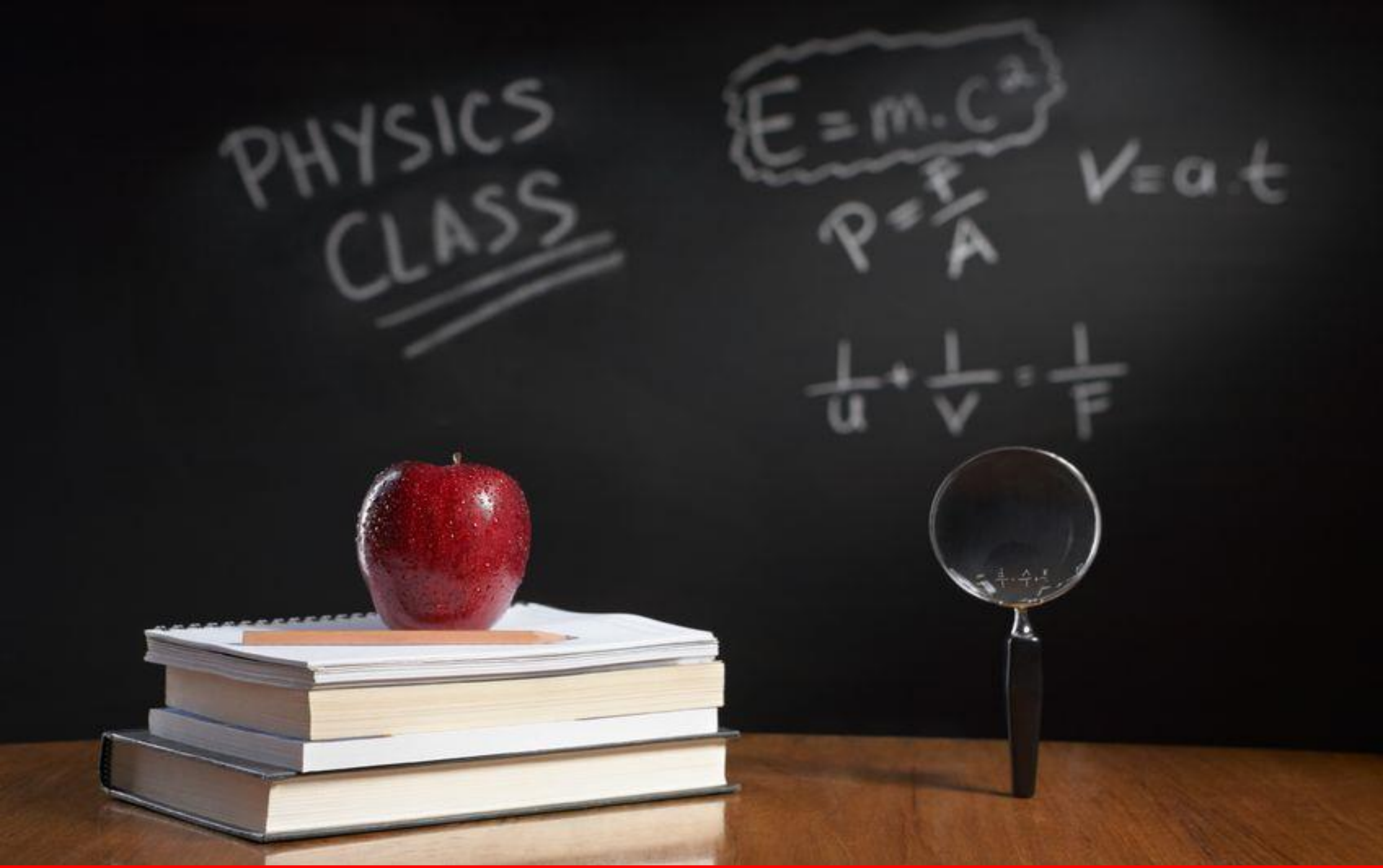


PHYSICS – The Nuclear Atom

LEARNING OBJECTIVES

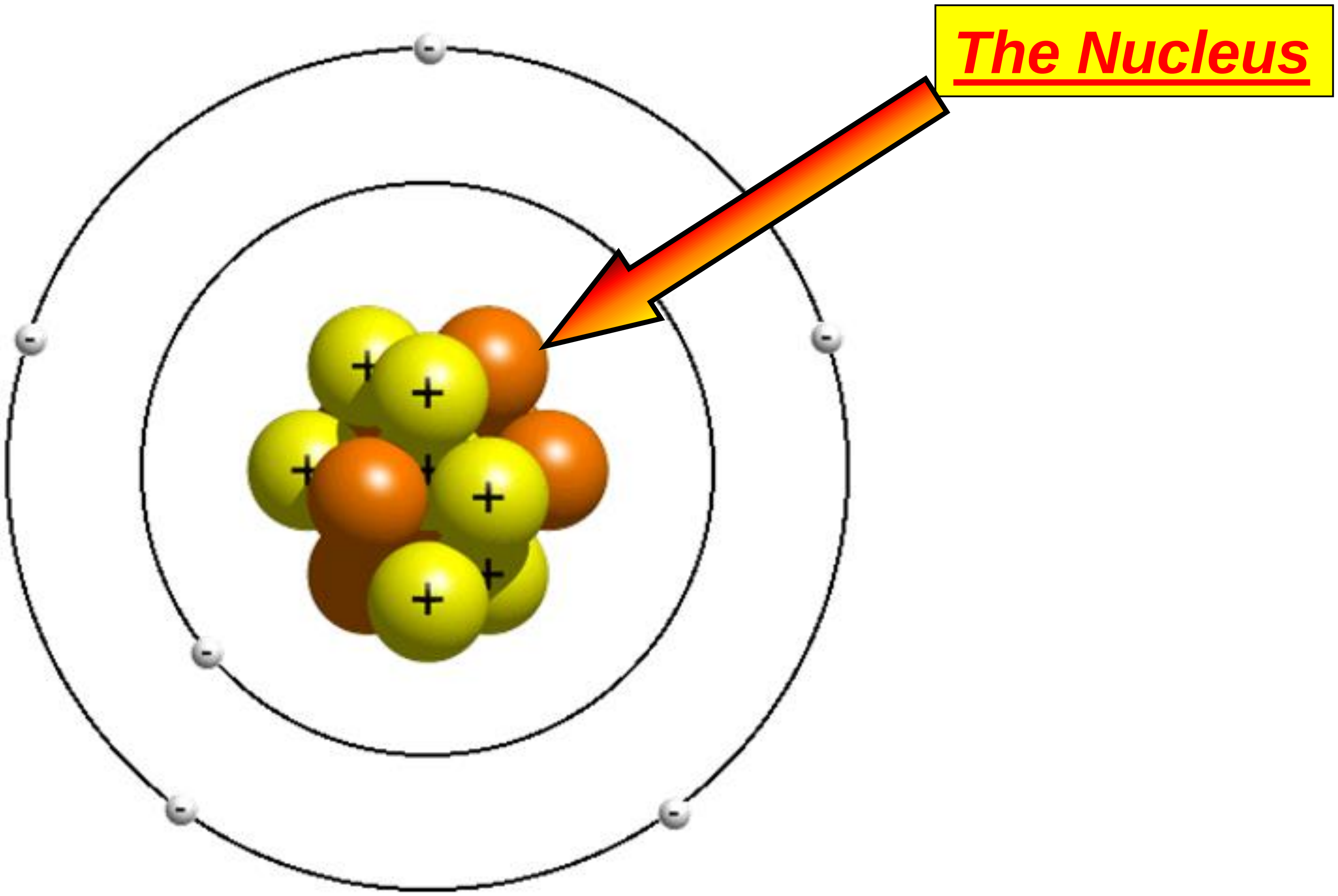
Core	Supplement
• Describe the structure of an atom in terms of a positive nucleus and negative electrons • Describe the composition of the nucleus in terms of protons and neutrons • State the charges of protons and neutrons • Use the term proton number Z • Use the term nucleon number A • Use the term nuclide and use the nuclide notation A ZX • Use and explain the term isotope	• Describe how the scattering of α-particles by thin metal foils provides evidence for the nuclear atom • State the meaning of nuclear fission and nuclear fusion • Balance equations involving nuclide notation

Atoms

Atomic structure

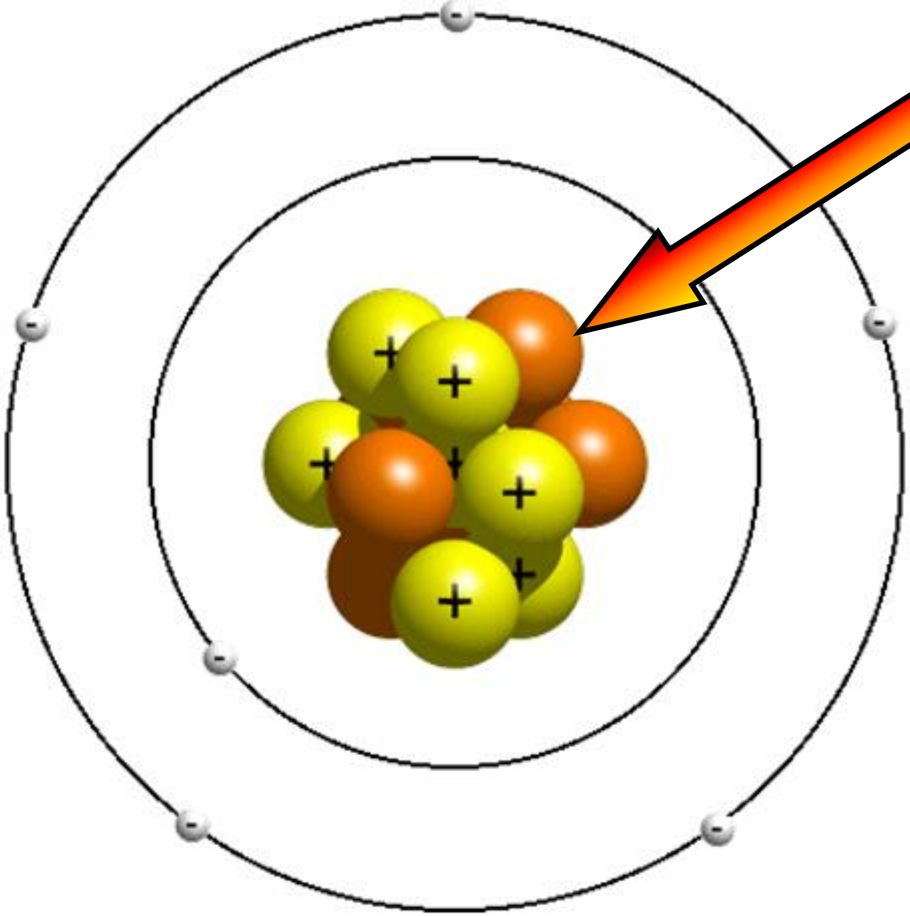
Atoms

Atomic structure



Atoms

Atomic structure

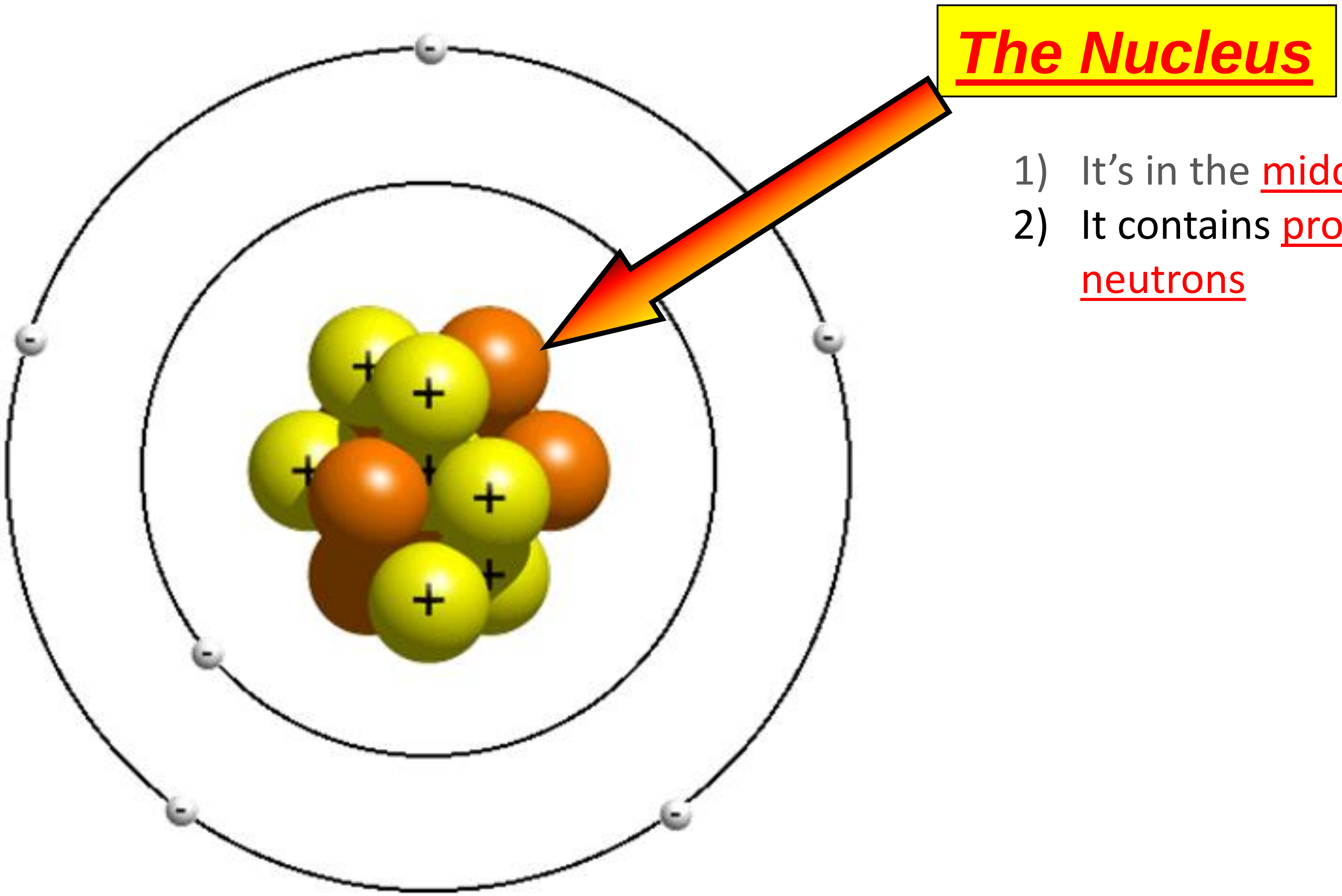


The Nucleus

1) It's in the middle of the atom

Atoms

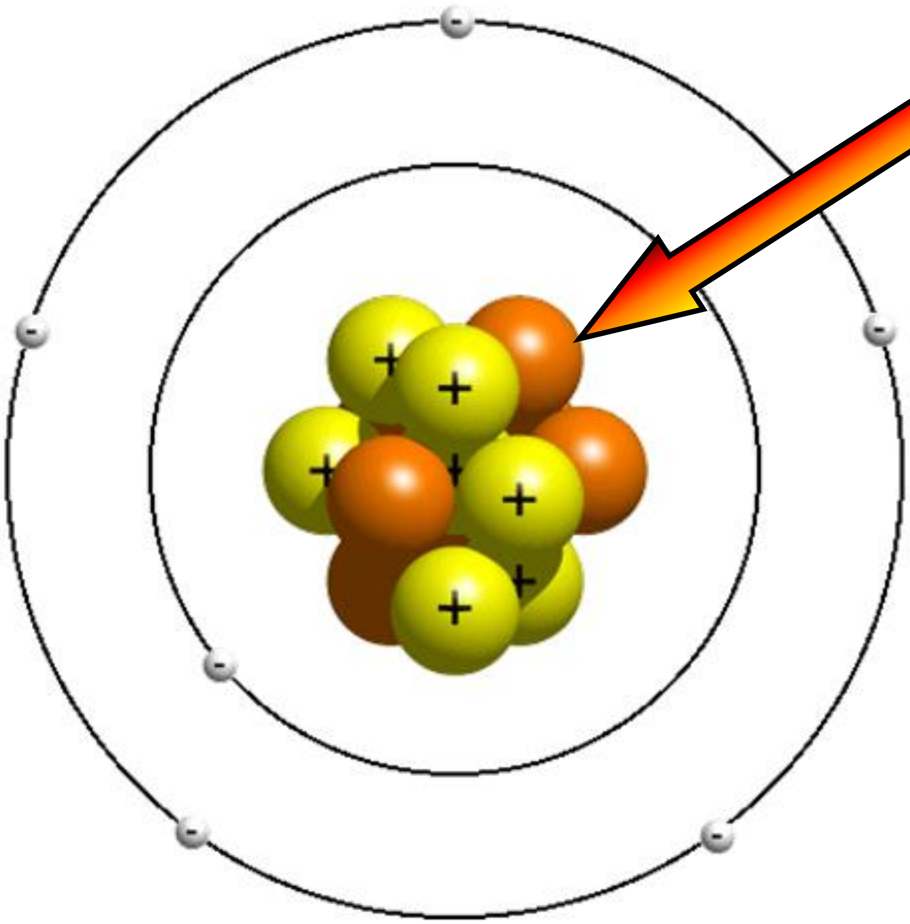
Atomic structure



1) It's in the middle of the atom
2) It contains protons and neutrons

Atoms

Atomic structure

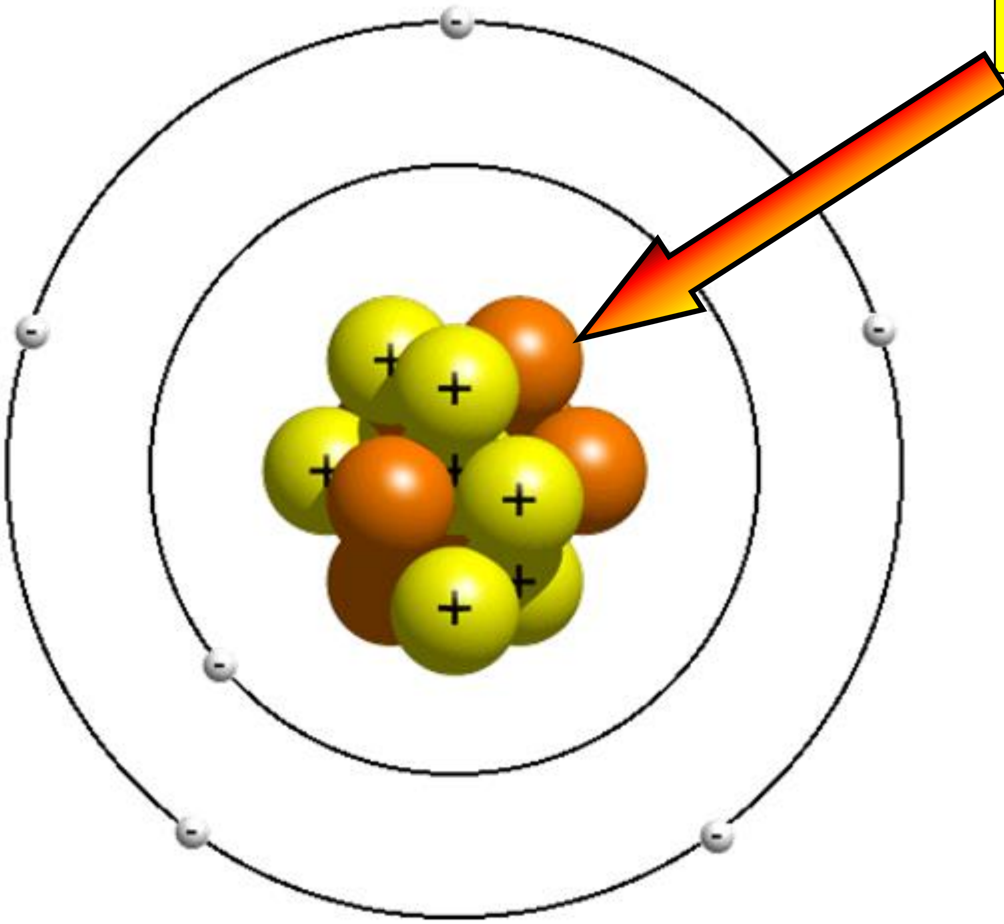


The Nucleus

1) It's in the middle of the atom
2) It contains protons and neutrons
3) It has a positive charge because of the protons.

Atoms

Atomic structure

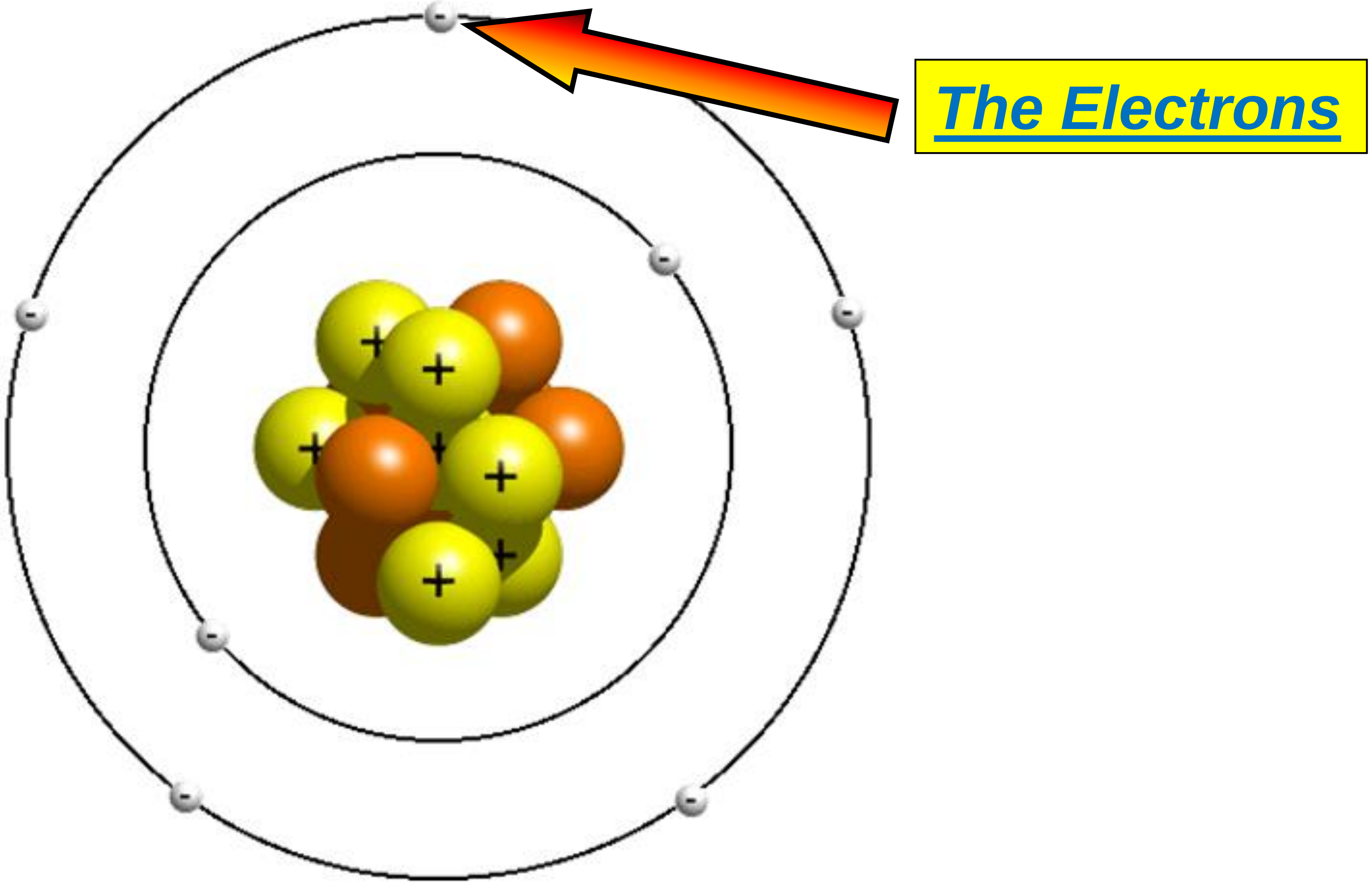


<u>The Nucleus</u>

1) It's in the <u>middle</u> of the atom
2) It contains <u>protons</u> and <u>neutrons</u>
3) It has a <u>positive charge</u> because of the <u>protons</u>.
4) Almost <u>the whole mass</u> of the atom is <u>concentrated in the nucleus.</u>

Atoms

Atomic structure



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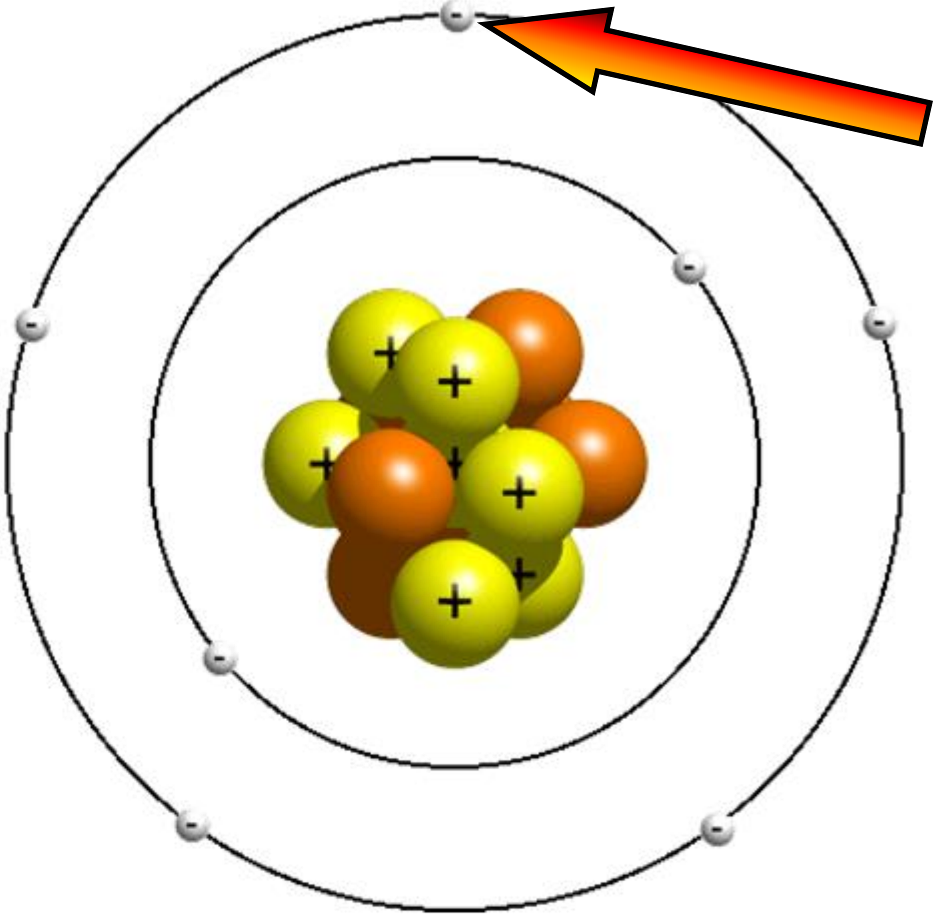
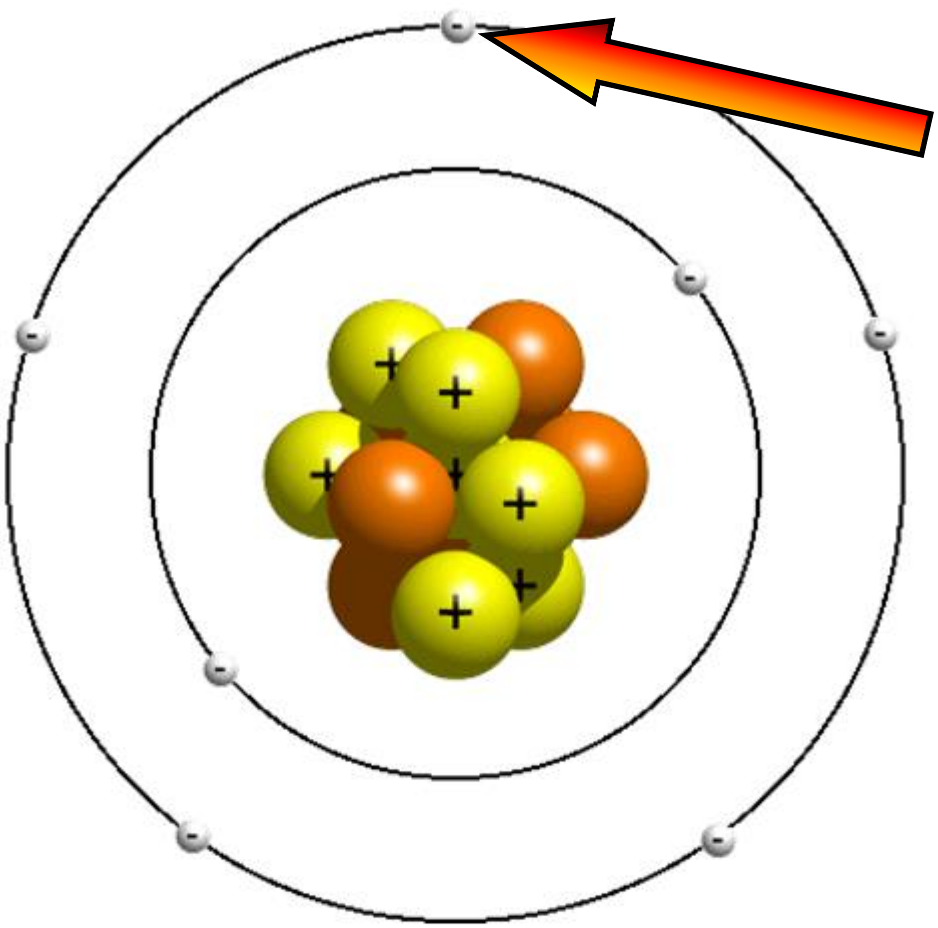
Atomic structure



1) Move around the nucleus.

Atoms

Atomic structure

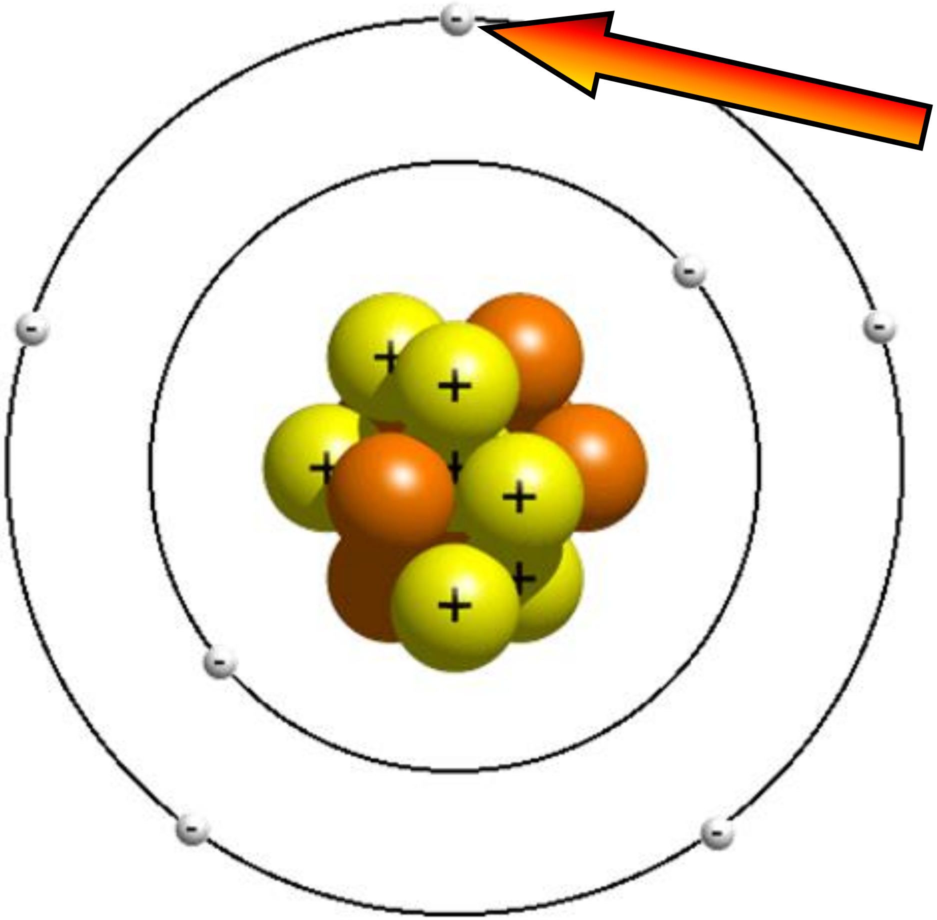


The Electrons

1) Move around the nucleus
2) They're negatively charged. .

Atoms

Atomic structure

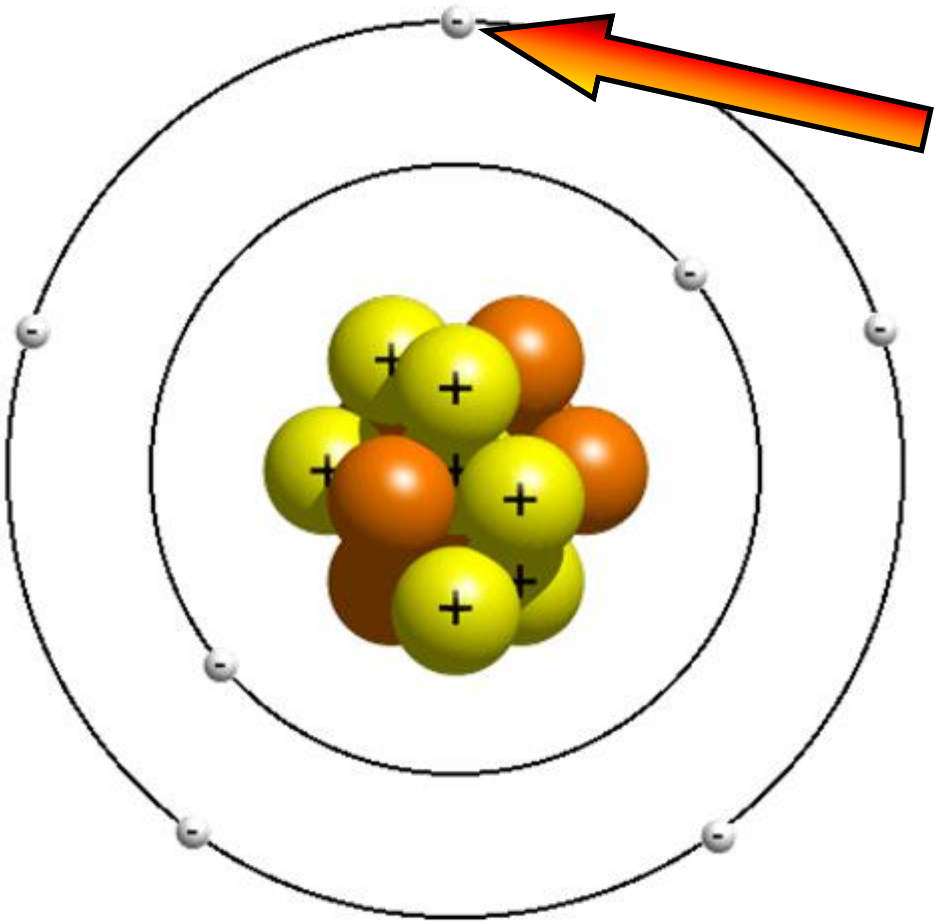


The Electrons

1) Move around the nucleus
2) They're negatively charged.
3) They're tiny, but they cover a lot of space..

Atoms

Atomic structure



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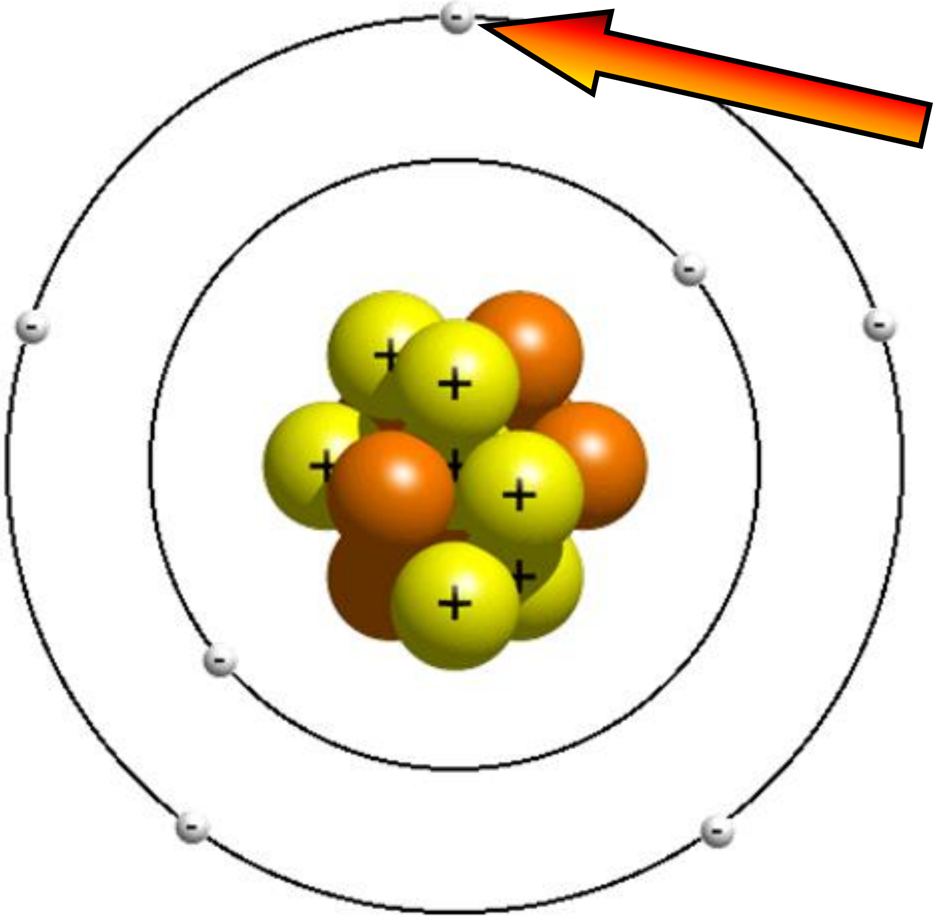
4) The volume their orbits occupy determines how big the atom is.

Atoms

Atomic structure



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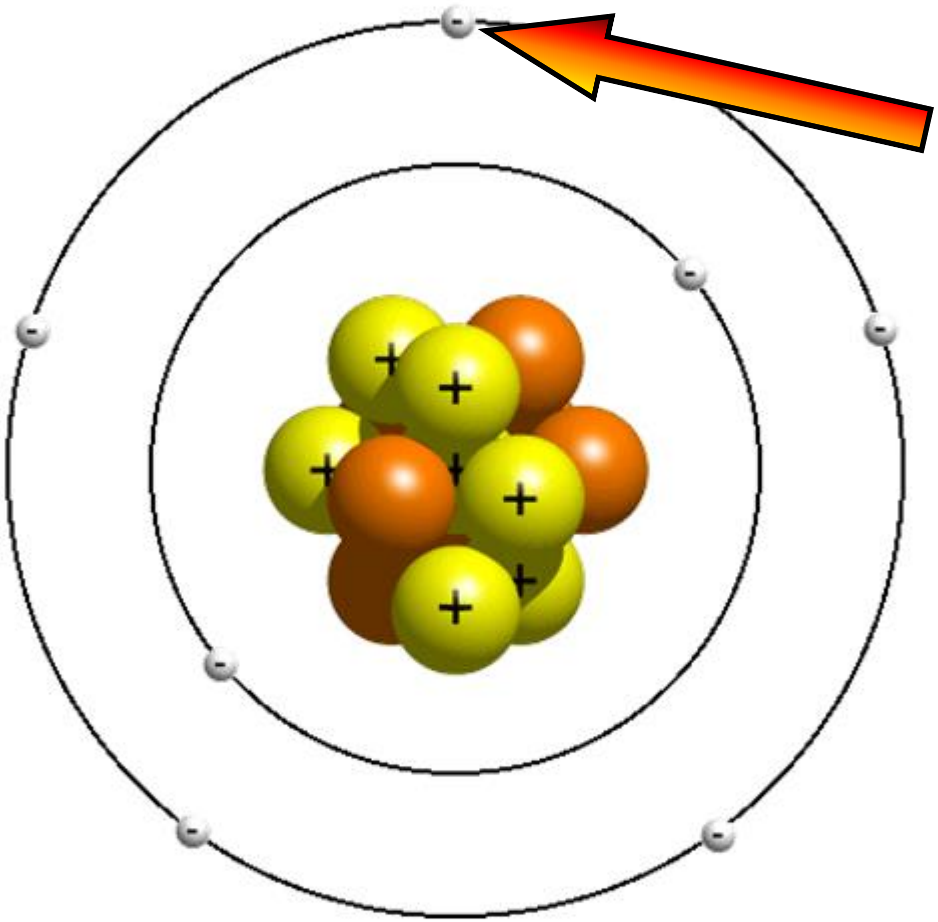

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6) They occupy shells around the nucleus.

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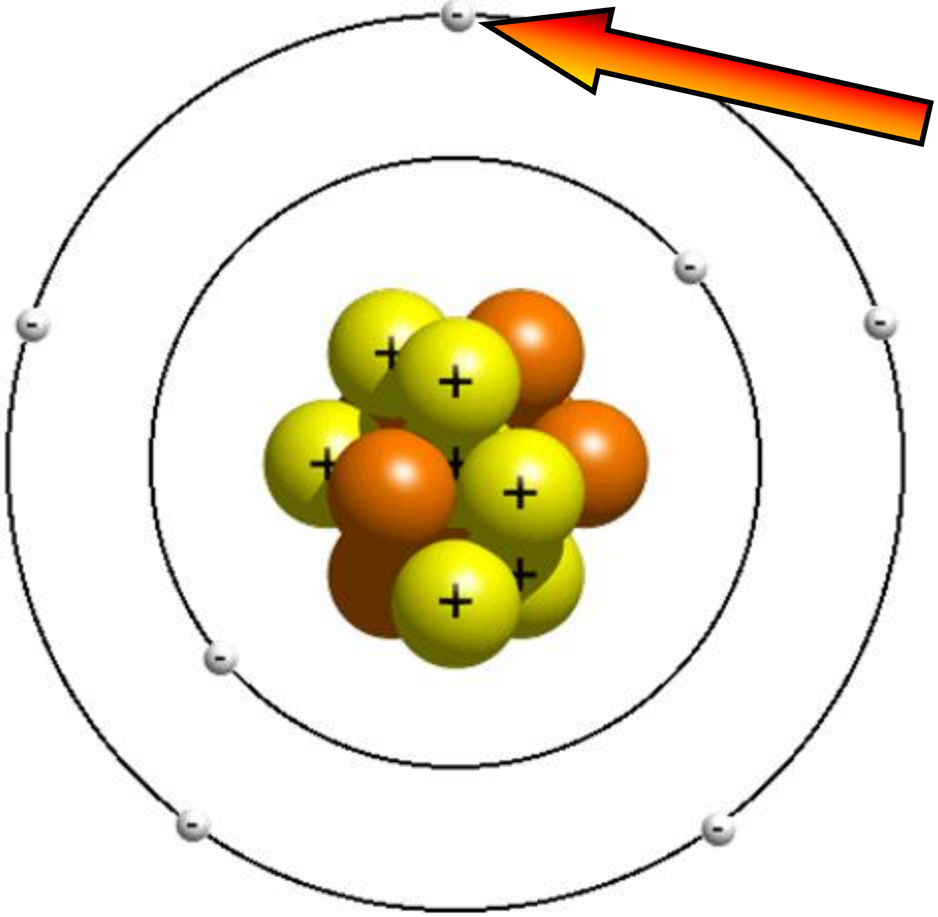

The Electrons

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2) They're negatively charged.
3) They're tiny, but they cover a lot of space..
4) The volume their orbits occupy determines how big the atom is.
5) They have virtually no mass.
6) They occupy shells around the nucleus.
7) These shells explain the whole of chemistry.

Atoms

Atomic structure

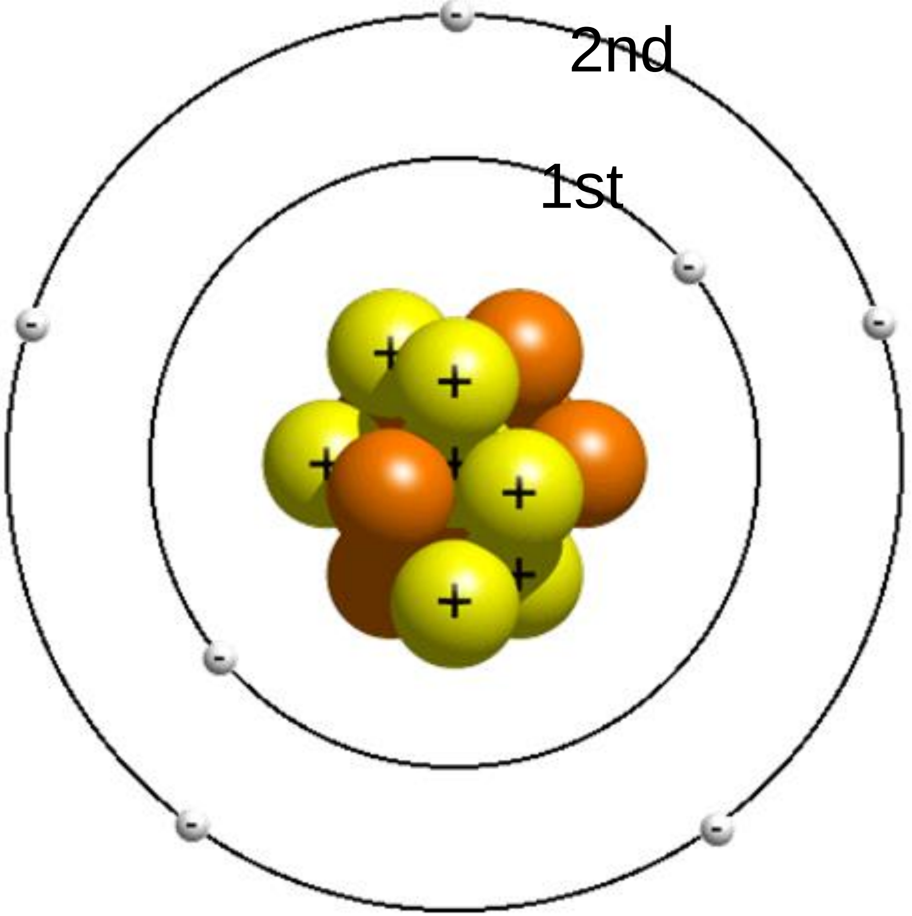
Summary

Particle	Mass	Charge
Proton	1	+1
Neutron	1	0
Electron	1/2000	-1

Atoms

Electron Shell Rules

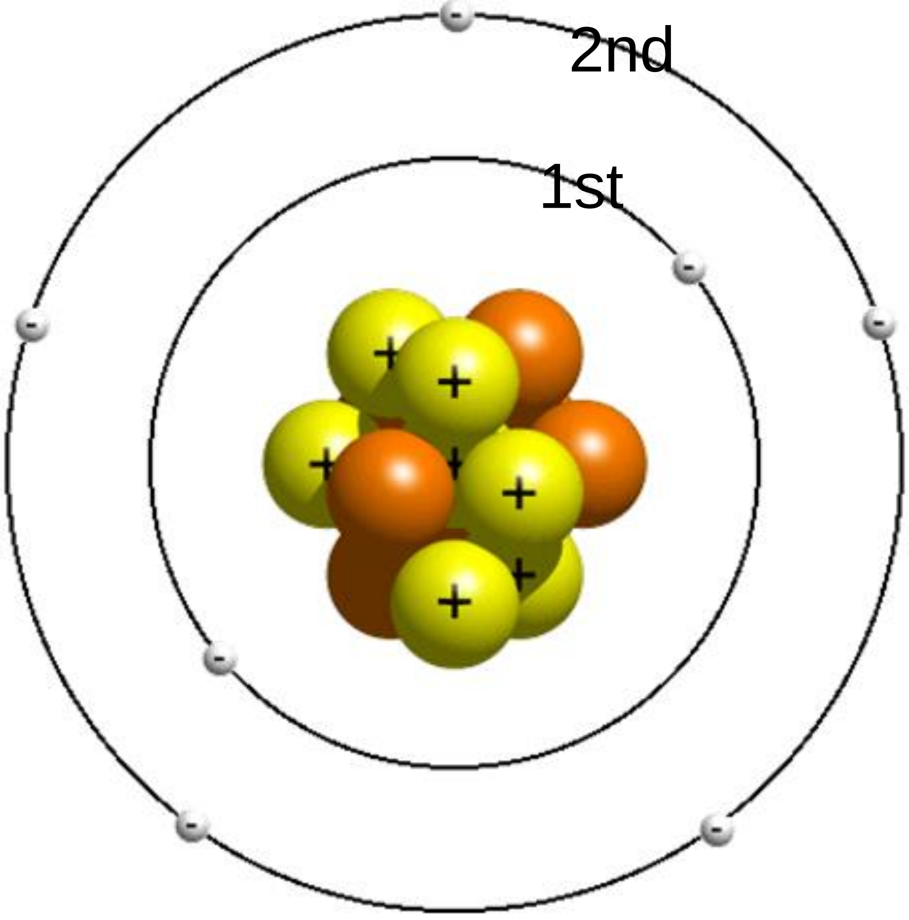
1) Electrons always occupy <u>SHELLS</u> or <u>ENERGY LEVELS</u>.



Atoms

Electron Shell Rules

1) Electrons always occupy <u>SHELLS</u> or <u>ENERGY LEVELS</u>.
2) The <u>LOWEST</u> energy levels are <u>ALWAYS FILLED FIRST</u>.

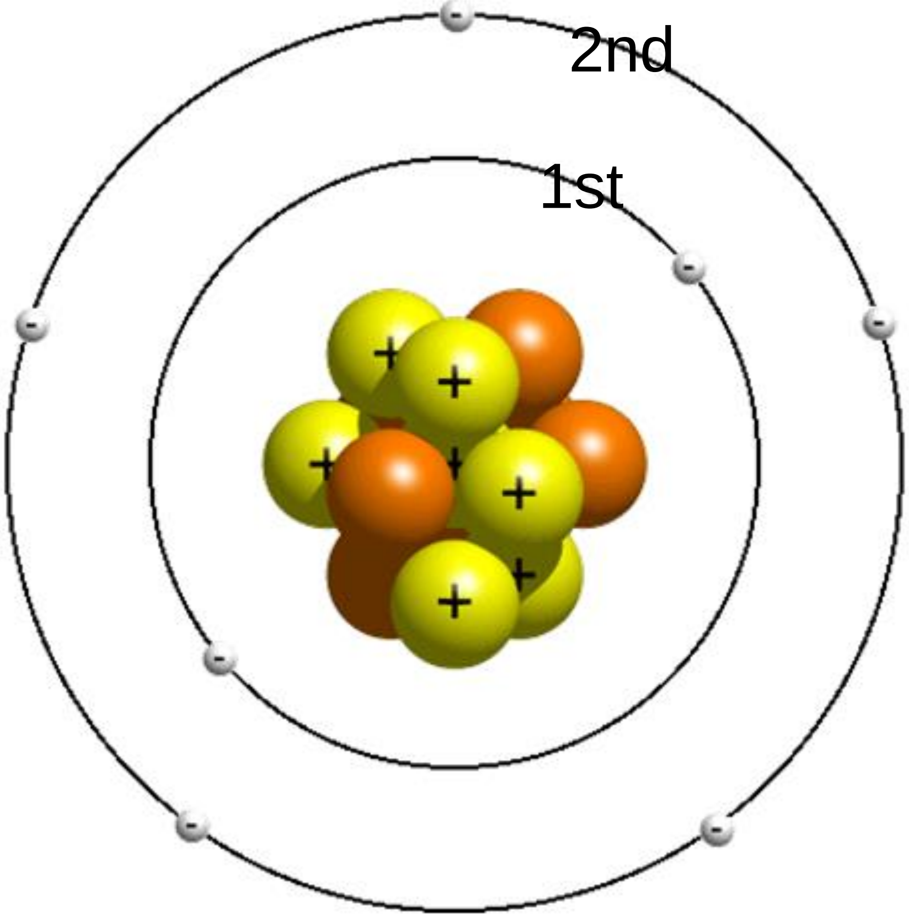


Atoms

Electron Shell Rules

1) Electrons always occupy SHELLS or ENERGY LEVELS.
2) The LOWEST energy levels are ALWAYS FILLED FIRST.
3) Only a certain number of electrons are allowed in each shell:

1st shell:	2
2nd shell:	8
3rd shell:	8



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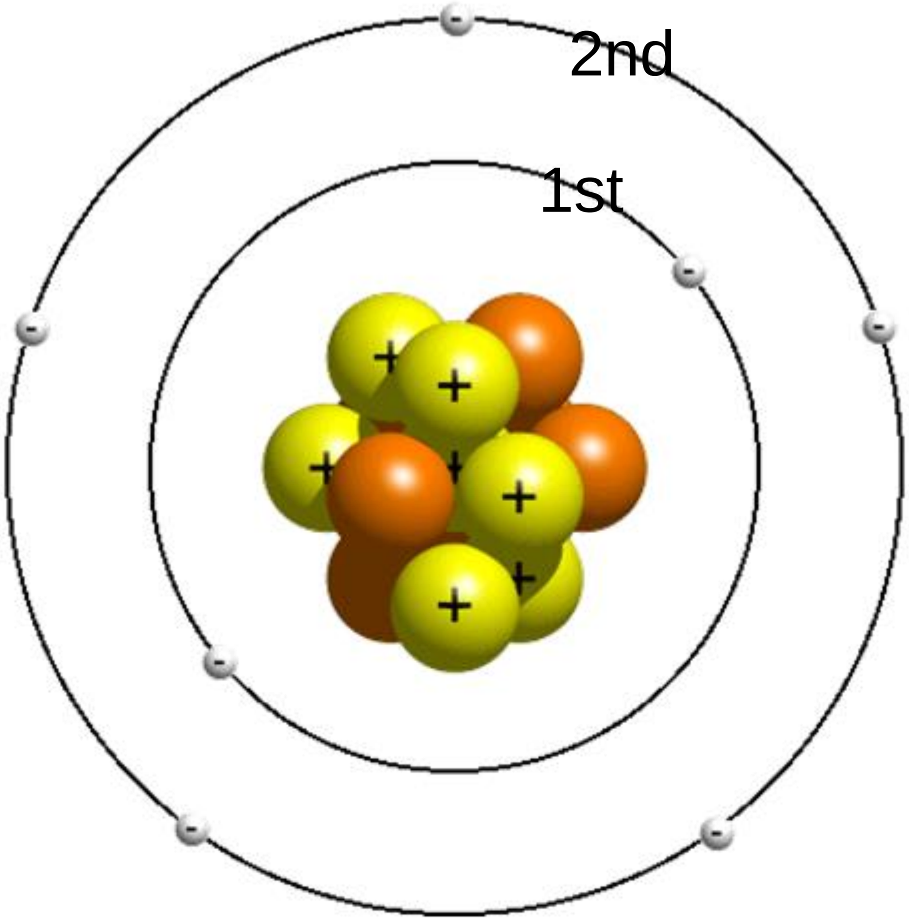
4) Atoms are much HAPPIER when they have FULL electron shells.



