PARTICULATE NATURE OF MATTER

Definition:
Matter is anything that occupies space and has weight.

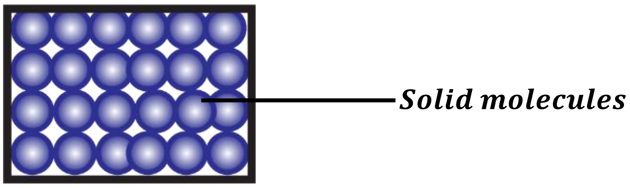
States of matter
There are three states of matter namely;

→ Solids e.g. stone, wood, ice, etc.
→ Liquids e.g. milk, water, paraffin, etc.
→ Gases e.g. oxygen, nitrogen, etc.

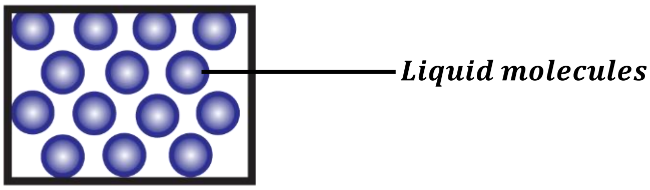
Each of the above particles is made up of tiny particles called molecules.

Properties of the states of matter:

a) SOLIDS:
- Molecules in solids are closely packed together.
- Solids have a definite shape.
- Solids have a definite volume.
- The intermolecular forces between molecules of a solid are very strong.
- Solids are incompressible. i.e. their volumes cannot be reduced by squeezing.

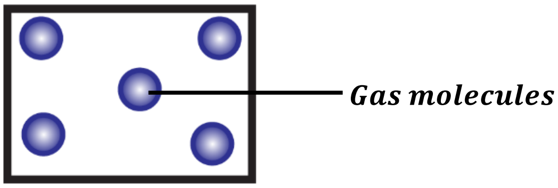


b) LIQUIDS:
- Molecules in liquids are fairly closely packed together.
- Liquids do not have a definite shape. They take the shape of the container in which they are put.
- Liquids do not have a definite volume. They take the volume of the container in which they are put.
- The intermolecular forces between molecules of a liquid are relatively weak compared to those of solids.
- Liquids are incompressible. i.e. their volumes cannot be reduced by squeezing.



c) GASES:
- Molecules in gases are widely spaced.
- Gases do not have a definite shape. They take the shape of the container in which they are put.
- Gases do not have a definite volume. They take the volume of the container in which they are put.

- The intermolecular forces between molecules of a gas are very weak compared to those of solids and liquids.
- Gases are compressible. i.e. their volumes can be reduced by squeezing.



Question: Explain how it is possible to compress gases than solids.

This is because the molecules of gases are widely spaced (have free spaces in between them) and the intermolecular forces between them are very weak. Therefore, if there is squeezing of the molecules of a gas, also the free spaces are occupied by the squeezed molecules thus reducing the amount of space occupied by these molecules.

<u>EFFECT OF HEATING MATTER</u>:

- When a solid is heated, its molecules gain kinetic energy and their speed is increased thus vibrating more violently. This weakens the intermolecular forces of attraction and repulsion between the solid molecules hence they start to separate. This causes a solid to change to liquid.

<u>Question 1</u>: Explain why ice melts to liquid when it is placed under sunshine.

This is because that the sun rays from the sun heats up the ice causing the molecules of ice to gain kinetic energy thus increasing their speeds. This causes them to vibrate more violently thus breaking or weakening the intermolecular forces between them hence causing ice to melt to liquid.

- When a liquid is heated, its molecules gain kinetic energy and their speed is increased thus vibrating violently. This weakens the intermolecular forces of attraction and repulsion between the liquid molecules. This causes a liquid to boil and change to vapour.

<u>Question 2</u>: Explain vapour is seen when water is boiled

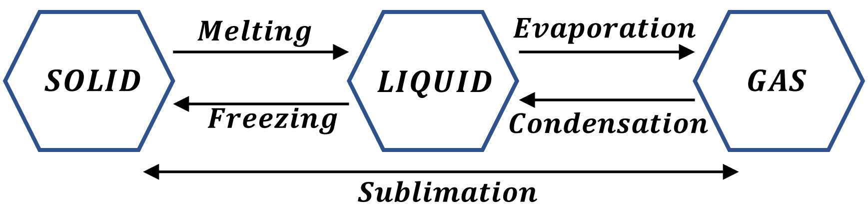
This is because when water is heated, its molecules gain kinetic energy thus increasing their speeds. This causes them to vibrate more violently thus breaking or weakening the intermolecular forces between them hence causing some molecules to escape from the surface of the liquid which are seen as vapour.

<u>EFFECT OF COOLING MATTER</u>:

- When a gas or vapour is cooled, its kinetic energy reduces hence the speed of its molecules also reduces. This causes the intermolecular forces between the gas molecules to start to build up. Therefore, the gas changes to a liquid.

On further cooling, the liquid changes to a solid.

CHANGES OF STATES OF MATTER



Melting: This is a process by which a solid change to a liquid. It occurs at a constant temperature called melting point.

Evaporation: This is a process by which a liquid change to a gas. It occurs at a constant temperature called boiling point.

Freezing: This is a process by which a liquid change to a solid. It occurs at a constant temperature called freezing point.

Condensation: This is a process by which a gas change to a liquid.

Sublimation: This is a process by which a solid change to a gas or a gas changes to a solid.

