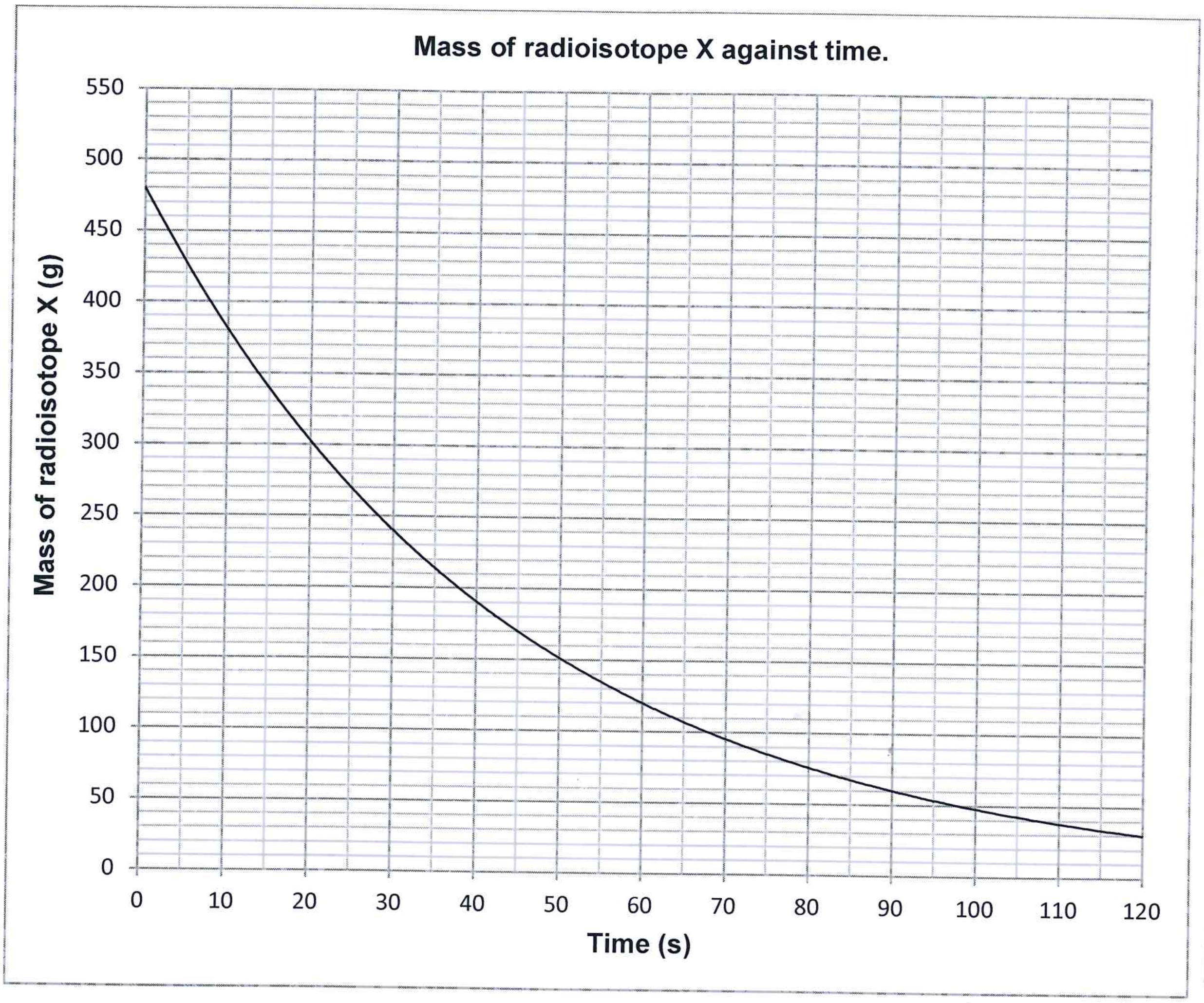
Solutions Ch 3·6 Year 11

Answer 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.



Description	Marks
Obvious curve clearly shown starting at 480	1
Mass at 30 s is about 240 g Mass at 120 s is about 30 g	1–2
Total	3

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Answer 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)

Description	Marks
α is $^{4}_{2}\mathbf{H}$ and β is $^{0}_{-1}\mathbf{e}$	1–4
220 + 4n + 0 = 232 (eq 1)	
4n = 232 – 220 = 12; so n = 3	
86 + 2n + (-1)m = 90 (eq 2)	
Substitute n = 3 into (eq 2) 86 + 2×3 – m = 90 m = 86 + 6 – 90 = 2 m = 2	
	Total 4

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)

Description	Marks
It takes 55 s for half of the radon atoms initially present to undergo radioactive decay	1–2
	Total 2

(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)

