Overview Physics P1 – Unit 3 Particle Model of Matter

Changes of state and the particle model

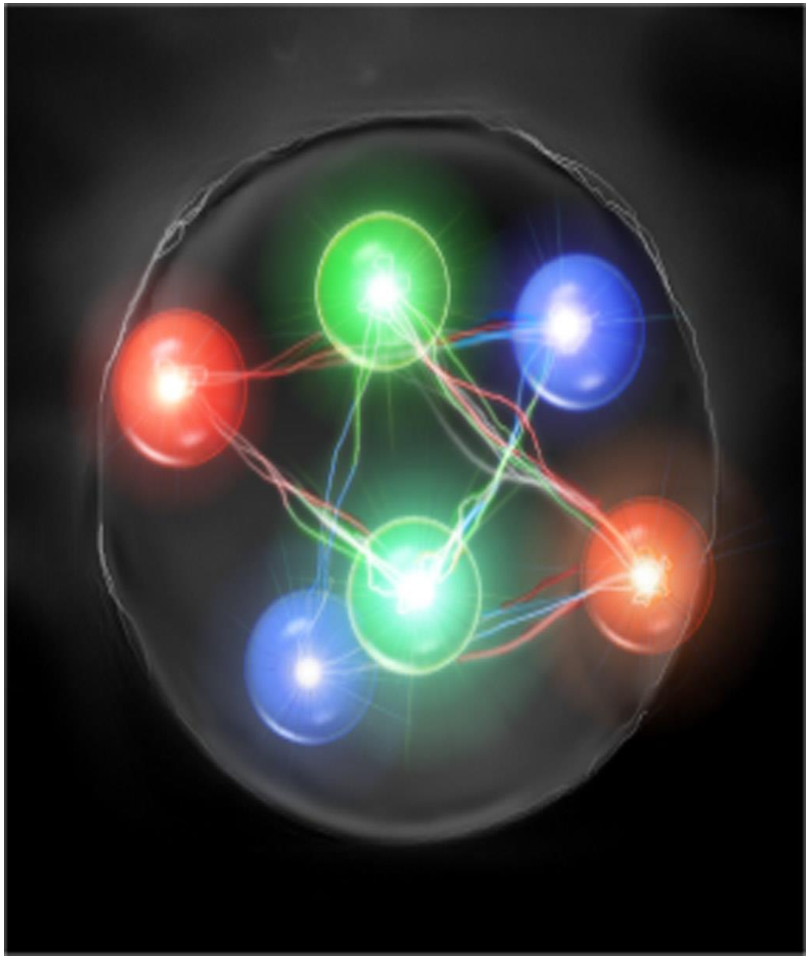
- Density of materials
- Changes of state

Internal energy and energy transfers

- Internal energy
- Temperature changes in a system and specific heat capacity
- Changes of heat and specific latent heat

Particle model and pressure

- Particle motion in gases
- Pressure in gases (physics only)
- Increasing the pressure of a gas (physics only – Higher Tier)



LearnIT!
KnowIT!

Changes of state and the particle model

- Density of materials
- Changes of state

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

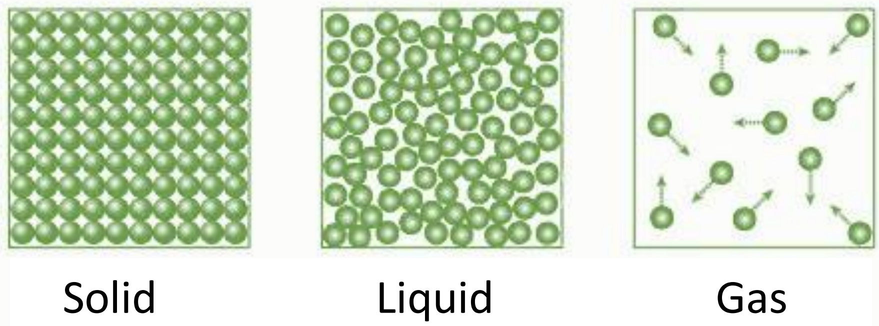
What is the density of a bar of gold if its volume is 350 cm^3 (0.00035 m^3) and its mass is 6.76 kg?

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

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

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



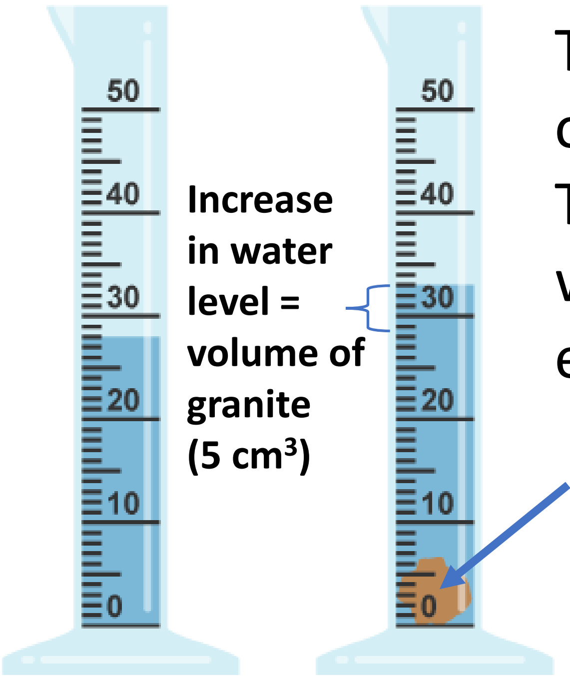
In **solids** the particles are packed close together.
In **liquids** the particles are free to move so the same mass takes up more space.
In **gases** the particles take up a much greater volume than in liquids and solids.