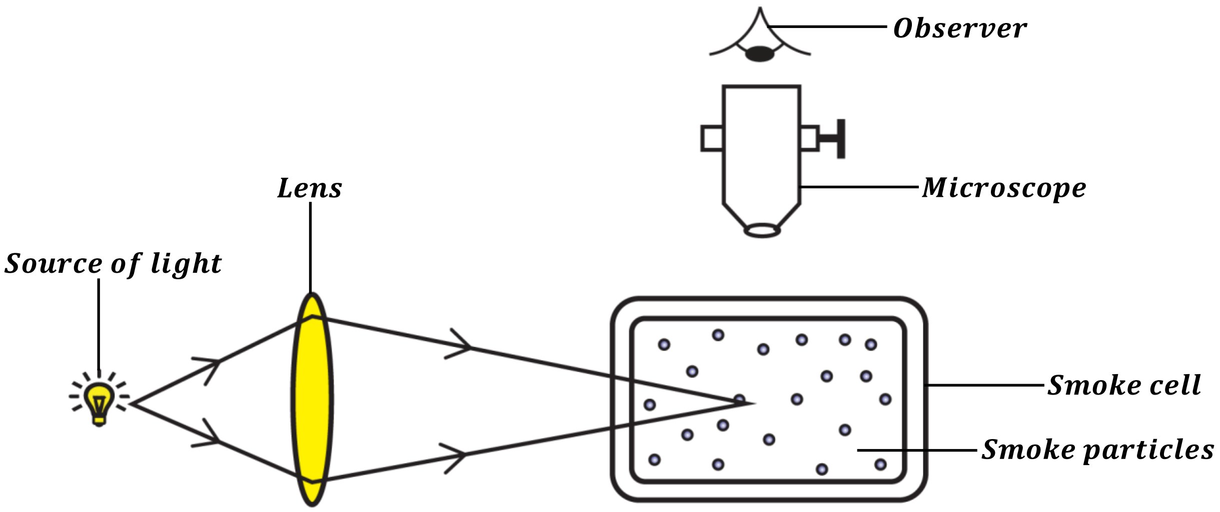
KINETIC THEORY OF MATTER

It states that matter is made up of small particles called molecules that are in a state of continuous random motion and increase in temperature increases their speed.

Matter possesses kinetic energy due to the continuous movement of its molecules.
The kinetic theory of matter can be proved by Brownian motion or diffusion.

BROWNIAN MOTION:
This was illustrated by an English man called Robert Brown.
Definition:
Brownian motion is the continuous random movement of molecules of fluids.

An experiment to demonstrate Brownian motion using a smoke cell.



Procedures:
- Smoke particles are put in a smoke cell.
- The smoke particles are illuminated by a source of light from one side of the smoke cell.
- The smoke particles are then viewed using a microscope placed above the smoke cell.

Observation:
- The smoke particles are seen moving in a continuous random motion.

Explanation:
- The continuous random motion of the smoke particles is due to collision with the air molecules in the smoke cell which are also in a constant random motion.

NOTE:

- Brownian motion in liquids can be demonstrated by using a glass container containing water with some pollen grains in it instead of a smoke cell. The pollen grains will also be seen moving with a constant or continuous random motion.

EFFECT OF TEMPERATURE ON BROWNIAN MOTION

→ **Increasing the temperature (heating):**
When the temperature of the smoke cell is increased, the smoke particles are seen moving faster and more randomly.
This is because the increase in temperature causes the kinetic energy of the smoke particles to also increase thus increasing their speed. This makes the smoke particles to move faster than before.

→ **Decreasing the temperature (cooling):**
When the temperature of the smoke cell is decreased (e.g. by placing the smoke cell in in ice cubes), the smoke particles are seen moving slowly and less randomly.
This is because the decrease in temperature causes the kinetic energy of the smoke particles to also decrease thus reducing their speed. This makes the smoke particles to move slower than before.

EXERCISE:

1. Smoke is enclosed in a cell and then viewed through a microscope.
   a) Explain what is observed.
   b) State what is observed when the smoke cell is placed in ice blocks. Give a reason for your answer.

2. Dust was introduced in a room with yellow light.
   a) Explain what was observed.
   b) Explain what happens when the temperature of the room is increased.

3. a) What is meant by the term "Brownian motion".
   b) Describe an experiment to demonstrate Brownian motion in liquids.

4. Describe the relationship between molecules of liquids, gases and solids in terms of;
   a) The arrangement of molecules.
   b) The separation of the molecules.
   c) The forces of attraction between the molecules.
   d) The compressibility of the three states of matter.

5. Draw a well labelled diagram you would use to describe Brownian motion using smoke.
   a) How is the motion of the smoke particles best described?
   b) Account for the motion of the smoke particles in (a) above.

MOLECULAR PROPERTIES OF MATTER

The molecular properties of matter are as a result of the behavior of its molecules.
The behavior of molecules is seen in the following processes.

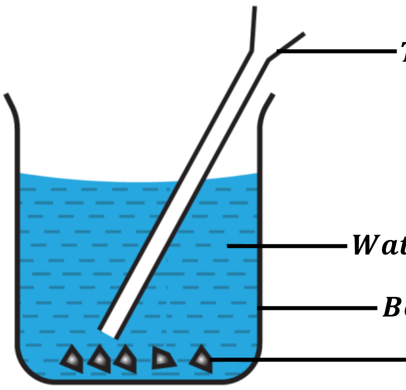
→ Diffusion.
→ Intermolecular forces.
→ Capillarity.
→ Surface tension.

DIFFUSION:

When a rotten egg is placed in one corner of a class room, the entire class room and even those in the far corners can notice the bad smell of the rotten egg.
This is because the smell is spreading or moving from where it was put to the other areas of the classroom.

Definition:
Diffusion is the movement of molecules from a region of high concentration to a region of low concentration.

An experiment to demonstrate diffusion in liquids.



Procedures:

- A beaker is filled with water.
- Some crystals of potassium permanganate (purple crystals) are placed at the bottom of the beaker using a thistle funnel.

Observation:

- It is observed that the crystals of potassium permanganate dissolve in water and they spread throughout the water forming a purple solution.

Explanation:

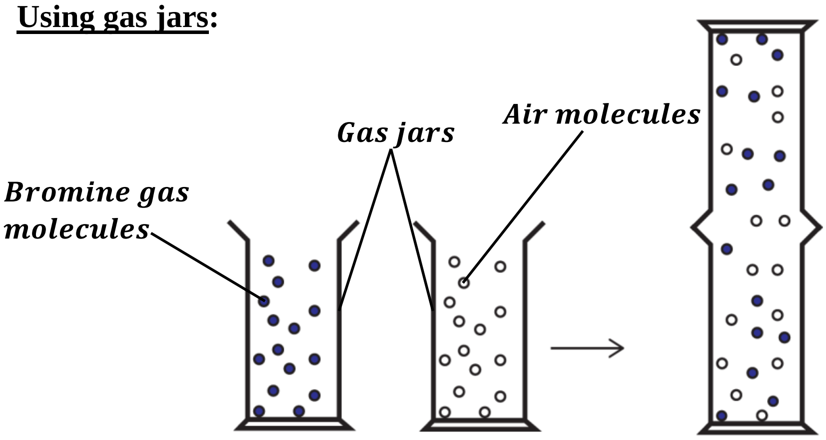
- The whole water becomes purple because the molecules of potassium permanganate have diffused into water from the bottom (high concentration) to the top (low concentration).

NOTE:

- Another coloured substance that can be used is copper (ii) sulphate crystals (blue crystals). The solution becomes blue if they are dissolved in water.

