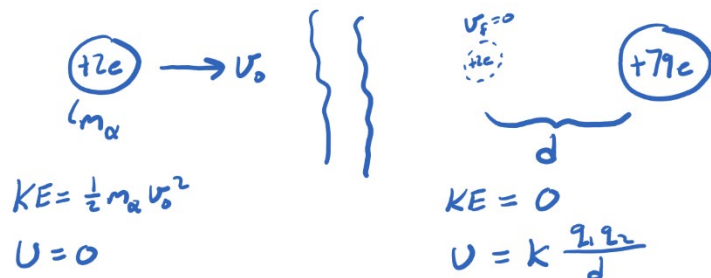


Week 6 Challenge Homework Solutions

Question 1

In 1911, Ernest Rutherford and his assistants Geiger and Marsden conducted an experiment in which they scattered alpha particles (nuclei of helium atoms) from thin sheets of gold. An alpha particle, having charge $+2e$ and mass 6.64×10^{-27} kg, is a product of certain radioactive decays. The results of the experiment led Rutherford to the idea that most of the atom's mass is in a very small nucleus, with electrons in orbit around it. (This is the planetary classic model.) Assume an alpha particle, initially very far from a stationary gold nucleus, is fired with a velocity of 2.00×10^7 m/s directly toward the nucleus (charge $+79e$).

- (a) What is the smallest distance between the alpha particle and the nucleus before the alpha particle reverses direction? Assume the gold nucleus remains stationary.
- (b) How might your answer change if the gold nucleus was allowed to move? Explain your answer qualitatively! There is no need to perform any calculations. (Hint: think a little about energy and/or momentum conservation!)



$$E_{\text{before}} = E_{\text{after}}$$

$$\frac{1}{2} m_\alpha v_0^2 = k \frac{(2e)(79e)}{d}$$

$$d = \frac{316 k e^2}{m_\alpha v_0^2} = \frac{(316)(9 \times 10^9)(1.6 \times 10^{-19})^2}{(6.64 \times 10^{-27})(2 \times 10^7)^2}$$

$$= 2.74 \times 10^{-14} \text{ m}$$

If we allow the gold nucleus to move, then the initial total energy (in kinetic form) will be transferred into the potential energy as before, but also the kinetic energy of the gold nucleus and kinetic energy of the alpha particle, as they will both be moving at the time of closest approach. Thus the maximum potential energy will be less, meaning the distance is larger.