Molecular structure of solids, liquids and gases

Distinguishing properties of solids , liquids and gases:

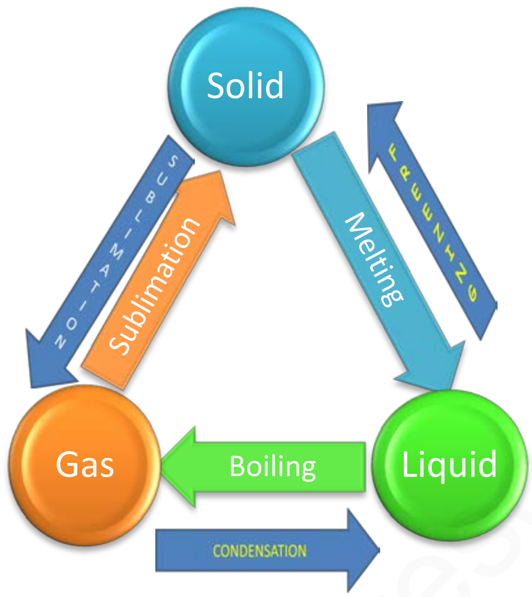
	Flow	Shape	Volume	Density
Solid	No	Fix	Fixed	Much higher than a gas
Liquid	Yes	Takes the shape of the container	Fixed	Much higher than a gas
Gas	Yes	Fills the container	Can be changed	Low compared to a solid and a liquid

---

All matter is made up of mostly three types of particles namely; solids. liquids and gases

----

Change of state:



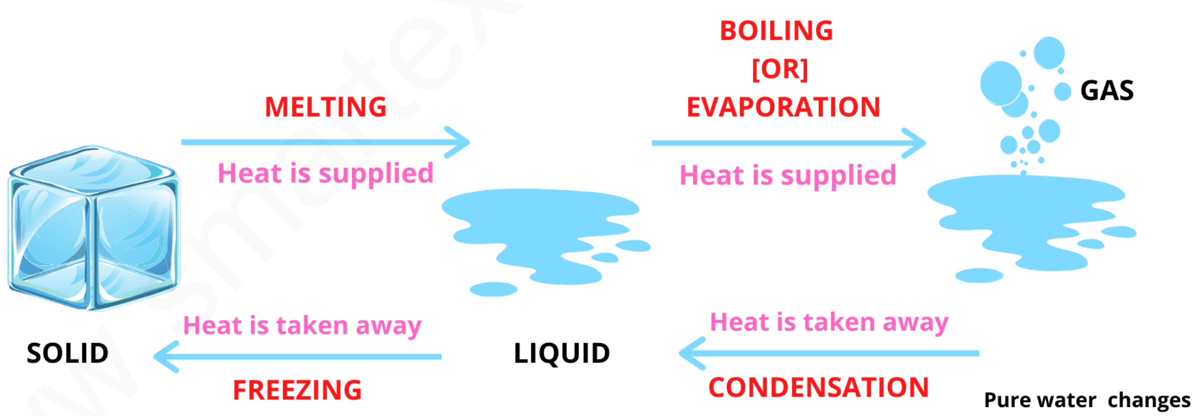
Note: For 2023 to 2025 examinations, the concept of sublimation is not required.

THE PARTICLE MODEL

Distinguishing properties of solids , liquids and gases:

	Solids	Liquids	Gases
Arrangement	The particles in a solid are arranged in a fixed pattern	The particles in a liquid are not arranged in any fixed pattern	The particles in a gas are arranged in a random manner
Separation	The particles of a solid are very close to each other	The particles in a liquid are close to each other	The particles of a gas are further apart from each other
Motion	The solid particles can only vibrate in their fixed(mean) positions	The liquid particles can slide past over each other	The gas particles are free to move everywhere rapidly

CHANGES IN THE STATES OF MATTER



Pure ice does not melt until the temperature reaches 0 °C

Pure ice melts at 0 °C and stays in the liquid state till the temperature is between 0 °C and 100 °C

Pure water changes into the gaseous form in the two ways:
1. Evaporation: This happens over a range of temperatures.
2. Boiling: This happens only a 100 °C

The forces and distances between particles (atoms, molecules, ions and electrons) and the motion of the particles affects the properties of solids, liquids and gases

In a solid:

- The molecules are arranged in a three dimensional structure.
- Each molecule vibrates about a fixed mean position.
- When a solid is heated its molecules gain kinetic energy and vibrate more.
- If sufficient heat is provided, then enough energy may be given to the molecules so that they weaken their bonds from the neighbouring molecules in the lattice structure. When this happens, the solid melts or sublimes.

In a liquid:

- The molecules are in contact with each other and also move around freely.
- The forces of attraction between the liquid molecules are weak compared to solids , so they can slide past over each other. Hence they can flow and do not have a fixed shape.
- The forces of attraction are strong enough to stop the molecules from leaving the liquid surface.
- When a liquid is heated, some of the molecules gain enough kinetic energy to break away from the other molecules and leave the liquid surface and change to a gaseous form.

In a gas:

- The forces of attraction between gas molecules is negligible. So a gas can flow and has no fixed shape.
- The molecules move about freely in the container, colliding with each other and with the walls of the container.
- When a gas is heated, its molecules gain kinetic energy and move more rapidly and collide more frequently , thus exerting gas pressure.

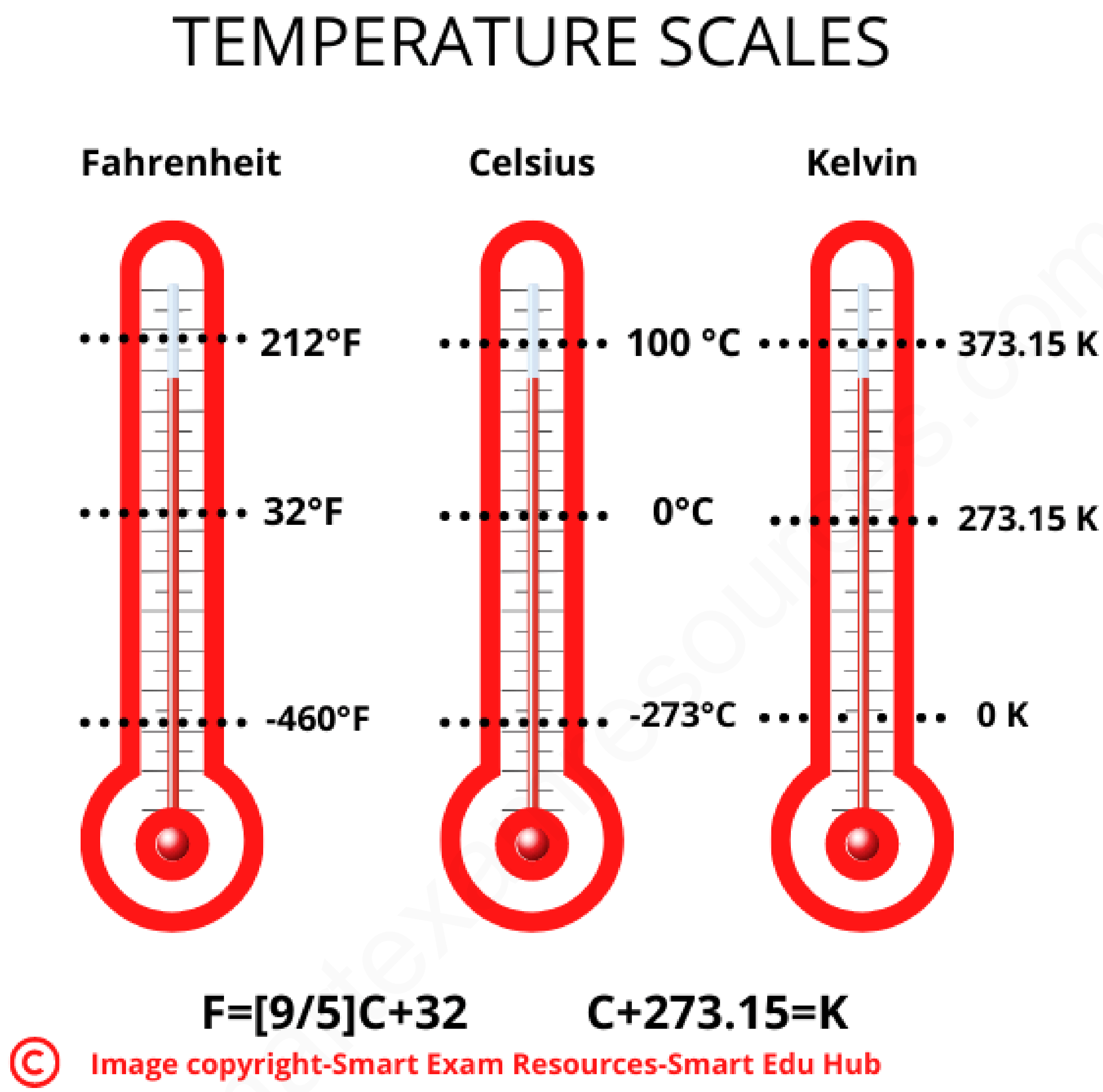
Relationship between the motion of particles and temperature

- Temperature refers to the degree of hotness or coldness of a substance.
- The motion of the particles is increased by raising the temperature. Conversely, the motion of the particles is reduced by lowering the temperature, until, at the absolute zero (0 K), the motion of the particles cease altogether.
- Since the particles are in motion, they have kinetic energy. Also, all the particles will not have the same energy. Also the energy of the particles is constantly changing as they undergo changes in speed. Thus, for a given sample of matter, we can only talk about the average kinetic energy of the particles. Temperature is thus defined as a measure of the average kinetic energy of the particles.

- **Three scales used to record temperatures are:**
  - ✓ The Celsius scale. On this scale, melting point of pure ice has a temperature of 0 °C, and the boiling point of pure water is shown as 100°C.
  - ✓ The Fahrenheit scale: This scale shows the melting point of pure ice as 32^0F and the boiling point of pure water as 212^0F
  - ✓ The Kelvin scale: The freezing point of pure water on the Kelvin scale is 273.15 K, while the boiling point of pure water is 373.15 K.

NOTE:

To convert Celsius temperature to Kelvin temperatures, simply add 273.16. The temperature of 0 K or -273^0C is known as the ABSOLUTE ZERO .It is the lowest temperature which can be obtained where the particles has the least kinetic energy.



The pressure and the changes in pressure of a gas in terms of the motion of its particles and their collisions with a surface

- The pressure of a gas results from collisions between the gas particles and the walls of the container.
- Each time a gas particle hits the wall, it exerts a force on the wall.
- An increase in the number of gas particles in the container increases the frequency of collisions with the walls and therefore the pressure of the gas.
- The forces exerted by particles colliding with surfaces, create a force per unit area[pressure] on the walls of the container.

Brownian motion

Note:
1. The random motion of microscopic particles in a suspension is evidence for the kinetic particle model of matter
2. The microscopic particles may be moved by collisions with light fast-moving molecules and correctly use the terms atoms or molecules as distinct from microscopic particles

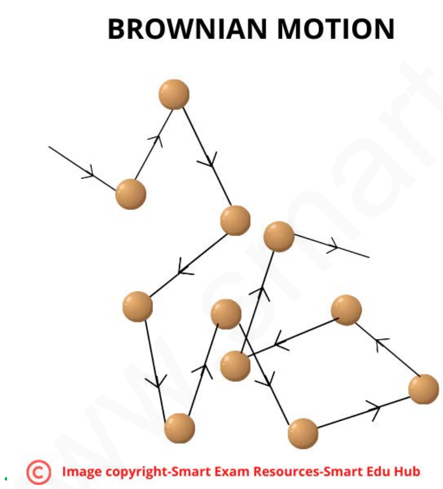
Explain Brownian motion in terms of random collisions between the microscopic particles in a suspension and the particles of the gas or liquid
NOTE: The microscopic particles may be moved by collisions with light fast-moving molecules and correctly use the terms atoms or molecules as distinct from microscopic particles

Define Brownian motion:

Brownian motion is the random collisions between the microscopic particles in a suspension and the particles of the gas or liquid

----

Brownian motion is represented by the following diagram.



- Motion is described as random and zig- zag.
- Collisions happen because the microscopic particles in a suspension collide with the particles of gas or liquid

----

Random motion of particles(pollen grains) in a suspension was observed by Robert Brown. This was the evidence for the kinetic molecular model of matter.

Application based questions:

----

5 (a) A microscope that produces a very high magnification is used to observe the Brownian motion of smoke particles in air.

Fig. 5.1(a) shows the apparatus used with the microscope. Fig. 5.1(b) represents the view through the microscope and shows one of the smoke particles being observed.

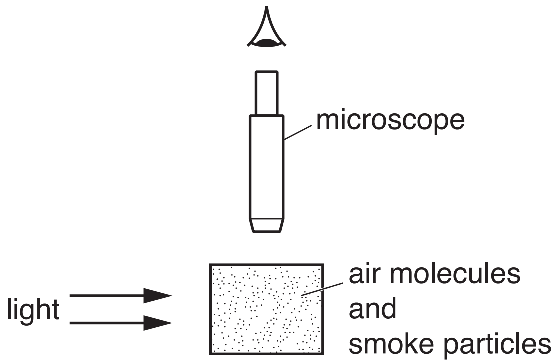


Fig. 5.1(a)

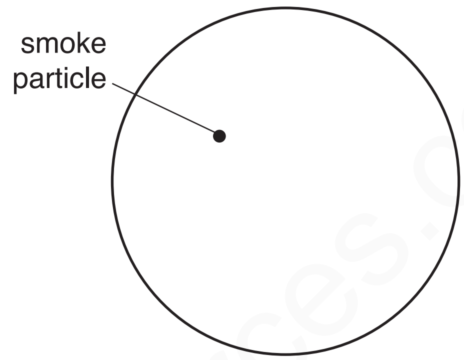


Fig. 5.1(b)

(i) On Fig. 5.1(b), draw a possible path for the smoke particle. [2]

(ii) Describe how air molecules cause the smoke particle to follow the observed path.

....

....

....