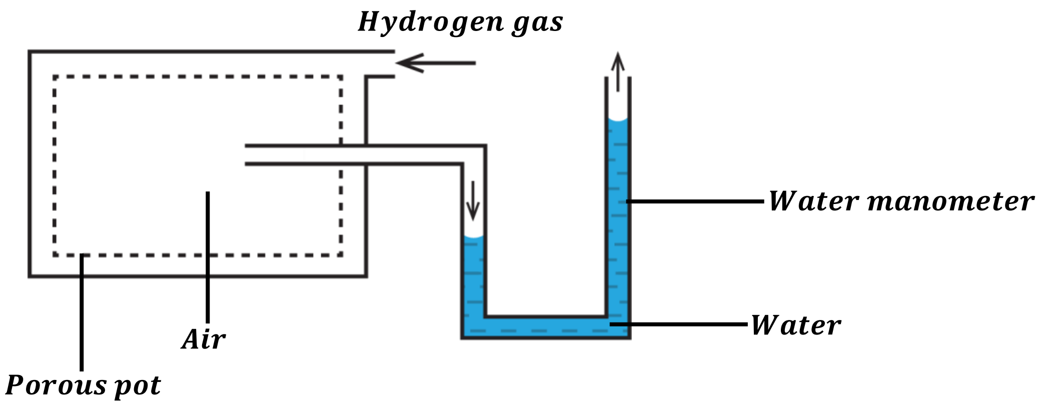
An experiment to demonstrate diffusion in gases.

a) **Using gas jars:**



- Two gas jars of the same diameter are obtained.
- One gas jar is filled with a coloured gas e.g. bromine gas (brown in colour) and the other gas jar is filled with air molecules.
- The gas jar containing air is inverted on the open end of the gas jar containing bromine gas.
- It is observed that after sometime, the brown colour of bromine gas is seen spreading into the gas jar containing air.
- This shows that brown bromine gas is diffusing from the gas jar where it is more concentrated to the gas jar where it is less concentrated.

b) **Using a porous pot:**



Procedures:
- A water manometer is connected to a porous pot containing water.
- Hydrogen gas is passed into the air enclosed in the porous pot as shown above.

Observation:
- It is observed that the water level in the left arm of the manometer falls while that in the right arm of the manometer rises.

Explanation:
- This shows that hydrogen gas molecules diffuse through the porous pot hence increasing the pressure on the surface of water in the manometer thus pushing water down in the left arm. This causes a rise in water in the right arm of the manometer.

FACTORS THAT AFFECT THE RATE OF DIFFUSION

1. **Temperature:**
   The rate of diffusion is directly proportional to the temperature.
   Therefore, the rate of diffusion increases with an increase in temperature and decreases with a decrease in temperature.
   This is because when temperature is increased, the speed of molecules increases thus spreading faster and when the temperature is lowered, the speed of molecules decreases thus spreading at a slow rate.
   This explains why the smell from a latrine spreads faster during a dry day.

2. **Size of diffusing molecules:**
   Smaller molecules diffuse faster than larger molecules. This is because large molecules occupy more space than the small molecules thus it becomes difficult for them to pass through a material with small pores.

3. **Pressure:**
   The rate of diffusion is directly proportional to the pressure.
   Therefore, the rate of diffusion increases with an increase in pressure and reduces with a decrease in pressure.
   This is because when pressure is increased, the molecules are highly squeezed thus causing them to collide more frequently hence making them to move faster.

4. **Density of the gas molecules:**
   The rate of diffusion is inversely proportional to the density of gas molecules.
   Therefore, the higher the density, the lower the rate of diffusion and the lower the density, the higher the rate of diffusion.
   Lighter molecules diffuse faster than heavier molecules.

5. **Concentration of diffusing material:**
   The higher the concentration of a diffusing material, the higher the rate of diffusion and the lower the concentration of a diffusing material, the lower the rate of diffusion.
   This explains why more concentrated sugar at the bottom of the cup spreads faster in porridge than a low concentration of sugar at the bottom.

6. **Size of pores in the porous material:**
   Large pores of a porous material allow many molecules to pass through them per unit time while small pores allow very few molecules to pass through them. As a result, the rate of diffusion is high when the size of pores is large and low when the size of pores is small.

NOTE:

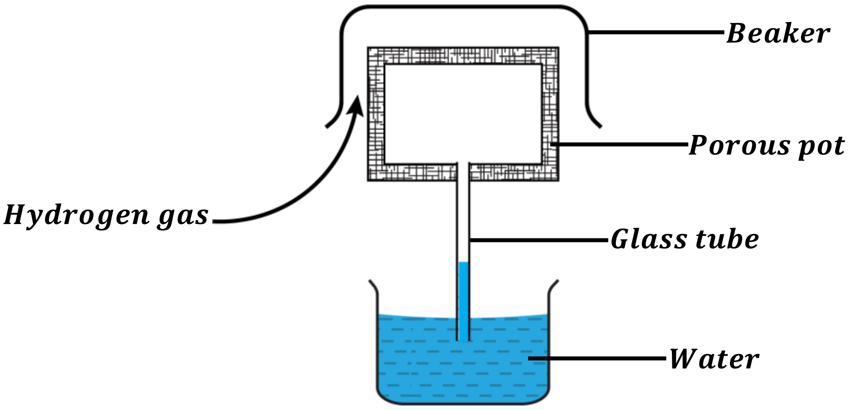
- Diffusion is fastest in gases, relatively faster in liquids and very slow in solids. In liquids and gases, particles or molecules move randomly from place to place. These particles collide with each other thus changing directions. Eventually, the particles are spread through the whole container.
- Diffusion is faster in gases because gas molecules are widely spaced therefore, the intermolecular forces between them are very weak thus the molecules can easily move randomly from place to place.

EXERCISE:

1. Explain the following observations in daily life.
   i) A small amount of perfume sprayed at one corner of a room spreads quickly and fills the whole room.
   ii) The smell from a pit latrine spreads faster to the surrounding areas on a dry day.
   iii) If you put much sugar in tea, the tea will become sweet even if you don't stir it.

2. a) What is meant by the term diffusion?
   b) Describe an experiment to show diffusion in liquids.
   c) A porous pot containing air is connected to a water mater manometer. Explain what happens if hydrogen gas is let in the space surrounding it.

3. The figure below shows an arrangement to demonstrate diffusion.



   Hydrogen gas is supplied for some time and then stopped. State and explain what is likely to be observed when hydrogen gas supply;
   a) is on.
   b) is stopped.

<u>INTERMOLECULAR FORCES</u>:

Molecular forces are forces of attraction or repulsion between molecules of matter.
These molecular forces hold molecules of matter. They become weak as temperature of matter is increased.
The molecular forces include;

→ cohesion forces.
→ Adhesion forces.

