Whitley Academy

Physics Paper 1 (H) Knowledge Recall Booklet

Paper Physics 1H 8464/P/1H

For this paper, the following list shows the major focus of the content of the exam:

- 6.1.1 Energy changes in a system, and the ways energy is stored before and after such changes
- 6.2.4 Energy transfers
- 6.3.1 Changes of state and the particle model
- 6.3.3 Particle model and pressure
- 6.4.1 Atoms and isotopes
- 6.4.2 Atoms and nuclear radiation

Required practical activities that **will be assessed**:

- Required practical activity 14: an investigation to determine the specific heat capacity of one or more materials. The investigation will involve linking the decrease of one energy store (or work done) to the increase in temperature and subsequent increase in thermal energy stored.
- Required practical activity 16: use circuit diagrams to construct appropriate circuits to investigate the I–V characteristics of a variety of circuit elements, including a filament lamp, a diode and a resistor at constant temperature.

Your teacher will tell you specific topic areas to focus on …

Topic	RAG			Revision technique					Date completed	Teacher Signed
	R	A	G	Flashcards	Mindmap	Notes	Video Watched (With notes)	Frog resource		

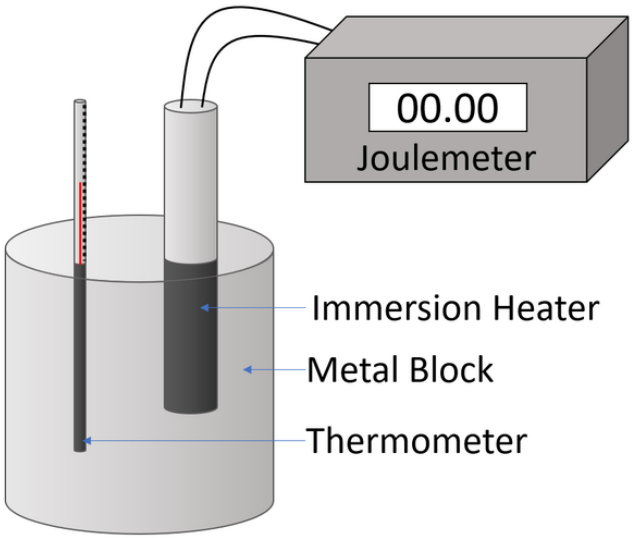
Required Practical – How to find the Specific Heat Capacity

Recall it …

Use the information in the following page(s) to answer these questions …

1. What equipment is needed for the practical?
2. Outline all the steps / method for this investigation in sufficient detail.
3. What is the formula to find the specific heat capacity?

Required Practical - Specific Heat Capacity



- Use a balance to find the mass of your metal block.
- Wrap the metal block in insulating material.
- Place an immersion heater into the metal block. Connect this to a joulemeter.
- Use a thermometer to find the start temperature of the metal block.
- Use the immersion heater to heat the metal block for at least 20 minutes. Use the thermometer to read the new temperature.
- Use the joulemeter to see how much energy was transferred into the metal block.
- Use the temperature change and energy to determine the specific heat capacity of the metal.
- Repeat the experiment using a different type of metal block.

Specific Heat Capacity

The specific heat capacity of a substance is the amount of energy required to raise the temperature of 1 kg of the substance by 1°C.

$$c = \frac{\Delta E}{m\Delta\theta}$$

$$\Delta E = mc\Delta\theta$$

m = mass (kg)
c = specific heat capacity (J/kg°C)
ΔE = change in thermal energy (J)
$\Delta\theta$= change in temperature (°C)

Find the specific heat capacity of the metal block by re-arranging

$$\Delta E = mc\Delta\theta$$

into:

$$c = \frac{\Delta E}{m\Delta\theta}$$

Required Practical – Finding the I/V characteristics of different electrical components

Recall it …

Use the information in the following page(s) to answer these questions …

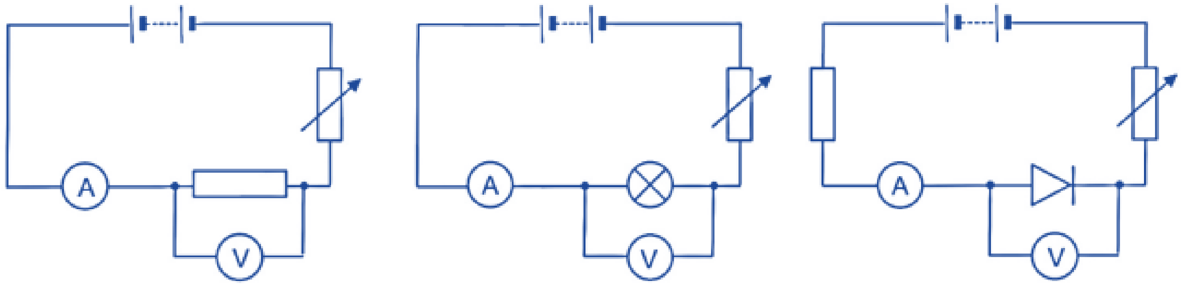
1. Name the three components that we are trying the find the I/V characteristics to?
2. Sketch the three circuits that need to be made?
3. Describe the method for the investigation?
4. Sketch the graphs for the results that you would find for resistor at constant temperature, filament lamp and diode?

Required Practical – Investigating the I/V characteristics of a filament lamp, diode and resistor at constant temperature

What happens to the current through a component when the potential difference across it changes?

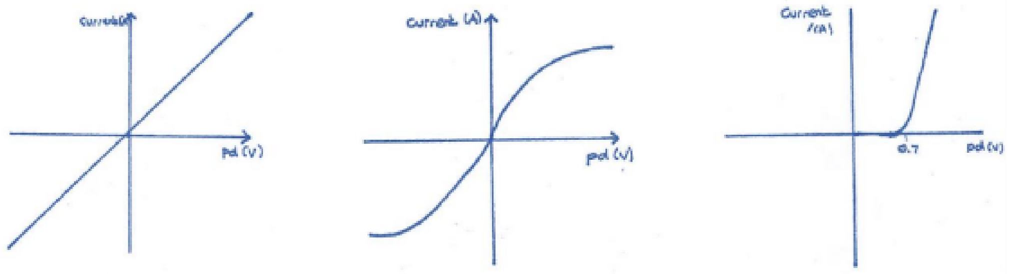
① Draw a circuit diagram to investigate the behaviour of a resistor, a lamp and a diode. In each one you are going to measure electric current in the component as you change the potential difference across it.

Resistor Lamp Diode



② Describe how you could use the circuits you drew to investigate the I-V characteristics of a filament lamp, a diode and a resistor at constant temperature.

- record the readings on the ammeter and voltmeter
- adjust the variable resistor and record the new ammeter and voltmeter readings
- repeat this to obtain several pairs of readings
- repeat for negative values
- plot a graph of current in *A* against potential difference in *V*
- expected graphs for resistor, lamp and diode:



Recall it ...

Energy

Use the information in the following page(s) to answer these questions …

1. What is an energy system?
2. What is the law of conservation of energy?
3. Describe the energy transformation in a motor?
4. Name 8 energy stores?
5. Describe the energy change when a ball in thrown upwards?
6. Describe the energy change when a ball is hitting an object?
7. Describe the energy change when a vehicle is slowing down?
8. Describe the energy change when bringing water to boil on a camping stove?
9. What is mechanical work? Give a worked example of how the formula for force or work can be used?
10. What is electrical work? Give a worked example of how electrical work is calculated?

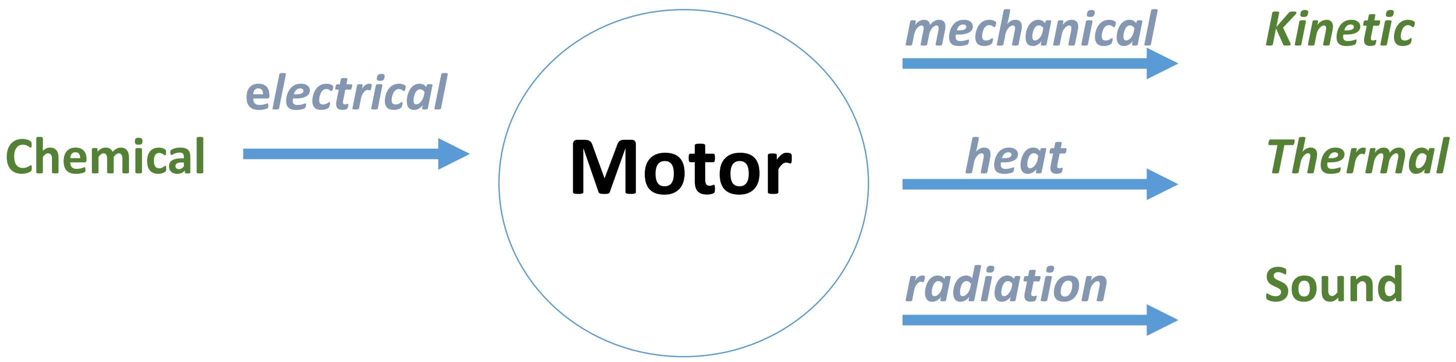
Energy stores and systems

An energy system is a group of objects that have the ability to do work.