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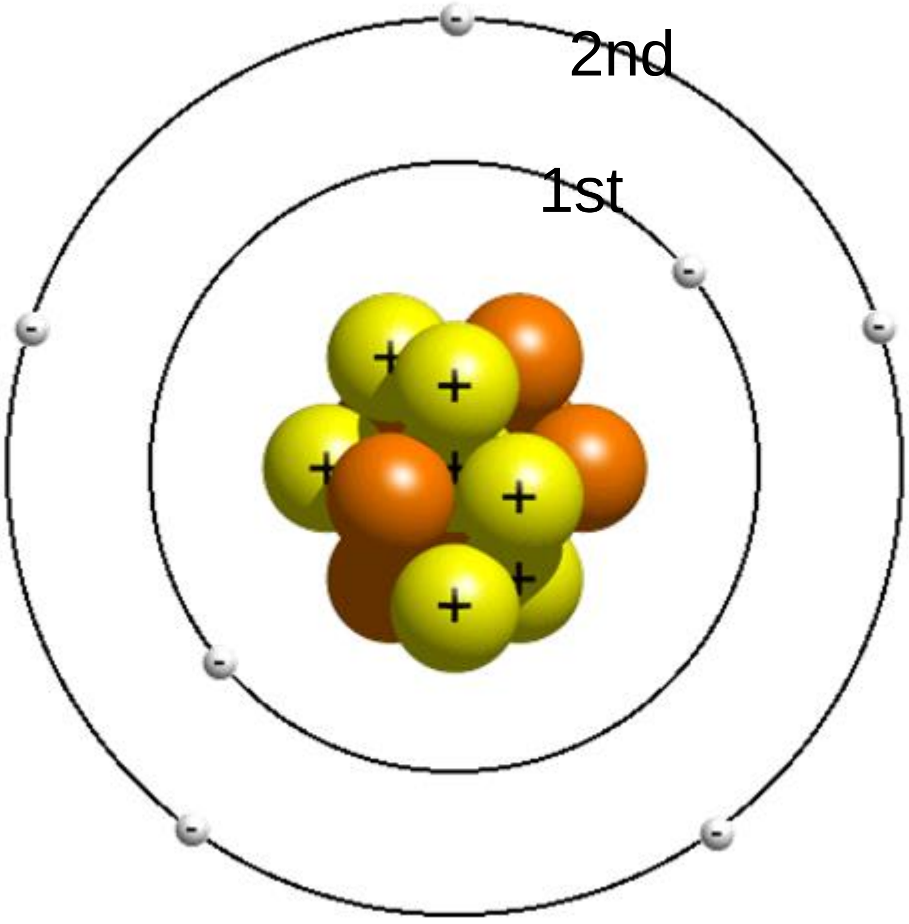
4) Atoms are much HAPPIER when they have FULL electron shells.
5) In most atoms the OUTER SHELL is NOT FULL and this makes the atom want to REACT.



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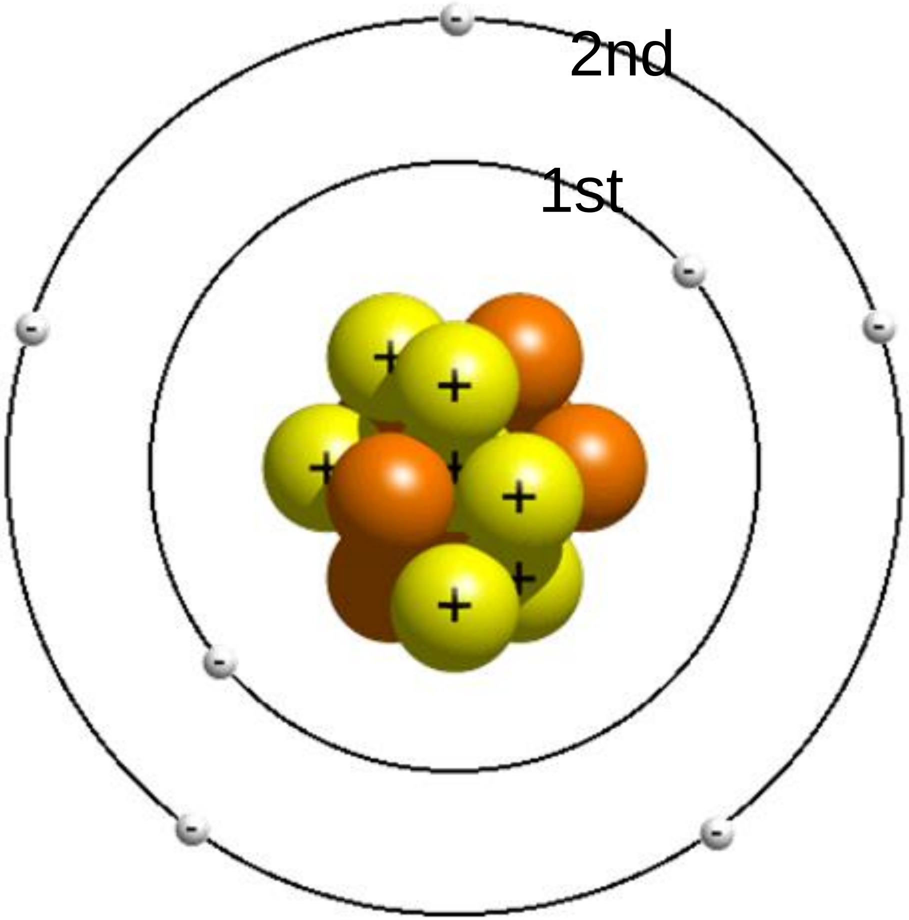

So, how do we know how many electrons, protons and neutrons there are?

Atoms

Atomic Number and Mass Number

We just need to know these two simple numbers

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$$^{23}_{11}\text{Na}$$

Atoms

Atomic Number and Mass Number

We just need to know these <u>two simple numbers</u>

THE MASS NUMBER

- **Total of Protons and Neutrons**

$$^{23}_{11}\mathrm{Na}$$

Atoms

Atomic Number and Mass Number

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THE MASS NUMBER

- Total of Protons and Neutrons

THE ATOMIC NUMBER

- Number of Protons (and electrons)

$$^{23}_{11}Na$$

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- Total of Protons and Neutrons

$^{23}_{11}Na$

THE ATOMIC NUMBER

- Number of Protons (and electrons)

1) The atomic number tells you how many protons there are.

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We just need to know these two simple numbers

$$^{23}_{11}\mathrm{Na}$$

THE MASS NUMBER

- **Total of Protons and Neutrons**

THE ATOMIC NUMBER

- **Number of Protons (and electrons)**

1) The atomic number tells you how many protons there are.
2) This also tells you how many electrons there are.

Atoms

Atomic Number and Mass Number

We just need to know these two simple numbers

THE MASS NUMBER — 23

- **Total of Protons and Neutrons**

$$^{23}_{11}\mathrm{Na}$$

THE ATOMIC NUMBER — 11

- **Number of Protons (and electrons)**

1) The atomic number tells you how many protons there are.
2) This also tells you how many electrons there are.
3) To get the number of neutrons – just subtract the atomic number from the mass number.

Atoms

Atomic Number and Mass Number

We just need to know these two simple numbers

THE MASS NUMBER

- Total of Protons and Neutrons

$$^{23}_{11}\mathrm{Na}$$

THE ATOMIC NUMBER

- Number of Protons (and electrons)

1) The atomic number tells you how many protons there are.
2) This also tells you how many electrons there are.
3) To get the number of neutrons – just subtract the atomic number from the mass number.
4) The mass number is always the biggest number. It tells you the relative mass of the atom.

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Atomic Number and Mass Number

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5) The mass number is always roughly double the atomic number.

Atoms

Atomic Number and Mass Number

We just need to know these <u>two simple numbers</u>

<u>THE MASS NUMBER</u>

- **Total of Protons and Neutrons**

$$^{23}_{11}\mathrm{Na}$$

<u>THE ATOMIC NUMBER</u>

- **Number of Protons (and electrons)**

1) The <u>atomic number</u> tells you how many <u>protons</u> there are.
2) This <u>also</u> tells you how many <u>electrons</u> there are.
3) To get the number of <u>neutrons</u> – just <u>subtract</u> the <u>atomic number</u> from the <u>mass number</u>.
4) The <u>mass number</u> is always the <u>biggest</u> number. It tells you the relative mass of the atom.
5) The <u>mass number</u> is always <u>roughly double</u> the atomic number.
6) Which means there's about the same number of protons as neutrons in any nucleus.

Atoms

Atomic Number and Mass Number

THE MASS NUMBER

- **Total of Protons and Neutrons**

$$^{23}_{11}\mathrm{Na}$$

THE ATOMIC NUMBER

- **Number of Protons (and electrons)**

Also known as the NUCLEON NUMBER (A)

Atoms

Atomic Number and Mass Number

$^{23}_{11}Na$

THE MASS NUMBER

- **Total of Protons and Neutrons**

Also known as the NUCLEON NUMBER (A)

THE ATOMIC NUMBER

- **Number of Protons (and electrons)**

Also known as the PROTON NUMBER (Z)

Atoms

Atomic Number and Mass Number

$$^{23}_{11}\mathrm{Na}$$

THE MASS NUMBER

- **Total of Protons and Neutrons**

Also known as the ***NUCLEON NUMBER (A)***

THE ATOMIC NUMBER

- **Number of Protons (and electrons)**

Also known as the ***PROTON NUMBER (Z)***

This is known as the NUCLIDE NOTATION

$$^{A}_{Z}\mathrm{X}$$

Each different type of atom is called a NUCLIDE

Atoms

Supplement

Atomic Number and Mass Number

$$^{23}_{11}Na$$

THE MASS NUMBER

- **Total of Protons and Neutrons**

Also known as the NUCLEON NUMBER (A)

THE ATOMIC NUMBER

- **Number of Protons (and electrons)**

Also known as the PROTON NUMBER (Z)

Balance equations involving nuclide notation

$$^{238}_{92}U \rightarrow$$

Atoms

Supplement

Atomic Number and Mass Number

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- **Total of Protons and Neutrons**

$$^{23}_{11}\mathrm{Na}$$

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Balance equations involving nuclide notation

$$^{238}_{92}\mathrm{U} \longrightarrow {}^{234}_{90}\mathrm{Th}$$

Atoms

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Balance equations involving nuclide notation

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

ISOTOPES

Different forms of the same element

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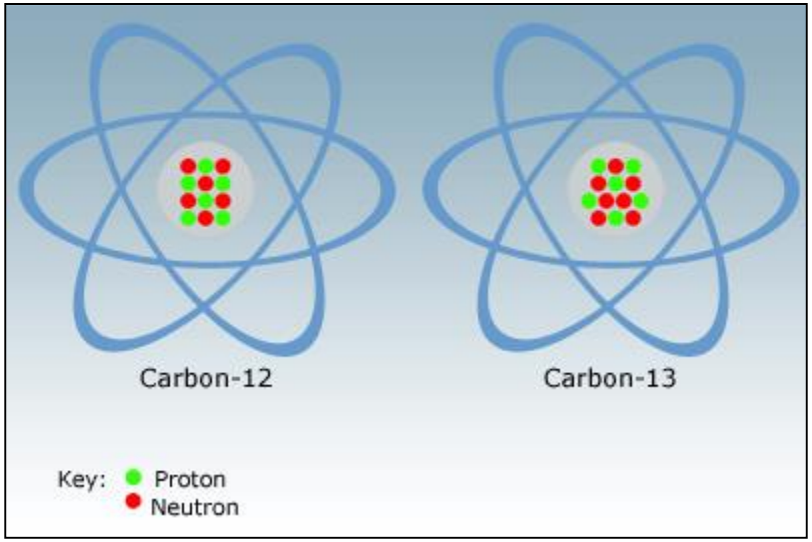
Different forms of the same element

What's the difference between these two?



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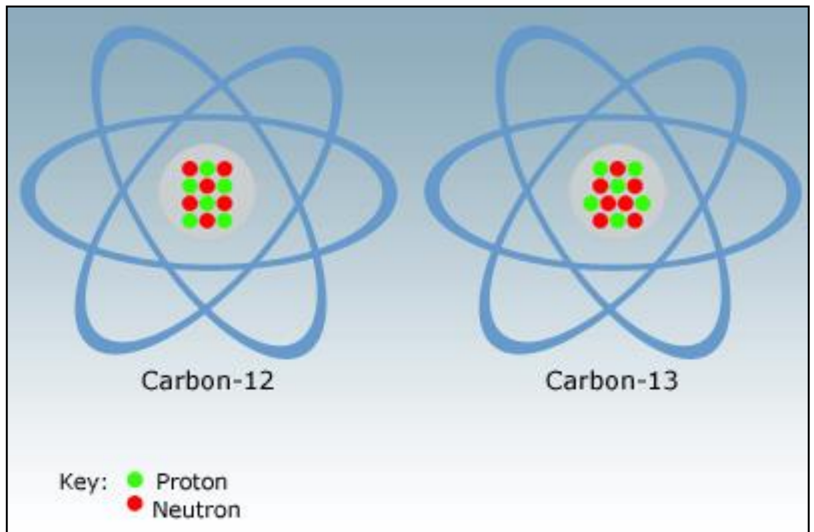

In the nucleus, this one has 6 **<u>protons</u>** and 6 **<u>neutrons</u>**.

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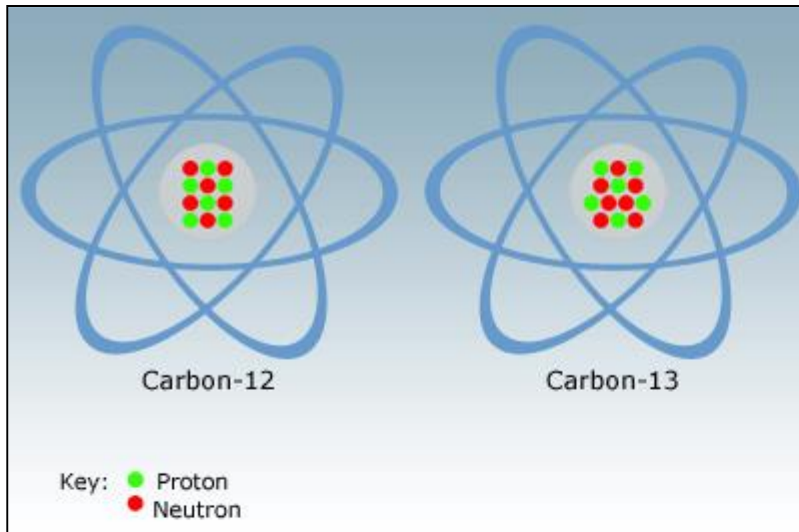

Isotopes are atoms with the **same number of protons** but a **different number of neutrons**.

In the nucleus, this one has 6 **protons** and 6 **neutrons**.

In the nucleus, this one has 6 **protons** and 7 **neutrons**.

ISOTOPES

Different forms of the same element

Isotopes have the same atomic number, but different mass numbers

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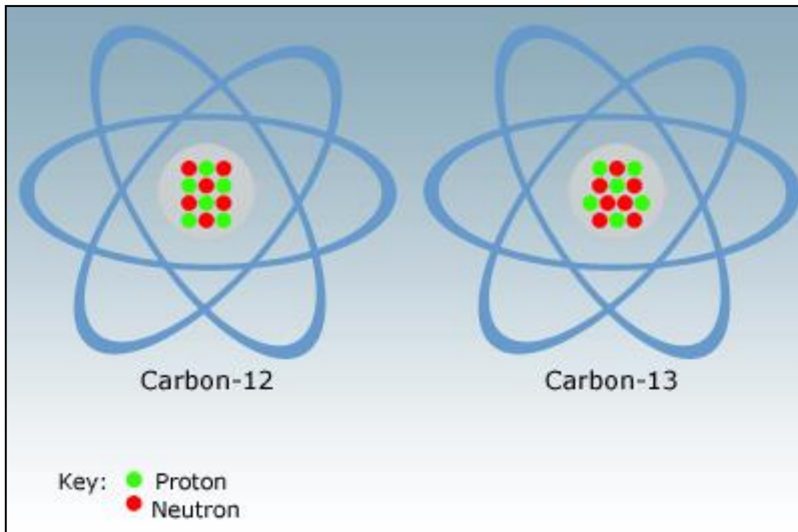

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ISOTOPES

$^{12}_{6}C$ $^{13}_{6}C$

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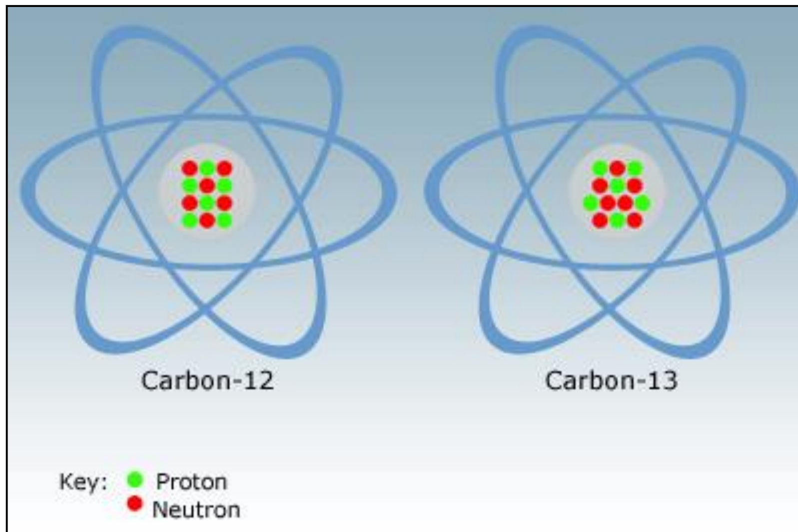

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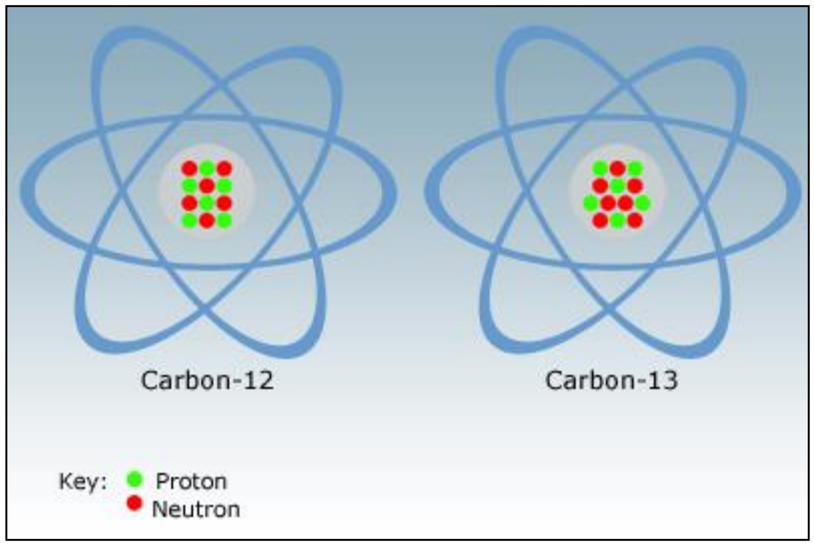
Different forms of the same element

What are the features of isotopes?



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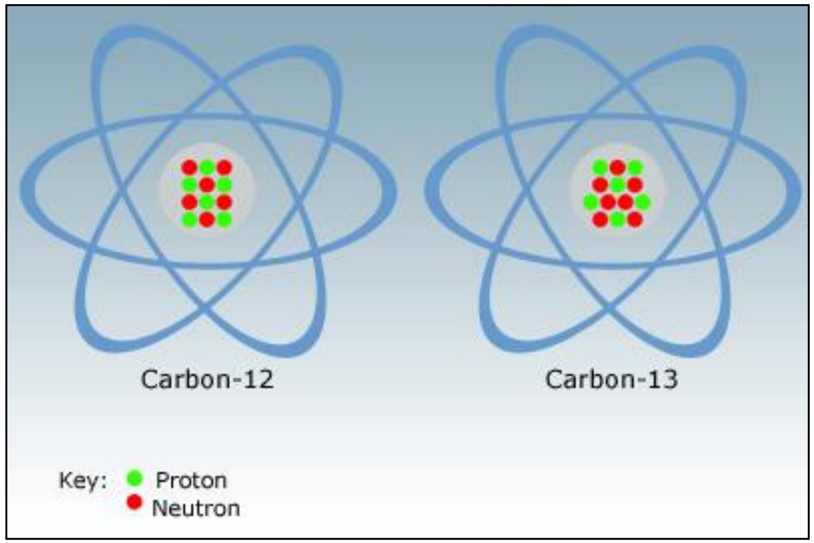

Most elements have different isotopes but there's usually only one or two **stable** ones.

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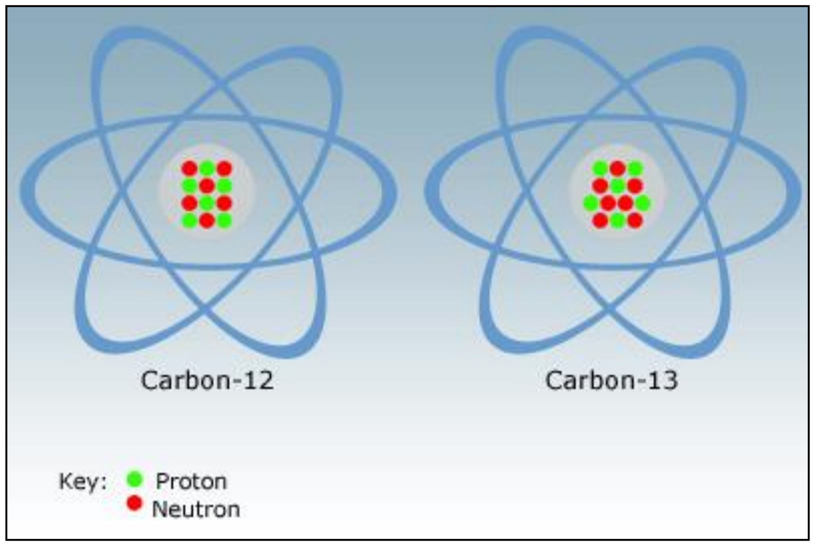

Most elements have different isotopes but there's usually only one or two **stable** ones.

The other isotopes tend to be **radioactive**, which means that they **decay** into **other elements** and **give out radiation**. This is where all **radioactivity** comes from – **unstable radioactive isotopes** undergoing **nuclear decay** and spitting out high energy particles.

ATOMIC STRUCTURE

Supplement

WHAT EVIDENCE IS THERE?

ATOMIC STRUCTURE

Supplement

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Describe how the scattering of α-particles by thin metal foils provides evidence for the nuclear atom

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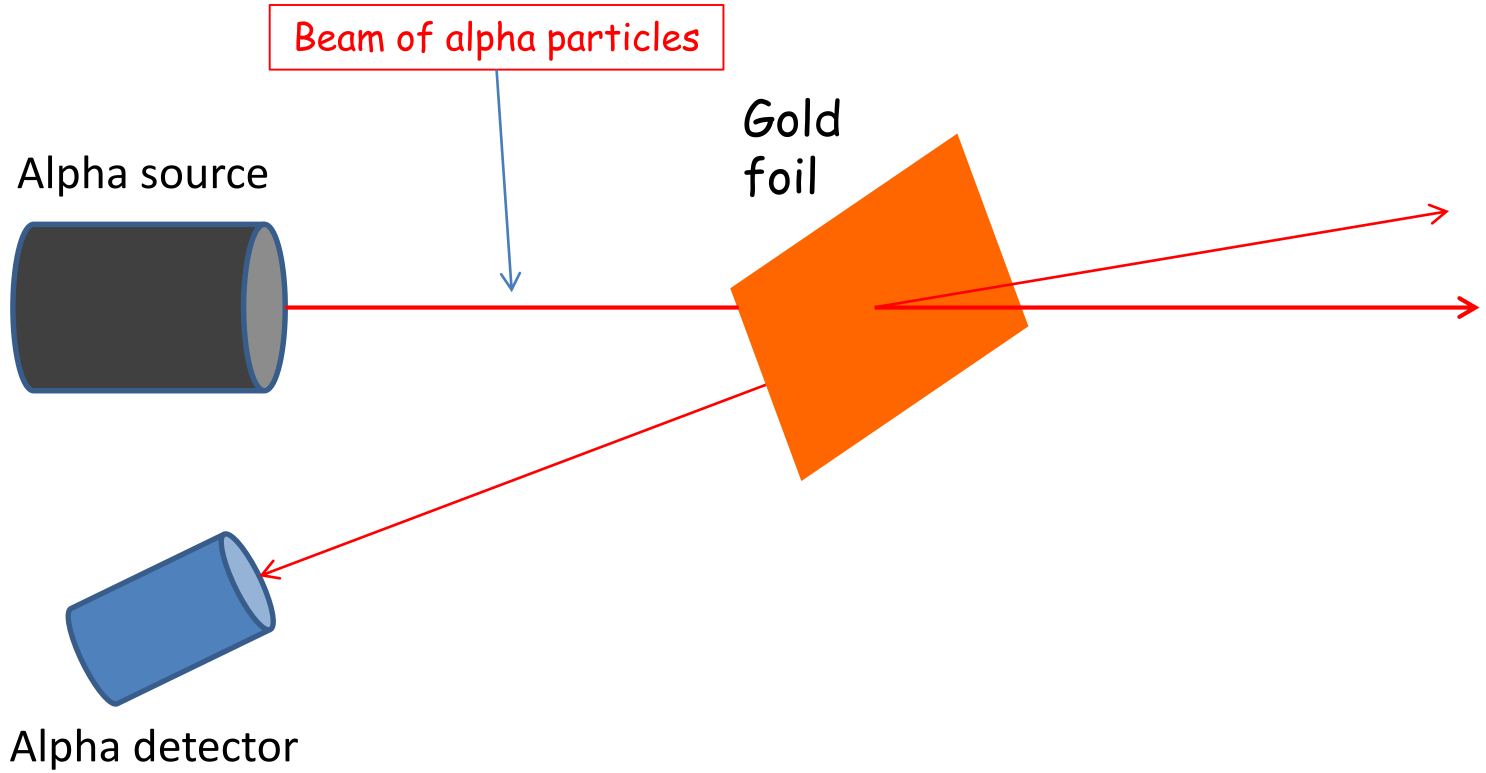
1911 Rutherford, Geiger and Marsden



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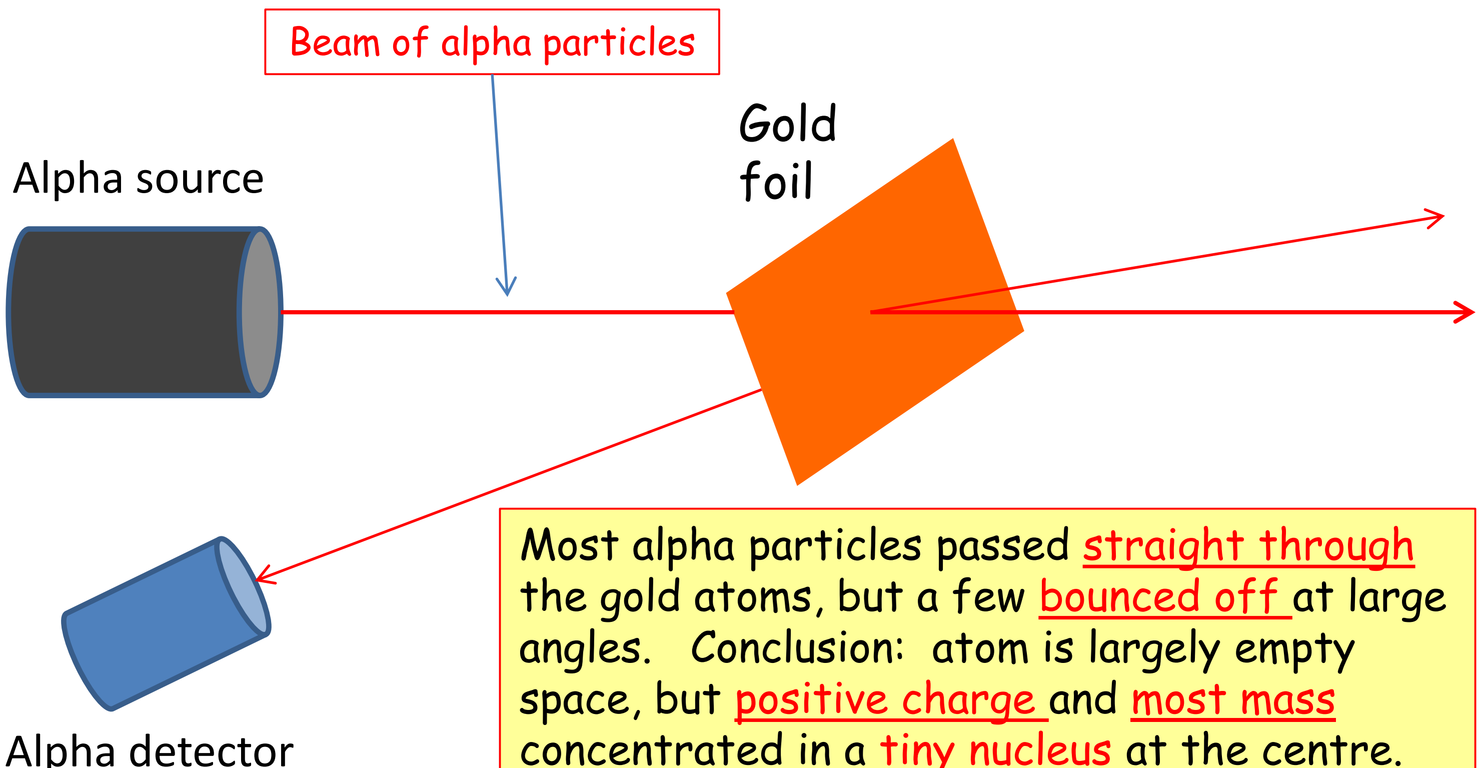

Most alpha particles passed straight through the gold atoms, but a few bounced off at large angles. Conclusion: atom is largely empty space, but positive charge and most mass concentrated in a tiny nucleus at the centre.

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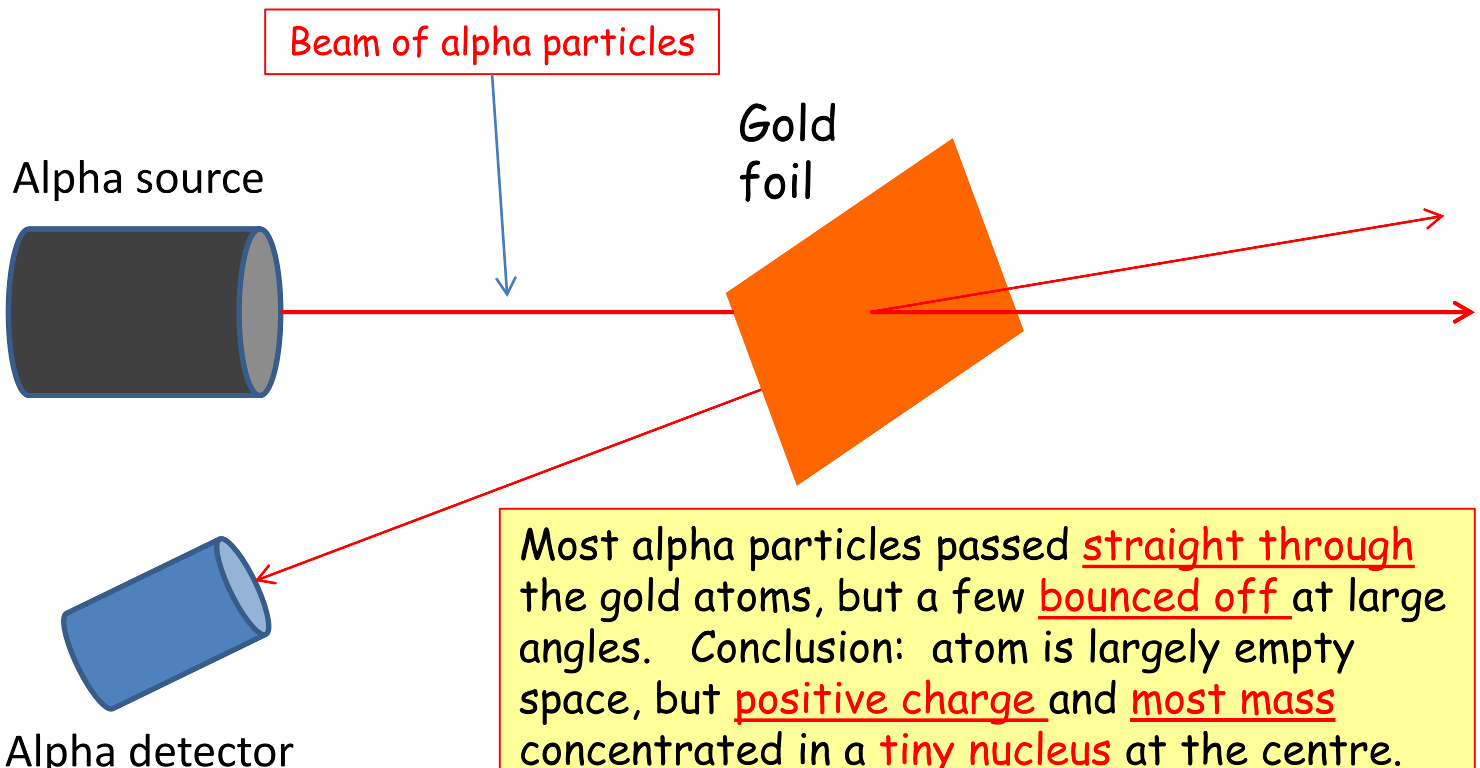

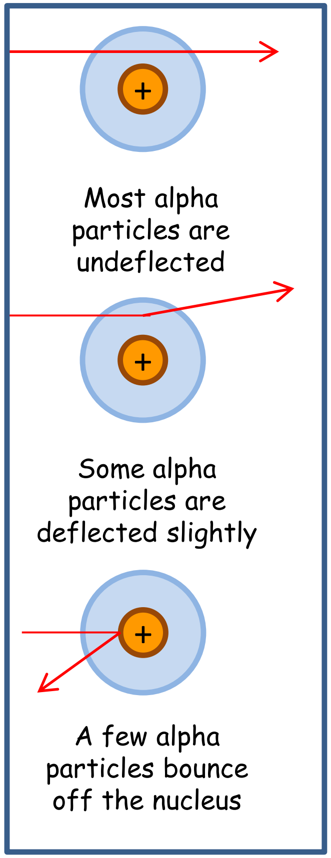

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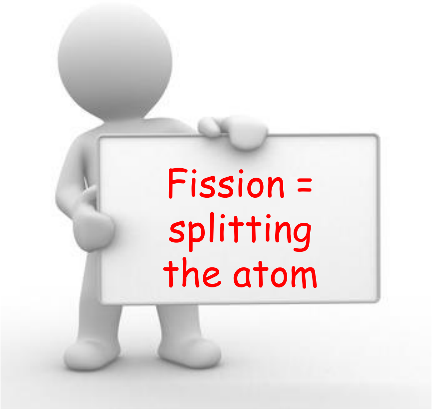
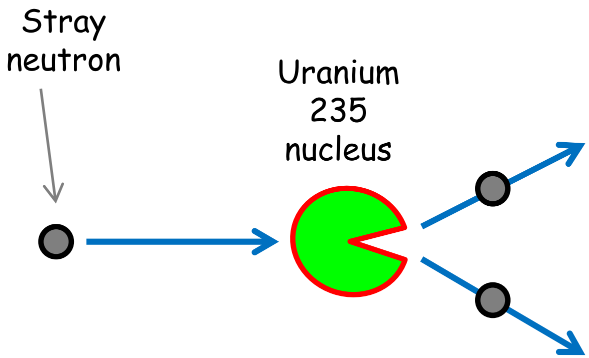
ATOMIC STRUCTURE

Supplement

State the meaning of nuclear fission and nuclear fusion





A neutron strikes a nucleus of Uranium 235 – this becomes unstable, splits into two lighter nuclei and releases 2 or 3 neutrons.

ATOMIC STRUCTURE

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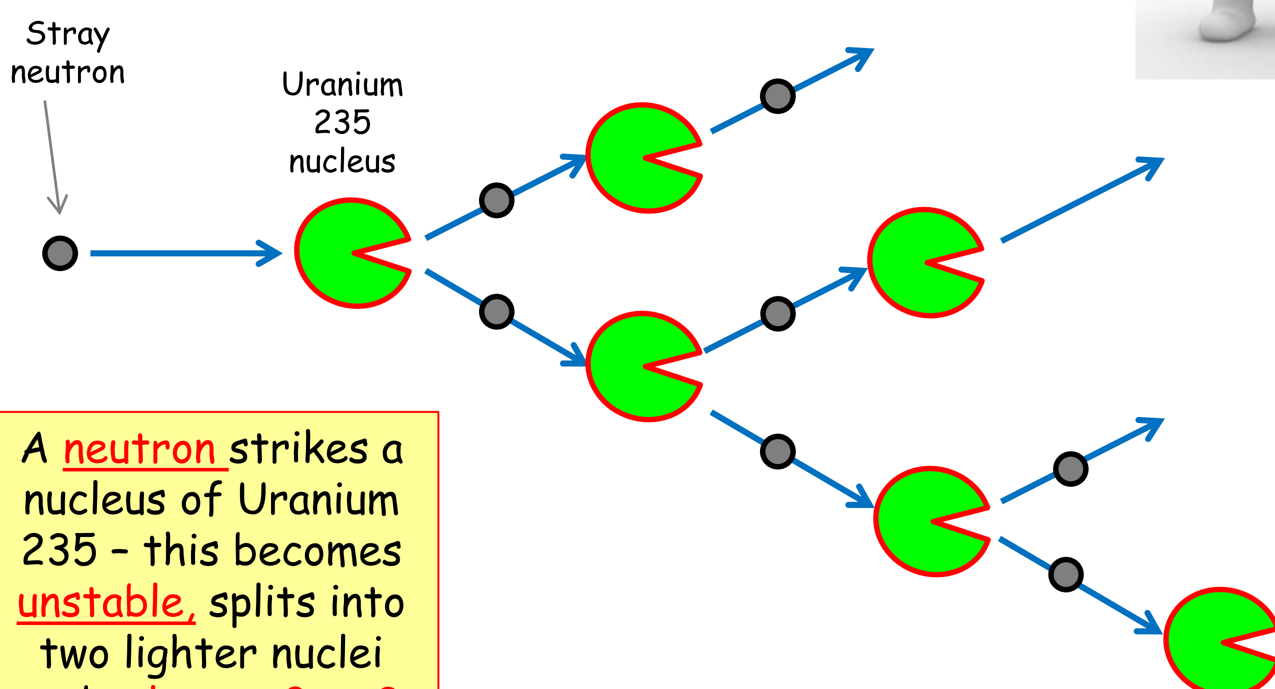


The emitted neutrons go on to split other nuclei, and so on … the result is a chain reaction, releasing huge amounts of energy

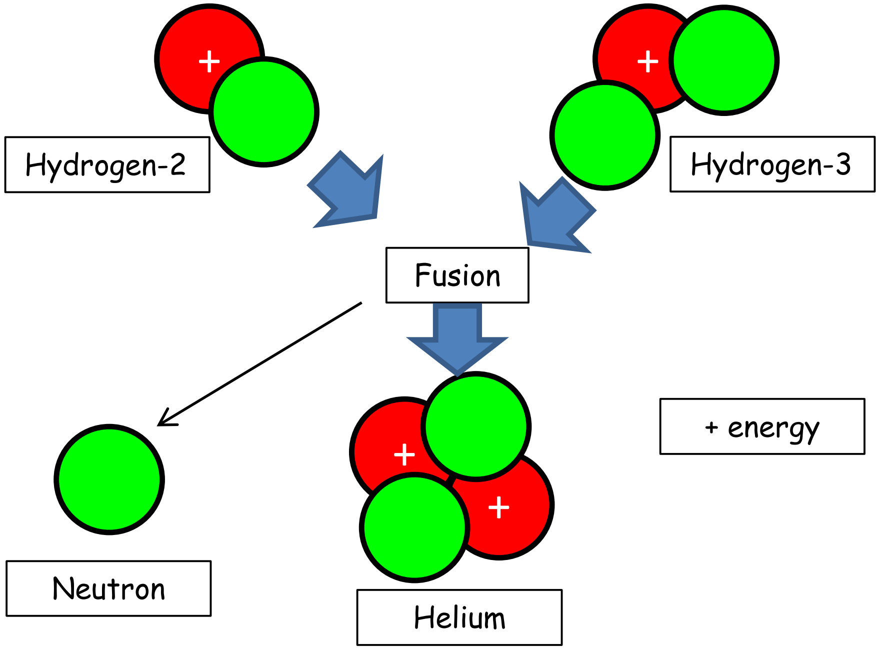
A neutron strikes a nucleus of Uranium 235 – this becomes unstable, splits into two lighter nuclei and releases 2 or 3 neutrons.

ATOMIC STRUCTURE

Supplement

State the meaning of nuclear fission and nuclear fusion

Energy can be released by **fusing** (joining together) **very light nuclei** to make **heavier ones**. For example, **two hydrogen nuclei** can be joined together to form **helium**.



ATOMIC STRUCTURE

Supplement

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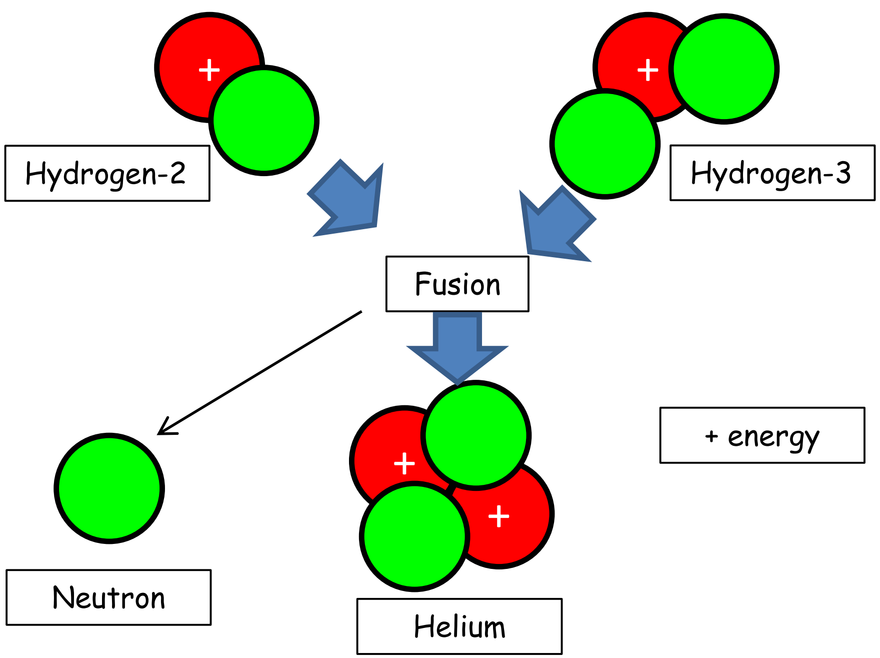
Energy can be released by **fusing** (joining together) **very light nuclei** to make **heavier ones**. For example, **two hydrogen nuclei** can be joined together to form **helium**.



Fusion is **very difficult** to achieve – the gas must be **much hotter** than any **temperatures** normally achieved on Earth to overcome the **natural repulsion** of the fast-moving nuclei.

ATOMIC STRUCTURE

Supplement

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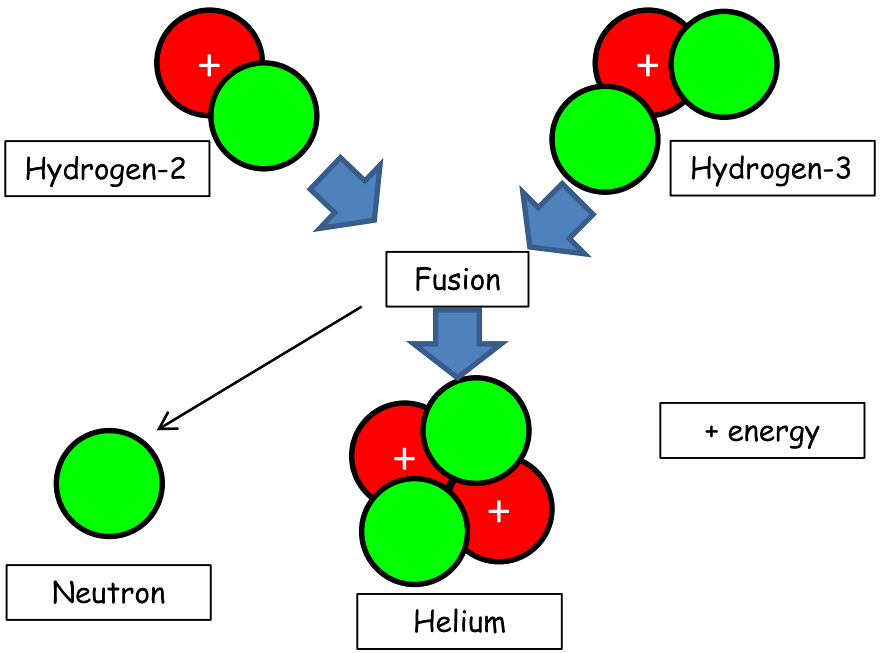

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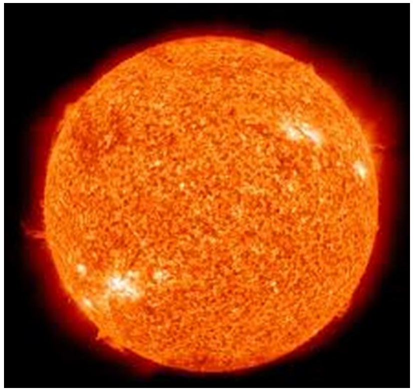
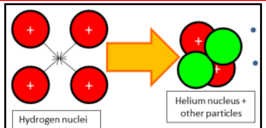
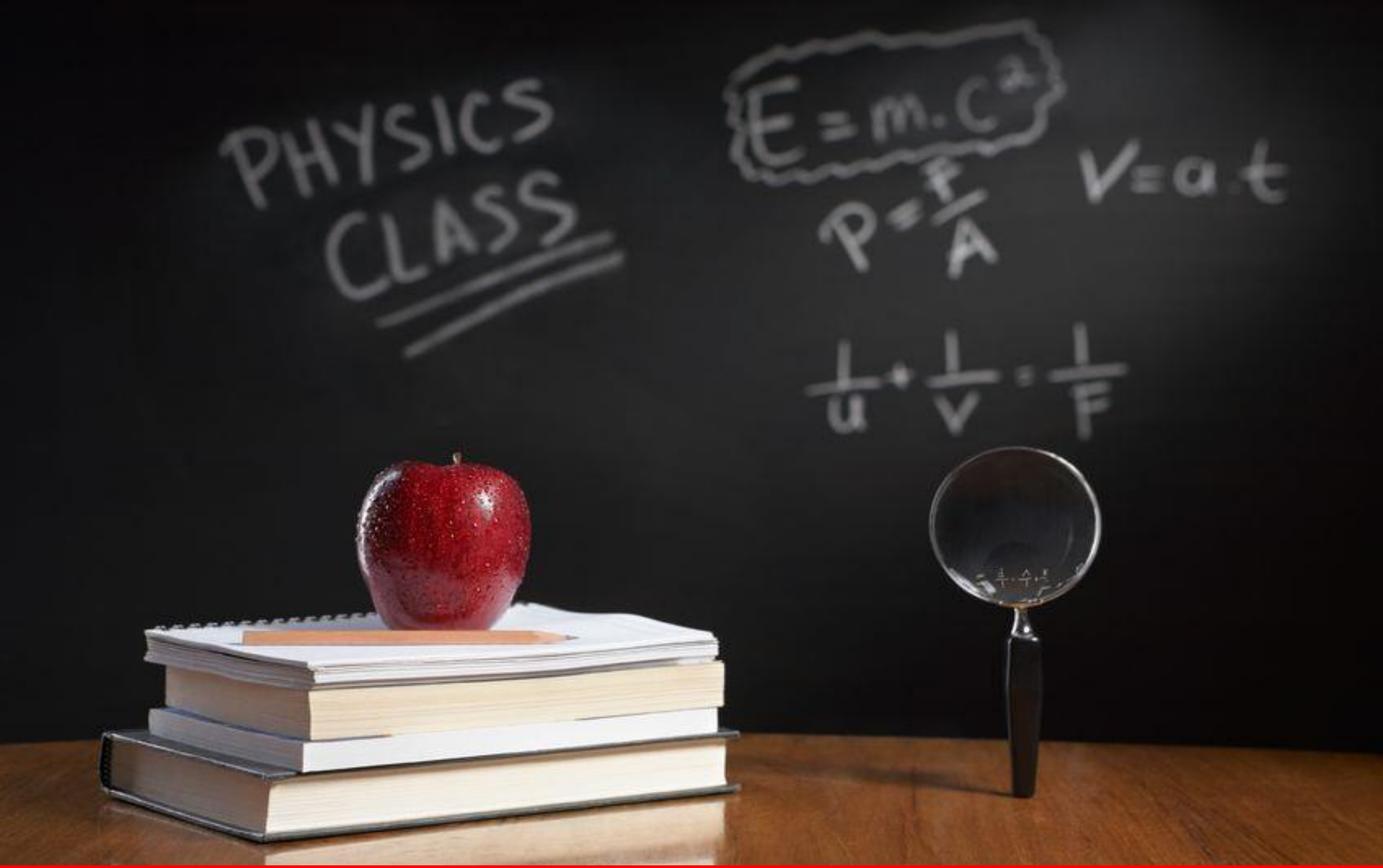


Fusion occurs naturally on the Sun, where **four hydrogen nuclei** fuse to form **helium**



LEARNING OBJECTIVES

Core	Supplement
• Describe the structure of an atom in terms of a positive nucleus and negative electrons • Describe the composition of the nucleus in terms of protons and neutrons • State the charges of protons and neutrons • Use the term proton number Z • Use the term nucleon number A • Use the term nuclide and use the nuclide notation A ZX • Use and explain the term isotope	• Describe how the scattering of α-particles by thin metal foils provides evidence for the nuclear atom • State the meaning of nuclear fission and nuclear fusion • Balance equations involving nuclide notation



PHYSICS – The Nuclear Atom

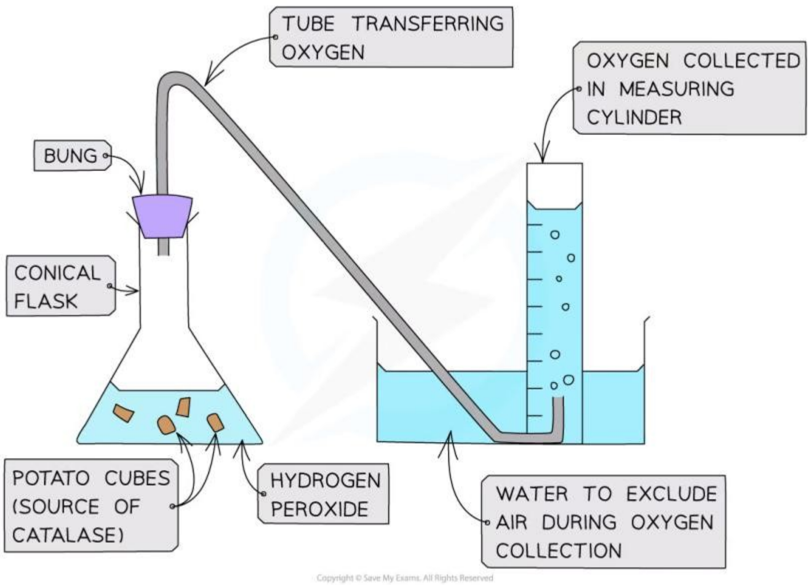
MYP 4 CRITERIA B AND C SUMMATIVE ASSESSMENT

Subject	Grade	Points	Duration	Start time.
Biology	MYP 4	B 20 C 10	60 mins	May 25, 01:40 pm

May 25, 01:40 pm (School TZ)

Section 1

There are many factors that affect the rate of decomposition of hydrogen peroxide by enzyme catalase. These include Substrate Concentration: Enzyme Concentration, Temperature, pH Level, Presence of Inhibitors, Presence of Co-factors, Substrate surface area. Varying the above factors may be used to speed up the rate of decomposition of hydrogen peroxide (H2O2) to form oxygen gas and water, as illustrated below.