Description	Marks
Gas – easily taken into lungs – internal dose more dangerous.	1
Either one of: Decays to solid polonium which remains in the lungs, itself emitting radiation. or Alpha emitter is highly ionising and the most dangerous form of radiation to body cells.	1
	Total 2

Answer 3

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

Description	Marks
Radiation ionises the gas atoms by removing electrons producing positive ions.	1–2
	Total 2

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Answer 3 continued

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

Description	Marks
Either side of power source on the circuit line away from the positive or towards the negative.	1
	Total 1

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

Description	Marks
Alpha particles are easily stopped when they pass through matter.	1
Mica is thin.	1
	Total 2

(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)

Description	Marks
Naturally occurring radiation in the environment	1
Comes from cosmic, sources, rocks and minerals	1
	Total 2

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

Description	Marks
Counts per min = 648/3 = 216	1
Counts per min due to source = 216 – 14 = 202	1
Activity = 202/60 Bq = 3.37 Bq	1
	Total 3

(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

Description	Marks
More activity	1
Less radiation is stopped by the air between the source and detector as the source gets closer to the detector (or inverse square law).	1
	Total 2

Answer 3 continued

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

Description	Marks
$q = 5.60 \times 10^{12} \times 1.60 \times 10^{-19}$ C	1
$I = q/t = 8.96 \times 10^{-7}/0.02 = 4.48 \times 10^{-5}$ A	1
	Total 2

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

Description	Marks
Machine doesn't discriminate between radiations of different energies.	1
Machine doesn't discriminate between different types of radiation – no quality factor determinations.	1
	Total 2

Answer 4

(3 marks)

Uranium-235, ${}^{235}_{92}\mathrm{U}$, has a half life of 7.35×10^5 years and uranium-238, ${}^{238}_{92}\mathrm{U}$, 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, ${}^{238}_{92}\mathrm{U}$, will decay into an isotope of thorium-234, ${}^{234}_{90}\mathrm{Th}$. Which other particle is produced by this decay? (1 mark)

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

Description	Marks
(a) Uranium-238	1
(b) Uranium-235	1
(c) ${}^{4}_{2}\alpha$	1
	Total 3

Answer 5

(6 marks)

Thorium, $^{228}_{90}\text{Th}$, is a radioactive isotope that undergoes decay via a series of steps to eventually reach bismuth, $^{212}_{83}\text{Bi}$, 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)

(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)

Description	Marks
(a) 228-212=16 mass difference means 16/4=4 alpha particles	1
90-83= 7 protons difference, but 8 from alpha decay,	1
so one beta decay to change neutron to proton	1
(b) The greatest number of decays per second occur at the beginning when there is a higher amount of unstable material	1
The weight will remain equal over the length of the experiment	1
The decayed particles have been kept in the container (could say matter has changed into energy, so is slightly lighter)	1
	Total 6

Answer 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)

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

Description	Marks
Identifies alpha decay particle as alpha, α, helium nucleus, He, etc.	1
Properly shows particle magnitudes as $^{4}_{2}$	1
Total	**2**

(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)

Description	Marks
Shows some calculations e.g. $A=A_0(½)^n$ or 2000;1000;500;250;125 $125 = 2000(½)^n$	1
Identifies number of half-lives = 4	1
4 × 138 = 552 days	1
Total	**3**

Answer 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 which is not stable, compared with one that is stable.

Description	Marks
An unstable element undergoes decay giving off radiation	1
A stable element does not decay	1
Total	**2**

Answer 8

(16 marks)

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

Description	Marks
Two samples that have the same number of protons (same atomic number)	1
But have different numbers of neutrons (different mass number)	1
Total	**2**

(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)

Description	Marks
Atomic number = 2	1
Mass number = 4	1
Total	**2**

(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)

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

Description	Marks
${}^{4}_{2}He$ or ${}^{4}_{2}\alpha$	1
Lead	1
Total	**2**

(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)

Description	Marks
Radiation that causes atoms to lose an electron	1
And become an ion	1
Total	**2**

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Answer 8 continued

(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)

Description	Marks
Number of half-lives = 30/3 = 10	1
$A = A_0 \times (0.5)^n = 21 \times (0.5)^{10}$	1
$A = 21 \times 9.766 \times 10^{-4}$ $= 0.0205$ kBq	1
Student could divide activity by 2 ten times to get answer but must show working for full marks	
Total	**3**

(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 described helped him to develop this model. (5 marks)

Description	Marks
Mainly space with small positively centrally charged nucleus and electrons outside nucleus OR labelled diagram	1–2
Most of the alpha particles went straight through so mainly space	1
Positively charged centre due to a few positively charged alpha particles being repelled (like charges repel)	1
Small, dense centre as occasional alpha particle rebounds	1
Total	**5**