1 (a) Sketch the electric field surrounding the gold nucleus drawn below.

(3)

(b) The spreadsheet shown approximately models the behaviour of an alpha particle as it approaches a gold nucleus.

The proton number of gold is 79.
mass of alpha particle = 6.64×10^{-27} kg

	A	B	C	D	E
1	**Distance from gold nucleus / m**	**Magnitude of force on alpha particle / N**	**Time interval / s**	**Velocity at end of time interval / m s^{-1}**	**Displacement of alpha particle in time interval / m**
2	8.60E-14	4.92E+00	1.00E-21	1.53E+07	1.56E-14
3	7.04E-14	7.34E+00	1.00E-21	1.42E+07	1.47E-14
4	5.57E-14	1.17E+01	1.00E-21	1.24E+07	1.33E-14
5	4.24E-14	2.02E+01	1.00E-21	9.34E+06	1.09E-14
6	3.15E-14	3.66E+01	1.00E-21	3.83E+06	6.58E-15
7	2.49E-14	5.84E+01	1.00E-21	−4.97E+06	−5.69E-16
8	2.55E-14	5.59E+01	1.00E-21	−1.34E+07	−9.18E-15
9	3.47E-14	3.02E+01	1.00E-21	−1.79E+07	−1.57E-14
10	5.03E-14	1.43E+01	1.00E-21	−2.01E+07	−1.90E-14

(i) Show how cell B3 is calculated.

(2)

(ii) Show how cell D5 is calculated.

(3)

(iii) Show how cell E6 is calculated.

(2)

(iv) Suggest a value for the maximum radius of a gold nucleus based on the results from this spreadsheet.

(1)

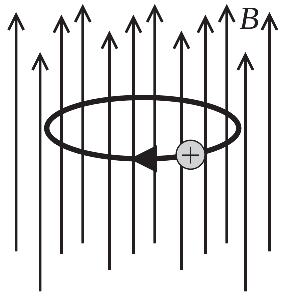
Maximum radius =

*(c) Describe the conclusions Rutherford reached about the structure of gold atoms as a result of the alpha particle scattering experiments.

(3)

(Total for Question = 14 marks)

2 A strong magnetic field of flux density B can be used to trap a positive ion by making it follow a circular orbit as shown.



(a) Explain how the magnetic field maintains the ion in a circular orbit. You may add to the diagram above if you wish.

(2)

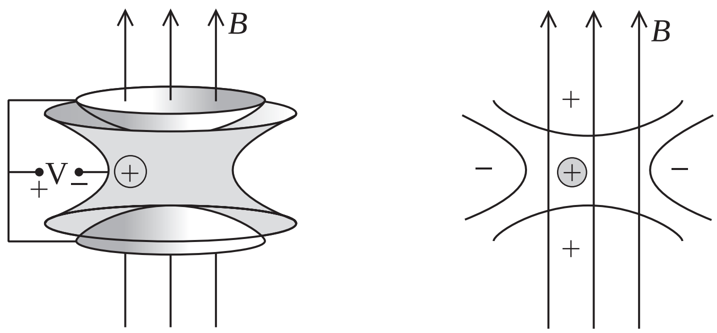
(b) Show that the mass m of the ion will be given by

$$m \quad \frac{Bq}{2\pi f}$$

where q is the charge on the ion and f is the number of revolutions per second.

(3)

(c) The above arrangement will not prevent a positive ion from moving vertically. To do this, a weak electric field is applied using the arrangement shown below.



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(i) Explain how the electric field prevents the ion moving vertically.

(2)

(ii) This device is known as a Penning Trap. It can be used to determine the mass of an ion to an accuracy of 3 parts in 10 million.

Confirm that the mass of a sulphur ion can be measured to the nearest 0.00001u.

mass of sulphur ion = 32.0645u

(2)

(iii) Under certain conditions nuclei of sulphur emit a gamma ray with a known energy of 2.2 MeV.

Calculate the resulting loss in mass of a sulphur ion in u and confirm that this value could be determined by the Penning Trap technique.

(4)

(Total for Question = 13 marks)

3 Early in the twentieth century physicists observed the scattering of alpha particles after they had passed through a thin gold foil. This scattering experiment provided evidence for the structure of the atom.

