CHEM110 – Chapter 6
Gases

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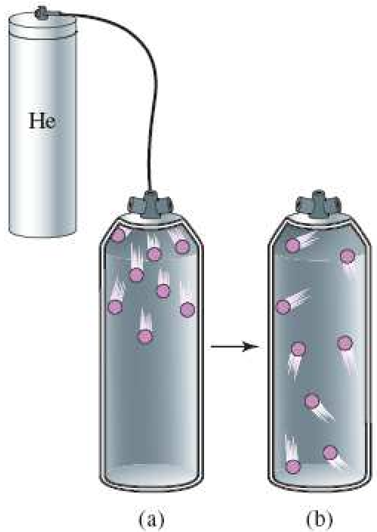
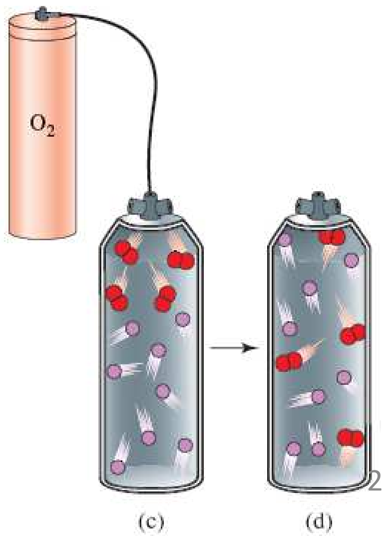
6.4 Gas Mixtures

- Gas behaviour depends on the number of gas atoms or molecules but not on their identity



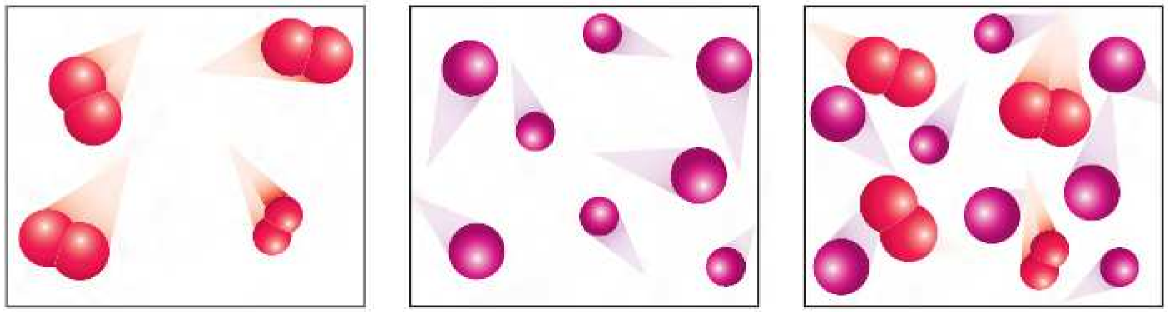
- Diffusion causes gas mixtures to become homogeneous



6.4 Gas Mixtures

Dalton's law of partial pressures

- In a mixture of gases in which no chemical reaction occurs, each gas contributes to the total pressure the amount that it would exert if the gas were present in the container by itself: $p_{total} = p_A + p_B$; p_A and p_B are the partial pressures of A and B, respectively



20.0 L at 273 K
0.100 mol O_2
$p_{O_2} = 1.13 \times 10^4$ Pa

20.0 L at 273 K
0.200 mol He
$p_{He} = 2.27 \times 10^4$ Pa

20.0 L at 273 K
0.300 mol gas
$p_{O_2} = 1.13 \times 10^4$ Pa
$p_{He} = 2.27 \times 10^4$ Pa
$p_{total} = 3.40 \times 10^4$ Pa

6.4 Gas Mixtures

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- Describing gas mixtures
  - Mole fraction (x)
    - The number of moles of a substance as a fraction of the number of moles of all substances in the mixture

$$\boxed{\text{mole fraction of A} = x_A = \frac{n_A}{n_{total}}}$$

    - The partial pressure of a component in a gas mixture is its mole fraction multiplied by the total pressure: $p_A = x_A\, p_{total}$

6.4 Gas Mixtures

- <u>Worked Example 6.5 (page 227)</u>

Exactly 8.00 g of O_2 and 2.00 g of He was placed in a 5.00L tank at 298K. Determine the total pressure of the mixture, and find the partial pressures and mole fractions of the two gases.

6.5 Applications of the Ideal Gas Equation

- Determination of molar mass
  - The ideal gas equation can be combined with

    $n = m/M$

    to find the molar mass of an unknown gas
    - $pV = nRT$ can be used to calculate how many moles are in the sample
    - If the mass of the gas sample is also known, the molar mass can be found: $M = m/n$

6.5 Applications of the Ideal Gas Equation

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- Worked Example 6.7 (page 229)
- Pure calcium carbide, CaC_2,is a hard, colourless solid that was used in caving lamps. It has a melting point of 2160°C, and it reacts vigorously with water to produce a gas and a solution containing OH^- ions.

