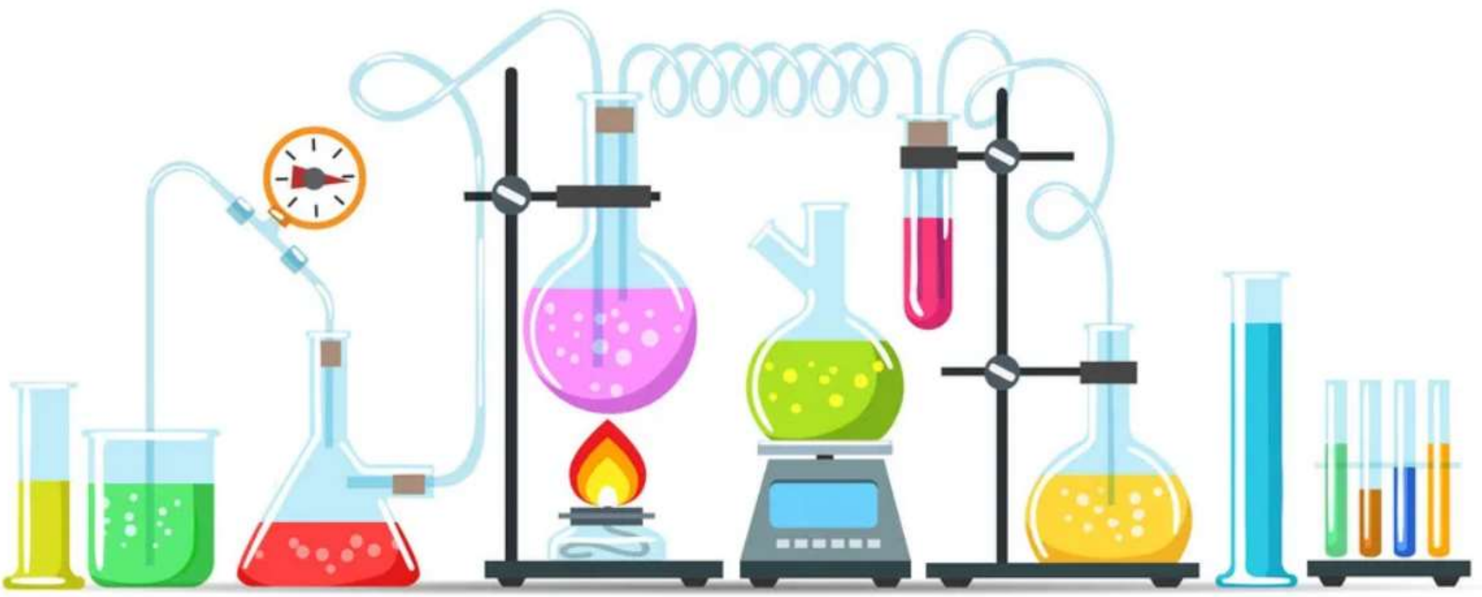
CHEMISTRY



STATES OF MATTER

Introduction

Gas is the state of matter in which molecules are always in random motion. Intermolecular interactions are extremely small (almost negligible) as compared to other states like solid and liquid. Gases are highly compressible state of matter and its state of diffusion is maximum. Gases have their own importance in living world. Air is a gaseous mixture of oxygen, nitrogen, CO2, Ar, etc.

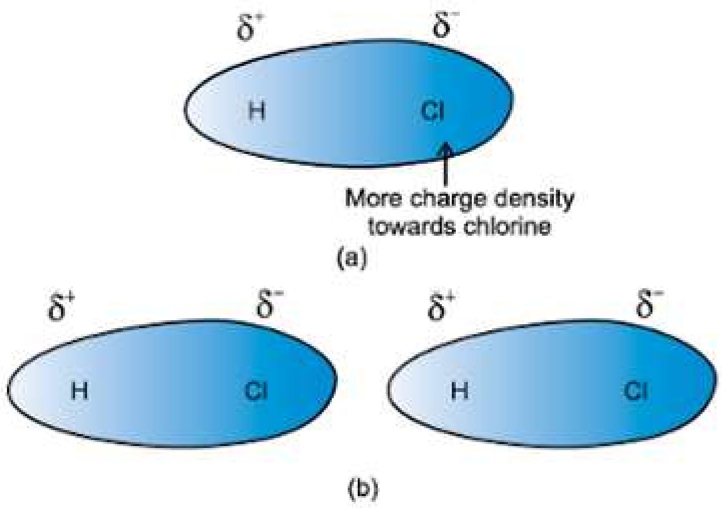
Intermolecular Forces

Intermolecular forces are the forces of attraction and repulsion between interacting particles. This term does not include the electrostatic forces that exist between the two oppositely charged ions.

Van der Waal's Forces

These are the weak forces of attraction between two molecules with or without any strong bond. These are electrostatic in nature. Types of van der Waal's forces are as follow:

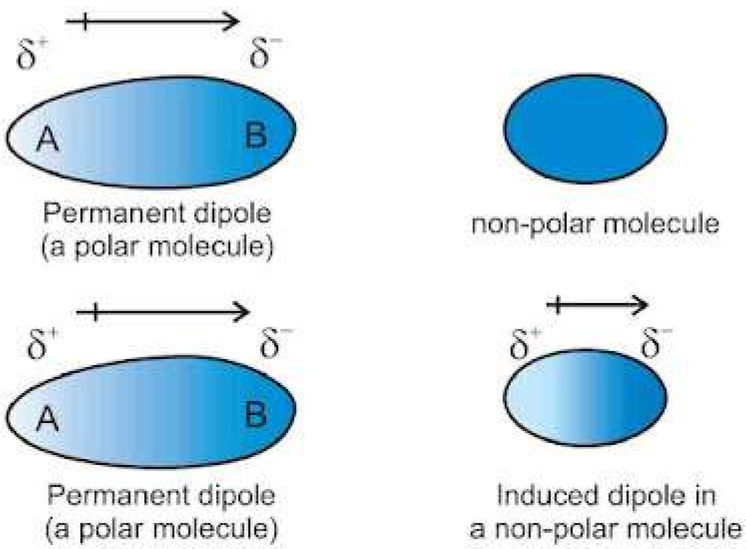
1. **Dipole-dipole interaction:** These forces exist between two molecules which are polar in nature. Opposite charges of two dipoles attract each other and produce interactions called keesom forces. In HCl, dipole-dipole interactions exist.