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

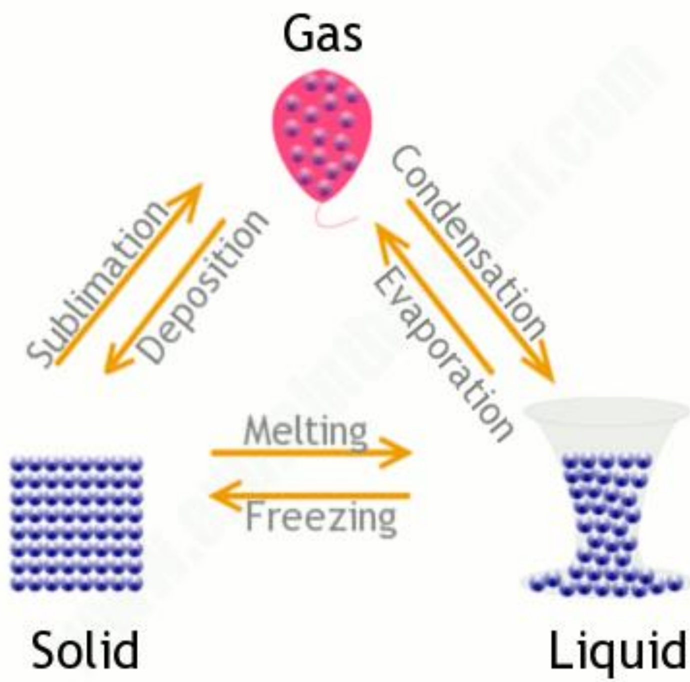
$$\text{Density of granite} = \frac{0.0135\ \text{kg}}{0.000005\ \text{m}^3} = 2\,690\ \text{kg/m}^3$$

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.

QuestionIT!

Changes of state and the particle model

- Density of materials
- Changes of state

Changes of state and the particle model – AnswerIT

1. Why is it incorrect to say iron is heavier than wood?

2. Water has a density of 1000 kg/m³. A piece of rubber has a density of 1024 kg/m³. Explain what would happen if the rubber was put in a pool of water?

3. This "ready-mix" concrete waggon contains 9600 kg of concrete. If the density of the concrete is 2400 kg/m³, what volume of concrete does the waggon contain?

Changes of state and the particle model – AnswerIT

4. a. A sheet of insulating foam measures 3 m x 1 m x 0.08 m. It has a mass of 9.6 kg. Calculate the density of the insulating foam.

   b. High density foam is made of the same material and can be used to give better insulation for the same thickness of foam. Describe how the arrangement of particles would differ in these two types of foam (you may draw diagrams to help your answer).

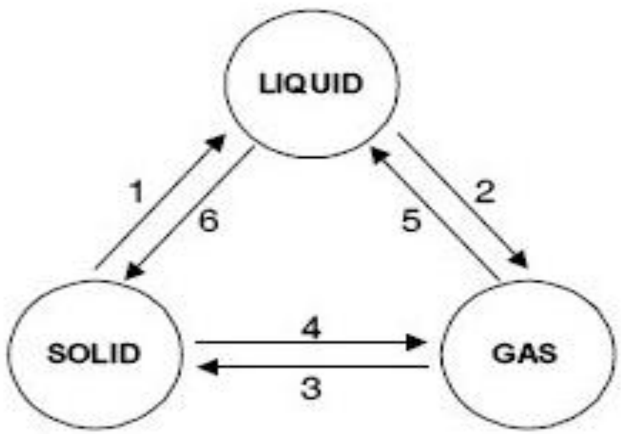
5. When copper metal is heated to 1100 ^{o}C it melts.
   a. Is this a chemical or physical change? Explain your answer.

   b. What will happen to the mass of the sample of copper after it has melted? Explain your answer.

Changes of state and the particle model – AnswerIT

6. Explain the difference between a physical and a chemical change.

7. Name the changes in state given in the diagram by the arrows 1 to 6.



8. If you wanted to find the density of a brass key, you first need to measure its volume. Describe how to determine the volume of a brass key.

AnswerIT!

Changes of state and the particle model

- Density of materials
- Changes of state

Changes of state and the particle model – AnswerIT

1. Why is it incorrect to say iron is heavier than wood?

   It depends how much iron and wood you have. You should say iron is denser than wood.

2. Water has a density of 1000 kg/m^3. A piece of rubber has a density of 1024 kg/m^3. Explain what would happen if the rubber was put in a pool of water?

   Rubber has a higher density than water so the rubber would sink in water.

3. This "ready-mix" concrete waggon contains 9600 kg of concrete. If the density of the concrete is 2400 kg/m^3, what volume of concrete does the waggon contain?

Density = $\frac{m}{v}$ v = $\frac{\text{mass}}{\text{density}}$ = $\frac{9600\ kg}{2400\ kg/m^3}$ = 4

volume of concrete in the waggon = 4 m^3

Changes of state and the particle model – AnswerIT

4. a. A sheet of insulating foam measures 3 m x 1 m x 0.08 m. It has a mass of 9.6 kg. Calculate the density of the insulating foam.

   $V = 3 \times 1 \times 0.08 = 0.24\ m^3$ **Density = $9.6 / 0.24 = 40\ kg/m^3$**

   b. High density foam is made of the same material and can be used to give better insulation for the same thickness of foam. Describe how the arrangement of particles would differ in these two types of foam (you may draw diagrams to help your answer).

   Particles in the high density foam will be closer together so there are more particles in a given volume, making it denser.

5. When copper metal is heated to 1100 ^oC it melts.

   a. Is this a chemical or physical change? Explain your answer.

   Physical change. No new products have been formed.

   b. What will happen to the mass of the sample of copper after it has melted? Explain your answer.

   It will stay the same. Mass is conserved when state changes.

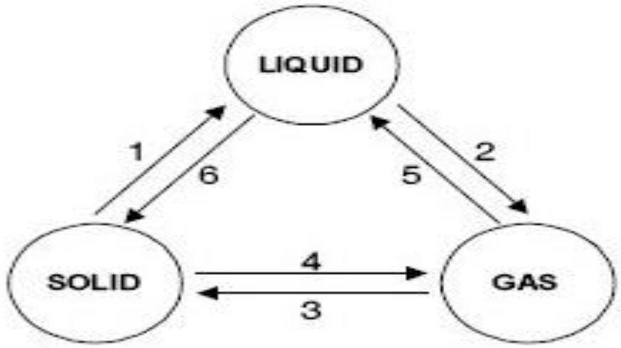
Changes of state and the particle model – AnswerIT

6. Explain the difference between a physical and a chemical change.

In a physical change no new products are formed and it can be easily reversed.