MYP 4 Biology students argued over the effect of surface area on the rate of decomposition of Hydrogen peroxide. Therefore, they decided to nd out which surface area would decompose the hydrogen peroxide faster and produce large volumes of oxygen gas quickly. You are provided with:

- 250cm3 of 0.1mol/dm3 of hydrogen peroxide.
- 250ml conical flasks
- Delivery tubes
- Irish potatoes
- Scalpel
- Mortar and pestel.

Q 1.1 **Write** a research question for the above investigation.

B 2

How does the surface area of a substrate affect the rate of decomposition of hydrogen peroxide as measured by the time taken for a large volume of oxygen gas to be produced?

Q 1.2**Formulate** a hypothesis to identify which substrate surface area will decompose hydrogen peroxide quickly.

B 3

If the surface area of the hydrogen peroxide is increased, then the rate of decomposition of hydrogen peroxide as measured by the time taken for large volume of oxygen gas to be produced will increase because there will be a larger surface area over which hydrogen peroxide will be acted in by the catalase enzyme and thus more oxygen and water will be produced faster.

Q 1.3**Design** an investigation to nd out which of the substrate surface area would decompose hydrogen peroxide quickly.

B 15

In your answer you should include:

- The independent, dependent and two control variables.
- Details on how to manipulate, measure or monitor all of the variables A
- list of any additional equipment you will need
- Details of your method to allow you to collect sufficient data
- how you will ensure the method is safe.

Independent Variable-Surface area of hydrogen peroxide. Using a ruler measure 30cm ruler, measure 5cm potato and crush them using a mortar and pestle as the same speed and pace for the times of 1 minute,2 minutes, 3minutes, 4 minutes and 5 minutes.

Dependent Variable-Time taken for large volume of hydrogen peroxide to be produced.Using a stopwatch measure the time taken for the oxygen gas to occupy 10 cubic cm in the measuring cylinder.

Control Variable:
1.Temperature.Using a water bath ensure that each set up uses 50 degrees Celsius.
2.Substrate concentration.Using a 30cm ruler ensure that each set up uses 5cm potato strips.

Additional equipment:

1. Water bath
2. 30 cm transparent ruler
3. Scalpel

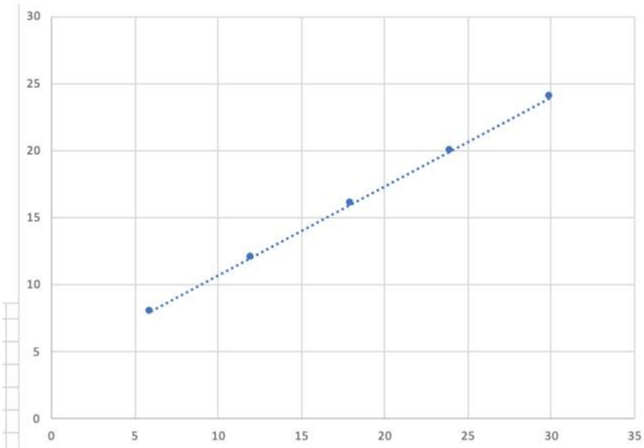
DETAILS OF HOW THE METHOD WILL COLLECT SUFFICIENT DATA:
1.5 increments of the Independent Variable to be obtained including 5cm potato strip crushed at the times of 1 minute, 2 minutes,3 minutes, 4 minutes and 5 minutes in order to increase the number of data points obtained in a range and thus allowing a more concrete and certain relationship between the variables to be built.
2.Ensure that for the 5 increments of the Independent Variable, there will be three trials in order to ensure the calculation of an average, the getting rid of any random errors made during the experiment, the collection of more accurate and reliable data and to enable the identification of outliers.

Risk Assessment:

1. Hot water from the water bath may lead to scalding.When carrying out the experiment the experimenters should wear protective gear that include gloves and goggles.
2. The scalpel might lead to cuts.When cutting the potato, ensure that you cut it away from your skin in order to prevent cuts and injuries.

Section 2

The graph below shows how surface area affects the volume of oxygen gas produced as a result of decomposition of hydrogen peroxide by enzyme catalase.



Q 2.1**Suggest** a title for the above graph. C 1

A graph showing the relationship between surface area of hydrogen peroxide and volume of oxygen gas produced as a result of decomposition of the hydrogen peroxide.

Q 2.2Correctly **label** the X and Y axes C 2

X-Surface area of hydrogen peroxide in square cm.

Y-Volume of oxygen gas produced is cubic cm.

Q 2.3Using the graph above, **suggest** which surface area produces more volume of oxygen gas. C 1

The crushed surface area into smaller pieces.

Q 2.4Use scienti c reasoning to **explain** the trend presented in the graph above. C 3

As the surface area of hydrogen peroxide is increased more volume of oxygen gas is produced.This is because there is a larger surface area over which the catalase enzymes work on the hydrogen peroxide is increased and thus the hydrogen peroxide is decomposed faster to form water and oxygen.

Q 2.5Based on the graph above, **discuss** if the data presented supports your hypothesis. C 3

The hypothesis is valid.Based on the data trend present on the graph it is evident that as you increase the surface area of hydrogen peroxide then a larger volume of oxygen gas is produced.This is because there is a larger surface area over which the catalase enzyme is working on the hydrogen peroxide thus the hydrogen peroxide decomposes faster and lots of oxygen and water is produced faster.Because the data trend in the graph correctly matches the hypothesis, the hypothesis is supported by the data trend and thus is valid.

Question 13 (11 marks)
Horses can perform work for farming activities. In the past, they were used to loosen the soil before planting. Physics can be used to explore the ways in which horses complete these tasks.

Question 13a (2 marks)
A horse covers a distance of 3 km in 45 minutes. Calculate its speed in km per hour (kmh^{-1}).

Question 13b (1 mark)
Power is the rate of transforming energy or the rate of doing work. Select the formula for energy transformed.

- A. energy transformed = power x distance
- B. energy transformed = power ÷ distance
- C. energy transformed = power x time
- D. energy transformed = power ÷ time

Question 13c (2 marks)

The table below gives some data about two horses A and B. Calculate the missing values and complete the table. You should assume the value of g = 10 N kg^{-1}.

Horse	Mass of horse/kg	Weight/N
A	350	
B		5100

Question 13d (1 mark)

Select the correct terms to complete the energy transformation diagram for a horse that starts from rest at the bottom of a hill, runs up the hill and then stops at the top of the hill.

Draggable items:

Chemical potential energy	Gravitational potential energy
Elastic potential energy	Electrical Energy

⟶ Kinetic energy ⟶

Question 13e (3 marks)
The hill in part (d) is 12 m high. Horse B reaches the top of the hill in 5.50 s. Use information from part (c) and the formula sheet to calculate the minimum power required for horse B to reach this height. You should give your answer in kW.

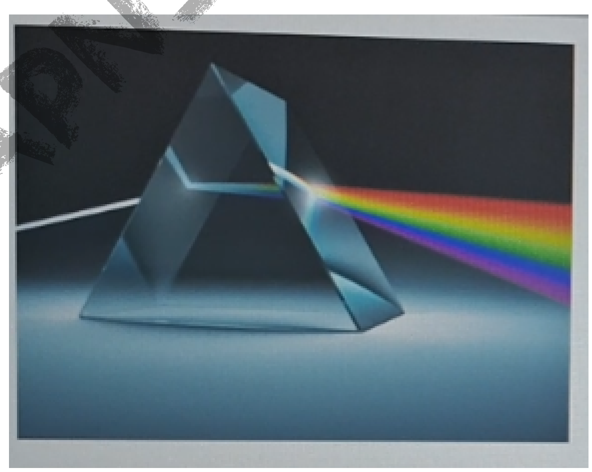
Question 13f (2 marks)

The power of some modern devices is given in horsepower (hp), where 1.0 hp is equivalent to 746 W. An example of such a device is an electric water pump. Calculate the current that would be needed by a water pump with a power of 2.0 hp operating at a voltage of 230 V.

Question 14 (7 mark)

Question 14a (1 mark)

The image shows white light being separated into different colours. Select the term for this process.



A. Absorption
B. Deflection
C. Reflection
D. Dispersion

Question 14b (3 marks)
Explain why red light is at the top of the image in part (a). You should use scientific terminology in your answer.

Question 14c (1 mark)
Another scientist called Herschel detected infrared waves beyond the visible spectrum. Unlike red light, infrared waves are not visible to the human eye. State one other difference between infrared waves and red light.

Question 14d (2 marks)
In air, all the colours of light in the spectrum travel at a speed of 3.00×10^8 m^{-1}. Use the formula sheet to calculate the frequency of red light with a wavelength of 750 nm. You should use scientific notation in your answer.

Question 15 (13 marks)
The pressure, volume and temperature of a gas are related. The ideal gas law describes the relationship between them. Gas is all around us in the form of air.
A student decides to investigate the effect of adding masses on the volume of air in a syringe. The student adds the masses slowly so that the temperature of the air in the syringe remains constant, as shown in the animation below.

Script
The tip of the syringe is sealed so that the amount of air is constant.
Masses are added and the plunger is pushed downwards, compressing the air in the syringe.

Question 15a (1 mark)
State the research question that could be answered in this scientific investigation.

Question 15b (2 marks)
Identify the variables for this investigation.

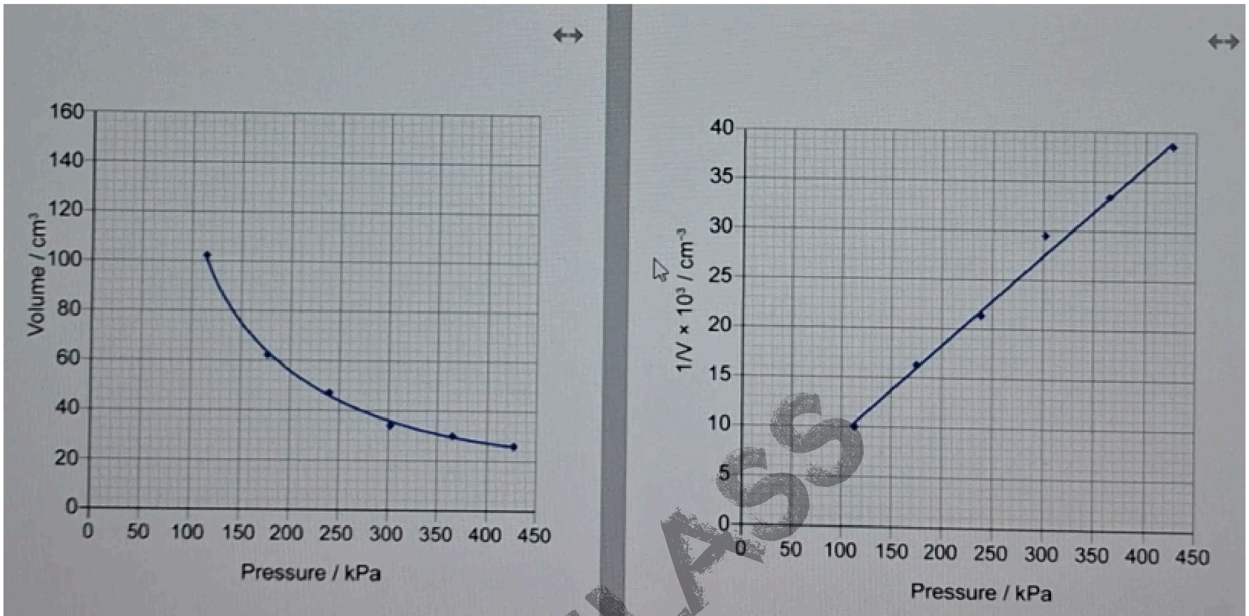
Variable	Independent	Dependent	Control
Amount of air in the syringe	☐	☐	☐
Mass added to plunger	☐	☐	☐
Size of syringe	☐	☐	☐
Temperature	☐	☐	☐
Volume of air	☐	☐	☐

Question 15c (1 mark)
Write the correct response to complete the sentence.
When masses are added to the plunger, the pressure will _______________ .

Question 15d (3 marks)
The plunger has an area of $7.9 \times 10^{-5} m^2$. Atmospheric pressure is 100 000 Pa. Use the formula sheet to calculate the total pressure on the air in the syringe if the mass applied is 1.2 kg. You should assume that the value of $g = 10\ Nkg^{-1}$.

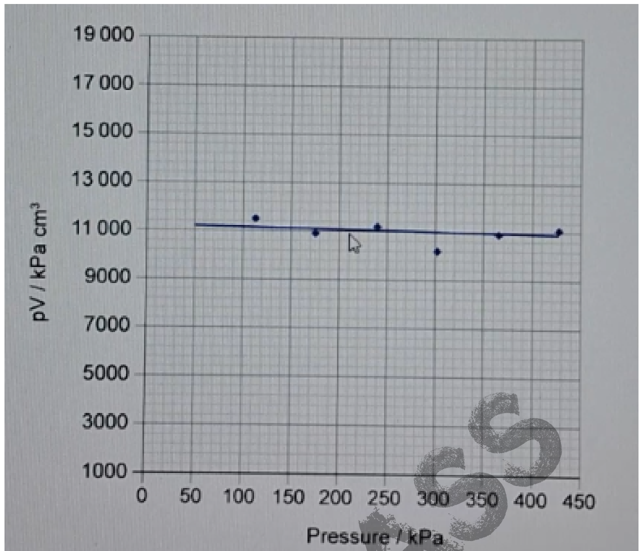
Question 15e (2 marks)

The student calculated the total pressure for each of the masses used. She presented the processed data in the graphs below.



Use both graphs above to describe the relationship between pressure and volume of a gas.

Question 15f (2 marks)
Another student decided to multiply pressure by volume (pV) and presented this on the graph below.



Boyle's law states that pV is constant for a fixed amount of gas at constant temperature.
Suggest whether the graph supports Boyle's law. Justify your answer.

Question 15g (2 marks)
Use the graph in part (f) to calculate the volume of gas when the pressure is 75 kPa. You should include a unit in your answer.

MYP 4&5 Physics - 4 - copy

Subject	Grade	Points
Physics	**MYP 5**	A 26 B 27 C 23 D 24

Question 1

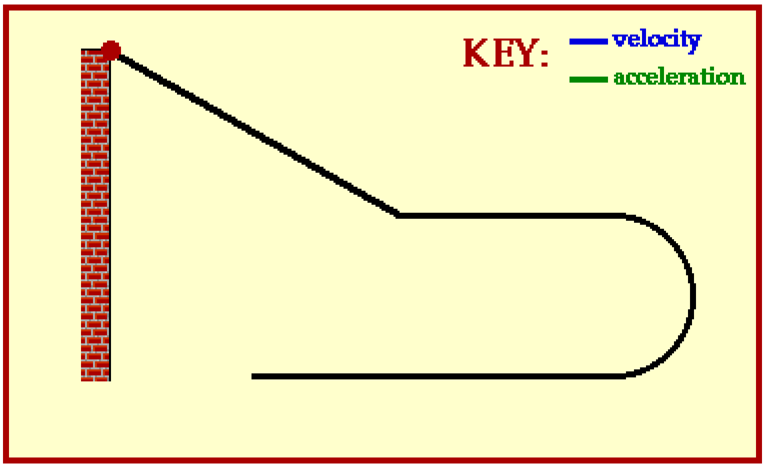
Knowing and understanding

This task (questions 1 to 3) addresses the key concept of **relationships** and focuses on **criterion A (Knowing and understanding).**

Constant velocity: steady speed, no change in direction.

Constant velocity means that the object in motion is moving in a straight line at a constant speed.

Image 1



Q 1.1 **Calculate** the average speed of a car if it travels 150 km north in 1.5 hrs, then 100 km south in 1 hr. **Present** your answer in proper units. A 2

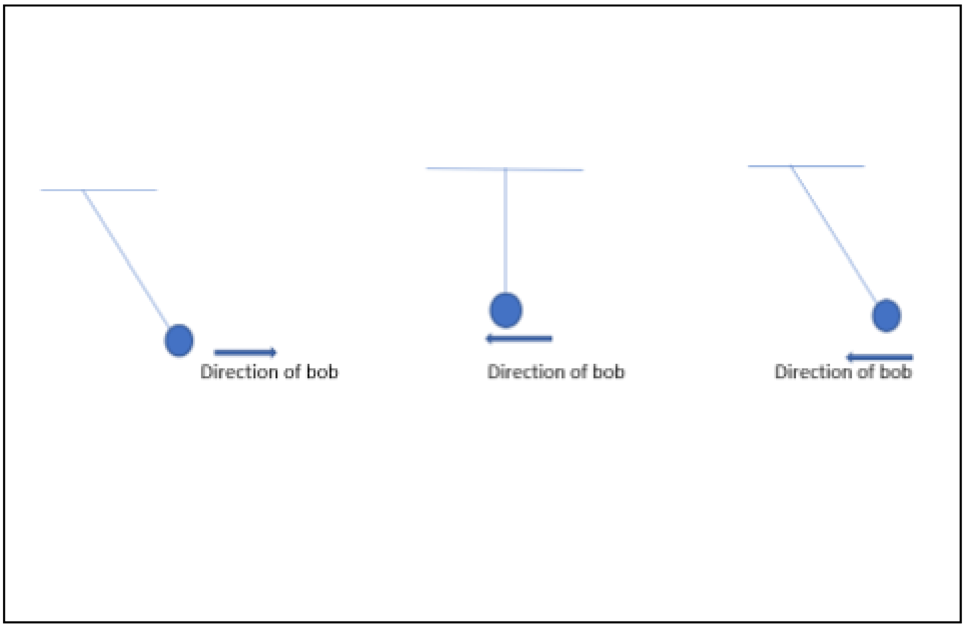
Words: 0

Q 1.2 A person from his house travels 30 km east, turns north and walks for another 40 km. Later he travels another 50 km in south-west direction. **Measure** the displacement of this person. A 2

Words: 0

Q 1.3 **Predict** the direction of acceleration and velocity of the bob in the simple pendulum shown in all the cases

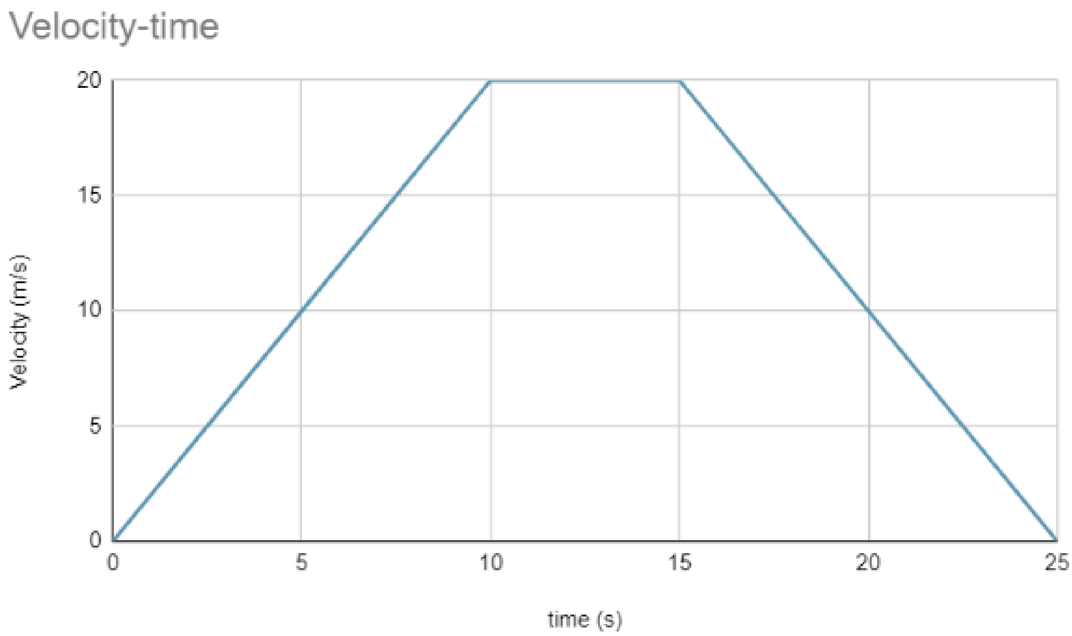
A 3



#22194D R 34 G 25 B 77

Q 1.4 **The graph shows the velocity change with time of a vehicle. From the graph, find the displacement covered by the vehicle between** 0 **to** 15 s**.**

A 2



Words: 0

Question 2

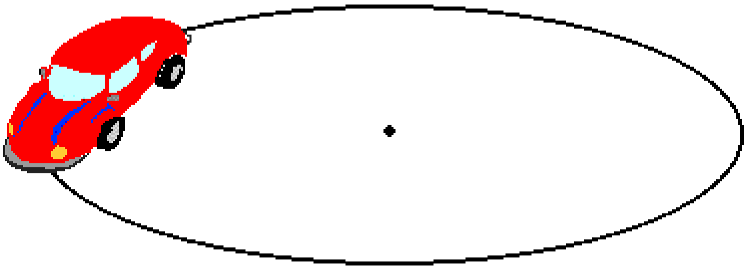
Circular motion: A force constantly pulling inward, keeping the object turning in a loop.

In physics, circular motion is a movement of an object along the circumference of a circle or rotation along a circular path. It can be uniform, with constant angular rate of rotation and constant speed, or non-uniform with a changing rate of rotation. The rotation around a fixed axis of a three-dimensional body involves circular motion of its parts. The equations of motion describe the movement of the center of mass of a body.
Examples of circular motion include: an artificial satellite orbiting the Earth at a constant height, a ceiling fan's blades rotating around a hub, a stone which is tied to a rope and is being swung in circles, a car turning through a curve in a race track, an electron moving perpendicular to a uniform magnetic field, and a gear turning inside a mechanism.

Q 2.1 **State** **the force responsible for the acceleration produced in a uniform circular motion.** A 1

Words: 0

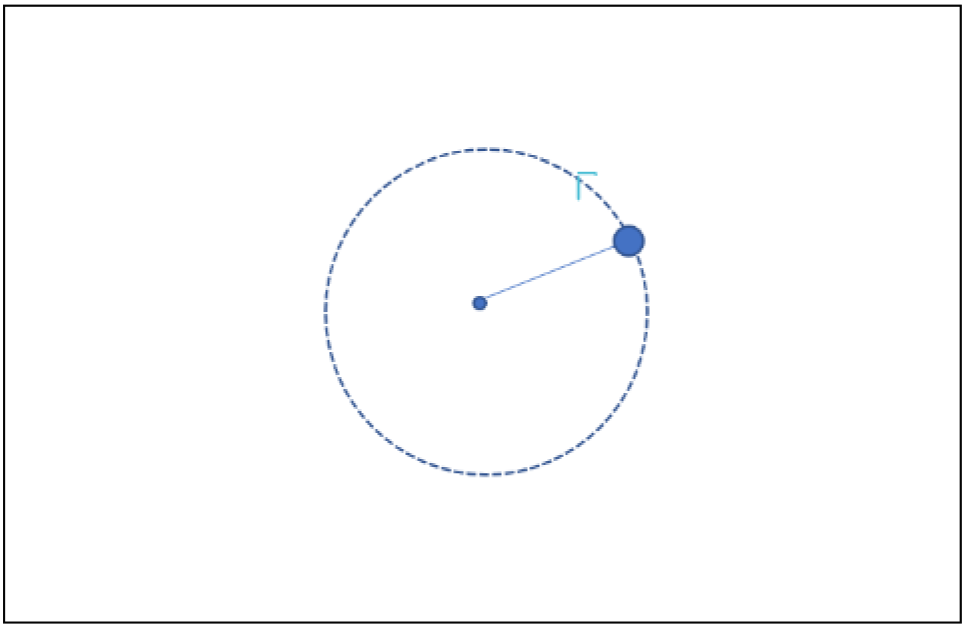
Image 1



Q 2.2 **Identify** the forces acting on the car. A 3

Words: 0

Q 2.3 **Draw** the direction of motion of the ball, if the string snaps suddenly at point shown. A 1



#22194D R 34 G 25 B 77

Q 2.4 If a car of mass 500 kg is moving with a uniform velocity $2\ \mathrm{m\ s^{-1}}$ on a circular track of radius 30 m, **calculate** the centripetal force acting on the car. A 2

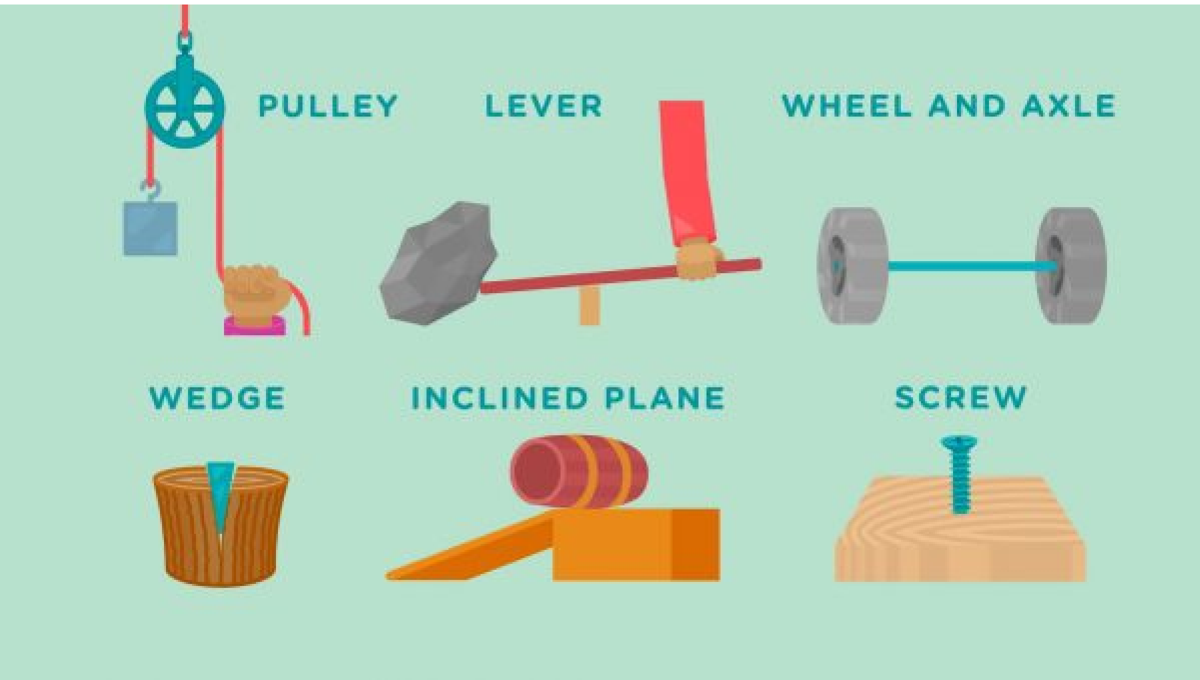
Words: 0

Question 3

Simple machines are basic tools that make work easier.

The simple machines used in mechanics are given below.

Image 1



Q 3.1 List any two examples of each of the simple machine. A 4

Lever:
Pulley:
Inclined Plane:
Wheel and axle:
Screw:

Words: 0

Q 3.2 **State** in which of the case, the input force is maximum. **Justify** your answer. A 2

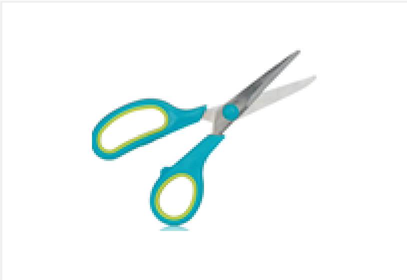
Words: 0

Q 3.3 **Calculate** the distance at which you should apply a force of 60 N to lift an object of weight 180 N using a lever. Let the length of load arm be 3 m. A 2

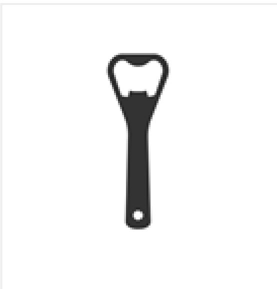
Words: 0

Q 3.4 **Classify** the levers into different categories. A 2

First class lever	Second class lever	Third class lever







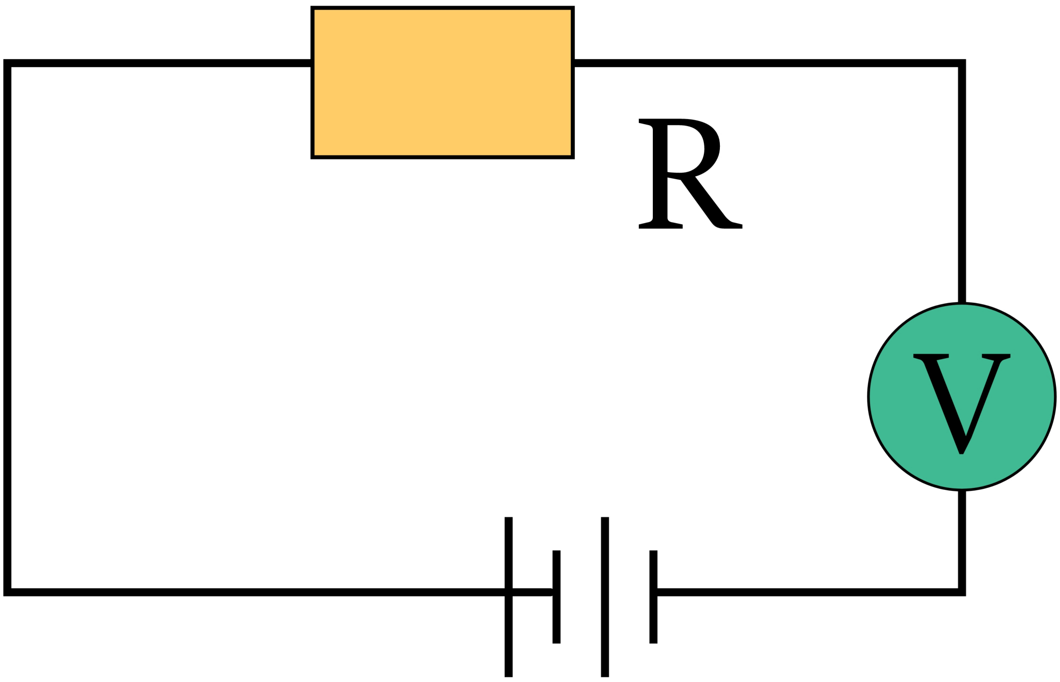

Question 4

Investigation skills

This task (questions 4 to 6) addresses the key concept of **change** and focuses on **criterion B** (Inquiring and designing) and **criterion C** (Processing and evaluating). In this task, you will investigate how different factors affect the current in an electric circuit.

Electric circuit is a network of interconnected components allowing electricity to flow.

An MYP student during his classes realized that there is a relationship between the potential difference across a wire and the current flowing through it. He decides to investigate it. For that he designs a circuit and moves forward with his investigation. But he is not able to get any results. The circuit used by him is given below.



Q 4.1 **State** a question that could be answered in this investigation. B 1

Words: 0

Q 4.2 **Formulate** and **explain** a hypothesis that could be tested in this question. B 3

Words: 0

Q 4.3 **Identify** the variables in this investigation. B 4

Dependent Variable:

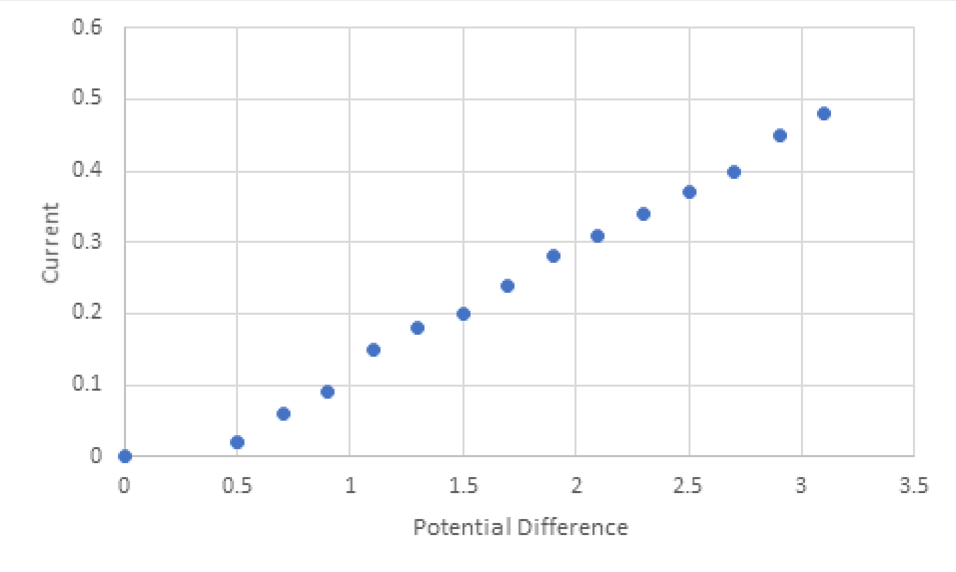
Independent Variable:

Control Variable:

Control Variable:

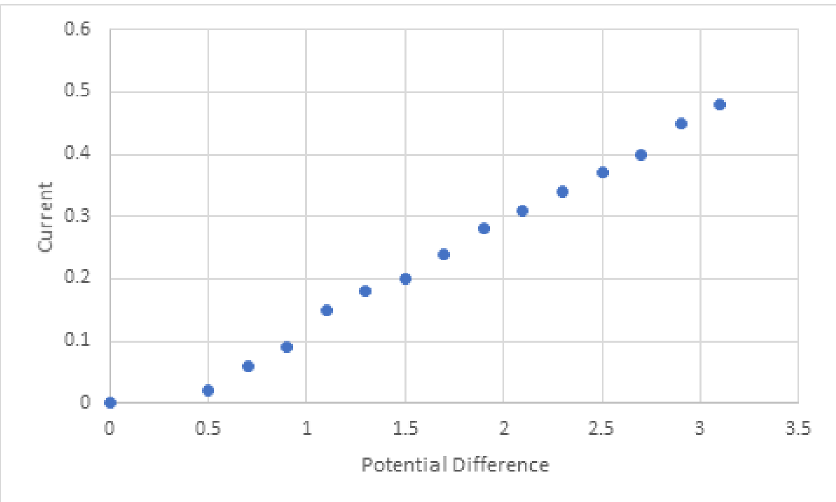
Words: 0

Another student completed the investigation and collected the data.



Q 4.4 **Present** a line that best fits the observation.

C 1



#22194D R 34 G 25 B 77

Q 4.5 **Identify** the relationship between the two variables of the investigation. C 2

Words: 0

Q 4.6 **Outline** the validity of the method followed to determine this relationship. C 2

Words: 0

Q 4.7 Using the observations, **estimate** an approximate value for the current flowing through the circuit when the potential difference across it is $4\ \mathrm{V}$. C 3

Words: 0

Q 4.8 **Evaluate** the validity of the hypothesis that was tested. C 3

Words: 0

Q 4.9 **Suggest** an extension to this investigation.

C 1

Words: 0

Question 5

Resistance is the vital element that controls current and ensures electrical safety.

Another MYP student decided to further investigate the variation in current with a change in resistance of the circuit.

Q 5.1 **Design** an experiment to undertake this study. In your design you should include: B 13

- The independent and dependent variables.
- Any assumptions you will make about control variables
- The equipment you use
- The method you will use
- How you will collect sufficient data

Words: 0

Question 6

Temperature alters resistance, impacting electrical characteristics.

A student decides to investigate the dependence of temperature on the resistance of a conductor.

Q 6.1 **State** a question that could be answered with this investigation. B 1

Words: 0

Q 6.2 **Formulate** and **explain** a hypothesis that could be tested with this question. B 3

Words: 0

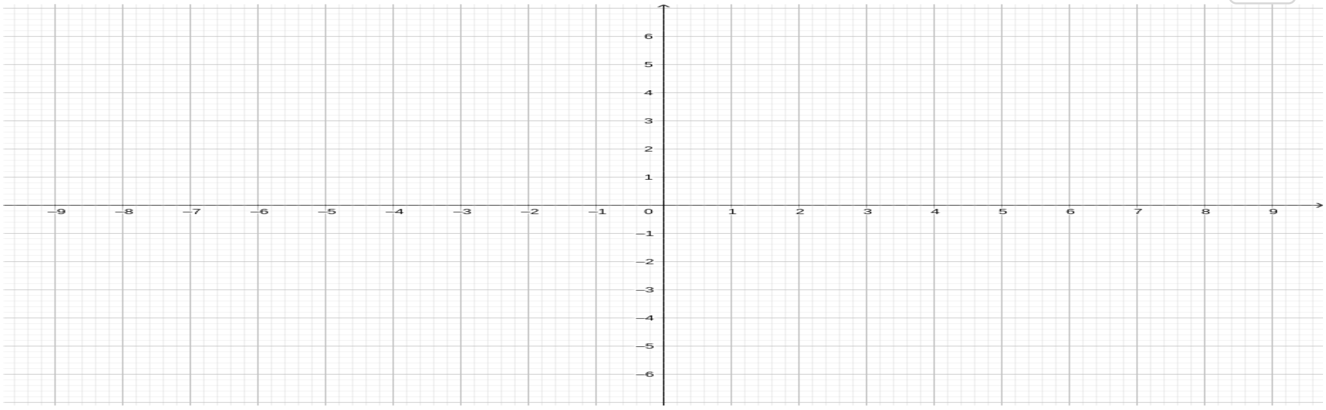
Q 6.3 **State** **one** variable that should be controlled in this investigation. **Describe** how and why this variable should be controlled. B 2

Words: 0

The data collected by the student is shown in the table below.

Temperature (in ^{o}C)	Resistance (in Ohms)
30	50
45	60
60	70
75	80
90	90

Q 6.4 **Plot** this collected data into graphical form giving suitable title to the graph. C 5



Q 6.5 **Interpret** the results from the graph. C 3

Words: 0

Q 6.6 **Discuss** the validity of your hypothesis. C 3

Words: 0

Question 7

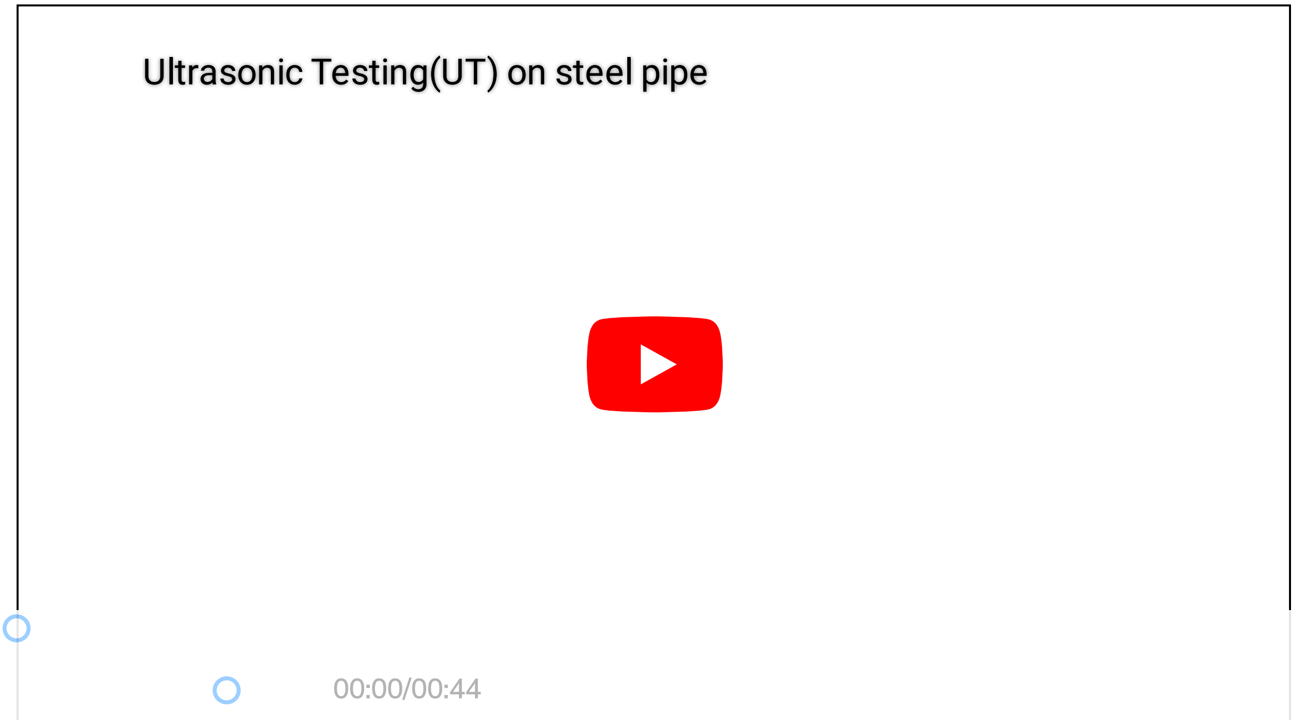
Applying science

The global context is **scientific and technical innovation**. This task (questions 7 and 8) addresses the key concept of **systems** and assesses **criterion D** (Reflecting on the impacts of science).

Ultrasound are high-frequency sound waves, used in medical imaging and beyond.

Sound is a vibration that propagates as an acoustic wave, through a transmission medium

Video 1



Q 7.1 **Select** the correct statement among the following. D 1

A Ultrasound are sound waves with frequencies lower than the audible frequency.

B Ultrasound are sound waves with frequencies higher than the audible frequency.

C Ultrasound is produced when an object in motion exceeds the speed of sound

D The wavelength of ultrasound is large and ranges to few meters.

Q 7.2 **Suggest** another application of ultrasound. D 1

Words: 0

Q 7.3 **Outline** how the above-mentioned technology is helping the industry in maintaining the safety standards D 4

Words: 0

Question 8

Ultrasound is versatile tool with applications in imaging, cleaning, and more.

In medicine, ultrasound is used to detect changes in the appearance of organs, tissues, and vessels and to detect abnormal masses, such as tumours.
In an ultrasound exam, a transducer both sends the sound waves and records the echoing waves. When the transducer is pressed against the skin, it sends small pulses of inaudible, high-frequency sound waves into the body. As the sound waves bounce off internal organs, fluids and tissues, the sensitive receiver in the transducer records tiny changes in the sound's pitch and direction. These signature waves are instantly measured and displayed by a computer, which in turn creates a real-time picture on the monitor. One or more frames of the moving pictures are typically captured as still images. Short video loops of the images may also be saved.
Doppler ultrasound, a special ultrasound technique, measures the direction and speed of blood cells as they move through vessels. The movement of blood cells causes a change in pitch of the reflected sound waves (called the Doppler effect). A computer collects and processes the sounds and creates graphs or colour pictures that represent the flow of blood through the blood vessels.

Q 8.1 **Suggest two** benefits of using ultrasound to detect the abnormalities instead of other medical techniques such as MRI. D 4

Words: 0

Q 8.2 Using the information provided and from your wider MYP studies, **discuss** and **evaluate** the use of this type of technological advances in the early detection of abnormalities in the organs. Your answer should include:

D 14

- The advantages of the technology
- The disadvantages of the technology
- Economic concerns
- Social concerns
- A concluding appraisal

Words: 0

1 (a) A radioactive source emits alpha (α), beta (β) and gamma (γ) radiation.

(i) Which **two** types of radiation will pass through a sheet of card?

....

(1)

(ii) Which **two** types of radiation would be deflected by an electric field?

....

(1)

(iii) Which type of radiation has the greatest range in air?

....

(1)

(b) A student suggests that the radioactive source should be stored in a freezer at – 20 °C. The student thinks that this would reduce the radiation emitted from the source.

Suggest why the student is wrong.

....

....

(1)

(c) Phosphorus-32 is a radioactive isotope that emits beta radiation.

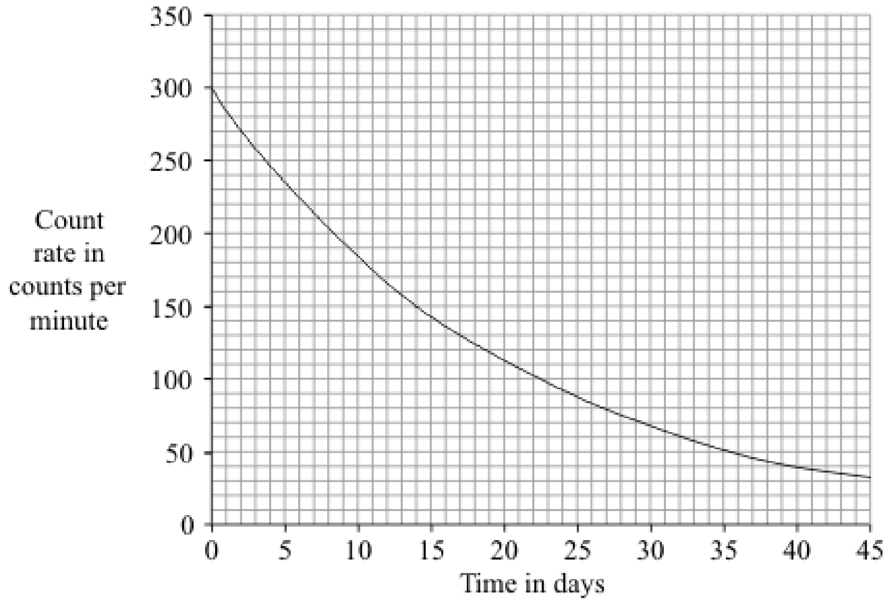
(i) How is an atom of phosphorus-32 different from an atom of the stable isotope phosphorus-31?

....

....

(1)

(ii) The graph shows how the count rate of a sample of phosphorus-32 changes with time.



Use the graph to calculate the half-life of phosphorus-32.

Show clearly how you used the graph to obtain your answer.

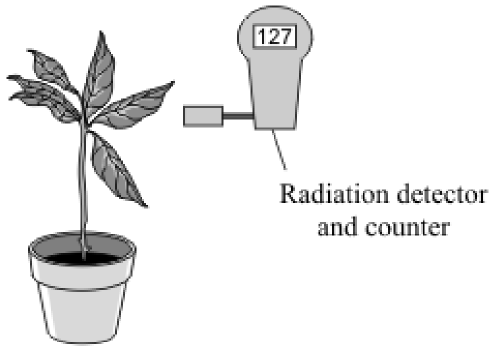
....

....

Half-life = ... days

(2)

(iii) Plants use phosphorus compounds to grow. Watering the root system of a plant with a solution containing a phosphorus-32 compound can help scientists to understand the growth process.



Explain why phosphorus-32 is suitable for use as a tracer in this situation.

....

....

....

....

(2)
(Total 9 marks)

2 (a) The names of three types of nuclear radiation are given in **List A**. Some properties of these three types of radiation are given in **List B**.

Draw a straight line to link each type of radiation in **List A** to its correct property in **List B**. Draw only three lines.

List A Type of nuclear radiation	**List B** Property of radiation
	not deflected by an electric field
alpha	stopped by thin metal but not paper
beta	the most strongly ionising
gamma	will not harm living cells

(3)

(b) Nuclear radiation is given out from the centre of some types of atom.

What name is given to the centre of an atom? ....

(1)

(c) One of the substances in the table is used as a radioactive tracer. A hospital patient breathes in air containing the tracer. The radiation given out is measured by a doctor using a detector outside the patient's body.

Substance	**Radiation given out**	**Solid, liquid or gas**
X	alpha	gas
Y	gamma	gas
Z	gamma	solid

Which **one** of the substances, **X**, **Y** or **Z**, should be used as the tracer? ....

Give **two** reasons for your answer.

1 ....

....

2 ....

....

(3)

(d) Radiation can also be used to kill the bacteria on fresh food.

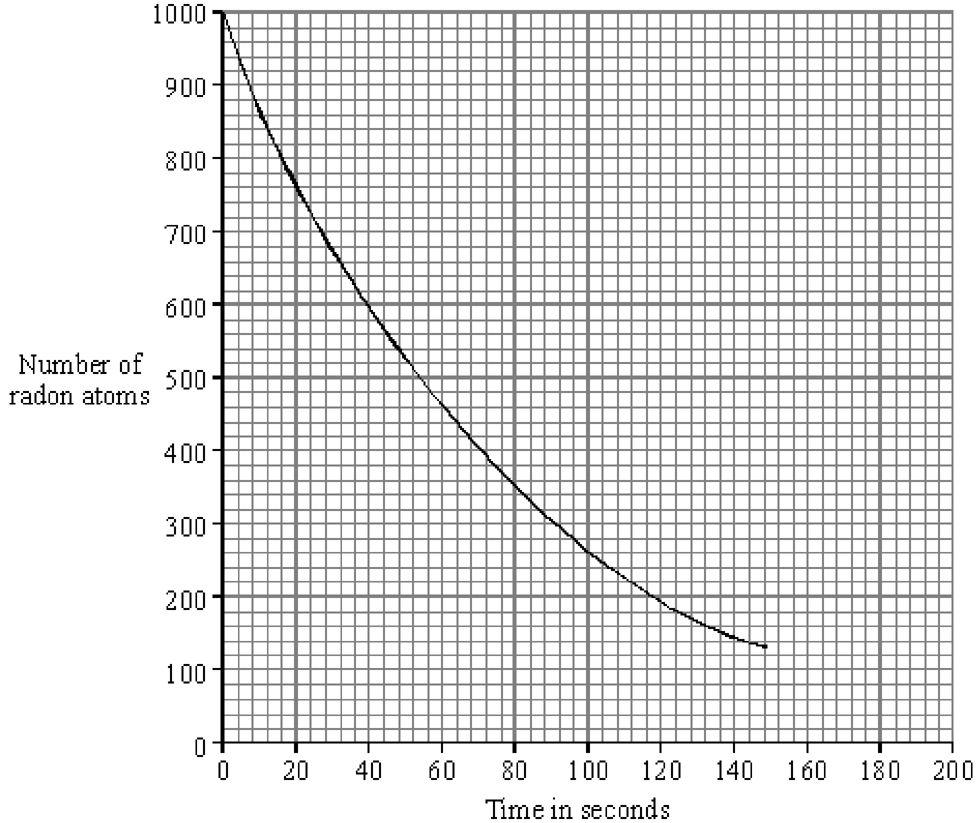
Give **one** reason why farmers, shop owners or consumers may want food to be treated with radiation.

....

....

(1)
(Total 8 marks)

3 Radon is a radioactive element. The graph shows how the number of radon atoms in a sample of air changes with time.



(i) How long did it take the number of radon atoms in the sample of air to fall from 1000 to 500?

Time = ... seconds

(1)

(ii) How long is the half-life of radon?

Half-life = ... seconds

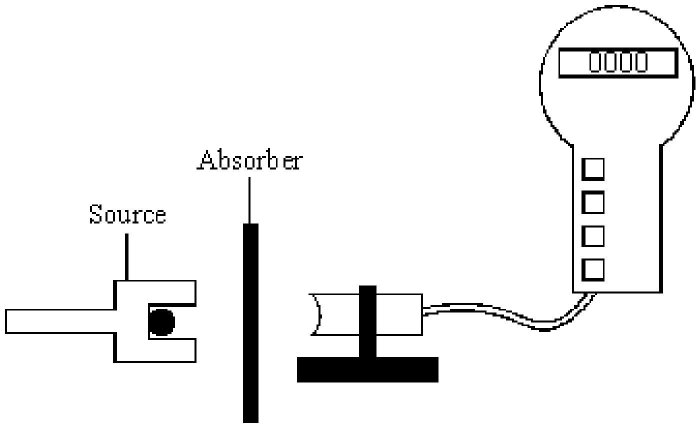
(1)

(iii) Complete this sentence by crossing out the **two** lines in the box that are wrong.

As a radioactive material gets older, it emits	less a constant level of more	radiation per second.

(1)
(Total 3 marks)

4 The detector and counter are used in an experiment to show that a radioactive source gives out alpha and beta radiation only.



Two different types of absorber are placed one at a time between the detector and the source. For each absorber, a count is taken over ten minutes and the average number of counts per second worked out. The results are shown in the table.