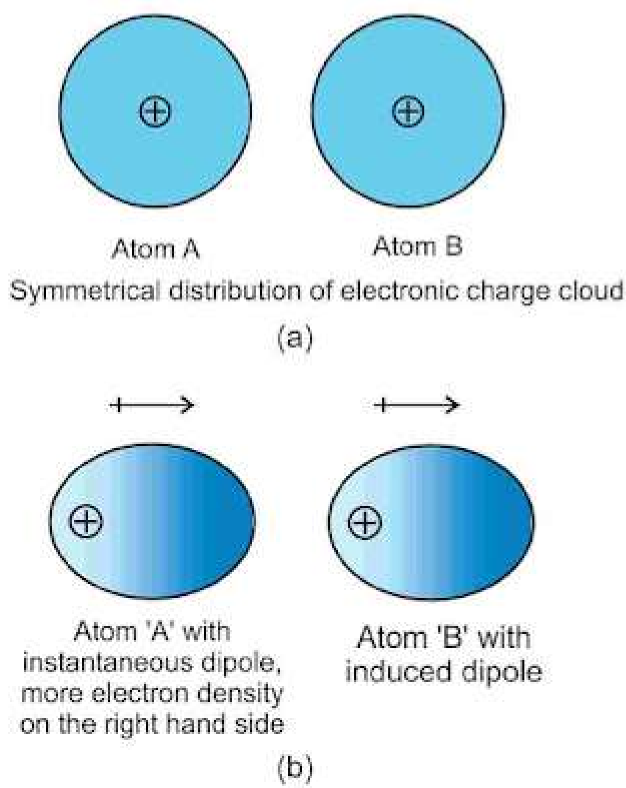
Dipole-dipole interaction energy is inversely proportional to the sixth power of the distance between the rotating polar molecules.

interaction energy $\propto \frac{\pi}{r^6}$

2. **Dipole-induced dipole interaction:** When a polar molecule comes closer to a non-polar molecule it induces weak polarity (dipole) in that molecule. Now, weak interactions develop between polar molecule and molecule in which polarity is induced. These interactions are known as Debye interactions.



3. **London dispersion forces:** This polar molecule produces polarity in other molecule. Weak interaction arises between instantaneous dipoles. These interactions are known as Dispersion forces or London forces.



Measurable Properties of Gases

1. **Temperature:** Temperature is a relative measure, or indication of hotness or coldness. At absolute zero on Kelvin scale is equivalent to –273.15°C on the Celsius scale. Both the Celsius and the Kelvin scales have units of equal magnitude that is one degree celsius equivalent to one kelvin.

   Thus T(K) = T(°C) + 273.15

2. **Pressure of a gas:** According to laws of motion, pressure is defined as force applied per unit area of surface. It is denoted by P and SI unit of it is pascal (Pa). It is a scalar quantity.

   $$P = \frac{F}{A}$$

3. **Atmospheric Pressure:** The atmospheric pressure at a point is equal to the weight of a column of air of unit cross-sectional area extending from that point to the top of the atmosphere. Its value is 1.013×10^5 Pa at sea level. Atmospheric pressure is measured using an instrument called barometer.

Gaseous Laws

Boyle's Law (Volume-Pressure Relation)

According to this, "The volume of a given mass of gas is inversely proportional to pressure at constant temperature." This law is given by Robert Boyle.

$$P \propto \frac{1}{v} \ldots \ldots \text{(at Constant T and n)}$$

$$P = k\frac{1}{v}$$

where k is the proportionality constant.

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:

$P_1V_1 = p_2V_2$ = constant

$$\frac{P_1}{P_2} = \frac{V_1}{V_2}$$

Charle's Law (Volume-Temperature Relation)

According to this, "The volume of a given mass of gas is directly proportional to its absolute temperature at constant pressure." This law is given by Jacques Charles.

$V \propto T$ .... (at constant P)

V = kT

where k is the proportionality constant.

If a fixed amount of gas at constant pressure P occupying volume V_1 at temperature T_1 undergoes expansion, so that volume becomes V_2 and temperature becomes T_2, then according to Charle's Law:

$$\frac{V}{T} = \cdots \ldots \ldots . \text{constant}$$

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

Gay Lussac's Law (Pressure-Temperature Relation)

It states that at constant volume, the pressure of a fixed mass of a gas is directly proportional to the Kelvin temperature. The law may be expressed mathematically as

$P \propto T$ .... (at constant V)

P = kT

where k is the proportionality constant.

If a fixed amount of gas at constant volume V occupying pressure P_1 at temperature T_1 undergoes expansion, so that pressure becomes P_2 and temperature becomes T_2, then according to Gay Lussac's Law:

$$\frac{P}{T} = \text{constant}$$

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

Avogadro's Law ((Volume - Amount Relationship)

According to this, "Equal volumes of all gases at same temperature and pressure contain equal numbers of molecules".

$V \propto n$

V = kn

where k is the proportionality constant.

$$\frac{V_1}{n_1} = \frac{V_2}{n_2}$$

Ideal Gas Equation

On combining the Boyle's law, Charles law and Avogadro's law we get an equation known as ideal gas equation which correlate P, V, T of a gas.

$V \propto \frac{1}{P}$ (according to Boyle's law at constant T)

$V \propto T$ (according to Charle's law at constant P)

$V \propto n$ (according to Avogadro's law at constant P and T)

$$V \propto \frac{nT}{P}$$

$$PV \propto nT$$

$$PV = nRT$$

Where R is proportionality constant known as universal gas constant.