....[2]

MARKSCHEME:

5(a)(i)	path shows three or more straight line sections	**B1**
	with sudden changes of direction **and** at least two different lengths	**B1**
5(a)(ii)	air molecules travelling in random (directions)	**B1**
	collide with the smoke particle	**B1**

(b) A syringe is used to transfer smokey air from above a flame to a small glass container.

Extremely small solid smoke particles are suspended in the air in the container.

The container is brightly illuminated from the side and viewed through a microscope.

(i) The movement of the suspended smoke particles is called Brownian motion. Describe this Brownian motion.

....

....

....[2]

(ii) Explain what causes the motion of the smoke particles.

....

....

....[2]

(b) (i)	(the particles move) <u>randomly</u>	B1
	(the particles move) slowly **OR** through small distances **OR** disappear **OR** zigzag **OR** directions change **OR** erratic **OR** straight lines between collisions	B1
(ii)	air <u>molecules</u> / <u>particles</u> collide with smoke particles (at high speed)	B1
	fast(er) air molecules **OR** move randomly **OR** many collisions	B1

3 (a) Fig. 3.1 represents the path taken in air by a smoke particle, as seen in a Brownian motion experiment. The smoke particles can be seen through a microscope, but the air molecules cannot.

O/N/2010-P33-Q3

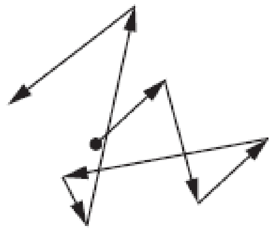


Fig. 3.1

(i) State what causes the smoke particles to move like this.

....

.... [1]

(ii) What conclusions about air molecules can be drawn from this observation of the smoke particles?

....

....

....

....

.... [2]

MCQ:

14 Viewed through a microscope, very small particles can be seen moving with Brownian motion.

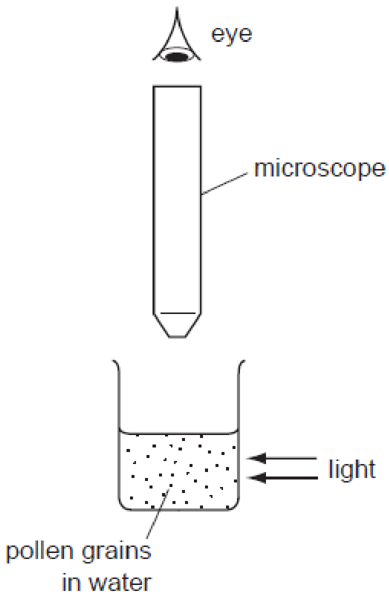
Which line in the table is correct?

0625/01/O/N/08

	type of motion of particles	particles are suspended in
A	vibration	a liquid or a gas
B	vibration	a solid, a liquid or a gas
C	random	a liquid or a gas
D	random	a solid, a liquid or a gas

10 Very small pollen grains are suspended in water. A bright light shines from the side.

Looking through a microscope, small specks of light are seen to be moving in a random, jerky manner.



0625/12/O/N/12

What are the moving specks of light?

A pollen grains being hit by other pollen grains

B pollen grains being hit by water molecules

C water molecules being hit by other water molecules

D water molecules being hit by pollen grains

14 Viewed through a microscope, very small particles can be seen moving with Brownian motion.

Which line in the table is correct?

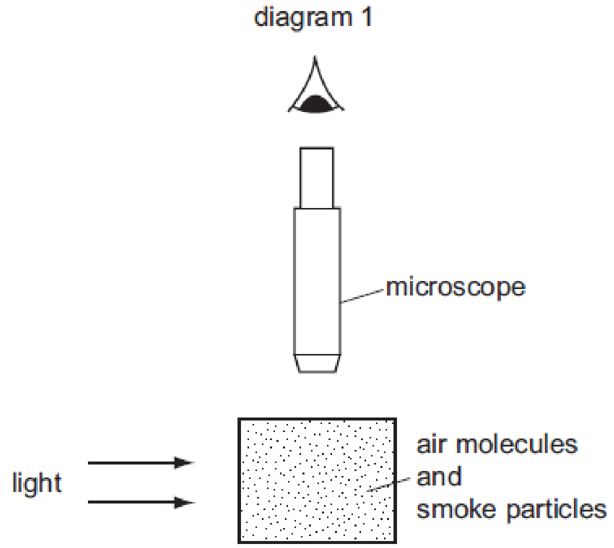
0625/01/M/J/05

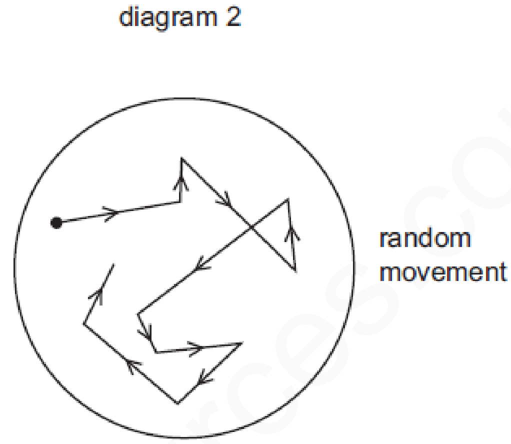
	type of motion of particles	particles are suspended in
A	vibration	a liquid or a gas
B	vibration	a solid, a liquid or a gas
C	random	a liquid or a gas
D	random	a solid, a liquid or a gas

14 Diagram 1 shows apparatus being used to observe smoke particles.

Diagram 2 shows how a smoke particle moves randomly.

0625/01/M/J/07





Why do the smoke particles move randomly?

A They are hit by air molecules.

B They are less dense than air.

C They are moved by convection currents.

D They gain energy from the light.

---

15 Brownian motion is observed by looking at smoke particles through a microscope.

How do the smoke particles move in Brownian motion?

0625/12/O/N/09

A all in the same direction

B at random

C in circles

D vibrating about fixed points

---

12 Extremely small pollen grains in water are viewed through a microscope. The grains are seen to move continually and randomly.

0625/12/F/M/15

What is the reason for this random movement?

A The grains are moved by randomly moving water molecules.

B The grains are moved by random convection currents in the water.

C The grains are moved by random rays of light reflecting off them.

D The grains are moved by the random motion of their own atoms.

---

14 Brownian motion is observed when using a microscope to look at smoke particles in air.

What causes the smoke particles to move at random? **M/J/17-P22**

A Smoke particles are hit by air molecules.

B Smoke particles are moved by convection currents in the air.

C Smoke particles have different weights and fall at different speeds.

D Smoke particles hit the walls of the container.

Where the markschemes are not given in the revision notes, you need to refer to the markschemes from the past exam papers by referring to the code

Gases and absolute scale of temperature

- **The effect on the pressure of a gas of a change of temperature at constant volume-(Pressure law)**

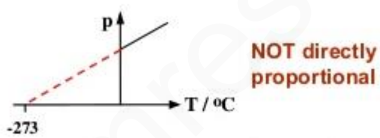
The pressure law states the pressure of a fixed mass of a gas is directly proportional to its absolute temperature if the volume is kept constant.

$$P \propto T$$

$$\frac{P_1}{T_1} = \frac{P_2}{T_2}$$

Graphs of Pressure Law

The straight line graph does not pass through the origin.



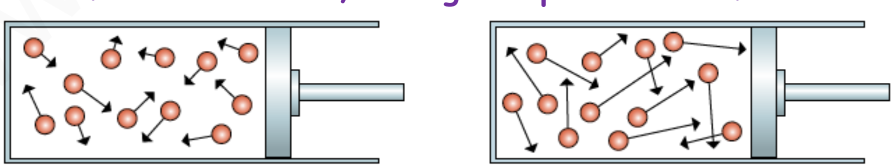
If the graph is extended back until the pressure reaches zero, it will cross the axis at -273°C. This is known as **absolute zero.**

If the pressure against temperature in kelvin graph is drawn, the graph will show pressure being directly proportional to temperature.

Once the volume is fixed and if you:

Increase the temperature you are giving more energy to the particles in the gas. By doing so their kinetic energies increase which will make them move faster and will collide with the walls of their container more frequently, causing the pressure to rise .

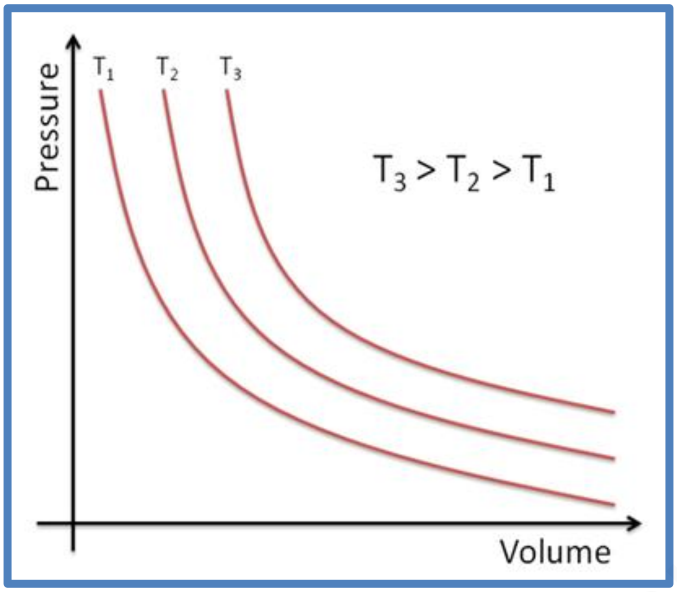
Decrease the temperature , the gas molecules will move slowly. Hence there will be fewer collisions ,causing the pressure to fall.



increased temperature → increased KE → increased pressure pV = constant for a fixed mass of gas at constant temperature including a graphical representation of this relationship

---

The effect on the pressure of a gas of a change of volume at constant temperature-(Boyles law)



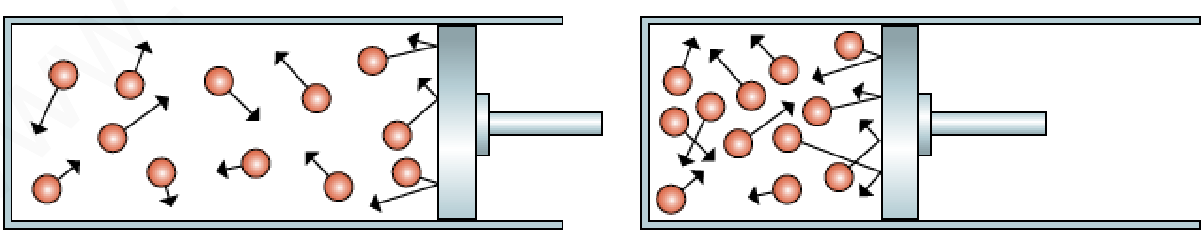
$V \propto \frac{1}{P}$, temperature =constant

HENCE;
PV=constant for a fixed mass of a gas at constant temperature

- For a given mass of gas at a constant temperature, the product of the pressure and the volume is a constant. As the volume decreases, the pressure increases in proportion, and vice versa.
- For example, when the pressure halves, the volume doubles.

Another explanation:

As the volume of a gas is reduced the gas will become denser, because the molecules are pushed together. The molecules will therefore collide with each other more often and also hit the walls more often, increasing the rate of change of momentum and hence the pressure as shown.



NUMCERICALS ON GAS LAWS:

(b) Air in a cylinder is compressed slowly, so that the temperature does not rise. The pressure changes from 2.0×10^5 Pa to 5.0×10^5 Pa. The original volume was 0.35 m^3. Calculate the new volume.

O/N/04-P3-Q5

$P_1V_1 = P_2V_2$ WHERE;

$P_1 = 2 \times 10^5$; $V_1 = 0.35$; $P_2 = 5 \times 10^5$

FIND V_2

$\Rightarrow 2 \times 10^5 \times 0.35 = 5 \times 10^5 \times V_2$

$V_2 = 0.14 m^3$

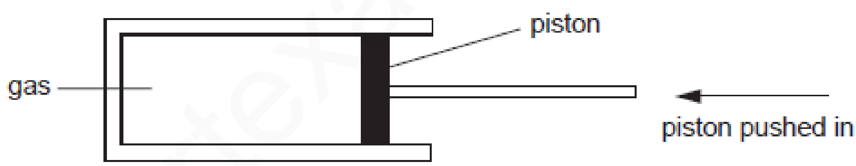
volume = ...[3]

APPLICATION BASED QUESTIONS:

MCQ:

15 A measured mass of gas is placed in a cylinder at atmospheric pressure and is then slowly compressed.

0625/1/O/N/02



If the temperature of the gas does not change, what happens to the pressure of the gas?

A It drops to zero.

B It decreases, but not to zero.

C It stays the same.

D It increases.

15 Driving a car raises the temperature of the tyres.

0625/01/O/N/03

This causes the pressure of the air in the tyres to increase.

Why is this?

A Air molecules break up to form separate atoms.

B Air molecules expand with the rise in temperature.

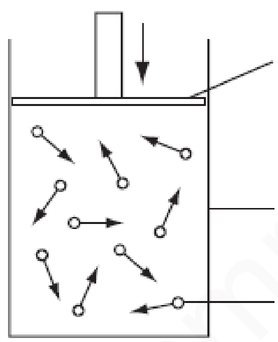
C The force between the air molecules increases.

D The speed of the air molecules increases.

---

14 The diagram represents gas molecules contained in a cylinder. The piston is moved slowly downwards and the temperature of the gas stays the same.

0625/01/O/N/04



Why does the pressure of the gas increase?

A The molecules collide harder with the walls.

B The molecules collide more often with the walls.

C The molecules move more quickly.

D The number of molecules increases.

---

14 A car tyre contains a constant volume of air.

0625/13/O/N/12

During use, the air gets hotter and the air pressure increases.

