Real Gases

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1. Boyle's Law ⇒ T = constant $P \propto \frac{1}{V}$.

Charle's law ⇒ P = constant $V \propto T$

Gay Lussac's law ⇒ V = constant $P \propto T$.

Avogadro's law ⇒ Equal volumes of all gases under the same conditions of temp. and pressure, contain the same no. of molecules.

2. $PV = nRT$ – Ideal gas equation. $PM = dRT$ $P = cRT$ [c = concentration (M)]

R = gas constant = 0.0821 lit-atm/mol/K
= 8.314 J/mol/K
= 2 cal/mol/K.

3. Graham's Law of Diffusion – (For non-reacting gases) (v = volume).

$$\frac{r_1}{r_2} = \frac{P_1}{P_2} = \frac{P_1}{P_2}\sqrt{\frac{M_2}{M_1}} = \frac{P_1}{P_2}\sqrt{\frac{d_2}{d_1}} = \frac{n_1/t_1}{n_2/t_2} = \frac{V_1/t_1}{V_2/t_2}$$

→ In diffusion, P_{ext} = constant.
In effusion, P_{ext} = varying.

4. The pressure exerted by saturated water vapour is called aqueous tension.

5. Dalton's law of partial pressure –

$P = p_A + p_B$. $p_A = x_A P$ $p_B = x_B P$. (x_A, x_B = mole fraction) ($x_A + x_B = 1$).

6. KTG (Maxwell)

→ $V_{rms} = \sqrt{\frac{3RT}{M}} = \sqrt{\frac{3P}{d}}$ $V_{avg} = \sqrt{\frac{8}{\pi}\frac{RT}{M}}$

$V_{mp} = \sqrt{\frac{2RT}{M}}$. $V_{rms} > V_{avg} > V_{mp}$

Gases show maximum deviation from ideal gas behaviour at high pressure and low temperature.

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7. Z = compressibility factor $= \frac{(V_m)_{obs}}{(V_m)_{ideal}} = \frac{P(V_m)_{observed}}{RT}$

$(V_m)_{ideal} = 22.4\ L.$

→ $Z > 1 \Rightarrow$ positive deviation $\Rightarrow$ less compressible / liquefaction not possible.
$Z = 1 \Rightarrow$ ideal gas behaviour $\Rightarrow$ liquefaction not possible
$Z < 1 \Rightarrow$ negative deviation $\Rightarrow$ easily compressible

8. Real Gas Equation - $\boxed{\left(P + \frac{an^2}{V^2}\right)(V - nb) = nRT.}$

a = intermolecular forces (pressure correction)
b = incompressible volume (volume correction) / effective volume occupied by molecules.
order of $a = 10^{-1}$ to 10^{-2}
order of $b = 10^{-3}$ to 10^{-4}.
For ideal gases $\Rightarrow a = 0$ (no forces)

→ At High Temp. and Low Pressure, real gases behaves as ideal gases.

→ If $a \uparrow \Rightarrow$ liquefaction ↑ (For H_2 and He, $a \approx b$)

If $b \downarrow \Rightarrow$ liquefaction ↑.

→ At very-very low pressure $\Rightarrow a \to 0$, $b \to 0$.
At low / moderate pressure $\Rightarrow b \to 0$.
At very high pressure $\Rightarrow a \to 0$.

9. Critical Temperature (T_c) $\Rightarrow$ temperature beyond which liquefaction is not possible.

$\boxed{T_c = \frac{8a}{27Rb}}$ $\boxed{P_c = \frac{a}{27b^2}}$ $\boxed{V_c = 3b}$ $\boxed{\frac{P_c V_c}{RT_c} = \frac{3}{8}}$

10. Boyle's Temperature (T_B) $\Rightarrow$ temp. beyond/above which all real gases behave as ideal gas. $\boxed{T_B = \frac{a}{Rb}}$

11. Inversion temperature (T_i) ⇒ Temp. at which Joule–Thomson coefficient changes its value from -ve to +ve.

$$T_i = \frac{2a}{Rb}$$

→ more T_c ⇒ easier liquefaction

12. To find which gas can be more easily liquefied - check -
(i) H-bonding ↓ decreasing priority
(ii) Molar mass ↓

Eg- case of liquefaction - $NH_3 > CO_2 > N_2 > CH_4$.