Chapter 3·6 Exam Q

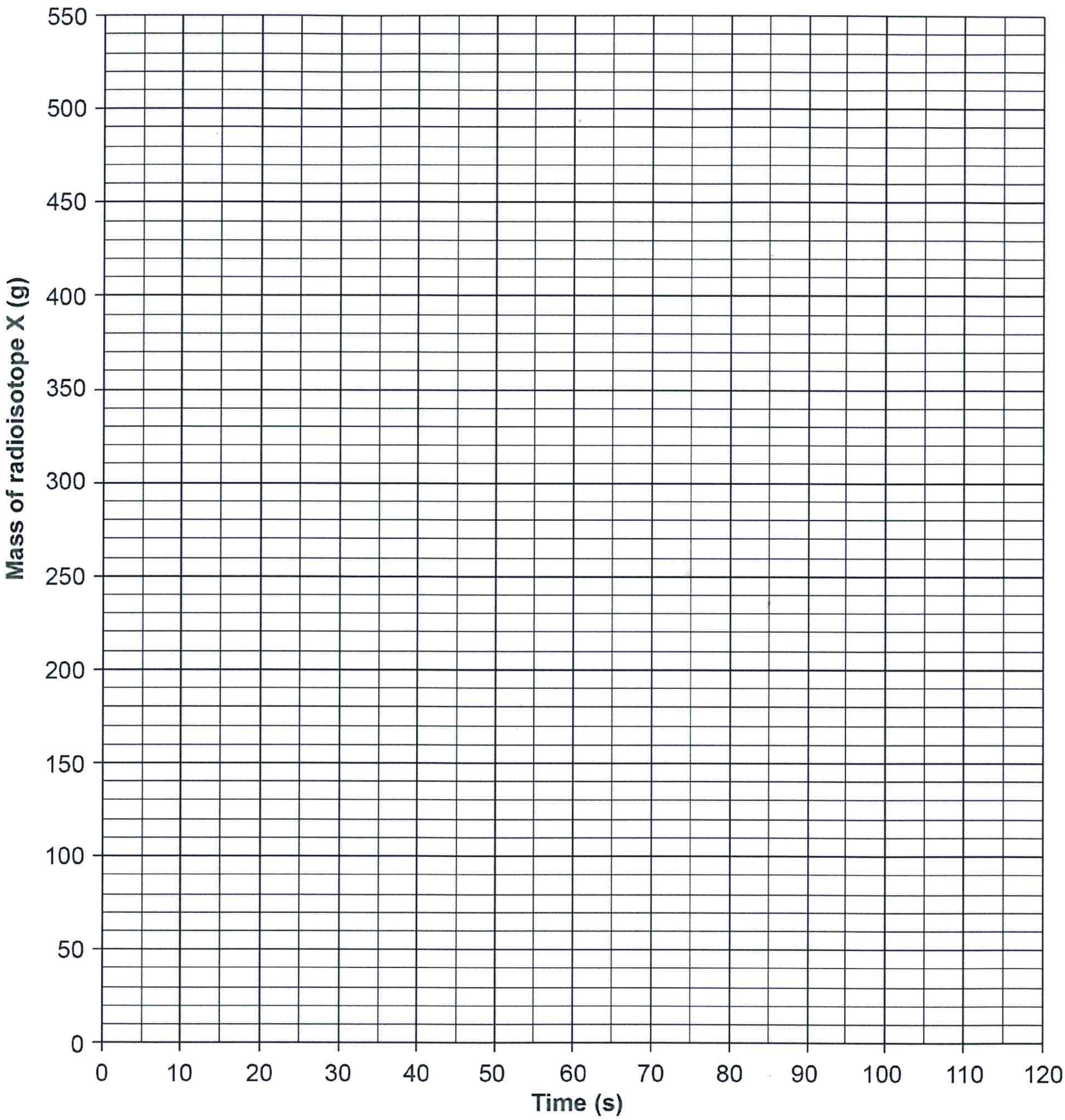
Year 11

Question 1

(3 marks)

Radioisotope X has a half-life of 30 s. Given an initial mass of 480 g of pure X, draw a graph of the mass of X present between time = 0 and time = 120 s.

Mass of radioisotope X against time.



If you wish to make a second attempt at this item, the grid is repeated at the end of this Question/Answer Booklet. Indicate clearly on this page if you have used the second grid and cancel the working on this page.

Chapter 3·6 Exam Q
Year 11

Question 2

(8 marks)

An isotope of thorium-232 undergoes radioactive decay via a number of α and β decays. The overall decay equation can be written as:

$$^{232}_{90}\mathbf{Th} \rightarrow {}^{220}_{86}\mathbf{Rn} + \mathbf{n}\alpha + \mathbf{m}\beta$$

(a) Calculate (showing all working) the values of **n** and **m**. (4 marks)

Thorium-232 is the most commonly occurring isotope of thorium and is a solid with a half-life of around 14.05 billion years. It occurs naturally and is in plentiful supply on the Earth's surface. Radon-220 is a gas at room temperature. It is also radioactive, with a half-life of approximately 55 seconds. It decays to polonium-216, with the release of an alpha particle.