Remember: energy can not be created or destroyed so when work is done, energy from one store is carried along a pathway to another energy store.

Consider the energy flow diagram for an electric shaver.

The battery has a store of chemical energy.
The current flows through an electrical pathway to the motor.
Energy from the motor follows a mechanical pathway to a kinetic store of the moving blades, a heat pathway to a thermal store and a radiation pathway to a sound store.



Energy stores and systems

Energy stores	Examples
Chemical	In food, fuel and electric batteries
Kinetic	In moving objects
Gravitational potential	In objects raised above a planets surface
Elastic potential	In a stretched, compressed or twisted object
Internal (thermal)	In any heated object
Magnetic	In any object with a magnetic field
Electrostatic	In electrostatic forces between charges
Nuclear	The forces acting between atomic nuclei

Force pathways include:

- Mechanically – when a force acts and an object moves
- Electrically – when an electric current flows
- Heating – a temperature difference between objects
- Radiation – electromagnetic waves or sound

Energy stores and systems

Examples of energy changes in a system:

An object thrown (projected) upwards e.g. You throw a tennis ball upwards.

- As the **ball leaves** your **hand** it has a **store** of **kinetic energy**.
- At its **highest point** it has a **store** of **gravitational potential energy (G.P.E)**.
- As you are about to catch it just **before it hits your hand** it has a **store** of **kinetic energy.**

A moving object hitting an obstacle e.g. A bowling ball hitting a pin

- As you move the muscles of your arm to throw the ball the **chemical energy store** in your muscles **decreases** and the **kinetic energy store** of the bowling ball **increases**.
- At the ball hits a pin some of the **kinetic energy** has been transferred to a **store** of **internal (thermal) energy** this causes the ball and its surroundings to warm up a little.
- You will hear a **sound** when the ball hits the pin, the **energy of the sound** is also transferred to the **internal energy store** of the **surroundings**.

Energy stores and systems

Examples of energy changes in a system:

A vehicle slowing down e.g. When you apply the brakes in a lorry

- The **moving** lorry has a **store** of **kinetic energy**.
- At the **brakes** are applied the **kinetic energy store decreases** the energy is transferred to the **internal (thermal) energy store** in the brakes and the brakes get hot.
- You will hear a **sound** when the brakes of the lorry are applied, the **energy of the sound** is also transferred to the **internal energy store** of the **surroundings**.
- When the lorry **stops** its **kinetic energy store** is **zero**.

Bringing water to a boil on a camping stove.

- As the fuel burns the **chemical energy store** in the fuel **decreases** and the **internal (thermal) energy store** of the water **increases.**
- The temperature of the water increases and as bubbles form the **kinetic energy store** of the water increases.

Energy is measured in Joules (J)

1 kilojoule (kJ) = 1000 J (10^3J)

1 megajoule = 1000 000 J (10^6J)

Energy stores and systems

Energy change – mechanical work is the amount of energy transferred by a force

When a pushback truck is used to move an aircraft, it does work.

Work (J) = Force (N) x Distance (along the line of the force) (m).

$$W = F s$$

If the aircraft has a mass of 30 000kg and it is moved a distance of 20m, calculate the work done by the pushback truck.

Force (weight) = mass x gravitational field strength

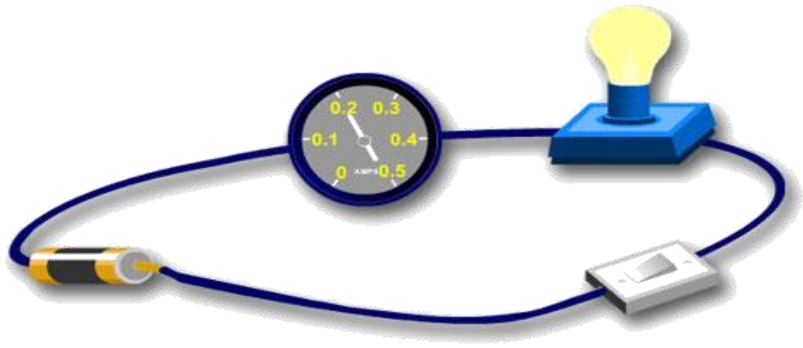
Force = 30 000 x 10 = 300 000 N

$$W = F\ s$$

Work = 300 000 x 20 = <u>6 000 000 J (6 MJ)</u>

Energy stores and systems

Energy change – Electrical work is done when charge flows in a circuit is the amount of energy transferred.



When a current flows through a circuit, work is done (energy is transferred) and the energy store changes.

Energy transferred (Work) (J) = Charge flow (Q) x Potential difference (V)

$$E = Q V$$

In one minute, 30 Coulombs of charge flows through the bulb when a potential difference of 3 V is placed across it. Calculate the work done (energy transferred).

$$E = Q V$$

$$E = 3 \times 30$$

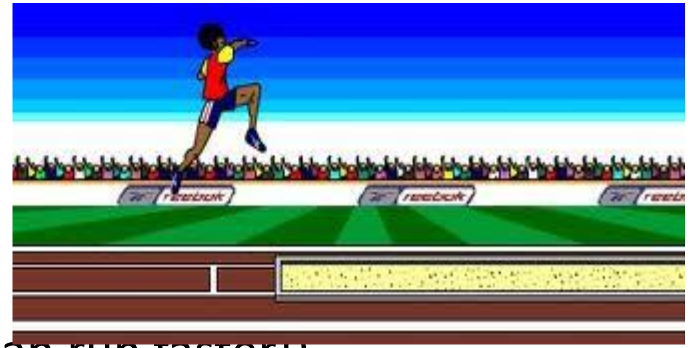
Energy transferred (Work) = <u>90 J</u>

Recall it … Energy Calculations

Use the information in the following page(s) to answer these questions …

1. Give a worked example of how kinetic energy is calculated?
2. What is elastic energy? Give a worked example of how elastic energy is calculated?
3. What is gravitational potential energy? Give a worked example of how gravitational potential energy is calculated?
4. How does the energy store of a metal change when it is heated?
5. What is specific heat capacity?
6. What is the specific heat capacity equation? Give a worked example of how this equation can be re-arranged to make specific heat capacity the subject?
7. What is meant by power?
8. Give an example of how power can be calculated?

Changes in Energy - Kinetic Energy



Moving objects have kinetic energy.

The long-jumper is using her **kinetic energy** to carry her body as far as possible. The more kinetic energy she has, the longer her jump will be. Her kinetic energy depends on her mass (which she can not change) and her velocity (she can run faster!).

The kinetic energy of a moving object can be calculated using the equation:

Kinetic energy (J) = 0.5 × Mass (kg)× Speed² (m/s)

$$E_k = \frac{1}{2} m v^2$$

If her mass is 46 kg and she is travelling at 8 m/s, her kinetic energy during her jump will be:

$$E_k = \frac{1}{2} m v^2$$

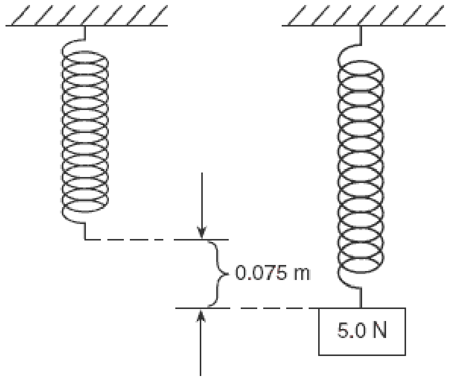
$$E_k = \frac{1}{2} \times 46 \times 8^2$$

The energy transferred in the jump is: E_k = **1472 J**

Changes in Energy - Elastic Energy

Stretched or bent objects have **elastic energy (E_e)** if they have the ability to **recover** to their original shape and dimensions.

