above results indicate that we have the potential, under favorable conditions, to make measurements to ~ 3%, there are also periods in which we observe greater variability in our standard, even over a
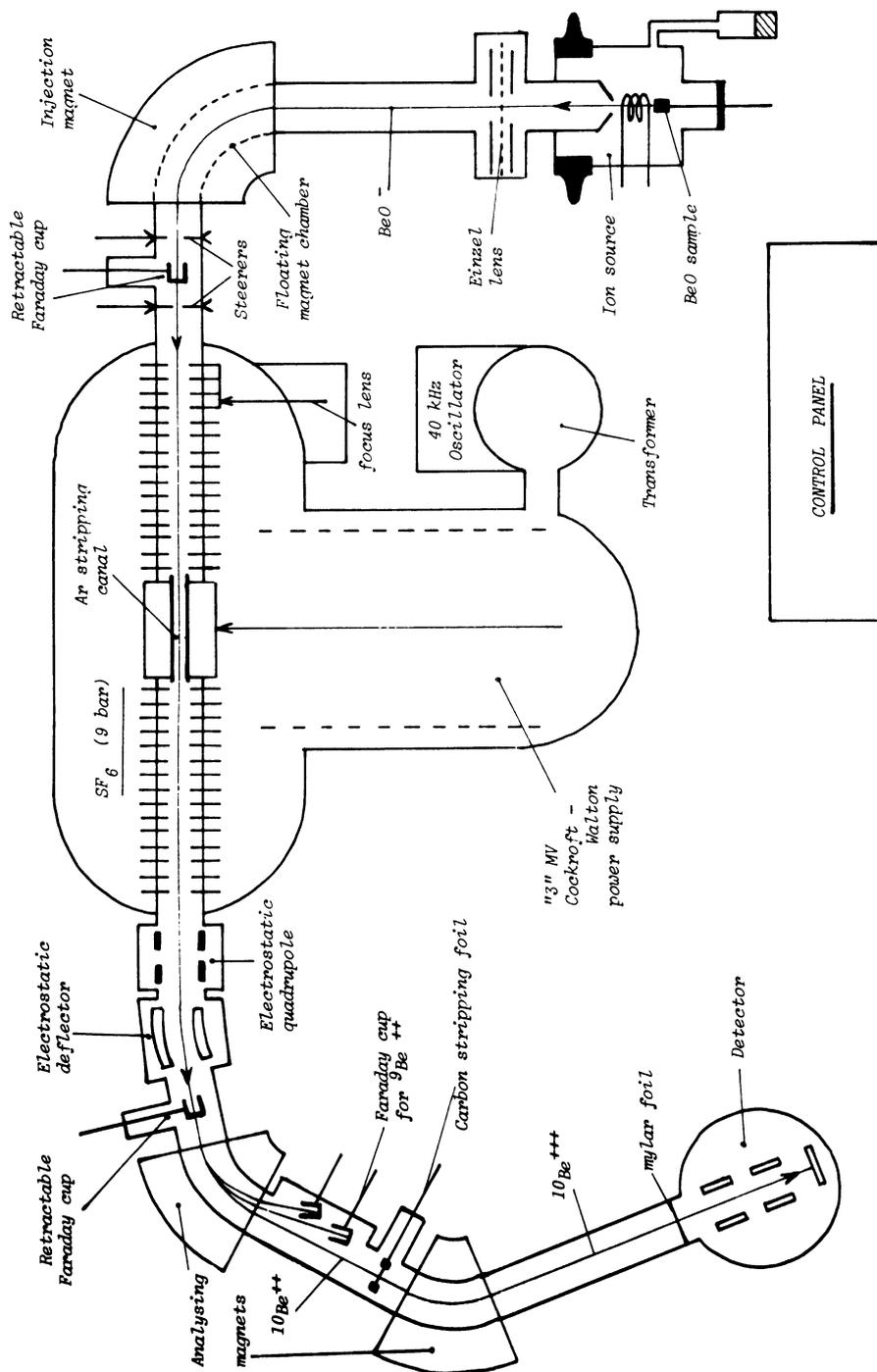
198

Fig 1. Schematic diagram of Tandetron accelerator configuration for ^{10}Be measurements

period of several hours. As mentioned in Raisbeck *et al* (1984), we believe the most important cause of this variation are small ($\sim 5 \times 10^{-4}$) changes in the fields of the high energy magnets. We have found the ^{10}Be to be much more sensitive than ^{14}C to changes in these fields, probably because of spreading in the beam due to breakup of the BeO molecule and diffusion in the carbon foil used to eliminate ^{10}B. The magnet gaps are too non-uniform to accept a NMR probe and our Hall probes are not temperature-stabilized. Since the temperature in the building housing the accelerator often varies over several degrees during the day, the drift in the Hall probes presently makes them unusable for controlling the magnets.