Absorber used	**Average counts per second**
No absorber	33
Card 1 mm thick	20
Metal 3 mm thick	2

Explain how these results show that alpha and beta radiation is being given out, but gamma radiation is **not** being given out.

....

....

....

....

....

....

(Total 3 marks)

5 (a) The table gives information about six radioactive isotopes.

Isotope	**Type of radiation emitted**	**Half-life**
hydrogen-3	beta particle	12 years
iridium-192	gamma ray	74 days
polonium-210	alpha particle	138 days
polonium-213	alpha particle	less than 1 second
technetium-99	gamma ray	6 days
uranium-239	beta particle	24 minutes

(i) What is an alpha particle?

....

(1)

(ii) Two isotopes of polonium are given in the table. How do the nuclei of these two isotopes differ?

....

(1)

(iii) A doctor needs to monitor the blood flow through a patient's heart. The doctor injects a radioactive isotope into the patient's bloodstream. The radiation emitted by the isotope is then detected outside the body.

Which **one** of the isotopes in the table would the doctor inject into the bloodstream?

....

Explain the reasons for your choice.

....

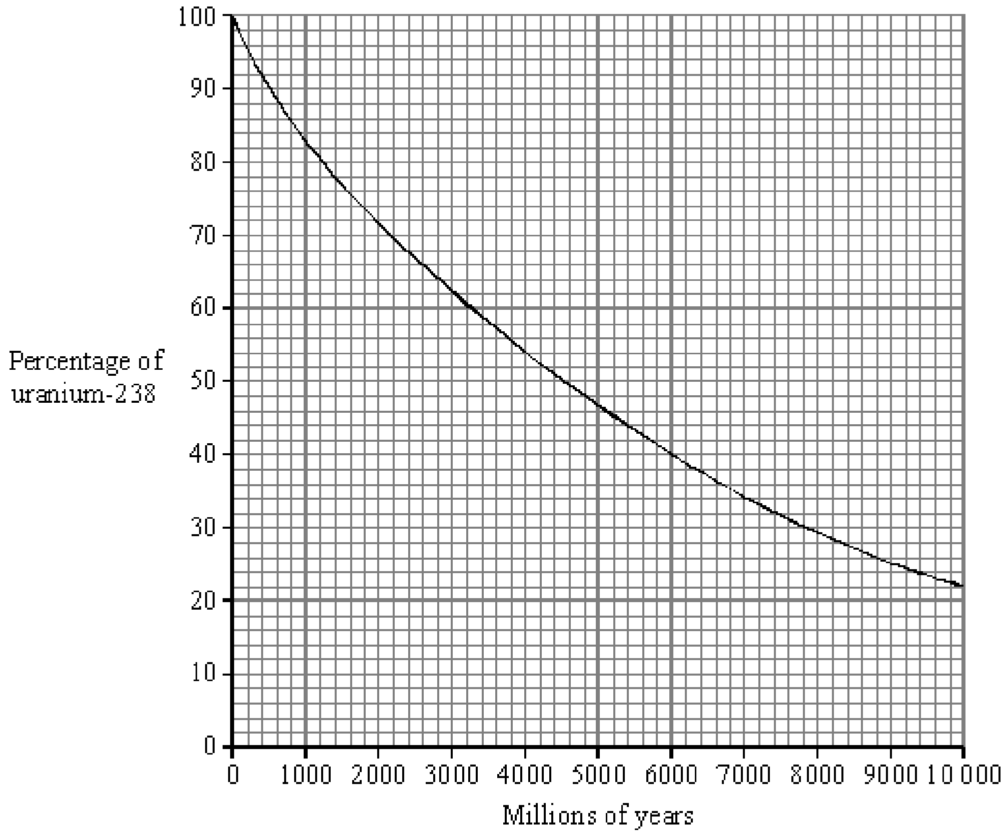
....

....

....

(3)

(b) Igneous rock contains uranium-238 which eventually changes to the stable isotope lead-206. The graph shows how the percentage of uranium-238 nuclei present in an igneous rock changes with time.



A rock sample is found to have seven atoms of uranium-238 for every three atoms of lead-206. Use the graph to estimate the age of the rock. Show clearly how you obtain your answer.

....

....

Age of rock = ... million years

(2)
(Total 7 marks)

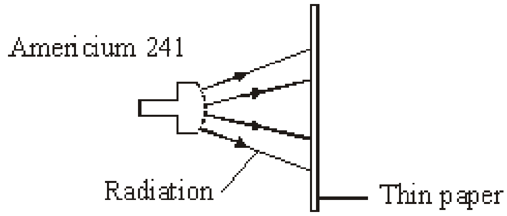
6 A smoke detector fitted inside a house contains a radioactive source, americium 241.

(a) Complete the following table of information for an atom of americium 241.

Number ofneutrons	146
Number ofprotons	95
Number ofelectrons	

(1)

(b) The diagram shows that the radiation given out by americium 241 does not go through paper.



Which type of radiation, alpha (α), beta (β), or gamma (γ) is given out by americium 241?

....

(1)

(c) Explain why the radiation given out by the americium 241 is unlikely to do any harm to people living in the house.

....

....

....

....

(2)

(d) Complete the sentence by choosing an answer from the box.

less than	**more than**	**the same as**

After many years the radiation emitted by americium 241 will be ....

when the smoke detector was new.

(1)
(Total 5 marks)

7 A beta particle is a high-energy electron.

(i) Which part of an atom emits a beta particle?

....

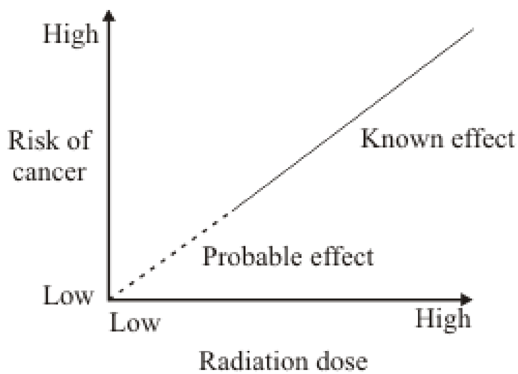
(1)

(ii) How does the composition of an atom change when it emits a beta particle?

....

(1)
(Total 2 marks)

8 (a) Radiation can cause cancer. The graph shows that the risk of cancer depends on the radiation dose a person is exposed to.

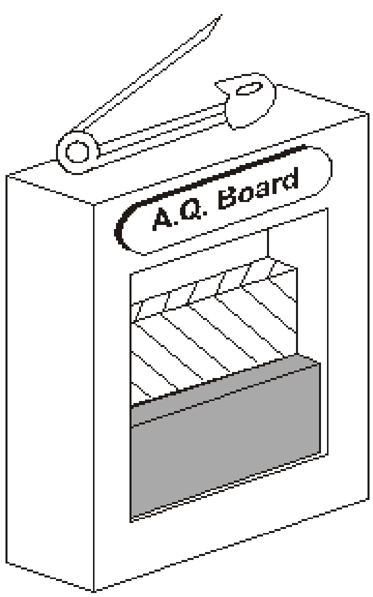


Complete the following sentence.

The .... the dose of radiation a person gets, the greater the risk of cancer.

(1)

(b) A worker in a nuclear power station wears a special badge (diagram **1**). Diagram **2** shows what is inside the badge. When the film inside the badge is developed, it will be dark in the places where it has absorbed radiation.



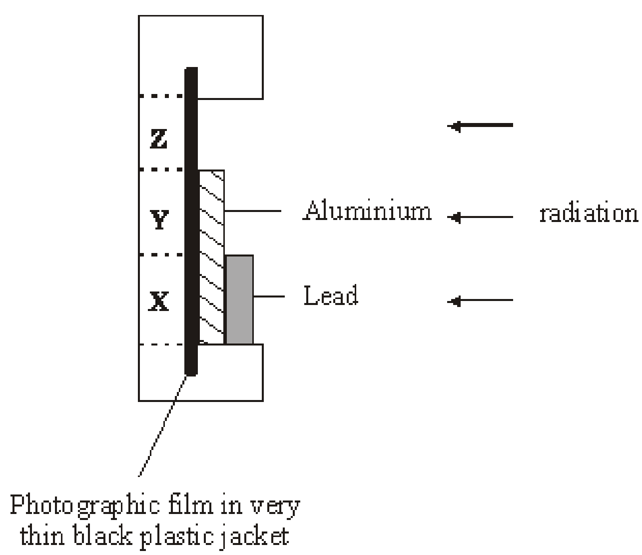


Diagram 1 **Diagram 2**

Which part of the film, **X**, **Y** or **Z,** would darken if the worker had received a dose of alpha radiation?

....

Give a reason for your answer.

....

....

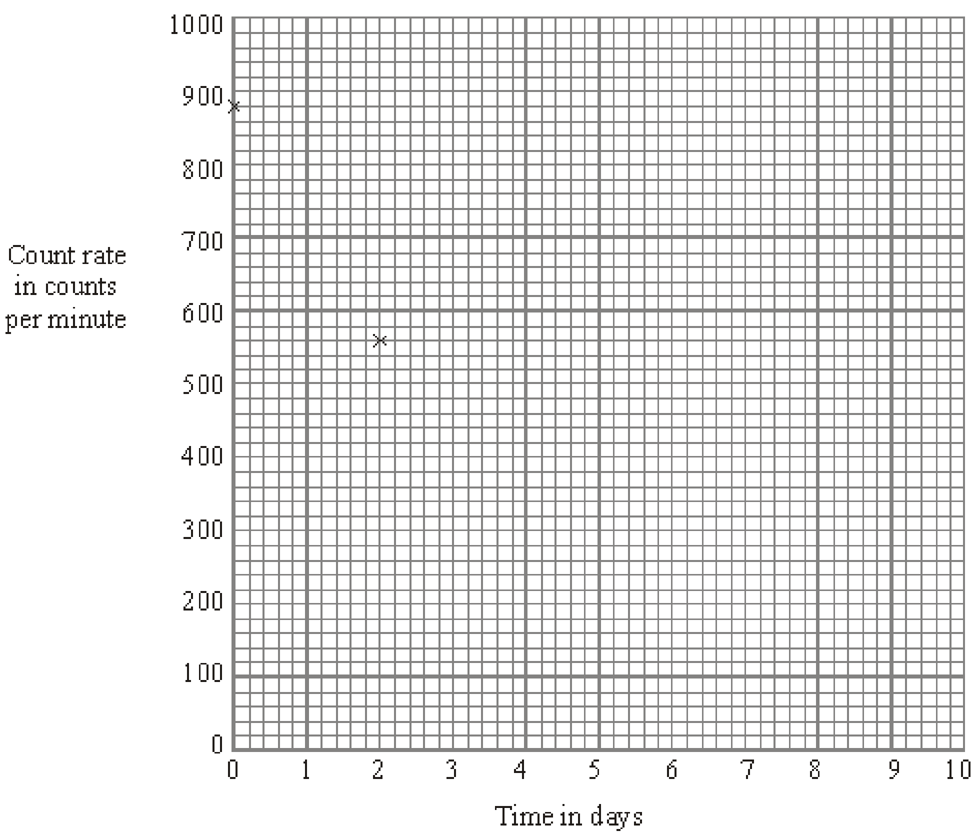
(2)
(Total 3 marks)

9 The table shows how the count rate from a radioactive substance changes in 10 days.

Time in days	0	2	4	6	8	10
Count rate in countsper minute	880	555	350	220	140	90

(a) Draw a graph of count rate against time.

The first two points have been plotted for you.



(3)

(b) (i) Use your graph to find out how long it takes for the count rate to fall from 880 counts per minute to 440 counts per minute.

Time = ... days

(1)

(ii) What is the half-life of this substance?

Half-life = ... days

(1)

(c) The table gives the half-life and type of radiation given out by four different radioactive isotopes.

Radioactive isotope	**Half-life in days**	**Radiation given out**
bismuth-210	5.0	beta
polonium-210	138.0	alpha and gamma
radon-222	3.8	alpha
thorium-234	24.1	beta and gamma

Some samples of each isotope have the same count rate today. Which sample will have the lowest count rate one month from today?

....

Give a reason for your answer.

....

(2)
(Total 7 marks)

10 Read the information in the box and then answer the questions.

Igneous rocks contain potassium-40. This is a radioactive isotope. It has a half-life of 1300 million years.

Potassium-40 decays into argon-40 which is stable.

Argon escapes from molten rock. Any argon found in an igneous rock must have been produced since the rock solidified.

A sample of an igneous rock has one atom of potassium-40 for every three atoms of argon-40.

(i) What fraction of the potassium-40 has not yet decayed?

....

(1)

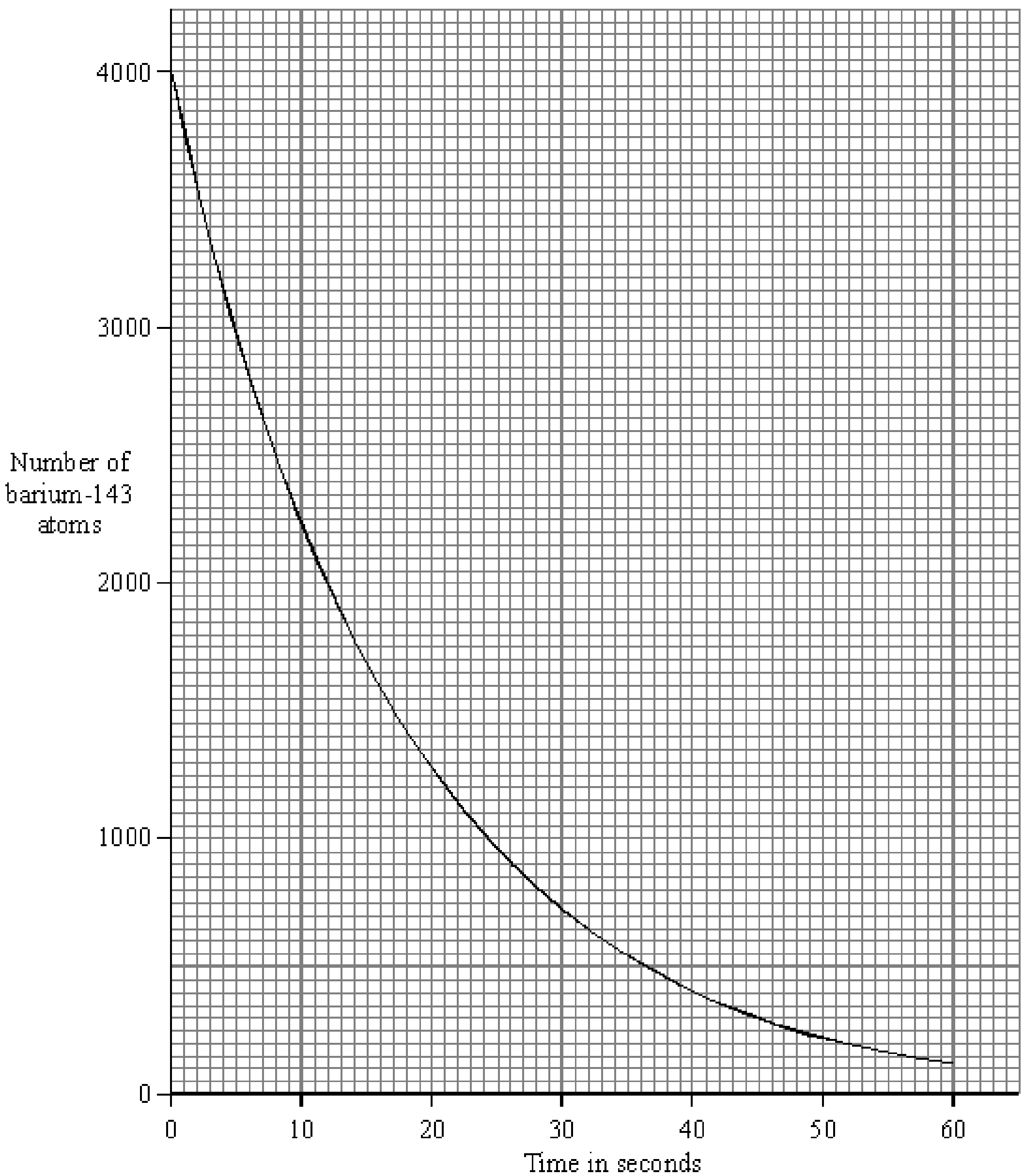
(ii) Calculate the age of the rock.

....

Age of rock = ... million years

(1)
(Total 2 marks)

11 (a) The graph shows how a sample of barium-143, a radioactive *isotope* with a short *half-life,* decays with time.



(i) What is meant by the term *isotope?*

....

....

(1)

(ii) What is meant by the term *half-life*?

....

....

(1)

(iii) Use the graph to find the half-life of barium-143.

Half-life = ... seconds

(1)

(b) Humans take in the radioactive isotope carbon-14 from their food. After their death, the proportion of carbon-14 in their bones can be used to tell how long it is since they died. Carbon-14 has a half-life of 5700 years.

(i) A bone in a living human contains 80 units of carbon-14. An identical bone taken from a skeleton found in an ancient burial ground contains 5 units of carbon-14. Calculate the age of the skeleton. Show clearly how you work out your answer.

....

....

....

Age of skeleton = ... years

(2)

(ii) Why is carbon-14 unsuitable for dating a skeleton believed to be about 150 years old?

....

....

(1)

(c) The increased industrial use of radioactive materials is leading to increased amounts of radioactive waste. Some people suggest that radioactive liquid waste can be mixed with water and then safely dumped at sea. Do you agree with this suggestion? Explain the reason for your answer.

....

....

....

....

....

....

....

....

(3)
(Total 9 marks)

12 The radioactive isotope, carbon-14, decays by beta (β) particle emission.

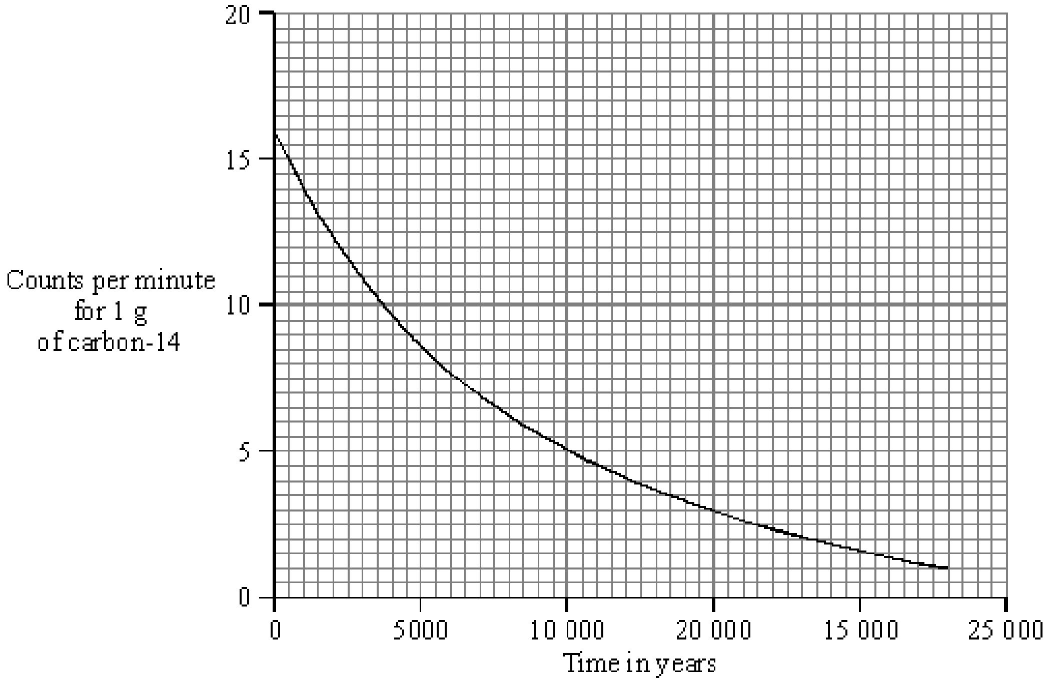
(a) What is a beta (β) particle?

....

....

(1)

(b) Plants absorb carbon-14 from the atmosphere. The graph shows the decay curve for 1 g of carbon-l4 taken from a flax plant.



Use the graph to find the half-life of carbon-l4. You should show clearly on your graph how you obtain your answer.

Half-life = ... years.

(2)

(c) Linen is a cloth made from the flax plant. A recent exhibition included part of a linen shirt, believed to have belonged to St. Thomas à Becket, who died in 1162. Extracting carbon-14 from the cloth would allow the age of the shirt to be verified.

If 1 g of carbon-14 extracted from the cloth were to give 870 counts in 1 hour, would it be possible for the shirt to have once belonged to St. Thomas à Becket? You must show clearly the steps used and reason for your decision.

....

....

....

....

(3)
(Total 6 marks)

13 (a) The table gives information about five radioactive isotopes.

Isotope	**Type of radiation emitted**	**Half-life**
Californium-241	alpha (α)	4 minutes
Cobalt-60	gamma (γ)	5 years
Hydrogen-3	beta (β)	12 years
Strontium-90	beta (β)	28 years
Technetium-99	gamma (γ)	6 hours

(i) What is an alpha (α) particle?

....

....

(1)

(ii) What is meant by the term half-life?

....

....

(1)

(iii) Which **one** of the isotopes could be used as a tracer in medicine? Explain the reason for your choice.

....

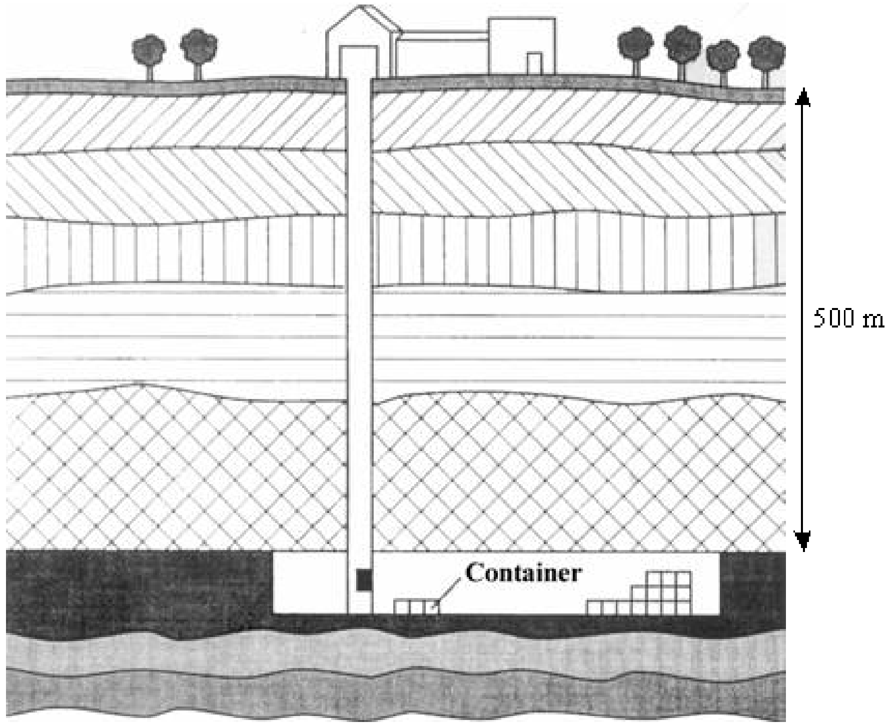
....

....

....

(3)

(b) The increased use of radioactive isotopes is leading to an increase in the amount of radioactive waste. One method for storing the waste is to seal it in containers which are then placed deep underground.



Some people may be worried about having such a storage site close to the area in which they live. Explain why.

....

....

....

....

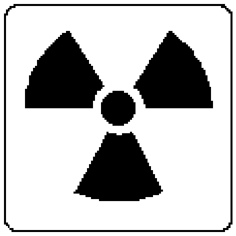
....

....

....

(3)
(Total 8 marks)

14 (a) The diagram shows a hazard sign.



What type of hazard does this sign warn you about?

....

(1)

(b) The names of three types of radiation are given in the box.

alpha (α)	beta (β)	gamma (γ)

Complete each sentence by choosing the correct type of radiation from those given in the box. Each type of radiation should be used once or not at all.

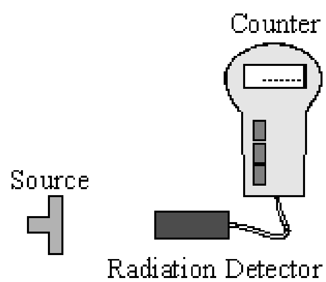
(i) The type of radiation that travels at the speed of light is ....

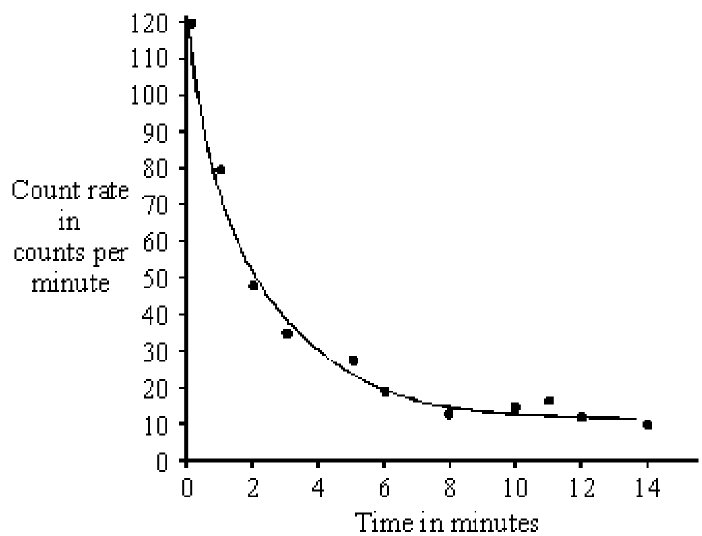
(1)

(ii) The type of radiation that is stopped by thick paper is ....

(1)
(Total 3 marks)

15 (a) A radiation detector and counter were used to detect and measure the radiation emitted from a weak source. The graph shows how the number of counts recorded in one minute changed with time.





(i) Even though the readings from the counter were accurately recorded, not all the points fit the smooth curve. What does this tell us about the process of radioactive decay?

....

(1)

(ii) After ten minutes the number of counts recorded each minute is almost constant. Explain why.

....

....

....

(2)

(b) The radioactive isotope sodium-24 injected into the bloodstream can be used to trace blood flow to the heart. Sodium-24 emits both *beta particles* and *gamma rays*.

(i) What is a *beta particle*?

....

(1)

(ii) What is a *gamma ray*?

....

....

(1)

(iii) The count rate from a solution containing sodium-24 decreases from 584 counts per minute to 73 counts per minute in 45 hours. Calculate the half-life of sodium-2.2. Show clearly how you work out your answer.

....

....

....

Half-life = ... hours

(3)

(iv) Give **one** advantage of using sodium-24 to trace blood flow compared to using an isotope with a half-life of:

[A] ten years; ....

....

(1)

[B] ten seconds. ....

....

(1)
(Total 10 marks)

16 (a) Two sources of radiation look identical. One source emits only alpha radiation, the other only beta radiation. Describe **one** way to find out which source emits the alpha radiation. You can assume a radiation detector and counter are available. You may wish to draw a diagram to help with your answer.

....

....

....

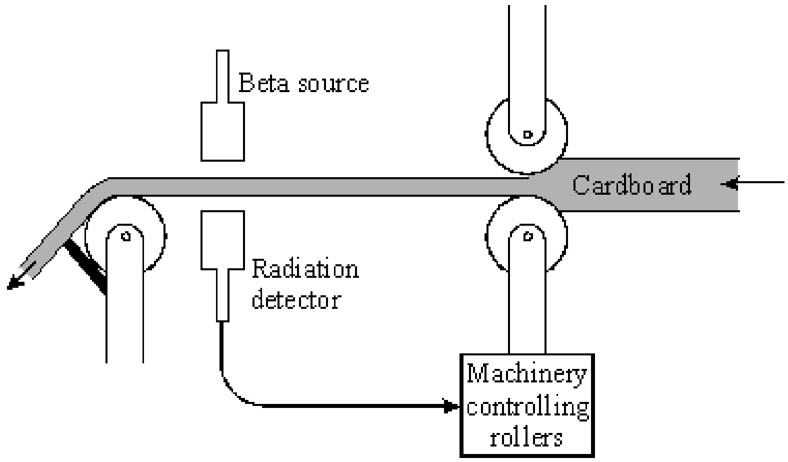
....

....

....

(3)

(b) The diagram shows a beta radiation source and detector used to measure the thickness of cardboard as it is made. The table gives the detected count rate at different times.



Time	**Count rate in counts/minute**
09:00	120
09:30	122
10:00	119
10:30	165
11:00	118

(i) Between 09:00 and 10:00 the cardboard is produced at the correct constant thickness. Give a reason for the small variation in count rate.

....

....

(1)

(ii) What can you say about the thickness of the cardboard being made at 10:30?

....

Explain the reason for your answer.

....

....

....

(3)

(iii) Explain why gamma radiation is not suitable for detecting changes to the thickness of the cardboard.

....

....

(1)
(Total 8 marks)

17 Radon is a radioactive gas. Radon makes a major contribution to background radiation levels. Radon atoms decay by the emission of *alpha particles*.

(a) (i) What is an *alpha particle*?

....

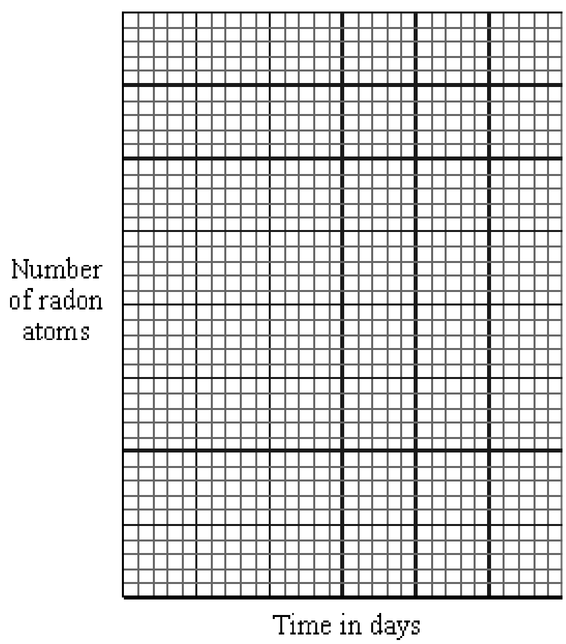
(1)

(ii) From which part of the radon atom does the alpha particle come?

....

(1)

(b) (i) A sample of air contains 40 000 radon atoms. The half-life of radon is four days. Draw a graph to show how the number of radon atoms present in a sample of air will change over a period of 12 days.



(3)

(ii) After 20 days, how many of the radon atoms from the original sample of air will have decayed? Show clearly how you work out your answer.

....

....

....

Number of radon atoms decayed = ...

(3)

(c) Fairly constant concentrations of radon gas have been found in some deep mine shafts.

(i) Suggest why the concentration of radon gas remains fairly constant although the radon gas decays.

....

....

(1)

(ii) Explain why the long term exposure to large concentrations of radon gas could be a danger to health.

....

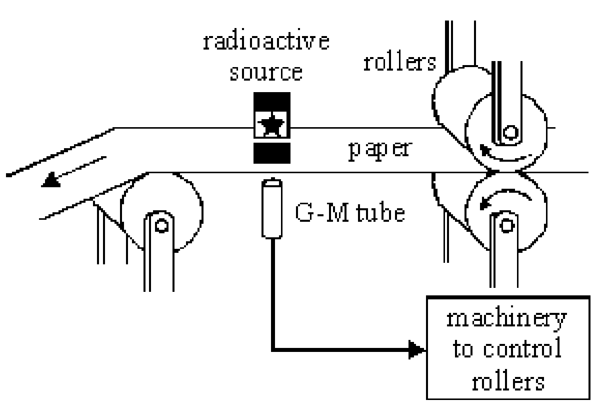
....

....

....

(2)
(Total 11 marks)

18 The diagram below shows a method of controlling the thickness of paper produced at a paper mill. A radioactive source which emits beta radiation is placed on one side of the paper and a radiation detector is placed on the other.



(a) How will the amount of radiation reaching the detector change as the paper gets thicker?

....

....

(1)

(b) Explain, as fully as you can:

(i) why a radioactive source which emits alpha (α) radiation could **not** be used for this application.

....

....

....

....

(1)

(ii) why a radioactive source which emits gamma (γ) radiation could **not** be used for this application.

....

....

....

....

(1)

(iii) why a radioactive source which emits beta (β) radiation **can** be used for this application.

....

....

....

....

(2)

(c) Americium-241 is a radioisotope used in smoke detectors. It has a proton number of 95 and a mass number of 241.

How long would it take the americium-241 in a smoke detector to decrease to one eighth of its original number of radioactive atoms?

....

....

....

Answer = ...

(3)
(Total 8 marks)

19 People who work in places where radiation is present, for example in X-ray departments in hospitals, have to wear a “film badge”. These badges are sent away regularly to check on the amount of radiation to which the person has been exposed. Simply described, the badge is some photographic film in a suitable holder.

(a) (i) Why is the “film badge” of little use in detecting alpha particles?

....

(1)

(ii) How does the “film badge” show radiation has reached it?

....

(1)

(b) Radioactivity can cause harm. It also has a number of valuable uses.

(i) How can radioactivity harm our bodies?

....

....

(1)

(ii) Give **two** medical uses of radioactive isotopes.

1. ....

2. ....

(2)

(c) A radioactive isotope of lead has a half-life of 10.6 hours.

A small sample of lead containing this isotope has a count rate of 8000 counts per minute.

How long will it be before the count rate is 1000 counts per minute?

....

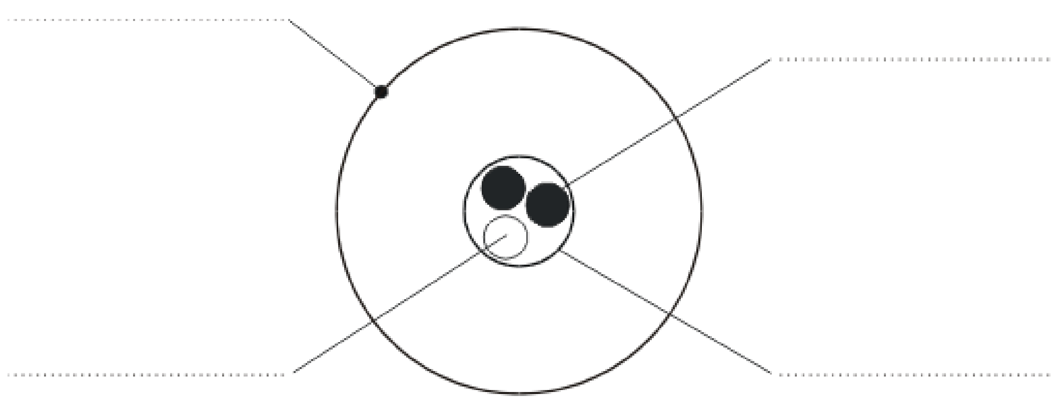
....

Time = ... hours

(2)
(Total 7 marks)

20 (a) Tritium ($^{3}_{1}H$) is an isotope of hydrogen. Tritium has a proton number of 1 and a mass number of 3.

(i) The diagram below shows a simple model of a tritium atom. Complete the diagram by adding the names of the particles indicated by the labels.



(4)

(ii) Explain how the nucleus of an ordinary hydrogen atom is different from the nucleus of a tritium atom. Ordinary hydrogen atoms ($^{1}_{1}H$) have a mass number of 1.

....

....

....

(2)

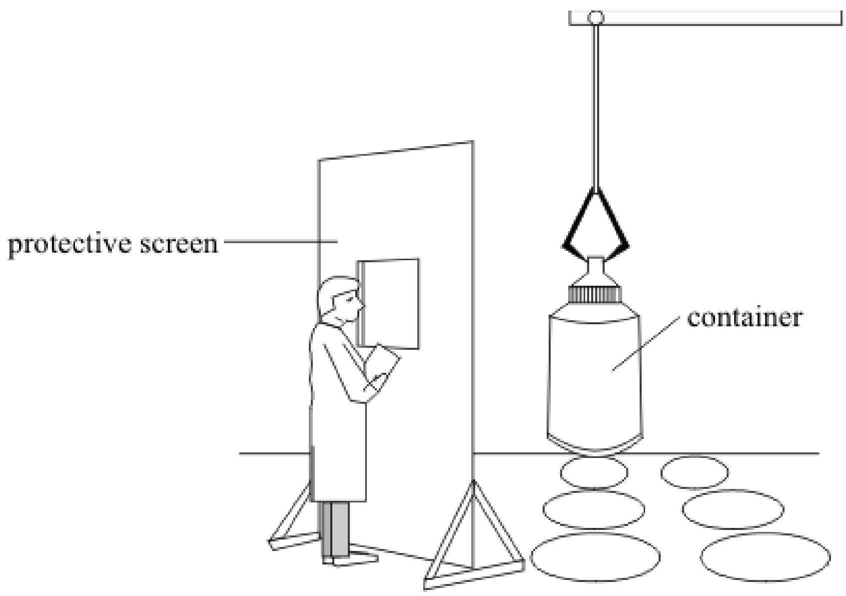
(iii) Tritium is a radioactive substance which emits beta (β) radiation.
Why do the atoms of some substances give out radiation?

....

....

(2)

(b) Tritium is one of the elements found in the waste material of the nuclear power industry. The diagram below shows a worker behind a protective screen. The container holds a mixture of different waste materials which emit alpha (α), beta (β) and gamma (γ) radiation.



Suggest a suitable material for the protective screen. The material should prevent radiation from the container reaching the worker. Explain your answer.

....

....

....

(2)
(Total 10 marks)

21 (a) Complete the table about atomic particles.

ATOMIC PARTICLE	RELATIVE MASS	RELATIVE CHARGE
proton		+1
neutron	1	0
electron	negligible	

(2)

(b) Use the Data Sheet to help you to answer some parts of this question.

Read the following passage about potassium.

Potassium is a metallic element in Group 1 of the Periodic Table.
It has a proton (atomic) number of 19.

Its most common isotope is potassium-39, ($^{40}_{19}K$).

Another isotope, potassium-40, ($^{40}_{19}K$), is a radioisotope.

(i) State the number of protons, neutrons and electrons in potassium-39.

Number of protons ....

Number of neutrons ....

Number of electrons ....

(2)

(ii) Explain why potassium-40 has a different mass number from potassium-39.

....

(1)

(iii) What is meant by a *radioisotope*?

....

....

(1)

(iv) Atoms of potassium-40 change into atoms of a different element. This element has a proton (atomic) number of 20 and a mass number of 40.

Name, or give the symbol of, this new element.

....

(1)

(v) Explain in terms of atomic structure, why potassium-39 and potassium-40 have the same chemical reactions.

....

(1)

(c) (i) Name a suitable detector that could be used to show that potassium-40 gives out radiation.

....

(1)

(ii) Name a disease which can be caused by too much exposure to a radioactive substance such as potassium-40.

....

(1)
(Total 10 marks)

22 (a) A radioactive isotope has a half-life of 10 minutes.
At the start of an experiment, the activity of a sample of this isotope was 800 counts per second after allowing for background radiation.

Calculate how long it would be before the activity fell from 800 counts per second to 200 counts per second.

....

....

Time .... min.

(2)

(b) A physicist investigates a solid radioactive material. It emits alpha particles, beta particles and gamma rays.
The physicist does not touch the material.

Explain why the alpha particles are less dangerous than the beta particles and gamma rays.

....

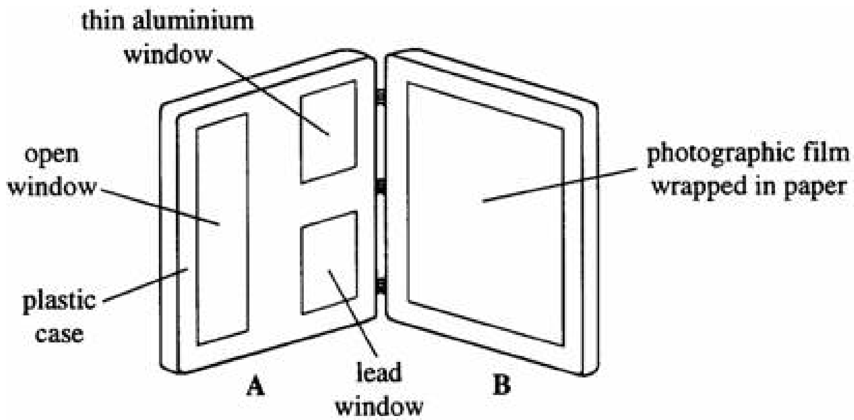
....

....

....

(2)
(Total 4 marks)

23 The diagram shows a film badge worn by people who work with radioactive materials. The badge has been opened. The badge is used to measure the amount of radiation to which the workers have been exposed.



(a) The detector is a piece of photographic film wrapped in paper inside part **B** of the badge. Part **A** has “windows” as shown.

Complete the sentences below.

When the badge is closed

(i) .... radiation and .... radiation can pass through the open window and affect the film.

(1)

(ii) Most of the .... radiation will pass through the lead window and affect the film.

(1)

(b) Other detectors of radiation use a gas which is ionised by the radiation.

(i) Explain what is meant by *ionised*.

....

....

(1)

(ii) Write down **one** use of ionising radiation.

....

(1)

(c) Uranium-238 has a very long half-life. It decays via a series of short-lived radioisotopes to produce the stable isotope lead-204.

Explain, in detail, what is meant by:

(i) *half-life*,

....

....

(1)

(ii) *radioisotopes*.

....

....

....

....

(2)

(d) The relative proportions of uranium-238 and lead-204 in a sample of igneous rock can be used to date the rock.
A rock sample contains three times as many lead atoms as uranium atoms.

(i) What fraction of the original uranium is left in the rock?

(Assume that there was no lead in the original rock.)

....

....

(1)

(ii) The half-life of uranium-238 is 4500 million years.

Calculate the age of the rock.

....

....

....

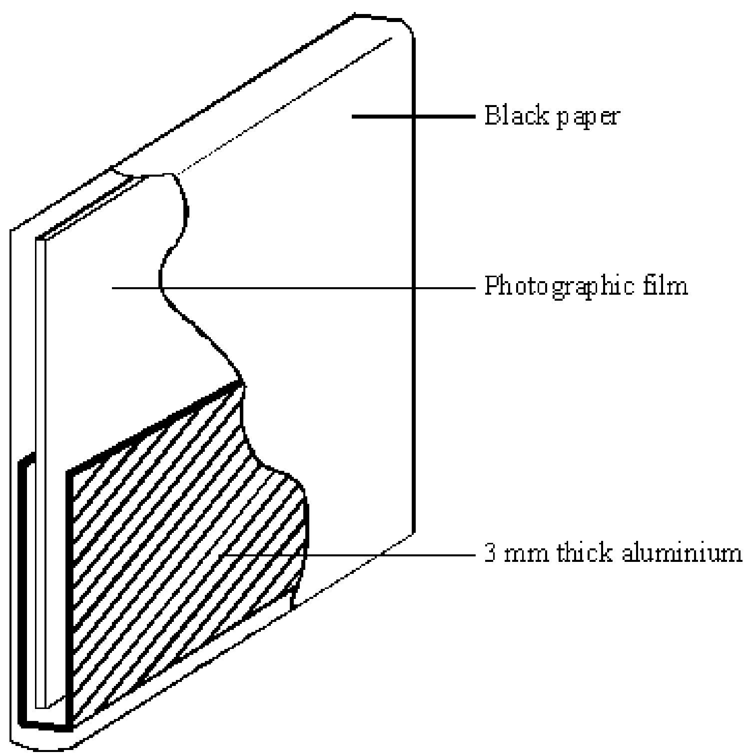
Age .... million years

(2)

(Total 10 marks)

24 The diagram shows a badge worn by a worker at a nuclear power station.

Part of the outer black paper has been removed so that you can see the inside of the badge.



Scientists examined the worker's badge at the end of a day's work.

They found that the top part of the badge had been affected by radiation, but the bottom half had not.

What type of radiation had the worker been exposed to? Explain the reasons for your answer.

....

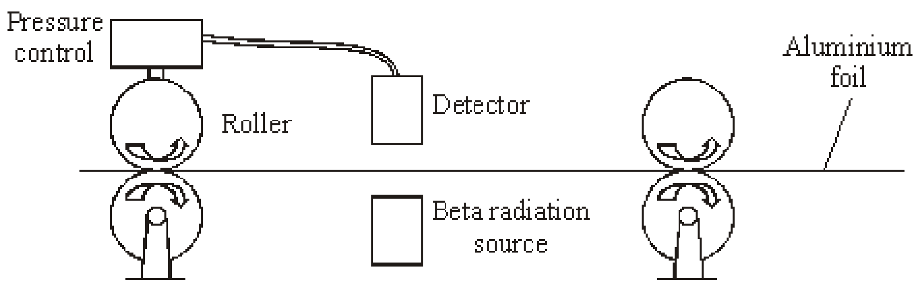
....

....

....

(Total 2 marks)

25 The diagram shows how the thickness of aluminium foil is controlled. The thicker the aluminium foil, the more radiation it absorbs.



(a) The designers used a beta radiation source for this control system.

(i) Why would an alpha radiation source be unsuitable in this control system?

....

....

(1)

(ii) Why would a gamma radiation source be unsuitable in this control system?

....

....

(1)

(b) The substance used in the beta radiation source is radioactive.

(i) Why are some atoms radioactive?

....

....

(1)

(ii) Explain why radiation is dangerous to humans.

....

....

....

....

(2)
(Total 5 marks)

26 (a) (i) Describe the structure of alpha particles.

....

....

....

....

(2)

(ii) What are beta particles?

....

....

....

(1)

(b) Describe how beta radiation is produced by a radioactive isotope.

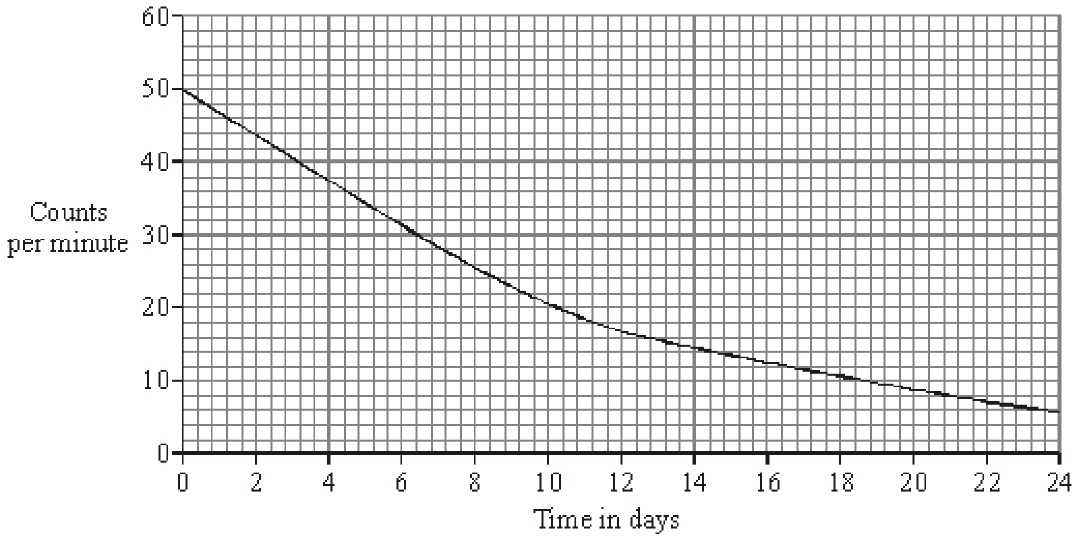
....

....

(1)
(Total 4 marks)

27 Iodine-131 (^{131}**I**) is a radioactive isotope used in medicine.

The graph shows how the count rate of a sample of iodine-131 changed over 24 days.



(i) Use the graph to calculate the half-life of iodine-131. To obtain full marks you should show clearly how you work out your answer.

....

....

....

Half-life .... days

(2)

(ii) Iodine-131 is used to destroy cancer cells in the human thyroid gland.

Explain why the length of the half-life of iodine-131 is important in this use.

....

....

....

....

(2)
(Total 4 marks)

28 (a) (i) Describe the structure of alpha particles.

....

....

....

....

(2)

(ii) What are beta particles?

....

....

....

(1)

(b) Describe how beta radiation is produced by a radioactive isotope.

....

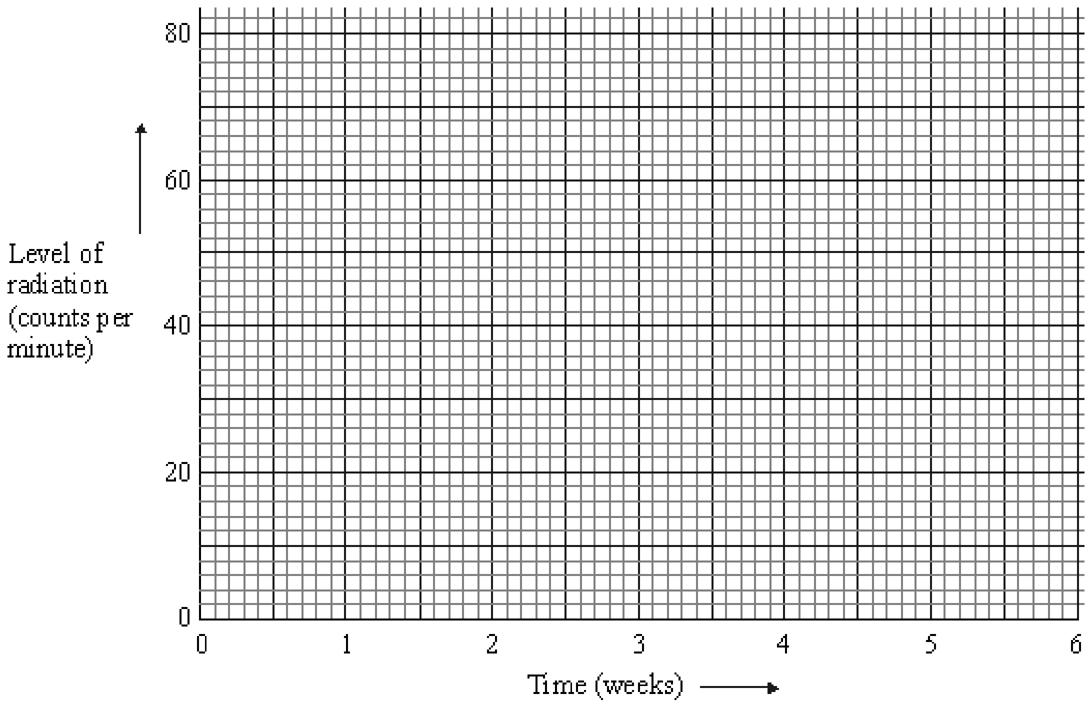
(1)
(Total 4 marks)

29 Some students measure the level of radiation from a radioactive source during the same lesson each week over a period of six weeks.

Here are the results. (They have been corrected for background radiation.)

Time (weeks)	start	1	2	3	4	5	6
Level of radiation (average counts per minute)	66	44	34	29	16	12	8

(a) Using the graph paper below, display these results in the most appropriate way.



(5)

(b) What overall pattern is there in the students' results?

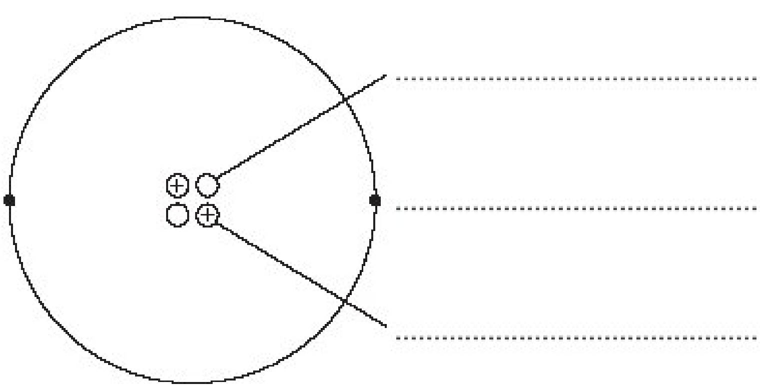
....

....

....

(3)
(Total 8 marks)

30 The diagram shows a helium atom.



(a) (i) Use the words in the box to label the diagram.

electron	**neutron**	**proton**

(2)

(ii) An alpha particle is the same as the nucleus of a helium atom.

