WEEK: 12

Week Beginning: 8-3-21

Subject: SCIENCE

Year: 11

Lesson Objective:

- Go over homework
- Questions

Keywords/ Concepts

- Isotopes, unstable nuclei, radiation, half-life

Class Worksheets

- Questions

Homework

- Questions

Additional Notes

Homework from last week

Warm-Up & Exam Questions

That's some more revision done and dusted and now it's time to test yourself on how much you've taken in. Have a go at the questions on this page to see if you need to revisit some topics.

Warm-Up Questions

1) Give an example of a natural resource which has been replaced by a man-made alternative.
2) What is sustainable development?
3) Give three positive effects of recycling metals.
4) What are the four stages that need to be considered to conduct a life cycle assessment?

Exam Questions

1 Natural resources are formed without human input and are used for construction, fuel and food. (Grade 4-6)

1.1 What is a finite natural resource?
Tick **one** box.

- A natural resource that can never be remade. ☐
- A natural resource that will never run out. ☐
- A natural resource that doesn't renew itself quickly enough to be considered replaceable. ☐
- A natural resource that can only be used in certain conditions. ☐

[1 mark]

1.2 Aluminium is used to make soft drink cans. Extracting aluminium is a very energy intensive process. Suggest **two** ways that the use of soft drink cans can be made more sustainable.

[2 marks]

2 Copper needs to be extracted from its ore before it can be used. (Grade 6-7)

2.1 Explain why scientists have developed ways of extracting copper from low-grade ores.

[1 mark]

2.2 Copper can be extracted from low-grade ores by a process called bioleaching.
Explain how the process works.

[2 marks]

2.3 Give **one** advantage of using processes such as bioleaching rather than traditional mining.

[1 marks]

2.4 Give **one** disadvantage of using processes such as bioleaching rather than traditional mining.

[1 mark]

3 A life cycle assessment looks at the environmental impact of a product over its lifetime. (Grade 6-7)

3.1 Describe why it can be difficult to give a complete assessment of a product over its entire life cycle.

[1 mark]

3.2 A company carried out a LCA on one of their products but didn't take into account its disposal. However, an independent LCA found the disposal of the product to have the greatest environmental impact of any part of the product's life cycle.
Suggest why the LCA performed by the company didn't include details of the disposal of the product.

[2 marks]

Developing the Model of the Atom

All this started with a Greek chap called Democritus in the 5th Century BC. He thought that all matter, whatever it was, was made up of identical lumps called "atomos". And that's as far as it got until the 1800s...

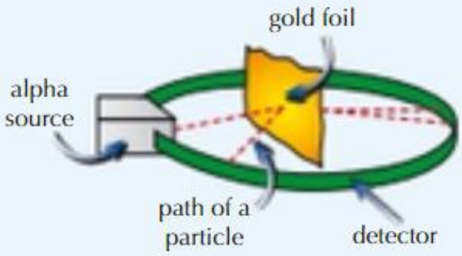
The Plum Pudding Model was Replaced with the Nuclear Model

1) In 1804 John Dalton agreed with Democritus that matter was made up of tiny spheres ("atoms") that couldn't be broken up, but he reckoned that each element was made up of a different type of "atom".

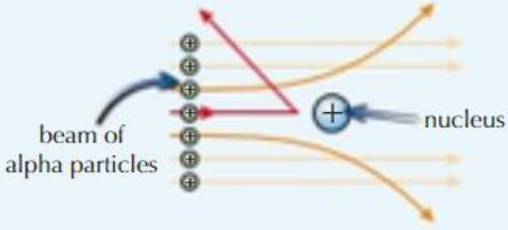
2) Nearly 100 years later, J. J. Thomson discovered particles called electrons that could be removed from atoms. So Dalton's theory wasn't quite right (atoms could be broken up). Thomson suggested that atoms were spheres of positive charge with tiny negative electrons stuck in them like the fruit in a plum pudding — the plum pudding model.

3) That "plum pudding" theory didn't last though... In 1909, scientists in Rutherford's lab tried firing a beam of alpha particles (see p.75) at thin gold foil — this was the alpha scattering experiment. From the plum pudding model, they expected the particles to pass straight through the gold sheet, or only be slightly deflected.

