Std-XI science- Lecture-30

Unit 5:

STATES OF MATTER

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INTERMOLECULAR FORCES

- **Intermolecular forces are the forces of** attraction and repulsion between interacting particles (atoms and molecules).
- This term does not include the electrostatic forces that exist between the two oppositely charged ions
- and the forces that hold atoms of a molecule together i.e., covalent bonds.

van der Waals forces

- **van der Waals forces vary considerably in magnitude and include**

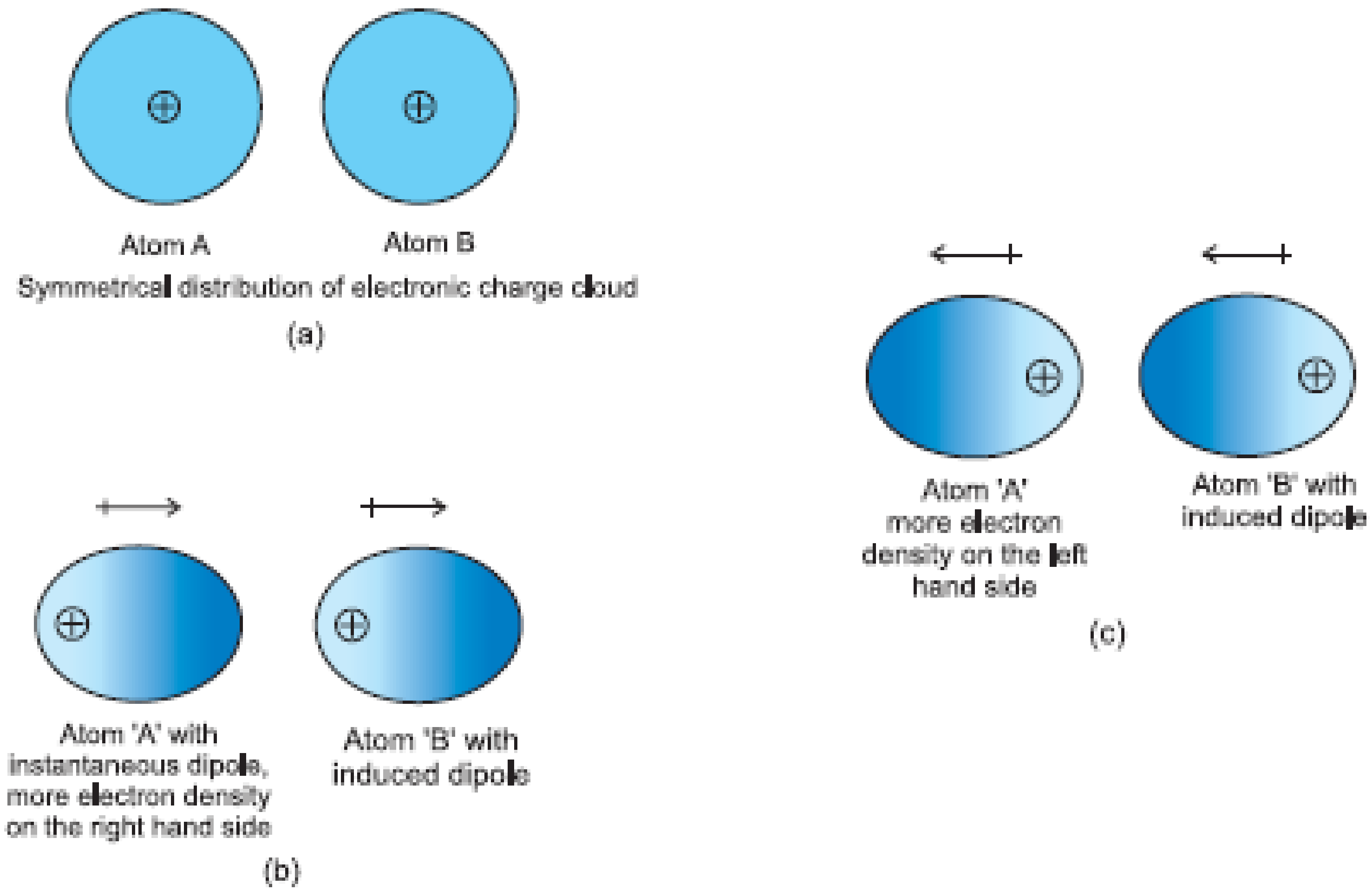
1. dispersion forces or London forces,
2. dipole-dipole forces, and
3. dipole-induced dipole forces.

- Note that attractive forces between an **ion** and a **dipole** are known as ion-dipole forces and these are **not van der Waals forces.**

Dispersion Forces or London Forces

- Atoms and nonpolar molecules are electrically symmetrical and have no dipole moment because their electronic charge cloud is symmetrically distributed.
- But a **dipole** may develop momentarily even in such atoms and molecules.
- Let us consider following example.

