Problem Based on Real Gases

* **Explanation for Derivation from Ideal Gas behaviour.**

*** Equation of state of Real gas (Vander Waals Equation)**

VERY SHORT ANSWER TYPE QUESTIONS :

VSA.1 What are real gases ?

Sol. Real gases are those which do not follow all the gas laws at all temperature and pressure.

VSA.2 Under what conditions of T and P, most of gases deviate form ideal gas behaviour ?

Sol. At low temperature and high pressure most of gases deviate from ideal gas behaviour.

VSA.3 Give Vander Waal's equation by giving meaning of each term.

Sol.

$$\left(P + \frac{a}{V^2}\right)(V - b) = RT$$

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

Where 'P' is pressure, V is volume, 'n' is number of moles, R = gas constant, T is temperature in Kelvin a and b are Vander Waal's constant which depend upon nature of the gas.

VSA.4 What is compressibility (Z) factor for ideal gases ?

Sol. Z = 1 for ideal gases.

VSA.5 What is meant by compressibility factor ?

Sol. Compressibility factor is ratio of PV to nRT.

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

VSA.6 Give units of 'a' and 'b' which are Vander Waal's constants.

Sol. Unit of a is atm L^2 mol^{-2} and b is L mol^{-1}.

VSA.7 What do you mean by Boyle's temperature ? Give its expression and its relation with inversion temperature.

Sol. Boyle's temperature is a temperature at which most of real gases show ideal gas behaviour over wide range of pressure.

$$T_b = \frac{a}{bR} \qquad T_i = 2T_b$$

VSA.8 What is the significance of the van der Waal's constants 'a' and 'b' ?

Sol. 'a' is a measure of the magnitude of the intermolecular forces of attraction while b is a measure of the effective size of the gas molecules.

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VSA.9 The van der Waal's constants for two gases are as follows :

Gas	a (atm L^2 mol^{-2})	b (L mol^{-1})
X	1.39	0.0391
Y	3.59	0.0427

Which of them is more easily liquefiable and which has greater molecular size ?

Sol. Greater the value of 'a', more easily the gas is liquefiable. Similarly, greater the value of 'b', greater is the molecular size. Hence gas Y will be more easily liquefiable and will have greater molecular size.

VSA.10 Out of NH_3 and N_2, which will have (i) larger value of a and (ii) larger value of b ?

Sol. (i) NH_3 will have larger value of a because of hydrogen bonding.
(ii) N_2 should have larger value of b because of larger molecular size.

SHORT ANSWER TYPE QUESTIONS :

SA.1 Why in case of hydrogen and helium, the compressibility factor is always greater than 1 and increases with increase of pressure ?

Sol. **Explanation of the exceptional behaviour of hydrogen and helium :** It may be seen that for H_2 and He, the compressibility factor Z is always greater than 1 and increases with increase of pressure. This is because H_2 and He being very small molecules, the intermolecular forces of attraction in them are negligible i.e. 'a' is very very small so that $\frac{a}{V^2}$ is negligible. The van der Waal equation, therefore, becomes

$$P(V - b) = RT$$

or $$PV = RT + Pb$$

or $$\frac{PV}{RT} = 1 + \frac{Pb}{RT}$$

Thus $\frac{PV}{RT}$ i.e. Z > 1 and increases with increase in the value of P.

SA.2 The van der Waal's constant 'b' for oxygen is 0.0318 L mol^{-1}. Calculate the diameter of the oxygen molecule.

Sol. $$b = 4v$$

or $$v = \frac{b}{4} = \frac{0.0318}{4} = 7.95 \times 10^{-3}\ L\ mol^{-1} = 7.95\ cm^3\ mol^{-1}$$

∴ Volume occupied by one O_2 molecule

$$= \frac{7.95}{6.02 \times 10^{23}} = 1.32 \times 10^{-23}\ cm^3$$

Considering the molecule to be spherical,

$$\frac{4}{3}\pi r^3 = 1.32 \times 10^{-23}$$

or $$r^3 = \frac{3}{4} \times \frac{7}{22} \times 1.32 \times 10^{-23} = 3.15 \times 10^{-24}$$

∴ $3 \log r = \log (3.15 \times 10^{-24}) = -24 + 0.4983 = -23.5017$

or $\log r = -7.8339 = \quad .1661$

∴ $r = \text{Antilog} \quad .1661 = 1.466 \times 10^{-8}$ cm

∴ Diameter of oxygen molecule

$= 2 \times r = 2.932 \times 10^{-8}$ cm = 2.932 Å.

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SA.3 What are the difference between Ideal gas and Real gas ?

Sol. **Difference between Ideal gas and Real gas :** The main points of difference are summed up in the table below :

Ideal Gas	Real gas
(i) It obeys gas laws under all conditions of temperature and pressure.	(i) It obeys gas laws only under low pressure and high temperature.
(ii) No gas is ideal.	(ii) All gases are real.
(iii) Volume occupied by the molecules in negligible as compared to the total volume occupied by the gas.	(iii) Volume occupied by the molecules is not negligible as compared to the total volume occupied by the gas.
(iv) The forces of attraction among the molecules of the gas are negligible.	(iv) The forces of attraction among the molecules cannot be neglected at high pressure and low temperature.
(v) It obeys the ideal gas equation PV = nRT	(v) It obeys van der Waal's equation $\left(P + \frac{an^2}{V^2}\right)$ (V – nb) = nRT.

SA.4 What do you mean by ideal gas and real gas ? Why do real gases deviate from ideal behaviour? Derive Vander Waal's equation for real gases.

Sol. Ideal gas is a gas which follows gas laws at all temperature. Real gases do not follow gas laws at all temperature and pressure.

Real gases deviate from ideal gas behaviour due to force of attraction as well as volume of molecules of gases are not negligible.

Real gas equation is

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

$$\left(P + \frac{n^2a}{V^2}\right)(V - nb) = nRT$$ where 'a', 'b' are Vander Waal's constants.

SA.5 Calculate the pressure exerted by 1.00 mol of CO_2(g) at 298K that occupies 65.4 mL using Vander Waal's equation. a for CO_2 is 3.592 L^2 bar/mol^2, b = 0.0427 L mol^{-1}.

Compare it with the pressure predicted by ideal gas equation for some conditions of T and P ?

Sol. (V – b) = RT

[0.0654 – 0.0427] = 0.083 × 298

[0.0227] = 24.734

$$P + 839.84 = \frac{23.734}{0.0227} = 1089.60$$

P = 1089.60 – 839.84 = 249.76 atm

PV = nRT

P × 65.4 × 10^{-3} = 1 × 0.083 × 298

$$\Rightarrow \quad P = \frac{24.734}{.0654} = 378.195 \text{ atm.}$$