When a weight (force) is added to a spring it extends (gets longer).
The spring now has a store of elastic potential energy which will be released if the weight is removed.



The amount of stored elastic energy (E_e) can be calculated using the following equation:

Elastic potential energy (J) = 0.5 × Spring constant (N/m) × Extension² (m)

$$E_e = \frac{1}{2} k e^2$$

In the above example the spring has a spring constant of 670 N/m. The elastic potential energy of the spring when a 50 N load is hung from it is:

$$E_e = \frac{1}{2} k e^2$$

$$E_e = 0.5 \times 670 \times 0.075^2$$

The elastic energy stored in the spring is: E_e = 1.88 J

Changes in Energy – Gravitational potential energy

When an object is raised above ground level it gains **gravitational potential energy** (GPE). This **stored energy** can be released if the object is allowed to **fall**.

A pile driver is a machine that lifts a heavy weight then drops it on a post to drive it into the ground.

The amount of gravitational potential energy (G.P.E) gained by an object raised above ground level can be calculated using the equation:

G.P.E (J) = Mass (kg) × Gravitational field strength (N/kg) × Height (m)

$$E_p = m\,g\,h$$

The pile driver hammer has a mass of 120 kg and it is raised to a height of 4 m above the ground. How much G.P.E will it have?

$$E_p = m\,g\,h$$

$$E_p = 120 \times 10 \times 4$$

The G.P.E gained is: $E_p = 4800$ J

The **thermal (internal) energy store** in a system changes if its **temperature changes**.

When metal is heated in a furnace the **thermal energy store** increases. The amount of energy gained depends on the **mass** of the metal, how much the **temperature increases** and the **specific heat capacity** of the metal.

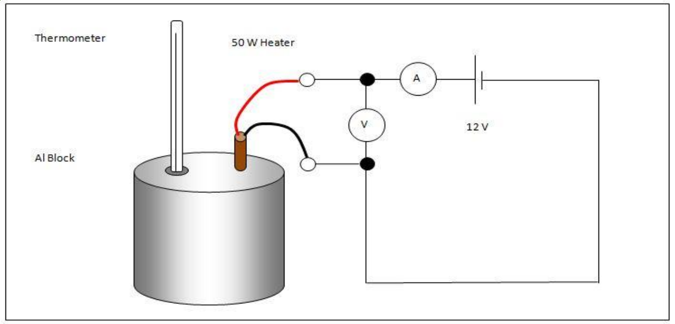
Specific Heat Capacity (*c*) – the amount of energy required to raise the temperature of 1 kg of a substance by one degree Celsius.

Steel has a specific heat capacity of 450 J/kg ^{o}C

Therefore a 1 kg block of steel needs 450 J of thermal energy adding to it to raise the temperature from 20 ^{o}C to 21 ^{o}C (1 ^{o}C rise).

Specific heat capacity

The apparatus shown can be used to determine the specific heat capacity of aluminium.



Example: When the heater was left on for 5 mins, the heater supplied 10 800 J of thermal energy to the aluminium block.

The temperature of the 2 kg block of aluminium rose by 6 ^{o}C.

The amount of energy stored in or released from a system as its temperature changes can be calculated using the equation:

Change in thermal energy (J) = Mass (kg) x Specific Heat Capacity J/kg^{o}C x Temperature Change (^{o}C)

$\Delta E = m \times c \times \Delta\theta$ rearrange to give $c = \Delta E / m \times \Delta\theta$

$c = 10\,800 / 2 \times 6$ **Specific heat capacity of aluminium = 900 J/kg ^{o}C**

Power

Power - the rate at which energy is transferred

the rate at which work is done (rate means "how quickly")

Power is measured in Joules / second 1 J/s = 1 Watt

An object which transfers energy does so at a certain rate.
The metal filament in this light bulb transfers the electrical energy store into heat and light.
This bulb transfers 2400 joules of energy in 60 seconds.

Power can be calculated using the following equation:

$$\text{Power (W)} = \frac{\text{Energy transferred (J)}}{\text{Time (s)}}$$

$$P = \frac{E}{t}$$

P= 2400 / 60 = 40 J/s

So this is a **40 Watt** light bulb.

Power

Power - the rate at which energy is transferred

the rate at which work is done (rate means "how quickly")

Mechanical power

Power = work done / time

The crane lifts the 2000 kg container through a height of 5.4m in 30s.
The power of the crane is:

Power = Work / time

But: Work = force x distance

= 20 000 N x 5.4 m = 108 000 J

Power = 108 000 J / 30 s

The Power of the crane is 3600 J/s or 3600 Watts

Electrical Power and Work done

Recall it ...

Use the information in the following page(s) to answer these questions ...

1. What is electrical power?
2. Give the two formula for how to calculated electrical power?
3. Provide worked examples for both formula?
4. Describe the energy transformation of motors, light bulbs and heaters?
5. What are the two formula to calculate work done in electric circuits?
6. Provide worked examples for both formula?
7. What is the national grid? What do step up and step down transformers do in the national grid?
8. Explain why high voltages are used in the national grid? What happens to current when voltages are increased and decreased?
9. Where to you find step up and step down transformers?

Power

Power: When electrical appliances are connected into a circuit energy is transferred to the appliance. The rate at which energy is transferred to the appliance is the power rating of the appliance.

To calculate the power of an electrical component:

Power (W)= Potential Difference (V) x Current (A)

$$P = V\,I$$

An alternative equation for calculating power is:

Power = (current)^2 x Resistance

$$P = I^2\,R$$

Name	Equation symbol	Unit	Unit Symbol
Power	P	Watts	W
Potential difference	V	Volts	V
Current	I	Amp	A
Resisitance	R	Ohms	Ω

Power Equations

Example

A microwave oven is powered by mains electricity at 230 V. The microwave oven has a power rating of 800 W.

Calculate the current flowing in the microwave oven.

Solution:

State the equation: P= VI

Rearrange: I = P/ V

Substitution: I= 800 / 230

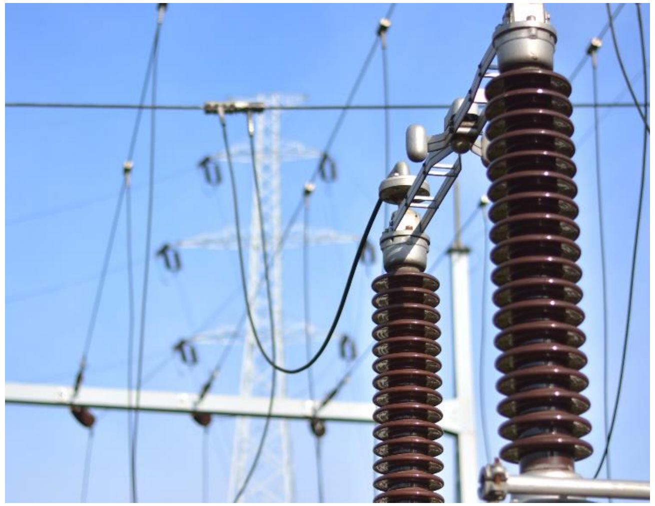
Answer: I= 3.5 A (to 1 decimal place)

Power Equations… continued

Example:

An overhead powerline is 100 miles long and carries a current of 400 A. The powerline has a resistance of 27.5 Ω.

Calculate the power loss in the 100 mile length of powerline.



Solution:

State the equation: $P = (I)^2 \times R$

Substitution: $P = (400)^2 \times 27.5$

Answer: P = 4.4 MW or 4 400 000 W

Therefore the power loss in the overhead powerline is 4.4 MW per 100 miles of cable.

Energy Transfers in Everyday Appliances

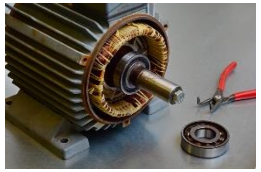
Everyday electrical appliances are designed to bring about energy transfers.

The amount of energy an appliance transfers depends on how long the appliance is switched on for and the power of the appliance.

Electrical appliances convert electrical energy from ac mains, or from batteries into more useful forms.

Some common energy transfers from electrical energy include…

- **motors converting electrical energy into kinetic energy**



- **lightbulbs converting electrical energy into light energy**

- **electric heaters converting electrical energy into heat energy.**

As with any energy transfer, some energy will be transferred usefully and some energy will be wasted (converted into forms that are not useful).

