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The Gaseous State and Liquid State

- **Five states of matter** are known, *viz*, solid, liquid, gas, plasma and Bose-Einstein condensate. Out of these solid, liquid and gas are commonly found while remaining two are found only under specific conditions.
- **Solid matter**: It is composed of tightly packed particles.
- **Liquid matter**: It is made of more loosely packed particles.
- **Gaseous matter**: It is composed of particles packed so loosely that it has neither a defined shape nor a defined volume.
- **Plasma:** It is a state of matter similar to gas in which a certain portion of the gaseous particles are ionized.
- **Bose-Einstein Condensate:** A Bose-Einstein condensate is a gaseous super fluid phase formed by atoms cooled to temperature very near to absolute zero.
- **Intermolecular forces** are the forces of attraction or repulsion between interacting particles(atoms and molecules).Attractive /repulsive, intermolecular forces are known as van der Waal's forces. Different types of van der Waal's forces are:
- **Dispersion forces or London forces:** The interaction which is present between two non polar molecules i.e., between induced dipole and induces dipole is called dispersion forces, for example: noble gases.
- **Dipole-dipole forces:** The interaction which is present between molecules having permanent dipoles i.e., between polar molecules, for example NH_3, HCl etc.
- **Dipole-induced dipole forces:** The interaction which is present between a polar and non polar molecule.
- **STP (Standard Temperature and Pressure):** STP means 273.15 K (0°C) temperature and 1 bar (i.e., exactly 105 Pascal.) Volume occupied by 1 mole gas at STP = 22.7 L.
- **Compressibility factor:** The extent of deviation of a real gas from an ideal behavior is expressed in terms of compressibility factor.
- **Molar gas volume**: The volume of one mole of a gas, i.e., 224 Lat STP (0°C, 1 atm) is known as molar gas volume.
- **Ideal gas:** The gas which obeys the equation **pV = nRT** at every temperature and pressure range strictly Is known as Ideal gas.
- **Real gases:** Since none of the gases present in universe strictly obey the equation pV =nRT. Hence they are known as real or non-ideal gases. Real gases behave, ideally at low p and high T.
- **Critical temperature (T_C):** It may be defined as the temperature above which no gas can be liquefied. Critical temperature of CO_2 is 31.1°C. $\mathbf{T_C = 8a / 27Rb}$
- **Critical pressure (P_c):** At critical temperature, the pressure needed to liquefy a gas is known as critical pressure. $\mathbf{P_c = a / 27 b^2}$
- **Critical volume (V_c):** The volume occupied by one mole of a gas at critical temperature and critical pressure is known as critical volume. $\mathbf{V_c = 3b}$
- **Boyle's temperature (T_b):** Temperature at which a real gas exhibits ideal behavior for considerable range of pressure is called Boyle's temperature. **Tb = a / bR**
- **Surface tension:** It is the force acting perunit length perpendicular to the imaginary line drawn on the surface of

liquid. It is denoted γ (gamma); SI unit: Nm-1 Dimensions: kgs-2

- **Viscosity:** Viscosity is a measure of resistance to flow which arises due to friction between layers of fluid.

  F = η Adv / dz

- 'η' is proportionality constant and is called coefficient of viscosity. Viscosity coefficient is the force when velocity gradient is unity and the area of contact is unit area. CGS unit of coefficient of viscosity is poise S.I. unit of coefficient of viscosity is Nsm^{-2}.
- **Dalton's law of partial pressures:** It is a gas law which states that the total pressure exerted by a mixture of gases is equal to the sum of the partial pressures exerted by each individual gas in the mixture.

  $pV = (n_1 + n_2 + n_3)RT$

- **Graham's Law of Diffusion:** Under Similar conditions of temperature and pressure, the rates of diffusion of gases are inversely proportional to the square root of their densities. Mathematically,

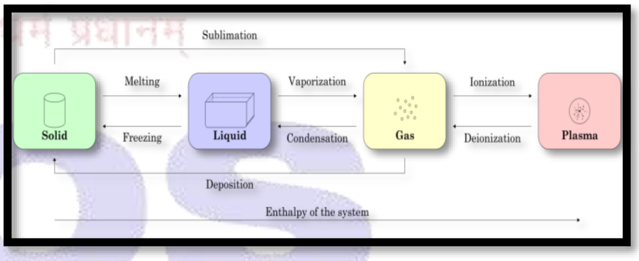
$$r_1 / r_2 = \sqrt{d_2} / \sqrt{d_1} = \sqrt{M_2} / \sqrt{M_1}$$

- **Boyle's Law:** The volume of a given mass of a gas is inversely proportional to its pressure at constant temperature.