Numerical value of R:

- $R = 0.0821$ litre atm K^{-1} mol^{-1}
- $R = 0.0831$ litre bar K^{-1} mol^{-1}
- $R = 8.314$ J K^{-1} mol^{-1}
- $R = 1.987 \approx 2$ cal K^{-1} mol^{-1}
- $R = 8.314 \times 107$ erg K^{-1} mol^{-1}

If temperature, volume and pressure of a fixed amount of gas vary from T_1, V_1 and p_1 to T_2, V_2 and p_2 then we can write

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$$

This equation is also known as Combined gas law.

Dalton's Law of Partial Pressure

Dalton's law of partial pressure and states that "the total pressure exerted by a mixture of non reacting gases is equal to the sum of partial pressure of each gas present in the mixture".

Total = $p_1 + p_2 + p_3 + \ldots\ldots$(at constant T, V)

Kinetic Theory of Gases

The postulates of kinetic theory of gases are as follows:

1. The gaseous molecules are considered to be point masses.
2. The volume of a molecule is negligible as compared to total volume of the gas.
3. The molecules neither attract nor repel each other.
4. The collisions are perfectly elastic i.e. there is no loss of energy during the molecular collisions.
5. The average kinetic energy of molecules is directly proportional to the absolute temperature of the gas.
6. The effect of gravity on molecular motion is negligible.

The Kinetic Gas Equation

where P =Pressure of the gas

$$PV = \frac{1}{3}mv^2$$

V = Volume of the gas

m = Mass of one molecule of a gas

n = number of molecules of gas

u = root mean square speed of the molecule

m × n = M = molecular weight of the gas.

$$PV = \frac{1}{3}Mu^2$$

Graham's Law of Diffusion

According to Graham's Law "at constant pressure and temperature, the rate of diffusion or effusion of a gas is inversely proportional to the square root of its vapour density or molecular mass".

$$r \propto \sqrt{\frac{1}{d}}$$

Behaviour of Real gases

Ideal gas: A gas which obeys the gas laws and the gas equation PV = nRT strictly at all temperatures and pressures is said to be an ideal gas. But actually the concept of ideal gas is hypothetical as there is no gas which practically is ideal. So, the non-ideal gases are the real gases which are the actually existing gases which obey gas equation approximately only under two conditions.

(i) Low pressure.

(ii) High temperature.

Causes of Deviation

There are two hypothetical postulates in the kinetic theory of gases. These are as follows:

1. The volume of a molecule is negligible as compared to total volume of the gas. Actually, gas molecules do possess some volume which account for the deviation.
2. There is no intermolecular forces of attraction between gaseous molecules.

By correcting these two postulates, we get an equation which can be applied to the gases which deviate from ideal behaviour. This deviation of a gas from ideal behaviour can also be expressed in terms of compressiblity factor (Z).

$$Z = \frac{PV}{RT}$$

Van der Waal’s Equation

$$\left(P + \frac{an^2}{V^2}\right)(V - nb) = nRT \; A = \pi r^2$$

Where a and b are van der waal's constant.

Liquifaction of Gases

Gases can be liquefied by applying high pressure or by cooling.

Critical Temperature: It is the temperature above which gas cannot be liquefied, no matter how high be pressure.

$$T_c = \frac{8a}{27Rb}$$

Critical Pressure: It is the minimum pressure that is required to liquefy a gas at critical temperature.

$$P_c = \frac{a}{27b^2}$$

Critical Volume: It is the volume occupied by gas at critical temperature and critical pressure.

Vc = 3b

1. **Liquid State:**

It is the intermediate state between gaseous and solid states. Liquids possess fluidity like gases but incompressibility like solids.

Properties of liquid are:

a. A liquid is made up of molecules. Only Hg(l) is in atomic state.
b. The intermolecular forces of attraction in a liquid are quite large.
c. Liquids have no definite shape but have definite volume as the cohesive forces are strong.
d. Liquids diffuses slowly in comparison to gas.
e. They have definite volume but irregular shapes or we can say that they can take the shape of the container.

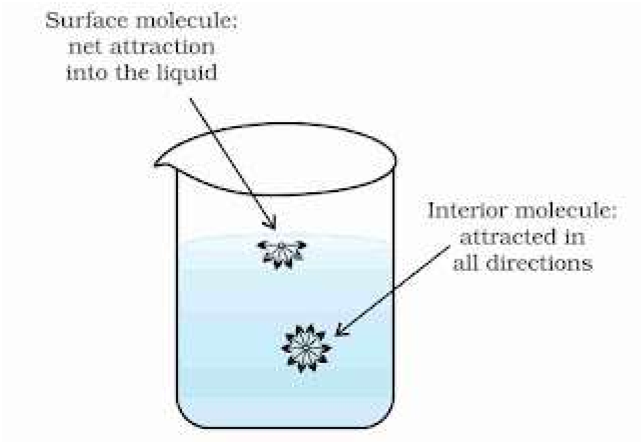
2. **Evaporation:** The process of change of liquid into vapour state at any given temperature is evaporation. Evaporation is accompanied by cooling as average kinetic energy of remaining molecules decreases. Example: Ether evaporates faster than alcohol.

3. **Vapour Pressure:** In a closed vessel when the rate of evaporation become equal to rate of condensation, i.e. equilibrium is established, the pressure exerted by the vapours of liquid on its on surface is known as vapour pressure.

4. **Boiling Point:** Boiling point of the liquid is the temperature at which the vapour pressure of the liquid is equal to the atmospheric pressure. Ex- Boiling point of pure water is 100 °C.

5. **Surface tension:** "It is the force acting on the surface at right angles to any line of unit length". The property of surface tension may also be described in terms of the tendency of a liquid to decrease its surface area. It's SI unit is N/m.