- A 12.8 g sample of CaC_2 was treated with excess water and the resulting gas was collected in an evacuated 5.00L bulb with a mass of 1254.49 g. The filled bulb had a mass of 1259.70 g and the pressure of the gas inside was 1.00×10^5 Pa when the temperature was 26.8 °C. Calculate the molar mass of the gas and determine its formula.

6.5 Applications of the Ideal Gas Equation

- Determination of gas density
  - The density of a gas varies significantly with the conditions
  - The ideal gas equation and n = m/M can be combined and rearranged to obtain an equation for density:

$$\rho_{\text{gas}} = \frac{m}{V} = \frac{pM}{RT}$$

6.5 Applications of the Ideal Gas Equation

- Determination of gas density
  – The equation reveals three features of gas

$$\rho_{\text{gas}} = \frac{m}{V} = \frac{pM}{RT}$$

- The density of an ideal gas increases linearly with pressure at fixed temperature: ($\rho \propto p$)

- The density of an ideal gas decreases linearly with temperature at a fixed pressure: ($\rho \propto \frac{1}{\mathrm{T}}$)

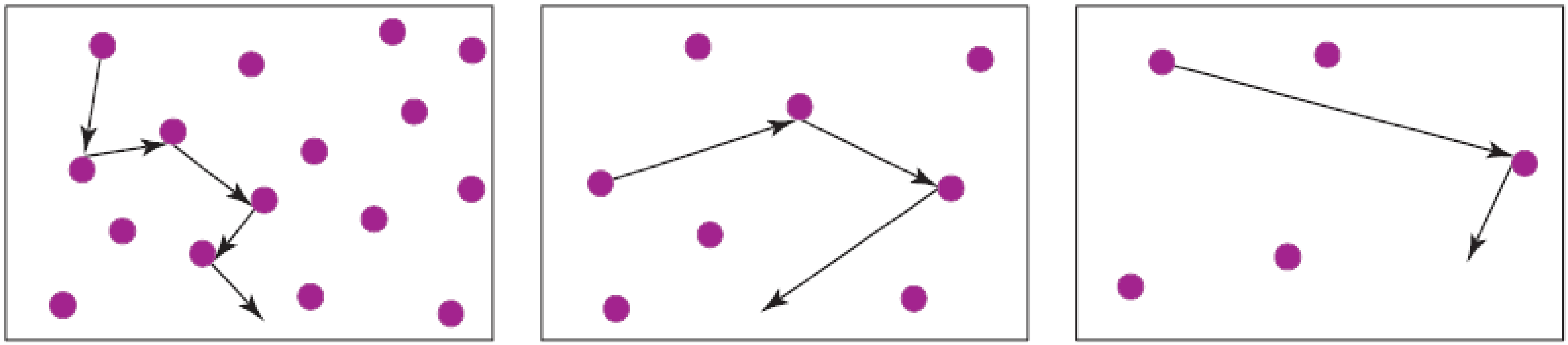
- The density of an ideal gas increases linearly with molar mass at a given temperature and pressure: ($\rho \propto M$)

6.5 Applications of the Ideal Gas Equation

- Worked Example 6.8 (page 231)
- A certain hot-air balloon will rise when the density of its air is 15.0% lower than that of the surrounding atmospheric air. Calculate the density of air at 295K and 1.00×10^5 Pa (assume that dry air is 78.0% N_2 and 22.0% O_2), and determine the minimum temperature of air inside the balloon that will cause the balloon to rise.

6.5 Applications of the Ideal Gas Equation

- **Determination of gas density**
  - Gas density has a significant effect on interactions between molecules of a gas



6.6 Gas Stoichiometry

- The principles of stoichiometry apply equally to solids, liquids and gases

- No matter what phase substances are in, their chemical behaviour can be described in molecular terms

- Stoichiometric calculations always require amounts in moles
  - For gases, amounts in moles are usually calculated from the ideal gas equation

6.6 Gas Stoichiometry

- Worked Example 6.9 (page 233)
- Modern industrial production of ethyne, C_2H_2, is based on a reaction of methane, CH_4, under carefully controlled conditions. At temperatures greater than 1600K, two methane molecules rearrange to give three molecules of hydrogen and one molecule of ethyne

$$2CH_4\,(g) \xrightarrow{1600K} C_2H_2\,(g) + 3H_2\,(g)$$

- A 50.0L steel vessel, filled with CH_4 to a pressure of 10.0×10^5 Pa at 298K is heated to exactly 1600K to convert CH_4 into C_2H_2. What is the maximum possible mass of C_2H_2 that can be produced? What pressure does the reactor reach at 1600K?

