

Name _____

Date _____

Score: _____ / 40

68 minutes · 40 marks · calculator and data booklet allowed

- Answer all the questions in the spaces provided.
- Show all your working. Marks are given for correct method.
- The marks for each part are shown in brackets [].

1. Alpha particles and a gold foil [9 marks]

In the Geiger-Marsden-Rutherford experiment, a narrow beam of alpha particles was directed at a very thin gold foil ($^{197}_{79}\text{Au}$) inside an evacuated chamber. A detector counted the alpha particles scattered at different angles.

(a) Describe the results of the experiment. **[2]**

(b) Outline the model of the atom that Rutherford proposed from these results. **[2]**

(c) In the earlier Thomson model, the positive charge is spread through the whole atom. **Explain** why this model cannot account for the large-angle deflections. **[2]**

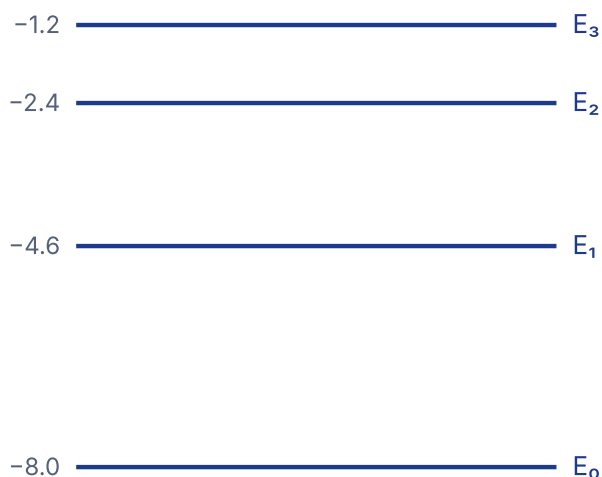
(d) Suggest why the foil was very thin and the chamber was evacuated. **[2]**

(e) State the number of neutrons in a gold-197 nucleus. **[1]**

2. Energy levels and spectra [12 marks]

The diagram shows four energy levels of an atom of a gas. E_0 is the ground state.

energy / eV



- (a) The gas is heated at low pressure and emits light. **Explain** why the emission spectrum consists of lines of particular wavelengths. **[2]**

- (b) **Calculate** the wavelength of the photon emitted in the transition from E_2 to E_0 . **[2]**

- (c) **State** the number of different wavelengths that can be emitted by atoms excited to E_3 . **[1]**

- (d) **Identify** the transition that emits the photon of longest wavelength, and **calculate** this wavelength. **[2]**

- (e) White light passes through the cool gas. **Explain**, with reference to the energy levels, the formation of the absorption spectrum. **[3]**

- (f) An atom in the ground state is hit by (i) a photon of energy 4.0 eV, (ii) an electron of kinetic energy 4.0 eV. **Discuss** what happens in each case. [2]

3. (HL) Closest approach and the size of a nucleus [10 marks]

Alpha particles of kinetic energy 5.5 MeV are fired at silver nuclei ($^{107}_{47}\text{Ag}$). Assume the silver nucleus does not move.

- (a) **Calculate** the distance of closest approach for an alpha particle that moves head-on towards a silver nucleus. [2]

- (b) **Calculate** the radius of the silver nucleus. [1]

- (c) Use (a) and (b) to **explain** why the scattering of these alpha particles agrees with Rutherford's model. [2]

- (d) As the alpha particle energy is increased, deviations from Rutherford's model appear. The radius of an alpha particle is 1.9×10^{-15} m. **Estimate** the alpha particle energy, in MeV, at which deviations start. [2]

- (e) **Show** that the density of a nucleus does not depend on its nucleon number. [2]

- (f) The silver foil is replaced by a gold foil ($Z = 79$). **State**, with a reason, whether deviations start at a higher or a lower energy. [1]

4. (HL) The Bohr model of hydrogen [9 marks]

In the Bohr model of the hydrogen atom, the electron moves in a circular orbit around the proton.

- (a) **Explain** why Bohr introduced the condition $mvr = nh/2\pi$. [3]

- (b) The electric force provides the centripetal force. **Show** that the radius of the orbit is $r = n^2 h^2 / (4\pi^2 k m e^2)$. [2]

- (c) The radius for $n = 1$ is 5.3×10^{-11} m. **Calculate** the radius for $n = 2$. [1]

- (d) The energy levels are $E = -13.6/n^2$ eV. **Calculate** the wavelength of the photon emitted in the transition from $n = 3$ to $n = 2$. [2]

- (e) **State one** limitation of the Bohr model. [1]