Work Done in Electrical Circuits
Work is done when charge flows in a circuit.

The amount of energy transferred by electrical work can be calculated using the equation:

Energy transferred (J) = Power (W) × Time (s)

$$E = P\,t$$

Also: Energy transferred = Charge flow (C) x Potential difference (V)

$$E = Q\,V$$

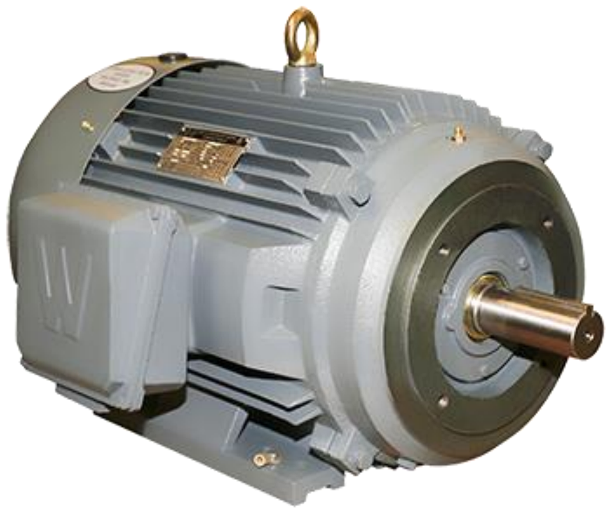
Name	Equation symbol	Unit	Unit Symbol
Energy transferred	E	Joules	J
Power	P	Watts	W
Time	t	Seconds	s
Charge flow	Q	Coulombs	C
Potential difference	V	Volts	V

Using Equations for Energy Transferred

Example:

An electric motor with a power rating of 5 kW is switched on for 2 minutes.

Work out the energy transferred by the electric motor.



Solution:

Conversion into standard units: 5000 W for power and 120 s for time.

State the equation: $E = P\,t$

Substitution: E= 5000 x 120

Answer: E= <u>600 000 J or 600 kJ</u>

Using Equations for Energy Transferred…continued

Example:

A different electric motor has a power rating of 8 kW. This electric motor runs off mains electricity at 230 V, 50 Hz ac.
Calculate the charge flow if this electric motor is left on for 1.5 minutes.

Solution:

Conversion into standard units: **8 kW = 8000 W and 1.5 minutes = 90 seconds**

Calculate the energy transferred:

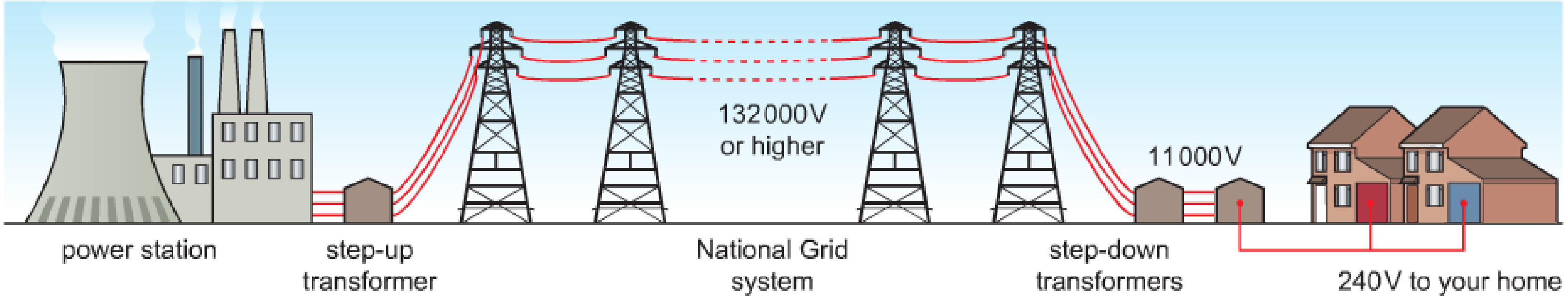
State the equation: $E = P\,t$
Substitution: E = 8000 x 90
Answer: E = 720 000 J

State the equation: $E = Q\,V$
Rearrange: $Q = E/V$
Substitution: Q = 720 000/ 230
Answer: Q= 3130 C

The National Grid is a system of cables and transformers linking power stations to consumers e.g. homes, shops, factories an.

Electrical power is transferred from power stations to consumers using:

The National Grid



- Step-up transformers are used to increase the potential difference from the power station to the transmission cables.
- Step-down transformers are used to decrease, to a much lower value, the potential difference for domestic use in homes.

Why are Transformers used in The National Grid?

Electric current generates heat as it moves through electrical wires.

If electricity is transmitted at a very high potential difference and low current this means less energy is wasted as heat making the whole system more efficient.

- **Step up transformers – Increase the potential difference and decrease the current.**
- **Step down transformers - Decrease the potential difference and Increase the current.**

A lower potential differences is used in the home as it is safer, so a step-down transformer is used near homes and offices.

Pylons carry overhead power cables

Particles and Pressure

Recall it ...

Use the information in the following page(s) to answer these questions …

1. What is density? How is it calculated? Give an example calculation for density?
2. Describe particles in solids, liquids and gases? Describe how density changes in solids, liquids and gases? What is the exception to this?
3. Describe how to find the density of an irregular object?
4. Describe 6 changes of state? How can we bring about a change in state?
5. What happens to mass during changes of state?
6. What is the difference between a physical change and a chemical change?
7. What is Brownian motion?
8. What causes gas pressure? Describe how different factors can increase gas pressure?
9. Describe and explain the link between gas pressure and temperature?

Density is the mass of a given volume of a substance

The density of a substance is determined by the mass of the atoms it is made from and how closely these atoms are packed together.

$$\text{Density} = \frac{\text{Mass}}{\text{Volume}}$$

mass in kg
volume in m^3

What is the density of a bar of gold if its volume is 350 cm^3 (0.00035 m^3) and its mass is 6.76 kg?

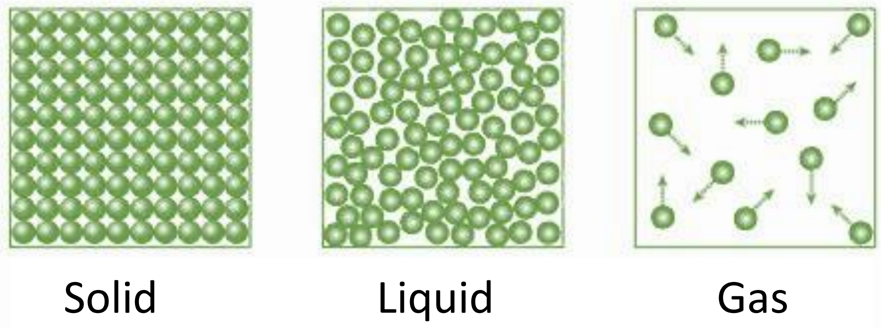
$$\text{Density } \rho = \frac{\text{mass (kg)}}{\text{volume (m}^3\text{)}} = \frac{6.76}{0.00035}$$

Density of gold = 19 314 kg/m^3

Substance	Density (kg/m^3)
Water (l)	1 000
Glass (s)	3 140
Iron (s)	7 700
Aluminium (s)	2 800
Hydrogen (g)	0.085

Changes of state and the particle model – Density of materials

Density also depends on the **state** of a substance.



In **solids** the particles are packed close together.

In **liquids** the particles are free to move so the same mass takes up more space.

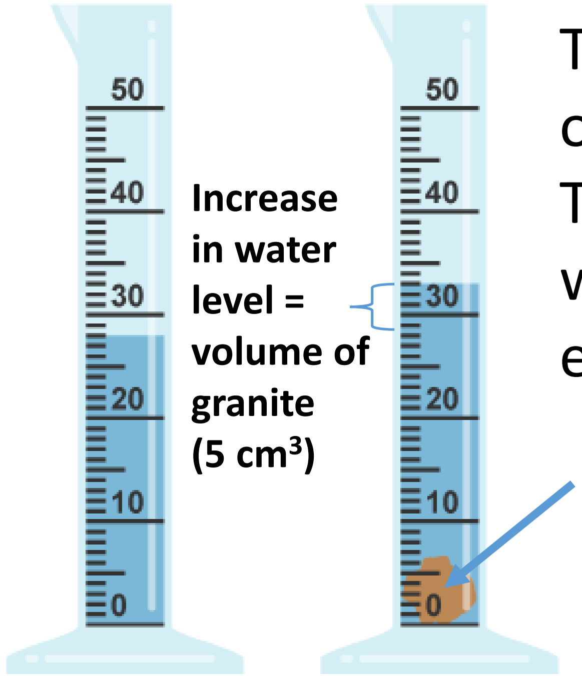
In **gases** the particles take up a much greater volume than in liquids and solids.

