

Name _____
 PIXE Homework #1 - Physics 100
 Union College Fall 2013

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 chambers (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 speed of an alpha particle after it leaves the accelerator? The bias voltage applied across the quartz bottle is 5 kV for Helium. (Hint: the alpha particle (2 protons + 2 neutrons) has a charge of +2 when it leaves the bottle, a +1 charge when it accelerates to the terminal, and a +2 charge when it leaves the terminal.)

$$\frac{1}{2} m_{\alpha} v_{\alpha}^2 = q_{\alpha}^+ \Delta V_{\text{bottle}} + q_{\alpha}^+ \Delta V_{\text{accelerate to terminal}} + q_{\alpha}^{++} \Delta V_{\text{accelerate away from terminal}}$$

$$\frac{1}{2} (2 \times 1.69 \times 10^{-27} \text{ kg} + 2 \times 1.67 \times 10^{-27} \text{ kg}) v_{\alpha}^2 = (2 \times 1.6 \times 10^{-19} \text{ C} \times 5000 \text{ V}) + (1 \times 1.6 \times 10^{-19} \text{ C} \times 1.1 \text{ MV}) + (2 \times 1.6 \times 10^{-19} \text{ C} \times 1.1 \text{ MV})$$

$$3.36 \times 10^{-27} \text{ kg} v_{\alpha}^2 = 1.6 \times 10^{-15} \text{ J} + 1.76 \times 10^{-13} \text{ J} + 3.52 \times 10^{-13} \text{ J} = 5.296 \times 10^{-13} \text{ J}$$

$$\therefore v_{\alpha}^2 = \frac{5.296 \times 10^{-13} \text{ J}}{3.36 \times 10^{-27} \text{ kg}} = 1.576 \times 10^{14} \frac{\text{m}^2}{\text{s}^2} \rightarrow v_{\alpha} = 1.256 \times 10^7 \frac{\text{m}}{\text{s}}$$

4. What is the kinetic energy of a lithium ion after our machine has accelerated it?

$$\frac{1}{2} m_{\text{Li}} v_{\text{Li}}^2 = q_{\text{Li}}^+ \Delta V_{\text{bottle}} + q_{\text{Li}}^+ \Delta V_{\text{accelerate to terminal}} + q_{\text{Li}}^{++} \Delta V_{\text{accelerate away from terminal}}$$

$$\frac{1}{2} (4 \times 1.69 \times 10^{-27} \text{ kg} + 3 \times 1.67 \times 10^{-27} \text{ kg}) v_{\text{Li}}^2 = (3 \times 1.6 \times 10^{-19} \text{ C} \times 5000 \text{ V}) + (1 \times 1.6 \times 10^{-19} \text{ C} \times 1.1 \text{ MV}) + (3 \times 1.6 \times 10^{-19} \text{ C} \times 1.1 \text{ MV})$$

$$5.71 \times 10^{-27} \text{ kg} v_{\text{Li}}^2 = 2.4 \times 10^{-15} \text{ J} + 1.76 \times 10^{-13} \text{ J} + 5.28 \times 10^{-13} \text{ J} = 7.064 \times 10^{-13} \text{ J}$$

$$\therefore v_{\text{Li}}^2 = \frac{7.064 \times 10^{-13} \text{ J}}{5.71 \times 10^{-27} \text{ kg}} = 1.237 \times 10^{14} \frac{\text{m}^2}{\text{s}^2} \rightarrow v_{\text{Li}} = 1.11 \times 10^7 \frac{\text{m}}{\text{s}}$$

5. If the radius of the alpha particle's orbit is 34.4cm (as the proton,) what magnitude of magnetic field is required to steer the alpha particle down the 30⁰ beamline?

$$B = \frac{m_{\alpha} v_{\alpha}}{q_{\alpha} R} = \frac{6.68 \times 10^{-27} \text{ kg} \times 1.256 \times 10^7 \frac{\text{m}}{\text{s}}}{2 \times 1.6 \times 10^{-19} \text{ C} \times 0.344 \text{ m}} = 0.7622 \text{ T}$$