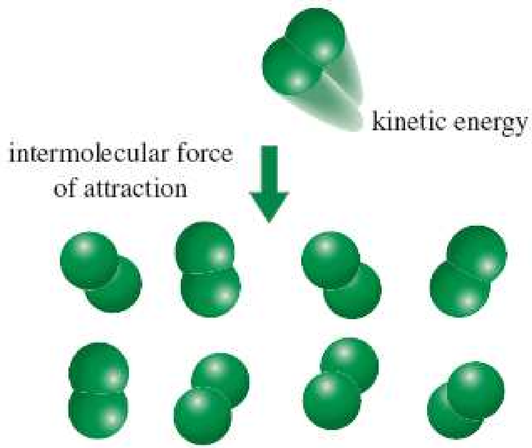
6.6 Gas Stoichiometry

- **Summary of mole conversions**

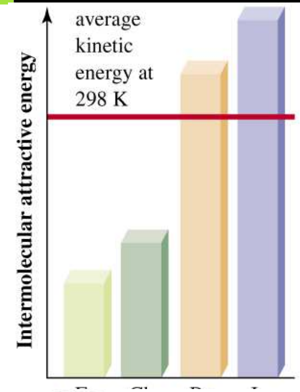
Substance	Relationship	Equation
pure solid, liquid or gas	$\text{amount (mol)} = \dfrac{\text{mass (g)}}{\text{molar mass (g mol}^{-1}\text{)}}$	$n = \dfrac{m}{M}$
solution	$\text{amount (mol)} = \text{concentration (mol L}^{-1}\text{)} \times \text{volume (L)}$	$n = cV$
gas	$\text{amount (mol)} = \dfrac{\text{pressure (Pa)} \times \text{volume (m}^3\text{)}}{\text{constant (J mol}^{-1}\text{ K}^{-1}\text{)} \times \text{temperature (K)}}$	$n = \dfrac{pV}{RT}$

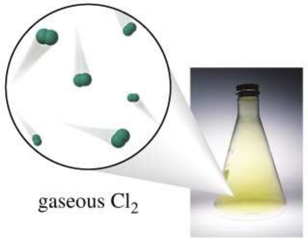
6.7 Real Gases

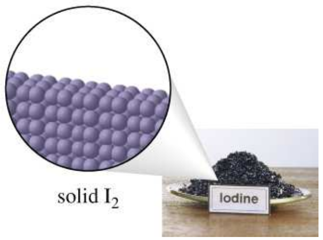
- Weak attractive intermolecular forces do occur in real gases
  - The balance between molecular kinetic energy and intermolecular attractive forces determines the state of matter for a substance



A condensed phase (liquid or solid) will form if $E_{kinectic}$ is too low to overcome intermolecular forces