(a) State why it is necessary to remove the air from the apparatus that is used for this experiment.

(1)

....

(b) From the results of such an experiment give **two** conclusions that can be deduced about the nucleus of an atom.

(2)

Conclusion 1 ....

....

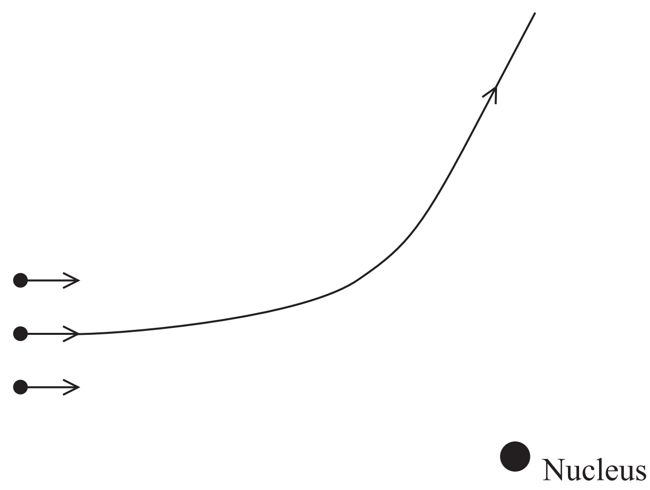
Conclusion 2 ....

....

(c) The diagram shows three α-particles, all with the same kinetic energy. The path followed by one of the particles is shown.

Add to the diagram to show the paths followed by the other two particles.

(3)



(Total for Question 6 marks)

4 The electron in a hydrogen atom can be described by a stationary wave which is confined within the atom. This means that the de Broglie wavelength associated with it must be similar to the size of the atom which is of the order of 10^{10} m.

(a) (i) Calculate the speed of an electron whose de Broglie wavelength is 1.00×10^{10} m.

(3)

Speed ....

(ii) Calculate the kinetic energy of this electron in electronvolts.

(3)

Kinetic energy .... eV

(b) When β radiation was first discovered, it was suggested that there were electrons in the atomic nucleus, but it was soon realised that this was impossible because the energy of such an electron would be too great.

Suggest why an electron confined within a nucleus would have a much greater energy than the energy calculated in (a)(ii).

(2)

(Total for Question 8 marks)

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***5** At the beginning of the last century, experiments were performed using alpha particles and gold foil. The alpha particles were directed at the gold foil and a detector was used to see if and where they were scattered.

Summarise the results from these experiments and the conclusions that were drawn from them.

(5)

(Total for Question 5 marks)

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6 (a) Describe the key observations of the alpha particle scattering experiments which led to Rutherford's nuclear model of the atom.

(3)

....

....

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....

....

(b) Experiments at Stanford University's linear accelerator (linac) accelerate electrons up to energies of 20 GeV.

(i) State the main features of a linac.

(3)

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(ii) Calculate the de Broglie wavelength of 20 GeV electrons. At these energies, the following relativistic equation applies $E \quad pc$.

(3)

....

....

....

De Broglie wavelength ....

(iii) Suggest why these electrons would be particularly useful for investigating nuclear structure.

(1)

....

....

....

(iv) These electrons can be aimed at a hydrogen target. Some of these electrons are scattered at large angles by the protons whilst others pass straight through.

Suggest what this tells you about the structure of a proton.

(2)

....

....

....

....

(v) The scattering process is inelastic. What is meant by an inelastic collision?

(1)

....

....

(Total for Question 13 marks)

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7 An electron gun uses a potential difference to accelerate electrons from rest to a speed of 2.00×10^{7} m s^{-1}.

(i) The potential difference is

☒ **A** 569 V

☒ **B** 1140 V

☒ **C** 2280 V

☒ **D** 4560 V

(ii) The de Broglie wavelength associated with electrons moving at 2.00×10^{7} m s^{-1} is

☒ **A** 3.3×10^{-41} m

☒ **B** 5.0×10^{-14} m

☒ **C** 3.6×10^{-11} m

☒ **D** 5.0×10^{-8} m

(Total for Question = 2 marks)