Dispersion Forces or London Forces



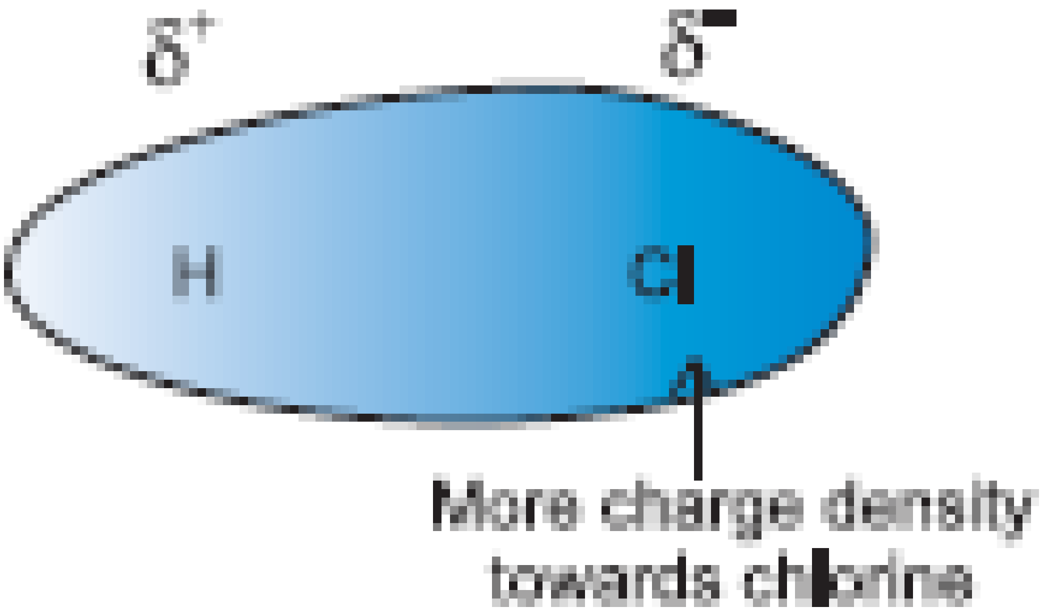
Dispersion Forces or London Forces

- The temporary dipoles of atom '**A**' and '**B**' attract each other.
- Similarly temporary dipoles are induced in molecules also.
- This force of attraction was first proposed by the German physicist **Fritz London**, and for this reason force of attraction between two temporary dipoles is known as **London force.**
- **Another** name for this force is **dispersion force.**

Dipole - Dipole Forces

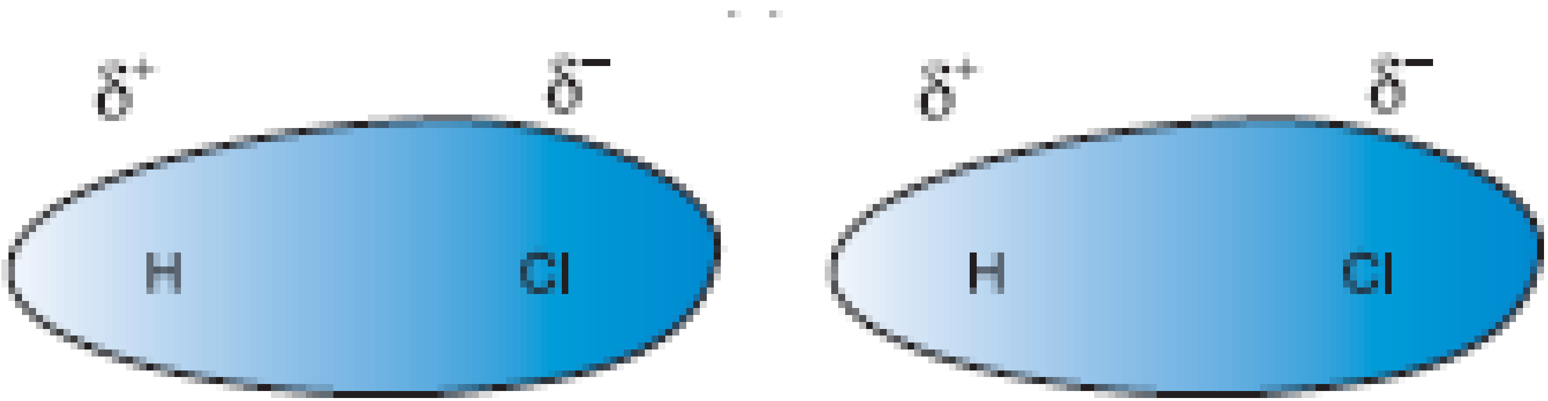
- **Dipole-dipole** forces act between the molecules possessing permanent dipole.
- Ends of the dipoles possess "**partial charges**" and these charges are shown by Greek letter ***delta (δ).***
- This interaction is **stronger** than the London forces but is weaker than **ion-ion** interaction because only partial charges are involved.

Distribution of electron cloud in HCl a polar molecule



(a)