   Surface tension, $S = \frac{F}{l}$



6. **Viscosity:** The property of the liquids which determines their resistance to flow, is called viscosity. The forces between the layers which oppose the relative motion between them are known as the forces of viscosity. Thus viscosity may be thought of as the internal function of a fluid in motion.

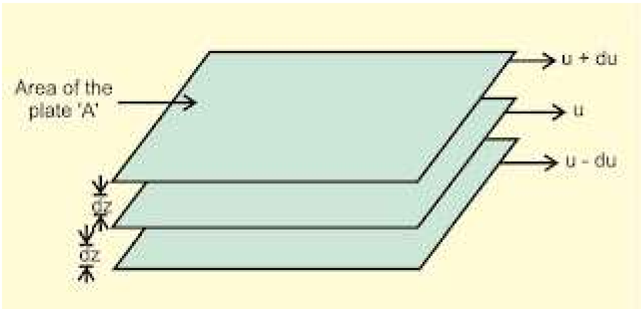
   $F \propto \frac{dv}{dz}$ is called velocity gradient]

   $F \propto A$

   $$F = nA\frac{dv}{dz}$$

η is the coefficient of viscosity. It is expressed in $Nm^{-2}s$ or poise

1 poise = 0.1 $Nm^{-2}s$



7. **Fluidity(Φ):** The reciprocal of the coefficient of viscosity is called Fluidity.

$$\Phi = \frac{1}{\eta}$$

1. **Three different states of matter (solid, liquid and gas):** Solid is that state of matter which has a definite shape and a definite volume, liquid has a definite volume but no definite shape whereas gas has neither definite shape nor definite volume.

2. **Two more states of matter:**

   i. Plasma state which consists of a mixture of electrons and positively charged ions formed due to super heating of gases, e.g., in sun or stars.

   ii. Super cooled solid state in which atoms lose their identity to form a single super atom.

3. **Triple point:** It is the temperature at which all the three states of matter or phases of the same substance exist together, e.g., ice, water and water vapour exist together at 0.01°C (273.16 K) and 4.58 mm pressure.

4. **Ideal and Real gases:** A gas which obeys ideal gas equation under all conditions of temperature and pressure is called an ideal gas. However, the concept of ideal gas is only hypothetical. The gases obey gas laws only if pressure is low or temperature is high. Such gases are called real gases.

5. **Significance of van der Waal's constants:** 'a' is a measure of the magnitude of attractive forces whereas 'b' is a measure of the effective size of the gas molecules. b = 4v where v is actual volume of gas molecules. 'b' is called excluded volume or co-volume.

6. **Boiling point:** It is the temperature at which vapour pressure of the liquid becomes equal to external pressure. When external pressure = 1 atm = 760 mm, it is called normal boiling point.

7. **Surface tension of liquids:** It is the force acting at right angles to the surface along one centimeter length of the surface. Its units are dynes cm–1 or Nm–1.

8. **Vapour pressure of a liquid:** It is the pressure exerted by the vapour present in equilibrium with a liquid in a closed vessel at a particular temperature. Cooling is caused by evaporation because more energetic molecules leave the liquid.

9. **Viscosity of liquids:** It is the internal resistance of a liquid to flow or it is the force of friction which one part of the liquid offers to another part of the liquid.

10. **Factors affecting viscosity:**

    i. **Nature of the liquid :** Greater the inter-molecular forces, higher is the viscosity.

    ii. **Temperature:** Viscosity of a liquid decreases with increase of temperature because kinetic energy increases and hence inter-molecular forces of attraction decrease.

11. **Boyle's law:** Temperature remaining constant, volume of a given mass of a gas is inversely proportional to its pressure, i.e., $V \propto \frac{1}{P}$ at constant T or PV = constant.

12. **Dalton's law of partial pressures:** If two or more gases which do not react chemically with

each other are enclosed in a vessel, then total pressure exerted by the gaseous mixture is the sum of their partial pressure.

13. **Graham's law of diffusion/effusion:** Under similar conditions of temperature and pressure, rates of diffusion/effusion of different gases are inversely proportional to the square root of their densities.

14. **Compressibility factor (Z):** The extent of deviation of a real gas from ideal behaviour is expressed in terms of compressibility factor (Z) viz. $\mathrm{Z} = \mathrm{P}\frac{\mathrm{V}}{\mathrm{n}}\mathrm{RT}$.

MIND MAP : LEARNING MADE SIMPLE CHAPTER - 5

States Of Matter: Gases, Liquids & Solids

Intermolecular Forces are the forces of attraction and repulsion between interacting particles

- London dispersion forces are the weakest intermolecular forces present among non-polar atoms and molecules.
- Dipole – dipole forces act between the molecules possessing permanent dipole.
- Dipole – induced dipole forces are the attractive forces operate between polar molecules having permanent dipole.
- Hydrogen bond is found in the molecules in which highly polar N–H, H–O and H–F bonds are present.

Thermal Energy is the energy of body arising from motion of its atoms or molecules

Intermolecular forces vs thermal interaction

Gas →Liquid →Solid: Predominance of intermolecular interactions

Gas ← Liquid ←Solid: Predominance of thermal energy

Gaseous State

Physical Properties:

- Gases are highly compressible.
- Gases exert pressure equally in all directions.
- Gases have much lower density than solids and liquids.
- Volume and shape of gases are not fixed.
- They mix evenly and completely in all proportions.