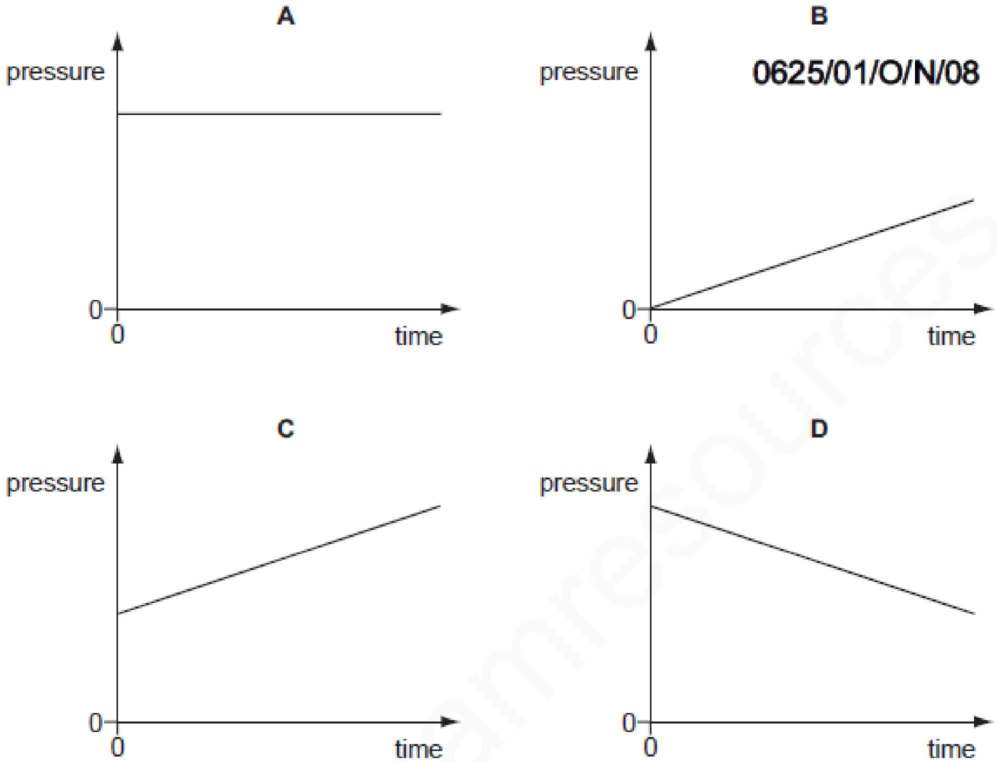
What explains this increase in pressure in terms of the motion of air molecules?

	number of air molecules in tyre	force between air molecules and tyre wall	number of collisions per second between air molecules and tyre wall
A	increased	increased	decreased
B	increased	unchanged	decreased
C	unchanged	increased	increased
D	unchanged	unchanged	increased

15 The pressure of a fixed mass of gas in a cylinder is measured. The volume of the gas in the cylinder is then slowly decreased.

Which graph could show the change of pressure of the gas during this process?

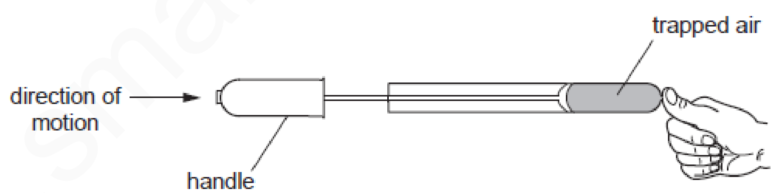
0625/01/O/N/08



---

12 A student places his thumb firmly on the outlet of a bicycle pump, to stop the air coming out.

0625/12/M/J/14

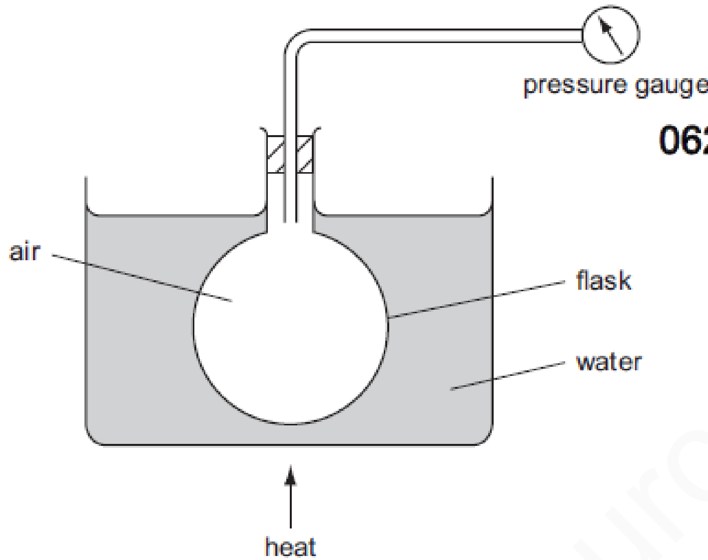


What happens to the pressure and what happens to the volume of the trapped air as the pump handle is pushed in?

	pressure	volume
A	decreases	decreases
B	decreases	remains the same
C	increases	decreases
D	increases	remains the same

17 An experiment is set up as shown.

0625/01/M/J/05



What does the pressure gauge show as the air in the flask becomes hotter?

A a steady pressure

B a decrease in pressure

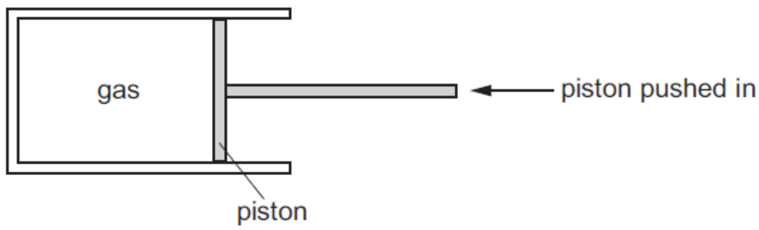
C an increase in pressure

D an increase and then a decrease in pressure

---

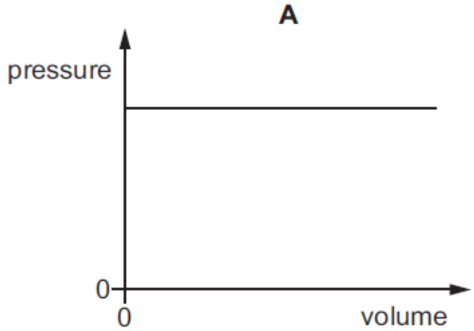
15 The diagram shows a quantity of gas trapped in a cylinder. The piston is pushed in slowly and the gas is compressed. The temperature of the gas does not change.

F/M/16-P22

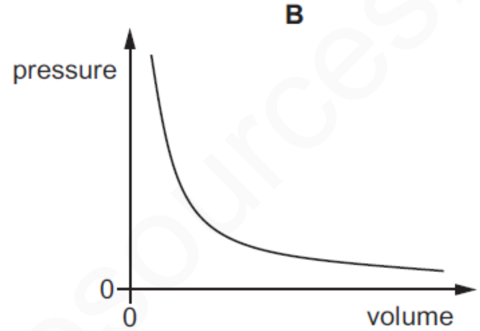


Which graph shows the relationship between the pressure and the volume of the gas?

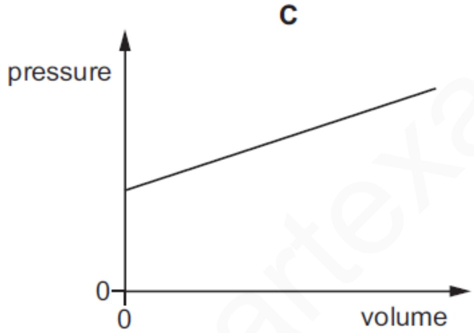
A



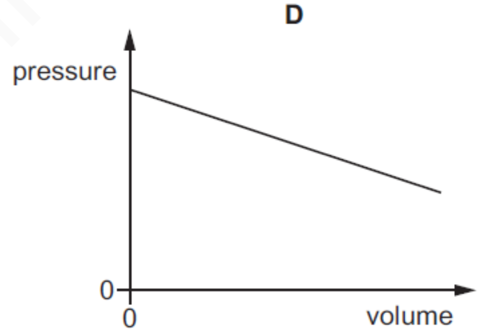
B



C



D



EXTENDED THEORY

5 Fig. 5.1 shows a way of indicating the positions and direction of movement of some molecules in a gas at one instant.

O/N/05-P3

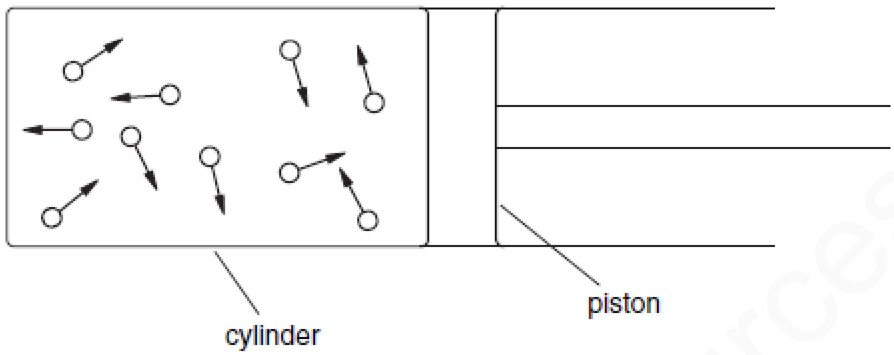


Fig. 5.1

(a) **(i)** Describe the movement of the molecules.

.... [1]

(ii) Explain how the molecules exert a pressure on the container walls.

....

.... [1]

(b) When the gas in the cylinder is heated, it pushes the piston further out of the cylinder.

State what happens to

(i) the average spacing of the molecules,

.... [1]

(ii) the average speed of the molecules.

.... [1]

4 Fig. 4.1 shows a sealed steel cylinder filled with high pressure steam.

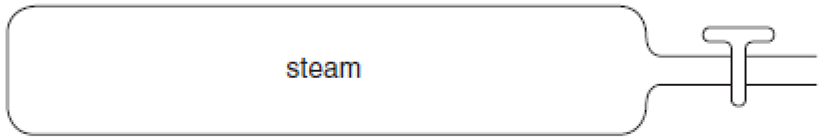


Fig. 4.1

Fig. 4.2 shows the same cylinder much later when all the steam has condensed.

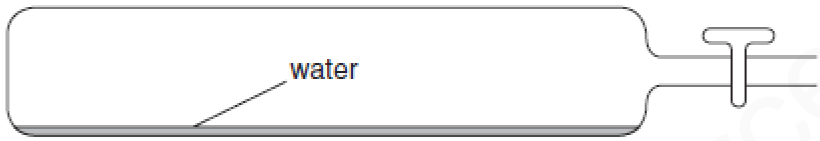


Fig. 4.2

(a) **(i)** Describe the movement of the molecules in the high pressure steam.

....

....

.... [2]

(ii) Explain how the molecules in the steam exert a high pressure on the inside walls of the cylinder.

....

....

.... [2]

(b) Describe, in terms of particles, the process by which heat is transferred through the cylinder wall.

....

....

.... [2]

4 A sealed balloon containing some helium gas is released and rises into the upper atmosphere. As the balloon rises the temperature of the helium falls and the balloon expands.

Explain, in terms of atoms,

O/N/11-P32

(a) the effect of the fall in temperature on the helium pressure,

....

....

....

....

.... [3]

(b) the effect of the expansion of the balloon on the helium pressure.

....

....

....

....

.... [3]

[Total: 6]

4 **(a)** Fig. 4.1 shows some gas contained in a cylinder by a heavy piston. The piston can move up and down in the cylinder with negligible friction.

O/N/12-p32

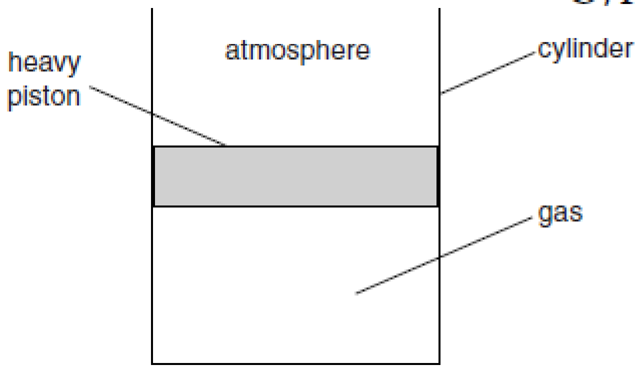


Fig. 4.1

There is a small increase in the pressure of the atmosphere above the piston.

(i) On Fig. 4.1, draw a possible new position for the lower face of the piston. [1]

(ii) Explain, in terms of the molecules of the gas and the molecules of the atmosphere, your answer to **(a)(i)**.

....

....

....

....

....

.... [3]

(b) Fig. 5.1 shows a quantity of gas in a cylinder sealed by a piston that is free to move.

O/N/15-P31-Q5

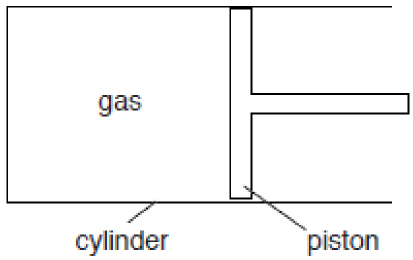


Fig. 5.1

(i) The temperature of the gas is increased.

State what happens, if anything,

1. to the piston,

....

2. to the pressure of the gas.

....
[2]

(ii) The piston is now fixed in place and the temperature of the gas is increased further.

Explain, in terms of the behaviour of molecules, what happens to the pressure of the gas.

....

....

....[2]

TEMPERATURES/SCALES/CONVERSION

- Temperature refers to the degree of hotness or coldness of a substance.
- The motion of the particles is increased by raising the temperature. Conversely, the motion of the particles is reduced by lowering the temperature, until, at the absolute zero (0 K), the motion of the particles cease altogether.
- Since the particles are in motion, they have kinetic energy. Also, all the particles will not have the same energy. Also the energy of the particles is constantly changing as they undergo changes in speed. Thus, for a given sample of matter, we can only talk about the average kinetic energy of the particles. Temperature is thus defined as a measure of the average kinetic energy of the particles.
- Three scales used to record temperatures are:

✓ **The Celsius scale.** On this scale, melting ice (in equilibrium with water vapour at one atmosphere pressure) has a temperature of 0.0 °C, and boiling water (at normal atmospheric pressure) has a temperature of 100.0 °C.

✓ **The Fahrenheit scale**: This scale records the melting ice at a temperature of 32 °F and boiling water at a temperature of 212 °F.

✓ **The Kelvin scale:** On this scale, melting ice has a temperature of 273.16 °C.