In a chemical change a new substance is formed which can not easily be changed back .

7. Name the changes in state given in the diagram by the arrows 1 to 6.



1. melting 2. evaporating 3. deposition 4. subliming 5. condensing 6. freezing

8. If you wanted to find the density of a brass key, you first need to measure its volume. Describe how to determine the volume of a brass key.

Drop the key into a known volume of water and measure the amount of water displaced by the key. This will be the volume of the key.

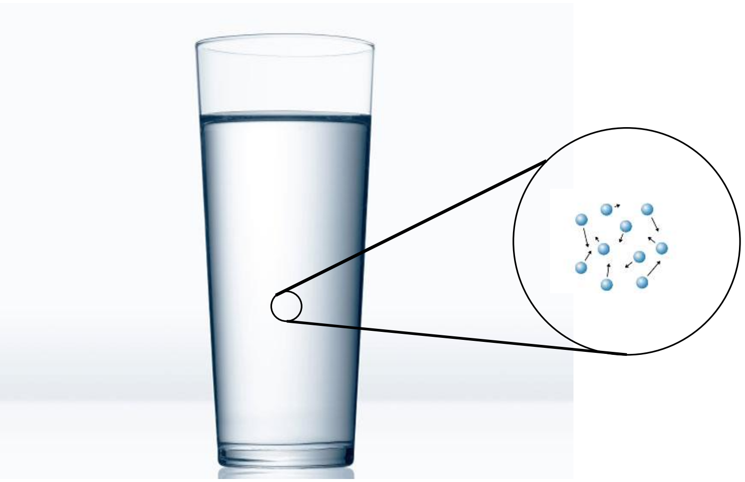
LearnIT!
KnowIT!

Internal energy and energy transfers

- Internal energy
- Temperature change in a system and specific heat capacity
- Changes of heat and specific latent heat

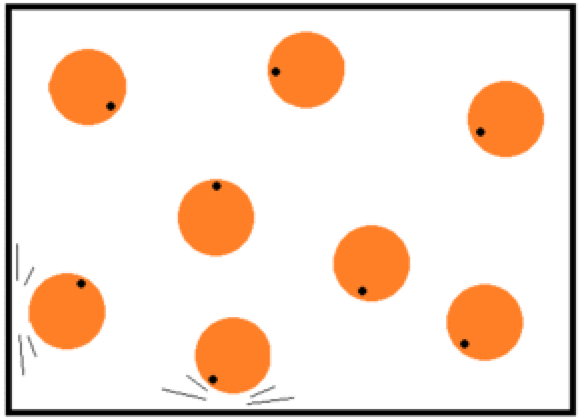
Internal energy and energy transfers – Internal energy

Internal energy is the energy stored in a system by the atoms and molecules that make up that system.



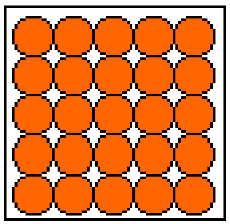
The molecules of water have kinetic (movement) energy and some potential energy. The total **kinetic (E_k)** and **potential (E_p)** energy in the system make up the **internal energy (U).**

The particles inside a **liquid** or a **gas** are in **constant motion**, colliding with each other and the walls of any container they are in.
In a **solid** the particles are **vibrating** around a fixed point.

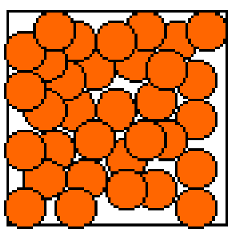


Internal energy and energy transfers – Internal energy

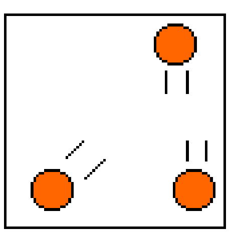
When heat is added to a system the **internal energy** of the particles increases. This can result in the material **changing state**.



In a **solid**, particles can only **vibrate** so they cannot move relative to each other. When the solid is heated the particles gain kinetic energy and vibrate faster and faster.



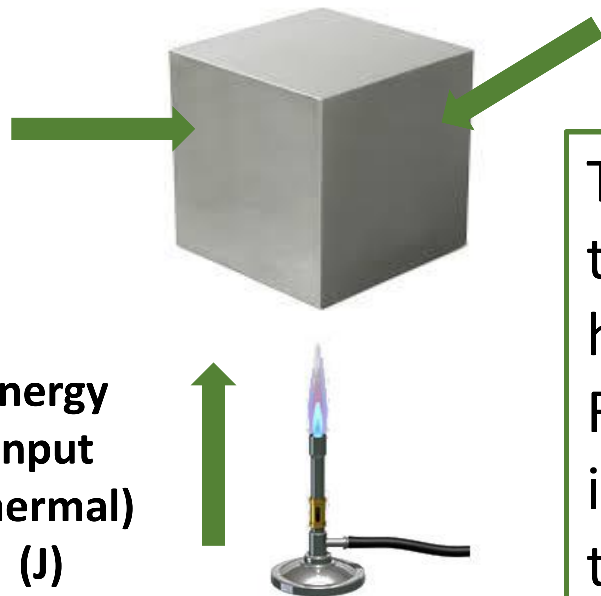
In a **liquid**, the particles are **moving** fast enough to break free from the solid. They are free to move relative to each other but are held within a container.



In a **gas**, the particles have sufficient energy to **break free** from their container. Gas particles can move away from their container and away from other gas particles.

Internal energy and energy transfers –
Temperature change in a system and specific heat capacity

The temperature increase of an object depends on what it is made of, the mass of the object and the amount of energy put into it.