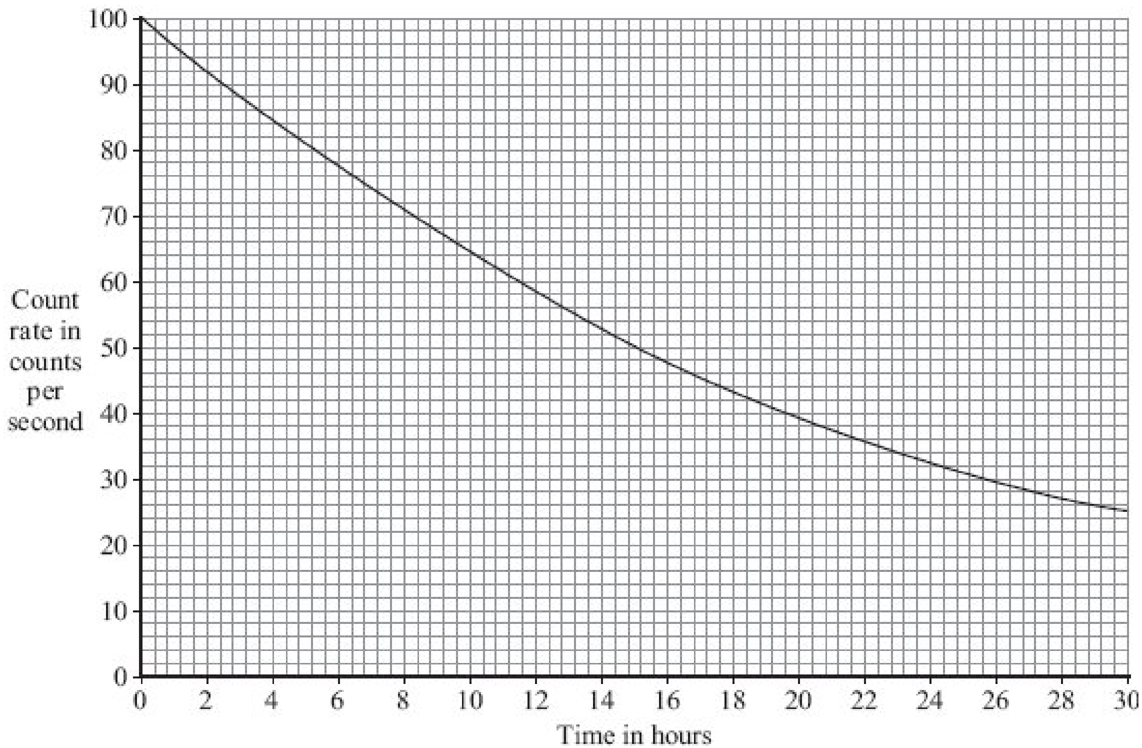
How is an alpha particle different from a helium atom?

....

....

(1)

(b) The graph shows how the count rate from a sample of radioactive sodium-24 changes with time.



(i) How many hours does it take for the count rate to fall from 100 counts per second to 50 counts per second?

Time = ... hours

(1)

(ii) What is the half-life of sodium-24?

Half-life = ... hours

(1)

(c) A smoke detector contains a small amount of americium-241.

Americium-241 is a radioactive substance which emits alpha particles. It has a half-life of 432 years.

(i) Which **one** of the following statements gives a reason why the americium-241 inside the smoke detector will **not** need replacing?

Put a tick (✓) in the box next to your answer.

The alpha particles have a low energy. ☐

People replace smoke detectors every few years. ☐

Americium-241 has a long half-life. ☐

(1)

(ii) The diagram shows the label on the back of the smoke detector.

Why do people need to know that the smoke detector contains a radioactive material?

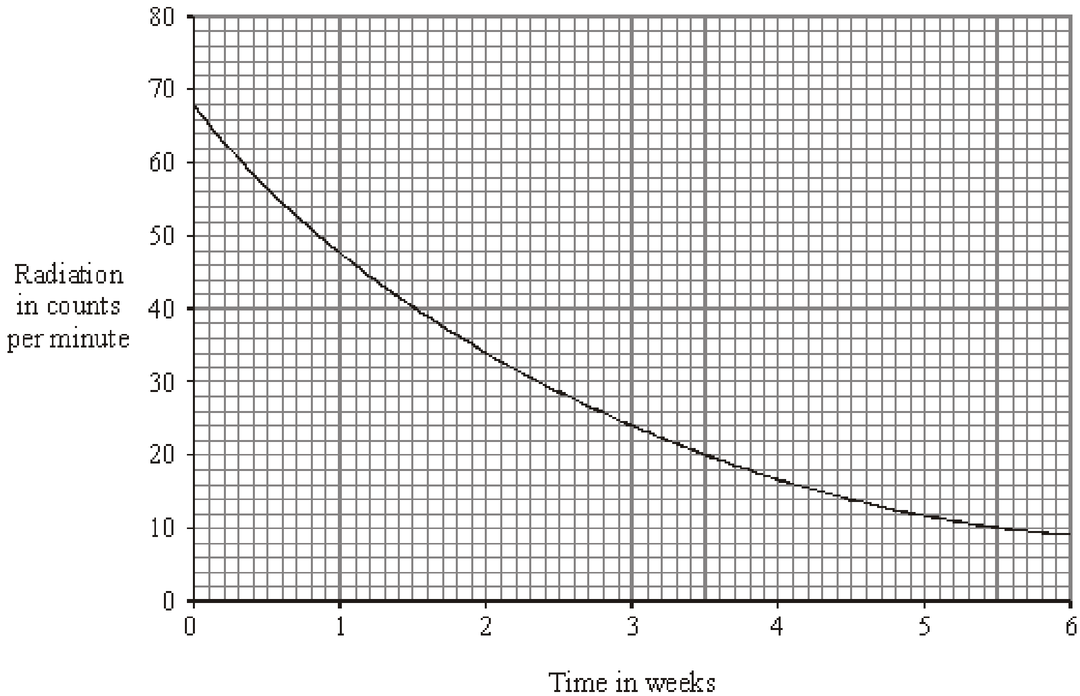
....

....

(1)
(Total 7 marks)

31 A teacher measured the amount of radiation from a radioactive source, during the same lesson each week, over a period of six weeks.

The results are shown on the graph.



How long does it take for the radiation to fall from 68 counts per minute to half that value?

Show clearly how you work out your answer.

....

....

....

Time taken for radiation to halve ....

(Total 3 marks)

32 $^{99}_{43}Tc$ (technetium) is produced by the radioactive decay of $^{99}_{42}Mb$ (molybdenum).

What change occurs in the nucleus of a molybdenum atom when this happens?

....

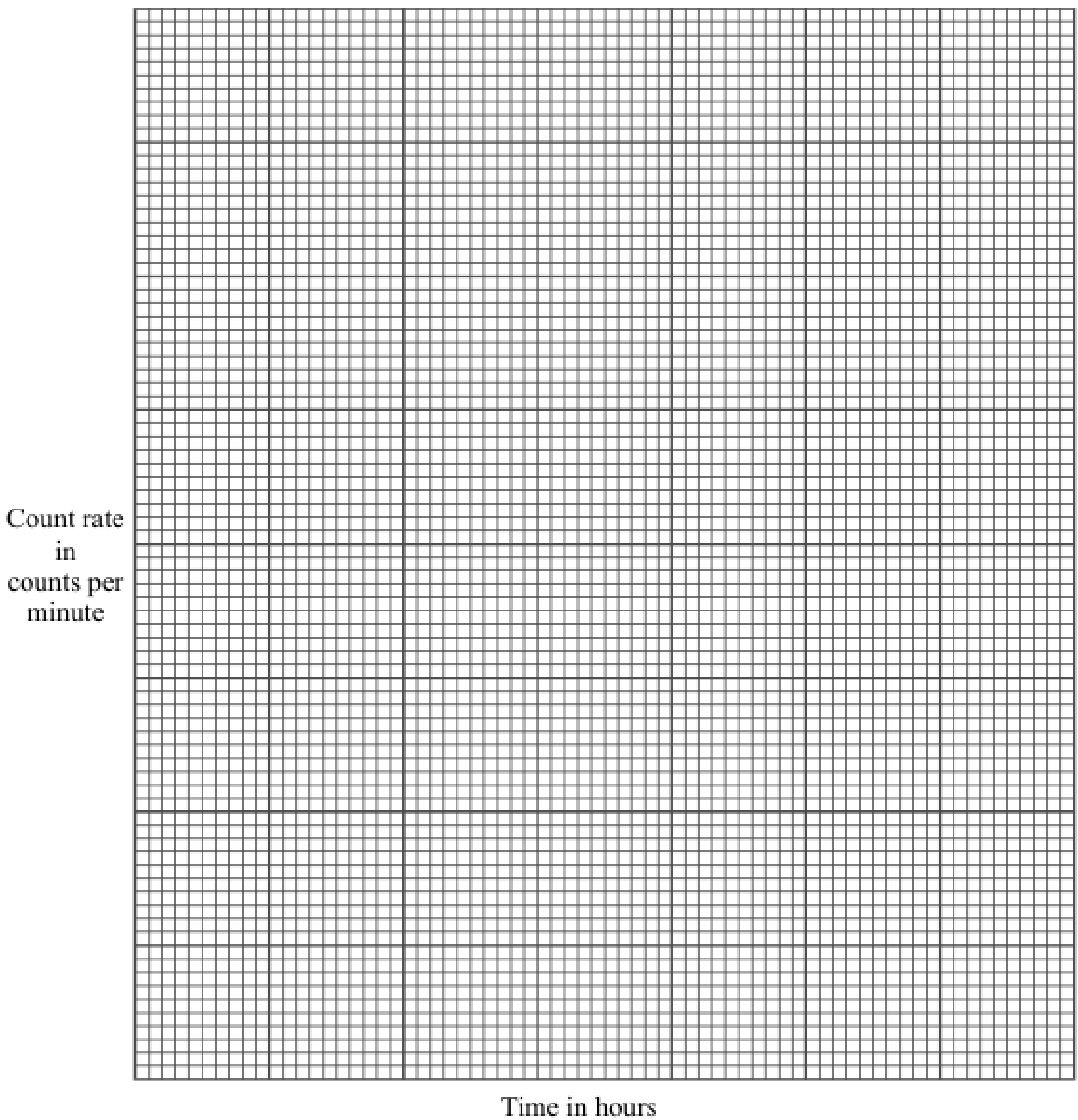
....

(Total 1 mark)

33 The isotope of sodium with a mass number of 24 is radioactive. The following data were obtained in an experiment to find the half-life of sodium-24.

Time in hours	**Count rate in counts per minute**
0	1600
10	1000
20	600
30	400
40	300
50	150
60	100

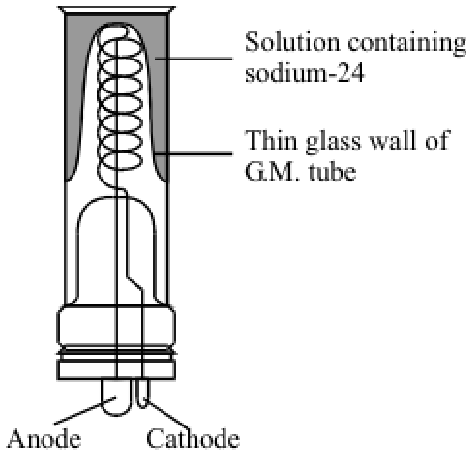
(a) Draw a graph of the results and find the half-life for the isotope. On the graph show how you obtain the half-life.



Half-life = ... hours

(4)

(b) Sodium-24 decays by beta emission. The G.M. tube used in the experiment is shown in the diagram. Each beta particle which gets through the glass causes a tiny electric current to pass in the circuit connected to the counter.



(i) Why must the glass wall of the G.M. tube be very thin?

....

....

(1)

(ii) Why is this type of arrangement of no use if the radioactive decay is by alpha emission?

....

....

(1)

(c) Sodium chloride solution is known as saline. It is the liquid used in 'drips' for seriously-ill patients. Radioactive sodium chloride, containing the isotope sodium-24, can be used as a tracer to follow the movement of sodium ions through living organisms.

Give **one** advantage of using a sodium isotope with a half-life of a few hours compared to using an isotope with a half-life of:

(i) five years; ....

....

(1)

(ii) five seconds. ....

....

(1)
(Total 8 marks)

34 A simple spark counter can be used to detect charged particles. It is made by having two wires close together with a large voltage across them. When a charged particle passes through the gap between the wires a spark is seen.

(a) Give the names and symbols of **two** particles which will cause a spark.

(i) Name .... Symbol ....

(2)

(ii) Name .... Symbol ....

(2)

(b) A radioactive source was placed within 2 cm of the spark counter and lots of sparks were seen. A piece of paper was slid between the source and the counter. The sparking stopped.

(i) What type of radiation was being given off?

....

(1)

(ii) The paper was removed and the source slowly moved away from the spark counter. Describe what will happen to the sparking.

....

....

....

(2)

(c) A radioactive source gave a high reading using a Geiger-Müller tube and counter, but did not cause sparking when brought near to the spark counter. Why?

....

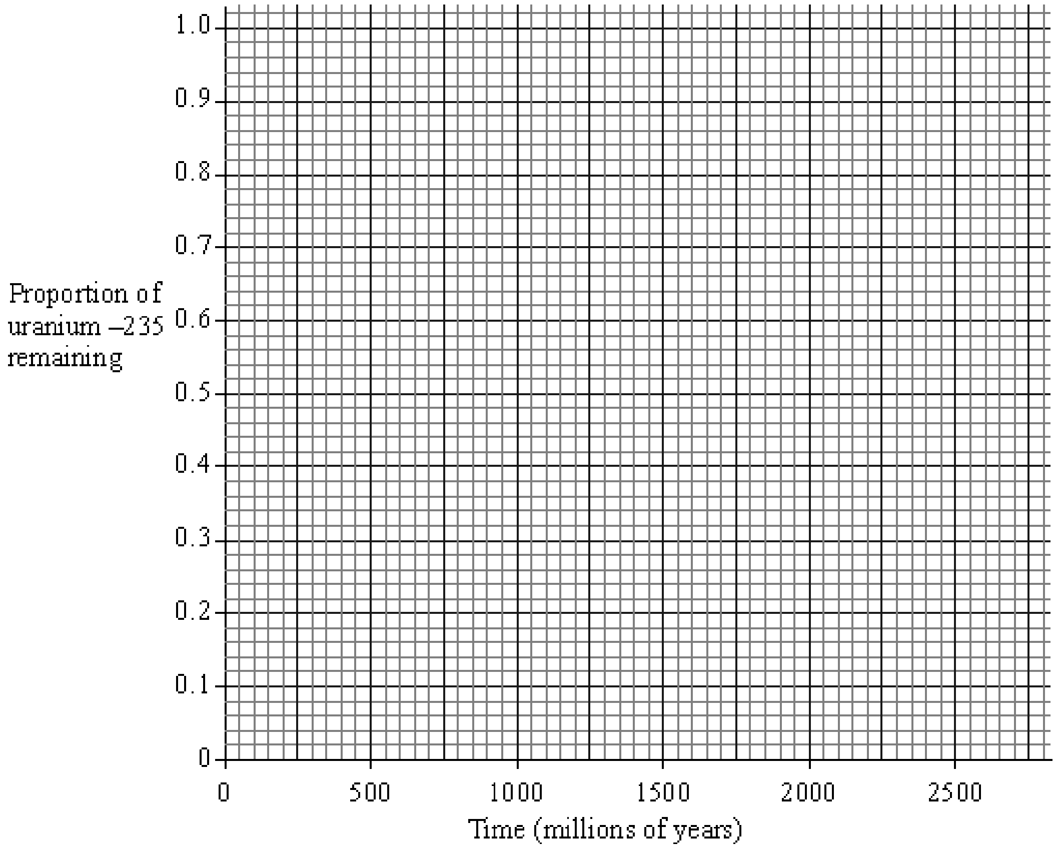
....

(1)
(Total 8 marks)

35 Some rocks contain the radioactive isotope uranium–235 (^{235}U).

^{235}U has a half-life of 700 million years and, as it decays, lead–207 (^{207}Pb) is eventually formed.

(a) Draw a decay curve for ^{235}U on the graph below.



(4)

(b) Samples of an igneous rock gave an average ratio of 70 atoms of ^{235}U to 30 atoms of 207 Pb.

Use the decay curve you have drawn to estimate the age of the igneous rock.

Answer .... million years.

(1)

(c) A sandstone rock which lies above the igneous rock contains traces of uranium-235 and of lead-207.

Why might it be unsatisfactory to use this uranium for dating the sandstone?

....

....

....

....

(2)
(Total 7 marks)

36 (a) When an atom of thorium-232 decays, an alpha (α) particle is emitted from the nucleus. An atom of radium is left behind.

An alpha particle consists of two protons and two neutrons.

We can represent this radioactive decay in a special kind of equation:

$$^{232}_{90}\mathrm{Th} \longrightarrow {}^{4}_{2}\mathrm{a} + {}^{228}_{88}\mathrm{Ra}$$

← number of nucleons (protons + neutrons)
← number of protons

Thorium-228 is also radioactive.

Atoms of this isotope also decay by emitting an alpha particle and producing an isotope of radium.

Complete the equation for this decay.

$$^{228}_{90}\mathrm{Th} \longrightarrow$$

(4)

(b) An atom of radium-228 decays by emitting a beta (β) particle from the nucleus.

A beta particle is in fact an electron (symbol $^{0}_{-1}\mathrm{e}$).

The effect of this is to change a neutron into a proton.

An atom of actinium remains.

This type of decay can also be represented by an equation:

$$^{228}_{88}\mathrm{Ra} \longrightarrow {}^{0}_{-1}\mathrm{e} + {}^{228}_{89}\mathrm{Ac}$$

← number of nucleons (protons + neutrons)
← number of protons

This isotope of actinium is radioactive.

An atom of actinium-228 also decays by emitting a beta particle.

An isotope of thorium is left behind.

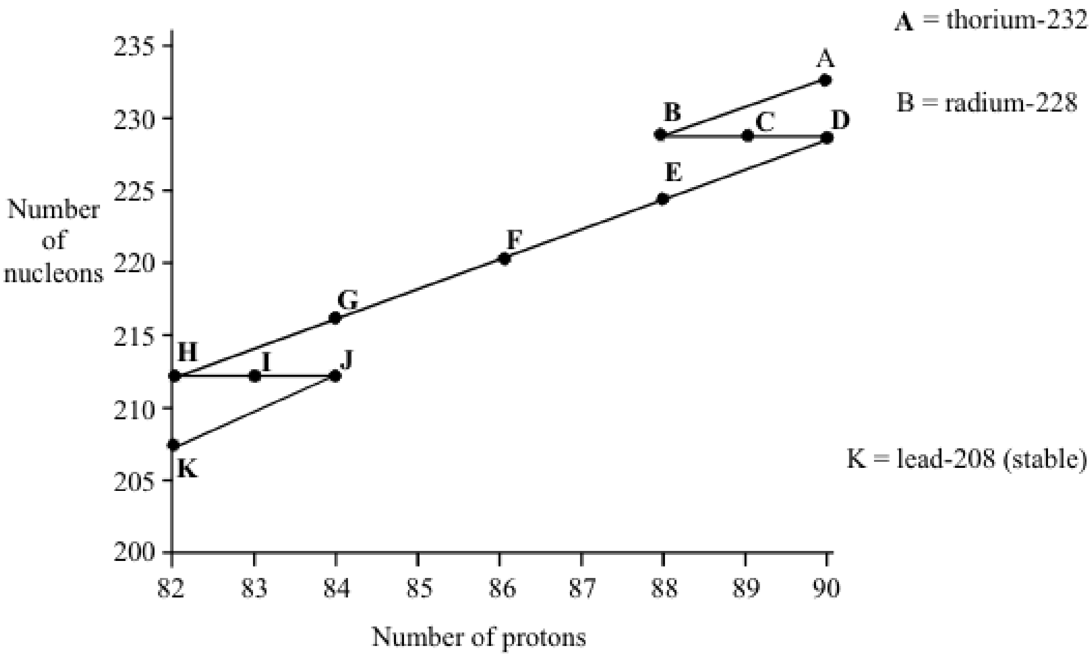
Complete the equation for this decay.

$^{228}_{89}\text{Ac} \longrightarrow$

(4)

(c) Thorium-232 eventually decays to the stable isotope lead-208.

All the steps in this process can be shown on a diagram.



(i) Complete the sentences:

During the decay from (A) to (B) a .... particle is emitted.

During the decay from (B) to (C) a .... particle is emitted.

During the decay from (E) to (F) a .... particle is emitted.

During the decay from (I) to (J) a .... particle is emitted.

(2)

(ii) The table shows how long it takes for half of the atoms of each isotope to decay.

ISOTOPE	TIME FOR HALF TO DECAY
A	billions of years
B	7 years
C	6 years
D	2 years
E	4 days
F	1 minute
G	0.4 seconds
H	10 hours
I	1 hour
J	0.3 microseconds

A rock sample contains:

- many atoms of thorium-232
- even more atoms of lead-208
- hardly any atoms of any of the other isotopes shown on the diagram

Explain this as fully as you can.

....

....

....

....

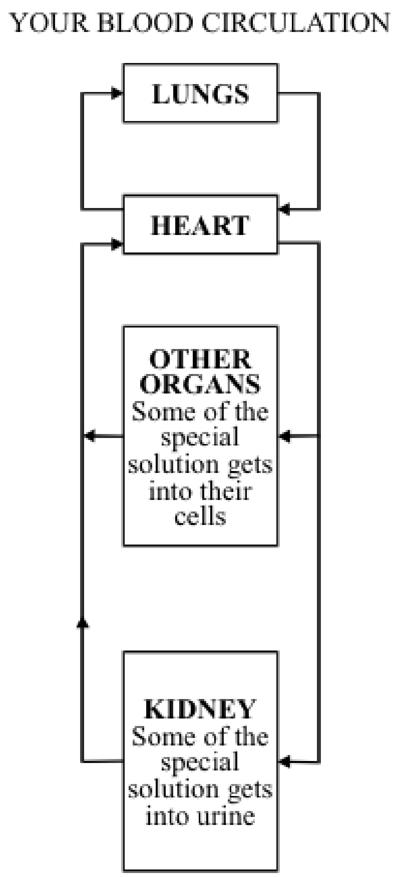
....

(3)
(Total 13 marks)

37 Doctors sometimes need to know how much blood a patient has.

They can find out by using a radioactive solution.

After measuring how radioactive a small syringe-full of the solution is they inject it into the patient's blood.



They then wait for 30 minutes so that the solution has time to become completely mixed into the blood.

Finally, they take a syringe-full of blood and measure how radioactive it is.

Example:

If the doctor injects 10 cm^3 of the radioactive solution and this is diluted 500 times by the blood there must be $10 \times 500 = 5000$ cm^3 of blood.

(a) After allowing for background radiation:

- $10\ cm^3$ of the radioactive solution gives a reading of 7350 counts per minute;
- a $10\ cm^3$ sample of blood gives a reading of 15 counts per minute.

Calculate the volume of the patient's blood.
(Show your working.)

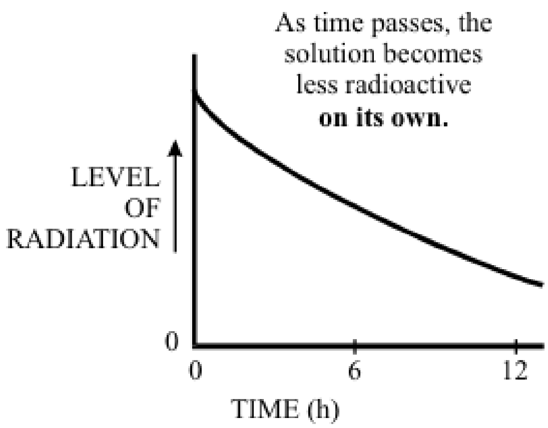
....

....

....

....

(4)



Radiation from radioactive substances can harm your body cells.

(b) The doctor's method of estimating blood volume will not be completely accurate.
Write down **three** reasons for this.

1 ....

2 ....

3 ....

(3)

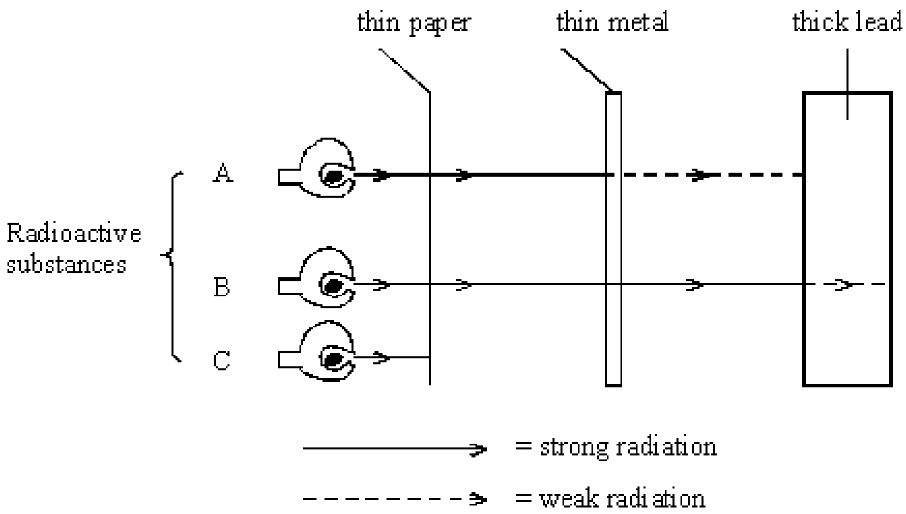
(c) The doctors use a radioactive substance which loses half of its radioactivity every six hours. Explain why this is a suitable radioactive substance to use.

....

....

(2)
(Total 9 marks)

38 The diagram shows what happens to the radiation from three radioactive substances when different materials are put in the way.



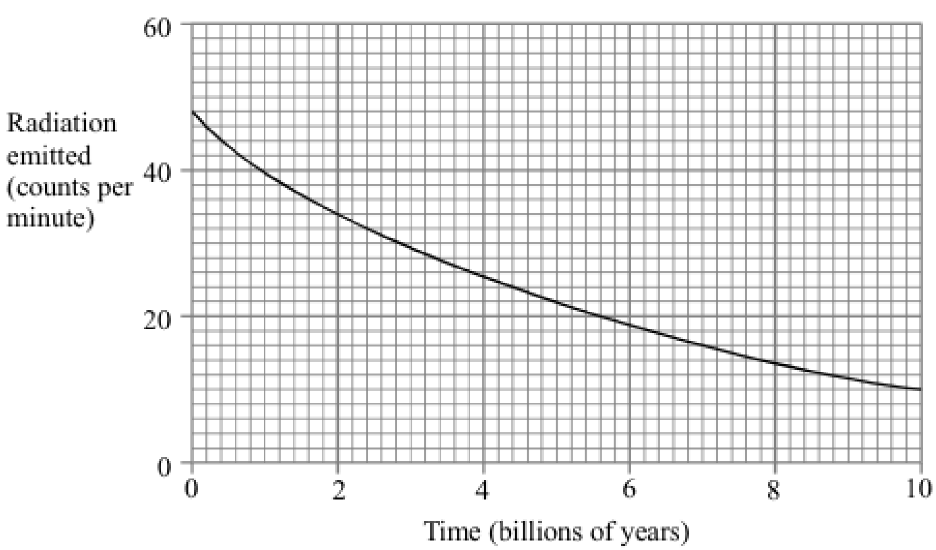
Choose types of radiation from this list to complete the table below.

α (**alpha**)   β (**beta**)   γ (**gamma**)   UV **(ultraviolet)**

RADIOACTIVE SUBSTANCE	TYPE OF RADIATION IT EMITS
A	
B	
C	

(Total 3 marks)

39 The graph shows how the amount of radiation emitted by a sample of the radionuclide uranium 238 (U^{238}) changes as time passes.



(a) What is the half-life of uranium 238 (U^{238})?
(You should show how you obtained your answer. You may do this on the graph if you wish.)

....

....

Answer ....

(3)

(b) What fraction (or percentage) of the uranium 238 (U^{238}) atoms will have decayed after 9 billion years?

....

(1)

(c) Uranium 238 (U^{238}) decays through a long series of intermediate radionuclides to stable atoms of the isotope lead 206 (Pb).

A sample of igneous rock contains 3 atoms of uranium 238 (U^{238}) for every atom of lead 206 (Pb^{206}).

(i) The intermediate radionuclides are not important when estimating the age of the rock. Explain why.

....

....

(1)

(ii) Estimate the age of the rock.
(You should explain how you obtained your answer.)

....

....

....

Answer .... billion years

(3)
(Total 8 marks)

40 When atoms of uranium 238 (U^{234}) decay they produce another radionuclide called thorium 234 (Th^{234})

Thorium 234 (Th^{234}) decays by emitting beta radiation.

(i) What does beta radiation consist of?

....

(1)

(ii) Thorium 234 (Th^{238}) decays to form protactinium 234 (Pa^{234}).

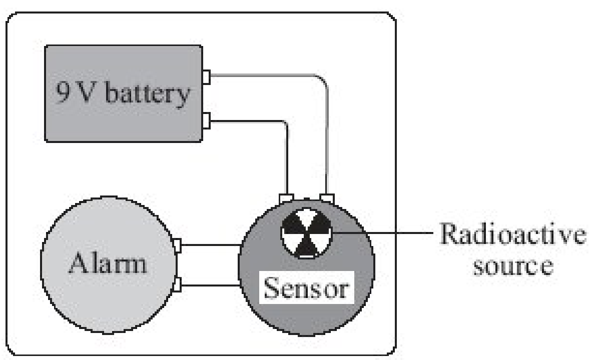
What differences are there between the nucleus of a protactinium 234 (Pa^{234}) atom and the nucleus of a thorium 234 (Th^{234}) atom?

....

....

(2)
(Total 3 marks)

41 (a) The diagram shows the parts of a smoke detector. The radioactive source emits alpha particles.



The alpha particles ionise the air inside the sensor which causes a small electric current. Any smoke getting into the sensor changes the current. The change in current sets the alarm off.

(i) The smoke detector would **not** work if a radioactive source that emitted only gamma rays was used.

Why not?

....

....

(1)

(ii) Curium-242 is a radioactive isotope with a half-life of 160 days. It emits alpha particles.

Why is curium-242 **not** suitable for use inside smoke detectors?

....

....

(1)

(iii) Curium-242 and curium-244 are two of the isotopes of the element curium.

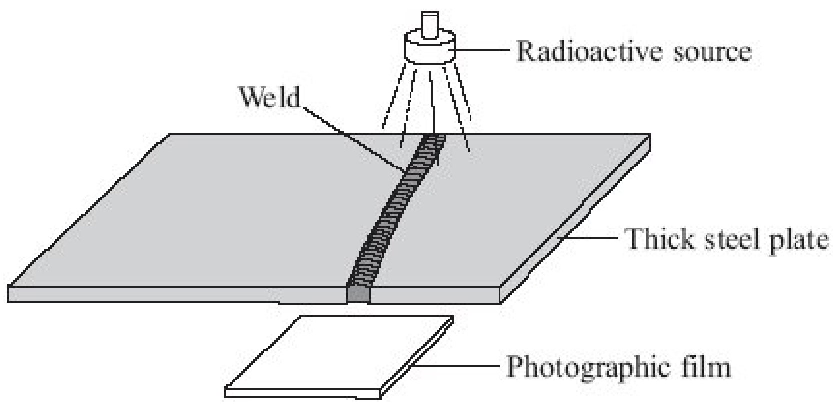
How is an atom of curium-242 different from an atom of curium-244?

....

....

(1)

(b) Sections of steel are often joined by welding them together. The diagram shows how a radioactive source can be used to check for tiny cracks in the weld.



Cracks in the weld will be shown up on the photographic film below the thick steel plate.

(i) Which type of source, alpha, beta or gamma, should be used to check the weld?

....

(1)

(ii) Give a reason why the other two types of source **cannot** be used.

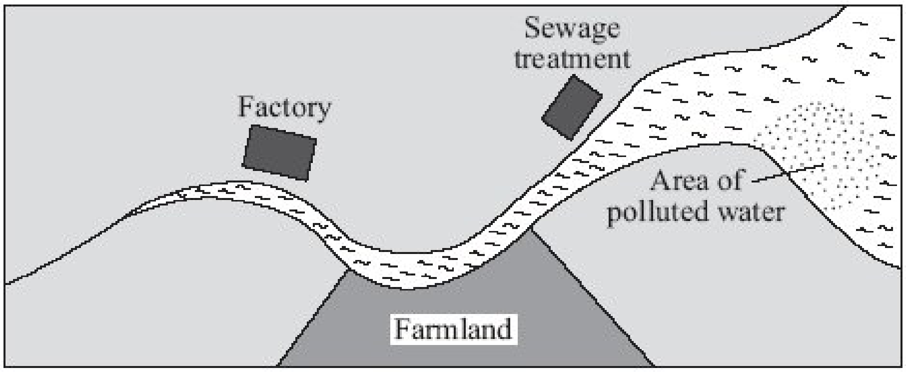
....

....

(1)

(c) The diagram shows a map of a river and its estuary.

Environmental scientists have found that the water flowing into one part of the river estuary is polluted. To find where the pollution is coming from, the scientists use a radioactive isotope, gold-198.



(i) Explain how the gold-198 is used to find where the pollution is coming from.

....

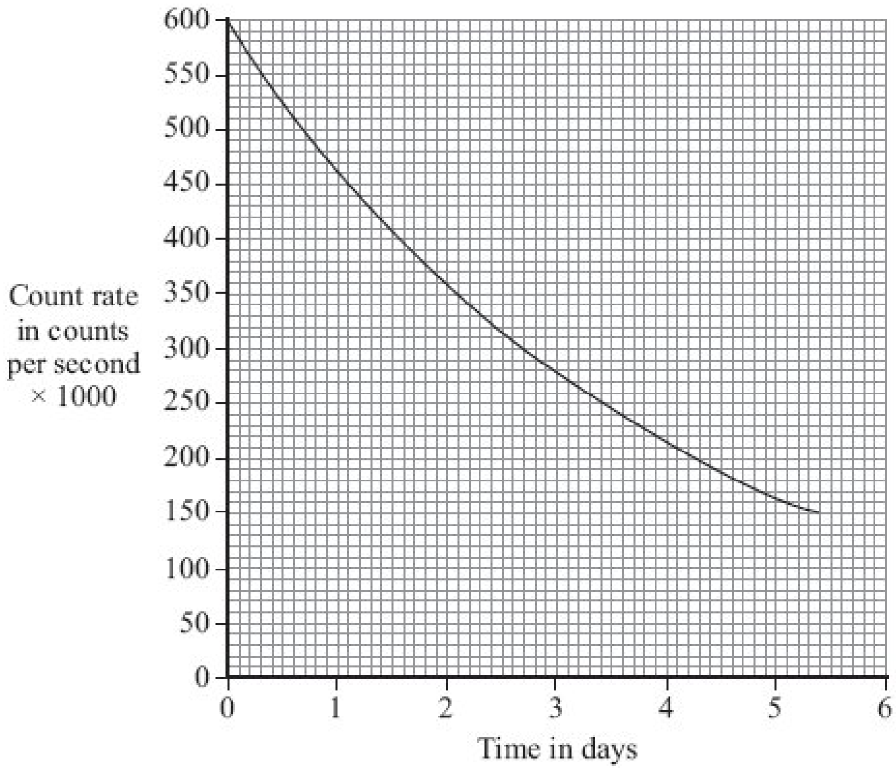
....

....

....

(2)

(ii) The graph shows how the count rate from a sample of gold-198 changes with time.



Use the graph to calculate the half-life of gold-198.

Show clearly on the graph how you obtain your answer.

....

....

Half-life = ... days

(2)
(Total 9 marks)

42 (a) The names of the three types of nuclear radiation are given in **List A**.
Some properties of these types of radiation are given in **List B**.

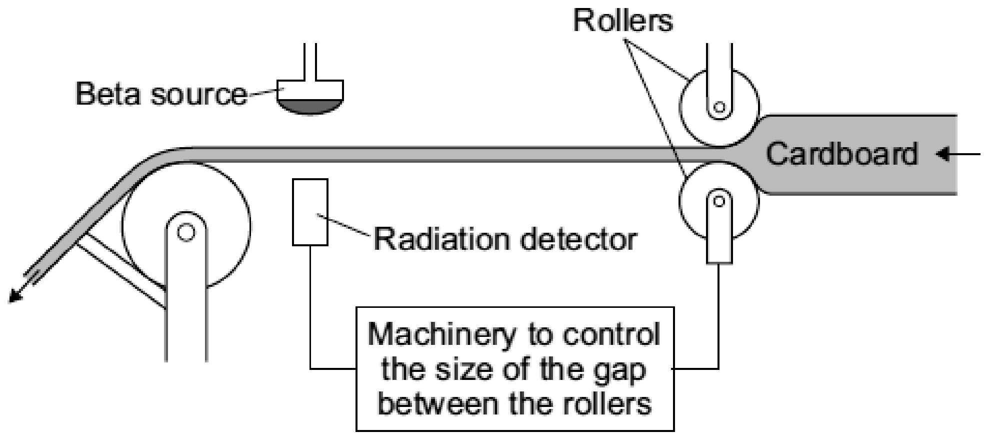
Draw a straight line to link each type of radiation in **List A** to its correct property in **List B**.

Draw only **three** lines.

List A **Type of nuclear radiation**	**List B** **Property of radiation**
	Has the same mass as an electron
Alpha	
	Very strongly ionising
Beta	
	Passes through 10 cm of aluminium
Gamma	
	Deflected by a magnetic field but not deflected by an electric field

(3)

(b) The diagram shows a system used to control the thickness of cardboard as it is made.



The cardboard passes through a narrow gap between a beta radiation source and a radiation detector.

The table gives the detector readings over 1 hour.

Time	Detector reading
08:00	150
08:15	148
08:30	151
08:45	101
09:00	149

(i) Between 08:00 and 08:30, the cardboard is produced at the usual, correct thickness.

Explain how you can tell from the detector readings that the cardboard produced at 08:45 is thicker than usual.

....

....

....

....

(2)

(ii) Which would be the most suitable half-life for the beta source?

Draw a ring around your answer.

six days **six months** **six years**

(1)

(iii) This control system would **not** work if the beta radiation source was replaced by an alpha radiation source.

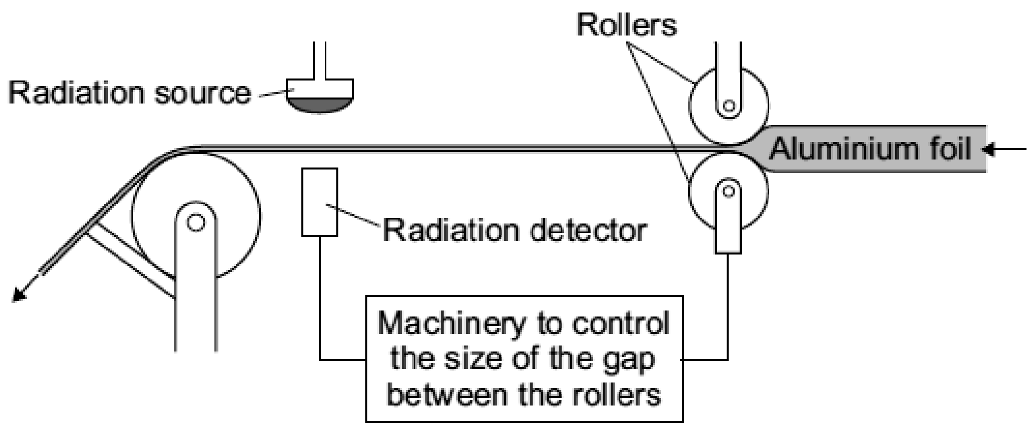
Why not?

....

....

(1)
(Total 7 marks)

43 The diagram shows a system used to control the thickness of aluminium foil as it is being rolled. A radiation source and detector are used to monitor the thickness of the foil.



(a) Which type of source, alpha, beta or gamma, should be used in this control system?

....

Explain why each of the other two types of source would **not** be suitable.

....

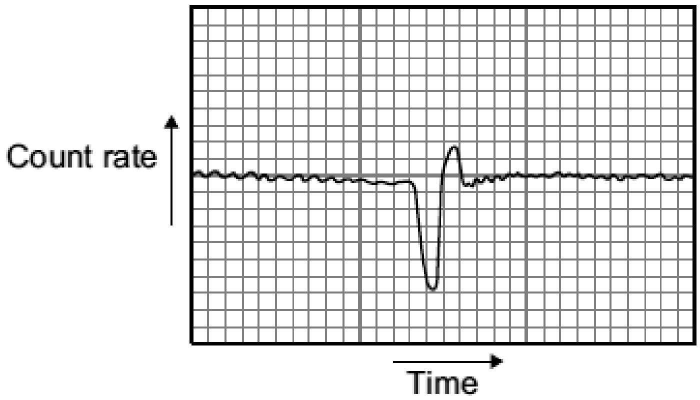
....

....

....

(3)

(b) The chart shows how the count rate recorded by the detector varies over a short period of time.



Use the graph to explain how the thickness of the foil changes, and how the control system responds to this change.

....

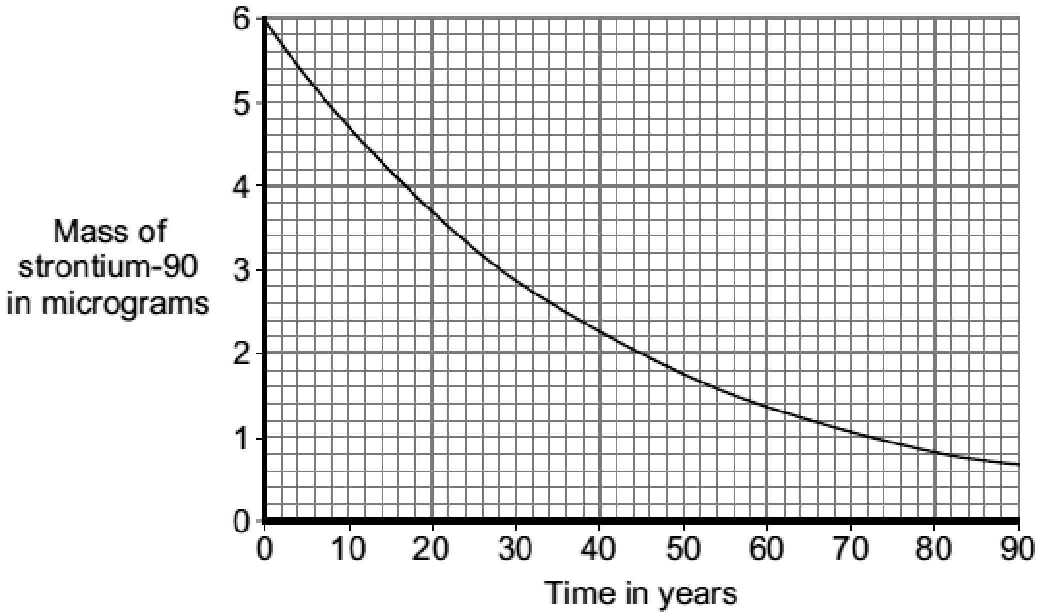
....

....

....

(2)

(c) When first used, the radiation source contains 6 micrograms of strontium-90.
The graph shows how the mass of the strontium-90 will decrease as the nuclei decay.



The control system will continue to work with the same source until 75 % of the original strontium-90 nuclei have decayed.

After how many years will the source need replacing?

Show clearly your calculation and how you use the graph to obtain your answer.

....

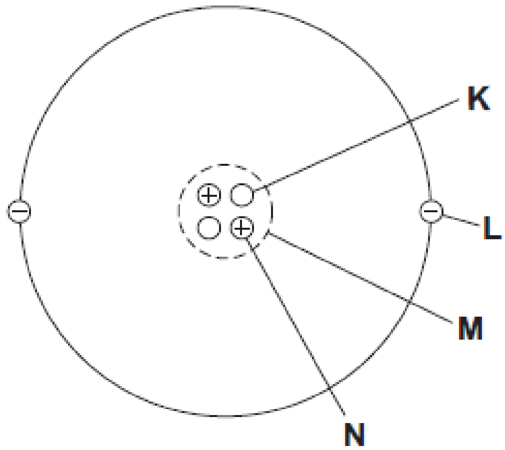
....

....

Number of years = ...

(2)
(Total 7 marks)

44 (a) The diagram represents a helium atom.



(i) Which part of the atom, **K**, **L**, **M** or **N**, is an electron?

Part ☐

(1)

(ii) Which part of the atom, **K**, **L**, **M** or **N**, is the same as an alpha particle?

Part ☐

(1)

(b) A radioactive source emits alpha particles.

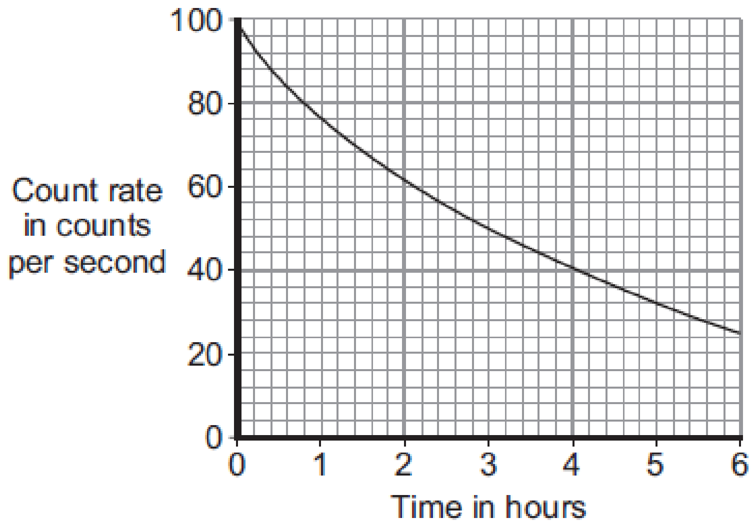
What might this source be used for?

Put a tick (✓) in the box next to your answer.

to monitor the thickness of aluminium foil as it is made in a factory	☐
to make a smoke detector work	☐
to inject into a person as a medical tracer	☐

(1)

(c) The graph shows how the count rate from a source of alpha radiation changes with time.



What is the count rate after 4 hours?

.... counts per second

(1)
(Total 4 marks)

45 (a) Carbon has three naturally occurring isotopes. The isotope, carbon-14, is radioactive. An atom of carbon-14 decays by emitting a beta particle.

(i) Complete the following sentences.

The atoms of the three carbon isotopes are the same as each other because

....

The atoms of the three carbon isotopes are different from each other because

....

(2)

(ii) What is a beta particle and from what part of an atom is it emitted?

....

....

(1)

(b) Carbon-14 is constantly being made in the atmosphere, yet for most of the last million years, the amount of carbon-14 in the atmosphere has not changed.

How is this possible?

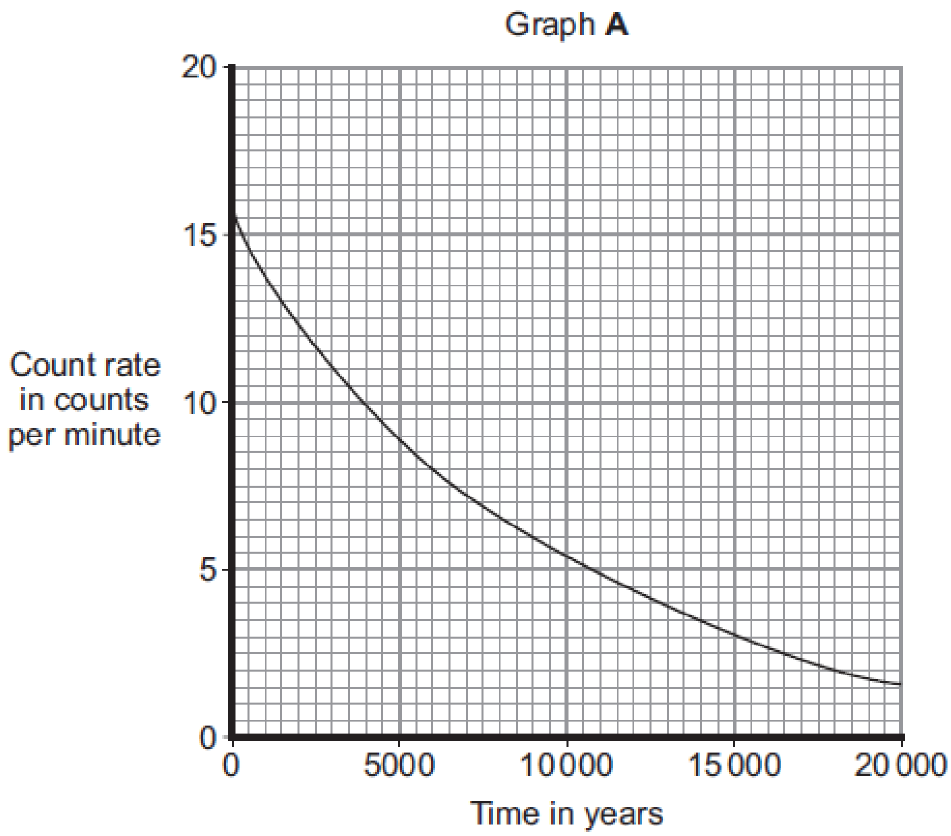
....

....

(1)

(c) Trees take in carbon-12 and carbon-14 from the atmosphere. After the tree dies, the proportion of carbon-14 that the tree contains decreases.

Graph **A** shows the decay curve for carbon-14.



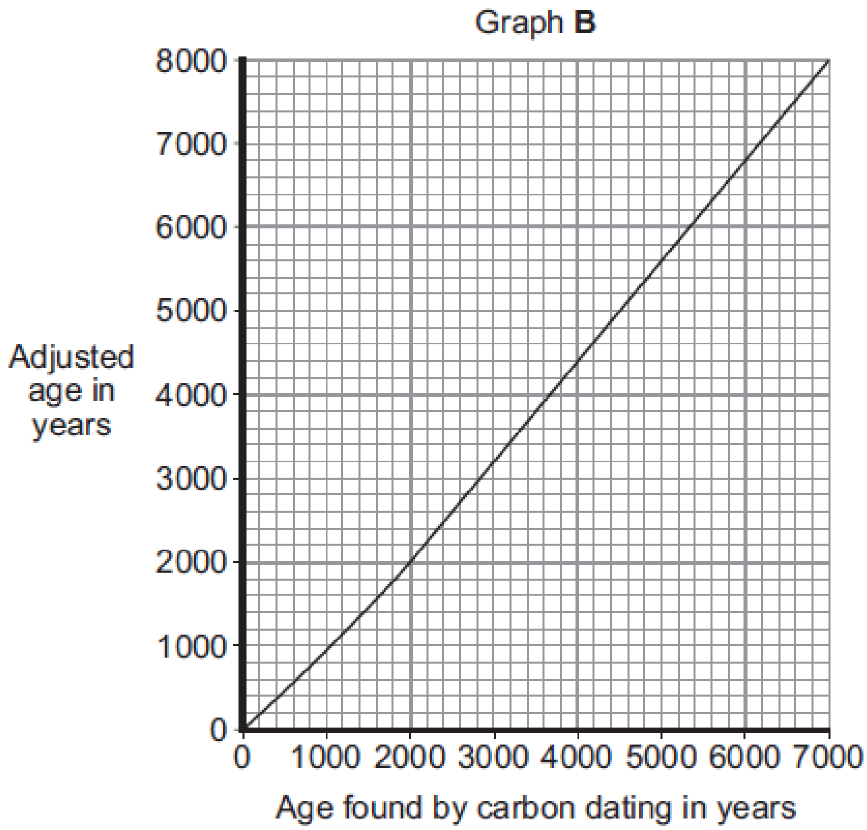
(i) Lake Cuicocha in Ecuador was formed after a volcanic eruption.
Carbon taken from a tree killed by the eruption was found to have a count rate of 10.5 counts per minute.
At the time of the eruption, the count rate would have been 16 counts per minute.

Use graph **A** to find the age of Lake Cuicocha.

Age of Lake Cuicocha = ... years

(1)

(ii) Finding the age of organic matter by measuring the proportion of carbon-14 that it contains is called carbon dating. This technique relies on the ratio of carbon-14 to carbon-12 in the atmosphere remaining constant. However, this ratio is not constant so the age found by carbon dating needs to be adjusted.



Graph **B** is used to adjust the age of an object found by carbon dating.
The value obtained from graph **B** will be no more than 50 years different to the true age of the object.

Use graph **B** and the information above to find the maximum age that Lake Cuicocha could be.

Show clearly how you obtain your answer.

....

....

Maximum age of Lake Cuicocha = ... years

(2)
(Total 7 marks)

46 Some rocks inside the Earth contain a radioactive element, uranium-238. When an atom of uranium-238 decays, it gives out an alpha particle.

(a) The following statement about alpha particles was written by a student.
The statement is **not** correct.

Alpha particles can pass through a very thin sheet of lead.

Change **one** word in the statement to make it correct.