4) But although most of the particles did go straight through the sheet, some were deflected more than they had expected, and a few were deflected back the way they had come — something the plum pudding model couldn't explain.



5) Because a few alpha particles were deflected back, the scientists realised that most of the mass of the atom was concentrated at the centre in a tiny nucleus. This nucleus must also have a positive charge, since it repelled the positive alpha particles.



6) They also realised that because nearly all the alpha particles passed straight through, most of an atom is just empty space. This was the first nuclear model of the atom.

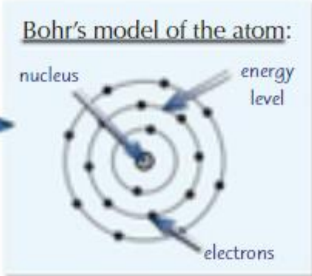
Developing the Model of the Atom

Rutherford and Marsden's model of the atom was a big leap forwards, but that's not the end of the story...

Bohr Refined Rutherford's Nuclear Model of the Atom

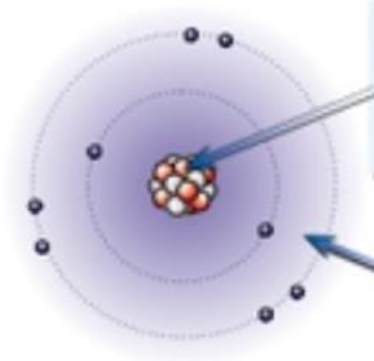
1) The nuclear model that resulted from the alpha particle scattering experiment was a positively charged nucleus surrounded by a cloud of negative electrons.
2) Niels Bohr said that electrons orbiting the nucleus do so at certain distances called energy levels. His theoretical calculations agreed with experimental data.
3) Evidence from further experiments changed the model to have a nucleus made up of a group of particles (protons) which all had the same positive charge that added up to the overall charge of the nucleus.

Bohr's model of the atom:



4) About 20 years after the idea of a nucleus was accepted, in 1932, James Chadwick proved the existence of the neutron, which explained the imbalance between the atomic and mass numbers (see next page).

Our Current Model of the Atom



The nucleus is tiny but it makes up most of the mass of the atom. It contains protons (which are positively charged — they have a +1 relative charge) and neutrons (which are neutral, with a relative charge of 0) — which gives it an overall positive charge. Its radius is about 10 000 times smaller than the radius of the atom.

The rest of the atom is mostly empty space. Negative electrons (which have a relative charge of –1) whizz round the outside of the nucleus really fast. They give the atom its overall size — the radius of an atom is about 1×10^{-10} m.

We're currently pretty happy with this model, but there's no saying it won't change. Just like for the plum pudding model, new experiments sometimes mean we have to change or completely get rid of current models.

Number of Protons Equals Number of Electrons

1) In atoms, the number of protons = the number of electrons, as protons and electrons have an equal but opposite charge and atoms have no overall charge.
2) Electrons in energy levels can move within (or sometimes leave) the atom. If they gain energy by absorbing EM radiation (p.136) they move to a higher energy level, further from the nucleus. If they release EM radiation, they move to a lower energy level that is closer to the nucleus. If one or more outer electrons leaves the atom, the atom becomes a positively charged ion.

Isotopes

Isotopes of an element look pretty similar, but watch out — they have different numbers of neutrons.

Atoms of the Same Element have the Same Number of Protons

1) All atoms of each element have a set number of protons (so each nucleus has a given positive charge). The number of protons in an atom is its atomic number.

2) The mass number of an atom (the mass of the nucleus) is the number of protons + the number of neutrons in its nucleus.

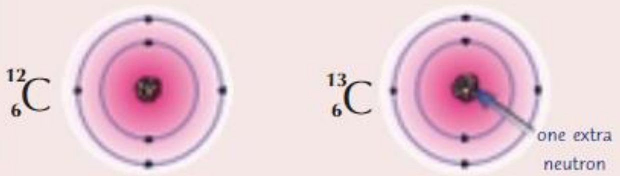
Example: A certain oxygen atom has the chemical symbol — $^{16}_{8}O$.