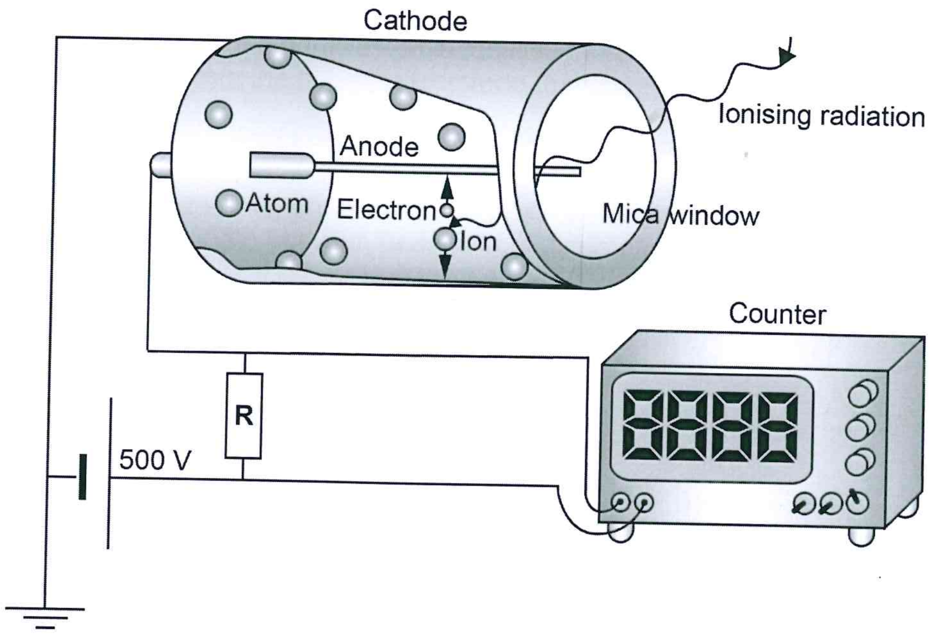
(b) Explain what is meant by 'the half-life of radon-220 is 55 seconds'. (2 marks)

(c) Even though radon gas has a very short half-life and is not abundant, it is more dangerous to humans than thorium. Explain why. (2 marks)

Question 3

(16 Marks)

A Geiger–Müller tube (or GM tube) is the sensing element of a Geiger counter instrument that can detect a single particle of ionising radiation.



A GM tube consists of a tube filled with a low-pressure inert gas such as helium, neon or argon. The tube contains electrodes, between which there is a potential difference of several hundred volts, but no current flowing. The walls of the tube are either entirely metal or have their inside surface coated with a conductor to form the cathode while the anode is a wire passing up the centre of the tube.

When ionising radiation passes through the tube, some of the gas molecules are ionised, creating positively charged ions and electrons. The strong electric field created by the tube's electrodes accelerates the ions towards the cathode and the electrons towards the anode. The ion pairs gain sufficient energy to ionise further gas molecules through collisions on the way, creating an avalanche of charged particles. This results in a short, intense pulse of electrons that passes (or cascades) from the negative electrode to the positive electrode and is measured or counted.

The number of pulses per second measures the intensity of the radiation present. Some Geiger counters display an exposure rate, but this does not relate easily to a dose rate as the instrument does not discriminate between radiations of different energies.

The usual form of tube is an end-window tube. This type is so-named because the tube has a window at one end through which ionising radiation can easily penetrate. The other end normally has the electrical connectors. There are two types of end-window tubes: the glass-window type and the mica (which can be split into very thin sheets) window type. The glass-window type will not detect alpha radiation since it is unable to penetrate the glass, but is usually cheaper and will usually detect beta radiation and gamma rays. The mica window type will detect alpha radiation but is more fragile.

(a) Explain how the ionising radiation causes the inert gas inside the GM tube to become charged. (2 marks)

(b) On the circuit diagram on page 24, draw an arrow to indicate the direction of conventional current flow. (1 mark)

(c) With reference to the properties of alpha particles, infer why a mica window will allow the detection of alpha particles while a glass window will not. (2 marks)

(d) During one experiment, the detector indicates 648 counts over a period of 3 minutes when located 10 cm from a source.

(i) Before the activity of the source can be calculated accurately, the background count is needed. What is meant by the 'background count' and how is it produced? (2 marks)

(ii) If the background count is 14 counts per minute, calculate the source's activity. (3 marks)

(iii) As the GM tube moves closer to the source, what would you expect the counter to indicate? (2 marks)

Circle the correct answer and give reasons for your choice:

more activity   less activity   same activity

(e) During another experiment, 5.6×10^{12} electrons were moved through the circuit over 0.02 seconds when detecting a radioactive source. Calculate the current in the circuit for this event. (2 marks)

(f) Give two reasons why this device can determine a decay rate, but not a dose rate. (2 marks)

Chapter 3·6 Exam Q

Year 11

Question 4

(3 marks)

Uranium-235, $^{235}_{92}U$, has a half life of 7.35×10^5 years and uranium-238, $^{238}_{92}U$, has a half life of 4.5×10^6 years. Compare the two isotopes of uranium, given that they both have the same number of atoms.