To calculate the temperature change, the formula for **specific heat capacity** has to be re-arranged.
Remember, specific heat capacity (***c***) is the energy required to raise the temperature of 1 kg of a substance by 1°C.

$$\text{Temperature change } (\boldsymbol{\Delta\theta}) = \frac{\text{change in thermal energy } (\boldsymbol{\Delta E})}{\text{mass } (\mathbf{m}) \times \text{specific heat capacity } (\boldsymbol{C})}$$

Internal energy and energy transfers – Temperature change in a system and specific heat capacity

Calculating temperature change

A kettle contains 1400 g of water at 12 ºC.
If 400 kJ of heat energy is supplied to the water, how much will the temperature rise?

$$\text{Temperature change } (\mathbf{\Delta\theta}) = \frac{\text{change in thermal energy } (\mathbf{\Delta E})}{\text{mass } (\mathbf{m}) \text{ x specific heat capacity } (\boldsymbol{C})}$$

$$\mathbf{\Delta\theta} = \frac{\mathbf{\Delta E}}{\mathbf{m \times \mathit{C}}} = \frac{400\,000}{1.4 \times 4200} = \mathbf{68\ ^{o}C}$$

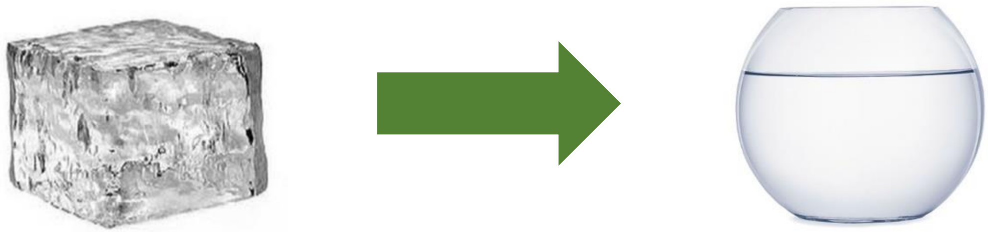
The temperature rise will be 68 ºC.
The new temperature of the water will be 68 + 12 = 80 ºC.

Latent heat is the energy needed to **change the state** of a substance without a change in temperature.
The energy supplied is used to change the **internal energy store** of the substance.

Latent heat for melting is called **specific latent heat of fusion** (L_f)
Latent heat for evaporating is called **specific latent heat of vaporisation** (L_v)

1kg of ice at 0ºC

1kg water at 0ºC



Specific latent heat of fusion for water = 336 000 J/kg
This means 336 000 J of energy are needed to turn 1 kg of ice into 1 kg of water with no temperature change.

Internal energy and energy transfers – Changes of heat and specific latent heat

5 g of gold is being melted to make a ring.
Once the gold reaches its melting temperature, how much heat energy is needed to melt the gold?

Specific latent heat of fusion for gold = 64 400 J/kg

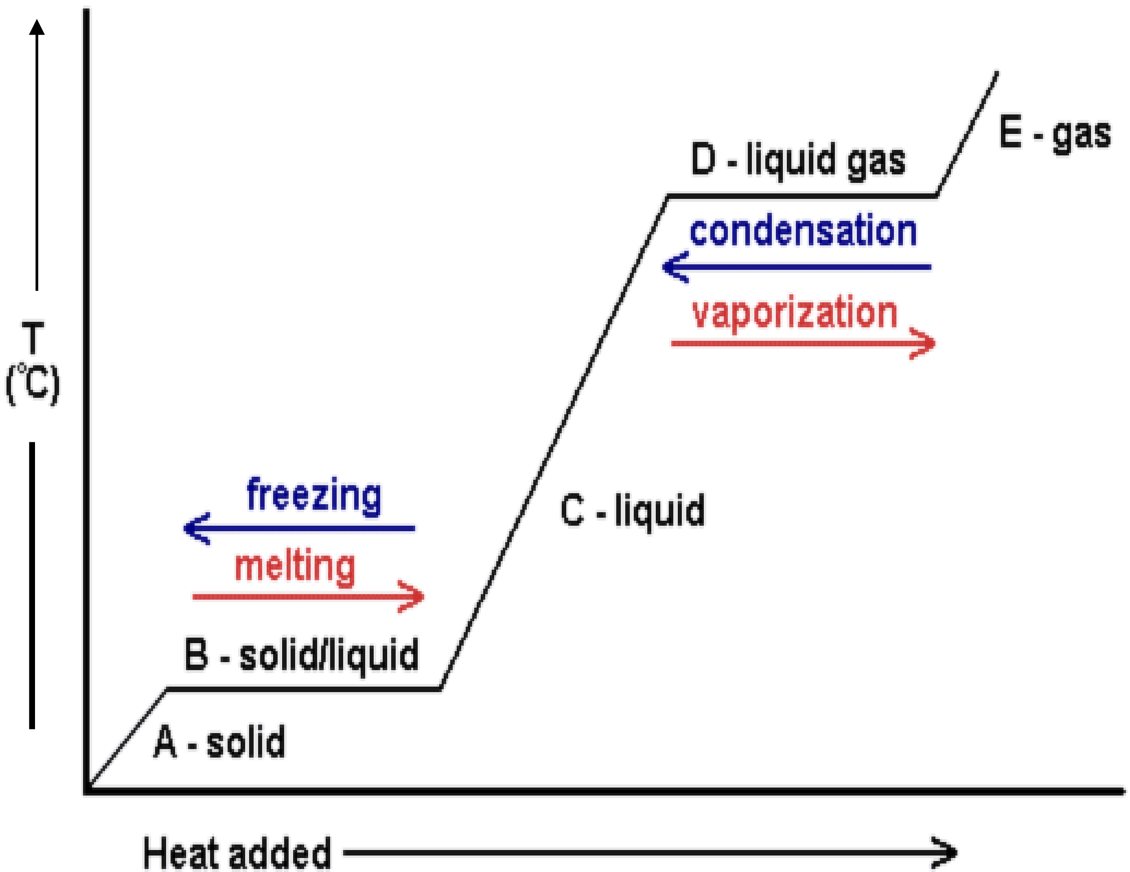
Energy to change state (J) = mass (kg) x specific latent heat (J/kg)

Remember there are two latent heats for each substance – fusion and vaporisation.
Fusion – melting and freezing Vaporisation – evaporating and condensing

Energy = 0.0005 kg x 64,400 J/kg = 322 J

322 J of heat energy is needed to melt 5 g of gold

Heating and cooling graphs



As heat energy is added to a solid, the temperature rises until it reaches its **melting point.**

As the substance melts, all the heat energy added is used to **change the state** of the substance with no temperature change.