Dipole-dipole interaction between two HCl molecules

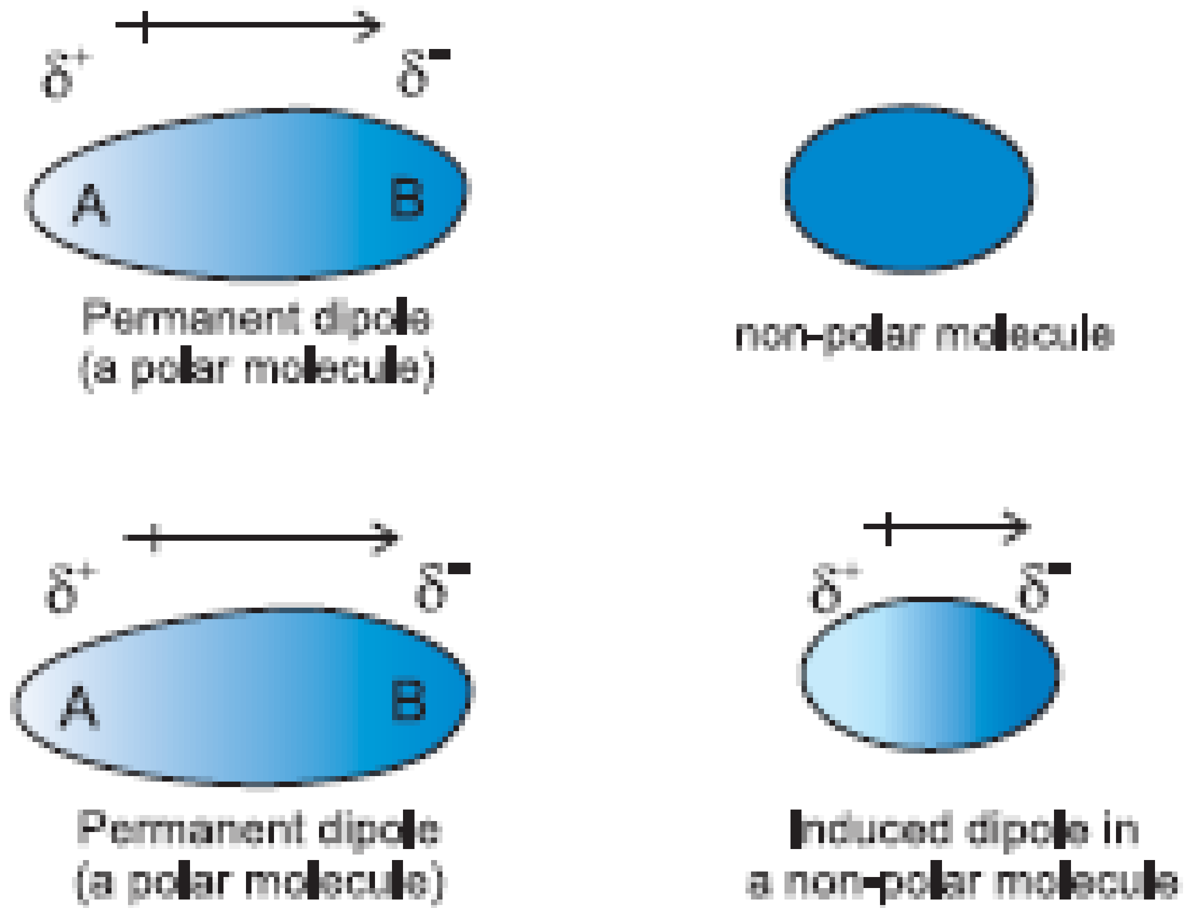


(b)

Dipole ñ Induced Dipole Forces

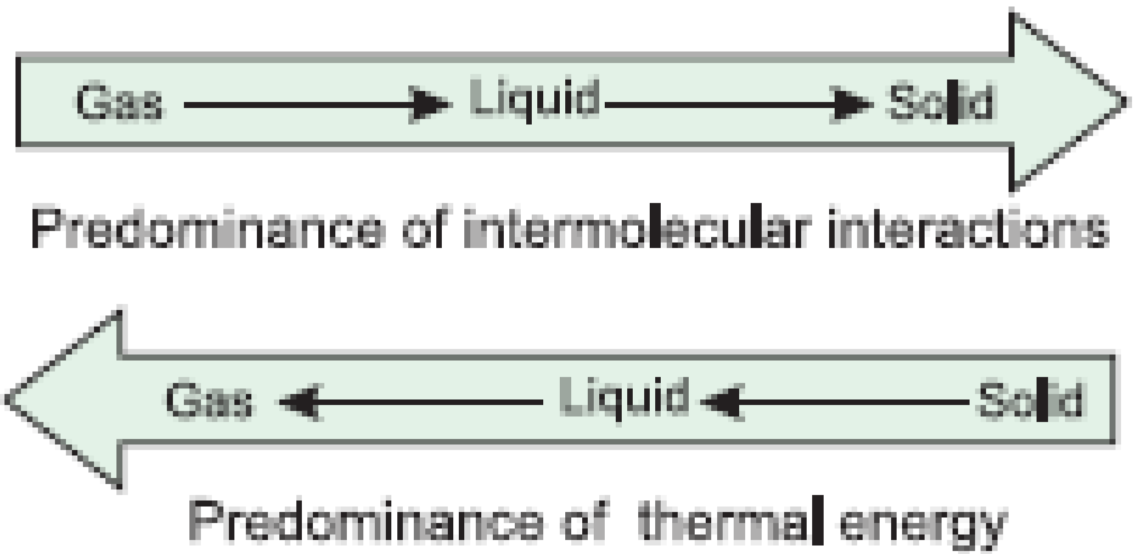
- This type of attractive forces operate between the **polar** molecules having **permanent dipole** and the **molecules lacking permanent dipole**.
- Permanent dipole of the polar molecule induces dipole on the electrically neutral molecule by deforming its electronic cloud
- Thus an induced dipole is developed in the other molecule.

Dipole ñ Induced Dipole Forces



THERMAL ENERGY

- Predominance of thermal energy and the molecular interaction energy of a substance in three states is depicted as follows



THE GASEOUS STATE

The gaseous state is characterized by the following physical properties.

1. Gases are highly compressible.
2. Gases exert pressure equally in all directions.
3. Gases have much lower density than the solids and liquids.
4. The volume and the shape of gases are not fixed. These assume volume and shape of the container.
5. Gases mix evenly and completely in all proportions without any mechanical aid.