- Oxygen has an atomic number of 8, this means all oxygen atoms have 8 protons.
- This atom of oxygen has a mass number of 16.
  Since it has 8 protons, it must have 16 – 8 = 8 neutrons.

Isotopes are Different Forms of the Same Element

1) Isotopes of an element are atoms with the same number of protons (the same atomic number, and so the same charge on the nucleus) but a different number of neutrons (a different mass number).

Example: Carbon-12 and carbon-13 are isotopes.



2) All elements have different isotopes, but there are usually only one or two stable ones.

3) The other unstable isotopes tend to decay into other elements and give out radiation as they try to become more stable. This process is called radioactive decay.

4) Radioactive substances spit out one or more types of ionising radiation from their nucleus — the ones you need to know are alpha, beta and gamma radiation (see next page).

5) They can also release neutrons (n) when they decay.

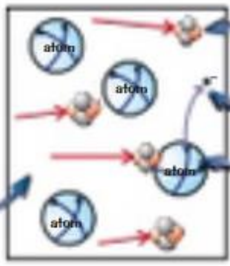
6) Ionising radiation is radiation that knocks electrons off atoms, creating positive ions. The ionising power of a radiation source is how easily it can do this.

Ionising Radiation

There are three types of ionising radiation you need to know about — these are alpha, beta and gamma.

Alpha Particles are Helium Nuclei

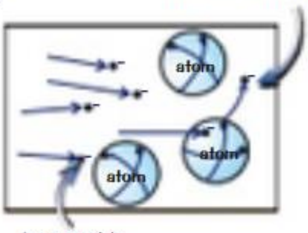
1) Alpha radiation is when an alpha particle (α) is emitted from the nucleus. An α-particle is two neutrons and two protons (like a helium nucleus).
2) They don't penetrate very far into materials and are stopped quickly — they can only travel a few cm in air and are absorbed by a sheet of paper.
3) Because of their size they are strongly ionising.
4) Alpha radiation has applications in the home:



> Alpha radiation is used in smoke detectors — it ionises air particles, causing a current to flow. If there is smoke in the air, it binds to the ions — meaning the current stops and the alarm sounds.

Beta Particles are High-Speed Electrons

1) A beta particle (β) is simply a fast-moving electron released by the nucleus. Beta particles have virtually no mass and a charge of –1.
2) They are moderately ionising (see right).
3) They also penetrate moderately far into materials before colliding and have a range in air of a few metres. They are absorbed by a sheet of aluminium (around 5 mm thick).
4) For every beta particle emitted, a neutron in the nucleus has turned into a proton.
5) Beta radiation can be useful due to the fact that it's moderately penetrating:

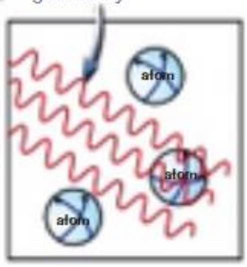


> Beta emitters are used to test the thickness of sheets of metal, as the particles are not immediately absorbed by the material like alpha radiation would be and do not penetrate as far as gamma rays. Therefore, slight variations in thickness affect the amount of radiation passing through the sheet.

Gamma Rays are EM Waves with a Short Wavelength

1) Gamma rays (γ) are waves of electromagnetic radiation (p.136) released by the nucleus.
2) They penetrate far into materials without being stopped and will travel a long distance through air.
3) This means they are weakly ionising because they tend to pass through rather than collide with atoms. Eventually they hit something and do damage.
4) They can be absorbed by thick sheets of lead or metres of concrete.

Uses of gamma rays are on p.83 and p.139.