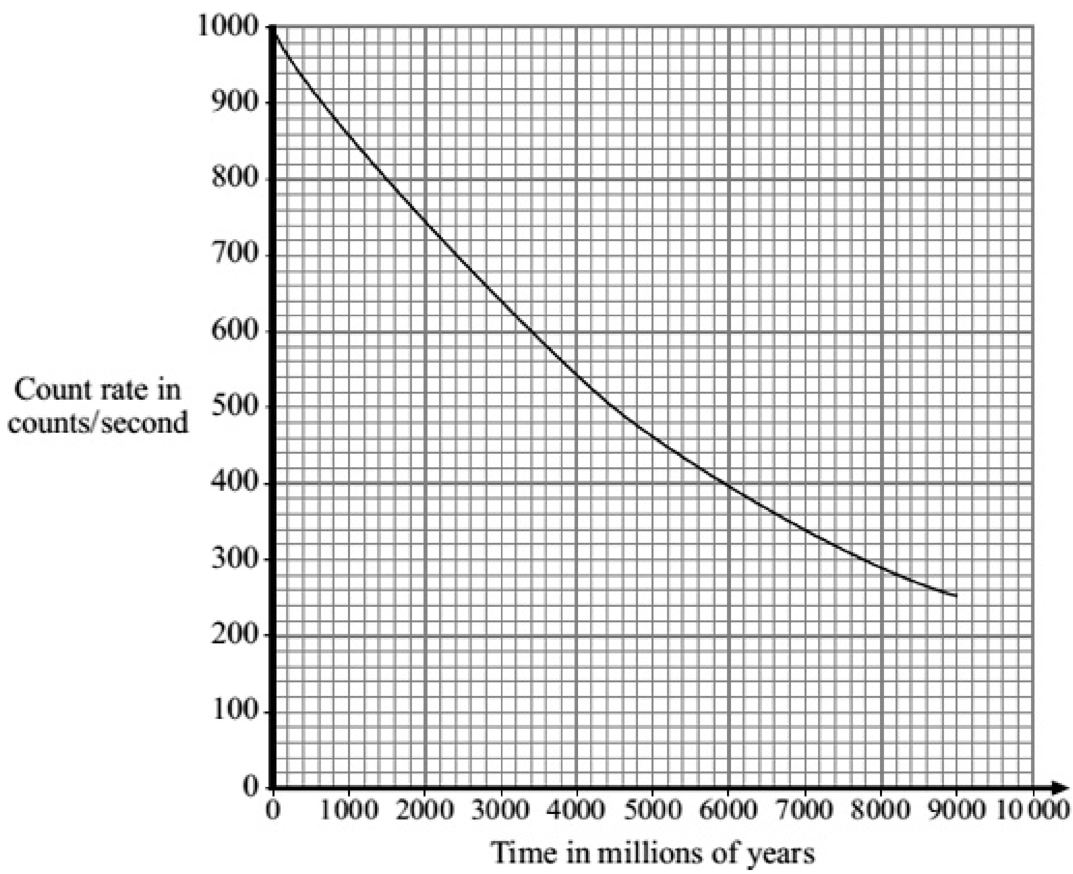
Write down your **new** statement.

....

....

(1)

(b) The graph shows how the count rate from a sample of uranium-238 changes with time.



The graph can be used to find the half-life of uranium-238. The half-life is 4 500 million years.

(i) Draw on the graph to show how it can be used to find the half-life of uranium -238.

(1)

(ii) There is now half as much uranium-238 in the rocks as there was when the Earth was formed.

How old is the Earth?

Draw a ring around your answer.

2250 million years **4500 million years** **9000 million years**

(1)

(iii) If a sample of uranium-238 were available, it would not be possible to measure the half-life in a school experiment.

Explain why.

....

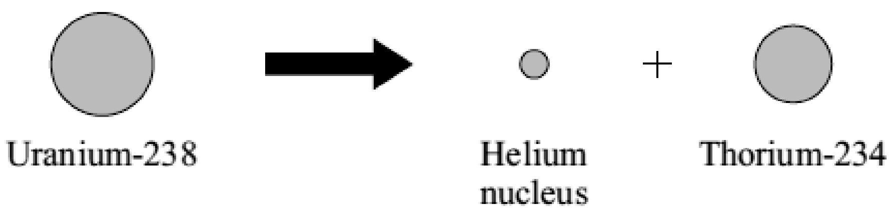
....

....

....

(2)
(Total 5 marks)

47 (a) Some rocks inside the Earth contain uranium-238, a radioactive isotope of uranium. When an atom of uranium-238 decays, it gives out radiation and changes into a thorium-234 atom.



(i) What type of radiation is emitted when a uranium-238 atom decays?

....

(1)

(ii) From which part of a uranium-238 atom is the radiation emitted?

....

(1)

(iii) Uranium-235 is another isotope of uranium.

How is an atom of uranium-235 similar to an atom of uranium-238?

....

(1)

(b) Uranium-238 has a half-life of 4500 million years.

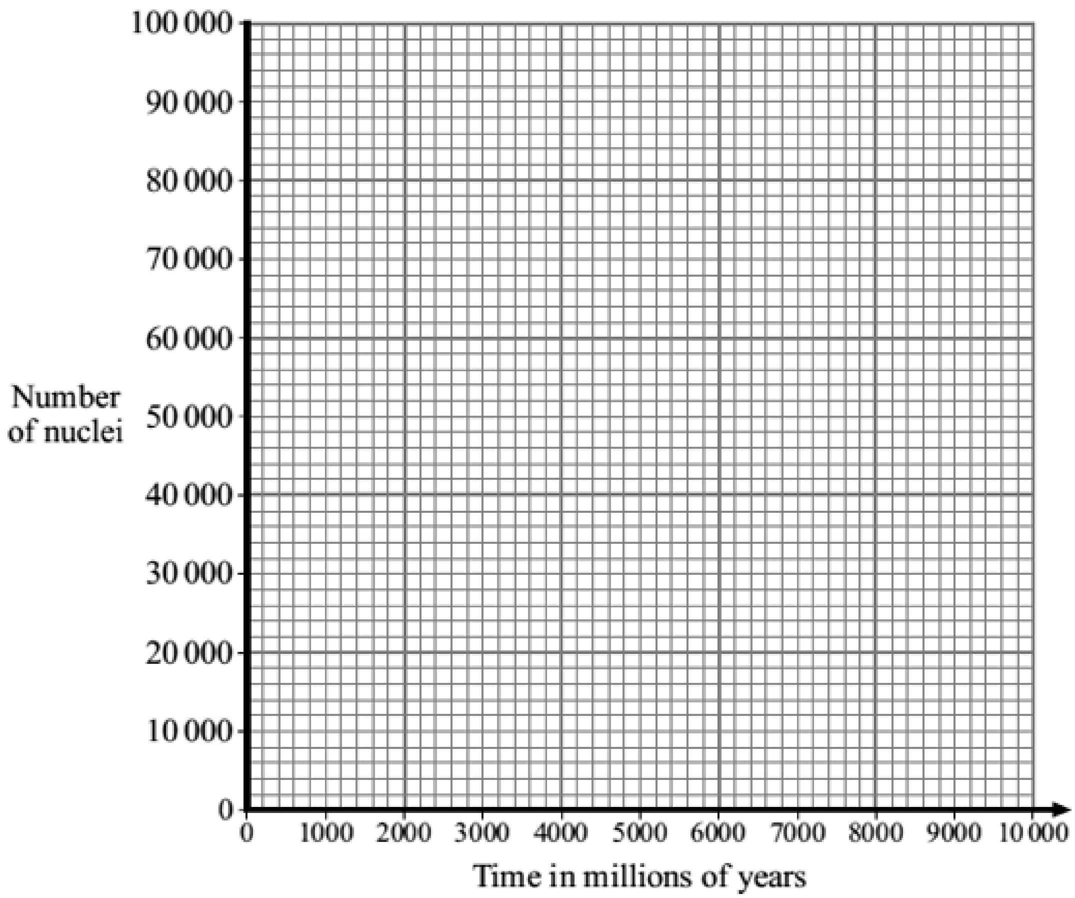
(i) When the Earth was formed, there was twice as much uranium-238 in the rocks as there is now.

What is the age of the Earth?

....

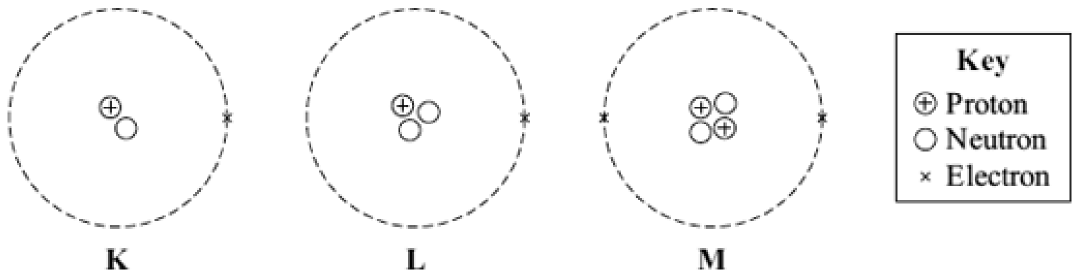
(1)

(ii) Complete the graph to show how the number of nuclei in a sample of uranium-238 will change with time.
Initially, there were 100 000 nuclei in the sample.



(2)
(Total 6 marks)

48 (a) The diagram represents 3 atoms, **K**, **L** and **M**.



(i) Which **two** of the atoms are isotopes of the same element?

.... and ....

(1)

(ii) Give a reason why the **two** atoms that you chose in part (a)(i) are:

(1) atoms of the same element ....

....

(2) different isotopes of the same element. ....

....

....

(2)

(b) The table gives some information about the radioactive isotope thorium-230.

mass number	230
atomic number	90

(i) How many electrons are there in an atom of thorium-230?

....

(1)

(ii) How many neutrons are there in an atom of thorium-230?

....

(1)

(c) When a thorium-230 nucleus decays, it emits radiation and changes into radium-226.

$$ {}^{230}_{90}\text{Th} \longrightarrow {}^{226}_{88}\text{Ra} + \boxed{\text{Radiation}} $$

What type of radiation, alpha, beta or gamma, is emitted by thorium-230?

....

Explain the reason for your answer.

....

....

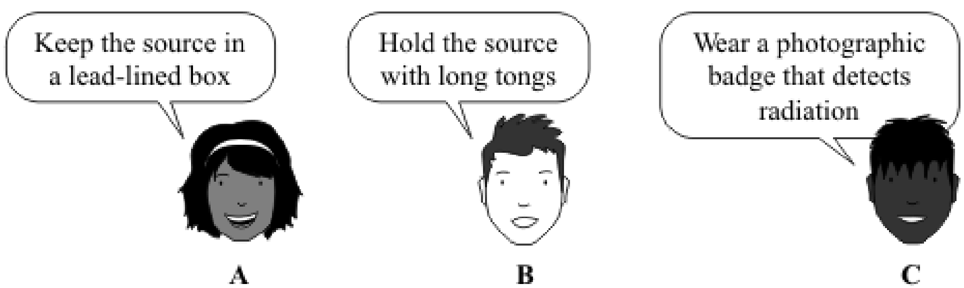
....

....

....

(3)
(Total 8 marks)

49 Before using a radioactive source, a teacher asked her students to suggest safety procedures that would reduce her exposure to the radiation. The students made the following

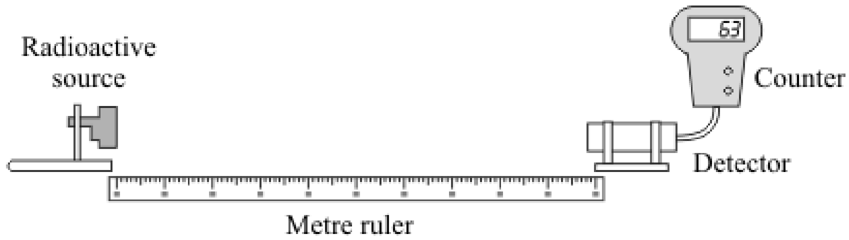


(a) Which suggestion, **A**, **B** or **C**, would **not** reduce the exposure of the teacher to radiation?

....

(1)

(b) The diagram shows how the teacher measured the distance that the radiation traveled from the source. The count-rate at different distances from the source was measured and recorded in the table.



Distance from source to detector in cm	Count-rate in counts per minute
20	85
40	81
60	58
80	53
100	23

What type of radiation was the source emitting, alpha, beta or gamma?

....

Explain the reasons for your choice.

....

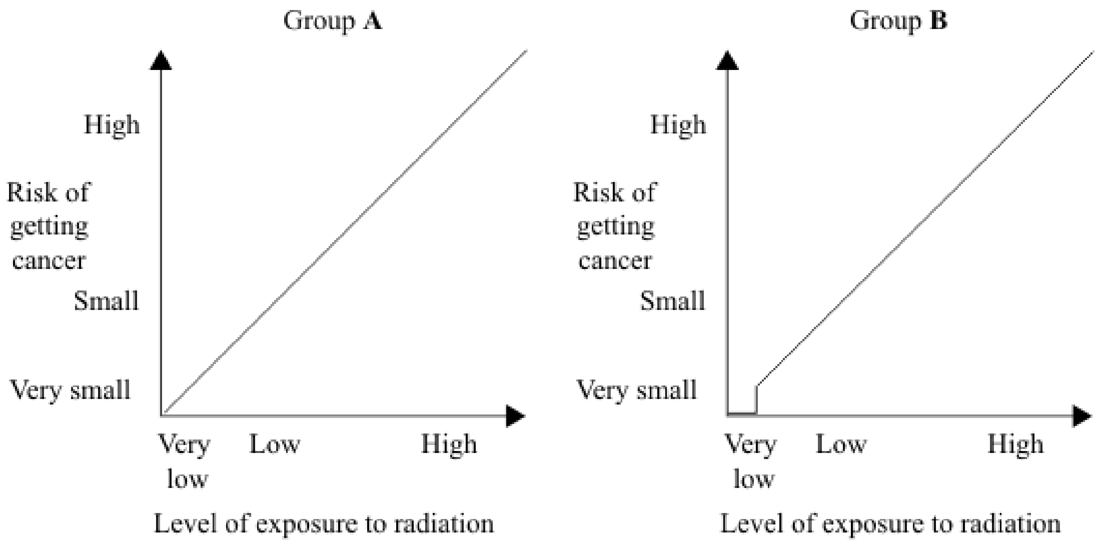
....

....

....

(3)

(c) The graphs show how two groups of scientists, **A** and **B**, link exposure to radiation and the risk of getting cancer.



(i) Complete the following sentence using a word or phrase from the box.

decreases	**has no effect on**	**increases**

Both groups of scientists agree that a high level of exposure to radiation

.... the risk of getting cancer.

(1)

(ii) Use the graphs to describe carefully how the two groups of scientists disagree when the level of exposure to radiation is very low.

....

....

....

....

(2)
(Total 7 marks)

50 Most elements have some *isotopes* which are *radioactive*.

(a) What is meant by the terms:

(i) *isotopes*

....

....

(1)

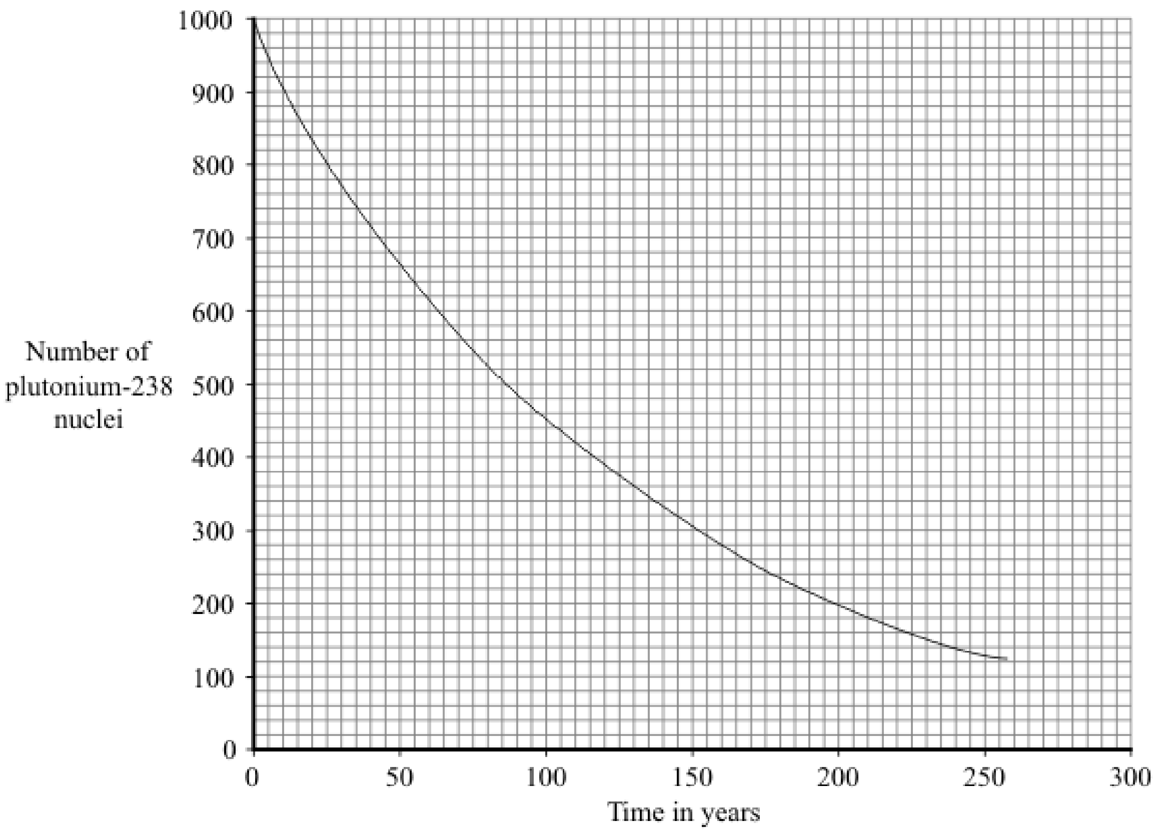
(ii) *radioactive*?

....

....

(1)

(b) The graph shows how the number of nuclei in a sample of the radioactive isotope plutonium-238 changes with time.



Use the graph to find the half-life of plutonium-238.

Show clearly on the graph how you obtain your answer.

Half-life = ... years

(2)

(c) The Cassini spacecraft launched in 1997 took seven years to reach Saturn.

The electricity to power the instruments on board the spacecraft is generated using the heat produced from the decay of plutonium-238.

(i) Plutonium-238 decays by emitting alpha particles.

What is an alpha particle?

....

(1)

(ii) During the 11 years that Cassini will orbit Saturn, the output from the generators will decrease.

Explain why.

....

....

....

....

(2)

(d) Plutonium-238 is highly dangerous. A tiny amount taken into the body is enough to kill a human.

(i) Plutonium-238 is unlikely to cause any harm if it is outside the body but is likely to kill if it is inside the body.

Explain why.

....

....

....

....

(2)

(ii) In 1964, a satellite powered by plutonium-238 was destroyed, causing the release of radioactive material into the atmosphere.

Suggest why some environmental groups protested about the launch of Cassini.

....

....

(1)
(Total 10 marks)

51 (a) Complete the following table for an atom of uranium-238 ($^{238}_{92}U$)

mass number	238
number of protons	92
number of neutrons	

(1)

(b) Complete the following sentence.

The name given to the number of protons in an atom is the proton number or the

....

(1)

(c) An atom of uranium-238 ($^{238}_{92}U$) decays to form an atom of thorium-234 ($^{234}_{90}Th$).

(i) What type of radiation, alpha, beta or gamma, is emitted by uranium-238?

....

(1)

(ii) Why does an atom that decays by emitting alpha or beta radiation become an atom of a different element?

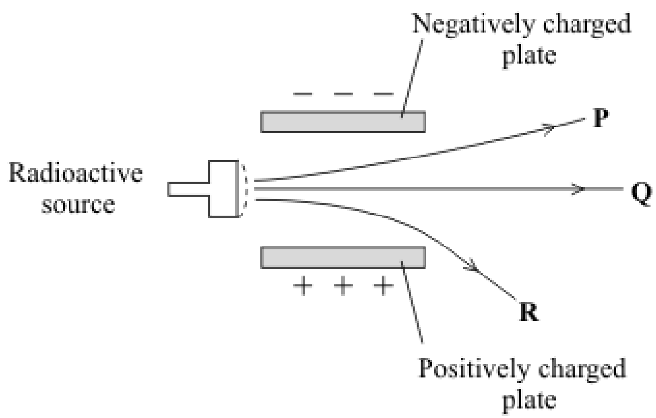
....

....

(1)
(Total 4 marks)

52 A radioactive source emits alpha (α), beta (β) and gamma (γ) radiation. The diagram shows what happens to the radiation as it passes between two charged metal plates.

Diagram 1

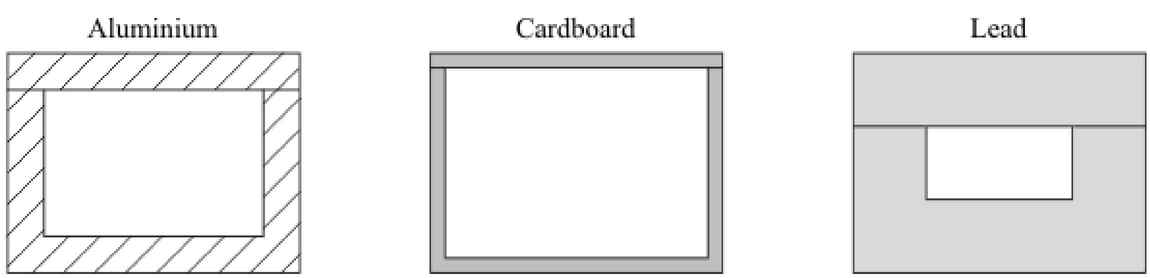


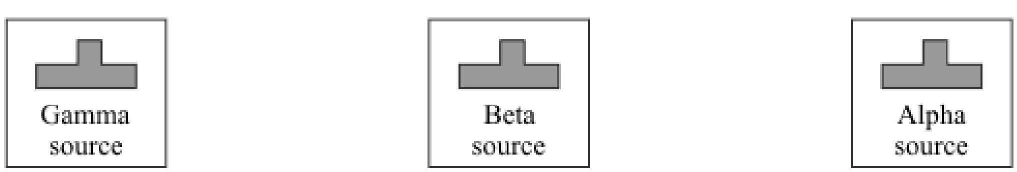
(a) Which line **P**, **Q** or **R** shows the path taken by:

(i) alpha radiation ....
(1)

(ii) gamma radiation? ....
(1)

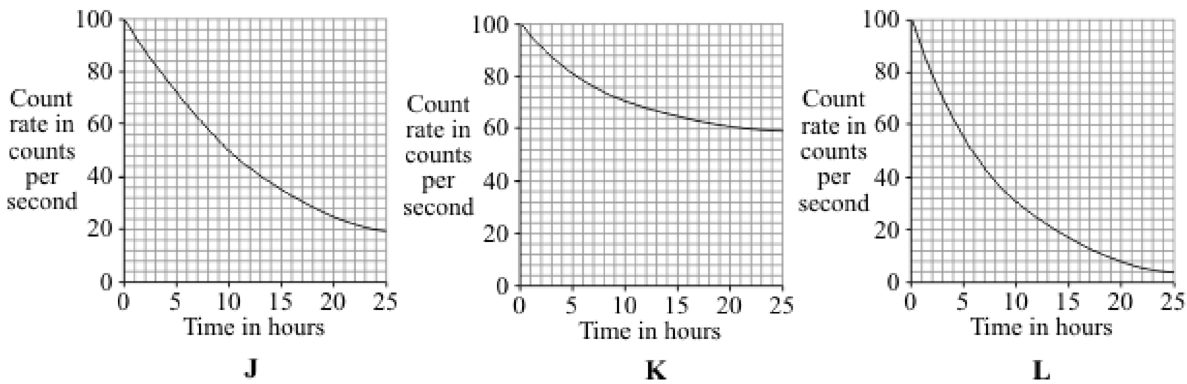
(b) The diagram shows three different boxes and three radioactive sources. Each source emits only one type of radiation and is stored in a different box. The box reduces the amount of radiation getting into the air.





Draw **three** lines to show which source should be stored in which box so that the minimum amount of radiation gets into the air.
(2)

(c) The graphs show how the count rates from three different radioactive sources, **J**, **K**, and **L**, change with time.



(i) Which source, **J, K**, or **L**, has the highest count rate after 24 hours?

....
(1)

(ii) For source **L**, what is the count rate after 5 hours?

.... counts per second
(1)

(iii) Which source, **J, K,** or **L**, has the longest half-life?

....
(1)

(iv) A radioactive source has a half-life of 6 hours.

What might this source be used for?

Put a tick (✓) in the box next to your choice.

To monitor the thickness of paper as it is made in a factory ☐

To inject into a person as a medical tracer ☐

To make a smoke alarm work ☐

(1)
(Total 8 marks)

IGCSE Physics CIE

5. Nuclear Physics

YOUR NOTES
↓

CONTENTS

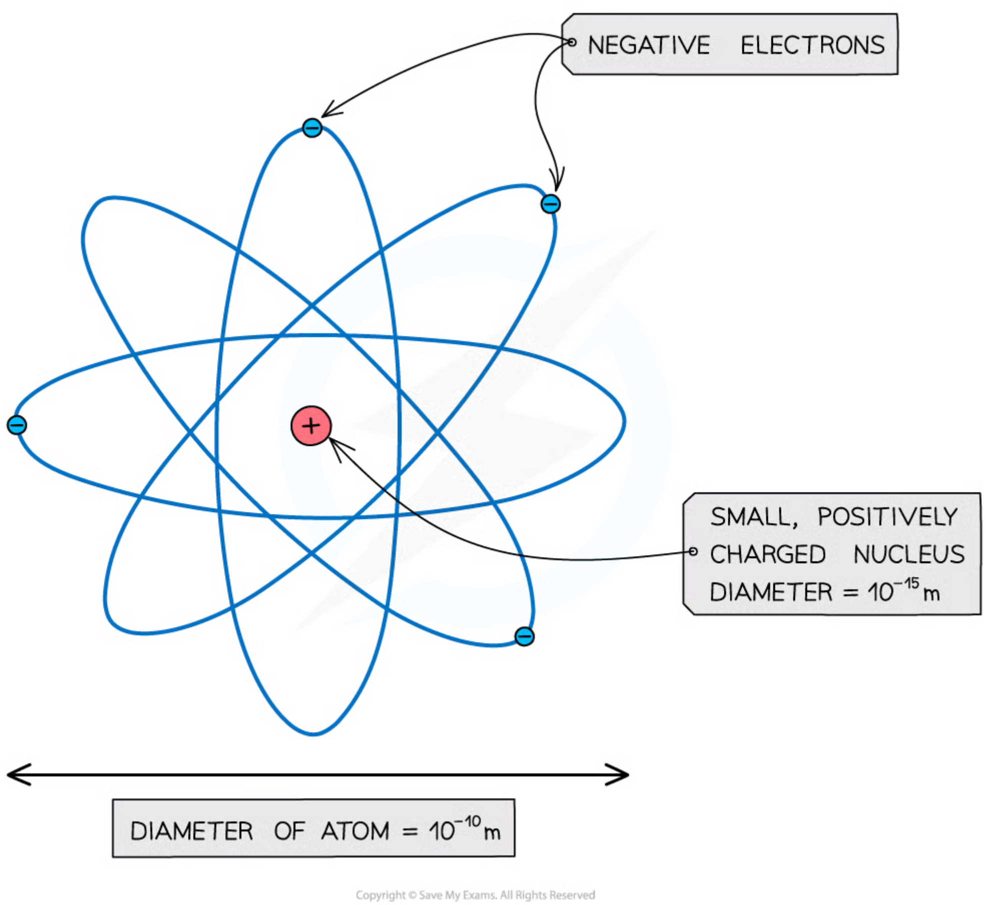
YOUR NOTES
⬇

5.1 The Nuclear Model of the Atom

5.1.1 The Atom

Atomic Structure

- Atoms are the building blocks of **all matter**
- They are incredibly small, with a radius of only 1×10^{-10} m
  - This means that about one hundred million atoms could fit side by side across your thumbnail
- Atoms have a tiny, dense **nucleus** at their centre, with **electrons** orbiting around the nucleus
- The radius of the nucleus is over 10,000 times smaller than the whole atom, but it contains almost **all of the mass** of the atom
- They consist of small dense **positively** charged nuclei, surrounded by **negatively** charged electrons



An atom: a small positive nucleus, surrounded by negative electrons

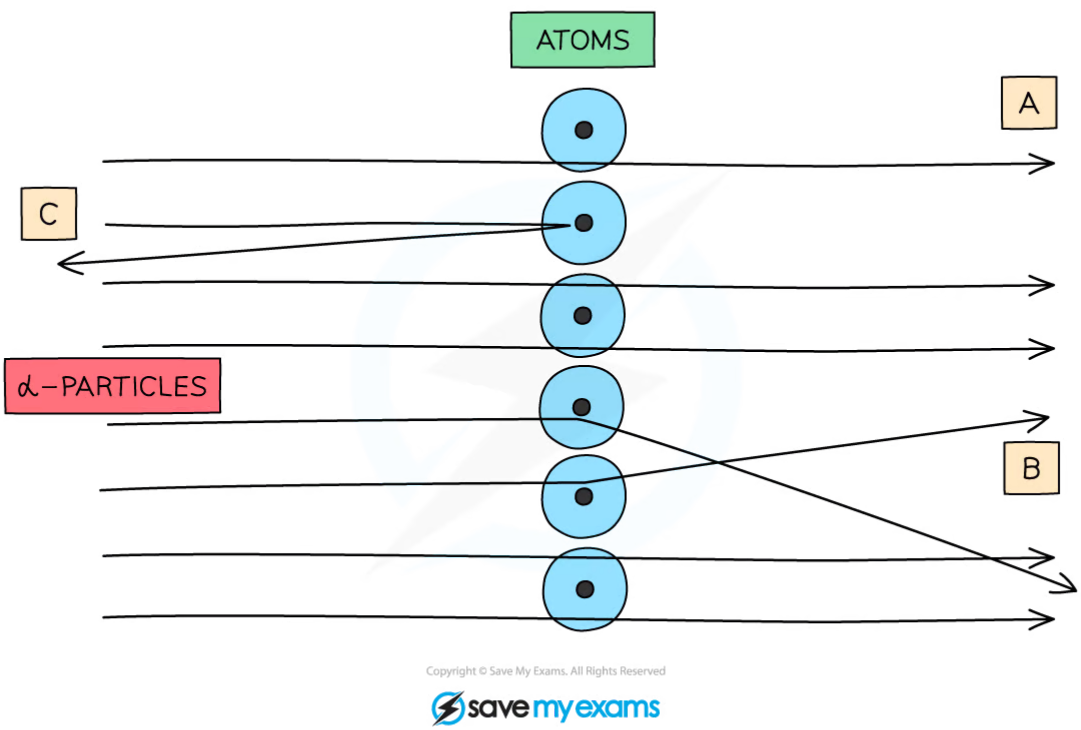
(Note: the atom is around 100,000 times larger than the nucleus!)

Rutherford's Experiment

YOUR NOTES
↓

EXTENDED

- In 1909 a group of scientists were investigating the Plum Pudding model
  - Physicist, **Ernest Rutherford** was instructing two of his students, Hans Geiger and Ernest Marsden to carry out the experiment
- This involved the scattering of alpha (α) particles by a sheet of thin metal supports the nuclear model of the atom
- A beam of **alpha particles** (He^{2+} ions) were directed at a thin gold foil
- They expected the alpha particles to travel through the gold foil, and maybe change direction a small amount
- Instead, they discovered that :
  - Most of the alpha particles **passed straight through** the foil
  - Some of the alpha particles **changed direction** but continued through the foil
  - A few of the alpha particles **bounced back** off the gold foil
- The bouncing back could not be explained by the Plum Pudding model, so a new model had to be created
  - This was the first evidence of the structure of the atom



When α-particles are fired at thin gold foil, most of them go straight through but a very small number bounce straight back

- When α-particles are fired at thin pieces of gold foil:
  - **The majority of them go straight through (A)**

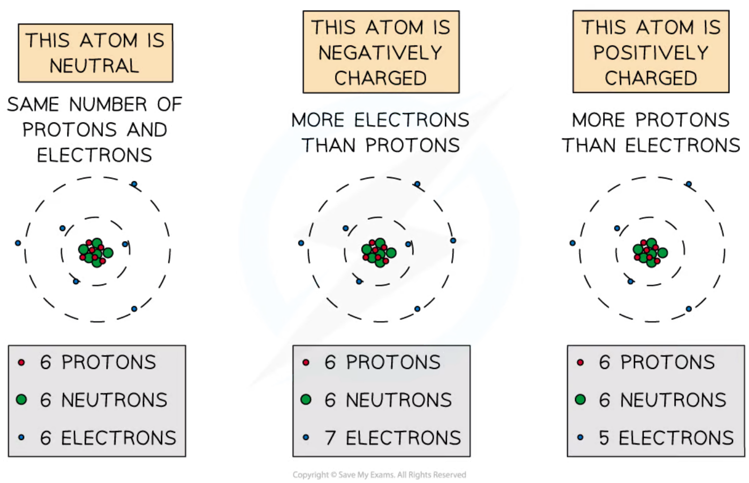
YOUR NOTES
⬇

This happens because the atom is mainly empty space

- **Some are deflected through small angles (B)**
  This happens because the positive α-particles are repelled by the positive nucleus which contains most of its mass
- **A very small number are deflected straight back (C)**
  This is because the nucleus is extremely small

Atoms & Ions

- An ion is an **electrically charged** atom or group of atoms formed by the **loss** or **gain** of **electrons**
  - An atom will lose or gain electrons to become more stable
- A stable atom is normally electrically neutral
  - This means it has the same number of protons (positive charge) and electrons (negative charge)
- Positive ions are therefore formed when atoms **lose** electrons
  - There will be more protons than electrons
- Negative ions are therefore formed when atoms **gain** electrons
  - There will be more electrons than protons



The difference between positive and negative ions

Exam Tip

You may hear the term 'net charge'. This just means the 'overall' charge of the atom. If an atom has 5 protons, 5 neutrons and 6 electrons, it has a **net** negative charge because it's a negative ion (more electrons than protons).

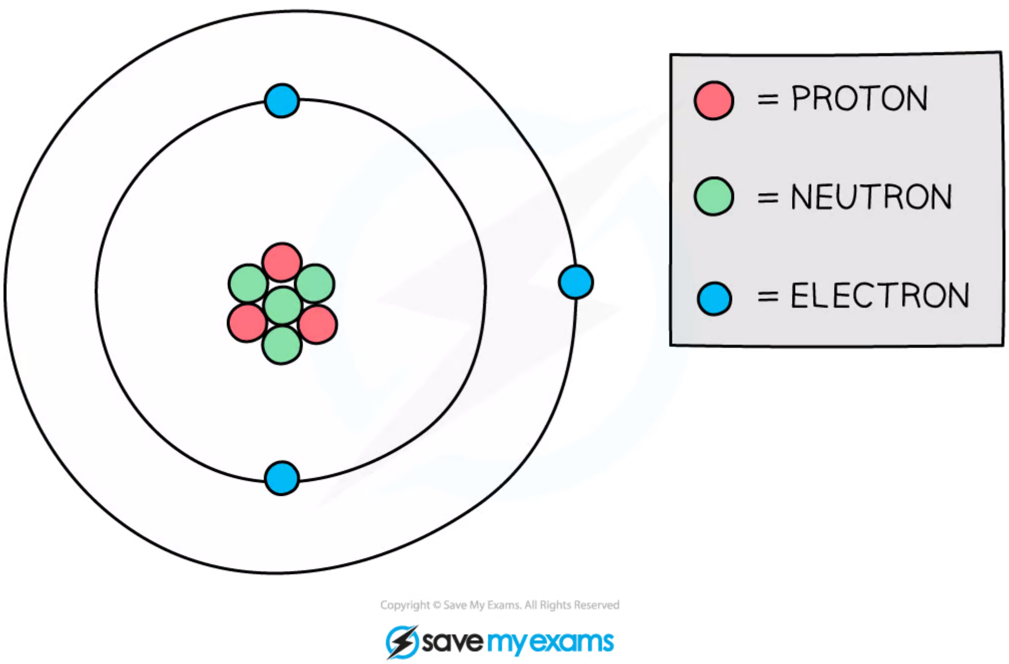
Remember which way around the charges are by **p**roton being **p**ositive.

5.1.2 The Nucleus

YOUR NOTES ↓

Composition of the Nucleus

- The structure of the atom is made up of a:
  - **Positively** charged nucleus at the centre (made up protons and neutrons)
  - **Negatively** charged electrons in orbit around the nucleus



Protons and neutrons are found in the nucleus of an atom

- Protons have a positive charge, whilst neutrons have no charge
  - This is why the nucleus is overall positive

Exam Tip

Be careful with your terminology:

- Atom = nucleus (proton and neutron) **and** electrons
- Nucleus = protons and neutrons at the centre of the atom

YOUR NOTES
⬇

Describing the Nucleus

Define the terms proton number (atomic number) Z and nucleon number (mass number) A and be able to calculate the number of neutrons in a nucleus

Proton Number, Z

- The number of protons in an atom is called its proton number (it can also be called the atomic number)
  - Elements in the periodic table are ordered by their atomic number
  - Therefore, the number of protons determines which element an atom is
- The atomic number of a particular element is always the same
- For example:
  - Hydrogen has an atomic number of 1. It always has just one proton
  - Sodium has an atomic number of 11. It has 11 protons
  - Uranium has an atomic number of 92. It has 92 protons
- The atomic number is also equal to the number of electrons in an atom
  - This is because atoms have the same number of electrons and protons in order to have no overall charge

Nucleon Number, A

- The total number of particles in the nucleus of an atom is called its **nucleon number** (or **mass** number)
- The mass number is the number of protons **and** neutrons in the atom
- The number of neutrons can be found by **subtracting** the **atomic** number from the **mass** number

Number of Neutrons = Nucleon Number – Proton Number

- For example, if a sodium atom has a mass number of 23 and an atomic number of 11, then the number of neutrons would be 23 – 11 = 12

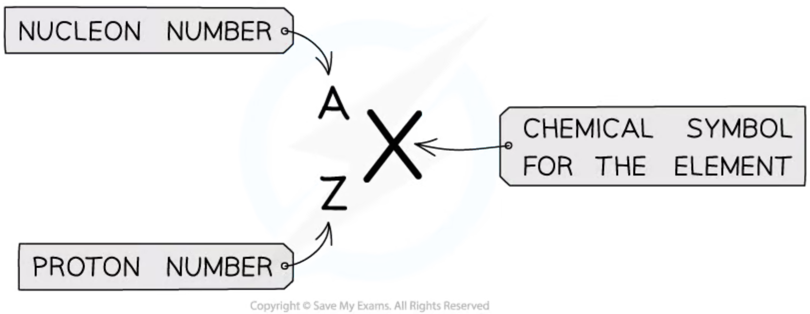
Exam Tip

You may have noticed that the number of electrons is not part of the mass number. This is because electrons have a **tiny** mass compared to neutrons and protons. We say their mass is negligible when compared to the particles in the nucleus.

Nuclide Notation

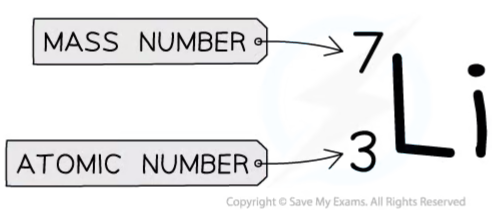
YOUR NOTES
↓

- A nuclide is a group of atoms containing the same number of protons and neutrons
  - For example, 5 atoms of oxygen are all the same nuclide but are 5 separate atoms
- Atomic symbols are written in a specific notation called **nuclide** or **ZXA notation**



Atomic symbols in AZX Notation describe the constituents of nuclei

- The top number A represents the **nucleon** number or the **mass** number
  - **Nucleon number (A)** = total number of **protons and neutrons** in the nucleus
- The lower number Z represents the **proton** or **atomic** number
  - **Proton number (Z)** = total number of **protons** in the nucleus
- Note: In Chemistry, the nucleon number is referred to as the mass number and the proton number as the atomic number. The periodic table is ordered by atomic number
- An example of an atomic symbol is:



Atomic symbols, like the one above, describe the constituents of nuclei

- When given an atomic symbol, you can figure out the total number of protons, neutrons and electrons in the atom:
  - **Protons:** The number of protons is equal to the proton number
  - **Electrons**: Atoms are neutral, and so in a neutral atom the number of negative electrons must be equal to the number of positive protons
  - **Neutrons**: The number of neutrons can be found by subtracting the proton number from the nucleon number
- The term **nucleon** is used to mean a particle in the nucleus – ie. either a proton or a neutron
- The term **nuclide** is used to refer to a nucleus with a specific combination of protons and neutrons

Worked Example

The element symbol for gold is Au. How many protons, neutrons and electrons are in the gold atom?

$$^{197}_{79}\text{Au}$$

	Protons	Neutrons	Electrons
A	79	79	79
B	197	79	118
C	118	118	79
D	79	118	79

ANSWER: D

Step 1: Determine the atomic and mass number

- The gold atom has an atomic number of 79 (lower number) and a mass number of 197 (top number)

Step 2: Determine the number of protons

- The **atomic** number is equal to the number of **protons**
- The atom has 79 protons

Step 3: Calculate the number of neutrons

- The mass number is equal to the number of protons and neutrons
- The number of neutrons is equal to the mass number minus the atomic number

$$197 - 79 = 118$$

- The atom has 118 neutrons

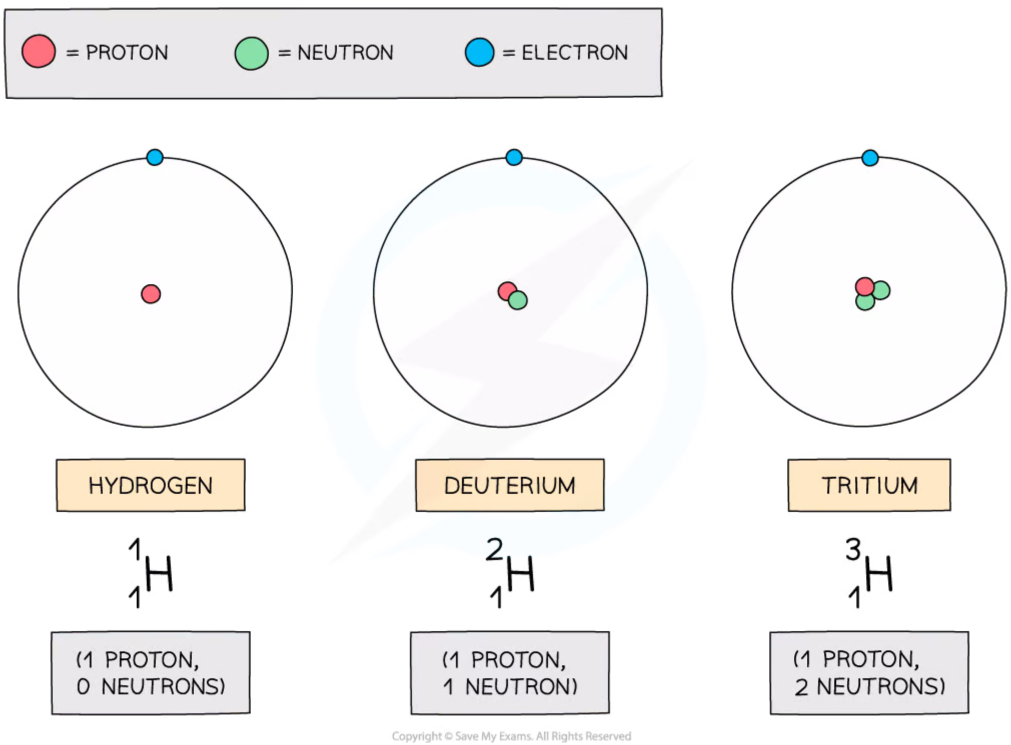
Step 4: Determine the number of electrons

- An atom has the **same** number of **protons and electrons**
- The atom has 79 electrons

YOUR NOTES
⬇

Isotopes

- Although the number of protons in a particular element is always the same, the number of **neutrons** can be different
- **Isotopes** are atoms of the same element that have an equal number of protons but a **different** number of **neutrons**
  - This means that each element can have more than one isotope
- Isotopes tend to be more **unstable** due to their imbalance of protons and neutrons
  - This means they're more likely to decay
- In the diagram below are three isotopes of Hydrogen:



Hydrogen has three isotopes, each with a different number of neutrons

- Isotopes occur naturally, but some are more rare than others
- For example, about 2 in every 10,000 Hydrogen atoms is Deuterium
  - Tritium is even more rare (about 1 in every billion billion hydrogen atoms)

YOUR NOTES

Worked Example

Which of the following elements are isotopes of each other?

A	$^{35}_{17}\mathrm{Cl}$ and $^{35}_{18}\mathrm{Cl}$
B	$^{238}_{92}\mathrm{U}$ and $^{235}_{92}\mathrm{U}$
C	$^{12}_{6}C$ and $^{14}_{8}\mathrm{C}$
D	$^{16}_{8}\mathrm{O}$ and $^{14}_{7}\mathrm{N}$

Answer: **B**

- In nuclide notion, the top number is the **nucleon** number (number of protons and neutrons) and the bottom number is the **proton** number (number of protons)
- Isotopes are two of the same elements
  - This eliminates option **D** since one is oxygen (O) and the other nitrogen (N)
- Which have the same number of protons
  - This eliminates option **C** and **A**
  - Their proton numbers are different for the same element
- But a different number of neutrons
  - Therefore, the correct answer is **B**

YOUR NOTES

Relative Charge

- The different particles that make up atoms have different properties
- Relative **mass** is a way of comparing particles. It is measured in **atomic mass units** (amu)
    - A relative mass of 1 is equal to mass of 1.67×10^{-27} kg
- **Charge** can be positive or negative
    - Relative charge is, again, used to compare particles
- The fundamental charge is equal to the **size** of the charge on a proton and an electron, however the electron's charge is negative
- The properties of each of the particles are shown in the table below:

Table of Relative Charge & Mass

PARTICLE	RELATIVE CHARGE	RELATIVE MASS
PROTON	+1	1
NEUTRON	0	1
ELECTRON	−1	1/2000 (NEGLIGIBLE)

- If have a particle has 0 relative charge, this means it is **neutral**

Nuclear Charge

YOUR NOTES
⬇

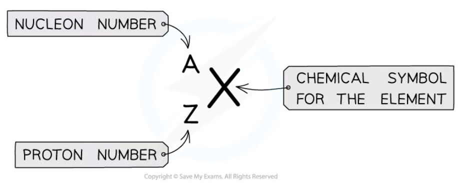
- Nuclear charge is normally stated as the relative charge of the nucleus
  - The term 'relative' refers to the charge of the particle divided by the charge of the proton
- The proton number is the number of protons in a nucleus
- Since nuclei are made up of only protons and neutrons, the proton number determines the **relative charge** on a nucleus

Worked Example

What is the relative charge of the Chromium nucleus $^{52}_{24}\text{Cr}$?

Step 1: Determine the number of protons

- The number of protons is the proton number
- This is the bottom number in the AZX notation



  - This Chromium nucleus has 24 protons and neutrons

Step 2: State the relative mass of 1 proton

- 1 proton has a relative charge of +1

Step 3: Multiple relative charge of 1 proton by the number of protons

- This nucleus of Chromium therefore has a relative charge of +24

Exam Tip

Charge can be either positive (+) or negative (−). Therefore, remember to include the sign when writing the relative charge!

Nuclear Mass

YOUR NOTES

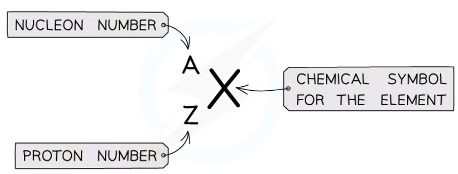
- Nuclear mass is stated as the relative mass of the nucleus
  - The term 'relative' refers to the mass of the particle divided by the mass of the proton
- The mass number is the total number of protons and neutrons in the nucleus
- The nucleon number (mass number) determines the **relative mass** of a nucleus

Worked Example

What is the relative mass of the Chromium nucleus $^{52}_{24}\text{Cr}$?

Step 1: Determine the number of protons and neutrons

- The number of protons and neutrons is the mass (nucleon) number
- This is the top number in the AZX notation



  - This Chromium nucleus has 52 protons and neutrons

Step 2: State the relative mass of 1 proton and neutron

- 1 proton has a relative mass of 1
- 1 neutron has a relative mass of 1

Step 3: Multiple relative charge of 1 proton and neutron by number of protons and neutrons

- This nucleus of Chromium therefore has a relative mass of 52

Exam Tip

The relative mass of a nucleus only includes the protons and neutrons. However, this is pretty much the relative mass of the whole atom because electrons have negligible (very little) mass in comparison to the proton and neutron.

YOUR NOTES
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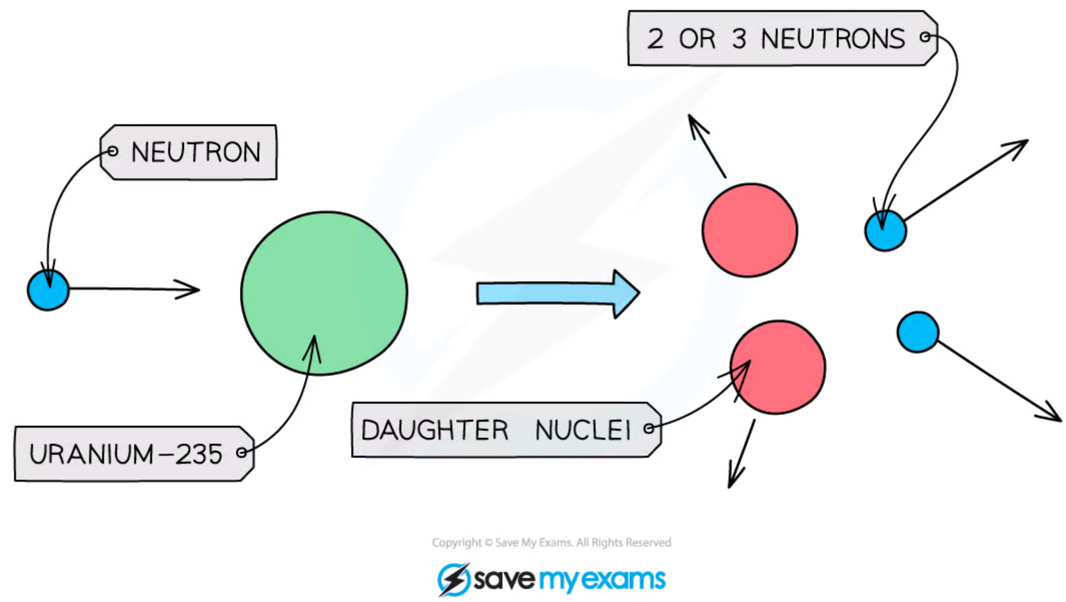
Fission & Fusion

Nuclear Fission

- There is a lot of energy stored within the nucleus of an atom
  - This energy can be released in a nuclear reaction such as **fission**
- Nuclear fission is defined as:

  The splitting of a large, unstable nucleus into two smaller nuclei

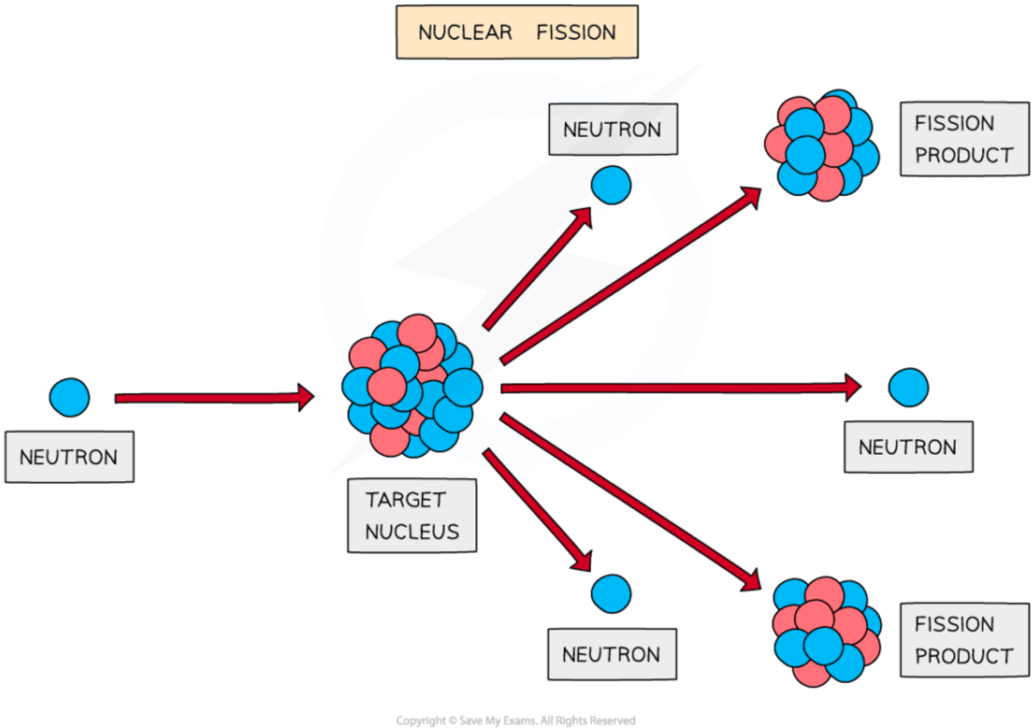
- Isotopes of **uranium** and **plutonium** both undergo fission and are used as fuels in nuclear power stations
- During fission, when a neutron collides with an unstable nucleus, the nucleus splits into **two smaller nuclei** (called daughter nuclei) as well as **two or three neutrons**
  - Gamma rays are also emitted



Large nuclei can decay by fission to produce smaller nuclei and neutrons with a lot of kinetic energy

- The products of fission move away very **quickly**
  - Energy transferred is from **nuclear potential energy** to kinetic energy
- The mass of the products (daughter nuclei and neutrons) is **less** than the mass of the original nucleus
  - This is because the remaining mass has been converted into **energy** which is released during the fission process
- The processes involved in nuclear fission can be shown in different ways as diagrams
- These diagrams show how the reaction happens in a way that is easy to understand

YOUR NOTES



A neutron is fired into the target nucleus, causing it to split

- The diagram above is useful because it shows clearly the different parts of the fission reaction
- An example of a nuclide equation for fission is:

$$^{235}_{92}\text{U} + {}^{1}_{0}\text{n} \rightarrow {}^{92}_{36}\text{Kr} + {}^{141}_{56}\text{Ba} + 3\,{}^{1}_{0}\text{n} + \text{energy}$$

- Where:
  - $^{235}_{92}\text{U}$ is an unstable isotope of Uranium
  - $^{1}_{0}\text{n}$ is a neutron
  - $^{92}_{36}\text{Kr}$ us an unstable isotope of Krypton
  - $^{141}_{56}\text{Ba}$ is an unstable isotope of Barium
- The above equation represents a fission reaction in which a Uranium nucleus is hit with a neutron and splits into two smaller nuclei – a Krypton nucleus and a Barium nucleus, releasing three neutrons in the process
  - The sum of top (nucleon) numbers on the left-hand side equals the sum of top number on the right-hand side:

$$235 + 1 = 92 + 141 + (3 \times 1)$$

  - The same is true for the lower (proton) numbers:

$$92 + 0 = 36 + 56 + (2 \times 0)$$

Nuclear Fusion

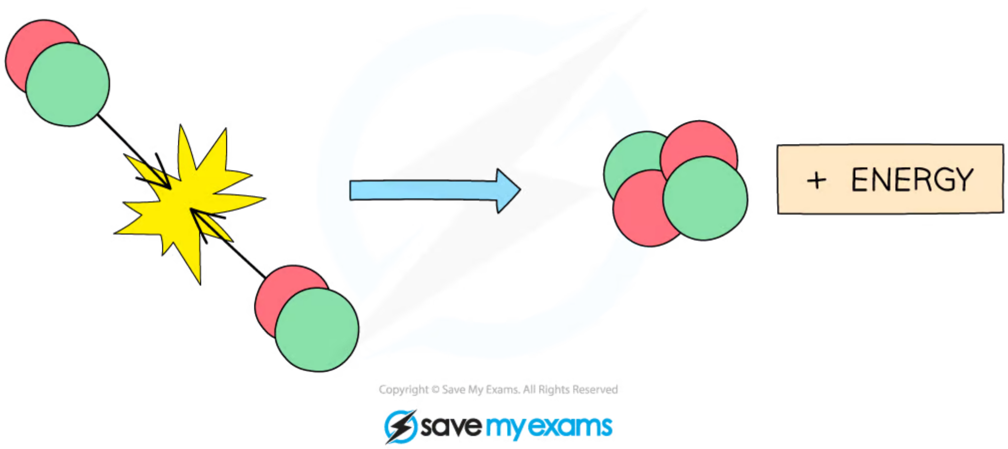
YOUR NOTES
⬇

- Small nuclei can react to release energy in a process called **nuclear fusion**
- Nuclear fusion is defined as:

When two light nuclei join to form a heavier nucleus

- This process requires extremely **high temperatures** to maintain
  - This is why nuclear fusion has proven very hard to reproduce on Earth

- Stars use nuclear fusion to produce energy
- In most stars, hydrogen atoms are fused together to form helium and produce lots of energy



Two hydrogen nuclei are fusing to form a helium nuclei

- The energy produced during nuclear fusion comes from a very small amount of the particle's mass being **converted** into energy
- Albert Einstein described the mass-energy equivalence with his famous equation:

$$E = m \times c^2$$

- Where:
  - E = energy released from fusion in Joules (J)
  - m = mass converted into energy in kilograms (kg)
  - c = the speed of light in metres per second (m/s)
- Therefore, the mass of the product (fused nucleus) is **less** than the mass of the two original nuclei
  - This is because the remaining mass has been converted into **energy** which is released when the nuclei fuse

- The amount of energy released during nuclear fusion is huge:
  - The energy from 1 kg of hydrogen that undergoes fusion is equivalent to the energy from burning about 10 million kilograms of coal

- An example of a nuclide equation for fusion is:

$$^{2}_{1}H + ^{1}_{1}H \rightarrow ^{3}_{2}\text{He} + \text{energy}$$

- Where:

- $^{2}_{1}H$ is deuterium (isotope of hydrogen with 1 proton and 1 neutron)
- $^{1}_{1}H$ is hydrogen (with one proton)
- $^{3}_{2}He$ is an isotope with helium (with two protons and one neutron)

YOUR NOTES
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Worked Example

A nuclide equation for nuclear fission is stated as:

$$^{235}_{92}U + ^{1}_{0}n \longrightarrow ^{96}_{37}Rb + ^{137}_{55}Cs + N^{1}_{0}n$$

Calculate the number of neutrons, *N* emitted in this reaction.