<u>COHESION FORCES</u>:

These are forces of attraction between molecules of the same substance or same kind.
E.g.:

- Forces of attraction between a water molecule and another water molecule.
- Forces of attraction between glass molecules themselves.

<u>ADHESION FORCES</u>:

These are forces of attraction between molecules of different substances.
E.g.:

- Forces of attraction between a water molecule and a glass molecule.
- Forces of attraction between mercury molecules and paraffin molecules.

EFFECTS OF ADHESION AND COHESION FORCES

The magnitude of cohesive and adhesive forces determines;

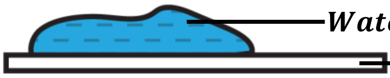
- The ability of a liquid to wet another material.
- Shape of meniscus of the liquid.
- The rise or fall of a liquid in the capillary tube.

When adhesion forces are greater than cohesion forces (e.g. water and glass molecules):

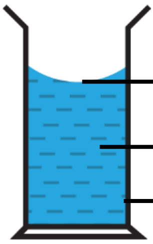
The forces of attraction between water molecules and molecules of other substances e.g. glass (adhesive forces) are greater than the forces of attraction between water molecules themselves (cohesive forces).

This explains the following observations:

- When water is spilled (poured) on a clean glass surface, water spreads out and wets the glass.



- When water is poured in a clean container, the meniscus of water curves upwards.

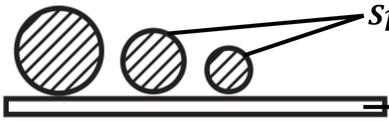


When cohesion forces are greater than adhesion forces (e.g. mercury molecules):

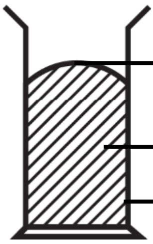
The forces of attraction between mercury molecules themselves (cohesive forces) are greater than the forces of attraction between mercury molecules and molecules of other substances (adhesive forces).

This explains the following observations:

- When mercury is spilled (poured) on a clean glass surface, mercury forms small spherical droplets and doesn't wet the glass.



- When mercury is poured in a clean container, the meniscus of mercury curves downwards.



Question 1: Explain why when water is poured on glass, water wets it.

Water spreads on the glass surface due to greater adhesion forces between glass and water molecules than the cohesion forces between water molecules themselves hence wetting the glass.

Question 2: Explain why rain falls in droplets rather than a fine mist.

This is because water has very strong cohesive forces which pulls its molecules tightly together forming droplets.

Revision questions:

1. Explain why water in a narrow glass tube has a concave meniscus (curves upwards) while mercury, in the same tube has a convex meniscus (curves downwards).
2. Explain why when washing glass utensils, water remains attached to the utensils.

CAPILLARITY:

When a wick of a lamp is placed in paraffin, paraffin rises up the wick. This is due to capillary action.

Definition:

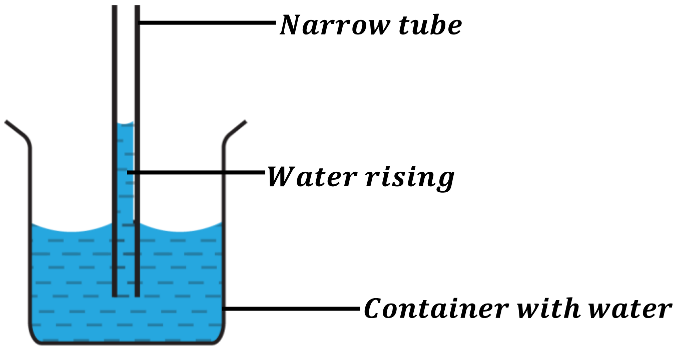
Capillarity is the rise or fall of a liquid in a narrow tube.

Capillary rise (elevation):

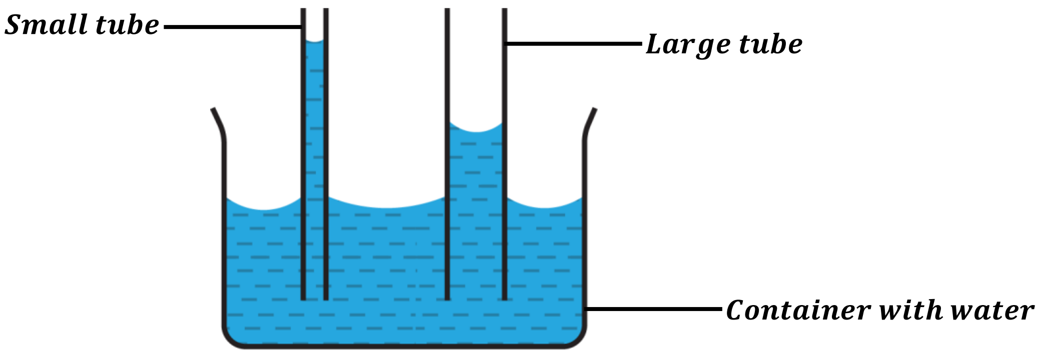
This is the rising of a liquid in a narrow tube (capillary tube).

Capillary rise occurs when adhesion forces between liquid molecules and glass tube molecules are greater than the cohesion forces between liquid molecules themselves. The liquid is attracted more to the surfaces of the tube thus causing it to rise.

- When a narrow tube (capillary tube) is dipped into a container containing water, water rises up in the tube.



- When two or more narrow tubes (capillary tubes) are dipped into a container containing water, the rise of water depends on the diameter of the tube i.e. the rise of water is higher or greatest in a small tube and lowest or least in the large tube.



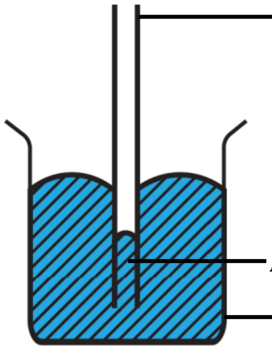
Question: Explain why water climbs up a piece of paper that has been dipped into a glass of water.

This is because the adhesive forces between water molecules and glass molecules are strong enough to pull the water molecules from glass and move them up the paper.

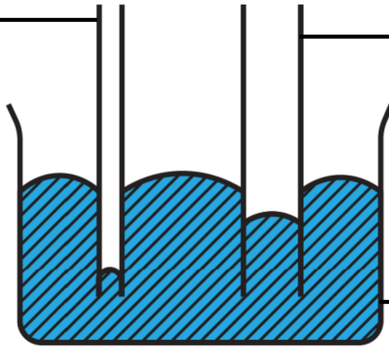
<u>Capillary fall (depression)</u>:
This is the falling of a liquid in a narrow tube (capillary tube).