THE GAS LAWS

- Simplicity of gases is due to the fact that the forces of interaction between their molecules are negligible.
- Their behaviour is governed by same general laws

1. **Boyleís Law (Pressure – Volume Relationship)**
2. **Charles Law (Temperature – Volume Relationship)**
3. **Gay Lussacís Law (Pressure- Temperature Relationship)**
4. **Avogadro Law (Volume – Amount Relationship)**

Boyle's law

- On the basis of his experiments, Robert Boyle reached to the conclusion that ***at constant temperature, the pressure of a fixed amount (i.e., number of moles n) of gas varies inversely with its volume.***
- **This is** known as **Boyle's law.**
- **Mathematically, it can** be written as

$$p \propto \frac{1}{V} \quad (\text{at constant } T \text{ and } n)$$

Boyle's law

$$\Rightarrow \; p = k_1 \, \frac{1}{V}$$

- where **k1** is the proportionality constant.
- The value of constant **k1** depends upon the **amount** of the gas, **temperature** of the gas and the units in which ***p** and **V** are expressed.*
- On rearranging above equation we obtain

$$pV = k_1$$

- It means that at **constant temperature**, **product** of **pressure and volume** of a fixed amount of gas is constant.

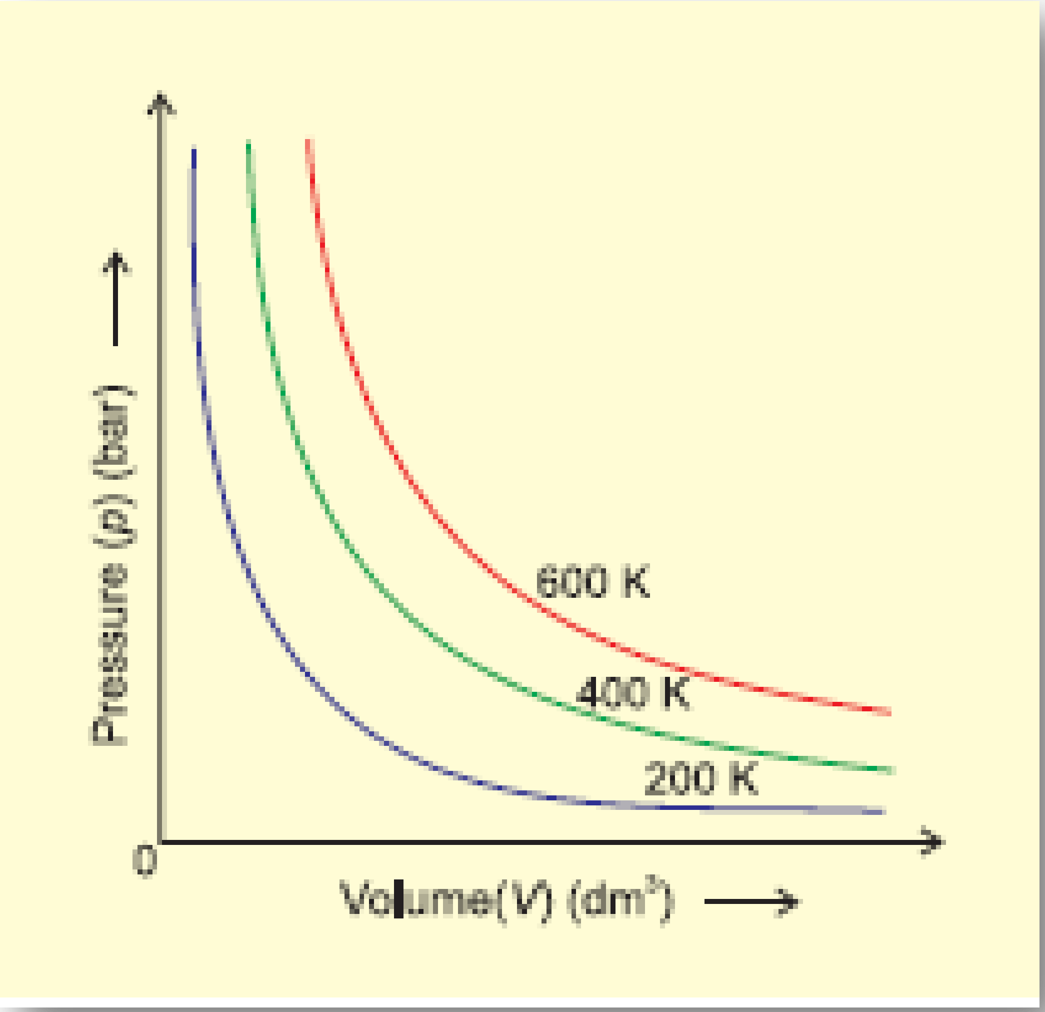
Boyle's law

- If a fixed amount of gas at constant temperature ***T*** *occupying volume* V_1 *at* pressure p_1 *undergoes expansion*, *so that* volume becomes V_2 *and pressure becomes* p_2 then according to Boyle's law :