For any particular substance, a solid is usually denser than its liquid and the liquid is usually denser than the gas.

However, there are exceptions to this. Solid water (ice) is less dense than liquid water. This is why ice floats on water.

Changes of state and the particle model –Density of materials

Finding the density of an irregular object



To find the density of an **irregular** shaped object, you need to determine its volume. To do this, it is placed in a known volume of water and the amount of water **displaced** equals the volume of the object.

Piece of **granite** stone with a mass of 13.5 g (0.0135 kg)

Volume = 0.000005 m^3

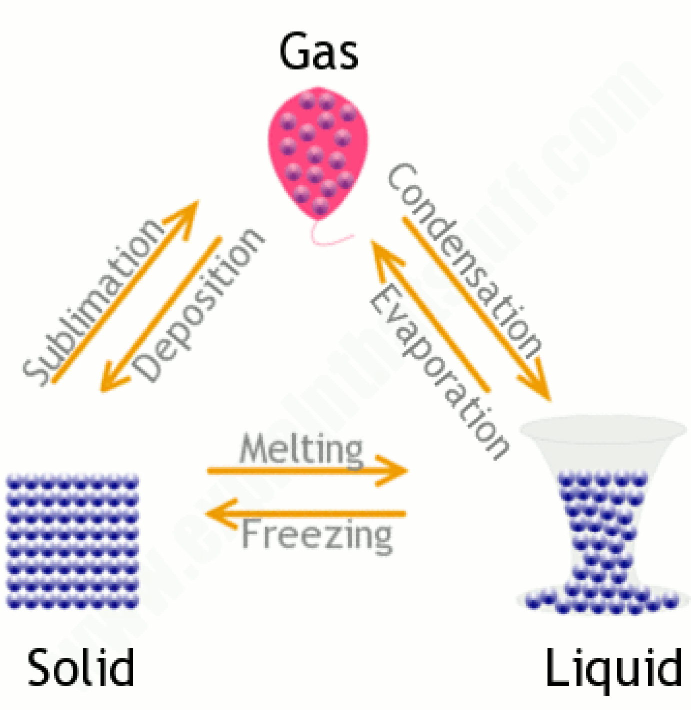
$$\text{Density of granite} = \frac{0.0135\ \text{kg}}{0.000005\ \text{m}^3} = 2\,690\ \text{kg/m}^3$$

Changes of state and the particle model – Changes of state

A change of state can be brought about by changing the **temperature** or **pressure** of a material.

If the solid shown has a mass of 1kg, then the liquid and gas will both have a mass of 1 kg.

Mass is conserved when a substance changes state, only the volume changes.

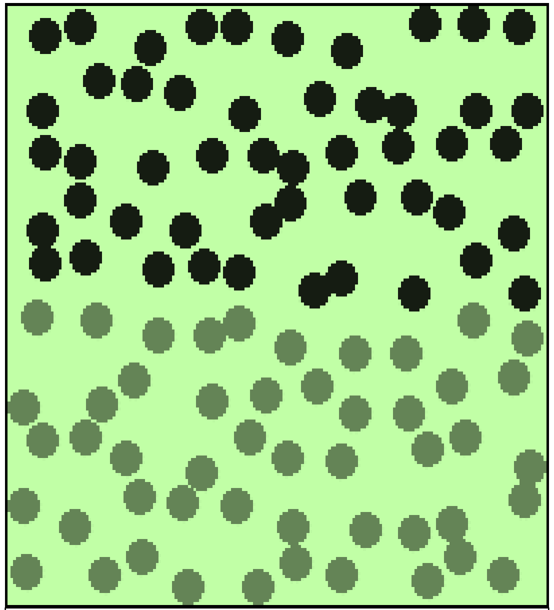


The arrows show the direction in change of state.

Changes of state are **physical changes not** chemical changes. The change can be **reversed** in a physical change so the material recovers its **original properties**. This does not happen with a chemical change.

Particle model and pressure- particle motion in gases

Molecules in a gas are in constant random motion (called Brownian motion)



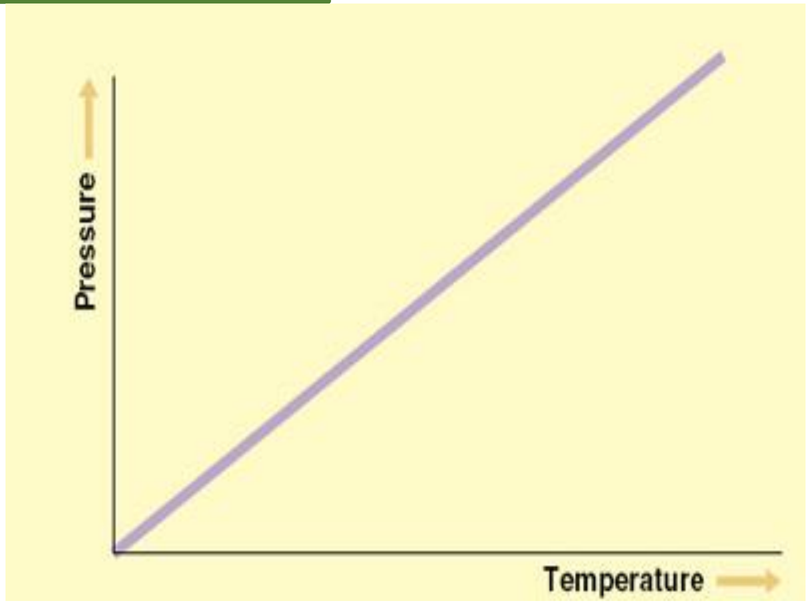
Particles of a gas inside a container have kinetic energy

- The **temperature** of this gas is related to the average **kinetic energy** of all the particles.
- If the temperature of the gas is increased, the particles will **move faster**.
- Faster moving particles exert a **greater force** on the walls of the container.
- This will either cause the container to **expand** (balloon) or **increase the pressure** of the gas (gas cylinder).

Particle model and pressure- particle motion in gases

If a sealed can of air (gas) is heated, the molecules of air move faster and faster.
The collisions of these molecules on the inside walls of the container create a pressure. The hotter the molecules, the faster they move and the more pressure they exert on the wall of the can.

If the can continues to be heated, the pressure will keep rising steadily.
The graph opposite shows that **gas pressure is directly related to its temperature**, if the volume remains constant.



Atoms and Isotopes

Recall it …

Use the information in the following page(s) to answer these questions …

1. What is the radius of an atom?
2. Describe the structure of an atom?
3. Describe the affect of electromagnetic radiation on electrons and energy levels?
4. What is a photon?
5. How do you find the number of protons, neutron and elections using the mass number and atomic number in the periodic table?
6. Describe what is an isotope giving an example?
7. Explain how ions are formed?
8. Describe the development of the atomic model explaining the difference between the plum pudding and nuclear model?
9. What did Rutherford do in the alpha scattering experiment?
10. What was Rutherford's observations and conclusions?

Structure of an atom

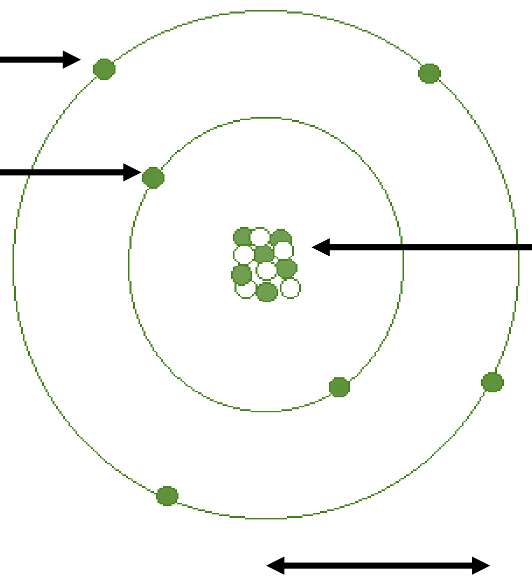
Atoms are made up of different numbers of protons, neutrons and electrons. Atoms have the same number of + protons as – electrons so they are electrically neutral.