Capillary fall occurs when cohesion forces between liquid molecules themselves are greater than the adhesion forces between liquid molecules and glass tube molecules. The liquid is attached or attracted less to the surfaces of the tube thus causing it to fall.

- When a narrow tube (capillary tube) is dipped into a container containing mercury, mercury level falls in the tube.



- When two or more narrow tubes (capillary tubes) are dipped into a container containing mercury, the fall of mercury depends on the diameter of the tube i.e. the fall of mercury is higher or greatest in a small tube and lowest or least in the large tube.



NOTE:

- Capillarity is disadvantageous and dangerous in construction of buildings because it causes water to rise through the walls of the building from the ground. This can be prevented by covering the damp proof course of a building with a non-porous material (water proof) e.g. polythene.

<u>Question 1</u>: Explain why a non-porous material is often put on the damp proof course of a building during construction.

The non-porous material prevents the rise of water through the walls of a building from the ground. Therefore, if it is not put on the damp proof course of a building, water rises through the walls by capillary action thus weakening the walls of the building.

<u>Question 2</u>: Explain why mercury level falls when a capillary tube is dipped into a beaker containing mercury.

This is because the cohesion forces between mercury molecules themselves are greater than the adhesion forces between mercury molecules and capillary tube molecules. The liquid is attached or attracted less to the surfaces of the tube thus causing it to fall.

APPLICATIONS OF CAPILLARITY:

→ Rising of paraffin in the wicks of stoves or lamps.
→ Movement of water and minerals from the roots to the other parts of the plant.
→ Absorption of water by a towel through its pores.
→ Absorption of liquids by a blotting paper or toilet paper.

Revision questions:

1. Explain how capillary rise occurs in a narrow tube.
2. Explain the following observations.
   i) Water wets clean glass surfaces but not waxed glass surfaces.
   ii) Water rises up in a narrow tube but mercury which is also a liquid falls in a narrow tube.
3. Explain why the lower part of the walls (near the floor) appear damp and begin to peel off a few years after construction.

SURFACE TENSION:

Several insects are able to walk on water surfaces; and when water drops slowly, it stretches and forms droplets. This is because at the surface of a water, there exists a force which makes the water surface to behave like a stretched elastic skin.

Definition:

Surface tension is force acting on the surface of the liquid that makes the liquid surface to behave like a stretched elastic skin.

OR

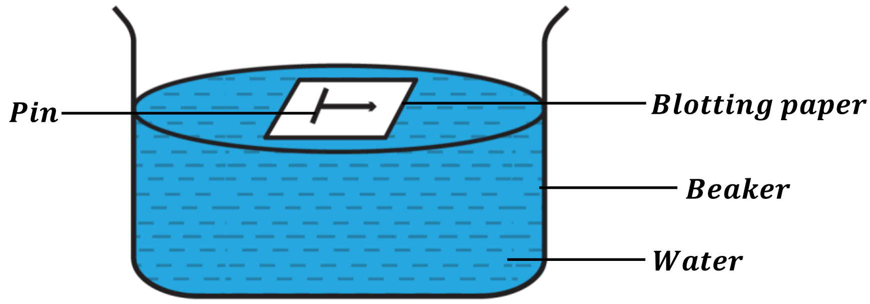
Surface tension is the tangential force acting normally per unit length of an imaginary line drawn on the surface of the liquid.

Therefore;

$$\boldsymbol{Surface\ tension = \frac{Force}{Length}}$$

The SI unit of surface tension is Newton per metre ($\boldsymbol{Nm^{-1}}$).

An experiment to show the existence of surface tension



Procedures:

- A beaker is filled with clean water.
- A blotting paper is placed carefully on the surface of water.
- A pin is gently placed on the blotting paper.

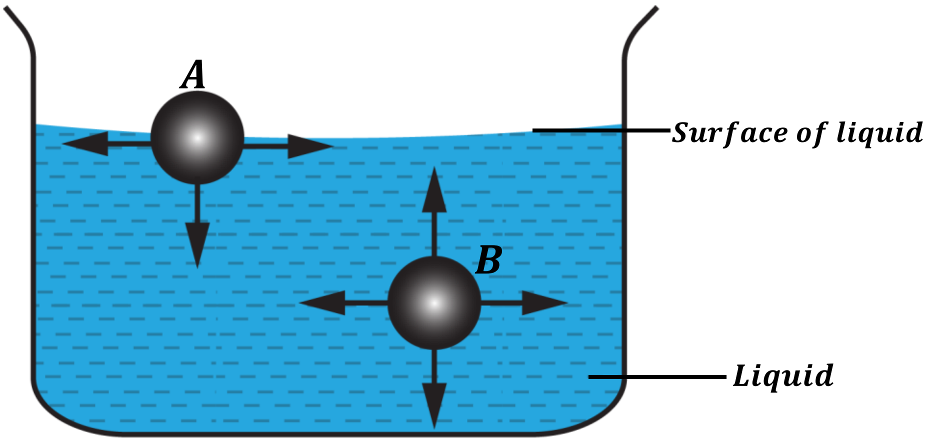
Observation:

- It is observed that after sometime, the blotting paper absorbs water and sinks to the bottom but the pin remains floating on the water surface.

Explanation:

- The pin remains floating on the water surface because the surface of water behaves like a stretched elastic skin.
- This demonstrates surface tension.

Explanation of surface tension using the kinetic theory of matter



- A molecule B inside the liquid is surrounded by equal number of molecules on all sides. Therefore, the intermolecular forces between it and the surrounding molecules is the same in all directions. Thus, the resultant force on molecule B is zero.
- A molecule A on the surface of the liquid is only surrounded by molecules below it. Therefore, the intermolecular forces between it and the surrounding molecules only acts downwards. Thus, the resultant force on molecule A acts downwards.
- This downward resultant force on molecule A pulls the surface of the liquid downwards thus the surface behaves like a stretched elastic skin.

<u>Factors that affect surface tension</u>:

a) **<u>Temperature</u>:**
Increase in temperature reduces surface tension. This is because an increase in temperature weakens (breaks down) the intermolecular forces between the liquid molecules.

b) **<u>Impurities</u>:**
Adding impurities like soap solution and detergents (e.g. Omo, Nomi, Vim, etc.) weakens the intermolecular forces between the liquid molecules thus reducing surface tension on the liquid surface.

<u>Question 1</u>: State two ways of reducing surface tension of a liquid.