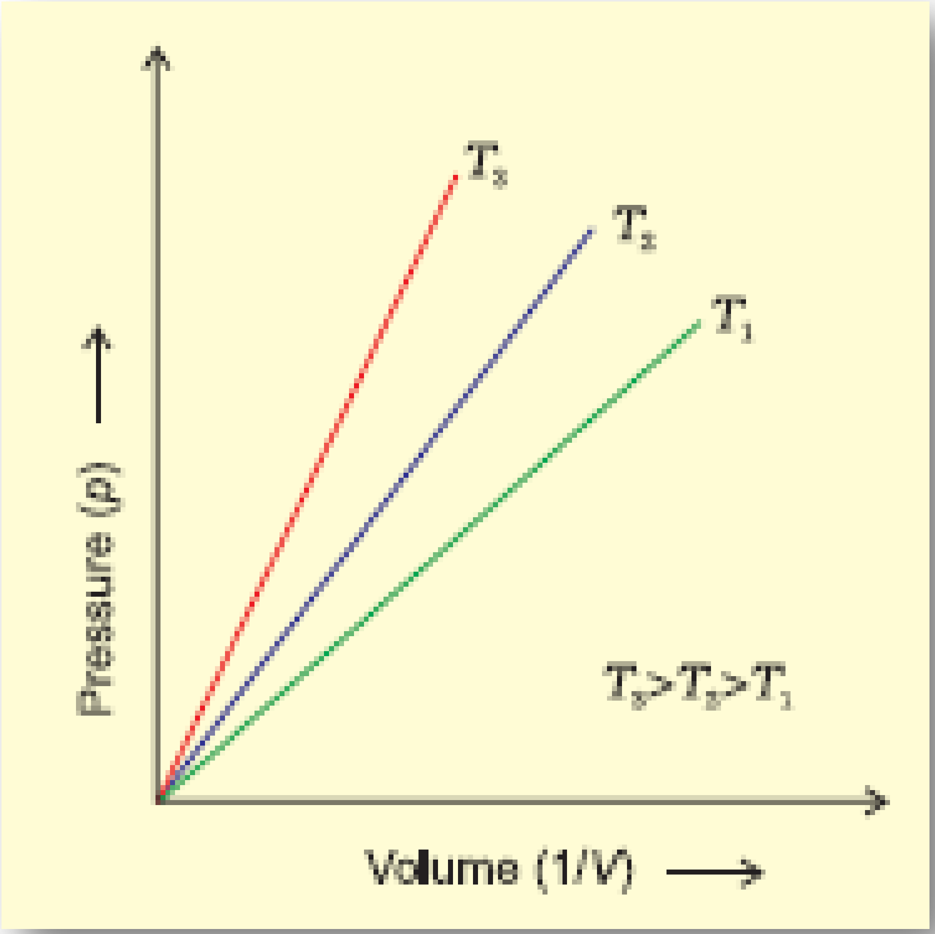
$$p_1V_1 = p_2V_2 = \text{constant}$$

$$\Rightarrow \frac{p_1}{p_2} = \frac{V_2}{V_1}$$

Graph of pressure, p vs. Volume, V of a gas at different temperatures.



Graph of pressure of a gas, p vs. 1/V



Charles Law

- Charles law states *that **pressure** remaining constant, the **volume** of a fixed mass of a gas is directly proportional to its **absolute temperature.***
- Mathematical expression for Charles law

$$\Rightarrow \frac{V}{T} = \text{constant} = k_2$$

$$\text{Thus } V = k_2\, T$$

Charles Law

- New scale of temperature such that **t °**c on new scale is given by
- ***T = 273.15 + t***
- ***and O °C will be given*** by T_0 ***= 273.15.***
- ***This new temperature scale*** is called the **Kelvin temperature scale or Absolute temperature scale**
- Thus **O°c** on the celsius scale is equal to **273.15** K at the **absolute scale**.

Charles Law

Thus we can write a general equation as follows.

$$\frac{V_2}{V_1} = \frac{T_2}{T_1} \qquad (5.8)$$

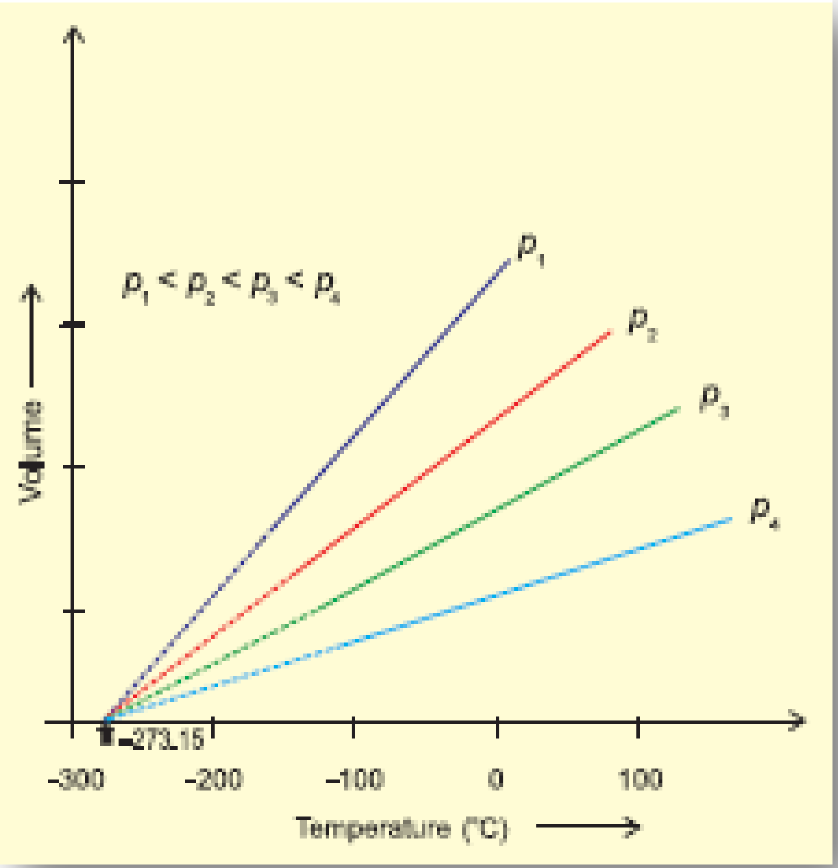
$$\Rightarrow \frac{V_1}{T_1} = \frac{V_2}{T_2}$$

$$\Rightarrow \frac{V}{T} = \text{constant} = k_2 \qquad (5.9)$$

Thus $V = k_2\ T$ (5.10)

The value of constant **k2** is determined by the pressure of the gas, its amount and the units in which volume ***V*** *is expressed***.**

Volume vs Temperature (°C) graph



Each line of the volume *vs temperature* graph is called isobar.

