only No. 1 + 3 are needed

ions that go straight through the velocity selector will have speed $v = E/B_1$, where e electric field strength and B_1 is the magnetic flux density in the velocity selector. elocity can be adjusted by controlling the magnitudes of the two fields. The neon at travel with this velocity then enter a uniform magnetic field of flux density B_2. In ld they will travel in a circular path. The radius of the path will be given by

rce $= B_2Qv = ma = m\frac{v^2}{r}$ and by rearranging the equation $r = \frac{mv}{B_2Q}$

minating v gives $r = \frac{mE}{QB_2B_1}$

easuring r, the mass of the ion can be obtained. When this experiment was first rmed, the results from it showed that neon ions mostly had a mass of 19.992 u but 0.26% of the ions had mass 20.994 u and 8.82% had mass 21.991 u. This overy of isotopes explained why so many atoms had almost whole-number ratios of ses. The differences were explained with the discovery of the neutron.

Key definition

Atomic and nuclear masses are usually measured in terms of the unified atomic mass unit u. It is a mass equal to 1/12 the mass of an atom of the nuclide $^{12}_{6}C$. One u = 1.66054×10^{-27} kg, to 6 sig. figs. More detail about this mass unit is given in spread 2.3.3.

ıer mass spectrometers

erent manufacturers of mass spectrometers use different methods of producing the l stream of ions. In one system, samples in liquid form are injected into the machine the substance is then ionised by bombardment from high-energy electrons.

ther type of mass spectrometer is called a time-of-flight (TOF) spectrometer and is wn in Figure 3.

time-of-flight secondary ion mass spectrometer, to give it its full name, a pulsed ion m or pulsed laser beam is used to remove batches of molecules from the outermost face of the sample. The molecules are ionised and accelerated towards a detector. time it takes them to reach the detector depends on their mass. The advantage of system is that macromolecules (such as polymers or proteins) are not disintegrated the beam. These instruments are used in coatings research, microelectronics and face contamination studies.

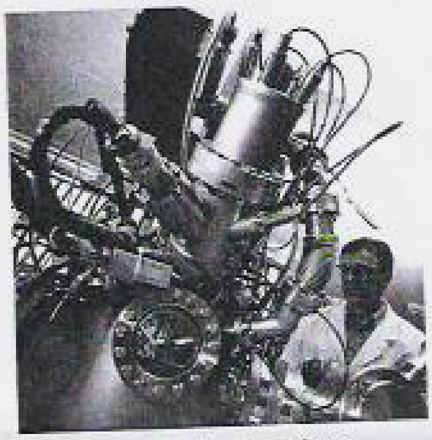

Figure 3 Researcher observing a time-of-flight secondary ion mass spectrometer (TOF SIMS). The sensor array can be seen through the round window (lower left)

ıestions

1. A large ion of mass 5.8×10^9 u and charge +18e is accelerated constantly towards a detector by a potential difference of 870 V. Assuming the ion starts from rest, calculate the time taken for the ion to travel 47 cm to the detector.
2. Figure 2 shows a Bainbridge mass spectrometer. The beam consists of singly ionised neon-20 atoms all travelling at the same speed, 3.0×10^5 m s^{-1}, through a vacuum. As the beam passes through the magnetic field it follows a circular path of radius 0.125 m.
   (a) Explain why the path is a semicircle.
   (b) Show that the force on each ion of mass 3.32×10^{-26} kg is 2.4×10^{-14} N. In which direction is this force?
   (c) Calculate the magnetic field strength or flux density in teslas.
   (d) Suggest where the detector should be positioned to detect ions of neon-22 travelling with the same speed. Explain your decision.
3. The spectrometer of Figure 4 is used to collect the nuclides $^{238}_{92}U$ and $^{206}_{82}Pb$ from a small sample of rock to date it.
   (a) Singly ionised nuclei of the two nuclides from the sample of rock pass through the hole in the 200 V electrode with negligible velocity. They are accelerated towards the electrode at 0 V. Show that the momentum gained by an ion of $^{206}_{82}Pb$, mass 3.5×10^{-25} kg, is about 5×10^{-21} N s.
   (b) Calculate the radius of the circular path of the lead ion when within the uniform region of magnetic field of flux density 0.12 T.
   (c) The lead and uranium ions have the same charge and kinetic energy when they enter the magnetic field, yet the uranium ions follow a path of greater radius. Explain why this is.

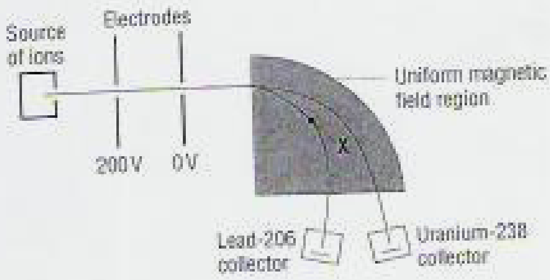

Figure 4