Nuclear Equations

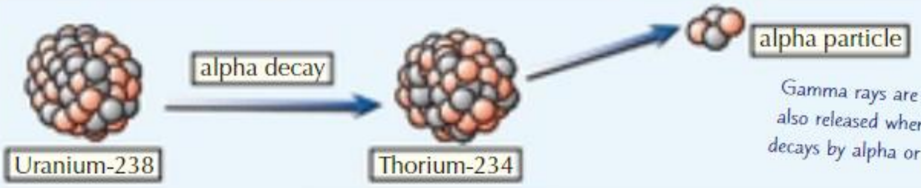
Nuclear equations show radioactive decay and once you get the hang of them they're dead easy. Get going.

Mass and Atomic Numbers Have to Balance

1) Nuclear equations are a way of showing radioactive decay by using element symbols (p.74). They're written in the form: atom before decay → atom(s) after decay + radiation emitted.
2) There is one golden rule to remember: the total mass and atomic numbers must be equal on both sides.

Alpha Decay Decreases the Charge and Mass of the Nucleus

1) Remember, alpha particles are made up of two protons and two neutrons. So when an atom emits an alpha particle, its atomic number reduces by 2 and its mass number reduces by 4.
2) A proton is positively charged and a neutron is neutral, so the charge of the nucleus decreases.
3) In nuclear equations, an alpha particle can be written as a helium nucleus: $^{4}_{2}He$.



Gamma rays are sometimes also released when a nucleus decays by alpha or beta decay.

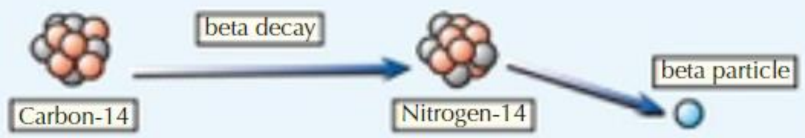
The nuclear equation for this decay would be:

$$^{238}_{92}U \rightarrow {}^{234}_{90}Th + {}^{4}_{2}He$$

238 → 234 + 4
92 → 90 + 2

Beta Decay Increases the Charge of the Nucleus

1) When beta decay occurs, a neutron in the nucleus turns into a proton and releases a fast-moving electron (the beta particle).
2) The number of protons in the nucleus has increased by 1. This increases the positive charge of the nucleus (the atomic number).
3) Because the nucleus has lost a neutron and gained a proton during beta decay, the mass of the nucleus doesn't change (protons and neutrons have the same mass).
4) A beta particle is written as $^{0}_{-1}e$ in nuclear equations.



The nuclear equation for this decay would be:

$$^{14}_{6}C \rightarrow {}^{14}_{7}N + {}^{0}_{-1}e$$

14 → 14 + 0
6 → 7 + (–1)

In both alpha and beta emissions, a new element will be formed, as the number of protons (atomic number) changes.

Gamma Rays Don't Change the Charge or Mass of the Nucleus

1) Gamma rays are a way of getting rid of excess energy from a nucleus.
2) This means that there is no change to the atomic mass or atomic number of the atom.
3) In nuclear equations, gamma radiation is written as γ^{0}_{0}.

Half-Life

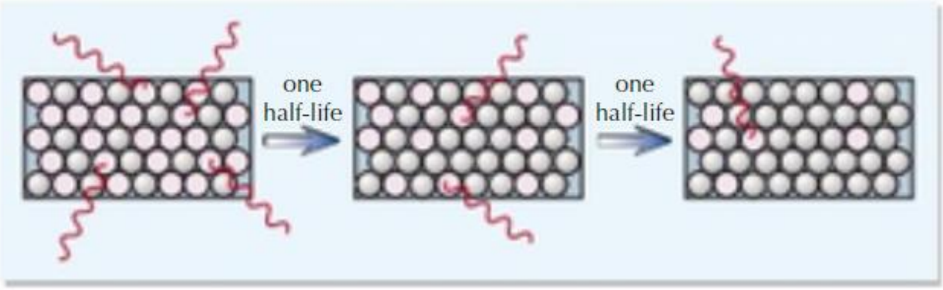
How quickly unstable nuclei decay is measured using activity and half-life — two very important terms.