→ ***By adding soap solution and detergents like Omo, Nomi and Vim into the liquid.***

→ ***By increasing the temperature of the liquid i.e. heating it.***

<u>Question 2</u>: A razor blade on a filter paper is gently placed on the surface of water in a container.

i) Explain what happens after some time.
After sometime, the filter paper will absorb water and sink to the bottom of the container but razor blade will remain floating on the surface of water.
The razor blade remains floating because the surface of water is behaving as a stretched elastic skin.

ii) Explain what happens when some soap solution is carefully added to the water.
The razor blade will also sink if soap solution is added to the water. This is because adding soap weakens the intermolecular forces between the water molecules thus reducing the surface tension of the water.

<u>Question 3</u>: Explain why it is advisable to wash clothes using warm water.
This is because warming water reduces its surface tension. This helps the clothes to absorb water and get wetted easily thus removing the dirt thoroughly well.

<u>Question 4</u>: Explain why soap is used in washing clothes.
This is because soap reduces surface tension of water hence causing water to penetrate the clothes easily. This helps to remove the dirt from the clothes easily.

<u>Question 5</u>: During a rainy season we use normally use umbrellas, tents and rain coats.

a) Explain why umbrellas do not leak when it rains yet they are porous.
They do not leak because surface tension of water prevents it from penetrating the fabric of the umbrella.

b) Explain why the inside of umbrellas in (a) above turn wet when the inside is touched.
Touching the inside of the umbrella increases the temperature of water on the outside part of the umbrella. This reduces the surface tension of water thus penetrating the fabric of the umbrella hence wetting the inside of the umbrella.

Application of surface tension (Instances to show existence of surface tension):

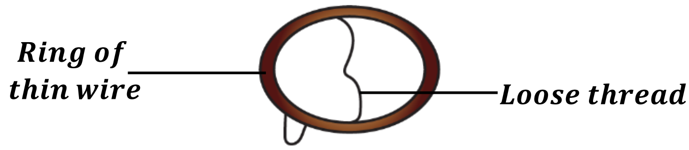
- Small insects can walk on the surface of water without sinking.
- Dirt get removed easily when soap and detergents are added to water when washing clothes.
- Umbrellas, tents and rain coats are able to keep water off due to surface tension.
- A pin or needle or razor blade can float on water when gently put on it surface even though they are denser than water.
- Water drops from a tap form spherical shape.
- When water is dropping slowly, a drop of water may remain attached from the tap for some time before falling.

NOTE:

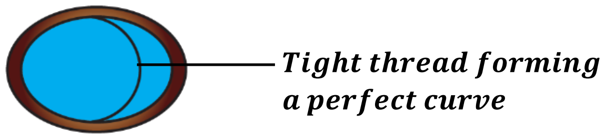
- Surface tension may also be demonstrated at home by using soap.

An experiment to demonstrate surface tension by using soap

- Make a ring of thin wire.
- Tie a thread loosely across the ring of thin wire as shown below.



- Dip the ring inside a soap solution so that the ring is filled the soap film and pull it out.
- Break the soap film on one side of the thread.
- It is observed that the thread pulls tight and forms a perfect curve as shown below.



- This shows that the thread is being pulled by a certain force on surface of the soap solution. This force is what we call surface tension.

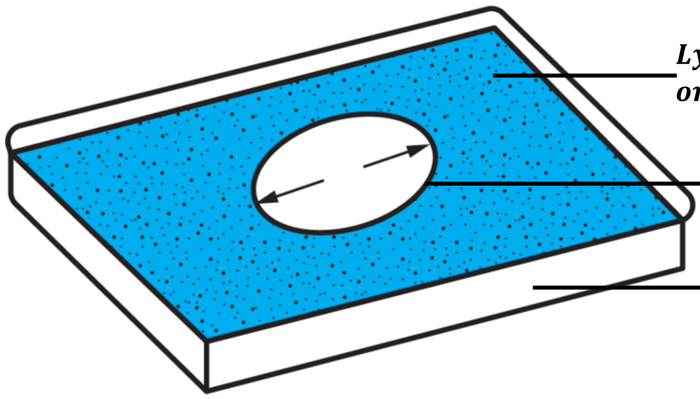
Revision questions:

1. Explain why it is not advisable to touch tent fabric material when it is raining.
2. Explain why it is not easy to wash clothes without soap.

SIZE OR THICKNESS OF AN OIL MOLECULE

Matter is made of small or tiny particles called molecules. These particles are too small to see with our human eyes. So how small are these molecules?
When oil is dropped on the surface of water, it spreads out until it forms an oil film which is just one molecule thick i.e. ($thickness\ of\ oil\ film = size\ of\ one\ oil\ molecule$).
Therefore, we can estimate the size of an oil molecule by finding the thickness of an oil film formed on water through the oil drop experiment.

An experiment to estimate the size or thickness of an oil molecule



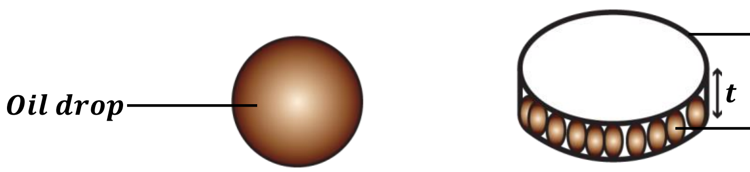
- A clean container is filled with clean water.
- Lycopodium powder is sprinkled on the surface of water.
- A small drop of oil of known volume, V is placed on the surface of water.
- The oil drop spreads and forms a circular oil film (patch) on the surface of water.
- The diameter, d of the circular oil film on the surface of water is measured and recorded.
- The area, A of the circular oil film is determined from;

$$A = \pi r^2 \text{ or } A = \frac{\pi d^2}{4}$$

- The thickness or size of oil molecule is then determined from;

$$t = \frac{V}{A}$$

Assumptions made in the oil drop experiment:
The following diagrams may be used to understand the assumptions.



- The oil drop is spherical.
- The oil film (patch) is cylindrical.
- The oil film is one molecule thick (monomolecular). i.e. thickness of an oil film is equal to size or diameter of one oil molecule.
- The spaces between oil molecules in the oil film are negligible.
- The volume of oil drop is equal to volume of oil film (oil patch).

Uses of lycopodium powder in the oil drop experiment:

→ It helps us to see the oil film clearly.

→ It makes the oil film stable for easy measurement of the diameter.