An atom of Carbon

Electrons (-1 charge) arranged in **orbits or energy levels** around the nucleus.

Energy levels can hold a maximum of:
2 e^- in the first level
8 e^- in the second level
8 e^- in the third level

The radius of the nucleus is less than **1/10 000** the radius of the atom – the atom is **99.9999999%** empty space!



9 x 10^{13} atoms in this dot of ink

Nucleus made up of:

Protons: charge +1
Neutrons: charge 0

Nucleus of an atom has a positive charge

Radius of an atom **1×10^{-10}m**

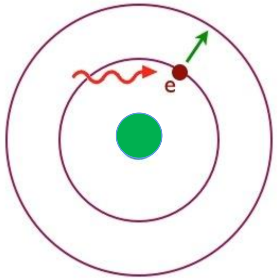
The nucleus holds **99%** of the mass of the atom

Structure of an atom

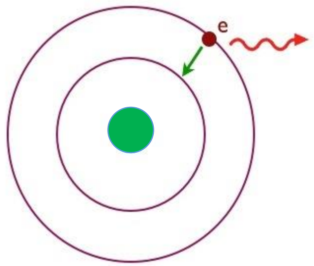
Electrons can absorb **electromagnetic radiation**. This excites the electron and can cause it to “jump” to a **higher energy level**.
It can then release this energy as an electromagnetic wave by falling back to its original energy level.

Electromagnetic radiation

absorbed by the electron causes it to move to a higher energy level.



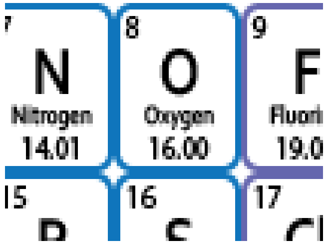
The electron can emit this stored energy as electromagnetic radiation.
As it loses energy the electron returns to its original energy level.

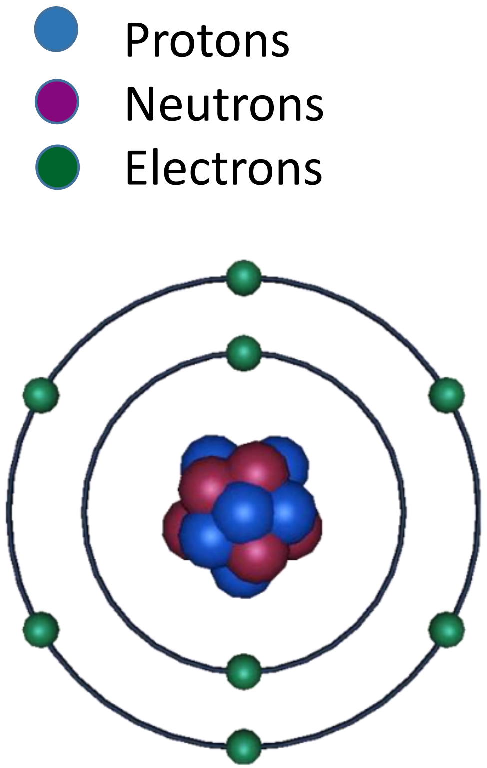


A photon is the amount of energy needed to make an electron jump an energy level. This same amount of energy will be emitted as a photon of electromagnetic radiation as the electron drops back to its original ground state.

Mass number, atomic number and isotopes

All atoms of a particular element have the **same number of protons**. The number of protons in an element is called its **atomic number**.





Protons
On the periodic table, **oxygen** is shown as having an **atomic number** of eight, therefore **8 protons**.

Neutrons
The total number of **protons and neutrons** in an atom is called its **mass number**.
Oxygen has a mass number of 16. If it has 8 protons it must therefore have **8 neutrons** to make a mass number of 16.

Electrons
Atoms are electrically neutral so there must be the **same number** of electrons (-) as protons (+); **8 electrons**.

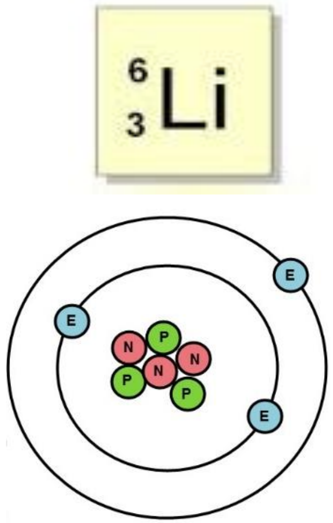
Oxygen has: 8 protons, (16 – 8) = 8 neutrons, and 8 electrons

Mass number, atomic number and isotopes

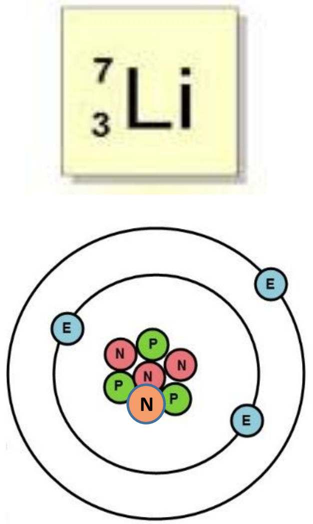
Isotopes are elements with **different atomic masses**.
The number of protons can not change or it would not be the same element so **an isotope is an element with different numbers of neutrons**.

Lithium has two stable isotopes, Lithium 6 and Lithium 7

Lithium 6 has
3 protons
3 neutrons



Lithium 7 has
3 protons
4 neutrons

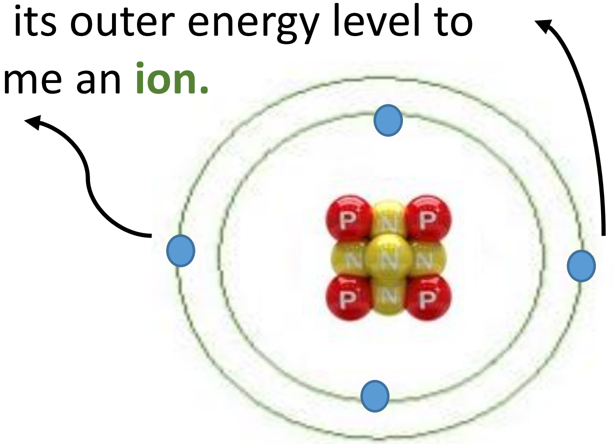


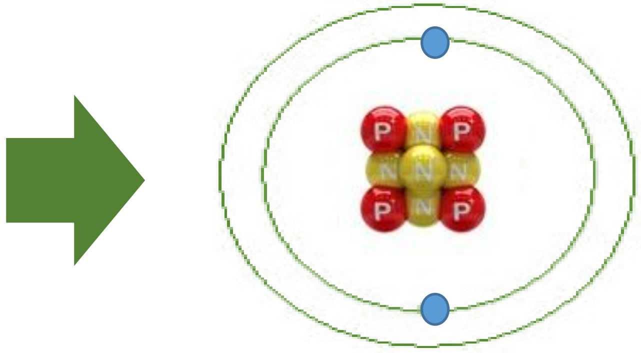
Both isotopes have the **same number of protons** and the **same number of electrons**.
Only the number of **neutrons changes** in an isotope.

Mass number, atomic number and isotopes

Atoms can form **ions** if they gain or lose **electrons.** Atoms do this so they have **full outer energy levels.**

Beryllium **can lose 2 electrons** from its outer energy level to become an **ion.**





If Beryllium
loses 2 e^-
it now has:

4 protons 4+
2 electrons 2-
2+

Berylium $^{2+}$

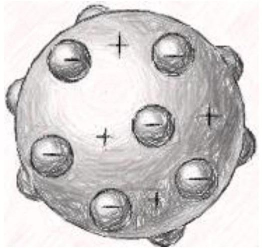
$$^{9}_{4}\mathrm{Be} \longrightarrow ^{9}_{4}\mathrm{Be}^{2+}$$

Atoms can **lose (-) electrons** to become **positive (+) ions** or **gain (-) electrons** to become **negative (-) ions**.