✓ There is a lowest possible temperature (−273°C), known as absolute zero, where the particles have least kinetic energy

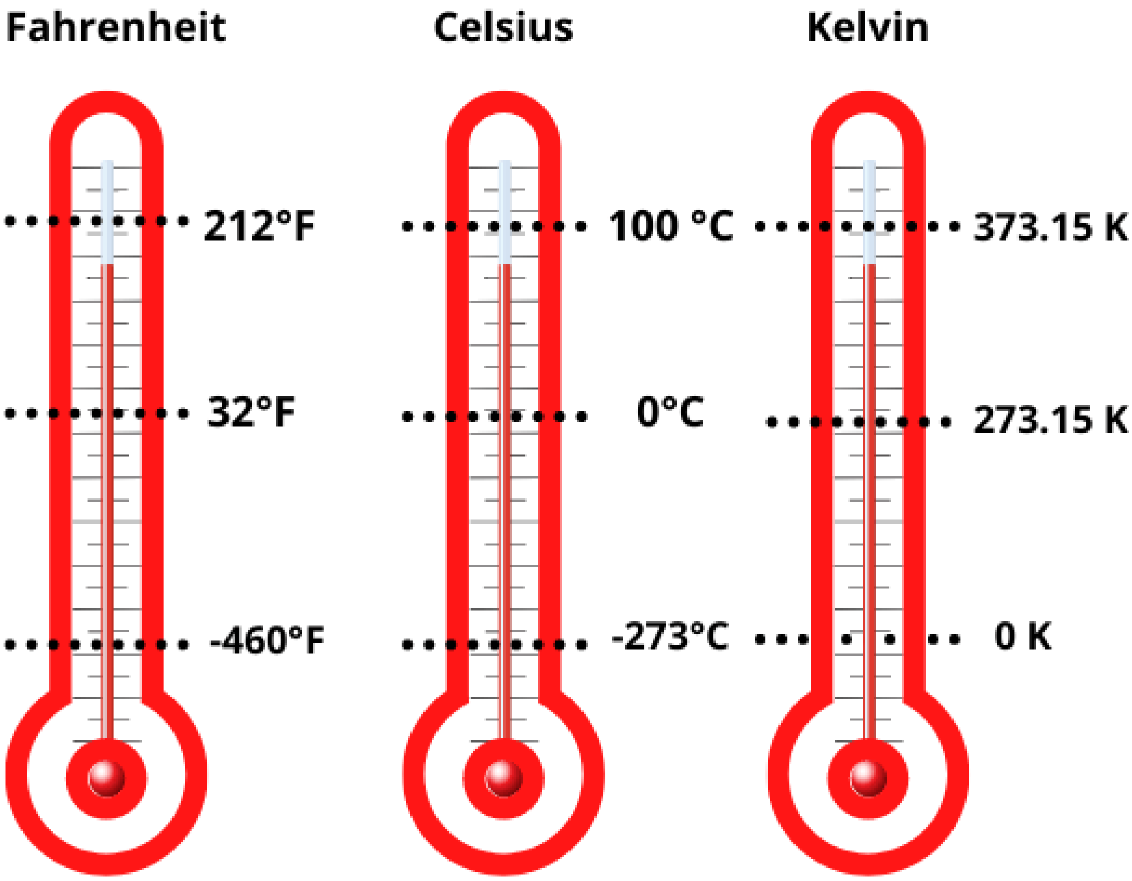
NOTE:

To convert Celsius temperature to Kelvin temperatures, simply add 273.16. The temperature of 0.0 K is known as the ABSOLUTE ZERO, the lowest temperature which can be obtained.

Convert temperatures between kelvin and degrees Celsius.

$$T \text{ (in K)} = \theta \text{ (in °C)} + 273$$

TEMPERATURE SCALES



F=[9/5]C+32 C+273.15=K

The pressure and the changes in pressure of a gas in terms of the motion of its particles and their collisions with a surface

- The pressure of a gas results from collisions between the gas particles and the walls of the container.
- Each time a gas particle hits the wall, it exerts a force on the wall.
- An increase in the number of gas particles in the container increases the frequency of collisions with the walls and therefore the pressure of the gas.
- The forces exerted by particles colliding with surfaces, create a force per unit area[pressure] on the walls of the container.

Where the markschemes are not given in the revision notes, kindly refer to the same by refering to the question code

2.2.1-Thermal expansion of solids, liquids and gases

Thermal expansion:

Thermal expansion is the increase of the size (length, area, or volume) of a body due to a change in temperature, usually a rise

Qualitative description of the thermal expansion of solids, liquids and gases at constant pressure

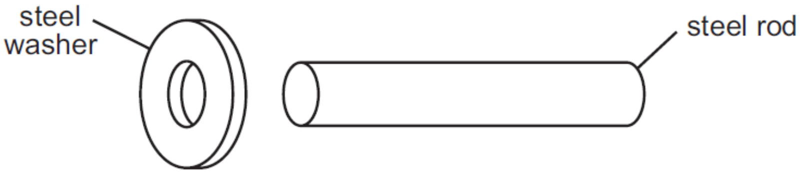
- When a solid is heated at constant pressure, it does expand a little and some heat is required for doing the mechanical work associated with this expansion.
- As a liquid is heated at constant pressure, its temperature increases. This trend continues until the boiling point of the liquid is reached. No further rise in temperature of the liquid can be induced by heating due to increase in kinetic energy.
- If the pressure of a gas is kept constant, then increasing its temperature will also increase its volume. This is called thermal expansion of a gas and is a similar process to the expansion of liquids and a solids when they are heated (although their expansion is much less noticeable compared to a gas). When heated under constant pressure, the gas particles collide harder with the container surfaces, forcing them out, and allowing the gas to expand. This can be seen when warming the gas in a gas syringe.

Some everyday applications and consequences of thermal expansion:

EXAMPLE:1

M/J/04/P1-Q17-ANSWER:AND M/J/12-P11-Q17-ANDWER:D

An engineer wants to fix a steel washer on to a steel rod. The rod is just too big to fit into the hole of the washer.



How can the engineer fit the washer onto the rod?

A cool the washer and put it over the rod

B cool the washer and rod to the same temperature and push them together

C heat the rod and then place it in the hole

D heat the washer and place it over the rod

EXPLANATION:

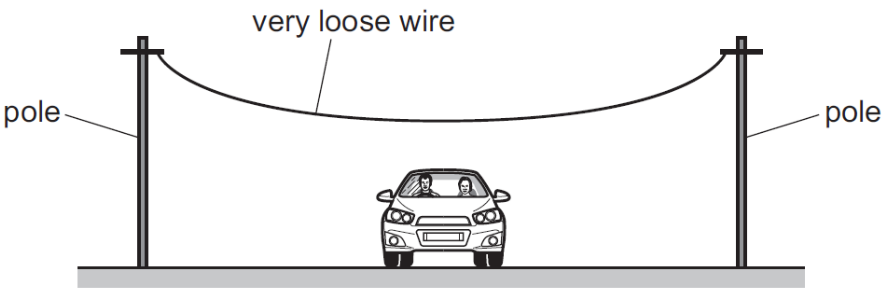
The engineer will heat the washer and then place it over the rod. This is because, heating the washer will make it expand and thus it will become bigger in sizer than before. This will help him in fitting the washer over the steel rod

EXAMPLE:2

M/J/14-P11-Q14-ANSWER:D

A telephone engineer connects a wire between two poles when the weather is very cold.

He makes the wire very loose. The wire passes over a road.



The weather changes and it becomes very hot.

What could happen to the wire and why?

	what could happen	why
A	it breaks	it contracts
B	it breaks	it expands
C	it sags and touches cars on the road	it contracts
D	it sags and touches cars on the road	it expands

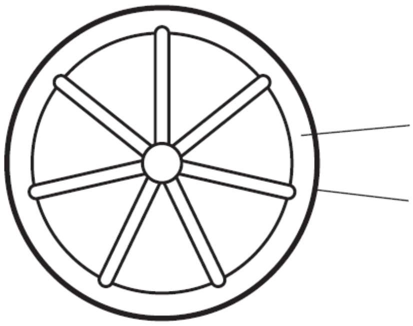
EXPLANATION:

The wire would sag and touch the car on roads due to an increase in the length of the wire [thermal expansion] caused due to heat.

EXAMPLE:3

M/J/07-P1-Q17-ANSWER:B

A wooden wheel can be strengthened by putting a tight circle of iron around it.



Which action would make it easier to fit the circle over the wood?

A cooling the iron circle

B heating the iron circle

C heating the wooden wheel

D heating the wooden wheel and cooling the iron circle

EXPLANATION:

Heating the iron circle would expand it temporarily. Then it could be quickly fixed on the wooden wheel. Upon cooling, the iron circle would contract , going back to its original size and thus fit tightly in the wooden wheel.

Relative order of magnitudes of the expansion of solids, liquids and gases as their temperatures rise

STATE	RELATIVE EXPANSION	REASON
SOLID	Least	The particles in a solid are held together by strong forces of attraction. Hence the inter-molecular distance between the solid particles is too small. Hence when solids are heated, the particles are only able to vibrate in their mean positions. Hence they expand the least when heated.
LIQUID	Moderate	The particles in a liquid are held together by weak forces of attraction. Hence the inter-molecular distance between the liquid particles is too large as compared to the solid particles. Hence when the liquids are heated, the particles are only able to slide past over each other and thus occupy a larger volume when heated. Hence they expand moderately when heated.
GAS	Large	The particles in a liquid are held together by weak forces of attraction. Hence the inter-molecular distance between the liquid particles is too large as compared to the solid particles. Hence when the liquids are heated, the particles are only able to slide past over each other and thus occupy a larger volume when heated. Hence they expand moderately when heated.

SPECIFIC HEAT CAPACITY

Specific heat capacity of an object: C:

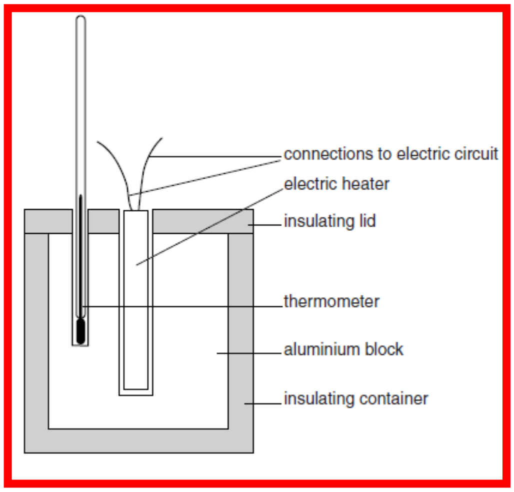
It is the energy required per unit mass per unit temperature increase.

Hence : $c = \frac{E}{m(\theta_2 - \theta_1)}$ $\Longrightarrow$ E= $mc(\theta_2 - \theta_1)$ **[OR]** $c = \frac{\Delta E}{m \Delta \theta}$

Units: J/kg^{0}C

Experiment:

Suppose you need to find our specific heat capacity of aluminium.



Take the following measurements:

- mass of aluminium,
- initial temperature (θ_1)
- final temperature(θ_2) of the aluminium block
- Time (t) for which heat is supplied
- Voltage(V)
- Current(I)
- Note that the formula for specific heat capacity is:

$c = \frac{E}{m(\theta_2 - \theta_1)}$; but since we do not have a joule meter we are calculating the value of E using the formula E=VIt

$$c = \frac{E}{m(\theta_2 - \theta_1)} = \frac{VIt}{m(\theta_2 - \theta_1)}$$

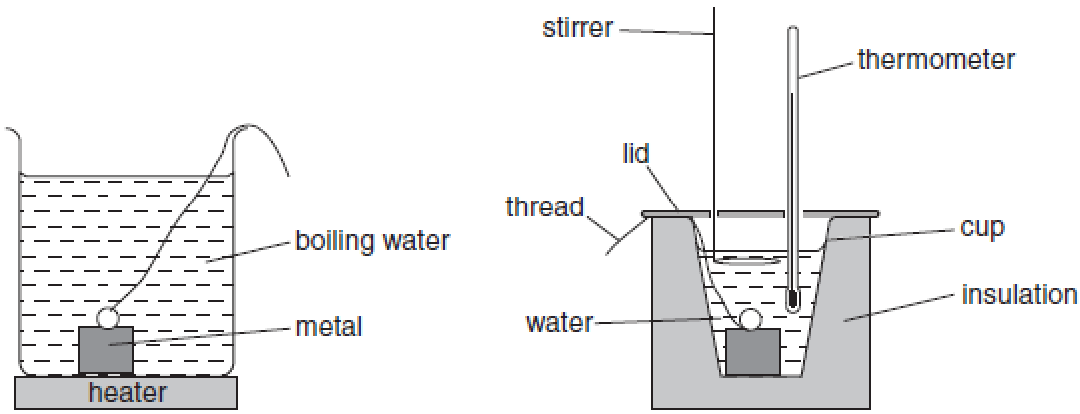
If heat losses occur:

If a lid is not present as shown in the above diagram then the value to specific heat capacity will be higher as more heat will be lost to the surroundings and hence the temperature rise will be less. So more heat will be needed to cause the same temperature rise.

Preventing heat losses:

- Care should be taken to prevent heat losses to the environment by using lagging or insulation around the block.
- By polishing the surface of the block or wrapping the block in a shiny material or it can be painted white
- Reduce draughts

If the following procedure is used to find the specific heat capacity of a given metal, then it will result in inaccuracy. This is because heat will be lost to the surroundings or the cup



Note:

Water has a very high specific heat capacity. This is a disadvantage for cooking because:

- It will take long time to heat up
- long time to cool down
- expensive as it takes lot of energy to heat up,

138

4 **(a)** Define the *specific heat capacity* of a substance.

....

.... [2]

(b) Fig. 4.1 shows a cylinder of aluminium heated by an electric heater.