EXPLANATIONS BEHIND THE OIL DROP EXPERIMENT:

$$Volume\ of\ the\ oil\ drop = Volume\ of\ the\ oil\ film$$
$$Volume\ of\ sphere = Volume\ of\ a\ cylinder$$
$$\frac{4}{3}\pi r_o^3 = \pi r_f^2 t \qquad Where\ height, \boldsymbol{h} = \boldsymbol{t}\ \ and\ \boldsymbol{r} = \frac{\boldsymbol{d}}{2}$$
$$\boldsymbol{r_o} - Radius\ of\ oil\ drop$$
$$\boldsymbol{r_f} - Radius\ of\ oil\ film\ or\ oil\ patch$$

NOTE:

- Sometimes, the oil drop may be determined or formed by mixing oil with another liquid to form a solution. Then, the solution is dropped on the water surface.
  Therefore, we have to find the volume of the oil drop (without the other liquid) dropped on the surface of water.

$$\boldsymbol{Volume\ of\ oil\ drop} = \left(\frac{\boldsymbol{Volume\ of\ oil\ dissolved}}{\boldsymbol{Total\ volume\ of\ solution}}\right) \times \boldsymbol{Volume\ of\ solution\ dropped}$$

- Number of oil molecules in an oil film can be obtained from;

$$\boldsymbol{Number\ of\ oil\ molecules} = \frac{\boldsymbol{Volume\ of\ oil\ drop}}{\boldsymbol{Volume\ of\ one\ oil\ molecule}}$$

NOTE: Diameter of an oil molecule is equal to thickness (size) of oil mol

Examples:

1. In an oil drop experiment, the diameter of the oil film is $5cm$ and the volume of oil drop used is $0.005cm^3$. Find the thickness of an oil film.

$$\boldsymbol{d = 5cm, \qquad V = 0.005cm^3}$$
$$\boldsymbol{r = \frac{d}{2} = \frac{5}{2} = 2.5cm}$$

Area of oil film:

$$\boldsymbol{A = \pi r^2}$$
$$\boldsymbol{A = \frac{22}{7} \times 2.5^2 = 1.96 \times 10^1 cm^2}$$

Thickness of oil film:

$$\boldsymbol{t = \frac{Volume\ of\ oil\ drop}{Area\ of\ oil\ film}}$$
$$\boldsymbol{t = \frac{V}{A}}$$
$$\boldsymbol{t = \frac{0.005}{1.96 \times 10^1}}$$
$$\boldsymbol{t = 2.55 \times 10^{-4}\ cm}$$

2. In an oil drop experiment, an oil patch of radius $10cm$ is formed by $2.5 \times 10^{-3} cm^3$ of oil drop.
 a) Calculate the approximate size of an oil molecule.

$$r = 10cm, \; V = 2.5 \times 10^{-3} cm^3$$

Volume of oil drop:

$$V = 2.5 \times 10^{-3} cm^3$$

Area of oil film:

$$A = \pi r^2$$

$$A = \frac{22}{7} \times 10^2 = 3.14 \times 10^2 cm^2$$

Thickness of oil molecule:

$$t = \frac{Volume\ of\ oil\ drop}{Area\ of\ oil\ film}$$

$$t = \frac{V}{A}$$

$$t = \frac{2.5 \times 10^{-3}}{3.14 \times 10^2}$$

$$t = 7.96 \times 10^{-6}\ cm$$

 b) State any two assumptions used.
 → ***Volume of oil drop is equal to volume of oil film.***
 → ***Oil film is cylindrical.***

3. In an oil drop experiment, the area of the oil film formed on the water surface is $0.655cm^2$ and the volume of oil drop used is $0.0015cm^3$. Find the thickness of oil molecule.

$$A = 0.655cm^2, \qquad V = 0.0015cm^3$$

Thickness of oil film:

$$t = \frac{Volume\ of\ oil\ drop}{Area\ of\ oil\ film}$$

$$t = \frac{V}{A}$$

$$t = \frac{0.0015}{0.655}$$

$$t = 2.29 \times 10^{-3}\ cm$$

4. In an experiment to estimate the thickness of an oil molecule, the radius of spherical oil drop is 0.25mm and the radius of the circular patch of oil formed on the water surface is 6.5cm. Calculate the thickness of an oil molecule.

$$radius\ of\ oil\ drop = 0.25mm = \frac{0.25}{10} cm$$

$$r = 2.5 \times 10^{-2}\ cm$$

Volume of oil drop:

$$V = \frac{4}{3}\pi r^3$$

$$V = \frac{4}{3} \times \left(\frac{22}{7}\right) \times (2.5 \times 10^{-2})^3$$

$$V = 6.55 \times 10^{-5} cm^3$$

$$radius\ of\ oil\ patch = 6.5cm$$

Area of oil patch:

$$A = \pi r^2$$

$$A = \frac{22}{7} \times 6.5^2 = 1.33 \times 10^2 cm^2$$

Thickness of oil film:

$$t = \frac{Volume\ of\ oil\ drop}{Area\ of\ oil\ film}$$

$$t = \frac{V}{A}$$

$$t = \frac{6.55 \times 10^{-5}}{1.33 \times 10^2}$$

$$t = 4.92 \times 10^{-7}\ cm$$

5. An oil drop of volume $10^{-3}cm^3$ forms a film on the water surface. The area of the film formed is $0.785cm^2$. If the oil film is one molecule thick, estimate the thickness of the film.

$$\boldsymbol{A = 0.785cm^2\ ,\qquad V = 10^{-3}cm^3}$$

<u>Thickness of oil film</u>:

$$t = \frac{Volume\ of\ oil\ drop}{Area\ of\ oil\ film}$$

$$t = \frac{V}{A}$$

$$t = \frac{10^{-3}}{0.785}$$

$$t = 1.27 \times 10^{-3}\ cm$$

6. A solution was made by dissolving $1cm^3$ of cooking oil in $199cm^3$ of methanol. When $0.004cm^3$ of the solution is dropped on the surface of water, an oil film of diameter $12cm$ is obtained. Calculate;

i) the volume of cooking oil in the drop.

$$Volume\ of\ oil\ drop = \left(\frac{Volume\ of\ oil\ dissolved}{Total\ volume\ of\ solution}\right) \times Volume\ of\ solution\ dropped$$

$$Volume\ of\ oil\ drop = \left(\frac{1}{1+199}\right) \times 0.004$$

$$Volume\ of\ oil\ drop = 0.00002cm^3$$

ii) the thickness of the cooking oil molecule.

$$r = \frac{d}{2} = \frac{12}{2} = 6cm$$

<u>Area of oil film</u>:

$$A = \pi r^2$$

$$A = \frac{22}{7} \times 6^2 = 1.13 \times 10^2 cm^2$$

<u>Thickness of oil film</u>:

$$t = \frac{Volume\ of\ oil\ drop}{Area\ of\ oil\ film}$$

$$t = \frac{V}{A}$$

$$t = \frac{0.00002}{1.13 \times 10^2}$$

$$t = 1.77 \times 10^{-7}\ cm$$

iii) the number of molecules in the oil film.