When all the substance is melted, the temperature will then rise until the **boiling point** is reached.

Again, heat energy is now required to **change the state** to a gas with no temperature change.

QuestionIT!

Internal energy and energy transfers

- Internal energy
- Temperature change in a system and specific heat capacity
- Changes of heat and specific latent heat

Internal energy and energy transfers – **AnswerIT**

1. Define internal energy.

2. Which of the following will change the internal energy of a stone?
    A. Lifting it to the top of a building.
    B. Heating it.
    C. Firing it from a catapult.

3. Water and the chemical isooctane both boil at 100 ºC. When the same mass of each substance is placed on a heater, the isooctane boils first. Explain why this happens.

Internal energy and energy transfers – AnswerIT

4. A hot stone is placed into a glass of water containing 200 g of cold water. The stone transfers 25 200 J of energy to the water. How much will the temperature of the water rise?

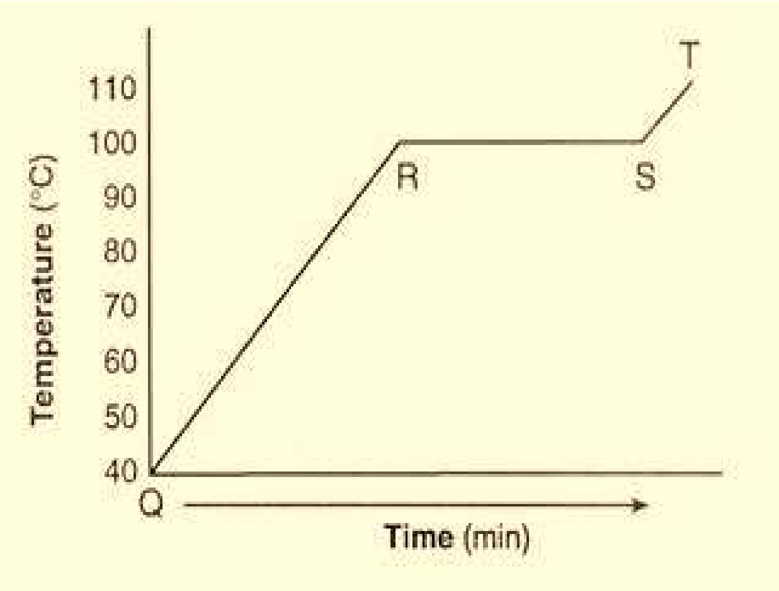
Specific heat capacity of water = 4200 J/kg °C **$\Delta E = m\, c\, \Delta\theta$**

5. What is specific latent heat?

6. Explain the difference between latent heat of fusion and latent heat of vaporisation.

Internal energy and energy transfers – **AnswerIT**

7. A boiler is being used to heat water. The graph shows the temperature of the water every 5 minutes.



a. What state is the water in between points Q and R?

b. At which point does the water begin to boil?

c. What state is the water in at 110 ºC?

8. Candle wax has a latent heat of fusion of 200 000 J/kg. If the candle is at its melting temperature, how much heat energy is needed to melt a 250 g candle?

$$\mathbf{E = m\ L_f}$$

AnswerIT!

Internal energy and energy transfers

- Internal energy
- Temperature change in a system and specific heat capacity
- Changes of heat and specific latent heat

Internal energy and energy transfers – AnswerIT

1. Define internal energy?

   The total kinetic and potential energy of all the particles within a system

2. Which of the following will change the internal energy of a stone?

   A. Lifting it to the top of a building
   B. Heating it
   C. Firing it from a catapult

   Heating it.

3. Water and the chemical isooctane both boil at 100 ºC. When the same amount of each substance is placed on a heater, the isooctane boils first. Explain why this happens.

   Isooctane has a lower specific heat capacity than water so less heat energy is needed to raise its temperature to its boiling point.

Internal energy and energy transfers – AnswerIT

4. A hot stone is placed into a glass of water containing 200 g of cold water. If the stone transfers 25 200 J of energy to the water, what will the temperature rise of the water be?

specific heat capacity of water = 4200 J/kg °C **$\Delta E = m\,c\,\Delta\theta$**

$$\Delta\theta = \frac{\Delta E}{m \times c} = \frac{25\,200}{0.2 \times 4200} = 30\ ^{\circ}\mathrm{C}$$

Temperature rise of the water = 30 °C

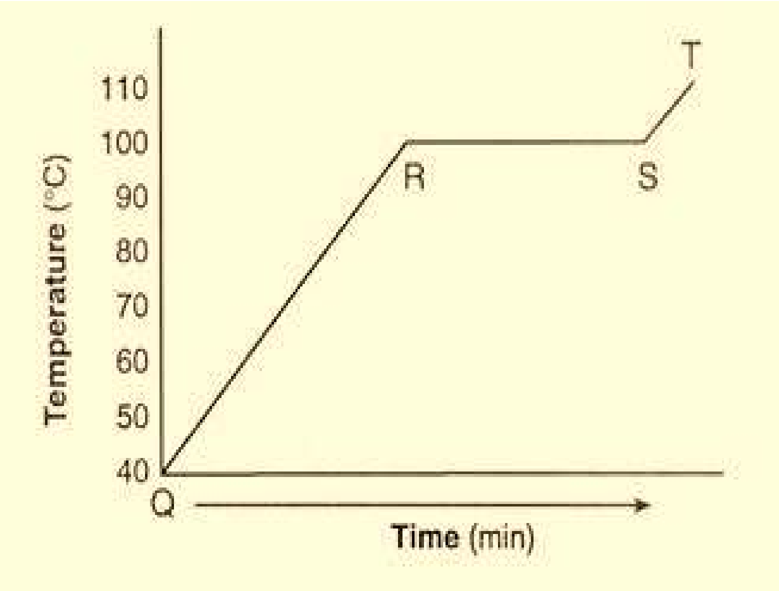
5. What is latent heat?