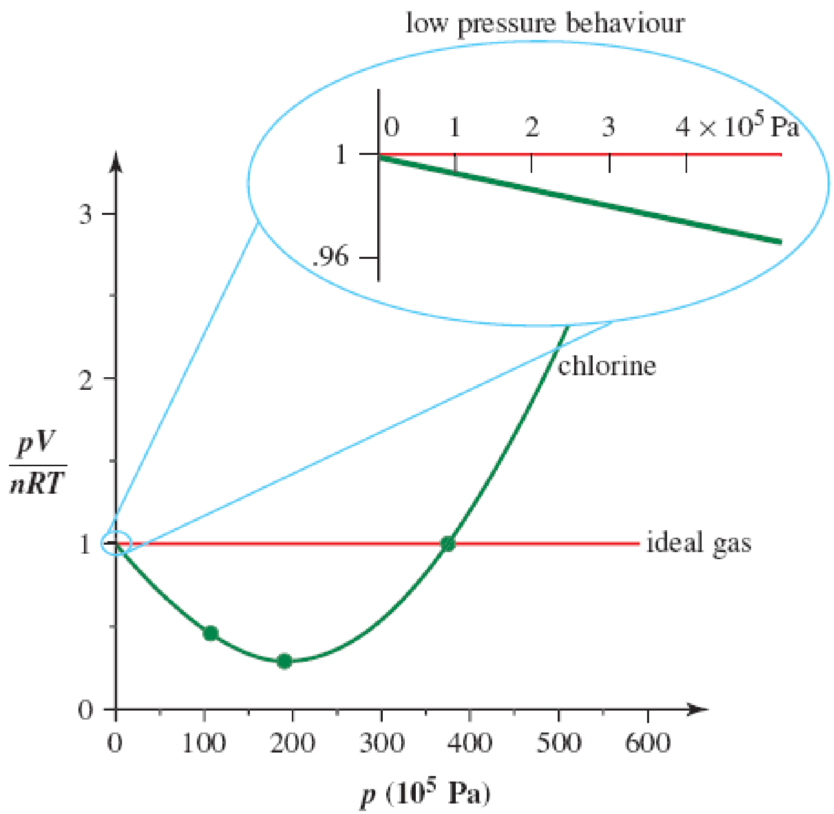






6.7 Real Gases

- The ideal gas model makes two assumptions:
  - A gas has negligible forces between its constituent atoms or molecules
  - Gas atoms or molecules have negligible volumes



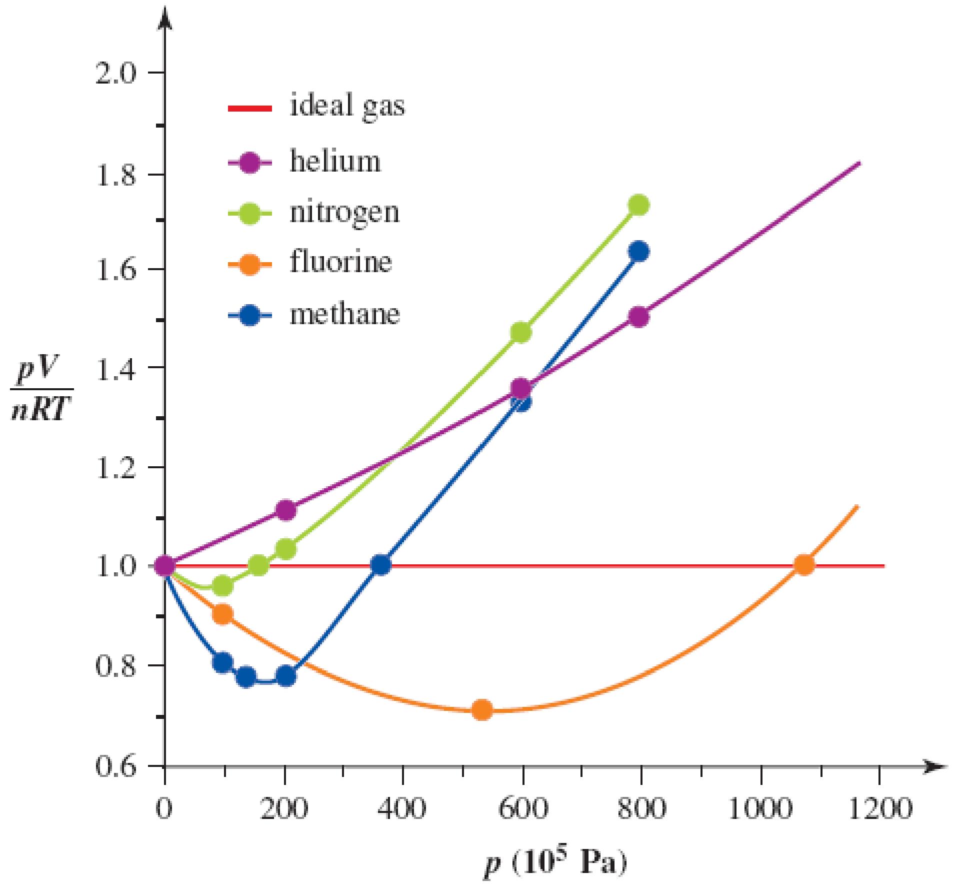
- Neither of these assumptions is true for a real gas

- How close do real gases come to ideal behaviour?

6.7 Real Gases

- The ideal gas model can still be used to discuss the properties of real gases, as long as conditions do not become too extreme

- Cl_2, He and N_2 are nearly ideal at room temperature at pressures below 10×10^5 Pa



6.7 Real Gases

- The van der Waals equation
  - A modified ideal gas equation that accounts for attractive forces and molecular volumes

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

  - Adds two correction terms to the ideal gas equation
  - Each correction term includes a constant that has a specific value for every gas

6.7 Real Gases

- Worked Example 6.12 (page 239)
- Gases such as methane are sold and shipped in compressed gas cylinders. A typical cylinder has a volume of 15.0L and, when full, contains 62.0 mol of CH_4. After prolonged use, 0.620 mol of CH_4 remains in the cylinder.
  - Use the van der Waals equation to calculate the pressures in the cylinder when full and after use, and compare the values to those obtained from the ideal gas equation. Assume a constant temperature of 25°C.