<u>Volume of an oil molecule</u>

<u>Recall</u>: Diameter of oil molecule is equal to thickness of oil molecule.

$$r = \frac{d}{2} = \frac{t}{2} = \frac{1.77 \times 10^{-7}}{2} = 8.85 \times 10^{-8}cm$$

$$V = \frac{4}{3}\pi r^3$$

$$V = \frac{4}{3} \times \left(\frac{22}{7}\right) \times (8.85 \times 10^{-8})^3$$

$$V = 2.90 \times 10^{-21}cm^3$$

<u>Number of oil molecules</u>:

$$N = \frac{Volume\ of\ oil\ drop}{Volume\ of\ one\ oil\ molecule}$$

$$N = \frac{0.00002}{2.90 \times 10^{-21}}$$

$$N = 6.897 \times 10^{15}\ molecules$$

7. $1cm^3$ of oleic acid was dissolved in $999cm^3$ of alcohol to form $1000cm^3$ of solution. $1cm^3$ drop of the solution was put on the water surface. The drop spread to form a patch of diameter $28cm$. Calculate;
   a) Volume of oleic acid in $1cm^3$ drop of the solution.

$$\boldsymbol{Volume\ of\ acid\ drop = \left(\frac{Volume\ of\ acid\ dissolved}{Total\ volume\ of\ solution}\right) \times Volume\ of\ solution\ dropped}$$

$$\boldsymbol{Volume\ of\ acid\ drop = \left(\frac{1}{1000}\right) \times 1}$$

$$\boldsymbol{Volume\ of\ acid\ drop = 0.001cm^3}$$

   b) The size of the oleic acid molecule.

$$\boldsymbol{r = \frac{d}{2} = \frac{28}{2} = 14cm}$$

Area of acid film:

$$\boldsymbol{A = \pi r^2}$$

$$\boldsymbol{A = \frac{22}{7} \times 14^2 = 616cm^2}$$

Thickness of acid film:

$$\boldsymbol{t = \frac{Volume\ of\ oil\ drop}{Area\ of\ oil\ film}}$$

$$\boldsymbol{t = \frac{V}{A}}$$

$$\boldsymbol{t = \frac{0.001}{616}}$$

$$\boldsymbol{t = 1.62 \times 10^{-6}\ cm}$$

   c) Volume of oleic acid molecule.
   Recall: Diameter of acid molecule is equal to thickness of acid molecule.

$$\boldsymbol{r = \frac{d}{2} = \frac{t}{2} = \frac{1.62 \times 10^{-6}}{2} = 8.1 \times 10^{-7}cm}$$

$$\boldsymbol{V = \frac{4}{3}\pi r^3}$$

$$\boldsymbol{V = \frac{4}{3} \times \left(\frac{22}{7}\right) \times (8.1 \times 10^{-7})^3}$$

$$\boldsymbol{V = 2.23 \times 10^{-18}cm^3}$$

   d) Number of oleic acid molecules in the patch.

$$\boldsymbol{N = \frac{Volume\ of\ acid\ drop}{Volume\ of\ acid\ molecule}}$$

$$\boldsymbol{N = \frac{0.001}{2.23 \times 10^{-18}}}$$

$$\boldsymbol{N = 4.48 \times 10^{14}\ molecules}$$

8. $1cm^3$ of olive oil was added to $99cm^3$ of ethanol to form a solution. $2cm^3$ drop of the solution was put on the water surface. The drop spread to form a film of radius 12cm. Calculate;
   a) Volume of olive oil in $2cm^3$ drop of the solution.

$$\boldsymbol{Volume\ of\ oil\ drop = \left(\frac{Volume\ of\ oil\ dissolved}{Total\ volume\ of\ solution}\right) \times Volume\ of\ solution\ dropped}$$

$$\boldsymbol{Volume\ of\ oil\ drop = \left(\frac{1}{1 + 99}\right) \times 2}$$

$$\boldsymbol{Volume\ of\ oil\ drop = 0.02cm^3}$$

b) The thickness of the oil film.

$r = 12cm$

Area of oil film:

$A = \pi r^2$

$A = \frac{22}{7} \times 12^2 = 4.53 \times 10^2 cm^2$

Thickness of oil film:

$t = \frac{Volume\ of\ oil\ drop}{Area\ of\ oil\ film}$

$t = \frac{V}{A}$

$t = \frac{0.02}{4.53 \times 10^2}$

$t = 4.42 \times 10^{-5}\ cm$

EXERCISE:

1. In an oil drop experiment, the radius of the oil film is 10cm and the volume oil drop used is $1.1 \times 10^{-5} cm^3$. Estimate the thickness of an oil molecule.

2. If $1.8 \times 10^{-4} cm^3$ of oil spreads to form a patch of area $150cm^2$, calculate the size of an oil molecule.

3. In an experiment to estimate the size of a molecule of olive oil, $0.12mm^3$ of the oil solution was dropped on a clean water surface in a trough. The oil spreads to form a circular patch of an area $1.0 \times 10^4 cm^2$. Estimate the size of a molecule of olive oil.

4. $1cm^3$ of oil was added to $299cm^3$ of ether to form a solution. $2cm^3$ drop of the solution was put on the water surface with sprinkled lycopodium powder. The drop spreads to form a film of diameter 14cm. Calculate;
   i) Thickness of the oil molecule.
   ii) Number of oil molecules in the film.
   iii) State any three assumptions made.
   iv) Why was lycopodium powder used?

5. An oil drop of volume $1.0 \times 10^{-9} m^3$ spreads on a water surface to form an oil patch of area $5 \times 10^{-2} m^2$. If the patch is one molecule thick, find the approximate number of molecules in the drop.

6. In an oil drop experiment to determine the thickness of an oil molecule, the following were done;
   - $1cm^3$ of oil was dissolved in $99cm^3$ of ethanol to form $200cm^3$ of solution.
   - $0.4cm^3$ of the dilute solution was dropped onto the surface of water.
   - The diameter of the film formed was found to be 7cm.

   Calculate the size of the oil molecule

7. A solution was made by dissolving $1cm^3$ of cooking oil in $1999cm^3$ of methanol. When $0.005cm^3$ of the solution is dropped on the surface of water, an oil film of diameter $14cm$ is obtained. Calculate;
   i) the volume of cooking oil in the drop.
   ii) The thickness of the oil molecule.
   iii) The number of molecules in the oil film.

8. In an oil drop experiment, the area of the oil patch formed on the water surface is $0.700cm^2$ and the volume of oil drop used is $0.0016cm^3$. Find the diameter of oil molecule.