Gas Laws

- Boyle's Law (Pressure – Volume relationship): At constant temperature, the pressure of a fixed amount of gas varies inversely with its volume. $P_1V_1 = P_2V_2 = \text{Constant} \Rightarrow \frac{P_1}{P_2} = \frac{V_1}{V_2}$
- Charle's Law (Temperature – Volume relationship) : At constant pressure, the volume of a fixed mass of a gas is directly proportional to the absolute temperature $\frac{V_1}{T_1} = \frac{V_2}{T_2} \Rightarrow \frac{V}{T} = \text{Constant}$
- Gay Lussac's Law (Pressure – Temperature relationship): At constant volume, pressure of a fixed amount of a gas varies directly with temperature. $\frac{P}{T} = \text{constant}$
- Avogadro Law :(Volume – Amount relationship): Equal volume of all gases under the same conditions of temperature and pressure contain equal number of molecules. $V = kn;\ n = \frac{\text{Mass of gas}}{\text{Molar Mass}}$

Ideal Gas Equation

$R = \frac{pV}{nT}$ R is gas constant / universal gas constant

$R = 8.314\ JK^{-1}\ mol^{-1}$

Viscosity

$F = \eta A \frac{dx}{dz}$

- Viscosity coefficient (η) is the force when velocity gradient is unity and the area of contact is unit area.
- SI unit of viscosity coefficient is Newton second per square metre ($N\ s\ m^{-2}$) = Pa s (Pascal second)

Liquid State

Intermolecular forces are stronger than gaseous state.

- Boiling is the condition of free vapourisation throughout the liquid.
- Normal b.p. is boiling point at 1 atm.
- Standard b.p.is boiling point at 1 bar.

Liquifaction of Gases

- Volume of one mole of gas at critical temperature is called critical volume (V_C) and pressure at this temperature is called critical pressure (P_C)

Deviation from ideal gas behaviour

- Real gases show deviations from ideal gas law because molecules interact with each other.
- Pressure exerted by the gas is lower than the pressure exerted by the ideal gas

$P_{ideal} = P_{real} + \frac{an^2}{V^2}$ (Observed pressure + Correction term)

- Compressibility factor $Z = \frac{PV}{nRT}$

Postulates of Kinetic –Molecular Theory of gases

- A gas contains a large number of small particles called molecules. Size and mass of all molecules of each gas are identical.
- There is no force of attraction between the particles of a gas at ordinary temperature and pressure.
- Particles of a gas are always in constant and random motion.
- Particles of a gas move in all possible directions in straight lines.
- Collisions of gas molecules are perfectly elastic.
- At any particular time, different particles in the gas have different speeds and hence different kinetic energies.
- If a molecule has variable speed, then it must have a variable kinetic energy.

Dalton's Law of Partial Pressure

Total pressure exerted by the mixture of non-reactive gases is equal to sum of the partial pressures of individual gases. $P_{total} = p_1 + p_2 + p_3$ .... (At constant T,V)

Density and molar mass at a gaseous substance

$M = \frac{dRT}{\rho}$

Surface Tension

is the force acting per unit length perpendicular to the line drawn on the surface of liquid.

Denoted by Gamma (γ) Unit: Nm^{-1}

Important Questions

Multiple Choice questions-

Question 1. Three containers A, B, C of equal volume contain oxygen, neon and methane respectively at same temperature and pressure. The increasing order of their masses is

(a) A < B < C

(b) B < C < A

(c) C < A < B

(d) C < B < A

Question 2. A gas will approach ideal behaviour at

(a) Low temperature, low pressure

(b) Low temperature, high pressure

(c) High temperature, low pressure

(d) High temperature, high pressure

Question 3. Containers A and B have same gas. Pressure, volume and temperature of A are all twice those of B. The ratio of number of molecules of A and B is

(a) 1 : 2

(b) 2 : 1

(c) 1 : 4

(d) 4 : 1

Question 4. According to kinetic theory of gases,in an ideal gas,between two successive collisions a gas molecule travels

(a) In a circular path

(b) In a wavy path

(c) In a straight line path

(d) With an accelerated velocity

Question 5. When did substances exist in different crystalline forms the phenomenon is called:

(a) Allotropy

(b) Polymorphism

(c) Polymerization

(d) Isomorphism

Question 6. SI unit of pressure is :

(a) Pascal

(b) torr

(c) mm of Hg

(d) none of the above

Question 7. If the pressure of a gas is increased then its mean free path becomes:

(a) 0

(b) Less

(c) More

(d) Infinity

Question 8. 1 atmosphere is equal to:

(a) 1 torr

(b) 760 cm

(c) 760 mm

(d) 76 torr

Question 9. Grahams law refers to :

(a) Boiling point of water

(b) Gaseous Diffusion

(c) Gas Compression

(d) Volume changes of gases

Question 10. The rise or fall of a liquid within a tube of small bore is called :

(a) Surface Tension

(b) Capillary Action

(c) Viscosity

(d) Formation of Curvature

Question 11. The rates of diffusion of gases are inversely proportional to square root of their densities . This statement refers to :

(a) Daltons Law

(b) Grahams Law

(c) Avogadros Law

(d) None of the Above

Question 12. Cooling is caused by :

(a) Evaporation

(b) Convection

(c) Conduction

(d) none of the above

Question 13. If helium and methane are allowed to diffuse out of the container under the similar conditions of temperature and pressure, then the ratio of rate of diffusion of helium to methane is:

(a) 2 : 1

(b) 1 : 2

(c) 3 : 5

(d) 4 : 1

Question 14. Equal masses of ethane and hydrogen are mixed in an empty container at 25°C . The fraction of total pressure exerted by hydrogen is

(a) 1 : 2

(b) 1 : 1

(c) 01 : 16

(d) 15 : 16

Question 15. The volume of 2.8 g of carbon monoxide at 27°C and 0.0821 atm is

(a) 30 L

(b) 3 L

(c) 0.3 L

(d) 1.5 L

Very Short:

1. What change in energy takes place when a molecule is formed from its atoms?
2. Arrange the following in order of increasing bond strengths.
3. Name the shapes of the following molecules: CH_4, C_2H_2, CO_2.
4. Arrange the following in order of increasing strengths of hydrogen bonding O, F, S, Cl, N
5. Identify the compound/compounds in the following in which S does not obey the Octet rule: SO_2, SF_2, SF_4, SF_6.
6. Name one compound each involving sp^3, sp^2, sp hybridization.
7. s-s, s-p, p-p form a bond, and only p-p form π bond.