Step 1: Calculate the nucleon number on the left side of the equation

$$235 + 1 = 236$$

Step 2: Calculate the nucleon number on the right side of the equation

$$96 + 138 + N = 233 + N$$

Step 3: Equate the nucleon number for both sides of the equation

$$236 = 233 + N$$

Step 4: Rearrange for the number of neutrons, N

$$N = 236 - 233 = 3$$

YOUR NOTES
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5.2 Radioactivity

5.2.1 Background Radiation

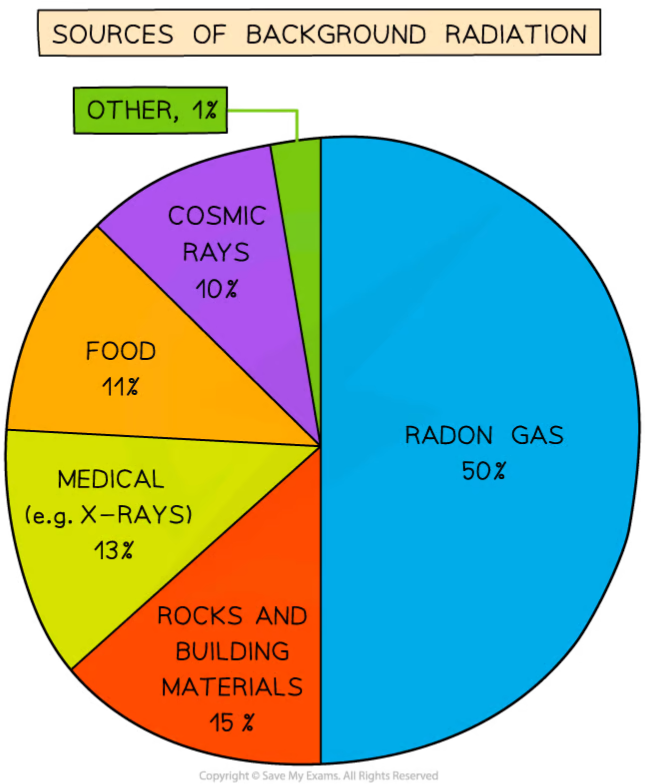
Background Radiation

- It is important to remember that radiation is a natural phenomenon
- Radioactive elements have **always** existed on Earth and in outer space
- However, human activity has added to the amount of radiation that humans are exposed to on Earth

- Background radiation is defined as:

The radiation that exists around us all the time

- There are two types of background radiation:
  - Natural sources
  - Man-made sources



Background radiation is the radiation that is present all around in the environment. Radon gas is given off from some types of rock

- Every second of the day there is some radiation emanating from **natural sources** such as:
  - Rocks
  - Cosmic rays from space
  - Foods

- Although most background radiation is natural, a small amount of it comes from artificial sources, such as **medical procedures** (including X-rays)
- Levels of background radiation can vary significantly from place to place

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Sources of Background Radiation

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- Background radiation can come from natural sources on Earth or space and man-made sources

Natural Sources

- **Radon gas (in the air)**
  - Airborne radon comes from the ground
  - This is from the natural decay of uranium in rocks and soil
  - The gas is tasteless, colourless and oderless but it not generally a health issue
- **Rocks and Buildings**
  - Heavy radioactive elements, such as uranium and thorium, occur naturally in rocks in the ground
  - Uranium decays into radon gas, which is an alpha emitter
  - This is particularly dangerous if inhaled into the lungs in large quantities
  - Natural radioactivity can be found in building materials, including decorative rocks, stone and brick
- **Cosmic rays from space**
  - The sun emits an enormous number of protons every second
  - Some of these enter the Earth's atmosphere at high speeds
  - When they collide with molecules in the air, this leads to the production of gamma radiation
  - Other sources of cosmic rays are supernovae and other high energy cosmic events
- **Carbon-14 in biological material**
  - All organic matter contains a tiny amount of carbon-14
  - Living plants and animals constantly replace the supply of carbon in their systems hence the amount of carbon-14 in the system stays almost constant
- **Radioactive material in food and drink**
  - Naturally occurring radioactive elements can get into food and water since they are in contact with rocks and soil containing these elements
  - Some foods contain higher amounts such as potassium-40 in bananas
  - However, the amount of radioactive material is minuscule and is not a cause for concern

Man-Made Sources

- **Medical sources**
  - In medicine, radiation is utilised all the time
  - Uses include X-rays, CT scans, radioactive tracers, and radiation therapy
- **Nuclear waste**
  - While nuclear waste itself does not contribute much to background radiation, it can be dangerous for the people handling it
- **Nuclear fallout from nuclear weapons**
  - Fallout is the residue radioactive material that is thrown into the air after a nuclear explosion, such as the bomb that exploded at Hiroshima

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- While the amount of fallout in the environment is presently very low, it would increase significantly in areas where nuclear weapons are tested

- **Nuclear accidents**
  - Accidents such as that in Chernobyl contributed a large dose of radiation into the environment
  - While these accidents are now extremely rare, they can be catastrophic and render areas devastated for centuries

Exam Tip

The sources that make the most significant contribution are the natural sources:

- Radon gas
- Rocks and buildings
- Food and drink
- Cosmic rays

Make sure you remember these for your exam!

Detecting Radiation

YOUR NOTES
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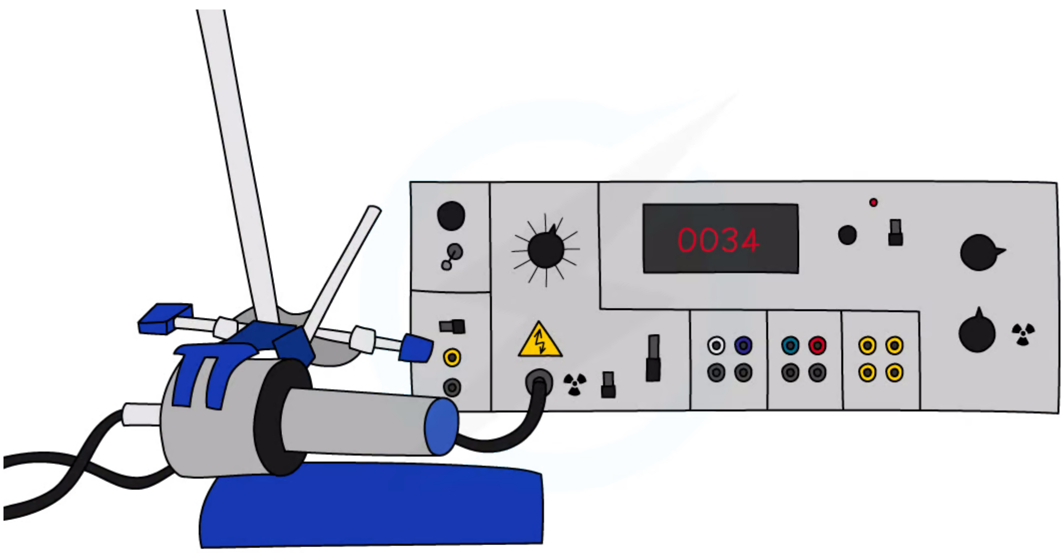
- It is important to regulate the exposure of humans to radiation
  - The amount of radiation received by a person is called the **dose**
- Ionising nuclear radiation is measured using a **detector** connected to a **counter**

Count Rate

- Count rate is the **number** of decays per second recorded by a detector and recorded by the **counter**
  - It is measured in **counts/s** or **counts/min**
- The count rate decreases the further the detector is from the source
  - This is because the radiation becomes more spread out the further away it is from the source

Geiger-Müller tube

- The Geiger-Müller tube is the most common device used to measure and detect radiation
- Each time it absorbs radiation, it transmits an electrical pulse to a counting machine
  - This makes a clicking sound or displays the **count rate**
- The greater the frequency of clicks, or the higher the count rate, the more radiation the Geiger-Müller tube is absorbing
  - Therefore, it matters how close the tube is to the radiation source
  - The further away from the source, the lower the count rate detected



A Geiger-Müller tube (or Geiger counter) is a common type of radiation detector

Examples of other radiation detectors include:

- **Photographic film** (often used in badges)
- **Ionisation chambers**
- **Scintillation counters**

- **Spark counters**

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Worked Example

A Geiger-Müller tube is used to detect radiation in a particular location. If it counts 16,000 decays in 1 hour, what is the count rate?

Step 1: Identify the different variables

- The number of decays is 16 000
- The time is 1 hour

Step 2: Determine the time period in seconds

- 1 hour is equal to 60 minutes, and 1 minute is equal to 60 seconds

$$\text{Time period} = 1 \times 60 \times 60 = 3600 \text{ seconds}$$

Step 3: Divide the total counts by the time period in seconds

$$\text{Counts} \div \text{Time period} = 16\,000 \div 3600 = 4.5$$

- Therefore, there are **4.5 decays per second**

Exam Tip

If asked to name a device for detecting radiation, the Geiger-Müller tube is a good example to give. You can also refer to it as a GM tube, a GM detector, GM counter, Geiger counter etc. (The examiners will allow some level of misspelling, providing it is readable). Don't, however, refer to it as a 'radiation detector' as this is too vague and may simply restate what was asked for in the question.

Accounting for Background Radiation

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EXTENDED

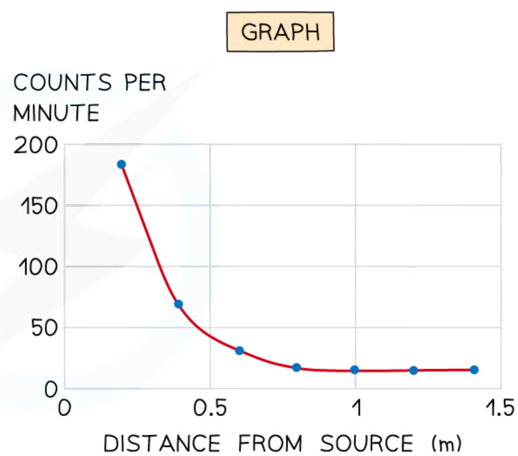
- Background radiation must be accounted for when taking readings in a laboratory
- This can be done by taking readings with no radioactive source present and then subtracting this from readings with the source present
  - This is known as the **corrected count rate**

Worked Example

A student is using a Geiger-counter to measure the counts per minute at different distances from a source of radiation. Their results and a graph of the results are shown here.

RESULTS TABLE

Distance from source (m)	Counts per minute
0.2	180
0.4	67
0.6	29
0.8	17
1.0	15
1.2	15
1.4	15



Determine the background radiation count.

Step 1: Determine the point at which the source radiation stops being detected

- The background radiation is the amount of radiation received all the time
- When the source is moved back far enough it is all absorbed by the air before reaching the Geiger-counter
- Results after 1 metre do not change
- Therefore, the amount after 1 metre is only due to background radiation

Step 2: State the background radiation count

- The background radiation count is **15 counts per minute**

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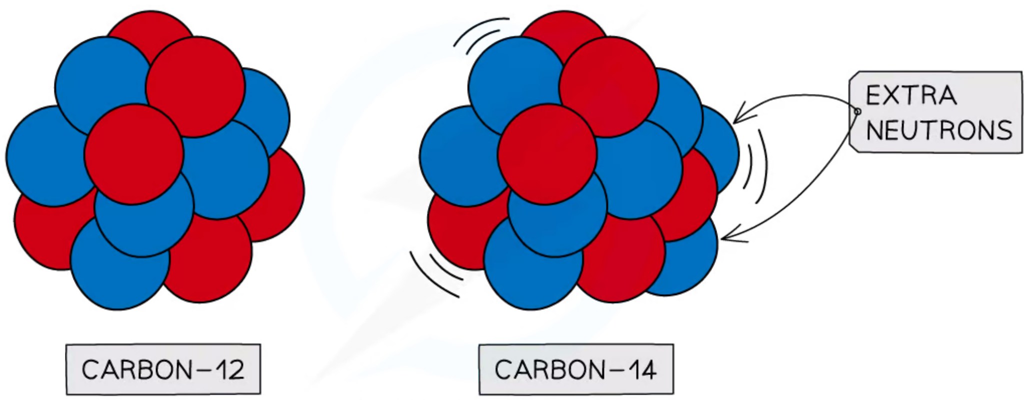
5.2.2 Types of Radiation

Radioactive Decay

- Some atomic nuclei are **unstable**
- This is because of an imbalance in the forces within the nucleus
  - Forces exist between the particles in the nucleus
  - This is commonly due to the nucleus have too many protons or neutrons

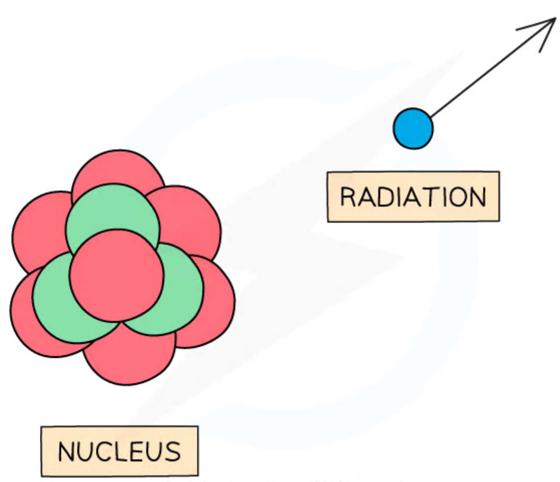
- Carbon-14 is an isotope of carbon which is **unstable**
  - It has two extra neutrons compared to stable carbon-12



Carbon-12 is stable, whereas carbon-14 is unstable. This is because carbon-14 has two extra neutrons

- Some isotopes are unstable because of their large size or because they have too many or too few neutrons

- Unstable nuclei can **emit radiation** to become more stable
  - Radiation can be in the form of a high energy particle or wave



Unstable nuclei decay by emitting high energy particles or waves

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- As the radiation moves away from the nucleus, it takes some energy with it
  - This reduces the overall energy of the nucleus
  - This makes the nucleus more **stable**
- The process of emitting radiation is called **radioactive decay**
- Radioactive decay is a **random** process
  - This means it is not possible to know exactly when a particular nucleus will decay
- It cannot be predicted when a particular unstable nucleus will decay
- This is because radioactive decay is a **random** process, this means that:
  - There is an **equal probability** of any nucleus decaying
  - It cannot be known **which particular nucleus will decay next**
  - It cannot be known **at what time a particular nucleus will decay**
  - The rate of decay is **unaffected** by the surrounding conditions
  - It is only possible to estimate the **probability** of a nuclei decaying in a given time period
- Therefore, the emission of radiation is:
  - Spontaneous
  - Random in direction

Worked Example

Which of the following statements is **not** true?

A Isotopes can be unstable because they have too many or too few neutrons

B The process of emitting particles or waves of energy from an unstable nucleus is called radioactive decay

C Scientists can predict when a nucleus will decay

D Radiation refers to the particles or waves emitted from a decaying nucleus

ANSWER: C

- Answer A is **true.** The number of neutrons in a nucleus determines the stability
- Answer B is **true.** This is a suitable description of radioactive decay
- Answer D is **true.** Radiation is about emissions. It is different to radioactive particles
- Answer C is **not true**
- Radioactive decay is a random process
- It is not possible to predict precisely when a particular nucleus will decay

Exam Tip

The terms **unstable**, **random** and **decay** have very particular meanings in this topic. Remember to use them correctly when answering questions!

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Types of Radioactive Decay

- When an unstable nucleus decays, it emits radiation called **nuclear radiation**
- There are different types of radiation that can be emitted:
  - **Alpha (α)** particles
  - **Beta (β⁻)** particles
  - **Gamma (γ)** radiation
- These changes are **spontaneous** and **random**

Alpha Particles

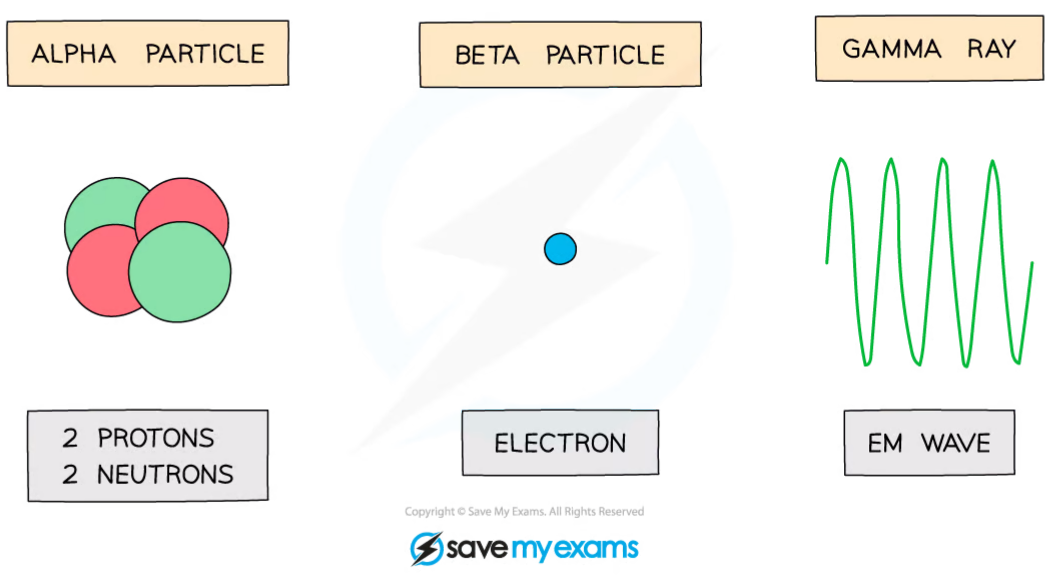
- The symbol for alpha is **α**
- An alpha particle is the same as a helium nucleus
  - This is because they consist of two neutrons and two protons
- Alpha particles have a charge of +2
  - This means they can be affected by an electric field

Beta Particles

- The symbol for beta is β^-
- Beta particles are fast-moving electrons
- They are produced in nuclei when a neutron changes into a proton and an electron
- Beta particles have a charge of -1
  - This means they can be affected by an electric field

Gamma Rays

- The symbol for gamma is **γ**
- Gamma rays are electromagnetic waves
- They have the highest energy of the different types of electromagnetic waves
- Gamma rays have no charge



Alpha particles, beta particles and gamma waves can be emitted from unstable nuclei

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Alpha, Beta & Gamma Emission

- α, β and γ radiation can be identified by the emission from a nucleus by recalling their:
  - Nature (what type of particle or radiation they are)
  - Their relative ionising effects (how easily they ionise other atoms)
  - Their relative penetrating abilities (how far can they travel before they are stopped completely)

- The properties of Alpha, Beta and Gamma are given in this table, and then described in more detail below

Different Properties of Nuclear Radiation

Particle	What is it	Charge	Range in air	Penetration	Ionisation
Alpha (α)	2 protons + 2 neutrons	+2	Few cm	Stopped by paper	High
Beta (β^-)	Electron	−1	Few 10s of cm	Stopped by few mm Aluminium	Medium
Gamma (γ)	Electromagnetic wave	0	Infinite	Reduced by few mm Lead	Low

- The trend down the table shows:
  - The range increases
  - Penetrating power increases
  - Ionisation decreases

Penetrating Power

- Alpha, beta and gamma have different properties
- They **penetrate** materials in different ways
  - This means they are stopped by different materials

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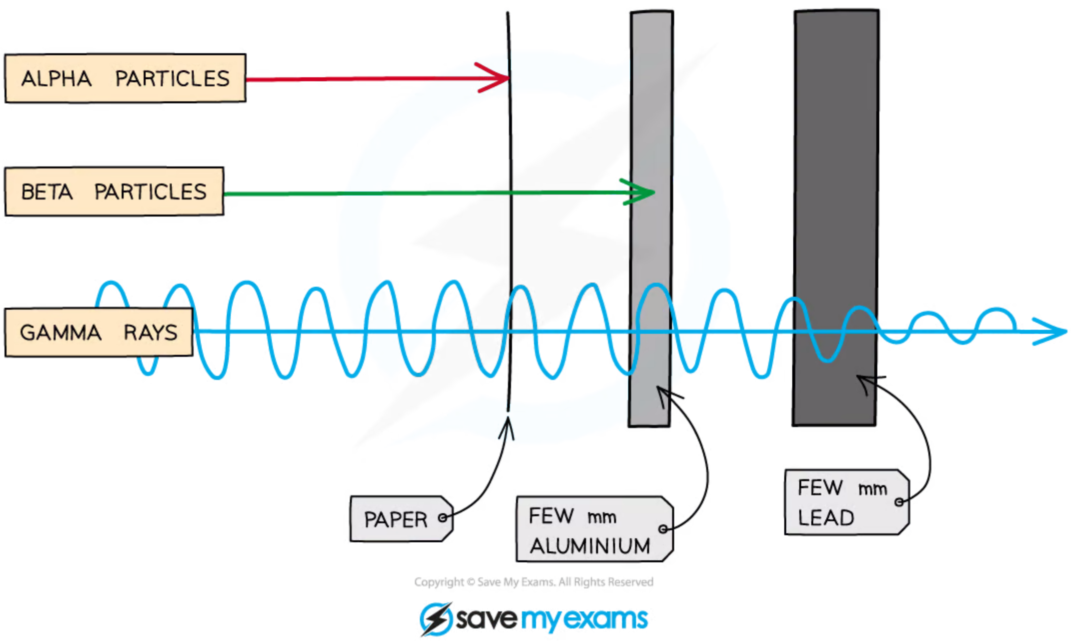

Alpha, beta and gamma are different in how they penetrate materials. Alpha is the least penetrating, and gamma is the most penetrating

- Alpha is stopped by **paper**, whereas beta and gamma pass through it
- Beta is stopped by a few millimetres of aluminium
  - Gamma can pass through **aluminium**
- Gamma rays are only partially stopped by thick **lead**

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Worked Example

A student has an unknown radioactive source. They are trying to work which type of radiation is being given off:

A Alpha particles

B Beta particles

C Gamma rays

D Neutrons

They measure the count-rate, using a Geiger-Muller tube, when the source is placed behind different material. Their results are shown in the table below:

	No material Between Source and Detector	Paper Between Source and Detector	5 mm Aluminium Between Source and Detector	5 mm Lead Between Source and Detector
Count-rate	4320	4218	256	34

Which type of radiation is being given off by the source?

ANSWER: B

- The answer is **not A** because the radiation passed through the paper almost unchanged
  - This means it is **not** alpha
- The answer is **not C or D** because the aluminium decreased the count-rate significantly
  - This means it is **not** gamma (gamma penetrates aluminium)
  - This also means it is **not** neutrons (neutrons penetrate aluminium, however you do not need to know this for your GCSE)
- Therefore, the source must be **Beta** particles

Exam Tip

Remembering the type of particle, penetration and ionising power for alpha, beta and gamma radiation is very important for your exam! Often the exam question will give some clues and you will have to choose which type of radiation it could be based off these.

5.2.3 Ionising Power & Deflection

YOUR NOTES
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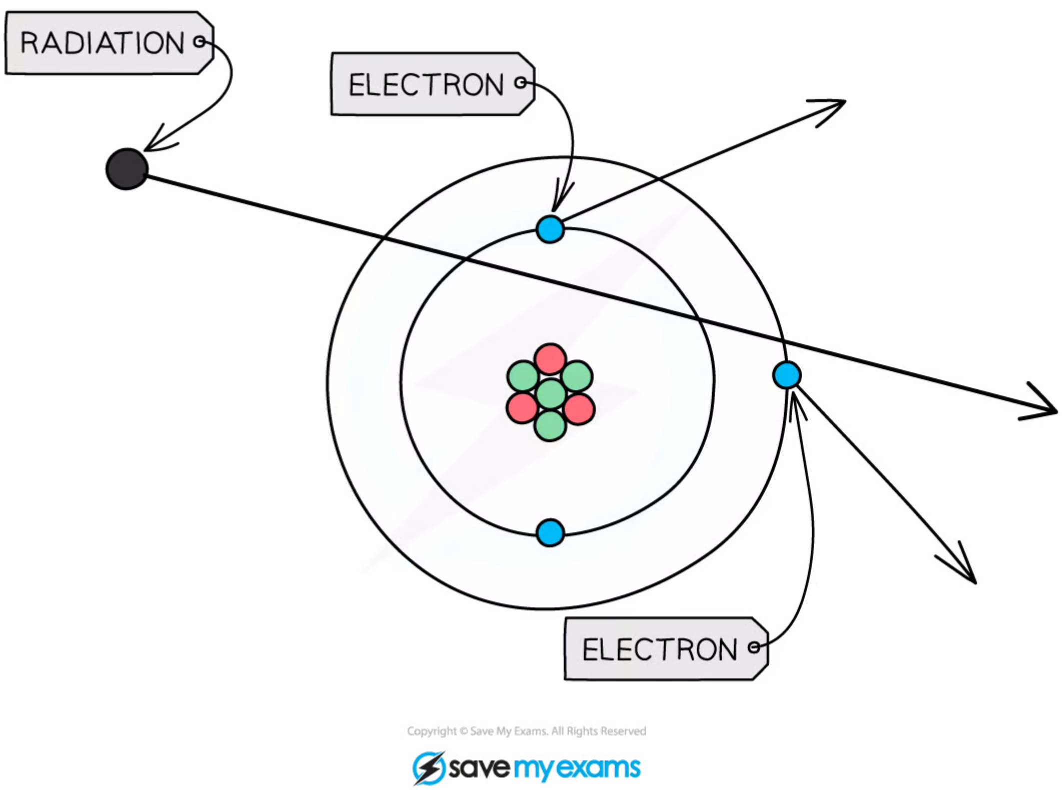
Ionising Effect of Radiation

EXTENDED

- Ionisation is the process of which an atom becomes negative or positive by gaining or losing electrons
- All nuclear radiation is capable of **ionising** atoms that it hits
  - When an atom is ionised, the number of electrons it has **changes**
- This is mostly done by knocking out an electron so the atom loses a negative charge and is left overall **positive**



When radiation passes close to atoms it can knock out electrons, ionising the atom

- **Alpha** is by far the most ionising form of radiation
  - Alpha particles leave a dense trail of ions behind them, affecting virtually every atom they meet
  - Because of this they quickly lose their energy and so have a short range
  - Their short range makes them relatively harmless if handled carefully, but they have the potential to be extremely dangerous if the alpha emitter enters the body
- **Beta** particles are moderately ionising

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- The particles create a less dense trail of ions than alpha, and consequently have a longer range
- They tend to be more dangerous than alpha because they are able to travel further and penetrate the skin, and yet are still ionising enough to cause significant damage

- **Gamma** is the least ionising form of radiation (although it is still dangerous)
  - Because Gamma rays don't produce as many ions as alpha or beta, they are more penetrating and have a greater range
  - This can make them hazardous in large amounts

- The ionising effects depend on the **kinetic energy** and **charge** of the type of radiation

- The **greater** the **charge** of the radiation, the **more** ionising it is
  - This means alpha radiation is the most ionising as it has a charge of +2
  - A beta particle has a charge of –1 so is moderately ionising
  - This means gamma radiation is the least ionising as it has a charge of 0 (no charge)

- The **higher** the **kinetic energy** of the radiation, the **more** ionising it is
  - This means alpha particle is still the most ionising because it has the greatest mass
  - However, a beta particle is very light (it is an electron) but travels at high speeds, therefore, it has a lot of kinetic energy and is still moderately ionising
  - Gamma radiation has virtually no mass so is weakly ionising

Exam Tip

Remembering the properties of alpha, beta and gamma radiation really helps with deducing how much ionising power they have. E.g. An alpha particle is a helium nucleus which contains two protons and two neutrons. It therefore has a charge of +2 since each proton has a charge of +1 and a neutron has no charge.

Kinetic energy is defined by the equation $\frac{1}{2}mv^2$ therefore it depends on the mass m of the particle and its velocity v.

Deflection in Electric & Magnetic Fields

YOUR NOTES
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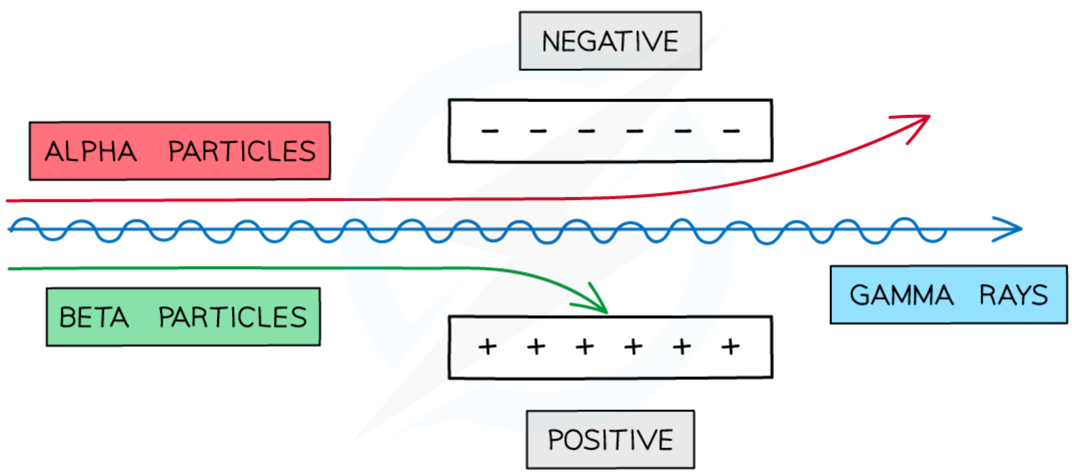
EXTENDED

- A particle is deflected in an electric field if it has **charge**
- A particle is deflected in a magnetic field if it has **charge** and is **moving** perpendicular to it
  - Therefore, since gamma (γ) particles have no charge, they are **not** deflected by either electric or magnetic fields
  - Only alpha (α) and beta (β) particles are

Electric Fields

- Alpha particles have a **charge of +2** (charge of a helium nucleus)
- Beta particles have a **charge of –1** (charge of an electron)
- Therefore, between an electric field created between a negatively charged and positively charged plate
  - Alpha particles are deflected towards the **negative** plate
  - Beta particles are deflected towards the **positive** plate
  - Gamma radiation is not deflected and travels straight through between the plates



Alpha and Beta particles can be deflected by electric fields

- Alpha particles are **heavier** than beta particles
  - Therefore, beta particles are deflected more in the electric field and alpha is deflected less

Magnetic Fields

- Similarly, alpha and beta particles are deflected by magnetic fields whilst they are moving
- They are deflected in **opposite** directions due to their opposite charges

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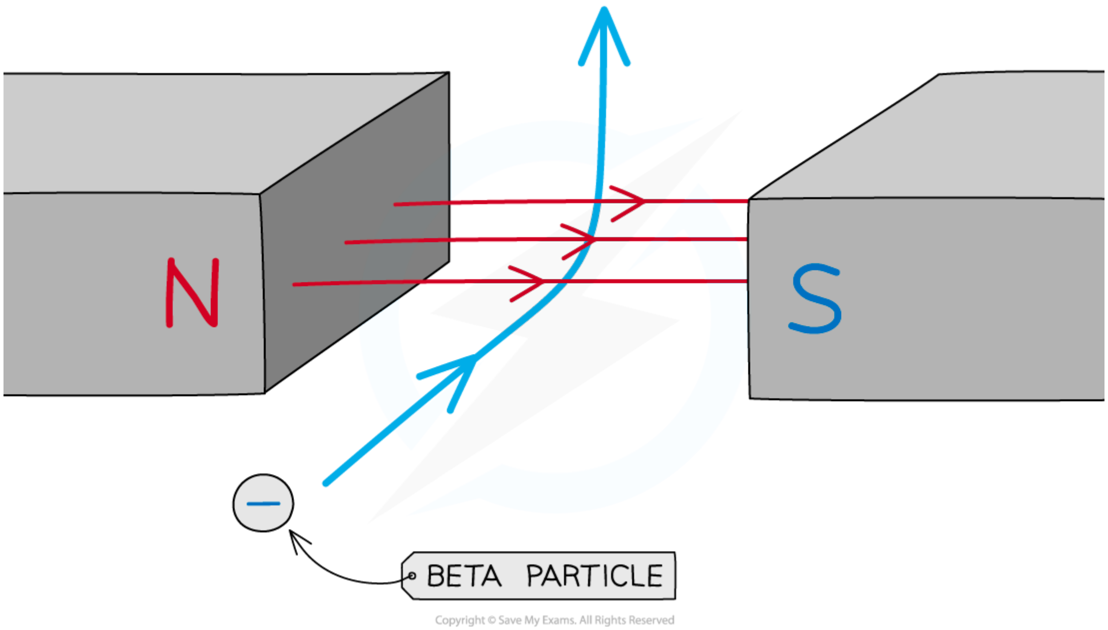

Alpha and Beta particles can also be deflected by magnetic fields

Exam Tip

It is important to note that because of their opposite charges, alpha and beta particles will deflect in **opposite** directions. You do not need to know which direction alpha and beta particles are deflected in a magnetic field (this is covered at A-level) but you should know that they are deflected, whilst gamma is not because they are charged and they deflect in opposite directions.

5.2.4 Radioactive Decay

YOUR NOTES
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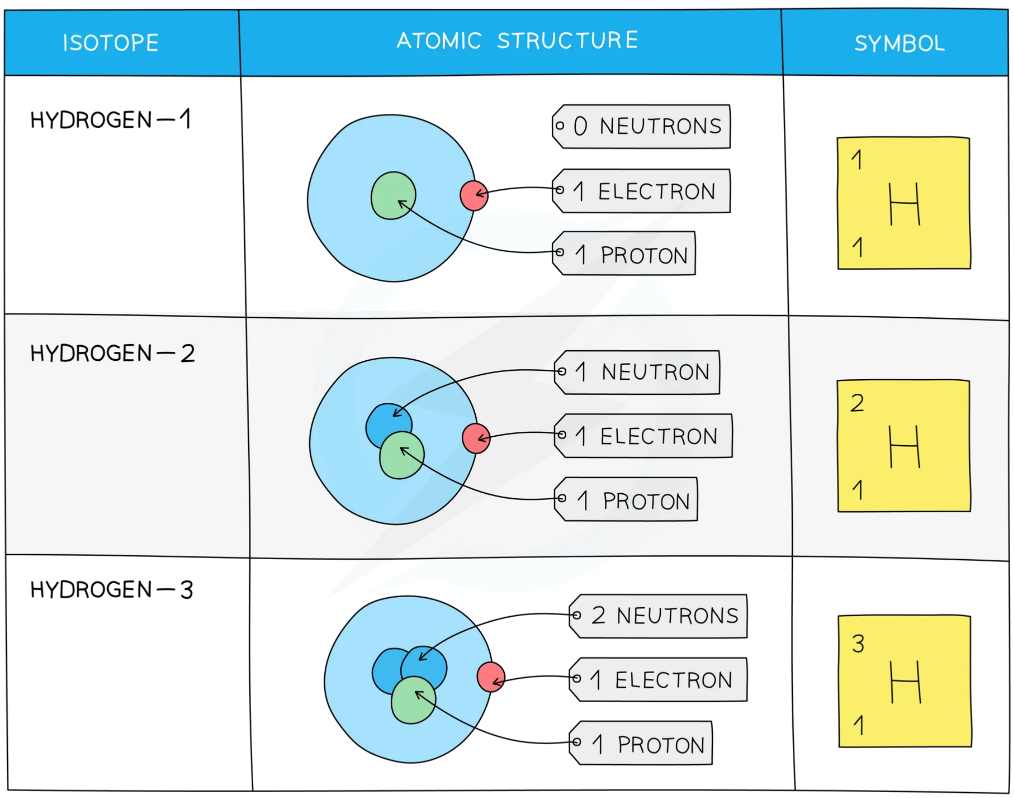
Effect of Nuclear Size on Decay

EXTENDED

- The most stable nuclei have roughly the same number of protons to neutrons
  - If there were too many protons, then the repulsive force caused by them all having the same positive charge which cause the nucleus to repel when it becomes very large
- Therefore, if a nucleus has an imbalance of protons or neutrons, it is more likely to decay into small nuclei until it gets to a stable nucleus with roughly the same number of each
- Therefore, Isotopes of an element may be radioactive due to:
  - An excess of neutrons in the nucleus
  - The nucleus being too heavy
- An example of these are the isotope of hydrogen-1

Hydrogen Isotopes



- H-1 is the stable nucleus of hydrogen
  - H-2 (deuterium) adds on one more neutron
  - H-3 (tritium) adds on another neutron, making 2 neutrons to 1 proton. This is much more unstable than H-1 or H-2
- If an nucleus is too **heavy**, this means it has too many protons and neutrons
  - The forces in the nucleus will be weaker in keeping the protons and neutrons together

YOUR NOTES
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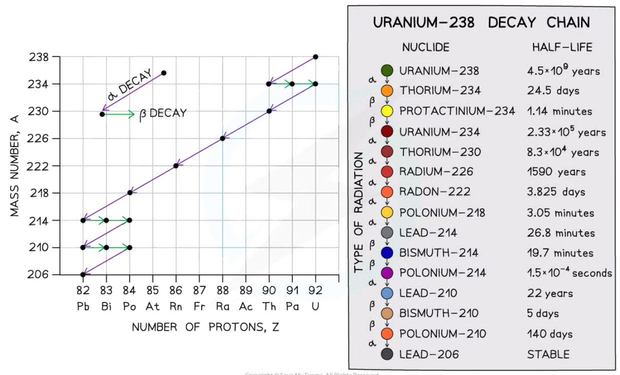
- This can also cause the nucleus to decay
- An example of this is Uranium-238 which is used in nuclear fission
  - This nucleus has 238 protons and neutrons
- The decay of Uranium-238 gradually reduces the mass number of the element which it decays into
  - This is done through alpha (α) or beta (β) decay

Uranium-238 Decay Chain



> **Exam Tip**
>
> The notation of C-12 for example, means the element 'Carbon' with the **mass** (or nucleon) number of 12.

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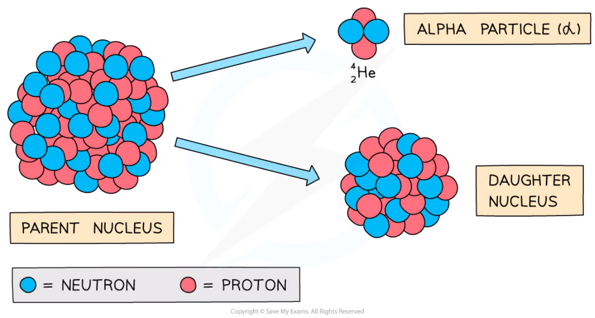
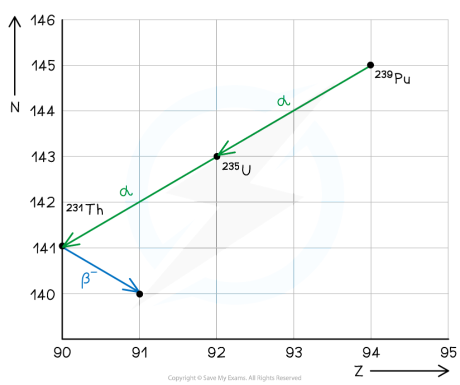
Change to a New Element

- During α-decay or β-decay, the nucleus changes to a **different element**
- The initial nucleus is often called the **parent nucleus**
- The nucleus of the new element is often called the **daughter** nucleus



Alpha decay creating change a parent nucleus to a daughter nucleus of a new element

- The daughter nucleus is a new element because it has a **different** proton and/or nucleon number to the original parent nucleus
- This can be seen on a graph of N (neutron number) against Z (proton number)



Graph of N against Z for the decay of Pu-239

- When Pu-239 decays by alpha to U-235, it loses 2 protons and 2 neutrons
  - U (Uranium) is a completely different element to Pu (Plutonium)

Reducing Neutron Number

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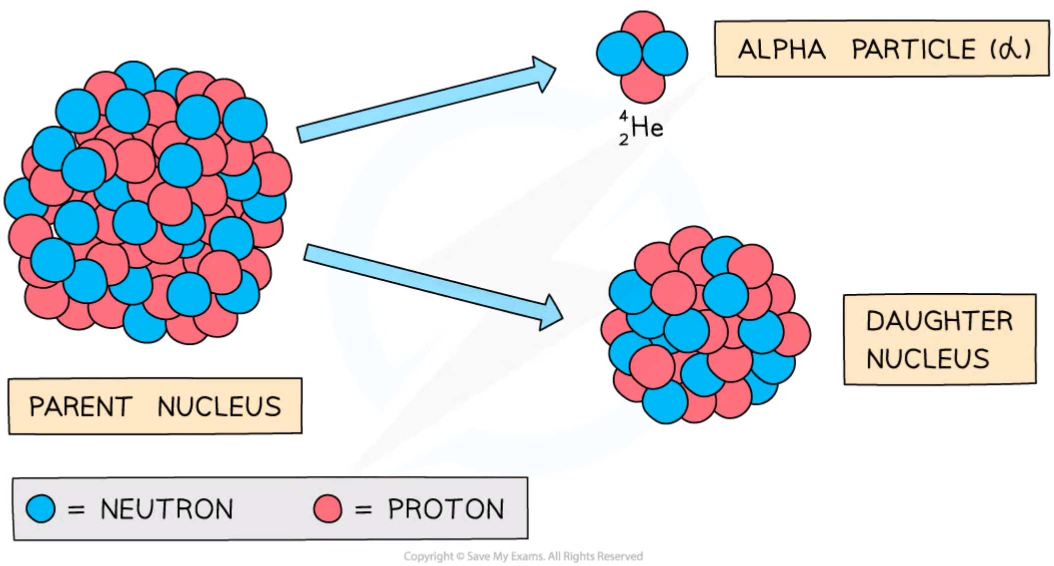
EXTENDED

- A nucleus decays to increase its stability by reducing the number of excess neutrons
  - This is done by alpha or beta decay
- If the nucleus has too much energy, this is given off in the form of radiation
  - This is often gamma radiation

Alpha Decay

- During alpha decay an alpha particle is emitted from an unstable nucleus
- A completely **new element** is formed in the process

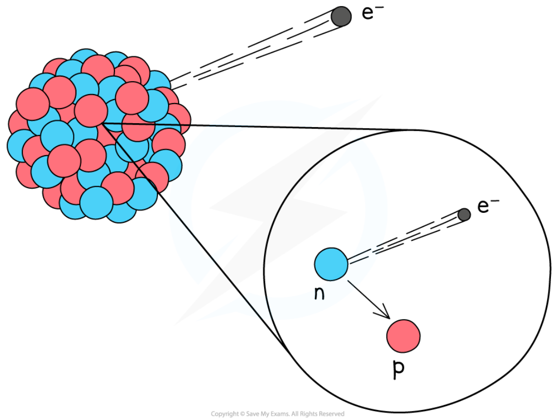


Alpha decay usually happens in large unstable nuclei, causing the overall mass and charge of the nucleus to decrease

- An alpha particle is a **helium nucleus**
  - It is made of 2 protons and 2 neutrons
- When the alpha particle is emitted from the unstable nucleus, the mass number and atomic number of the nucleus changes
  - The mass number **decreases** by 4
  - The atomic number **decreases** by 2
- The charge on the nucleus also decreases by 2
  - This is because protons have a charge of +1 each

Beta Decay

- During **beta** decay, a **neutron** changes into a **proton** and an **electron**
  - The electron is **emitted** and the proton **remains** in the nuclei
- A completely new element is formed because the **atomic number** changes

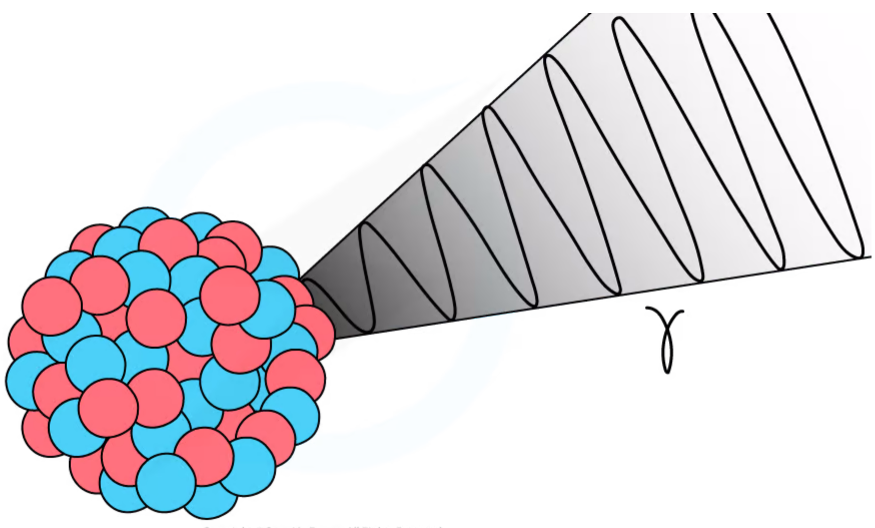


Beta decay often happens in unstable nuclei that have too many neutrons. The mass number stays the same, but the atomic number increases by one

- A beta particle is a high-speed **electron**
- It has a mass number of 0
  - This is because the electron has a negligible mass, compared to neutrons and protons
- Therefore, the **mass number** of the decaying nuclei **remains the same**
- Electrons have an atomic number of -1
  - This means that the new nuclei will **increase its atomic number by 1** in order to maintain the overall atomic number before and after the decay
- The following equation shows carbon-14 undergoing beta decay
  - It forms nitrogen-14 and a beta particle
  - Beta particles are written as an electron in this equation

Gamma Decay

- During gamma decay, a gamma ray is emitted from an unstable nucleus
- The process that makes the nucleus less energetic but does not change its structure



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Gamma decay does not affect the mass number or the atomic number of the radioactive nucleus, but it does reduce the energy of the nucleus

- The gamma ray that is emitted has a lot of energy, but no mass or charge

Exam Tip

There is a second form of beta decay during which a proton changes into a neutron. This is called beta-plus decay - you might come across it while revising, but you don't need to know about it for your exam. Only use the information here for your iGCSE.

It is easy to forget that an alpha particle **is** a helium nucleus, or that a beta particle is an electron. Look out for either wording!