M/J/14-P32

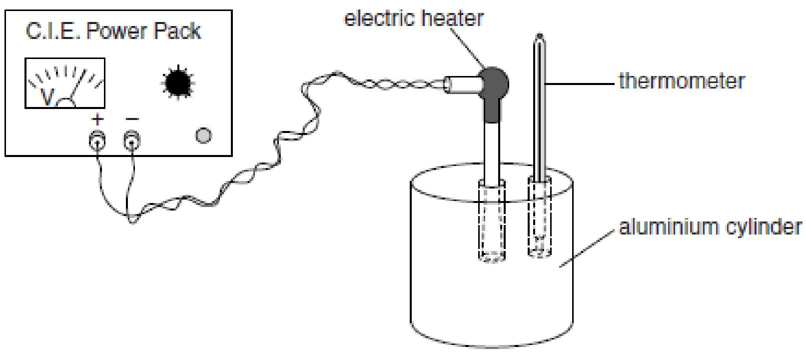


Fig. 4.1

The mass of the cylinder is 800 g. The heater delivers 8700 J of thermal energy to the cylinder and the temperature of the cylinder increases by 12 °C.

(i) Calculate a value for the specific heat capacity of aluminium.

specific heat capacity = ... [2]

(ii) Calculate the thermal capacity (heat capacity) of the aluminium cylinder.

thermal capacity = ... [2]

(c) State and explain a method of improving the accuracy of the experiment.

....

....

.... [2]

169

M/J/06-P3

4 (a) State two differences between evaporation of water and boiling of water.

1. ....

2. ....[2]

(b) The specific latent heat of vaporisation of water is 2260 kJ/kg.
Explain why this energy is needed to boil water and why the temperature of the water does not change during the boiling.

....

....

....

....[3]

(c) A laboratory determination of the specific latent heat of vaporisation of water uses a 120 W heater to keep water boiling at its boiling point. Water is turned into steam at the rate of 0.050 g/s.
Calculate the value of the specific latent heat of vaporisation obtained from this experiment. Show your working.

specific latent heat of vaporisation = ...[3]

5 A certain substance is in the solid state at a temperature of –36 °C. It is heated at a constant rate for 32 minutes. The record of its temperature is given in Fig. 5.1.

time / min	0	1	2	6	10	14	18	22	24	26	28	30	32
temperature / °C	–36	–16	–9	–9	–9	–9	32	75	101	121	121	121	121

Fig. 5.1

M/J/10-P31

(a) State what is meant by the term *latent heat*.

....

.... [2]

(b) State a time at which the energy is being supplied as latent heat of fusion.

.... [1]

(c) Explain the energy changes undergone by the molecules of a substance during the period when latent heat of vaporisation is being supplied.

....

....

.... [2]

(d) **(i)** The rate of heating is 2.0 kW.

Calculate how much energy is supplied to the substance during the period 18 – 22 minutes.

energy supplied = ... [2]

170

(ii) The specific heat capacity of the substance is 1760 J / (kg °C).

Use the information in the table for the period 18 – 22 minutes to calculate the mass of the substance being heated.

mass heated = ... [3]

[Total: 10]

4 Use the information in the table when answering this question.

specific heat capacity of ice	2.0 J/(g °C)
specific heat capacity of water	4.2 J/(g °C)
specific latent heat of fusion of ice	330 J/g
specific latent heat of vaporisation of water	2260 J/g

(a) Explain what is meant by the statement: 'the specific latent heat of fusion of ice is 330 J/g'.

....

....

....[1]

(b) A block of ice is taken from a freezer at –25 °C, placed in a metal container, and heated by a source of constant power.

The graph in Fig. 4.1 shows how the temperature of the contents of the container changes with time. At point E on the graph the container is empty.

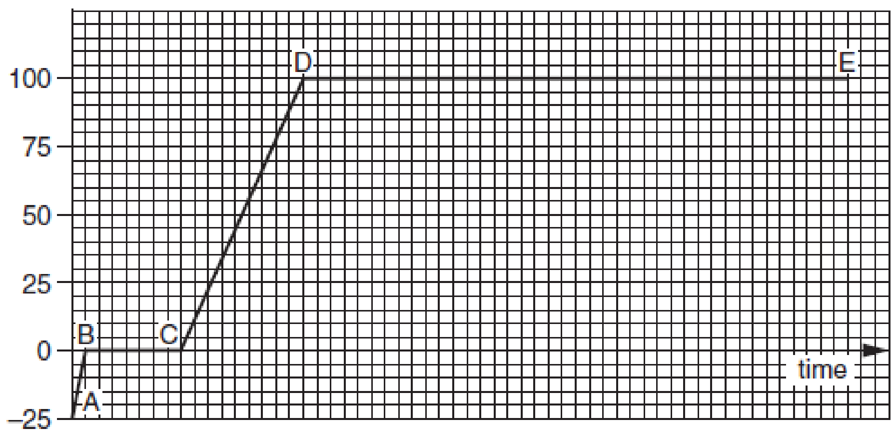


Fig. 4.1

(i) State what is taking place in the regions of the graph from B to C, and from D to E.

B to C ....

....

D to E ....

....[2]

(ii) Use the information in the table to explain why the line DE is longer than the line BC.

....

....

....[1]

(iii) Use the information in the table to explain why the graph is steeper from A to B than from C to D.

....

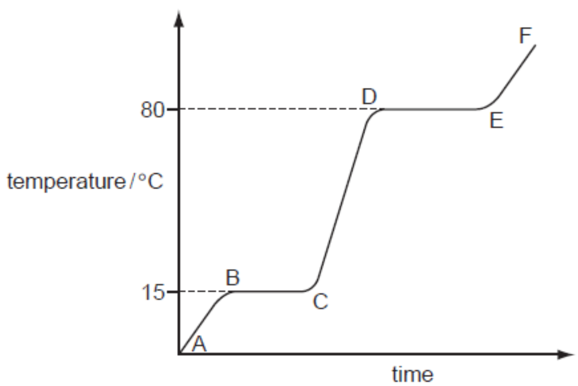
....

....[2]

[Total: 6]

Melting/Boiling/Evaporation

Explaining the change of state on the basis of kinetic theory



- Between A -B:The temperature of the solid increases. This is because increasing the heat energy increases the vibration of the particles in the solid.
- Between B-C:The force of attraction between the particles is weakened so the particles are able to slide past over each other. The temperature does not increase as all the heat supplied goes into overcoming the forces between the particles instead of raising the temperature. The substance melts.
- Between C-D. As time progresses the average kinetic energy of the liquid particles increases. Hence the temperature increases.
- Between D-E: The force of attraction between the particles is further weakened, so much so that the particles move well away from each other. The temperature is constant because the energy supplied goes into overcoming the forces between the particles instead of raising the temperature. The substance boils.
- Between E and F:The average kinetic energy of the particles increases and hence the speed of the particles also increases. Hence the temperature increases. The gas particles are now further away from each other.
- Note: In the region BC, The equation of the equilibrium is:

$$\text{Solid} \rightleftharpoons \text{Liquid} \qquad X(s) \rightleftharpoons X(l)$$

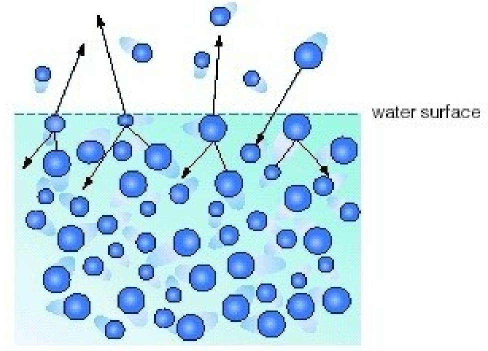
- The graph proves that a pure substance was used as the substance has a sharp melting point (at BC) and a sharp boiling point (at DE.)
- The temperatures $15^{0}C$ and $80^{0}C$ are important as they represent the melting and the boiling points.
- If an impure sample would have been used, the line BC would have been lower and the line DE would have been higher.

	C TO D	E TO F
Separation between particles	Close and touching	Far apart
Movement of particles	Random and slow	Fast and random
Can the particles move apart to fill the volume	Cannot move apart	Can move apart

---

Process of evaporation:

There are weak attractive force between the molecules in a liquid. When a liquid is heated , the kinetic energy of the molecules increases, Molecules with sufficient kinetic energy are able to break away from the neighbouring molecules and escape.



[Note that energy is used to overcome the attractive forces existing between molecules, so only the molecules with highest kinetic energy escape. Also work is done during evaporation]

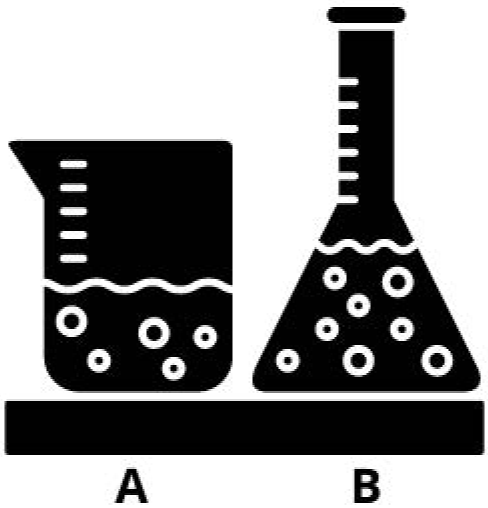
Evaporation causes cooling:

The molecules with the highest kinetic energy escape. Hence the average kinetic energy of the molecules decreases. So the liquid becomes cooler after evaporation takes place.

Factors affecting rate of evaporation:

- Temperature , surface area and a draught of air

EFFECT OF SURFACE AREA ON THE RATE OF EVAPORATION

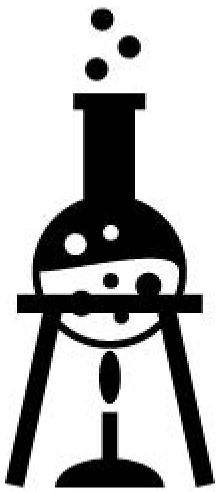


- Consider same type of hot liquid taken at the same starting temperature and kept in insulating cans A and B , of the same material but of shapes and sizes as shown in the figure aside.
- The liquid in container A will cool faster as it has a large surface area exposed to air as compared to liquid in container B

Explanation: Evaporation is a surface phenomenon. With larger surface area, more liquid molecules have enough kinetic energy to overcome the intermolecular forces of attraction and break away from the liquid and escape into the atmosphere as a gas (or vapour).

EFFECT OF TEMPERATURE ON THE RATE OF EVAPORATION

A



B

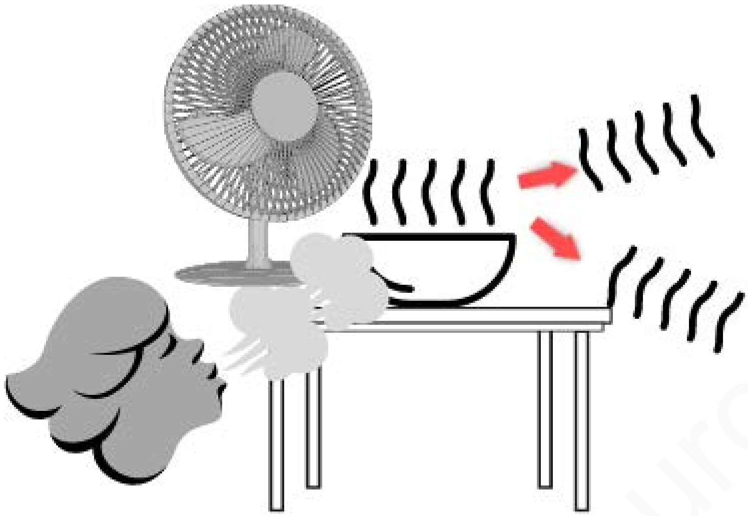
Liquid kept over a flame in figure **A** will evaporate faster as compared to the liquid in the bowl **B**.

EXPLANATION:

in the figure **A**, as the temperature increases, the molecules start moving faster and more molecules have sufficient energy to break the intermolecular forces of attraction and escape

In figure **B**, The evaporation will be slower as very few molecules have the energy needed to break the intermolecular bonds and escape as vapour

EFFECT OF DRAUGHT OF AIR ON THE RATE OF EVAPORATION



A draught of air over a hot surface helps to cool it faster as more molecules of the liquid evaporate

EXPLANATION: After molecules have left the liquid surface, they tend to form a vapour cloud over the liquid surface. A higher wind speed helps remove this vapour cloud. This helps the relative humidity stay unsaturated near the liquid surface. When the air is saturated, the amount of water vapour that evaporates into the air is minimized. Higher windspeed thus helps in faster evaporation by allowing more molecules with sufficient energy to leave the liquid surface and escape after having broken their bonds with their neighbouring molecules

---

Uses of evaporation:

- Making salt in salt pans: Salt is made in salt pans by evaporating the water from it.
- Wet clothes will dry faster on a hot day because more of the water molecules have sufficient energy to escape from the surface of the liquid.
- Hot tea gets cooled over time due to evaporation.

Difference between evaporation and boiling:

Sr. No	Evaporation	Boiling
1	Evaporation is a surface phenomenon. (or it does not happen within the liquid)	Boiling happens throughout the liquid
2	Evaporation happens at any temperature	Boiling happens at the liquid's boiling point
3	Evaporation causes cooling	Boiling does not cause cooling, the temperature stays constant.
4	There is no bubbling in evaporation	There is bubbling during boiling

---

APPLICATION BASED QUESTIONS:

MCQ:

13 During evaporation, molecules escape rapidly from the surface of a liquid.

What happens to the average energy of the molecules of the remaining liquid and what happens to the temperature of the remaining liquid?

0625/11/M/J/14

	average energy of remaining molecules	temperature of remaining liquid
A	decreases	decreases
B	decreases	increases
C	stays the same	decreases
D	stays the same	increases

13 Evaporation occurs when molecules escape from a liquid surface into the air above it. During this process the temperature of the liquid falls.

Why does the temperature of the liquid fall?

0625/11/O/N/11

A The molecules in the vapour expand because the pressure is less.

