Phys 586 Laboratory

Lab 9

Goal: In this lab you will use a parallel plate ion chamber to measure the range of light ions accelerated with the Van de Graaf accelerator.

Reading: Knoll p. 148-154.

1. Familiarize yourself with the main components of the AMS instrument. Explain how a magnetic filter works. Explain how an electrostatic filter works.

2. A handout gives a photograph and diagram of the ionization chamber. What gas is used in the chamber? What is the HV used in the chamber?

3. What is the beam used? What is the beam charge? What is the beam energy? What is the beam intensity (approximately)?

4. Describe what happens to a single ^{14}C ion as it enters the detector. The ionization chamber makes use of a Frisch grid. What is the purpose of this grid?

5. Use the oscilloscope to measure the amplitude, rise time, and fall time of the signals from the preamplifier and amplifier. Sketch the trace of a signal from the preamplifier and one from the amplifier.

6. Measure the count rate and pulse height from the amplifier in the oscilloscope with no beam. This is the background noise. What is the maximum voltage of these pulses? Use the low level discriminator to eliminate the noise.

7. Determine the approximate magnetic and electrostatic filter settings to send 10 MeV $^{14}C^{3+}$ particles through the AMS. How do these compare for the actual values used to get the beam into the detector?

For magnetic filtering: $B^2 = \frac{2mE_k}{rq^2}$

where B is expressed in tesla, m is the mass in kilograms, E_k is the kinetic energy of the particles in joules, r is the magnet radius (1.27 m) and q is the charge in coulombs.

For electrostatic filtering: $E = \frac{2E_k}{rq}$

where E is the electric field in the electostatic analyzer. The electrostatic analyzer has a radius of 2.0 m, and plate separation of 40 mm.

8. You have 3 different carbon targets to make measurements on: 1) a modern standard, 2) a chemical blank, and 3) an unprocessed graphite blank. The first two contain iron and the third is pure graphite. Learn how to start and stop data collection. Look at the dE spectrum in the modern standard. Why is this distribution not a Landau distribution?

9. Look at the spectra for E_{final} x dE. Determine the count rate for the standard using a 200 second collection time. Print a copy of the spectrum. Are there any other peaks besides ^{14}C? Determine the transmission of the $^{14}C^{3+}$ beam to the detector.

10. Repeat step 10 for the chemical blank and the unprocessed graphite blank. Print the spectra. What do these spectra tell you about the spectra for the modern standard? Given that the standard has a $^{14}C/^{13}C$ ratio of about 10^{-12}, what is the detection limit of the method, based on the 2 blank measurements you have made? We call the ratio $^{14}C/^{13}C_{sample}/^{14}C/^{13}C_{standard}$ the fraction modern carbon (F). The radiocarbon age of a sample in years is: ^{14}C age = -8033 lnF. Based on your results, what are the equivalent ages of the 2 blanks?

11. Based on the magnetic and electrostatic filter settings for the C^{3+} ions, scale these filtering elements to allow C^{4+} to pass through the accelerator and into the detector.

12. Repeat step 10 above using the 4+ charge state, with the modern standard. How does the transmission of the 4+ charge state compare to the transmission in the 3+ charge state? Why? Is the position of the ^{14}C peak in the 4+ charge state the same as in the 3+ charge state? Explain.

14. Repeat step 11 above in the 4+ charge state, with each blank. What are the detection limits for the 4+ charge state?.

15. Change the gas pressure of the detector from 18 torr to 21 torr and collect a spectrum for the modern standard. How does the change in gas pressure affect the position of the ^{14}C peak in the spectrum?. Explain. Change the gas pressure to 15 torr and collect a spectrum for the modern standard. How does the change in gas pressure affect the position of the ^{14}C peak in the spectrum? Is this consistent with your explanation of the fate of a single ^{14}C ion entering the detector (question 4 above)?