CARST : MARST Course : Nuclear Physics Module : 2006

Class Test : Detection of radiation, Nuclear reaction mechanisms, Accelerators

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Instructions: Answer all questions.
Time: 1 hour = 60 minutes
Total Marks: 70 marks (70 marks = 100%)

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1. In discussing the energy loss of radiation passing through matter, we can consider separately the categories of heavy charged particles, light charged particles, photons and neutral particles.

   (a) Mention five energy loss mechanisms which are appropriate to each of these categories. (10)

   (b) Show that for a particle of mass M, charge z and non-relativistic energy E. the relation $E \times dE/dx = kMz^2$ holds approximately for some k. (3)

   (c) Deduce from this a possible experimental method for identifying charged particles. (7)

   (d) Calculate the energy gap between the photo-peak and the high energy edge of the Compton distribution in a pulse height spectrum from a scintillator detecting gamma radiation from positron annihilation. (5)

   (e) In an industrial manufacturing process the thickness of a metallic foil is regulated by observing the attenuation of a photon beam passing through the foil. The desired thickness is 0.1. mm, and for the chosen photon energy the attenuation is 50%. The detection efficiency without the foil in place is 1%. The thickness must be determined quit fast, in about 1s, and the tolerance is 5%. Calculate the necessary source strength. (5)

   [30]

2. The figure below depicts the scattering cross-section for $^{16}_{8}$O incident on $^{96}_{40}$Zr, plotted relative to the Rutherford cross-section. Note that the horizontal axis presents the distance of closest approach, $r_{\min}$.

   (a) Identify the physics processes that lead to the shape of this graph. Explain also how the measurement would have been designed, so that the cross-sections could be measured as a function of r_{min} using only one incident energy for each set of points. (6)

   (b) Assuming that nuclei are hard spheres with radius $R = 1.2A^{1/3}$ fm, predict the value of $r_{\min}$ when the Rutherford scattering model could be expected to breakdown. (5)

   (c) What would the largest incident energy be where one would could still expect pure Rutherford scattering based on this model. (5)

   (d) Discuss why the Rutherford scattering model breaks down earlier than expected. (2)

   (e) What can you infer from the sharpness of the kink in the graph. (2)

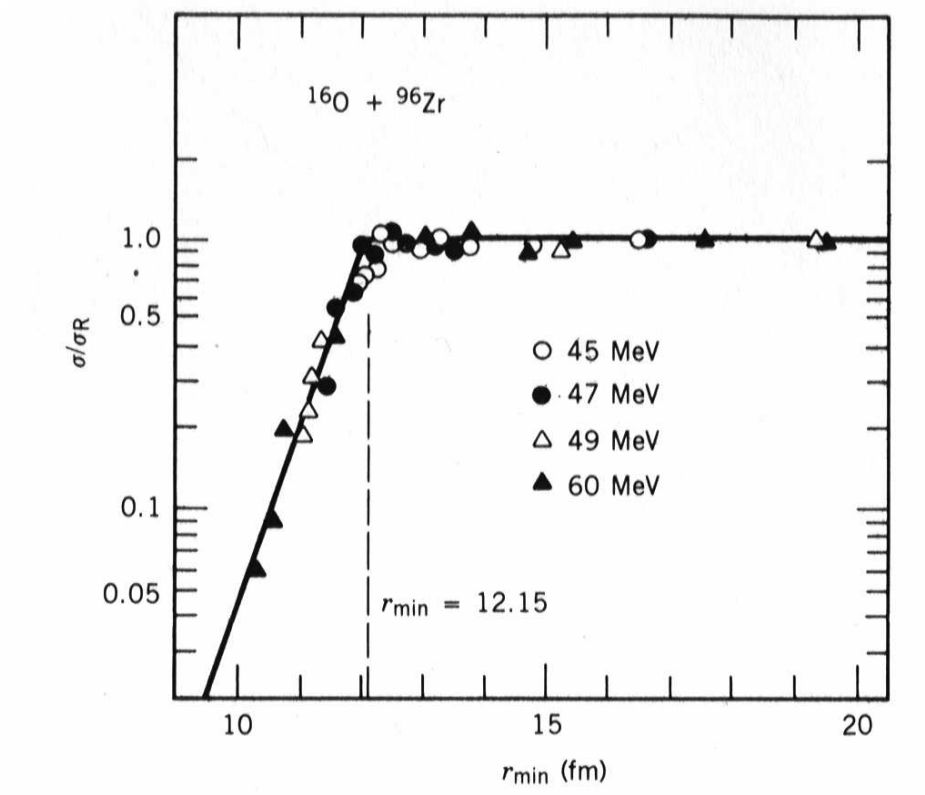
   [20]

3. (a) Starting from an expression for the Lorentz force on a particle undergoing circular motion in a magnetic field, derive the expression for the cyclotron frequency and maximum kinetic energy of a charged particle. (6)

(b) Consider a cyclotron with a maximum radius and field, R=1.25 m and B=1.3 T. Compute the maximum proton energy (in MeV) and the corresponding frequency of the varying voltage. Also find the energy of a Xenon beam (Z=54, A = 131). (7)

(c) Describe the two effects which cause a deviation from the expected behaviour of constant period for each orbit regardless of orbit radius that appear for higher energy particles. There are two solutions for this behaviour, leading to two new types of cyclotron. Give the names of these and describe briefly their operation principle. (7)

[20]



Total **[70]**