Absolute zero

- Observations of Charles can be interpreted if we put the value of t in equation (5.6) as **– 273.15 °C**.
- We can see that the volume of the gas at **– 273.15 °**C will be **zero**.
- This means that gas will not exist. In fact all the gases get liquified before this temperature is reached.
- The lowest hypothetical or imaginary temperature at which gases are supposed to occupy zero volume is called **Absolute zero.**

All gases obey Charles' law at very low pressures and high temperatures

Gay Lussac's Law

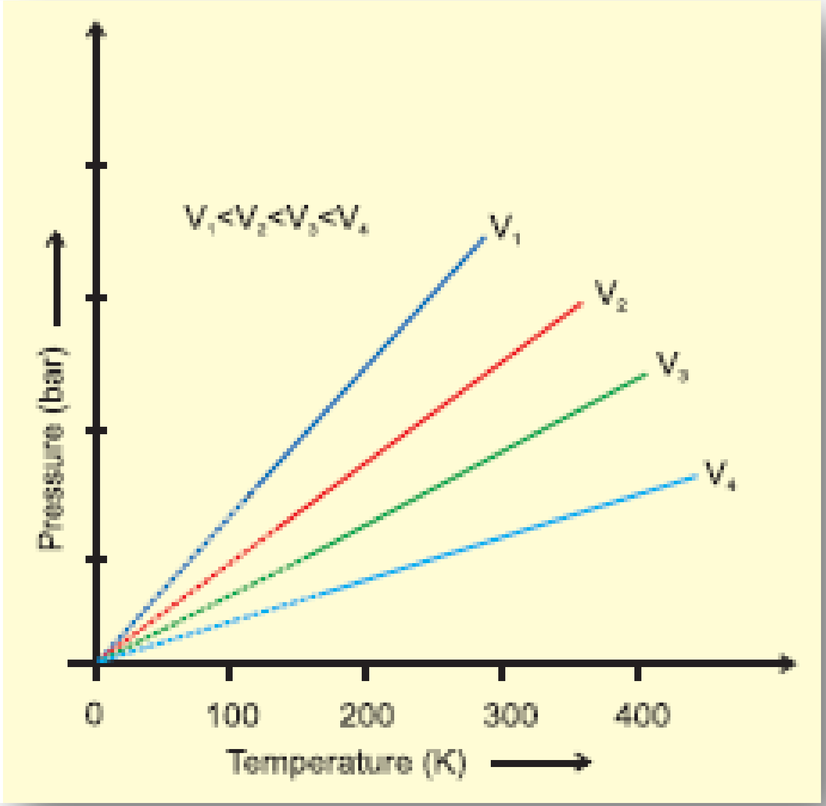
- It states that ***at constant volume, pressure of a fixed amount of a gas varies directly with the temperature.***

- Mathematically,

$$p \propto T$$

$$\Rightarrow \frac{p}{T} = \text{constant} = k_3$$

Pressure vs temperature (K) graph (Isochores) of a gas.



Each line of this graph is called **isochore.**

Avogadro Law

- **It states that** ***equal volumes of all gases under the same conditions of temperature and pressure contain equal number of molecules.***
- Mathematically we can write

$V \propto n$ where n is the number of moles of the gas.

$$\Rightarrow V = k_4 n \qquad (5.11)$$

Avogadro constant

- The number of molecules in one mole of a gas has been determined to be 6.022×10^{23} and is known as **Avogadro constant.**

- **1 mole** of all gases under similar condition of Temperature & Pressure occupy **22.4 litres** of volume

IDEAL GAS EQUATION

- The three laws which we have learnt till now can be combined together in a single equation which is known as **ideal gas equation.**

At constant T and n; $V \propto \frac{1}{p}$ **Boyleis Law**

At constant p and n; $V \propto T$ **Charlesi Law**

At constant p and T : $V \propto n$ **Avogadro Law**

Thus,

$$V \propto \frac{nT}{p} \qquad (5.15)$$

$$\Rightarrow \quad V = R\frac{nT}{p} \qquad (5.16)$$

IDEAL GAS EQUATION

- where R is proportionality constant.
- On rearranging the equation (5.16) we obtain

$$pV = nRT \qquad (5.17)$$

$$\Rightarrow R = \frac{pV}{nT} \qquad (5.18)$$

R is called gas constant. It is same for all gases. Therefore it is also called **Universal Gas Constant.** **Equation (5.17) is called ideal gas equation.**

Dalton's Law of Partial Pressures

- It states that ***the total pressure exerted by the mixture of non-reactive gases is equal to the sum of the partial pressures of individual gases***
- In a mixture of gases, the pressure exerted by the individual gas is called **partial pressure.**
- Mathematically,
- $\boldsymbol{p_{Total} = p_1 + p_2 + p_3 + \ldots\ldots}$ *(at constant T, V)*

KINETIC MOLECULAR THEORY OF GASES
.......Main Points

1. All gases are made up of large number of minute particles called molecules.
2. Large distances separate the molecules so that the actual volume of the molecules is negligible as compared to the total volume of the gas.
3. The molecules are in a state of constant rapid motion in all directions, colliding with one another and also with the walls of the container.

KINETIC MOLECULAR THEORY OF GASES ………Contd

4. The molecular collisions are perfectly elastic with no loss of energy and only redistribution of energy during collision.
5. There are no attractive or repulsive forces between the molecules.
6. The pressure exerted by the gas is due to the bombardment of its molecules on the walls of the container per unit area.
7. The average kinetic energy of the gas molecules is directly proportional to the absolute temperature.

LIQUID STATE

- Intermolecular forces are stronger in liquid state than in gaseous state.