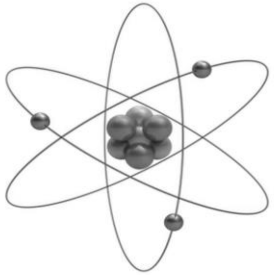
Development of the model of the atom

Pre 1900

Pre 1911



1911 to present

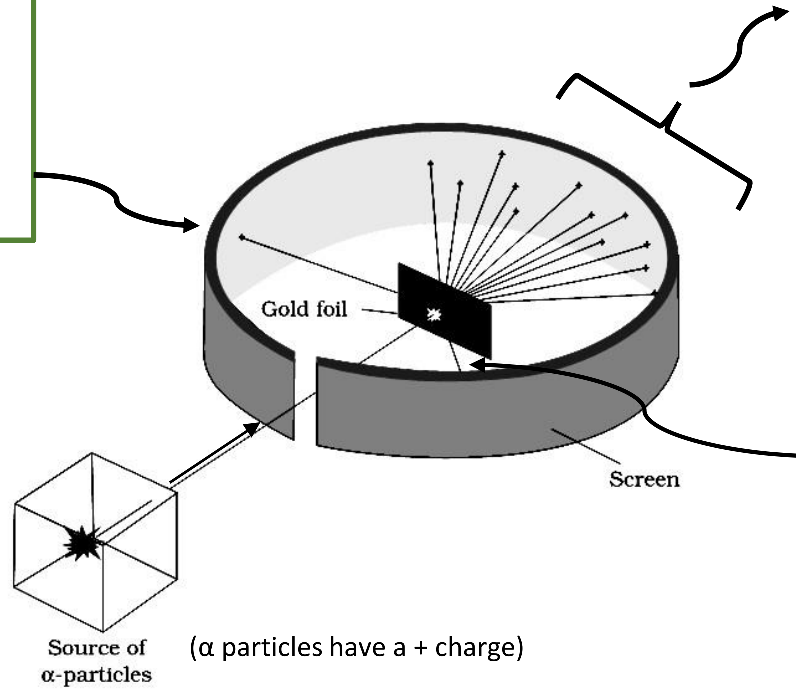


Sphere	Plum pudding model	Nuclear model
Before the **discovery of the electron**, atoms were thought to be **tiny spheres that could not be divided**.	The **discovery of the electron** led to the **plum pudding model** of the atom. The **plum pudding model** suggested the **atom is a ball of positive charge with negative electrons embedded in it**.	• **Alpha scattering experiment** – mass of the atom is concentrated in the **nucleus, which is charged**. • **Niels Bohr** – **electrons orbit nucleus** at **different distances**. • **Later experiments** – **positive charge in nucleus** divided into whole number of **smaller particles with positive charge**. • **James Chadwick** – 20 years after nucleus accepted – provided evidence for existence of **neutrons in nucleus**.

Rutherford's alpha scattering experiment

A beam of alpha particles are directed at a very thin gold foil screen.

A few (+) alpha particles are deflected by a positive nucleus within the gold atoms.



(α particles have a + charge)

Most (99.99%) of the alpha particles pass straight through the gold foil unaffected by its presence.

A tiny number of alpha particles are reflected because they collide with the nucleus of the gold atoms.

Rutherford concluded that the gold atoms are mostly empty space with a positively charged nucleus that contains nearly all the mass of the atom.

Nuclear Radiation

Recall it ...

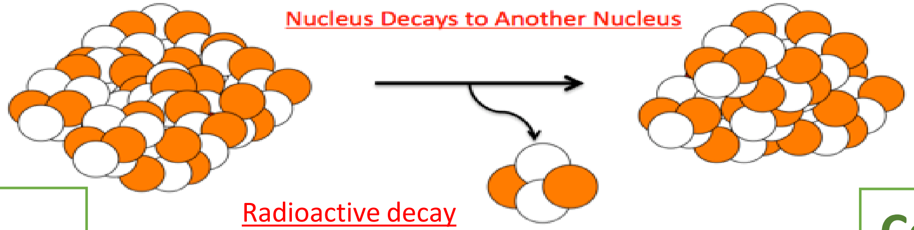
Use the information in the following page(s) to answer these questions ...

1. What happens when an atom decays?
2. How is radioactivity measured? Do all radioactive isotopes decay at the same rate?
3. What is alpha, beta and gamma radiation? What are the symbols for them?
4. What does alpha, beta and gamma radiation penetrate through? What blocks alpha, beta and gamma radiation?
5. What is ionisation? Describe the properties of alpha, beta and gamma radiation e.g. range in air, ionisation, speed?
6. Is radioactive decay random or fixed? What is meant by half life? How can you find out half life on a graph?
7. Describe what is irradiation?
8. Describe what is contamination?

Radioactive decay and nuclear radiation

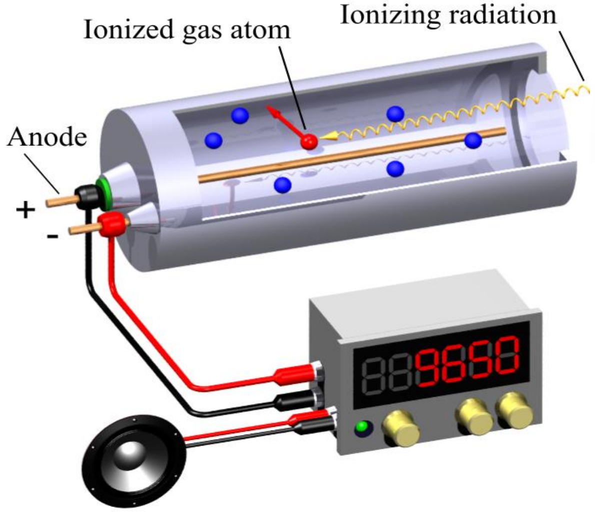
**The nuclei of some atoms are unstable.
To become more stable these nuclei give out radiation.
This process is called radioactive decay.**

Unstable atom



Stable atom

Activity = **rate at which a source of unstable nuclei decays**, measured in **becquerels (Bq).**



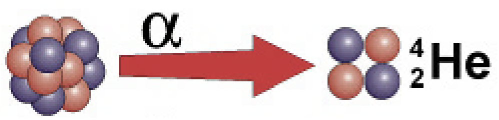
Radioactive rock

Count-rate = **number of decays recorded each second by a detector** (e.g. Geiger-Muller tube)

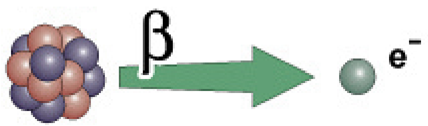
Different radioactive isotopes decay at different rates and emit different types of radiation.

Radioactive decay and nuclear radiation

There are three types of radioactive decay, **alpha, beta and gamma**. All come from the **nucleus of the atom**. In the examples below, only the nucleus is shown.



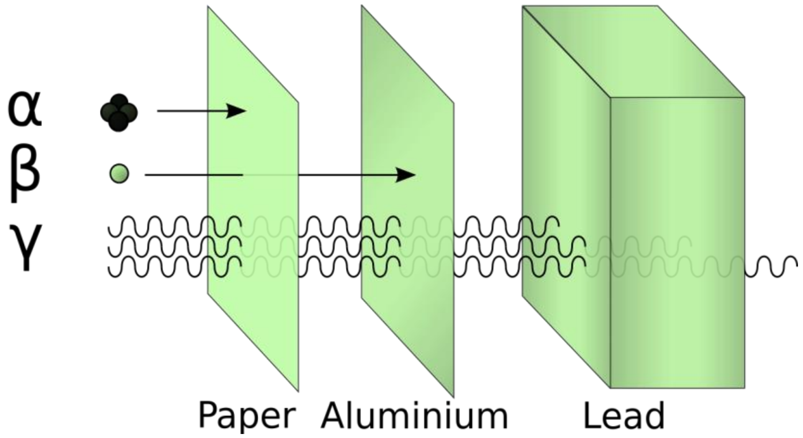
Alpha (symbol α or ^4_2He) consist of **2 protons and 2 neutrons** emitted from the nucleus. They have a **positive** charge as they contain 2 (+) protons.



Beta (symbol β or $^{0}_{-1}e$) consist of an **electron** emitted from the nucleus. This results from a neutron splitting into a proton and an electron. Beta particles are **negatively** charged.

Gamma rays (symbol γ) are **electromagnetic radiation** emitted from the nucleus. Gamma radiation has **no mass** and **no electrical charge.**

Properties of alpha, beta and gamma radiation.



Alpha, beta and gamma radiation can penetrate different materials due to their differing nature.

Alpha – easily stopped by **a few sheets of paper**.

Beta – penetrates paper but stopped by a thin **sheet of aluminium**.

Gamma – only stopped by **thick lead** or several metres of **concrete**.