Background

Raisbeck *et al* (1984) estimated our background as ^{10}Be/^{9}Be $\sim 3 \times 10^{-14}$. Over the past year we have measured this background a number of times, with values falling in the range $1 \pm 0.3 \times 10^{-14}$. Since this is much lower than any of the samples we have measured to date, we have not made any attempt to improve on it. It should be noted, however, that this background is due to real ^{10}Be, and not stray counts or ^{10}B induced ^{7}Be. Thus, it appears that our beryllium (BeO and Be(NO$_3$)$_2$, Merck) has a ^{10}Be level similar to that found by Middleton *et al* (1984) for several other sources of commercial beryllium.

Efficiency

Our overall efficiency (^{10}Be detected per BeO$^-$ injected into Tandetron) has remained relatively constant at 5–6% throughout the past year. However, increased experience with the source operation has improved the BeO$^-$ output available. For a normal sample (prepared with 250μg of ^{9}Be carrier) we now typically obtain 1–2μA of BeO$^-$, although we have had as much as 4μA. On occasion, when samples are not sufficiently pure chemically, we still must limit the BeO$^-$ current because of an intolerable ($> 40,000$ cps) ^{10}B count rate.

Data acquisition

Cycling between ^{9}Be and ^{10}Be, and data recording, are still being done manually. However, the ΔE-E spectra from the multichannel analyzer are now transfered to diskette by way of a micro-PDP11/23 computer. We plan to use this computer to automatize the data acquisition in the near future.

^{26}Al

We have discussed (Raisbeck *et al* 1979; Raisbeck & Yiou, 1984) the motivation for measuring ^{26}Al by AMS, both in terrestrial and extraterrestrial matter. For example, measurements in marine sediments, in conjunction with ^{10}Be, might provide a dating method insensitive to production variations (Lal, 1962), while measurements in cosmic spherules, again in conjunction with ^{10}Be, can give information on the origin and irradiation conditions of these spherules (Raisbeck *et al*, 1983).

In considering the procedure to develop for measuring ^{26}Al with the Tandetron, we were influenced by the following factors: 1) the present voltage capabilities of the machine ($\sim$2 MV); 2) the desire to maximize the effi-

ciency through the machine (and thus to use an abundant charge state); 3) the advantages of using a prime number for the charge state, 4) the desire to retain the capability of making $\Delta E - E$ identification in the detector; 5) the desire to minimize the changes necessary between ^{10}Be and ^{26}Al measurements. Taking into consideration the above factors, we decided to try to develop a technique using: 1) Al$^-$ injection from Al$_2$O$_3$ samples from a General Ionex Model 860 source; 2) analysis of Al^{+3} at the output of the machine, and 3) retention of the mylar window and $\Delta E - E$ configuration of the detector. These choices, therefore, differ significantly from those adopted by Aardsma (1984) using a similar Tandetron. Using the Al^{+3} charge state, and the present current limits of the high-energy magnets, we
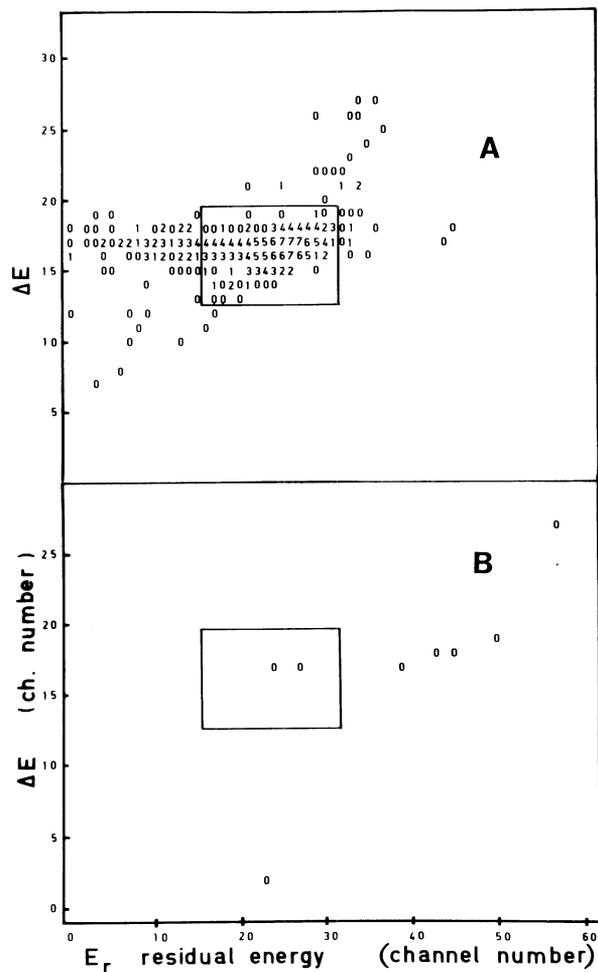

