

VC210 Notes

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1 Fundamentals

2 Atomic Theory

3 Basic Quantum Mechanics

4 Chemical Bonds

5 Gases

5.1 The Nature of Gases

Eleven elements are gases under normal conditions: H, He, N, O, F, Ne, Cl, Ar, Kr, Xe, Rn. Low molar mass compounds such as carbon dioxide, hydrogen chloride are also gases.

5.2 The Unit of Pressure

$$1\text{Pa} = 1\text{kg} \cdot \text{m}^{-1} \cdot \text{s}^{-2}. \quad 10^5\text{Pa} = 1\text{bar}.$$
$$760\text{mmHg} = 760\text{Torr} = 1\text{atm} = 1.013 \times 10^5\text{Pa}.$$

5.3 The Gas Laws

Boyle's Pressure Experiment $PV = \text{Const.}$

Charles' Law $V/T = \text{Const.}$

No real gas has zero volume. Lowest possible temperature: -273.15°C .

5.4 Avogadro's Principle

All gases occupy the same volume under the same conditions of temperature and pressures. The molar volume of all gases is close to $22.4\text{L} \cdot \text{mol}^{-1}$ at 0°C and 1 atm.

5.5 Standard Conditions

Standard Ambient Temperature and Pressure (SATP)

SATP means exactly 25°C (298.15 K) and exactly 1 bar. The molar volume of an ideal gas is $24.79\text{L} \cdot \text{mol}^{-1}$.

Standard Temperature and Pressure (STP)

STP means 0°C (273.15 K) and 1 atm (both exactly). The molar volume of an ideal gas is $22.41\text{L} \cdot \text{mol}^{-1}$.

5.6 The Ideal Gas Law

$$pV = nRT$$

The constant $R = 8.314\text{J} \cdot \text{K}^{-1} \cdot \text{mol}^{-1}$.

The ideal gas law is a limiting law, valid only as $p \rightarrow 0$.

The differences between ideal gases and real gases are significant at high pressures and low temperatures.

5.7 Combined Gas Law

$$\frac{p_1 V_1}{n_1 T_1} = \frac{p_2 V_2}{n_2 T_2}$$

5.8 Change n for The Ideal Gas Law

Molar Concentration $M = \frac{p}{RT}$.

Gas Density $d = \frac{Mp}{RT}$.

5.9 Mixtures of Gases

A mixture of gases behaves like a single pure gas.

Dalton's Law of Partial Pressures

Dalton concluded that the total pressure is the sum of the individual pressures of each gas.

$$\chi_A = \frac{n_A}{n_A + n_B + \dots}, p_A = \chi_A p_T$$

5.10 The Kinetic Model of Gases

The kinetic model (KMT) of a gas allows us to derive the quantitative relation between pressure and the speeds of the molecules.

Root Mean Square Speed $v_{rms} = \left(\frac{3RT}{M}\right)^{1/2}$.

Effusion In effusion, molecules escape through a small hole in a barrier into a region of low pressure. And we can find $\bar{v} \propto \frac{1}{\sqrt{m}}$.

The Maxwell Distribution of Speeds $f(v) = 4\pi \left(\frac{M}{2\pi RT}\right)^{3/2} v^2 e^{-Mv^2/2RT}$.

For the same temperature, the greater the molar mass, the lower the speed.

For the same molar mass, the higher the temperature, the higher the average speed and the broader the spread of speeds.

5.11 Deviations from Ideality

Gases can be condensed to liquids when cooled or compressed.

A measurement of the compression factor $Z = \frac{V_{m,real}}{V_{m,ideal}}$.

At low pressures the attractive forces are dominant and $Z < 1$.

At high pressures, repulsive forces become dominant and $Z > 1$ for all gases.

van der Waals equation $(p + a\frac{n^2}{V^2})(V - nb) = nRT$.

Parameter “a” represents the attraction between molecules; the value is large for strongly attracting molecules. Parameter “b” represents the role of repulsions; it can be thought of as representing the volume.

6 Liquids and Solids

6.1 Different Types of Intermolecular Forces

Type of interaction	E_p dependence	Interacting species
ion-ion	$1/r$	ions
ion-dipole	$1/r^2$	ions and polar molecules
dipole-dipole (stationary)	$1/r^3$	stationary polar molecules
dipole-dipole (rotating)	$1/r^6$	rotating polar molecules
hydrogen bonding		special case of dipole-dipole: N-H, O-H, F-H

6.2 London Forces

Attractive forces between nonpolar molecules are London forces.

Even nonpolar noble gases can be liquefied, as well as many nonpolar compounds.

London interaction $E_p \propto \frac{\alpha_1 \alpha_2}{r^6}$.

Influence

Size: As size increases (more shells) \Rightarrow polarizability increases \Rightarrow melting and boiling points increase.

Shape: Rod-like molecules have a greater surface area, more contact points for molecules to join together (high melting and boiling points); Ball or spherical shaped molecules have fewer contact points for molecules to join together (low melting and boiling points).

6.3 Hydrogen Bonding

Very strong interaction between molecules that is specific to molecules with certain types of atoms (the second strongest only to ion-ion interaction).

A hydrogen bond is denoted by a dotted line, $X - H \dots X$, $X = N, O, F$.

6.4 Surface Tension

Viscosity is a liquid's resistance to flow: the higher the viscosity of the liquid, the more sluggish the flow. \uparrow Viscosity indicates, \uparrow intermolecular strength.

Surface tension is the reason that the surface of a liquid is smooth. Strong forces pull the molecules together, with a net inward pull.

The upward curved meniscus (concave) of water forms because both water and glass have comparable forces: Adhesion \approx Cohesion.

The downward meniscus (convex) of mercury forms because the cohesive forces in mercury is stronger than between mercury atoms and the glass: Cohesion $>$ Adhesion.