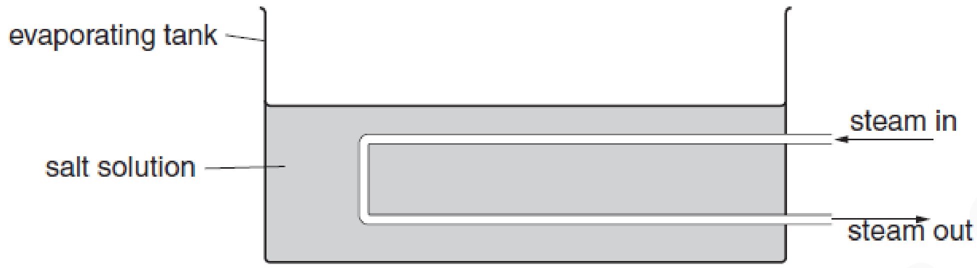
B The molecules left in the liquid have more space to move around.

C The molecules move more slowly when they escape into the air.

D The molecules with the highest energies escape into the air.

88

5 (a) Fig. 5.1 shows a tank used for evaporating salt solution to produce crystals.



M/J/2006-P3

Fig. 5.1

Suggest two ways of increasing the rate of evaporation of the water from the solution. Changes may be made to the apparatus, but the rate of steam supply must stay constant. You may assume the temperature of the salt solution remains constant.

1. ....

....

2. ....

....[2]

137

3 Water molecules evaporate from a puddle and escape to the atmosphere. Water molecules also escape to the atmosphere from water boiling in a kettle.

(a) State two ways in which *evaporation* differs from *boiling*.

1. ....

....

2. ....

....

[2]

5 **(a)** Puddles of water form on a path after rainfall on a windy day.

In terms of molecules, state and explain how the rate of evaporation of the puddles is affected by

M/J/14-p32-q5

(i) a reduction of wind speed,

....

....

....

.... [2]

(ii) an increase of water temperature.

....

....

....

.... [2]

(b) Fig. 5.1 shows two puddles.

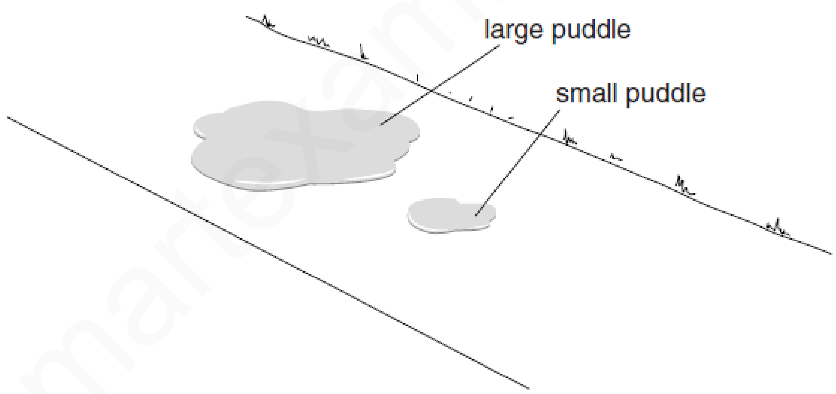


Fig. 5.1

State and explain how the rate of evaporation from the large puddle compares to that from the small puddle under the same conditions.

....

....

....

.... [2]

3 Water molecules evaporate from a puddle and escape to the atmosphere. Water molecules also escape to the atmosphere from water boiling in a kettle. **M/J/13-P32**

(a) State two ways in which *evaporation* differs from *boiling*.

1. ....

....

2. ....

....
[2]

---

5 **(a)** On a hot day, sweat forms on the surface of a person's body and the sweat evaporates.

Explain, in terms of the behaviour of molecules, m/j/13-p31

(i) the process of evaporation,

....

....

....

(ii) how this process helps the body to cool down.

....

....

....

....

....

....
[3]

(b) In a place where refrigeration is not possible, a person attempts to keep a bottle of milk cool by using the procedure illustrated in Fig. 7.2.

M/J/09-p32-q7

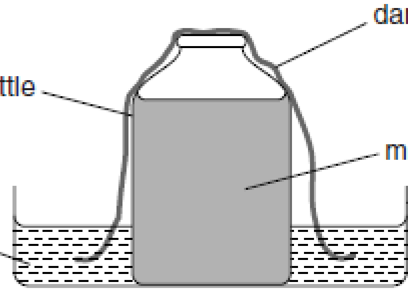


Fig. 7.2

Explain in terms of molecules why this procedure would be successful.

....

....

.... [3]

6 (a) Two students hang out identical T-shirts to dry at the same time in the same neighbourhood. The only difference between the drying conditions is that one T-shirt is sheltered from any wind and the other is in a strong breeze, as shown in Fig. 6.1.

M/J/12-P32

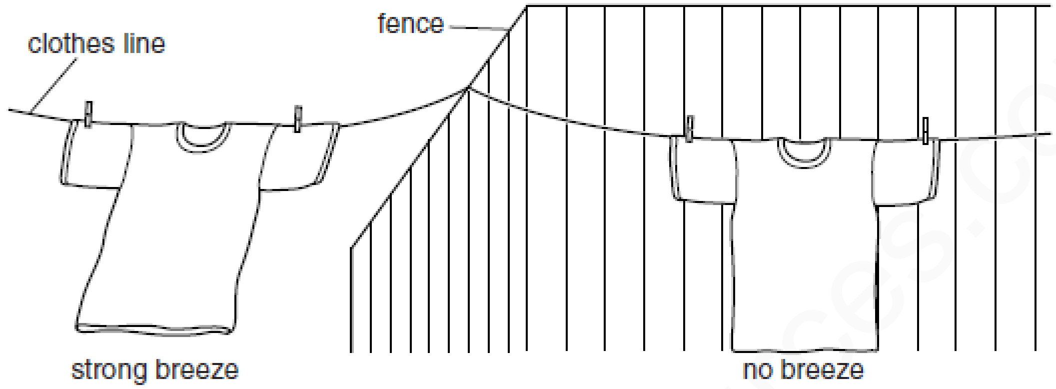


Fig. 6.1

State and explain, in terms of water molecules, the difference between the drying times of the T-shirts.

....

....

....

....

.... [2]

Kindly refer to the markschemes of the past papers if the study note board exam questions do not have the markschemes given to you

---

Conduction

Conduction:

Conduction in metals:

- Most metals contain a lot of free electrons called as mobile or conduction electrons. These are the atoms that have broken free from their atoms and thus changed them into positively charged ions. These electrons keep moving throughout the metals and are bonded by electrostatic forces of attraction to the positive ions.
- When a metal is heated at one end, the free electrons at the hot end gain kinetic energy and move faster.
- These electrons diffuse, move faster and in the process collide with other free electrons and metal ions in the cooler parts of the metal. Thus the kinetic energy is transferred by the electrons to other electrons and ions. In addition the ions vibrate faster due to an increase in their kinetic energy . Thus heat energy gets transferred from the hot end to the cold end by electrons and ions.

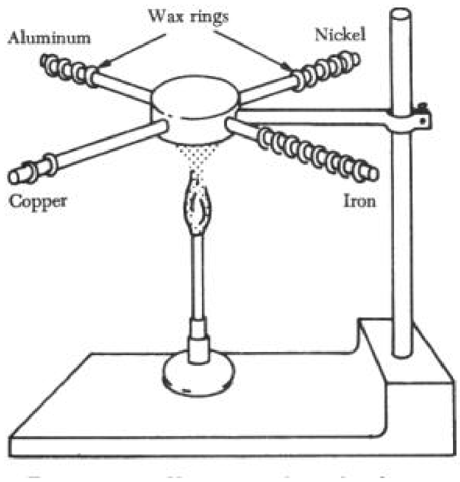
Conduction in non-metallic solids:

- In non metals, there are no free electrons. Hence when it is heated, heat only gets transferred via the atomic vibrations as the atoms are closely packed.
- This method of heat transfer is less effective as compared to conduction in metals.
- Hence non metals are bad conductors as compared to metals.

Conduction facts:

- Conduction cannot happen in vacuum.
- Metals conduct better than non metals.
- Conduction can happen in solids , liquids and gases.

Identify the best conductor:



In the adjoining figure, equal heat is supplied to the different metallic rods. The rod that has the minimum number of wax rings left at the end of a particular time interval is the best conductor of heat.

Note:

1. Thermal conduction is bad in gases and most liquids

-> Thermal conduction is bad in gases because gases have only a relatively low number of molecules which are also very far apart.Hence , only little energy can be transported through them.Also thermal conduction in gases and liquids is due to the collisions and the diffusion of the molecules during their random motion.

2. There are many solids that conduct thermal energy better than thermal **insulators but do so less well than good thermal conductors**

LIST OF THERMAL CONDUCTORS AND INSULATORS

Diamond
Copper
Gold
Aluminium
Concrete
Glass
Water
Wood
Polystyrene
Glass wool
Styrofoam
Air
Argon

Good thermal conductors
[or]
Poor insulators

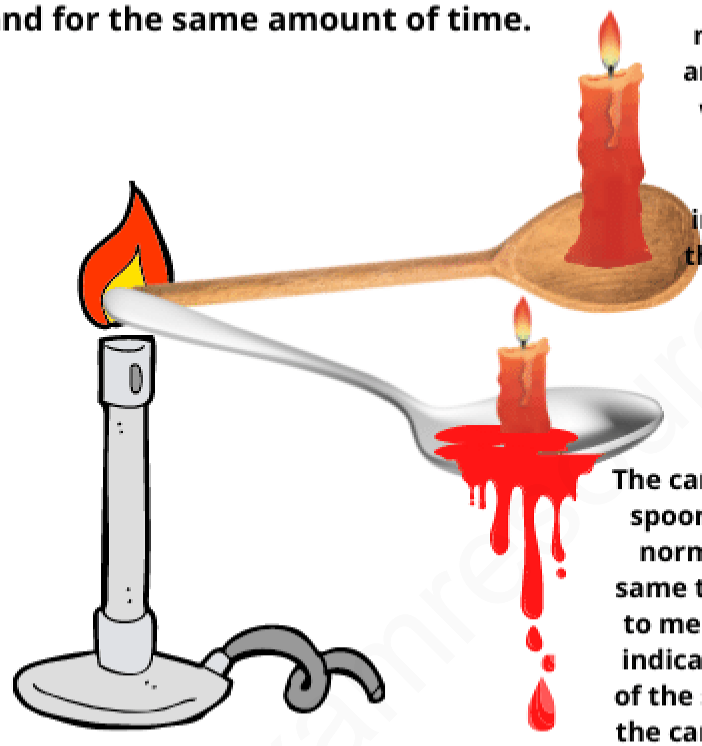
↓

Bad thermal conductors
[or]
Good insulators

THERMAL CONDUCTORS AND INSULATORS

Experimental set up:

2 spoons [of different materials] kept in the yellow part of the flame, with same type of candles and for the same amount of time.



The candle in the wooden spoon keeps burning normally without any dripping of the wax. This proves that wood is a good thermal insulator or a bad thermal conductor

The candle in the metal spoon keeps burning normally but at the same time, wax is seen to melt and drip . This indicates that the end of the spoon that holds the candle has become hot due to conduction and that metal is a good conductor

CONVECTION

Convection:

- Convection takes place when a liquid is heated due to circulation currents
- Convection can take place only in liquids and gases.
- Convection currents transfer heat energy from the hotter parts to the cooler parts of the fluid

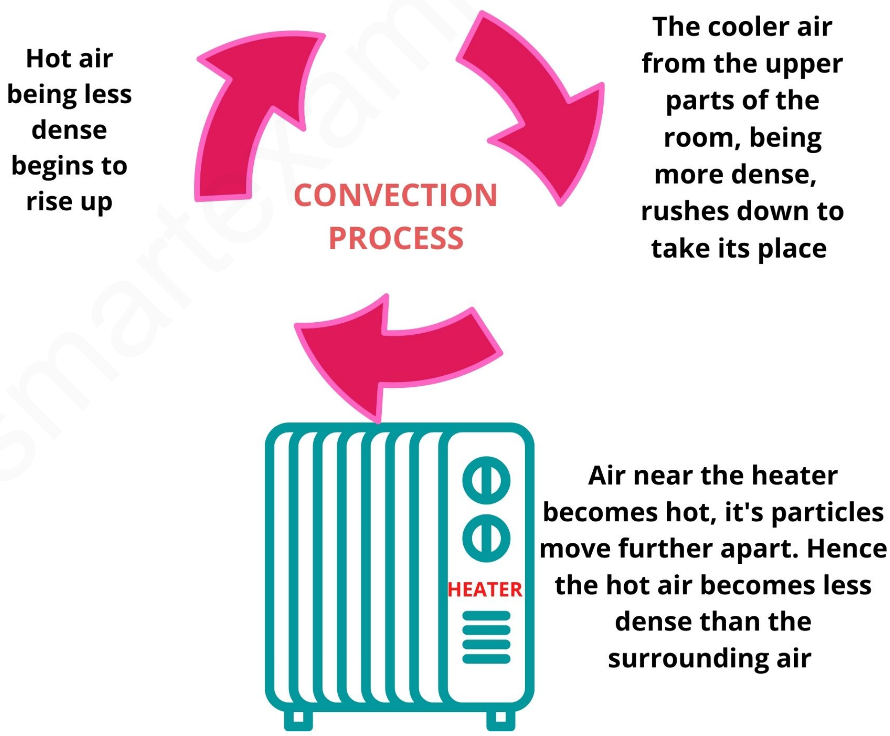
---

Explaining convection in terms of density changes

When a fluid is heated. its particles move further apart and occupy a larger volume. Since the mass stays the same , the overall density of the fluid decreases and it rises up.

Process of convection:

When a fluid is heated, it expands and becomes less dense. Hence it rises up The fluid at the top is cooler and more dense . Hence it moves down . There is a continuous flow of dense and less dense fluid. This gives rise to a convection current.