Short Questions:

1. Which out of CH_3F and CH_3Cl has a higher dipole moment and why?
2. Define the term chemical bond. What are its different types?
3. Why covalent bonds are called directional bonds whereas ionic bonds are called non-directional?
4. AlF_3 is a high melting solid whereas SiF4 is a gas. Explain why?
5. Using the VSEPR theory identifies the type of hybridization and draw the structure of OF_2 What are oxidation states of O and F?
6. Account for the following: The experimentally determined N-F bond length in NF_3 is greater than the sum of the single covalent radii of N and F.

Long Questions:

1. State with reasons, which is more polar CO_2 or N_2O?
2. Out of peroxide ion (O_2) and superoxide ion (O_2) which has larger bond length and why?
3. Explain the formation of the following molecules according to the orbital concept, F2, HF, O_2, H_2O, N_2, NH_3 molecules.
4. What is a hydrogen bond, what are its causes, and give the conditions for hydrogen bonding? What is the strength of hydrogen bonding? Describe the two types of hydrogen bonding.

Assertion Reason Questions:

1. In the following questions, a statement of Assertion (A) followed by a statement of Reason (R) is given. Choose the correct option out of the choices given below each question.

   Assertion (A): Three states of matter are the result of balance between intermolecular forces and thermal energy of the molecules.

   Reason (R): Intermolecular forces tend to keep the molecules together but thermal energy of molecules tends to keep them apart.

   (i) Both A and R are true and R is the correct explanation of A.

   (ii) Both A and R are true but R is not the correct explanation of A.

   (iii) A is true but R is false.

   (iv) A is false but R is true.

2. In the following questions, a statement of Assertion (A) followed by a statement of Reason (R) is given. Choose the correct option out of the choices given below each question.

Assertion (A): At constant temperature, pV vs V plot for real gases is not a straight line.

Reason (R) : At high pressure all gases have Z > 1 but at intermediate pressure most gases have Z < 1.

(i) Both A and R are true and R is the correct explanation of A.

(ii) Both A and R are true but R is not the correct explanation of A.

(iii) A is true but R is false.

(iv) A is false but R is true.

Case Study Based Question:

1. Intermolecular forces are the forces of attraction and repulsion that exist between molecules of a compound. These cause the compound to exist in a certain state of matter – solid, liquid or gas and affect the melting and boiling points of compounds as well as the solubilities of one substance in another. Attractive intermolecular forces are also called van der Waals' forces. These are weak forces.

(1) Dipole-dipole forces act between the molecules possessing permanent dipole. Ends of dipoles possess 'partial charges'. The partial charge is:

(a) More than unit electronic charge

(b) Equal to unit electronic charge

(c) Less than unit electronic charge

(d) Double the unit electronic charge

(2) The nature of inter-particle forces in benzene is:

(a) Dipole-dipole interaction

(b) Dispersion force

(c) Ion-dipole interaction

(d) H-bonding.

(3) The interaction energy between two temporary dipoles is proportional to (where r is the distance between the two particles)

(a) $1/r^4$

(b) $1/r^2$

(c) $1/r^5$

(d) $1/r^6$

(4) Attractive intermolecular forces known as van der Waals forces do not include which of the following types of interactions?

(a) London forces

(b) Dipole-dipole forces

(c) Ion-dipole forces

(d) Dipole-induced dipole forces

(5) In which of the following molecules, the van der Waals forces are likely to be the most important in determining the m.pt. and b.pt?

(a) CO

(b) H_2S

(c) Br_2

(d) HCl

2. If a hydrogen atom is bonded to a highly electronegative element such as fluorine, oxygen, nitrogen, then the shared pair of electrons lies more towards the electronegative element. This leads to a polarity in the bond in such a way that a slight positive charge gets developed on H-atom, viz

$$H^{\delta+} : O^{\delta-} \qquad H^{\delta+} : F^{\delta-} \qquad H^{\delta+} : N^{\delta-}$$

Such a bond between the hydrogen atom of one molecule and the more electronegative atom of the same or another molecule is called a hydrogen bond.

(1) Which of the following compounds can form hydrogen bond?

(a) CH_4

(b) H_2O

(c) NaCl

(d) $CHCl_3$

(2) The boiling point is not affected due to hydrogen bonding in:

(a) Water

(b) Ammonia

(c) Methyl alcohol

(d) Hydrogen chloride

(3) Unusual high b.p. of water is result of:

(a) Intermolecular hydrogen bonding

(b) Intramolecular hydrogen bonding

(c) Both intra and intermolecular hydrogen bonding

(d) High specific heat

(4) Which of the following statements is not true?

(a) Intermolecular hydrogen bonds are formed between two different molecules of compounds.

(b) Intramolecular hydrogen bonds are formed between two different molecules of the same compound.

(c) Intramolecular hydrogen bonds are formed within the same molecule.

(d) Hydrogen bonds have a strong influence on the physical properties of a compound.

Answer Key:

MCQ

1. (a) 0
2. (a) Sp^2
3. (b) Sp and sp^2
4. (c) sp^3, 0
5. (d) $K^+ < Ca^{2+} < Mg^{2+} < Be^{2+}$
6. (c) Acetonitrile
7. (c) O_2^-
8. (c) Triangular
9. (b) $A_2 B_3$
10. (b) SF_4
11. (c) NaCl
12. (d) Ice
13. (d) NO^+ and CN^+
14. (c) HCl and He atoms
15. (b) sp and sp^2

Very Short Answer:

1. There is a fall in energy.

2. $F_2 < Cl_2 < O_2 < N_2$

3. CH_4: Tetrahedral; C_2H_2: Cylindrical; CO_2: linear

4. Cl < S < N < O <F.

5. SF_4, SF_6.

6. sp^3: CH_4: sp^2: C_2H_4: sp: C_2H_2

7. s-s, s-p, p-p form a bond, and only p-p form π bond.