Radioactivity is a Totally Random Process

1) Radioactive substances give out radiation from the nuclei of their atoms — no matter what.
2) This radiation can be measured with a Geiger-Muller tube and counter, which records the count-rate — the number of radiation counts reaching it per second.
3) Radioactive decay is entirely random. So you can't predict exactly which nucleus in a sample will decay next, or when any one of them will decay.
4) But you can find out the time it takes for the amount of radiation emitted by a source to halve, this is known as the half-life. It can be used to make predictions about radioactive sources, even though their decays are random.
5) Half-life can be used to find the rate at which a source decays — its ACTIVITY. Activity is measured in becquerels, Bq (where 1 Bq is 1 decay per second).

The Radioactivity of a Source Decreases Over Time

1) Each time a radioactive nucleus decays to become a stable nucleus, the activity as a whole will decrease. (Older sources emit less radiation.)



2) For some isotopes it takes just a few hours before nearly all the unstable nuclei have decayed, whilst others last for millions of years.
3) The problem with trying to measure this is that the activity never reaches zero, which is why we have to use the idea of half-life to measure how quickly the activity drops off.

The half-life is the time taken for the number of radioactive nuclei in an isotope to halve.

4) Half-life can also be described as the time taken for the activity, and so count-rate, to halve.
5) A short half-life means the activity falls quickly, because the nuclei are very unstable and rapidly decay. Sources with a short half-life can be dangerous because of the high amount of radiation they emit at the start, but they quickly become safe.
6) A long half-life means the activity falls more slowly because most of the nuclei don't decay for a long time — the source just sits there, releasing small amounts of radiation for a long time. This can be dangerous because nearby areas are exposed to radiation for (millions of) years.

Half-Life

You learnt all about what half-life is on the last page, but now it's time to find out how to calculate it. Fortunately, there's a pretty simple method you can use that involves an activity-time graph.

The Radioactivity of a Source Decreases Over Time

You might be asked to give the decline of activity or count-rate after a certain number of half-lives as a percentage of the original activity, like this:

EXAMPLE: **The initial activity of a sample is 640 Bq. Calculate the final activity as a percentage of the initial activity after two half-lives.**

1) Find the activity after each half-life.
   1 half-life: 640 ÷ 2 = 320
   2 half-lives: 320 ÷ 2 = 160
2) Now divide the final activity by the initial activity, then multiply by 100 to make it a percentage.
   (160 ÷ 640) × 100
   = 0.25 × 100
   = 25%

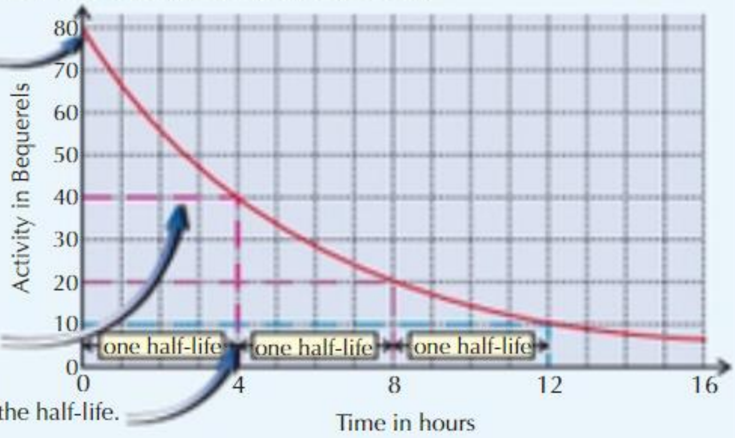
Always double check what the question is asking for — it may want a fraction, ratio or a percentage.

Finding the Half-Life of a Sample using a Graph

1) If you plot a graph of activity against time (taking into account background radiation, p.81), it will always be shaped like the one below.
2) The half-life is found from the graph by finding the time interval on the bottom axis corresponding to a halving of the activity on the vertical axis. Easy.

EXAMPLE: **The activity of a sample of a radioactive material, X, is shown on the graph below. Calculate the half-life of material X.**

1) Read the initial activity off the graph. This is the activity when time = 0.
2) Divide the initial activity by 2 to find the value of half the initial activity.
   80 ÷ 2 = 40
3) Find this value on the y-axis and read along horizontally to the curve.
4) Then read down from the curve at this point to find the half-life.