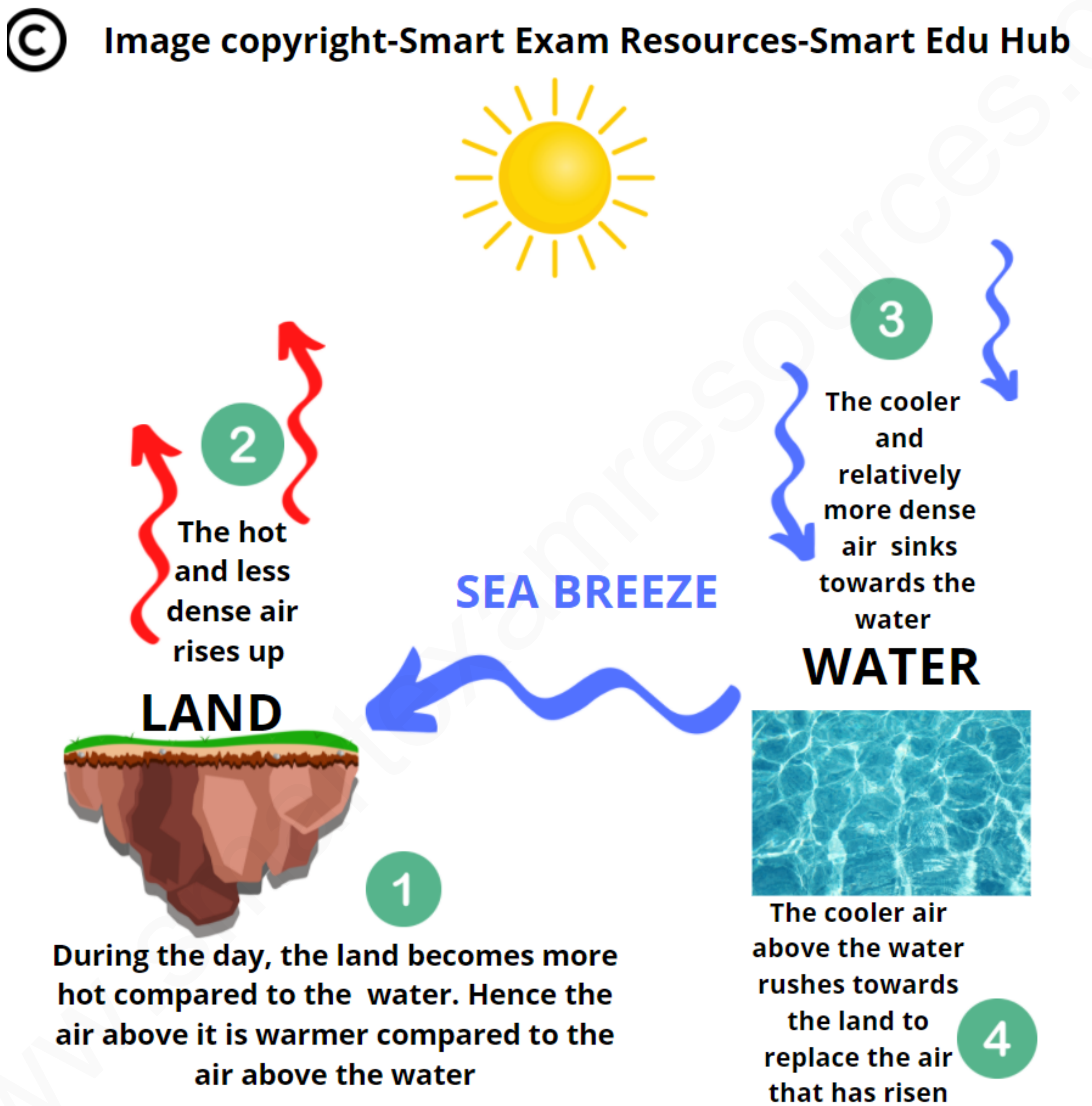
Note:

1.Convection is an important method of thermal energy transfer in liquids and gases

----

Example of convection current are land and sea breezes.

Sea breeze: During the day, the land is hotter. Hence the air above it is hotter and less dense. Hence the hot air from the land rises up and rushes towards the water and the cooler air from above the water rushes to take its place.



===

Land breeze: During the night, the water is warmer. Hence the air above it is hotter and less dense. Hence the hot air from the water rises up and rushes towards the land and the cooler air from above the land rushes to take its place.

RADIATION

Note:

- The thermal radiation is infrared radiation and that all objects emit this radiation.
- The thermal energy transfer by thermal radiation does not require a medium.
- For an object to be at a constant temperature, it needs to transfer energy away from the object at the same rate that ir receives energy

EFFECT OF SURFACE COLOUR AND TEXTURE ON THE ABSORPTION AND REFLECTION OF INFRA-RED RADIATION:

GOOD EMITTERS AND ABSORBERS OF INFRA-RED [IR] RADIATION

The above image shows the following set-up:

- **Two beakers are taken with equal amount of water and at the same starting temperature.**
- **Each beaker is kept at the same distance from the light source.**
- **The beakers are exposed to the light for the same length of time**

It is observed that:

- **The silvered beaker with a shiny surface has less temperature rise as compared to the dark matt black coloured beaker for the same amount of time.**
- **When the light source is removed, it is observed that the dull black matt coloured beaker loses heat more quickly than the shiny-silvered beaker during the same length of time**

Conclusion: Dark, matt surfaces are good absorbers and emitters of infrared radiation. Light, shiny surfaces are poor absorbers and emitters of infrared radiation.

SPECIAL CASES:

1. If the rate at which an object emits radiation is greater than the rate at which it absorbs radiation, it indicates that the object is cooling.
2. When the rate at which an object emits radiation = Rate at which it absorbs radiation, it means the object is at the same constant temperature as its surroundings.
3. When the rate of emitted radiation is less than the rate of the absorbed radiation, it means the object is heating up. The temperature of the object is increasing.

The rate of emission of radiation depends on:

- ✓ **The surface temperature and**
- ✓ **The surface area of an object**

THE TEMPERATURE OF THE EARTH IS AFFECTED BY THE FACTORS CONTROLLING THE BALANCE BETWEEN INCOMING AND THE RADIATION EMITTED BY THE EARTH'S SURFACE

DAYTIME:

- ✓ A large amount of EM radiation is transferred to the Earth's surface and atmosphere during the daytime .
- ✓ During bright sunlight, the temperature of the earth's surface increases. This is because although some radiation does get absorbed by the atmosphere ,most of it passes through the atmosphere and then gets absorbed by the Earth's surface. When the earth's surface gets warmed up, the air around it also gets warmer. The overall result the rising of the Earth's temperature as more EM radiation is absorbed as compared to what is emitted.
- ✓ Also a clearer sky, results in even higher temperatures as very less amount of the Sun's energy is reflected back into space and more is rather absorbed.

NIGHT-TIME:

- ✓ During night, more EM radiation is emitted than is absorbed. Temperature is seen to decrease due to the lack of sunlight .There is also an increase in the heat loss on the days when the sky is clear .
- ✓ The EM is also absorbed by greenhouse gases like carbon dioxide and methane, which overall adds to a reduction in the temperature of the earth's surface.
- ✓ When the night sky is clear, there occurs a great fall in the temperature This is because the emitted infrared radiation is not reflected or absorbed by clouds.
- ✓ Conversely, with cloudy nights, some of the emitted radiation from the Earth's surface is reflected back off the clouds or absorbed by them, so the night-time temperature fall is not as great.

On the whole, there exists a fairly constant temperature on the Earth and allows for the survival of different life-forms.

Infra-red radiation:

Infra-red radiation:

- It is a part of the electromagnetic spectrum.
- Every object around us emits infra-red radiation.
- The hotter the object is, the more infra-red radiation its emits.
- Very hot objects emit light as well as infrared radiation.
- Infra red radiation does not require a medium to travel.

Experiment for detecting infra-red radiation:

A glass prism splits the white light into a spectrum of colours. When the thermometer is placed beyond the red part of the spectrum, the temperature of the thermometer is increased due to some invisible radiation. This invisible radiation is called as infra-red radiation as its frequency is less than the frequency of the red part of the visible spectrum.

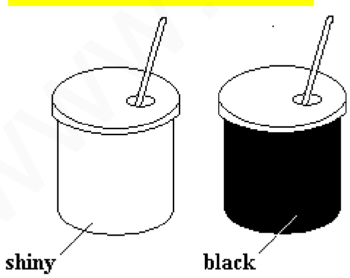
Thermal radiation: The radiation emitted by an object because of its temperature is also called as thermal radiation. Because this type of radiation may also emit light along with infra red radiation.

Effect of surface colour (black or white) and texture(dull or shiny) on the emission , absorption and reflection of radiation.

Dark, matt surfaces:

- ✓ Emit infra-red radiations better than light , shiny surfaces.
- ✓ Absorb infra red radiations better than light , shiny surfaces.

Experiment to check which surface is a good absorber and a good emitter of infra red radiation:

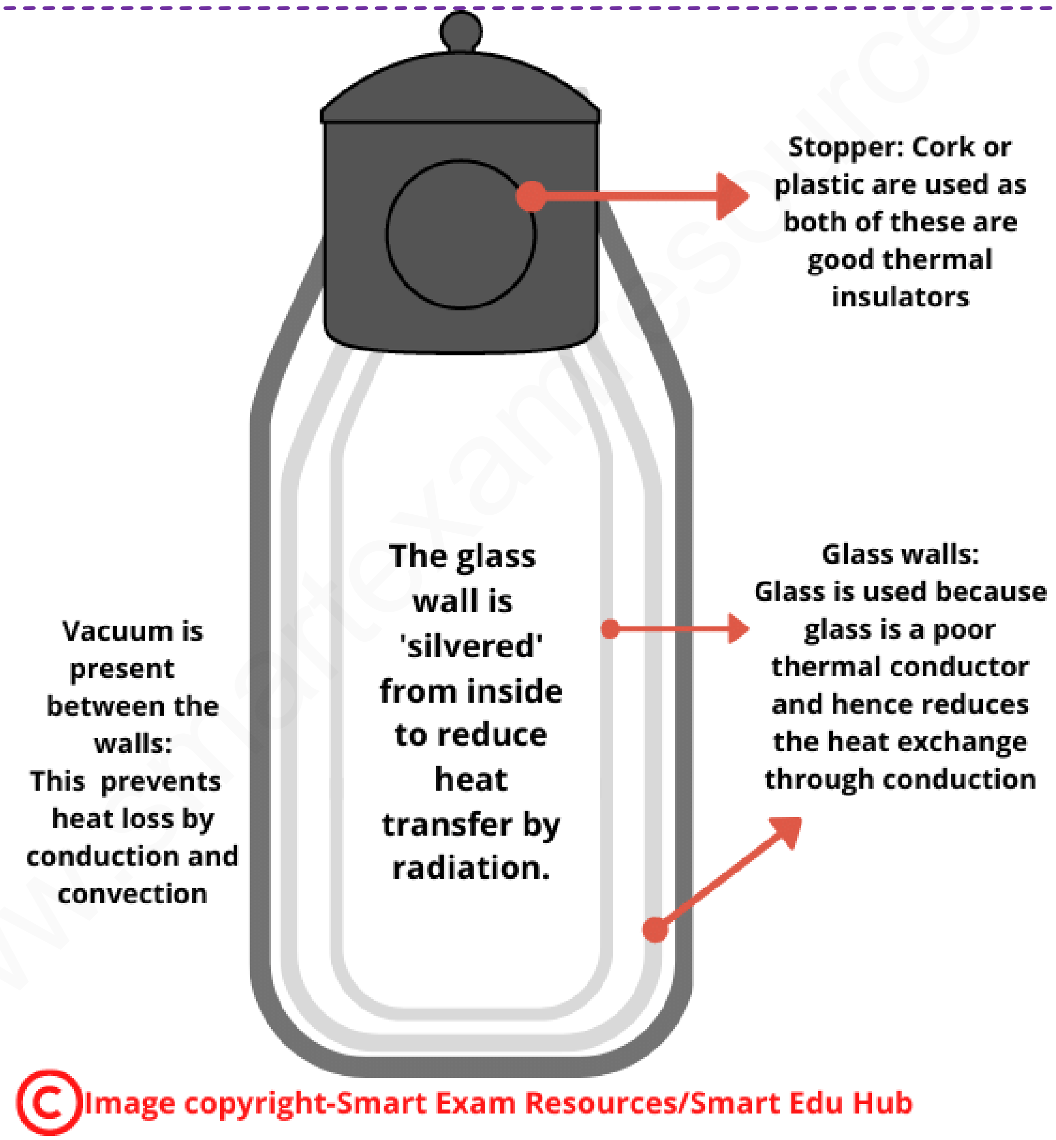


Paint one beaker white and shiny and silvery. Paint the other beaker dark matt. Fill equal volume of hot water at the same temperature. After the same time observe the change in temperature. You will find that the black matt painted beaker cools down faster.

Controlling the amount of radiations getting absorbed:

- In hot countries, houses are painted white so that the rays are reflected back into space and the amount of heat absorbed will be less.
- White coloured blinds or window shutters also reduce the amount on radiations absorbed by the house.
- Thick walls are constructed so that less heat is transferred due to conduction.