(a) Which sample would have the greater weight? (1 mark)

Circle the correct answer: uranium-235 equal uranium-238

(b) Which sample would have the greater number of decays per second? (1 mark)

Circle the correct answer: uranium-235 equal uranium-238

(c) The isotope uranium-238, $^{238}_{92}U$, will decay into an isotope of thorium-234, $^{234}_{90}Th$. Which other particle is produced by this decay? (1 mark)

Circle the correct answer: $^{4}_{2}\alpha$ $^{0}_{1}\beta$ $^{0}_{-1}\beta$

Question 5

(6 marks)

Thorium, $^{228}_{90}Th$, is a radioactive isotope that undergoes decay via a series of steps to eventually reach bismuth, $^{212}_{83}Bi$, a stable isotope. Each of these steps involves the release of ionising radiation.

(a) Determine how many alpha $^{4}_{2}\alpha$ and beta $^{0}_{-1}\beta$ particles in total are released in the transitions between these two isotopes. Show your working. (3 marks)

Number of alpha particles: ____________ Number of beta particles: ____________

(b) In an experiment to study radioactive decay, a 100 gram sample of thorium is placed in a sealed container to decay. After a suitable length of time, the thorium atoms have become mostly bismuth atoms. The container is regularly analysed over this time. Describe how the number of decays per second and the weight of the container change during this time. (3 marks)

Question 6

(5 marks)

The radioactive isotope polonium-210 decays directly to lead-206, which is stable.

(a) Complete the equation below showing this decay. (2 marks)

$$^{210}_{84}Po \rightarrow ^{206}_{82}Pb + \_\_\_\_\_\_\_\_$$

(b) The half-life of polonium-210 is 138 days. If a sample of polonium-210 has an initial activity of 2000 Bq, calculate how long will it take before the sample's activity decreases to 125 Bq. (3 marks)

Chapter 3·6 Exam Q Year 11

Question 7

(2 marks)

Many chemical elements that have large numbers of protons and neutrons in their nuclei are unstable. Describe what eventually occurs to an atom that is not stable, compared with one that is stable.

Question 8

(16 marks)

(a) Polonium-212 is one of the many isotopes of polonium. Explain what is meant by the term 'isotope'. (2 marks)

(b) Polonium-212 is unstable and can decay to emit alpha radiation from its nucleus. An alpha particle is identical to a helium nucleus. State the atomic number and mass number of an alpha particle. (2 marks)

Atomic number = ____________________ Mass number = ____________________

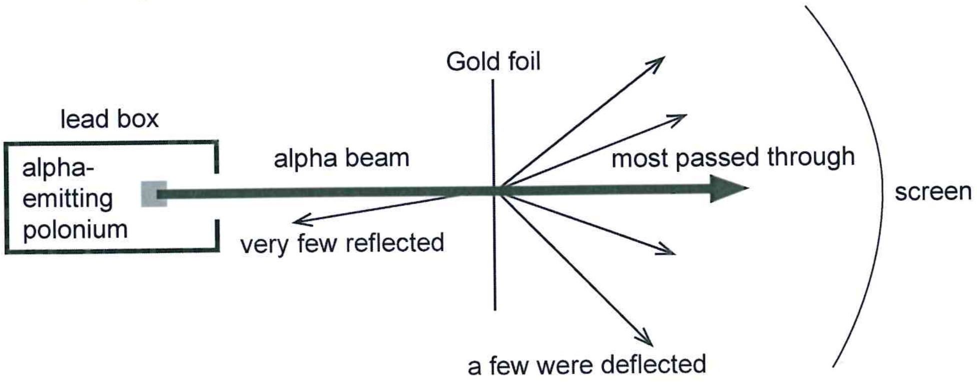
(c) When polonium-212 emits an alpha particle, it also forms a new element, which has been called 'element X' in the equation below. Write the nuclide (symbol) for the alpha particle and then name element X. (2 marks)

$$^{212}_{84}\text{Po} \rightarrow {}^{208}_{82}\text{X} + \alpha$$

(d) Alpha radiation is dangerous to the human body, as it is an ionising radiation. Explain what is meant by the term 'ionising radiation'. (2 marks)

(e) Consider polonium-218. This isotope has a half-life of 3.00 minutes. If a sample of polonium-218 has an activity of 21.0 kBq, calculate the activity of the sample 30.0 minutes later. (3 marks)

Ernest Rutherford (1871–1937) experimented with alpha radiation. He built an alpha probe that consisted of a point source of alpha radiation. This radiation was shot through very thin gold foil to a screen surrounding the equipment. He found that most of the alpha particles passed through the gold foil with little or no change in direction; occasionally a particle was deflected significantly to the side; and, very rarely, a particle was reflected off the foil. The diagram below illustrates Rutherford's experiment.



(f) Before Rutherford's experiment, the model of the atom developed by J.J. Thomson was of negatively-charged electrons embedded within a positively-charged gel. This was called the 'plum pudding' model. Rutherford's model of the atom formed the foundation for our current understanding of the atom. Describe Rutherford's model of the atom and explain how the experiment above helped him to develop this model. (5 marks)