  $V \propto 1 / p$ or $Vp = K$

  K is a constant ∴ $p_1V_1 = p_2V_2$

- **Isotherms:** A graphs of V vs p or pV vs p at constant temperature known as **Isotherms**
- **Charles' Law:** The volume of the given mass of a gas increases or decrease by 1 / 273 of its volume for each degree rise or fall of temperature respectively at constant pressure. **$V_t = V_o (1 + t / 273)$** t constant p or The volume of a given mass of a gas is directly proportional to the absolute temperature at constant pressure. $V \propto T$ (at constant p),
- **V / T = constant or $V_1 / T_1 = V_2 / T_2$**
- **Absolute zero**: It is the theoretically possible temperature at which the volume of the gas becomes zero. It is equal to 0°C or 273.15 K.
- **Isobars**: A graph of V vs T at constant pressure is known as isobar
- **Gay Lussac's Law:** The pressure of a given mass of gas increases or decreases by 1 /273 of its pressure for each degree rise or fall of temperature respectively at constant volume. **$p_t = p_o (1 + t / 273)$** at constant V and n or The pressure of a given mass of a gas at constant volume is directly proportional to absolute temperature.
- **$p \propto T$** or **$p = KT$** or **$p / T = K$** at constant V and n or **$P_1 / T_1 = P_2 / T_2$**
- **Isochores**: A graph of p vs T at constant volume is known as isochore
- **Avogadro's Law:** It states that equal volumes of all gases under the same conditions of temperature and pressure contain equal number of molecules.
- **Mathematically** V infi; n (at constant T and p) **or $V / n = K$**



- **Van der Waal's equation:**

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

  For n moles of the gas

- **Compressibility factor:**

  $$Z = \frac{pV}{nRT}$$

- **Ideal gas equation:**

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

- **Density and molar mass of a gaseous substance:**

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

Check Yourself

1. What are the conditions for gas like Carbon monoxide to obey the ideal gas laws?

(A) Low temperature and low pressure
(B) Low temperature and high pressure
(C) High temperature and low pressure
(D) High temperature and high pressure

2. If the temperature is doubled, the average velocity of a gaseous molecule increases by

(A) 4 **(B)** 1.4 **(C)** 2 **(D)** 2.8

3. At the same temperature, the average molar kinetic energy of N2 and CO is

(A) $KE_1 > KE_2$ **(B)** $KE_1 < KE_2$

(C) $KE_1 = KE_2$

(D) Insufficient information given

4. Find the temperature at which the rate of effusion of N_2 is 1.625 times to that of SO_2 at 500℃

(A) 620℃ **(B)** 173℃

(C) 110℃ **(D)** 373℃

5. Find the fraction of the total pressure exerted by hydrogen if it is mixed with ethane in an empty container at 25℃

(A) 15/16 **(B)** 1/16 **(C)** 1/2 **(D)** 1

Test Yourself

Question: A balloon is filled with hydrogen at room temperature. It will burst if pressure exceeds 0.3 bar. If at 1 bar pressure the gas occupies 3.27 L volume, upto what volume can the balloon be expanded?

Answer: According to Boyle's Law $p_1V_1 = p_2V_2$ If p_1 is 1 bar, V_1 will be 3.27 L If p_2 = 0.3 bar, then **$V_2 = p_1V_1/p_2$ or $V2 =$** 1bar×3.27L/0.3bar ⇒ = V_2 =10.9 L Since balloon bursts at 0.2 bar pressure, the volume of balloon should be less than 10.9 L.

Stretch Yourself

1. Define the terms:

(i) Standard boiling point.

(ii) Vapor pressure of a liquid.

2. Drops of liquid are spherical in nature. Explain. Mention the effect of temperature on surface tension.

3. Write the S.I. units of:

(i) Surface tension.

(ii) Coefficient of viscosity.

4. 300 ml of oxygen gas at ñ 10°C are heated to 10°C. Find the volume of gas at 10°C if pressure remains constant. [Ans. 322.8 mL]

5. A gas at a pressure of 5 atm is heated from 0° to 546°C nd is simultaneously compressed to one third of its originl volume. Find the final pressure f the gas.

Answers

Check Yourself

Answer: 1(C); 2(B); 3(C); 4(A); 5(A)

Stretch Yourself

1. (i) Standard Boiling Point: If the pressure is 1 bar, the boiling point of the liquid is called standard boiling point. (ii) Vapor Pressure of Liquid: The pressure exerted by the vapor of a liquid at a particular temperature in a state of dynamic equilibrium is called vapor pressure of that liquid at that temperature.
2. Liquid tends to have a minimum surface area due to surface tension. For a given volume of a liquid, sphere has the minimum surface area. So, the small drops of liquid are spherical in nature. Surface tension decreases with increase in temperature because force acting per unit length decreases due to increase in kinetic energy of molecules.
3. (i) S.I. unit of surface tension = Nm^{-1} (ii) S.I. unit of coefficient of viscosity = Nm^{-2} s or Kg ms^{-1} s^{-1}.
4. **Given,** V_1=300mL V_2=? T_2=10+273=283K
   According to Charles's law, $V_1/T_1=V_2/T_2$ **or** $V_2=V_1T_2/T_1$
   Then, V2= 300×283/263= 322.8mL
5. **Hint: Ideal gas equation**

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