The energy needed to change the state of a substance without changing the temperature.

6. Explain the difference between latent heat of fusion and latent heat of vaporisation.

Latent heat of fusion is the energy needed to change between solid and liquid. Latent heat of vaporisation is the energy needed to change state between liquid and gas.

7. A boiler is being used to heat water. The graph shows the temperature of the water every 5 minutes.



a. What state is the water in between points Q and R?

Liquid

b. At which point does the water begin to boil?

R

c. What state is the water in at 110 °C?

Gas

8. Candle wax has a latent heat of fusion of 200 000 J/kg. If the candle is at its melting temperature, how much heat energy is needed to melt a 250 g candle?

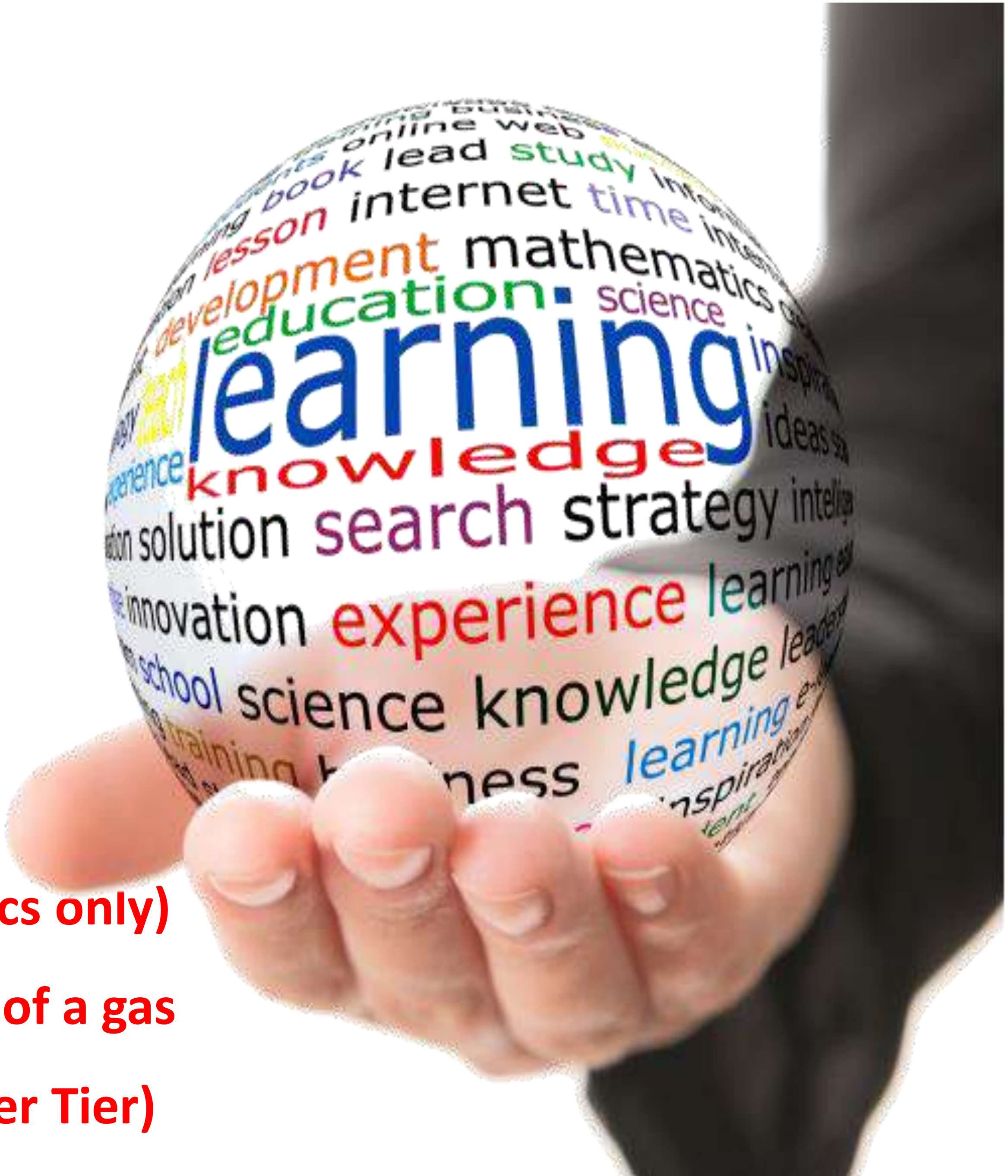
$$E = m L_f$$

$$E = 0.25 \times 200\,000 \quad = 50\,000 \text{ J}$$

LearnIT! KnowIT!