- Molecules in liquids are so close that there is very little empty space between them and under normal conditions liquids are denser than gases.

LIQUID STATE

- Molecules of liquids are held together by attractive intermolecular forces.

- Liquids have definite volume because molecules do not separate from each other. However, molecules of liquids can move past one another freely, therefore, liquids can flow, can be poured and can assume the shape of the container in which these are stored.

Physical properties of the liquids

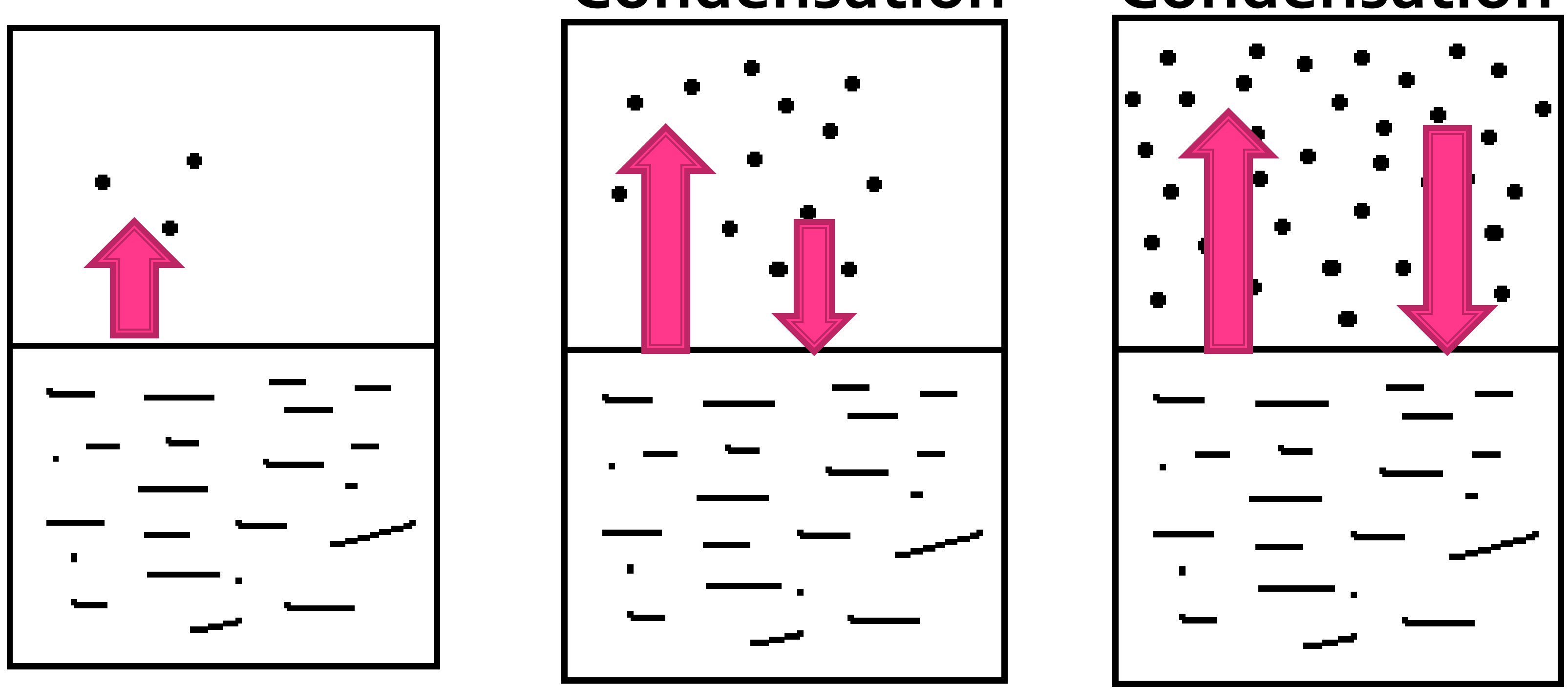
1. Vapour pressure,
2. surface tension and
3. viscosity.