Decay Equations

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EXTENDED

- Radioactive decay events can be shown using a **decay equation**
- A decay equation is similar to a chemical reaction equation
  - The particles present before the decay are shown **before** the arrow
  - The particles produced in the decay are shown **after** the arrow

- During decay equations the sum of the mass and atomic numbers **before** the reaction must be the same as the sum of the mass and atomic numbers **after** the reaction

- The following decay equation shows Polonium-212 undergoing alpha decay
  - It forms Lead-208 and an alpha particle
  - An alpha particle can also be written as a helium nucleus (Symbol He)

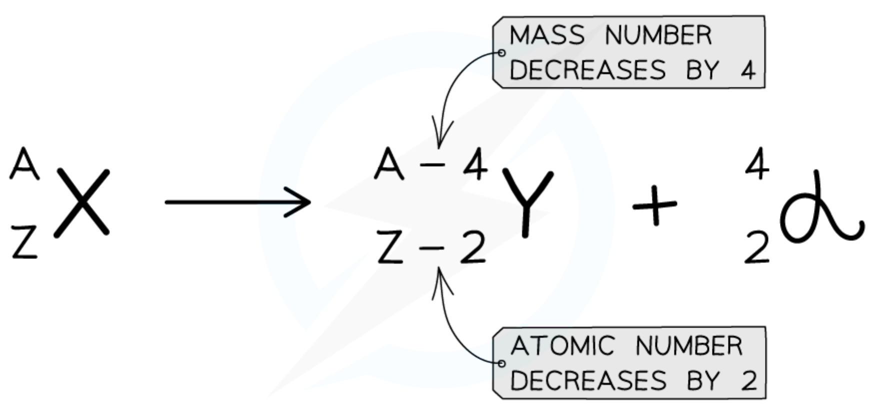
$$^{A}_{Z}X \rightarrow \,^{A-4}_{Z-2}Y + \,^{4}_{2}\alpha$$

$$\text{e.g.} \quad ^{212}_{84}Po \rightarrow \,^{208}_{82}Pb + \,^{4}_{2}\alpha$$

The polonium nucleus emits an alpha particle, causing its mass and charge to decrease. This means it changes into a new element

Alpha Decay Equation

- When the alpha particle is emitted from the unstable nucleus, the mass number and atomic number of the nucleus changes
  - The mass number **decreases** by 4
  - The atomic number **decreases** by 2



Alpha decay equation

Beta Decay Equation

- During **beta** decay, a **neutron** changes into a **proton** and an **electron**
  - The electron is **emitted** and the proton **remains** in the nuclei

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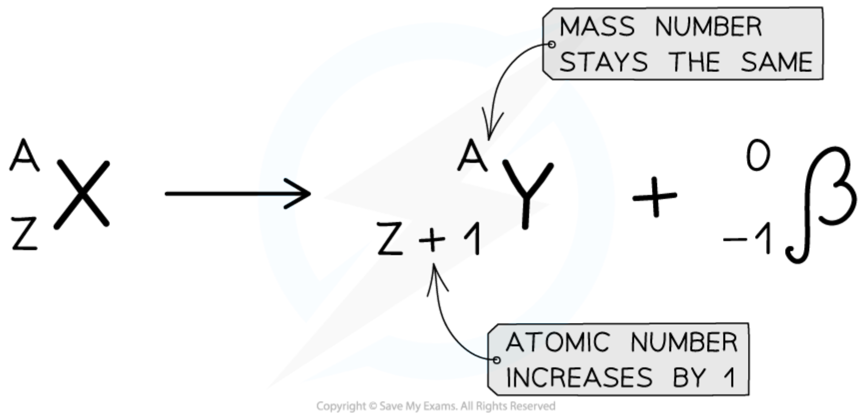
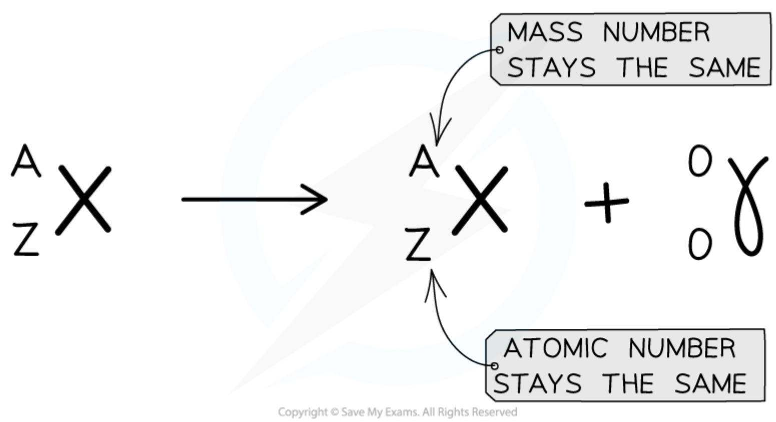


Beta decay equation

Gamma Decay

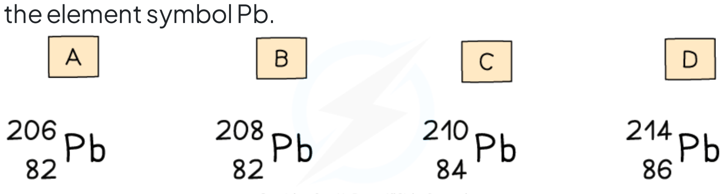
- The gamma ray that is emitted has a lot of energy, but no mass or charge
- Here is an example of Uranium-238 undergoing gamma decay
  - Notice that the mass number and atomic number of the unstable nuclei remains the same during the decay



Gamma decay equation

Worked Example

A nucleus with 84 protons and 126 neutrons undergoes alpha decay. It forms lead, which has the element symbol Pb.



Which of the isotopes of lead pictured is the correct one formed during the decay?

ANSWER: A

Step 1: Calculate the mass number of the original nucleus

- The mass number is equal to the number of protons plus the number of neutrons
- The original nucleus has 84 protons and 126 neutrons

$$84 + 126 = 210$$

- The mass number of the original nucleus is 210

Step 2: Calculate the new atomic number

- The alpha particle emitted is made of two protons and two neutrons
- Protons have an atomic number of 1, and neutrons have an atomic number of 0
- Removing two protons and two neutrons will reduce the atomic number by 2

$$84 – 2 = 82$$

- The new nucleus has an atomic number of **82**

Step 3: Calculate the new mass number

- Protons and neutrons both have a mass number of 1
- Removing two protons and two neutrons will reduce the mass number by 4

$$210 – 4 = 206$$

- The new nucleus has a mass number of **206**

Worked Example

A nucleus with 11 protons and 13 neutrons undergoes beta decay. It forms magnesium, which has the element symbol Mg.

A	B	C	D
$^{20}_{9}\text{Mg}$	$^{24}_{10}\text{Mg}$	$^{23}_{11}\text{Mg}$	$^{24}_{12}\text{Mg}$

Which is the correct isotope of magnesium formed during the decay?

ANSWER: D

Step 1: Calculate the mass number of the original nucleus

- The mass number is equal to the number of protons plus the number of neutrons
- The original nucleus has 11 protons and 13 neutrons

$$11 + 13 = 24$$

- The mass number of the original nucleus is 24

Step 2: Calculate the new atomic number

- During beta decay a neutron changes into a proton and an electron
- The electron is emitted as a beta particle

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- The neutron has an atomic number of 0 and the proton has an atomic number of 1
- So the atomic number increases by 1

$$11 + 1 = 12$$

- The new nucleus has an atomic number of 12

Step 3: Calculate the new mass number

- Protons and neutrons both have a mass number of 1
- Changing a neutron to a proton will not affect the mass number
- The new nucleus has a mass number of 24 (the same as before)

Exam Tip

You are not expected to know the names of the elements produced during radioactive decays, but you do need to be able to calculate the mass and atomic numbers by making sure they are balanced on either side of the reaction.

5.2.5 Half-Life

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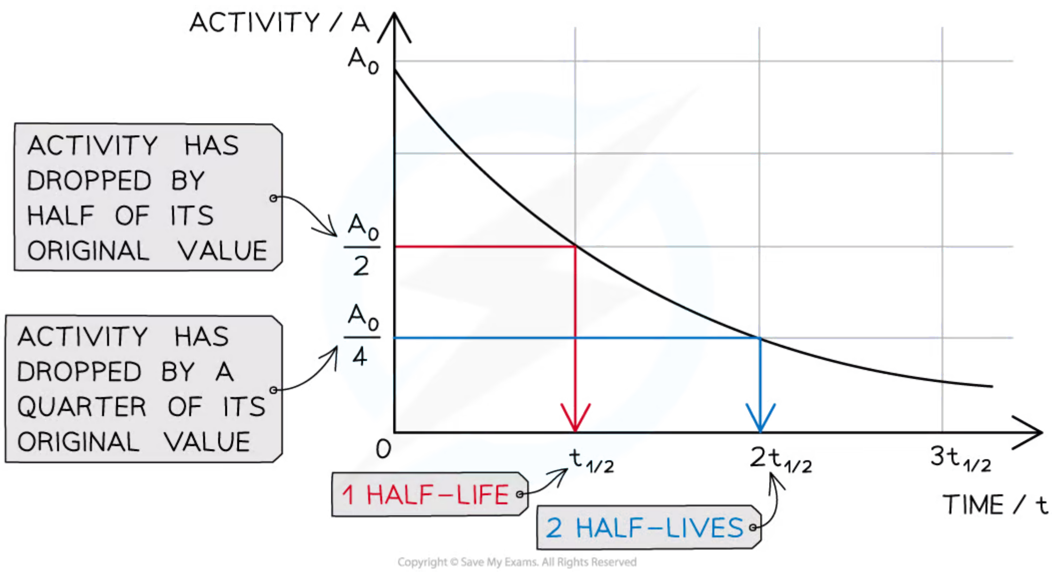
Half-Life Basics

- It is impossible to know when a particular unstable nucleus will decay
- But the **rate** at which the activity of a sample decreases can be known
    - This is known as the **half-life**
- Half-life is defined as:

The time taken for half the nuclei of that isotope in any sample to decay

- In other words, the time it takes for the activity of a sample to fall to half its original level
- Different isotopes have different half-lives and half-lives can vary from a fraction of a second to billions of years in length
- Half-life can be determined from an activity-time graph



The graph shows how the activity of a radioactive sample changes over time. Each time the original activity halves, another half-life has passed

- The time it takes for the activity of the sample to decrease from 100 % to 50 % is the half-life
    - It is the same length of time as it would take to decrease from 50 % activity to 25 % activity
    - The half-life is **constant** for a particular isotope

- Half-life can also be represented on a table
    - As the number of half life increases, the proportion of the isotope remaining **halves**

Table For Number of Half Lives to Proportion of Isotope

NUMBER OF HALF-LIVES	PROPORTION OF ISOTOPE REMAINING
0	1
1	1/2
2	1/4
3	1/8
4	1/16
...	...

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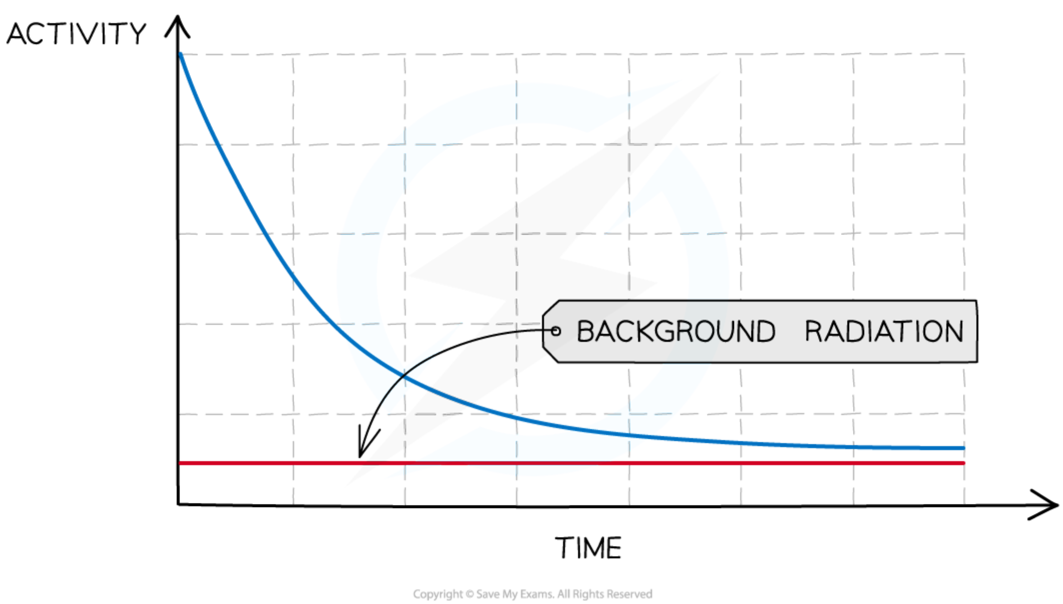
Half-Life Graphs

- To calculate the half-life of a sample from a graph:
    - Check the original activity (where the line crosses the y-axies), A_0
    - Halve this value and look for this activity
    - Go across from the halved value (on the y-axis) to the best fit curve, and then straight down to the x-axis
    - The point where you reach the x-axis should be the half-life
- The time taken for the activity to decrease to half its original value is the **half-life**

Background Radiation

- Background radiation is radiation that is always present in the environment around us
- As a consequence, whenever an experiment involving radiation is carried out, some of the radiation that is detected will be background radiation
- When carrying out experiments to measure half-life, the presence of background radiation must be taken into account



When measuring radioactive emissions, some of the detected radiation will be background

- To do this you must:
    - Start by measuring background radiation (with no sources present) – this is called your **background count**
    - Then carry out your experiment
    - Subtract the background count from each of your readings, in order to give a **corrected count**
    - The corrected count is your best estimate of the radiation emitted from the source, and should be used to measure its half-life

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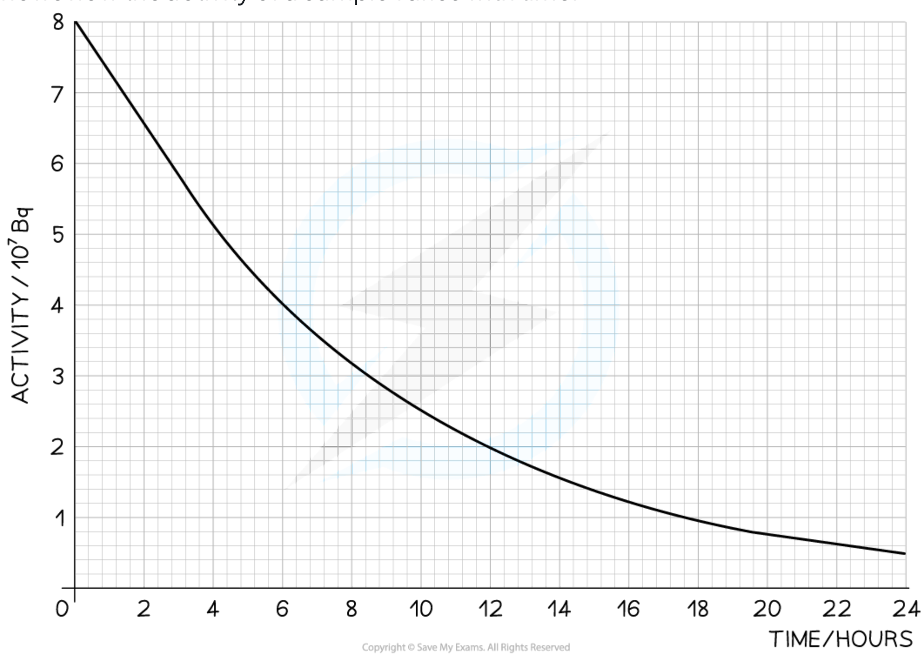
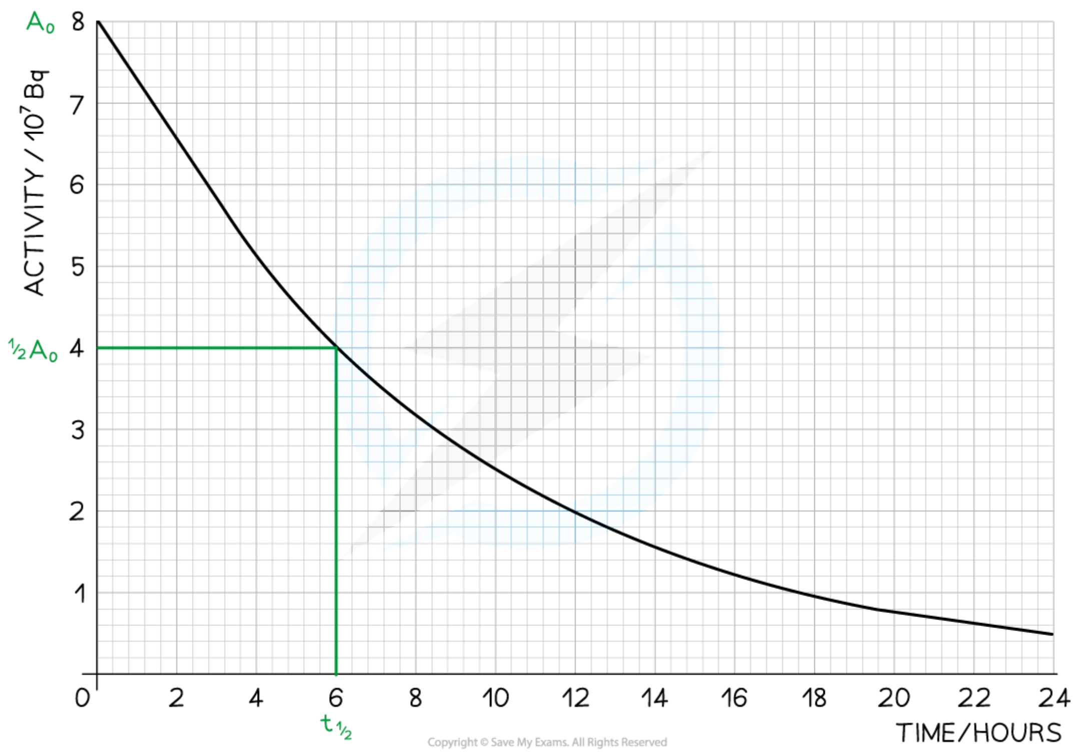
Worked Example

The radioisotope technetium is used extensively in medicine. The graph below shows how the activity of a sample varies with time.



Determine the half-life of this material.

Step 1: Draw lines on the graph to determine the time it takes for technetium to drop to half of its original activity



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Step 2: Read the half-life from the graph

- In the diagram above the initial activity, A_0, is 8×10^7 Bq
- The time taken to decrease to 4×10^7 Bq, or ½ A_0, is 6 hours
- The time taken to decrease to 2×10^7 Bq is 6 **more** hours
- The time taken to decrease to 1×10^7 Bq is 6 **more** hours
- Therefore, the half-life of this isotope is **6 hours**

Worked Example

A particular radioactive sample contains 2 million un-decayed atoms. After a year, there is only 500 000 atoms left un-decayed. What is the half-life of this material?

Step 1: Calculate how many times the number of un-decayed atoms has halved

- There were 2 000 000 atoms to start with
- **1 000 000** atoms would remain after **1 half-life**
- **500 000** atoms would remain after **2 half-lives**
- Therefore, the sample has undergone 2 half-lives

Step 2: Divide the time period by the number of half-lives

- The time period is a year
- The number of half-lives is 2
- 1 year divided by 2 is half a year or 6 months
- Therefore, the half-life is **6 months**

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Exam Tip

When looking for the corresponding time for the activity, it is good practice to draw a line on the graph with your ruler like is done in the mark scheme of the worked example. This ensures you're reading the most accurate value possible.

5.2.6 Uses of Radiation

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Uses of Radiation

- Radiation is used in a number of different ways:
  1. Medical procedures including diagnosis and treatment of cancer
  2. Sterilising food (irradiating food to kill bacteria)
  3. Sterilising medical equipment (using gamma rays)
  4. Determining the age of ancient artefacts
  5. Checking the thickness of materials
  6. Smoke detectors (alarms)

- The properties of the different types of radiation determine which one is used in a particular application

Smoke Detectors

- Alpha particles are used in smoke detectors
- The alpha radiation will normally **ionise** the air within the detector, creating a current
- The alpha emitter is blocked when smoke enters the detector
- The alarm is triggered by a microchip when the sensor no longer detects alpha

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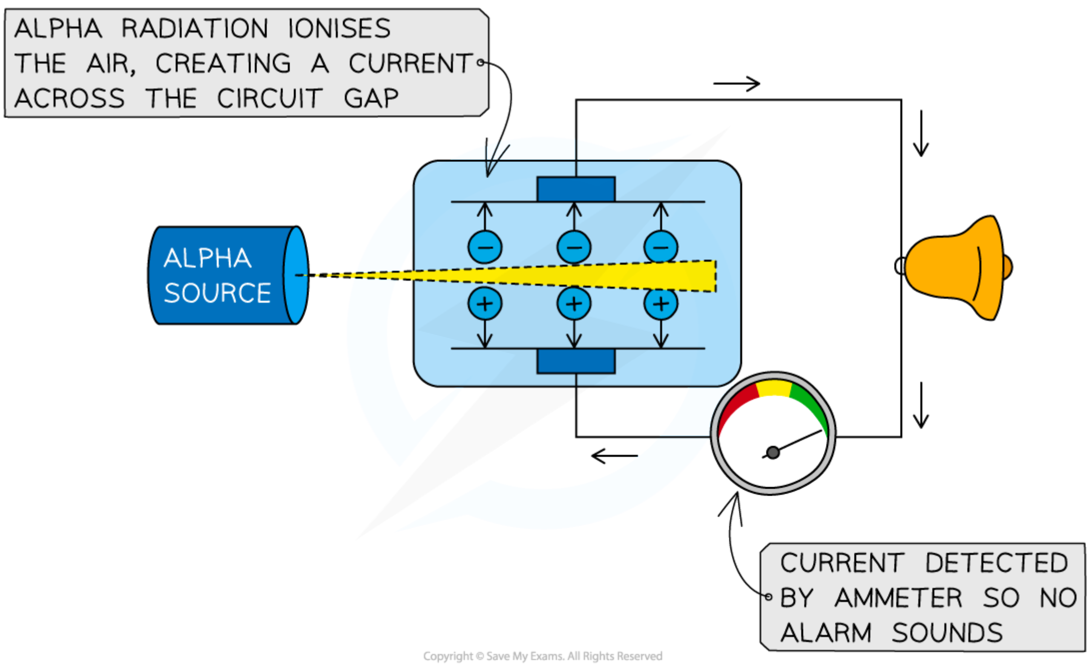

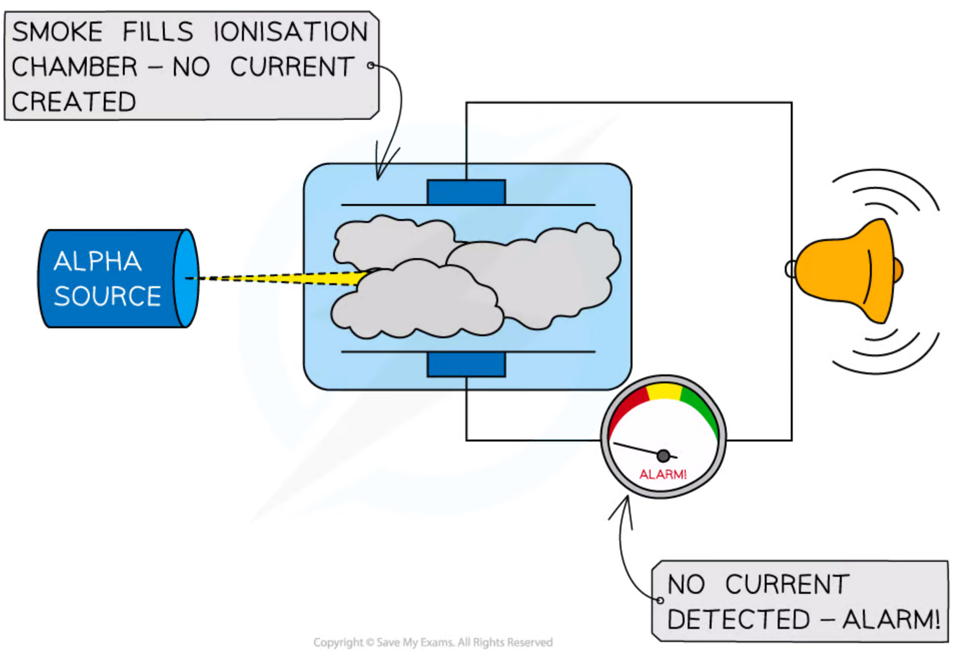

In the diagram on the right, alpha particles are stopped by the smoke, preventing the flow of current and triggering the alarm

Measuring the Thickness of Materials

- Radiation can be used for tracing and gauging thickness
  - Mostly commonly this is **beta** particles
- As a material moves above a **beta** source, the particles that are able to penetrate it can be monitored using a detector

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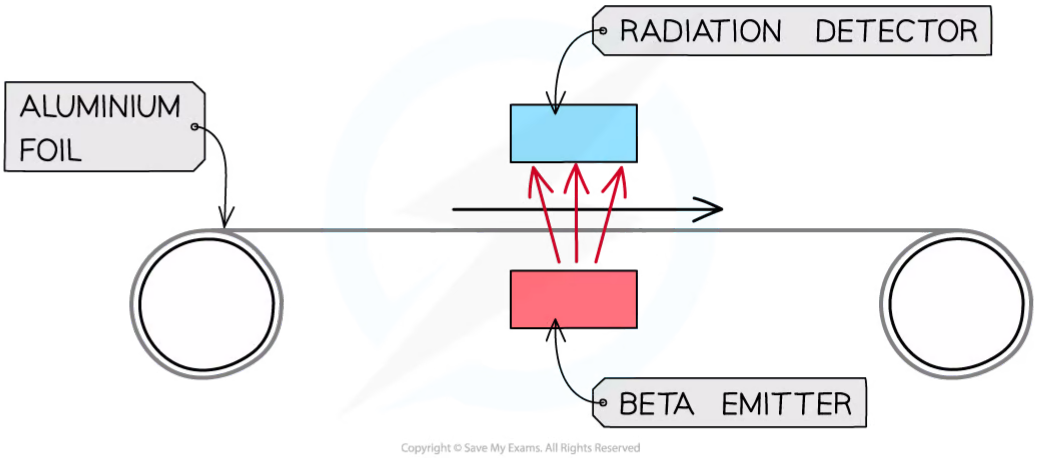
- If the material gets **thicker, more** particles will be absorbed, meaning that **less** will get through
  - If the material gets **thinner** the **opposite** happens
- This allows the machine to make **adjustments** to keep the thickness of the material **constant**



Beta particles can be used to measure the thickness of thin materials such as paper, cardboard or aluminium foil

- Beta radiation is used because it will be **partially absorbed** by the material
  - If **alpha** particles were used **all of them would be absorbed** and none would get through
  - If **gamma** were used almost **all of it would get through** and the detector would not be able to sense any difference if the thickness were to change

Diagnosis and Treatment of Cancer

- **Radiotherapy** is the name given to the treatment of cancer using radiation (Chemotherapy is treatment using chemicals)
- Although radiation can cause cancer, it is also highly effective at **treating** it
- Radiation can kill living cells. Some cells, such as bacteria and cancer cells, are more susceptible to radiation than others
- Beams of gamma rays are directed at the cancerous tumour
  - Gamma rays are used because they are **able to penetrate the body**, reaching the tumour
  - The beams are moved around to minimise harm to healthy tissue whilst still being aimed at the tumour
- A **tracer** is a radioactive isotope that can be used to track the movement of substances, like blood, around the body
  - A PET scan can detect the emissions from a tracer to diagnose cancer and determine the location of a tumour

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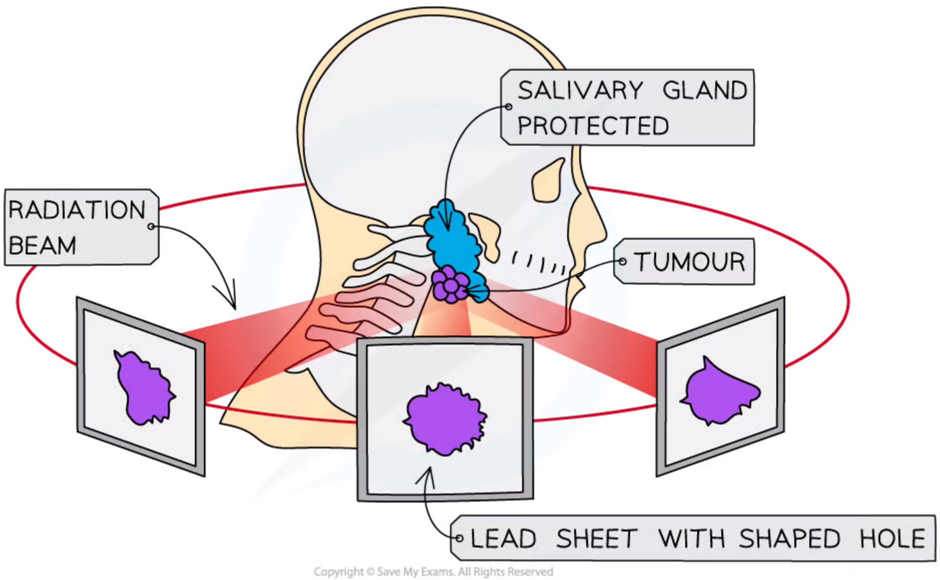

Radiation therapy to remove a tumour

Sterilising Food and Medical Equipment

- Gamma radiation is widely used to **sterilise** medical equipment
- Gamma is most suited to this because:
  - It is the most **penetrating** out of all the types of radiation
  - It is penetrating enough to irradiate **all sides** of the instruments
  - Instruments can be sterilised without removing the **packaging**

- Food can be irradiated in order to **kill any microorganisms** that are present on it
- This makes the food last longer, and reduces the risk of food-borne infections

Food that has been irradiated carries this symbol, called the Radura. Different countries allow different foods to be irradiated

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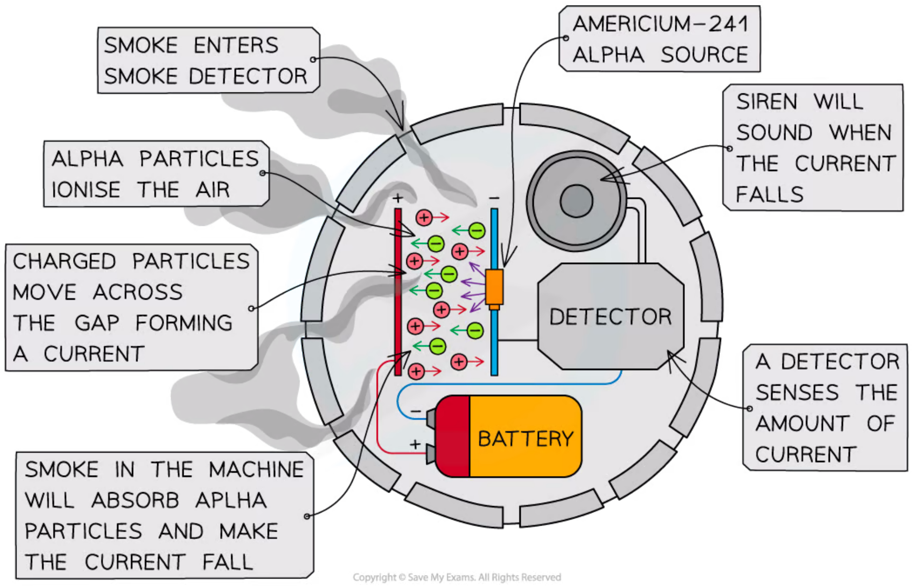
Worked Example

Use the diagram to explain why is alpha radiation used in smoke detectors, and not beta or gamma radiation.



- Consider the different properties of alpha, beta and gamma:
  - **Alpha** is the most **weakly** penetrating and **strongest** ioniser
  - **Beta** and **gamma** have **stronger** penetrating power and **weaker** ionising power
- If beta or gamma radiation were used in this situation then they would pass straight through the smoke and the alarm would not go off
- Therefore, since alpha is **absorbed** by smoke, and beta and gamma are not, this makes it **most suitable** for use in a smoke detector

Exam Tip

If you are presented with an unfamiliar situation in your exam don't panic! Just apply your understanding of the properties of alpha, beta and gamma radiation. Mainly think about the range (how far it can travel) and ionising power of the radiation to help understand which radiation is used in which situation.

5.2.7 Dangers of Radiation

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Dangers of Radioactivity

- Ionising radiation can damage human cells and tissues at high doses:
- This could be in terms of:
    1. Cell death
    2. Tissue damage
    3. Mutations
    4. Cancer

- As a result, its use needs to be kept to a minimum
- However, the benefits of using radiation in medicine can out way the potential risks
    - The risks posed by the radiation are smaller than the risks associated with leaving the condition untreated

- For example, if a person has a cancerous tumour that is likely to kill them, then it is **less** of a risk to use radiotherapy than to leave the tumour

Tissue Damage

- Radiation is effectively used to destroy cancerous tumour cells
- However, it can cause damage to healthy tissue if it is not properly targeted
- This is mostly from high-energy radiation such as gamma rays and X-rays

Mutations

- If the atoms that make up a DNA strand are ionised then the DNA strand can be damaged
- If the DNA is damaged then the cell may die, or the DNA may be **mutated** when it reforms
- If a mutated cell is able to replicate itself then a **tumour** may form
    - This is an example of **cancer**, which is a significant danger of radiation exposure

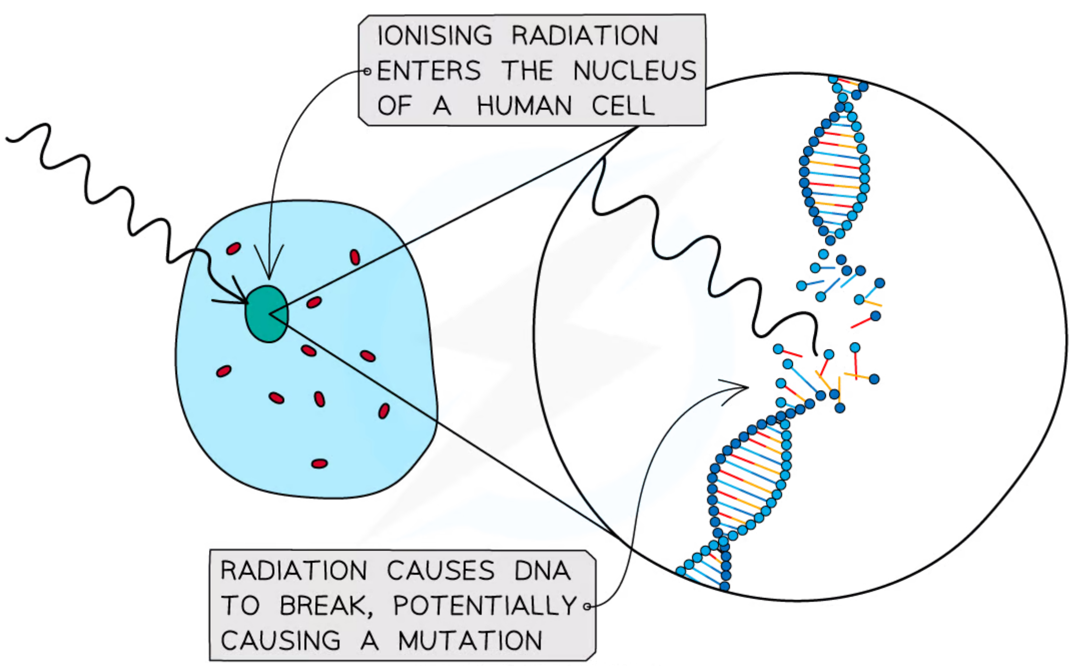

Diagram showing the damage caused to DNA by ionising radiation. Sometimes the cell is able to successfully repair the DNA, but incorrect repairs can cause a mutation

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- Acute radiation exposure can have other serious symptoms:
  - It can cause skin **burns**, similar to severe sunburn
  - Radiation can **reduce** the amount of **white blood cells** in the body, making a person more susceptible to infections by lowering their immune system
- Because of this, it is very important to handle radioactive sources carefully

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Safe Storage

- The risks associated with handling radioactive sources can be minimised by following a few simple procedures:
  - Store the sources in lead-lined boxes and keep at a distance from people
  - Minimise the amount of time you handle sources for and return them to their boxes as soon as you have finished using them
  - During use, keep yourself (and other people) as far from the sources as feasible. When handling the sources do so at arm's length, using a pair of tongs

Radioactivity warning sign

- When using tongs, gloves and safety specs are usually unnecessary when handling radioactive materials, unless there is a risk of the material leaking on to things

Disposing of Radioactive Waste

- If an isotope has a long half-life then a sample of it will decay slowly
  - Although it may not emit a lot of radiation, it will **remain radioactive for a very long time**
- Sources with long half-life values present a risk of contamination for a much longer time
- Radioactive waste with a long half-life is buried underground to prevent it from being released into the environment

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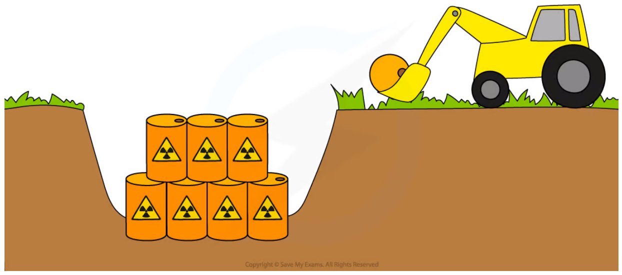

Radioactive waste with long half lifes are buried deep underground

Worked Example

A student plans to use a gamma source to conduct an experiment. List four things that the student should do in order to minimise the risk to themselves when using the source.

Any four from:

- Keep the source in a lead lined container until the time it is needed
- Use tongs to move the source, rather than handling it directly
- The source should be kept at as far a distance from the student as possible during the experiment
- The time that the source is being used should be minimised
- After the experiment the student should wash their hands
- The date and the time that the radiation has been used for should be recorded

Safety Precautions

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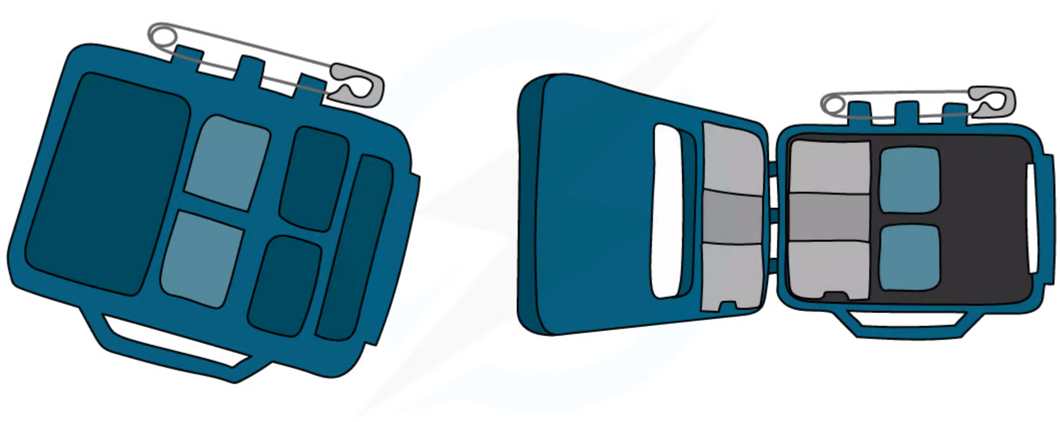
EXTENDED

- To mitigate the risks of radiation exposure, there are some safe practices that should be used:
  - Radioactive sources should be kept in a **shielded container** when not in use, for example, a lead-lined box
  - Radioactive materials should only be handled when wearing **gloves**, and with **tongs** to increase the distance from them
  - It may be appropriate to wear **protective clothing** to prevent the body becoming contaminated
  - The **time** that a radioactive source is being used for should be **limited**

Regulating Exposure

- Because of the harmful effects of radiation, it is important to **regulate** the exposure of humans to radiation
- The amount of radiation received by a person is called the dose and is measured in **sieverts** (Sv)
- One sievert is a very big dose of radiation
  - It would cause acute **radiation poisoning**

- People would normally receive about 3 mSv (0.003 Sv) in one year
- To protect against over-exposure, the dose received by different activities is measured
- A dosemeter measures the amount of radiation in particular areas and is often worn my radiographers, or anyone working with radiation



A dosemeter, or radiation badge, can be worn by a person working with radiation in order to keep track of the amount of radiation they are receiving

Differences in Exposure

- The amount of radiation that a person receives is affected by a person's **occupation, lifestyle** or **location**

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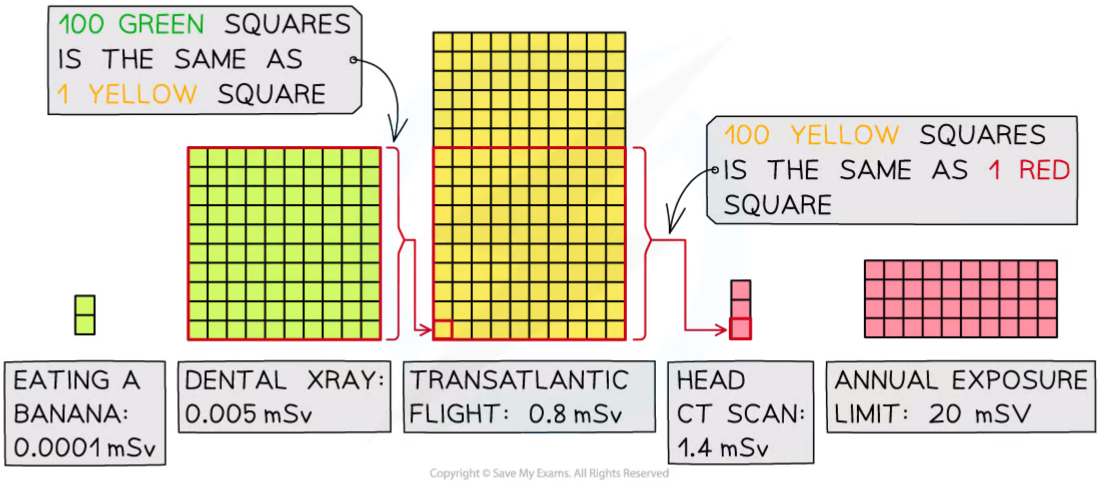
- Some areas around the world have higher **background radiation** because they are closer to sources of radiation
- People that work with nuclear radiation receive more radiation
  - The UK limit for nuclear industry employees is 20 mSv in one year
- The diagram below compares the dose received by some different activities



All living things emit a small amount of radiation: the amount of radiation within a banana is tiny, and not at all dangerous!

1 **(a)** An iodine isotope $^{131}_{53}\text{I}$ decays by β-emission to an isotope of xenon (Xe).

(i) State the number of each type of particle in a neutral atom of $^{131}_{53}\text{I}$.

protons .... neutrons .... electrons .... [2]

(ii) State the symbol, in nuclide notation, for the xenon nucleus.

....[2]

(b) The background count rate of radioactivity in a laboratory is 30 counts / min.

A radioactive sample has a half-life of 50 minutes. The sample is placed at a fixed distance from a detector. The detector measures an initial count rate from the sample, including background, of 310 counts / min.

On Fig. 10.1, plot suitable points and draw a graph of the count rate from the sample, **corrected for background**, as it changes with time.

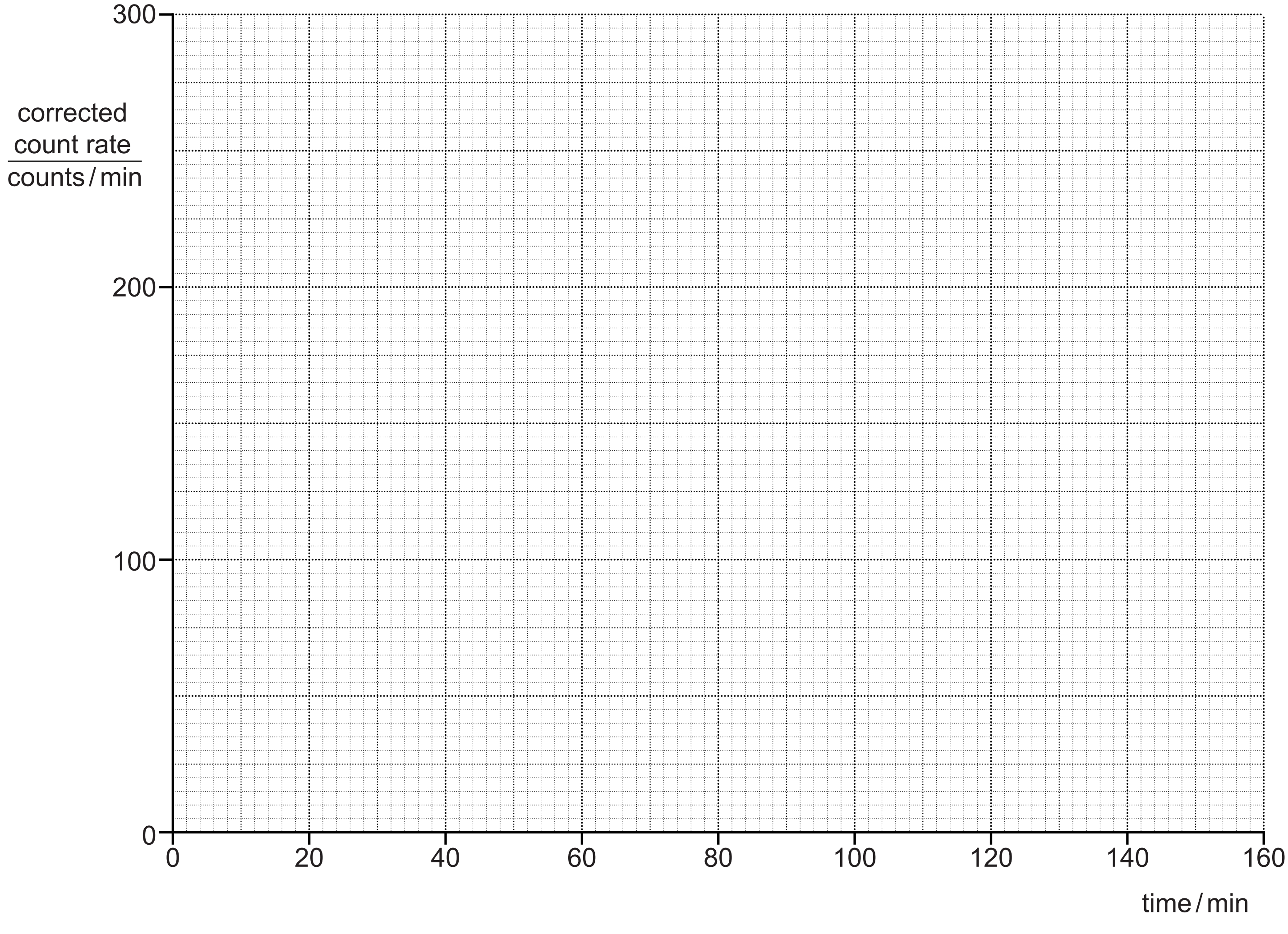


Fig. 10.1

[3]

[Total: 7]

2 Emissions from a radioactive source pass through a hole in a lead screen and into a magnetic field, as shown in Fig. 10.1. The experiment is carried out in a vacuum.

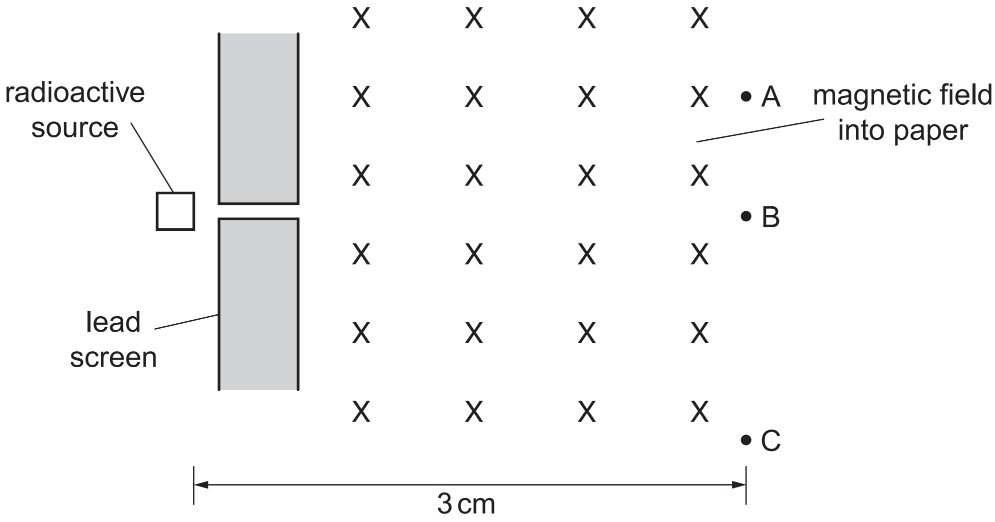


Fig. 10.1

Radiation detectors are placed at A, B and C. They give the following readings:

A		C
32 counts / min	5 counts / min	3 counts / min

The radioactive source is then completely removed, and the readings become:

A		C
33 counts / min	counts / min	counts / min

From the data given for positions A, B and C, deduce the type of emissions coming from the radioactive source. Explain your reasoning.

[7]

[Total: 7]

3 **(a)** State the nature of γ-rays.

....

.... [1]

(b) A beam of α-particles and β-particles passes, in a vacuum, between the poles of a strong magnet.

Compare the deflections of the paths of the two types of particle.

....

....

.... [2]

(c) A beam of β-particles passes, in a vacuum, through the electric field between a pair of oppositely charged metal plates.

Describe the path of the particles.

....

....

.... [2]

(d) The nuclear equation shows the decay of an isotope of polonium.

$$^{A}_{Z}\mathrm{Po} \rightarrow {}^{206}_{82}\mathrm{Pb} + {}^{4}_{2}\mathrm{X}$$

(i) State the nature of X.

....

.... [1]

(ii) Calculate the values of A and Z.

A = ... Z = ... [1]

[Total: 7]

4 **(a)** State the nature of an α-particle.

....

....[1]

(b) Describe how an electric field between two charged plates could be used to determine whether a beam of particles consists of α- or β-particles.

....

....

....[2]

(c) Describe the path of γ-rays in a magnetic field.

....

....[1]

(d) State what is meant by the term *isotopes*. Use the terms proton number and nucleon number in your explanation.

....

....

....

....

....[3]

[Total: 7]

5 **(a)** An underground water pipe has cracked and water is leaking into the surrounding ground.

Fig. 11.1 shows a technician locating the position of the leak.

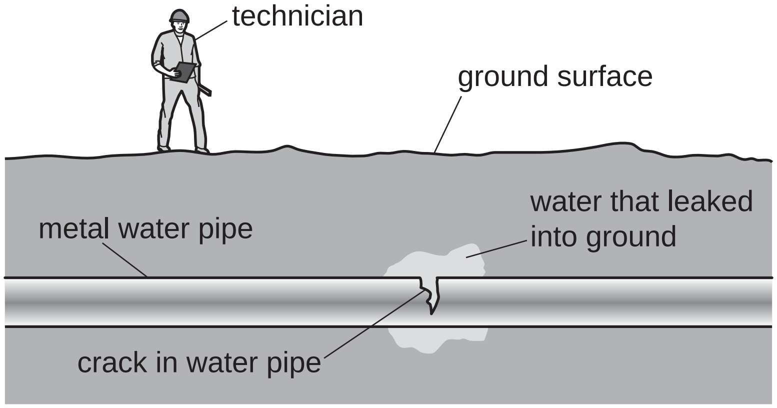


Fig. 11.1

A radioactive isotope is introduced into the water supply and the water that leaks from the crack is radioactive.

The technician tries to locate an area above the pipe where the radioactive count rate is higher than in the surrounding area.

(i) State and explain the type of radiation that must be emitted by the isotope for the leak to be detected.

....

....

....[2]

(ii) The half-life of the isotope used is 6.0 hours.

Explain why an isotope with this half-life is suitable.

....

....

....

....[2]

(b) Caesium-133 is a stable isotope of the element caesium, but caesium-135 is radioactive.

A nucleus of caesium-133 contains 78 neutrons and a nucleus of caesium-135 contains 80 neutrons.

Put **one** tick in each row of the table to indicate how the number of particles in a neutral atom of caesium-133 compares with the number of particles in a neutral atom of caesium-135.

The first row has been completed already.

	particles in caesium-133				
	2 more than caesium-135	1 more than caesium-135	equal to caesium-135	1 fewer than caesium-135	2 fewer than caesium-135
number of neutrons					✓
number of protons					
number of nucleons					
number of electrons					

[2]

[Total: 6]

6 **(a)** The counter of a radiation detector placed close to a radioactive source gives a count rate of 1600 counts / s. The half-life of the source is 1 week.

Ignoring background radiation, calculate the count rate

(i) 1 week after the first measurement,

count rate = ...[1]

(ii) 3 weeks after the first measurement.

count rate = ...[1]

(b) Fig. 11.1 shows the arrangement for an experiment to investigate the shielding of radioactive sources.

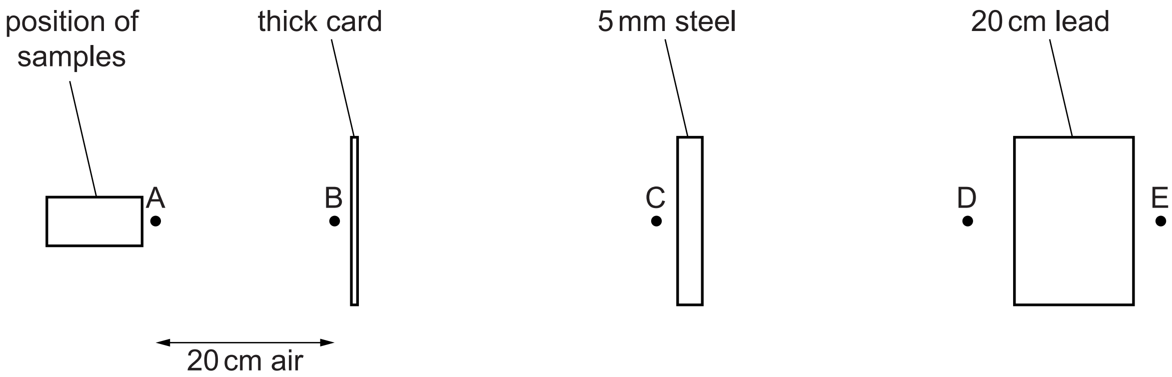


Fig. 11.1 (not to scale)

Samples containing three different radioactive sources are placed, one at a time, in the position shown.

The table shows the count rates when a radiation detector is placed at the positions A to E.

Complete the table to indicate whether α-particles, β-particles or γ-rays are emitted from each sample.

	A	B	C	D	E	type of radiation emitted
sample 1	high	high	high	high	low	
sample 2	high	high	low	0	0	
sample 3	high	0	0	0	0	

[3]

(c) State which type of radiation, α, β or γ, is the most strongly ionising.

....[1]

[Total: 6]

7 **(a)** Complete the table below for the three types of radiation.

radiation	nature	charge	stopped by
γ	electromagnetic radiation		
β		negative	
α			thick paper

[3]

(b) An isotope of strontium is represented in nuclide notation as ${}^{90}_{38}Sr$.

For a neutral atom of this isotope, state

(i) the proton number, ...

(ii) the nucleon number, ...

(iii) the number of neutrons, ...

(iv) the number of electrons. ....

[3]

(c) A sample of a radioactive material is placed near a radiation detector. A count-rate of 4800 counts/s is detected from the sample. After 36 hours the count-rate has fallen to 600 counts/s.

Calculate how many more hours must pass for the count-rate to become 150 counts/s.

number of hours = ... [3]

[Total: 9]