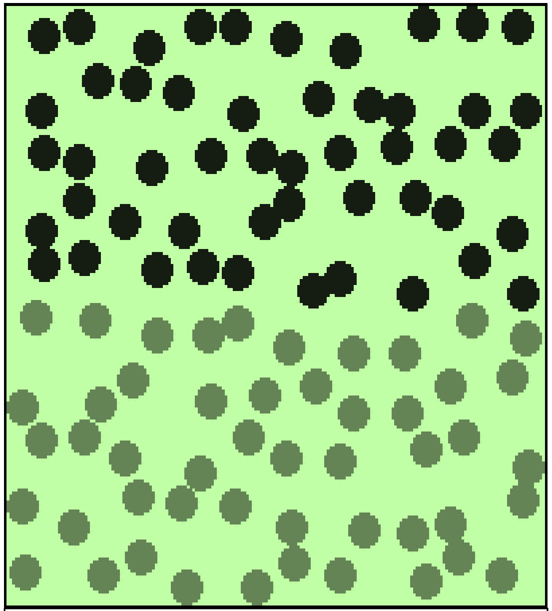
Particle model and pressure

- Particle motion in gases
- **Pressure in gases (physics only)**
- **Increasing the pressure of a gas (physics only – Higher Tier)**



Particle model and pressure- particle motion in gases

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



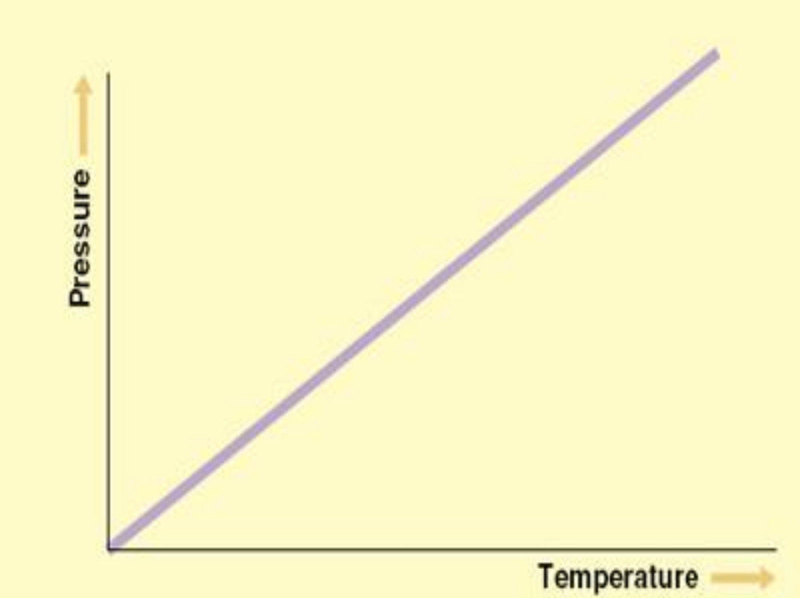
Particles of a gas inside a container have kinetic energy

- 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

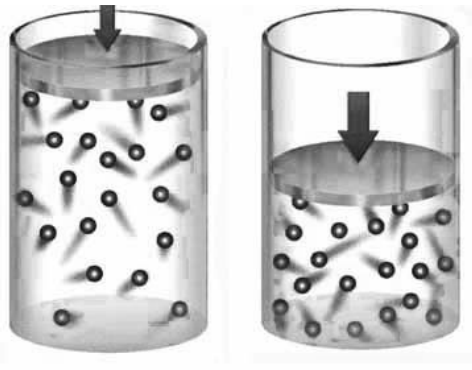
If a sealed can of air (gas) is heated, the molecules of air move faster and faster.
The collisions of these molecules on the inside walls of the container create a pressure. The hotter the molecules, the faster they move and the more pressure they exert on the wall of the can.

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.



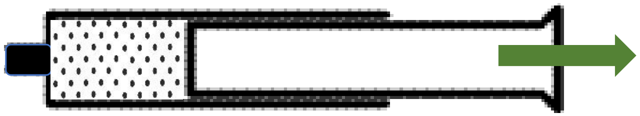
Particle model and pressure- pressure in gases (physics only – not for combine students)

When a gas is **compressed** inside a fixed container, there are more particles in a given volume to **strike the walls** of the container, therefore the **pressure on the container walls increases.**



The pressure produces a net force at right angles to the wall which means the pressure will act evenly in all directions.

Think about a sealed syringe with a fixed amount of gas inside. The particles will be colliding with the syringe walls creating a pressure.



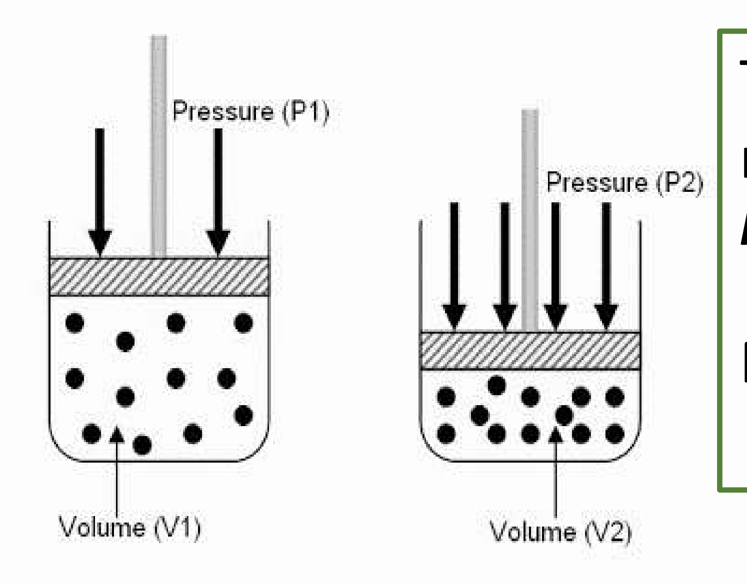
If the plunger is pulled out, the same amount (mass) of gas will be occupying a greater volume.
This will result in fewer collisions over a given area of the syringe wall.

Gas pressure will be reduced

Particle model and pressure - pressure in gases (physics only – not for combine students)

When a fixed mass of gas is compressed the volume decreases

In the example shown, if the pressure applied to the gas doubles, the volume halves.



This is an inverse relationship:

$P = \frac{1}{V}$ or pV = constant

For calculations:

$$p_1V_1 = p_2V_2$$

If the container has a volume of 0.04 m³ and a pressure of 100 000 Pa, calculate the new volume if the pressure is increased to 320 000 Pa.

$p_1V_1 = p_2V_2$ $\quad V_2 = \frac{p_1V_1}{p_2} = \frac{100\,000 \times 0.04}{320\,000}$ New volume = 0.0125 m³

Particle model and pressure- Increasing the pressure of a gas (physics only – Higher Tier)

When work is done on a gas, energy is transferred to the gas by a force. This transfer of energy to the gas increases its temperature.