Fig 2. (A) Spectra of ΔE *vs* E_r (residual energy) for Al$_2$O$_3$ standard having ^{26}Al/^{27}Al = 4.87×10^{-10}. The numbers in the spectra (n) indicate the number of events in a given channel (N) through the relationship $2^{n-1} < N \leq 2^n$. The number of events in ^{26}Al window is 1009. (B) Spectra of blank Al$_2$O$_3$ giving ^{26}Al/^{27}Al $\sim 7 \times 10^{-14}$

were forced to limit our terminal voltage to a nominal value of 1.75 MV (we have not yet calibrated our GVM with a nuclear reaction). We calculated, however, that this would still permit $\Delta E - E$ identification in the detector.

Figure 2 shows a spectrum from an Al_2O_3 standard having $^{26}Al/^{27}Al = 4.87 \times 10^{-10}$. This Al_2O_3 was made by diluting a calibrated ^{26}Al solution, obtained from LMRI, Saclay, and transformed to the oxide. The ionization detector was operated at a pressure of 30 torr of 90% Ar–10% methane mixture, and 250 volts cathode voltage. The overall transmission, from Al^- injected into the machine to $^{26}Al^{+3}$ counted in the detector is ~10%. This is comparable to that obtained in a higher energy tandem (Middleton *et al*, 1983). Figure 2B shows an example of a spectrum from a blank Al_2O_3. The background, which appears to consist of real ^{26}Al events, corresponds to an $^{26}Al/^{27}Al$ ratio of ~7×10^{-14}. This is about an order of magnitude higher than observed at the University of Pennsylvania (Middleton *et al*, 1983). This blank run was made immediately after the standard at 4.87×10^{-10}. It is, therefore, quite possible that the background represents a memory effect, at a level of ~10^{-4}, quite consistent with that observed by Middleton *et al* (1983).

One of the main difficulties in measuring ^{26}Al by AMS in a tandem accelerator is the relatively poor emission for Al^- ions. To date, the best current we have been able to obtain is ~100 nA. This is insufficient to permit measurements of ^{26}Al in terrestrial sediments, where the expected ratio is $^{26}Al/^{27}Al \sim 10^{-14}$, without prior enrichment (Raisbeck & Yiou, 1981). However, the technique described above is capable of determining ^{26}Al in various extraterrestrial material, and we are presently using it to determine ^{26}Al in cosmic spherules.

CONCLUSION

A Tandetron accelerator mass spectrometry system operating at a terminal voltage of ~2 MV appears capable of measuring the isotopes ^{10}Be and ^{26}Al with performances comparable to higher energy tandems.

REFERENCES

Aardsma, G E, 1985, Accelerator mass spectrometry of ^{26}Al at 1.2 MV using charge state +2: Nuclear Instruments & Methods, vA238, p 170–172.
Lal, D, 1962, Cosmic ray produced radionuclides in the sea: Jour Oceanog Soc Japan, v 18, p 600–614.
Middleton, R, Klein, J, Brown, L and Tera, F, 1984, ^{10}Be in commercial beryllium: Nuclear Instruments & Methods, v B5, p 511–513.
Middleton, R, Klein, J, Raisbeck, G M and Yiou, F, 1983, Accelerator mass spectrometry with ^{26}Al: Nuclear Instruments & Methods, v 218, p 430–438.
Raisbeck, G M and Yiou, F, 1981, Electromagnetic isotope separation as a method of improving the detection limits of accelerator spectrometry: Nuclear Instruments & Methods, v 186, p 483–486.
————1984, Production of cosmogenic nuclei and their applications: Nuclear Instruments & Methods, v B5, p 91–99.
Raisbeck, G M, Yiou, F, Bourles, D, Lestringuez, J and Deboffle, D, 1984, Measurement of

^{10}Be with a Tandetron accelerator operating at 2 MV: Nuclear Instruments & Methods, v B5, p 175–178.

Raisbeck, G M, Yiou, F, Klein, J, Middleton, R, Yamakoshi, K and Brownlee, D E, 1983, ^{26}Al and ^{10}Be in deep sea stony spherules; evidence for small parent bodies: Lunar Planetary Sci, v 14, p 622–623.

Raisbeck, G M, Yiou, F and Stephan, C, 1979, ^{26}Al measurement with a cyclotron: Jour Physique-Lettres, v 40, p L241–L244.