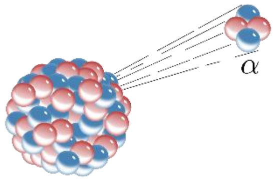
All three types of radiation cause **ionisation** of other atoms. If these atoms are in **living cells** it can cause damage which could lead to **cancer.**

Name	Symbol	Speed	Range in air	Ionising power
Alpha	α	Slowest	6 - 8 cm	High
Beta	β	Medium	1 – 2 m	Medium
Gamma	γ	Fastest	300 - 500 m	Low

Nuclear equations

Nuclear equations show the changes to an atom when it emits radiation.

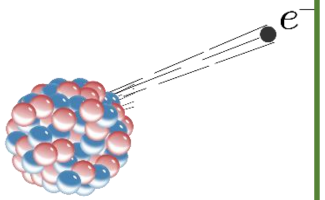
Alpha emission



Nucleus **loses 2 protons** and **2 neutrons**.
Atomic number will reduce by 2 and atomic mass by 4.

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

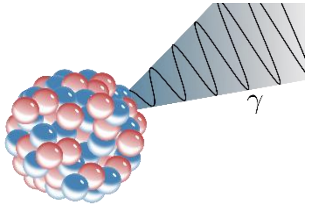
Beta emission



Nucleus **loses an electron** which is produced when a neutron turns into a proton. So **mass stays the same** but **atomic number of the product increases by one**.

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

Gamma emission



No particles are emitted so there is **no change to the nucleus**. Atomic mass and atomic number stay the same.

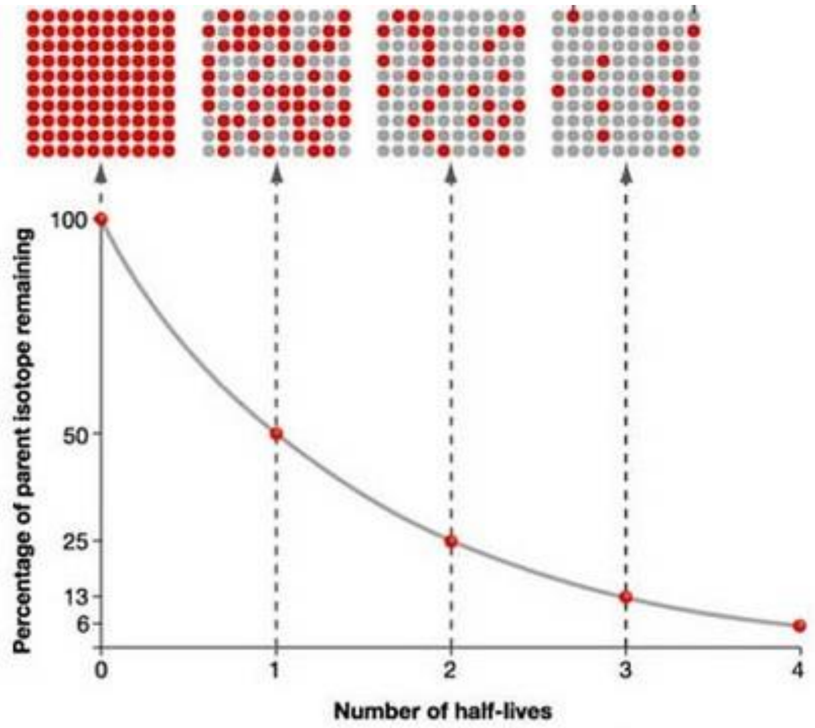
$$^{99}_{43}Tc \longrightarrow {}^{99}_{43}Tc + \gamma$$

Half life and the random nature of radioactive decay

Radioactive decay is a random process so the likelihood of a decay taking place is a probability problem. For this reason, the **half-life** of an isotope is given rather than saying how long it will take to fully decay.

The **half-life** of a radioactive isotope is the time it takes for the **number of nuclei** of the isotope in the sample to halve, or the time it takes for the **count rate** from a sample containing the isotope to fall to half its initial level.

The net decline of the isotope is the fraction remaining after a number of half lives.
E.g. 100 → 50 → 25
After 2 half lives net decline is 75/100 = **3/4**



Half life and the random nature of radioactive decay

Calculating the half life of a radioactive isotope.

If you know the start and finish count rate and the time taken, you can calculate the half life.

Example:

The count rate of an isotope is 1008 Bq. This falls to a count rate of 126 over a period of 21 days.

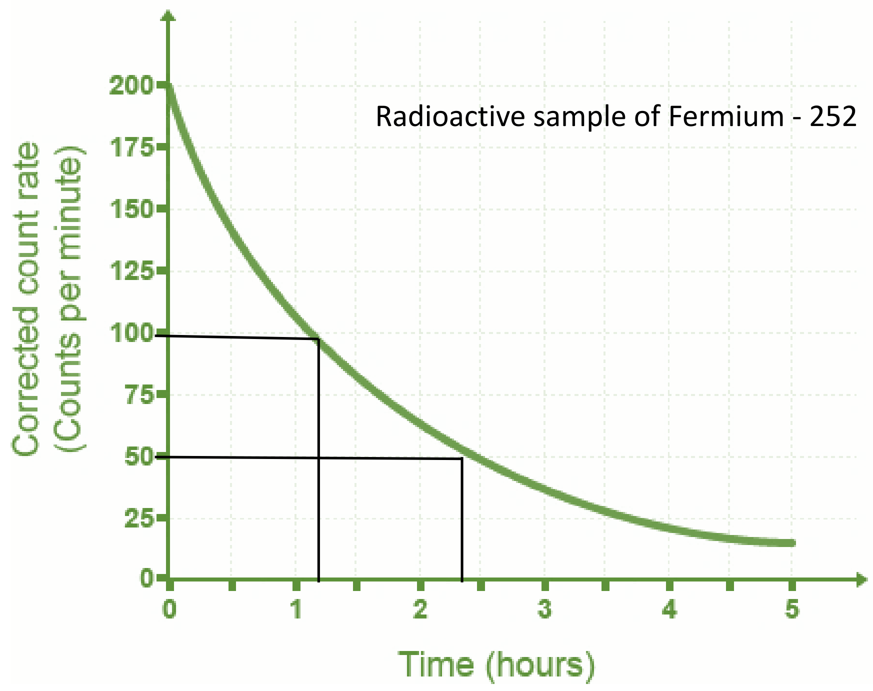
1008 → 504 → 252 → 126

1 2 3

3 half lives for count rate to fall to 126.

These 3 half lives took 21 days so each half life took 7 days.

Half life if this isotope = 7 days

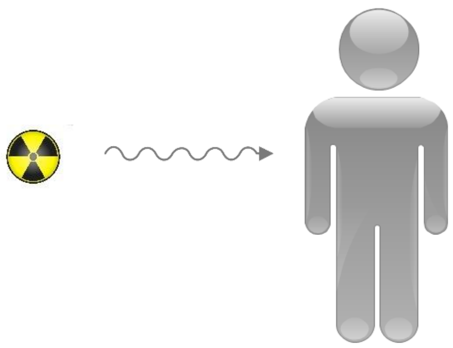


200 counts / min at the beginning.
100 counts/min occurred after 1.2 hours.
50 counts/min occurred after 2.4 hours.
It always takes 1.2 hours for the count rate to halve.

Half life of Fermium - 252 = 1.2 hours.

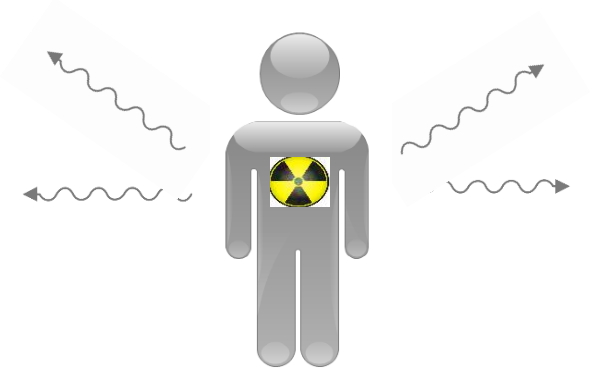
Radioactive substances can be hazardous by contamination or irradiation.

Irradiation is when an object or person is **exposed** to radiation. Protection from irradiation means stopping the radiation from reaching you.



Medical dressings are often irradiated but present no danger to the user.

Contamination is when a radioactive source is in **contact** with an object or person. The radioactive substance rather than the emissions are present.



The object remains radioactive until the contamination is removed or decays naturally.