Short Answer:

Ans: 1. The dipole moment of CH_3Cl is greater than that of CH_3F. The C-F bond length in CH_3F is smaller than the C-Cl bond length in CH_3Cl. The charge separation in the C-F bond is more than in the Cl-C bond- fluoride being more electronegative than chlorine. The bond length has a greater effect than the charge separation. Hence the dipole moment of CH_3C1 is greater than that of CH_3F.

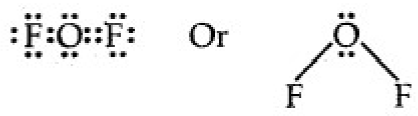
Ans: 2. The attractive forces which hold the constituent atoms in molecules or species in lattices etc. are called a chemical bond.
They are of the following types:

1. Electrovalent or ionic bond
2. Covalent bond
3. Coordinate or dative bond
4. metallic bond
5. hydrogen bond
6. van der Waals forces.

Ans: 3. A covalent bond is formed by the overlap of half-filled atomic orbitals which have definite directions. Hence covalent bond is directional. In ionic compounds, each ion is surrounded by a number of oppositely charged ions and hence there is no definite direction.

Ans: 4. AlF_3 is an ionic solid due to the large difference in electronegativities of Al and F whereas SiF_4 is a covalent compound and hence there are only weak van der Waal's forces among its molecules.

Ans: 5. The electron dot structure of OF_2 is

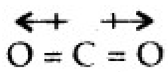


Thus, the central atom (O-atom) has 4 pairs of electrons (2 bond pairs and 2 lone pairs). Hence oxygen in OF_2 is sp^3 hybridized and the molecule is V-shaped oxidation state of F = – 1, oxidation state of O = + 2.

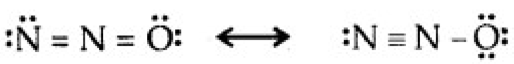
Ans: 6. This is because both N and F are small and hence have high-electron density. So they repel the bond pairs thereby making the N-F bond length larger.

Long Answer:

Ans: 1. N_2O is more polar than CO_2 which is a linear molecule and thus symmetrical. Its net dipole moment is zero.



N_2O is linear but unsymmetrical. It is a resonance hybrid of the following canonical structures:

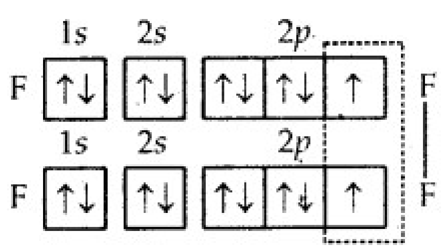


It has a net dipole moment of 0.116 D.

Ans: 2. The bond order of O_2^- is 1.5 while that of O_2^{2-} is 1.0.

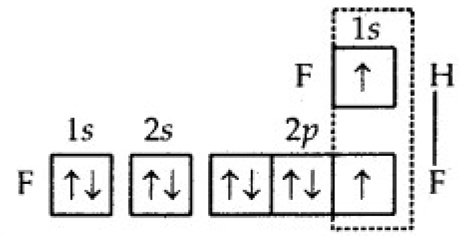
The lesser the bond order, the greater is the bond length as the bond order is inversely proportional to bond length. (Hence O_2^{2-} has a larger bond length than O_2^{2-}.

Ans: 3. 1. Formation of F2 molecule. Atomic number (Z) of fluorine is 9 and its orbital electronic configuration is $1s^2$ $2s^2$ $2p^2x$, $2p^2y$, $2p^1z$. Thus, a fluorine atom has one half-filled atomic orbital. Therefore, two atoms of fluorine combine to form the fluorine molecule as a result of the combination for their half-filled atomic orbitals shown in Fig. The two atoms get linked by a single covalent bond

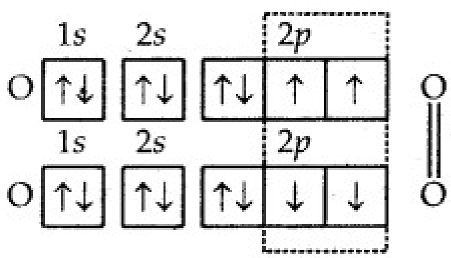


Formation of F_2 molecule

2. Formation of HF molecule. Fluorine atom, as stated above, has one half-filled atomic orbital. Hydrogen atom (Z = 1) has only one electron in Is orbital. Thus, the hydrogen fluoride (HF) molecule. is formed as a result of the combination (or overlap) of the half-filled orbitals belonging to the participating atoms.



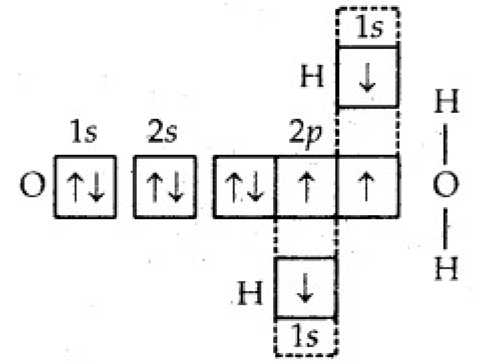
3. Formation of O_2 molecules. The atomic number (Z) of oxygen is 8 and its orbital electronic configuration is $1s^2$ $2s^2$ $2p^2x$ $2p^1x$ $2p^1z$. This means that an oxygen atom has two half-filled orbitals with one electron each. Two such atoms will combine to form a molecule of oxygen as a result of the overlap of the half-filled orbitals with opposite spins of electrons.



Formation of O_2 molecule

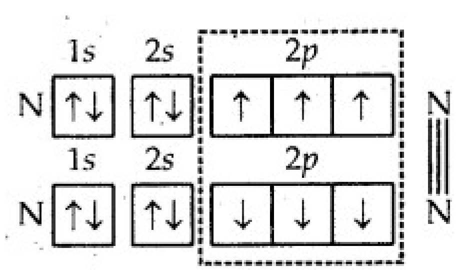
Thus, the two atoms of oxygen are bonded to each other by two covalent bonds or double bonds (O = O).