Controlling the heat losses through a thermos flask:

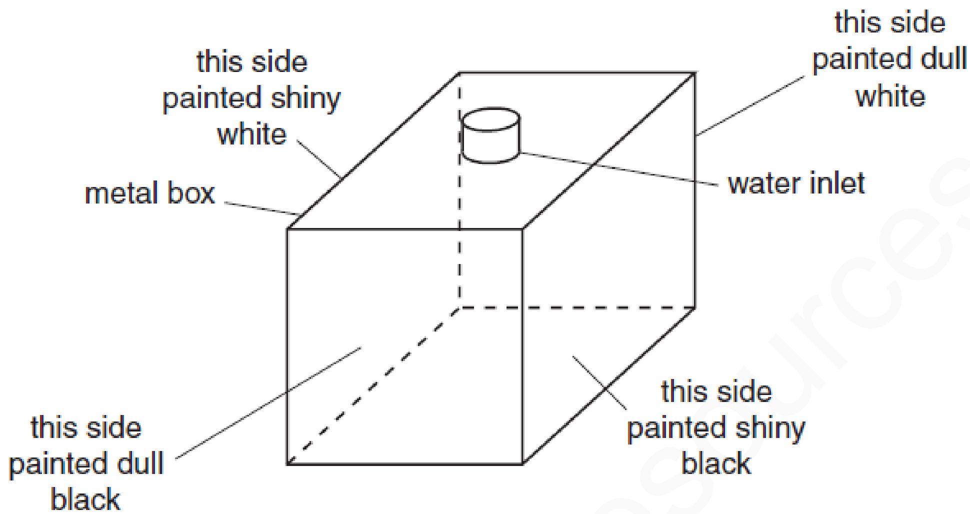


Note: The amount of heat emitted depends upon the surface temperature and surface area of the body

---

CONDUCTION CONVECTION RADIATION-MIXED BAG

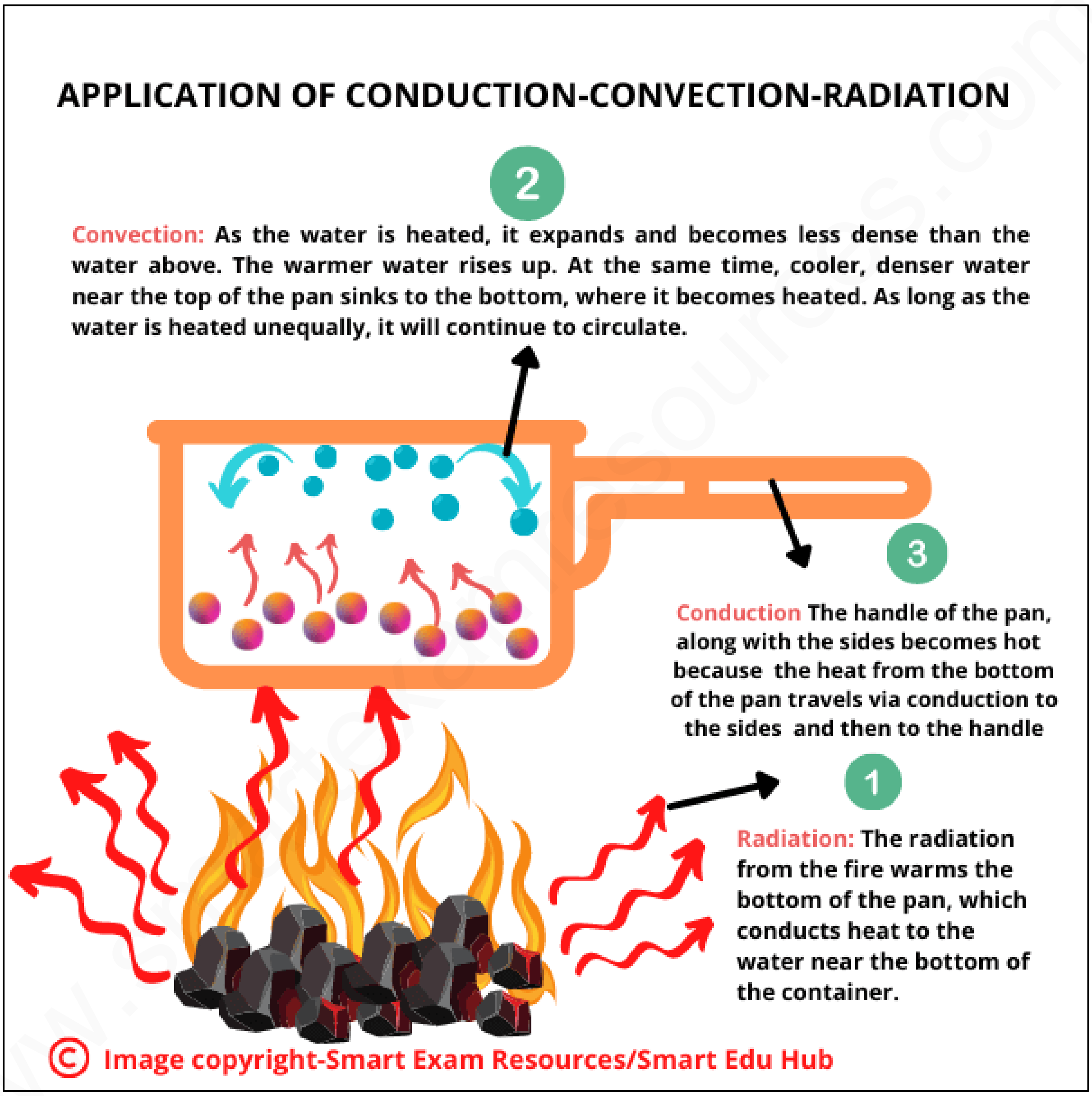
To use the following apparatus to check the emission of infra red radiations from different surfaces.



- Near the center of each side place an identical infra-red detector.
- Note the temperature of each thermometer.
- Then pour hot water in the box above.
- Note the temperature of each thermometer after some time again for all the thermometers .
- Note the rise in temperature of each thermometer.
- You will find that dull black is the best emitter.
- And the painted shiny white is the worst emitter.

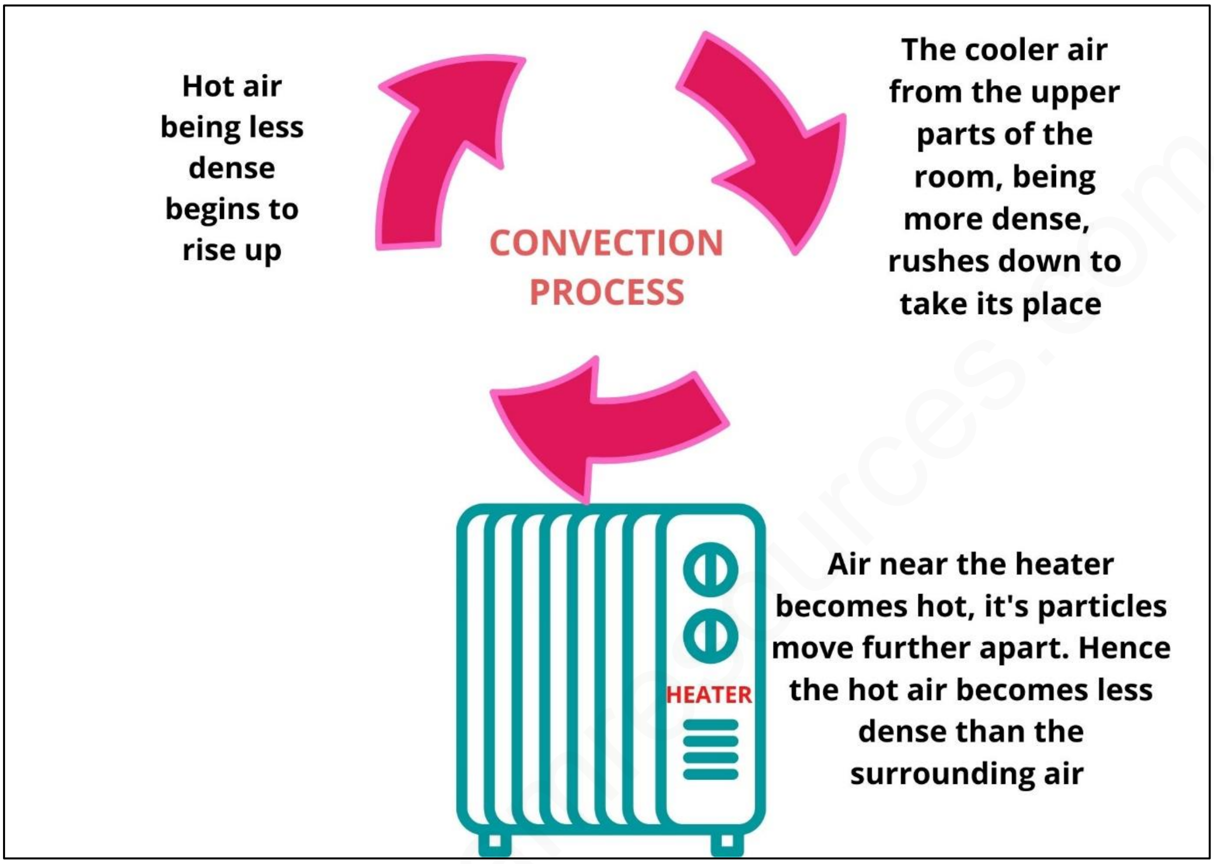
Consequences of thermal energy transfer

EVERYDAY APPLICATIONS OF THERMAL ENERGY TRANSFER EXAMPLE:1 HEATING OF A PAN



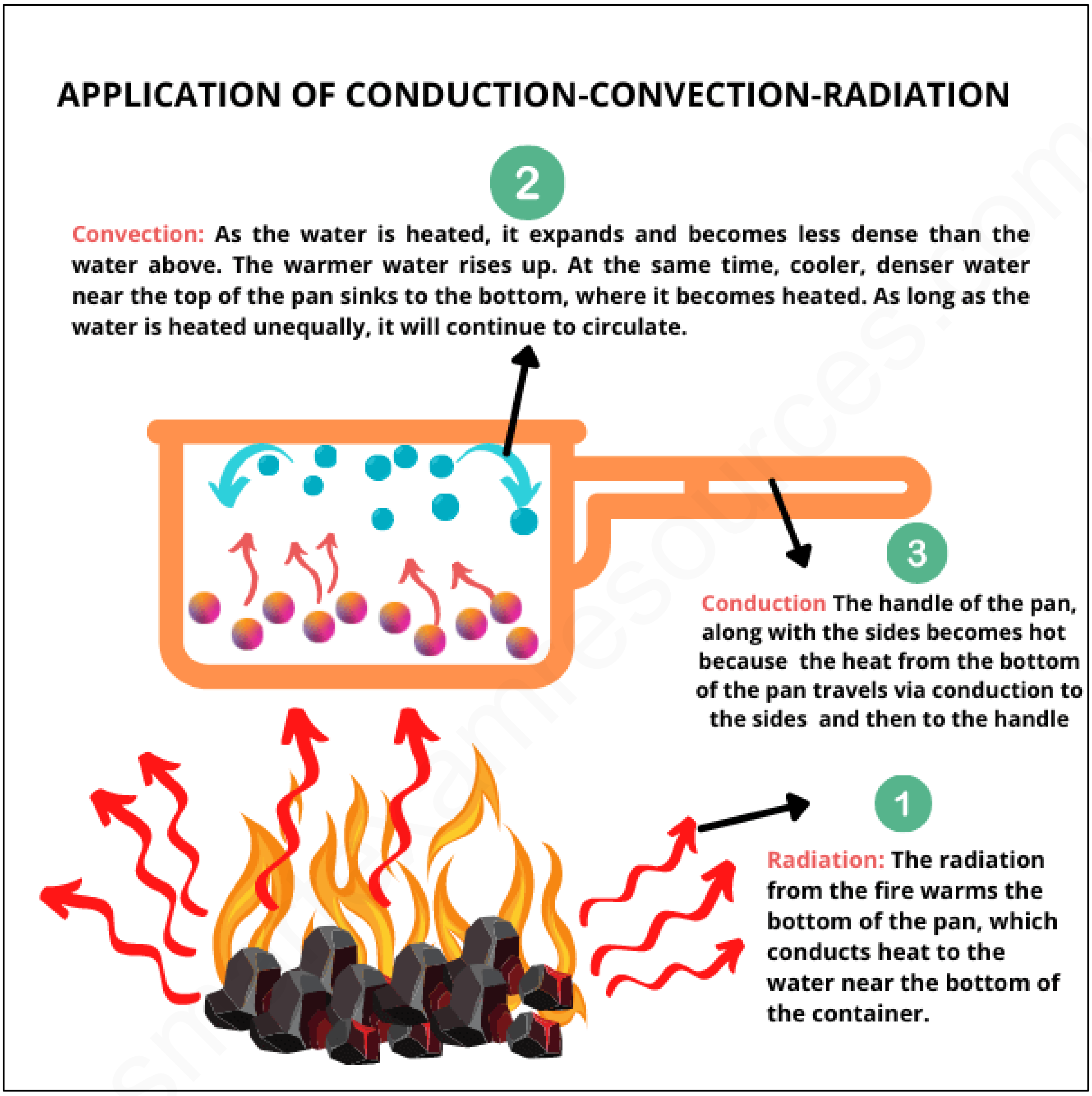
EXAMPLE:2

HEATING A ROOM BY CONVECTION



EXAMPLE:3

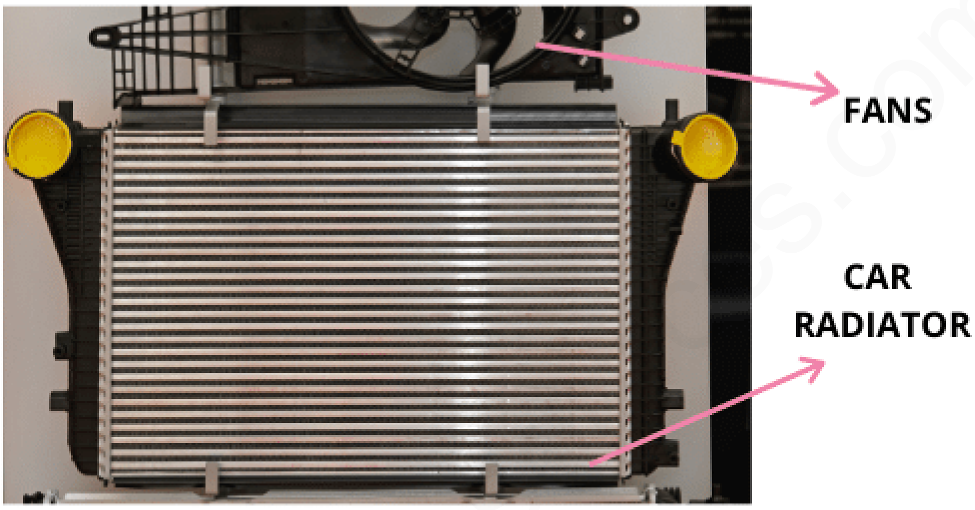
A FIRE BURNING COAL



EXAMPLE:4

A RADIATOR IN A CAR

HEAT EXCHANGE-CAR RADIATOR



- The coolant jacket surrounding the car engines gets heated due to the heat of the internal combustion engine through radiation and convection
- The radiator absorbs this heat when the hot coolant flows through it nd itself becomes hot through a process called as conduction .The radiator is positioned so as to enable it to exchange the coolant heat with the surroundings via radiation
- The radiator fan is positioned between the radiator and the engine. This fan increases the draught of air and thereby increases the heat transfer from the hot coolant to the surroundings. Thus convection currents are set up and the hot air is expelled out of the car and the coolant is cooled and returns back to the engine.