Vapour pressure

Evaporation

Evaporation
&
Condensation

Evaporation
Condensation



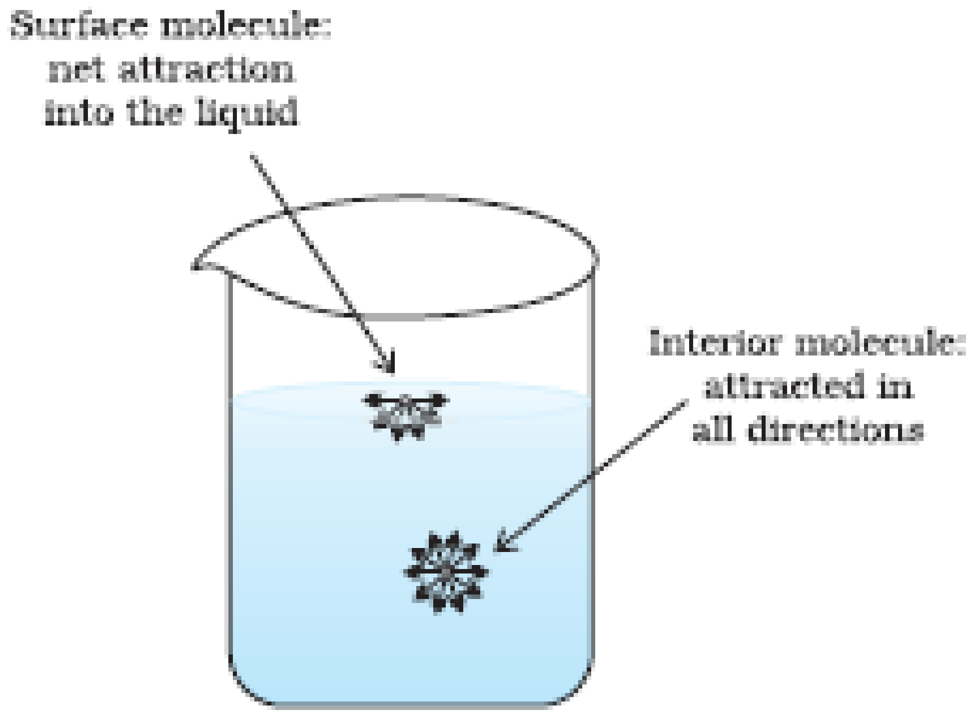
Vapour pressure

- *The Pressure exerted by the vapours in equilibrium with the liquid at a particular temperature is called* ***vapour pressure*** *of the liquid.*
- The **vapour pressure** of the liquid is constant at a given temperature.
- It does not depend on the amount of the liquid or size of the vessel.

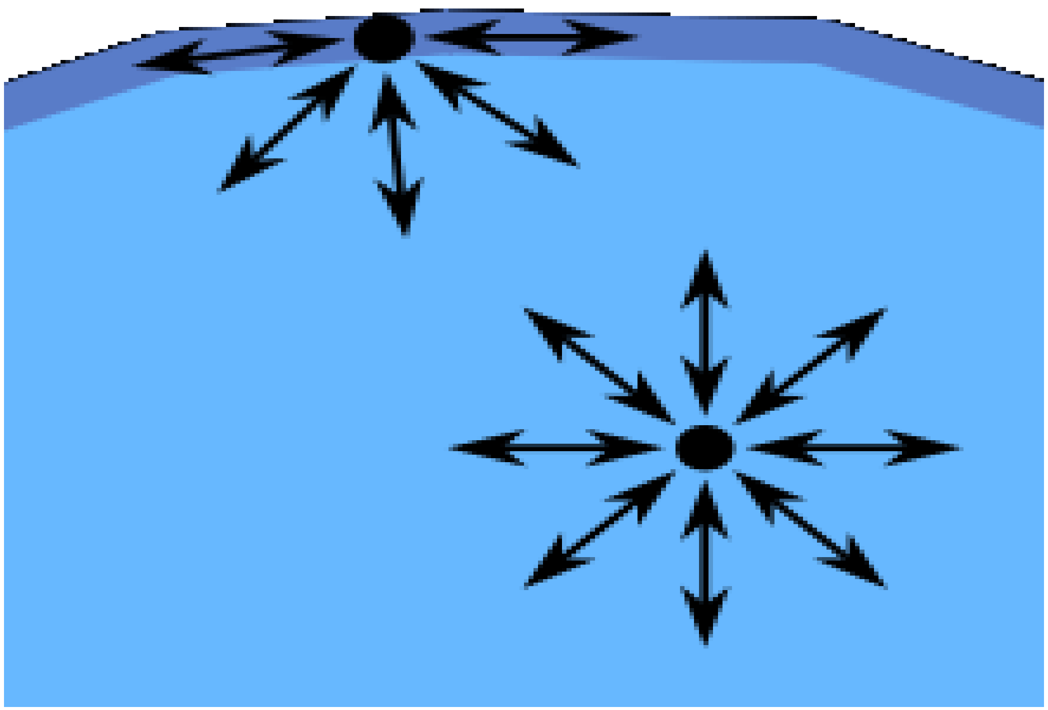
Surface tension

- It is well known fact that liquids assume the shape of the container.
- Why is it then small drops of mercury form spherical bead instead of spreading on the surface.
- Why do particles of soil at the bottom of river remain separated but they stick together when taken out ?
- Why does a liquid rise (or fall) in a thin capillary as soon as the capillary touches the surface of the liquid ?
- All these phenomena are caused due to the characteristic property of liquids, called **surface tension.**

Surface tension



Surface tension



Viscosity

- Viscosity is a measure of resistance to flow which arises due to the internal friction between layers of fluid as they slip past one another while liquid flows.

- Strong intermolecular forces between molecules hold them together and resist movement of layers past one another.

Viscosity

- Viscosity of liquids decreases as the temperature rises
- **because** at high temperature molecules have high kinetic energy and can overcome the intermolecular forces to slip past one another between the layers.

Numerical Problems

- **Boyle's Law Problems**
- **1**. The volume of the lungs is measured by the volume of air inhaled or exhaled. If the volume of the lungs is 2.400 L during exhalation and the pressure is 101.70 KPa, and the pressure during inhalation is 101.01 KPa, what is the volume of the lungs during inhalation?

- **2.** The total volume of a soda can is 415 mL. Of this 415 mL, there is 60.0 mL of headspace for the CO_2 gas put in to carbonate the beverage. If a volume of 100.0 mL of gas at standard pressure is added to the can, what is the pressure in the can when it has been sealed?

- **3.** It is hard to begin inflating a balloon. A pressure of 800.0 Kpa is required to initially inflate the balloon 225.0 mL. What is the final pressure when the balloon has reached it's capacity of 1.2 L?

- **4.** If a piston compresses the air in the cylinder to 1/8 it's total volume and the volume is 930 cm^3 at STP, what is the pressure after the gas is compressed?

- **5.** If a scuba tank that has a capacity of 10.0 dm^3 is filled with air to 500.0 KPa, what will be the volume of the air at 702.6 KPa?

Solution

- $V_2 = \frac{[V_1][P_1]}{[P_2]}$ $V_2 = \frac{[2.400L][101.70KPa]}{[101.01KPa]} = 2.412L$

Thank you

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