So the half-life of the sample is 4 hours.

Warm-Up & Exam Questions

Atoms may be tiny, but you could bag some big marks in your exams if you know them inside-out. Here are some questions to check just how great your understanding of atoms and radiation really is...

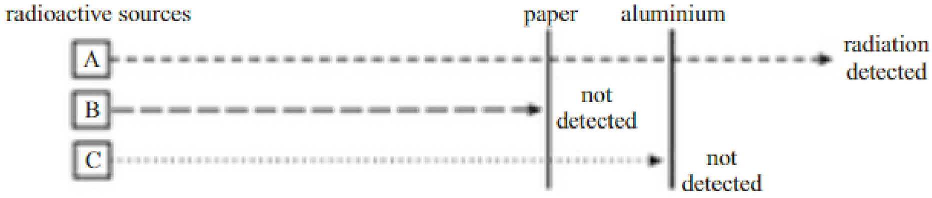
Warm-Up Questions

1) Describe our current, nuclear model of the atom.
2) Give the definition of the term 'isotope'.
3) Which are the most ionising — alpha particles or gamma rays?
4) Outline why beta emitters, rather than alpha or gamma emitters, are used to test the thickness of sheets of metal.
5) Name the type of nuclear radiation, the particles of which are electrons.
6) Name the type of nuclear radiation that is an electromagnetic wave.
7) Radioactive substances with short half-lives can be initially very dangerous. Explain why.

Exam Questions

1 Alpha, beta and gamma radiation sources were used to direct radiation at thin sheets of paper and aluminium. A detector was used to measure where radiation had passed through the sheets. The results are shown in **Figure 1**.

Figure 1



1.1 Name the type of radiation that source C emits. Explain your answer.

[2 marks]

1.2 Give **one** example of a detector that could have been used to detect the radiation.

[1 mark]

2 A sample of a highly ionising radioactive gas has a half-life of two minutes.

2.1 Define what is meant by the term 'half-life'.

[1 mark]

The sample contains a number of unstable nuclei.

2.2 Calculate the fraction of these nuclei that will be present after four minutes.

[2 marks]

3 A radioactive isotope sample has a half-life of 40 seconds. The initial activity of the sample is 8000 Bq.

3.1 Calculate the activity after 2 minutes. Give your answer in becquerels.

[2 marks]

3.2 After how many half-lives will the activity have fallen to 250 Bq?

[2 marks]

3.3 The radioactive source is left until its activity falls to 100 Bq. Calculate the final activity as a percentage of the initial activity.

[2 marks]

4 **Table 1** contains information about three atoms.

Table 1

	Mass number	Atomic number
Atom A	32	17
Atom B	33	17
Atom C	32	16

4.1 Name the two types of particle that the nucleus of an atom contains.

[2 marks]

4.2 Define the term 'mass number' in the context of atoms.

[1 mark]

4.3 Which of the two atoms in **Table 1** are isotopes of the same element? Explain your answer.

[2 marks]

Alpha and beta particles are deflected in electric fields.

4.4 Suggest why alpha and beta particles are deflected in opposite directions.

[1 mark]

5 Nuclear equations show what is produced when unstable nuclei decay.

5.1 Draw a symbol that can be used to represent a beta particle in a nuclear equation.

[1 mark]

5.2 Describe what happens to the atomic number and the mass number of an atom when it undergoes beta decay.

[2 marks]

5.3 Describe what happens to the atomic number and the mass number of an atom when it undergoes gamma decay.

[2 marks]

5.4 Complete the nuclear equation, shown in **Figure 2**, which shows a polonium isotope decaying by alpha emission.

Figure 2

$$^{\dots\dots}_{84}\text{Po} \longrightarrow {}^{205}_{\dots\dots}\text{Pb} + {}^{\dots\dots}_{\dots\dots}\text{He}$$

[3 marks]

Alpha, beta and gamma are types of nuclear radiation.