4. Formation of H_2O molecule. In the formation of the H_2O molecule, the two half-filled orbitals of the oxygen atom combine with the half-filled orbitals (1s) of the hydrogen atoms. Thus, the oxygen atom gets linked to the two hydrogen atoms by single covalent bonds as shown in



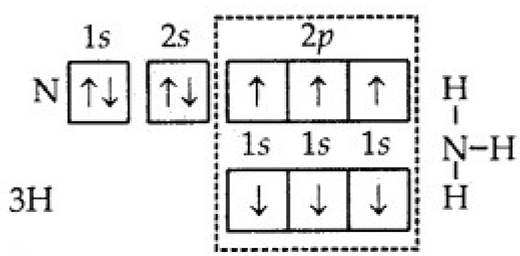
Formation of H_2O molecule

5. Formation of N_2 molecule. The atomic number of nitrogen is 7 and its orbital electronic configuration is $1s^2\ 2s^2\ 2p^1x\ 2p^1y\ 2p^1\ z$. This shows that the nitrogen atom has three half-filled atomic orbitals. Two such atoms combine as a result of the overlap of the three half-filled orbitals and a triple bond gets formed (N = N)



Formation of N_2 molecule

6. Formation of NH_3 molecule. In the formation of ammonia (NH_3) molecule, three half-filled orbitals present in the valence shell of nitrogen atom combine with 1s orbital of three hydrogen atoms with one electron each. As a result, the nitrogen atom completes its octet and a molecule of NH_3 is formed in which the nitrogen atom is linked to three hydrogen atoms by covalent bonds.



Formation of NH_3 molecule

Ans: 4. When hydrogen is connected to small highly electronegative atoms such as F, O, and N in such cases hydrogen forms an electrostatic weak bond with an electronegative atom of the second molecule, this type of bond binds the hydrogen atom of one molecule and the electronegative atom of the 2nd molecule is called as hydrogen bond. It is a weak bond and it is denoted by dotted lines e.g., in HF, hydrogen forms a weak bond with the electronegative F atom of the 2nd molecule neighboring HF.

$$\overset{\delta+}{H}-\overset{\delta-}{F}.....\overset{\delta+}{H}-\overset{\delta-}{F}.....\overset{\delta+}{H}-\overset{\delta-}{F}$$

So it means hydrogen is acting as a bridge between two molecules by one covalent bond and the other by a hydrogen bond. Due to this hydrogen bonding, HF will not exist as a single molecule but it will exist as an associated molecule $(HF)_n$. So hydrogen bond may be defined as a weak electrostatic bond that binds the hydrogen atom of one molecule and electronegative bond atoms (F, O, N) of the second neighboring molecule.

Cause of hydrogen bonding: When a hydrogen atom is bonded to an electronegative atom (say F, O, N) through a covalent bond, due to electronegativity difference, the electronegative atom attracts the shared pair of electrons towards its side with a great force as a result of which the shared pair of electrons will be displaced toward electronegative atom and away from a hydrogen atom.

Due to which hydrogen atom will acquire a slightly negative charge and if another molecule is brought nearer to it in such a way that electronegative atom of the second molecule faces hydrogen atom of the 1st molecule, due to opposite charges present on the atoms, an electrostatic bond will be formed between the hydrogen atom of one molecule and electronegative atom of 2nd molecule and this is called as hydrogen bond.

$$\overset{\delta+}{H}-\overset{\delta-}{F}.....\overset{\delta+}{H}-\overset{\delta-}{F}.....\overset{\delta+}{H}-\overset{\delta-}{F}$$

Conditions for hydrogen bonding. The following two necessary conditions for hydrogen bonding are:

1. Hydrogen atom should be connected to highly electronegative atom say F, O, or N.

2. The electronegative atom of which the hydrogen atom is connected should be the same in size.

The smaller the size of the electronegative atom greater will be the attraction of that atom for shared pair of electrons and hence that pair will be displaced more nearer to that atom and hence that atom will develop greater negative charge and the hydrogen atom will develop a greater positive charge and hence hydrogen atom of this molecule will easily attract negative atom of the Ian molecule and hence a hydrogen bond will be easily formed.

As both these conditions are satisfied only by F, O, N atoms so only three atoms show hydrogen bond.

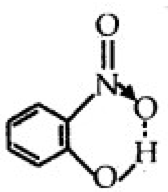
Strength of Hydrogen Bond: A hydrogen bond is a very weak bond. It is weaker than an ionic or a covalent bond. Its strength ranges from 13 kJ mol-1 to 42 kJ mol^{-1}. The strength of the hydrogen bond for some of the molecules is the order H-F H (40 kJ mol-1) > O-H...... O (28 kJ mol^{-1}) > H-N...... H (13 kJ mol^{-1}) whereas the strength of a covalent bond is quite high. For example, the bond strength of the H-H bond in H_2 is 433 kJ mol^{-1}

Types of H-bonding

There are two types of hydrogen-bonds

1. Intermolecular hydrogen bond. It is formed between two different molecules of the same or different compounds. For example H-bond in case of HF, alcohol, or water.

2. Intramolecular Hydrogen bond. It is formed when a hydrogen atom is in between the two highly electronegative (F, O, N) atoms present within the same molecule. For example, in o-nitrophenol, hydrogen is in between the two oxygen atoms.



Assertion Reason Answer:

1. (i) Both A and R are true and R is the correct explanation of A.

2. (ii) Both A and R are true but R is not the correct explanation of A.

Case Study Answer:

1. Answer:

(1) (c) Less than unit electronic charge

(2) (b) Dispersion force

(3) (d) $1/r^6$

(4) (c) Ion-dipole forces

(5) (c) Br_2

2. Answer:

(1) (b) H_2O

(2) (d) Hydrogen chloride

(3) (a) Intermolecular hydrogen bonding

(4) (b) Intramolecular hydrogen bonds are formed between two different molecules of the same compound.