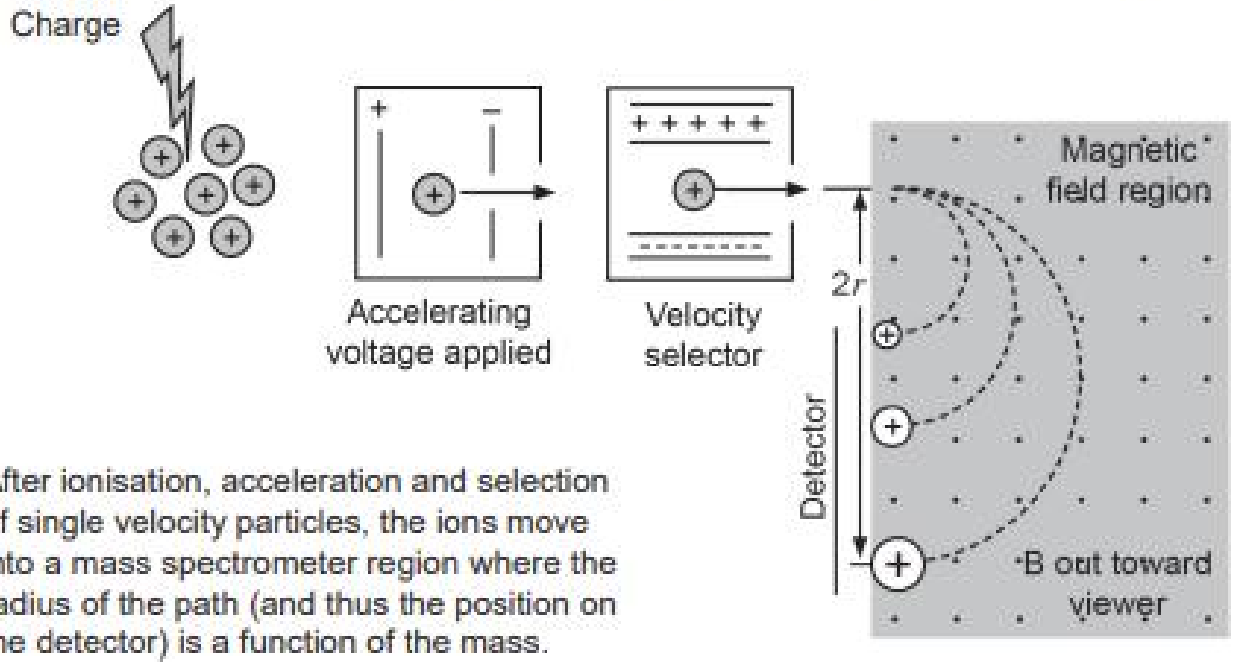
Question 19 **(20 marks)**

Mass spectrometer

The mass spectrometer is an instrument that can measure the masses and relative concentrations of atoms in a mixed sample. It makes use of the magnetic force on a moving charged particle.

Different elements are ionised so they all have a charge of +1. They are then accelerated across a potential difference that increases their velocities. They move through a velocity selector and are then fired into a magnetic field where they undergo circular motion and land on a detector. The different masses of the elements will determine where they land on the detector. The concentration of each element can be determined by how many ions land in the one place.



After ionisation, acceleration and selection of single velocity particles, the ions move into a mass spectrometer region where the radius of the path (and thus the position on the detector) is a function of the mass.

Velocity selector

In many experiments involving moving charged particles, it is important that the particles all move with essentially the same velocity. This can be achieved by applying a combination of an electric field and a magnetic field oriented as shown in the diagram above. A uniform electric field is directed vertically downward, and a uniform magnetic field is applied in the direction perpendicular to the electric field and into the page. For positive particles, the magnetic force is equal to qvB upward and the electric force (qE) is downward.

(a) Give an expression for the radius of a charged particle's path when fired into a uniform magnetic field. (1 mark)

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(b) Explain why it is important to make sure that all the ions that enter the detector have the same velocity. (3 marks)

(c) Below is a table of ions and their masses in kg.

An unknown ion enters the detector at 9.24×10^4 m s^{-1}. It strikes the detector plate 12.38 cm from the entrance point. If the magnetic field strength is 3.50 T, calculate the mass of the unknown particle and identify it from the table above. (5 marks)

_____ kg Particle: _____

(d) Calculate the accelerating voltage needed for the ion to attain a velocity of 9.24×10^4 m s^{-1} when entering the velocity selector. If you could not obtain an answer to part (c), use 3.11×10^{-25} kg. (4 marks)

(e) The velocity selector shown on page 29 uses a combination of electric and magnetic fields to select only ions with a specific velocity to enter the detector. These ions travel directly across the selector parallel to the charged plates. Derive an expression for the selected velocity in terms of B and E. (3 marks)

(f) Explain in detail why an ion travelling at a velocity greater than the selected velocity would not enter the detector. Use the diagram below to show the path the ion would take. (4 marks)