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PIXE Homework #1 - Physics 100
Union College Fall 2025

1. Explain the main components of the Pelletron particle accelerator and the significance of each.

   Source (ion production), accelerator (accelerates the ions to high energy), steering of the ions (filters out the wanted ions based on their momentum, or energy), and the scattering chamber (where the experiment takes place.)

2. Explain the charge exchange process that occurs for a helium ion.

   As He interacts with the Rb ion the charge exchanger, it picks up anywhere from zero to three negative charges. Ideally it should pick up three negative charges, two to get to "neutral" helium and one more in order to be accelerated by the Pelletron. When the He^- ion is accelerated from ground to the terminal the charge keeps its acquired electrons. At the terminal the He^- ion passes through a low-density nitrogen vapor that strips the He of its electrons and then the He^{+2} ions are accelerated away from the terminal.

3. What is the kinetic energy (in electron-volts eV) of the He ion after our machine has accelerated it? Hints: Use the work-kinetic energy theorem to and calculate the work done in each of the stages of the accelerator and the bias voltage applied across the quartz bottle is $+3.8kV$ for Helium. In addition, the alpha particle (2 protons and 2 neutrons) has a charge of $+2e$ when it leaves the bottle, a $-1e$ charge when it accelerates towards the terminal, and a $+2e$ charge when it accelerates away from the terminal.

   $$W_{net} = W_{IS} + W_{LEE} + W_{HEE}$$
   $$W_{net} = -(2e)[0V - 3800V] - (-e)[1.1 \times 10^6 V - 0V] - (2e)[0V - 1.1 \times 10^6 V]$$
   $$W_{net} = 7600eV + 1.1 \times 10^6 eV + 2.2 \times 10^6 eV = 3.3076 \times 10^6 eV \sim 3.3MeV$$

   $$W_{net} = 3.3 \times 10^6 eV \times \frac{1.6 \times 10^{-19} J}{1eV} = 5.292 \times 10^{-13} J$$

4. From the kinetic energy you calculated in question 3, what is the speed in meters per second $\left(\frac{m}{s}\right)$ of an alpha particle after it leaves the accelerator?

   $$W_{net} = \Delta K = K_f - K_i = K_f = \tfrac{1}{2} m v_f^2 \rightarrow v_f = \sqrt{\frac{2W_{net}}{m}} = \sqrt{\frac{2W_{net}}{(2m_p + 2m_n)}}$$
   $$v_f = \sqrt{\frac{2 \times 5.292 \times 10^{-13} J}{2(1.67 \times 10^{-27} kg + 1.69 \times 10^{-27} kg)}} = 1.26 \times 10^7 \frac{m}{s}$$

5. If the radius of the alpha particle's orbit is $34.4cm$ (exactly the same as that of the proton,) what magnitude of magnetic field B in Teslas is required to steer the alpha particle down the 30^0 beamline?

$$B = \frac{m_\alpha v_\alpha}{q_\alpha R} = \frac{6.68 \times 10^{-27} kg \times 1.255 \times 10^7 \frac{m}{s}}{2 \times 1.6 \times 10^{-19} C \times 0.344 m} = 0.7616T$$