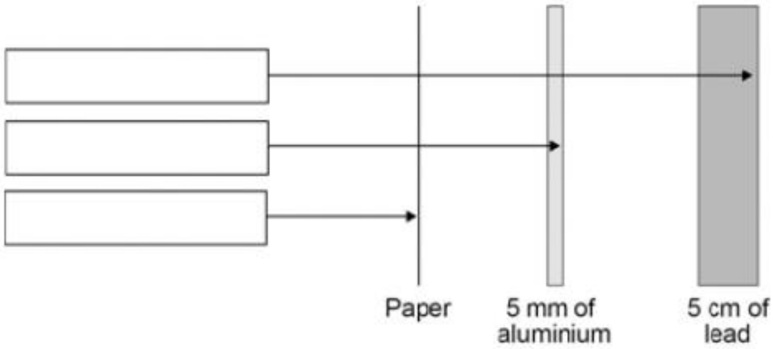
(a) Draw **one** line from each type of radiation to what the radiation consists of.

Type of radiation	**What radiation consists of**
	Electron from the nucleus
Alpha	
	Two protons and two neutrons
Beta	
	Electromagnetic radiation
Gamma	
	Neutron from the nucleus

(3)

(b) A teacher demonstrates the penetration of alpha, beta and gamma radiation through different materials.

The demonstration is shown in the figure below.



Complete the figure above by writing the name of the correct radiation in each box.

(2)

(c) Give **two** safety precautions the teacher should have taken in the demonstration.

1. ____

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2. ____

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(2)

(d) The table below shows how the count rate from a radioactive source changes with time.

Time in seconds	0	40	80	120	160
Count rate in counts/second	400	283	200	141	100

Use the table to calculate the count rate after 200 seconds.

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(2)

(e) The half-life of the radioactive source used was very short.

Give **one** reason why this radioactive source would be much less hazardous after 800 seconds.

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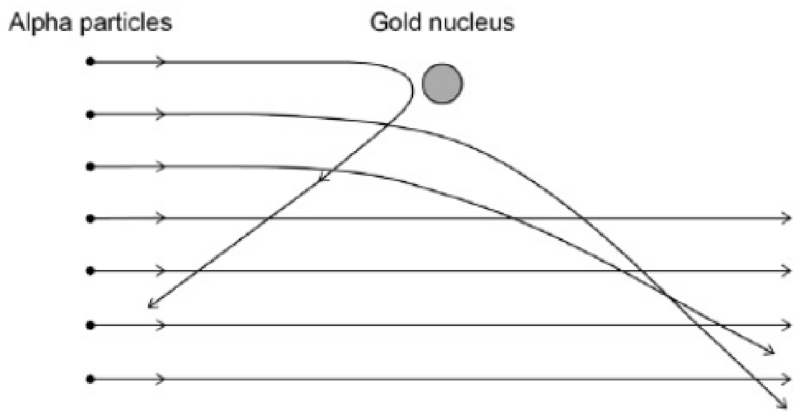
(1)

(Total 10 marks)

In the early 20th century, scientists developed an alpha particle scattering experiment using gold foil.

The diagram shows the paths of some of the alpha particles in the alpha particle scattering experiment.



(a) Explain how the paths of the alpha particles were used to develop the nuclear model of the atom.

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(4)

(b) Niels Bohr adapted the nuclear model by suggesting electrons orbited the nucleus at specific distances.

Explain how the distance at which an electron orbits the nucleus may be changed.

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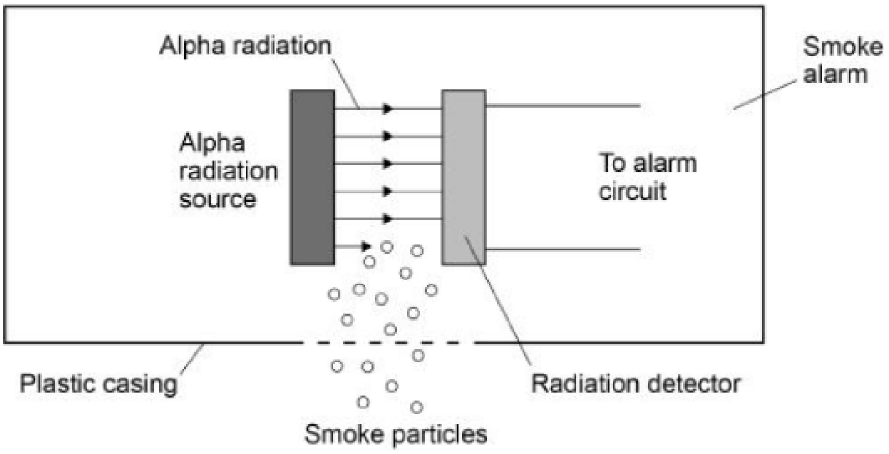
(3)