When a foot pump is used to inflate a tyre, **work is done** by the piston on the **vibrating air particles** inside the pump. There is therefore a **transfer of energy** between the piston and the particles and this results in an increase in **kinetic energy** of the air particles.

If the kinetic energy of the air particles increases then there will be more collisions between gas particles. This will cause the temperature of the gas to rise

QuestionIT!

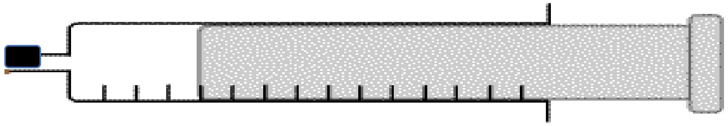
Particle model and pressure

- Particle motion in gases
- Pressure in gases (physics only)
- Increasing the pressure of a gas (physics only – Higher Tier)

Particle model and pressure – AnswerIT

1. What happens to the temperature of a gas if the average kinetic energy of the particles of the gas increases?

2. The sealed gas syringe is filled with air.



Explain what will happen to the syringe if the air inside is gently heated.

3. As a weather balloon rises high in the atmosphere its volume increases. Explain why this happens.

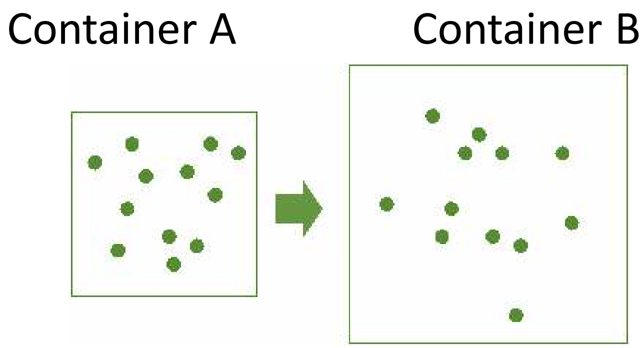
Particle model and pressure – **AnswerIT**

4. A cylinder of oxygen is left in the sunshine for an hour.
   a. Explain what will happen to the oxygen molecules in the cylinder as they warm up.

   b. Explain why these heated molecules cause a greater pressure inside the cylinder.

5. When air is blown into a balloon, it expands equally in all directions. The best explanation for this is:
   A - The gas molecules in the balloon are expanding
   B - Internal air pressure acts at right angles to the balloon surface.
   C - As more air is blown in, the temperature increases causing the balloon to expand.

6. Container A is filled with a gas represented by the dots. The container size is increased but the mass of gas remains the same.



a. Explain, using the particle model, why the pressure will be less inside container B.

b. Container A has a volume of 2 m^3 and a pressure of 100 000 Pa. If the expanded container has a volume of 5 m^3, what will the pressure be in container B?

AnswerIT!

Particle model and pressure

- Particle motion in gases
- Pressure in gases (physics only)
- Increasing the pressure of a gas

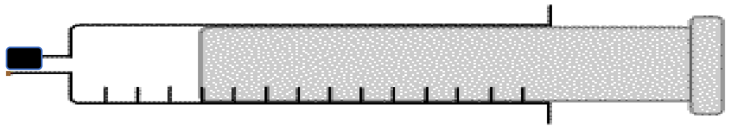
  (physics only – Higher Tier)

Particle model and pressure – AnswerIT

1. What happens to the temperature of a gas if the average kinetic energy of the particles of the gas increases?

   The temperature will increase.

2. The sealed gas syringe is filled with air.



   Explain what will happen to the syringe if the air inside is gently heated.

   The air molecules will gain kinetic energy. This will create a greater force inside the syringe so the piston will move outwards.

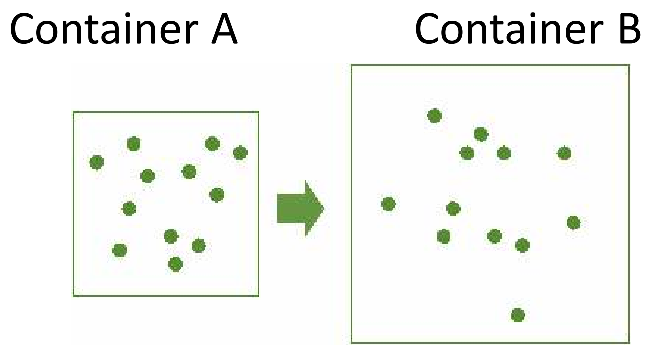
3. As a weather balloon rises high in the atmosphere its volume increases. Explain why this happens.

   As the weather balloon gets higher the pressure on the outside of the balloon decreases, making the balloon expand. The temperature decreases as you get higher, but the effect of pressure decreasing is greater.

Particle model and pressure – AnswerIT

4. A cylinder of oxygen is left in the sunshine for an hour.
   a. Explain what will happen to the oxygen molecules in the cylinder as they warm up.
      They will gain kinetic energy, so move faster.
   b. Explain why these heated molecules cause a greater pressure inside the cylinder.
      The higher kinetic energy causes the molecules to hit the surface of the cylinder more often and with greater force.
5. When air is blown into a balloon, it expands equally in all directions. The best explanation for this is:
   A - The gas molecules in the balloon are expanding
   B - Internal air pressure acts at right angles to the balloon surface.
   C - As more air is blown in, the temperature increases causing the balloon to expand.

6. Container A is filled with a gas represented by the dots. The container size is increased but the mass of gas remains the same.



a. Explain, using the particle model, why the pressure will be less inside container B.

Over a given area there will be fewer gas molecule collisions so the pressure will be less.

b. Container A has a volume of 2 m^3 and a pressure of 100 000 Pa. If the expanded container has a volume of 5 m^3, what will the pressure be in container B?

$p_1V_1 = p_2V_2$ $\frac{100\,000 \times 2}{5} = p_2$ **New pressure = 40 000Pa**