Smoke alarms contain an alpha radiation source and a radiation detector.

Figure 1 shows part of the inside of a smoke alarm.

Figure 1



(a) The smoke alarm stays off while alpha radiation reaches the detector.

Why does the alarm switch on when smoke particles enter the plastic casing?

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(1)

(b) Why is it safe to use a source of alpha radiation in a house?

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(1)

(c) The smoke alarm would not work with a radiation source that emits beta or gamma radiation.

Explain why.

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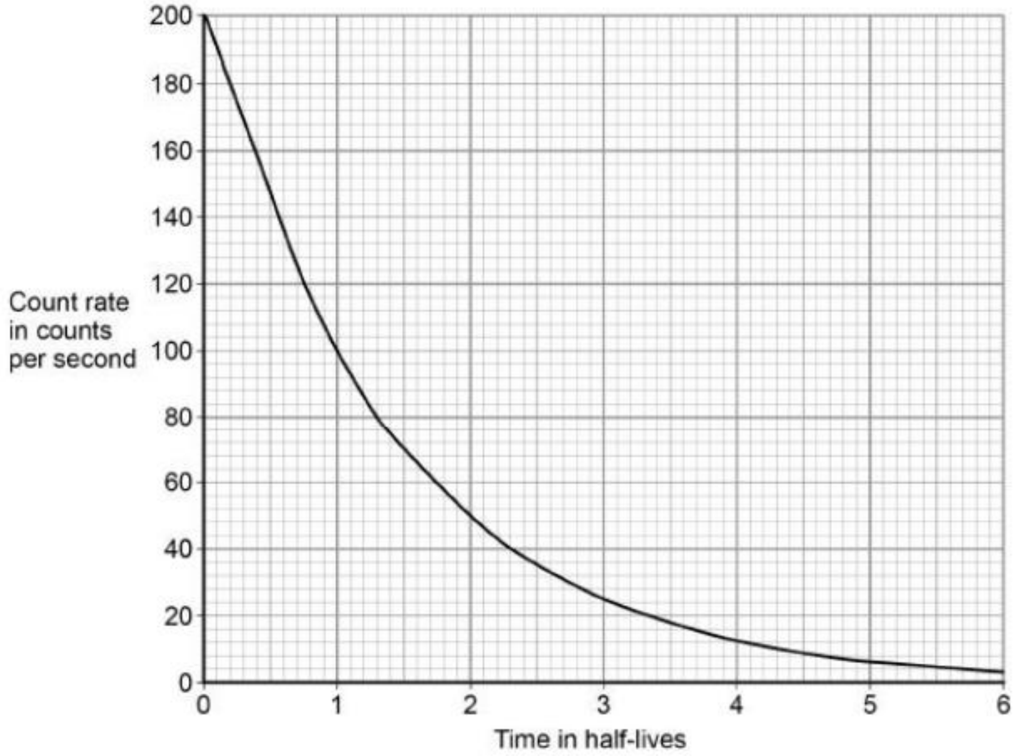
(2)

(d) **Figure 2** shows how the count rate detected from the radiation source in the smoke alarm changes with time.

Figure 2



The smoke alarm switches on when the count rate falls to 80 counts per second.

Explain why the radiation source inside the smoke alarm should have a long half-life.

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(2)

(e) **Figure 3** shows a patient who has been injected with a radioactive source for medical diagnosis.

Figure 3

Explain the ideal properties of a radioactive source for use in medical diagnosis.

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(4)