Molecular Effusion and Diffusion

Advanced Chemistry

Effusion & Diffusion

- The dependence of molecular speed on mass has two interesting consequences.
  - (1) Effusion: the escape of gas molecules through a tiny hole
    - Light atoms or molecules escape through the hole faster than heavier ones
    - Smaller atoms can fit through the hole better
    - Faster atoms are more likely to hit the hole, and smaller atoms are faster at the same temp
  - (2) Diffusion: the spread of one substance throughout a space or throughout a second substance
    - Faster for light molecules than for heavier ones
    - Slower than effusion due to the random motion of molecular collisions. There is no net direction of motion

Diffusion and Mean Free Path

- Due to molecular collisions, the direction of motion of a gas molecule is constantly changing.
- Mean Free Path: average distance traveled by a molecule between collisions
  - High pressure → short mean free path
  - Low pressure → long mean free path

Graham's Law of Effusion

- Effusion rate of a gas is inversely proportional to the square root of its molar mass. Assume two gases are at same temperature and pressure with identical pinholes.
- Graham's Law:

$$\frac{r1}{r2} = \sqrt{\frac{\mathscr{M}2}{\mathscr{M}1}}$$

r = rate of gas
or
speed
or
ratio of speed

* $\mathscr{M}$ is in g/mol

7 diatomic: H_2, O_2, N_2, F_2, Cl_2, Br_2, I_2

Applying Graham's Law

- An unknown gas composed of homonuclear diatomic molecules effuses at a rate that is 0.355 times the rate at which O_2 gas effuses at the same temperature. Calculate the molar mass of the unknown and identify it.

(1) unknown; (2) O_2; homo = same; diatomic = 2 atoms

$$\frac{r_1}{r_2} = \sqrt{\frac{M_2}{M_1}}$$

$$\left(\frac{.355}{1}\right)^2 = \left(\sqrt{\frac{31.998}{x}}\right)^2$$

$$\frac{.126025}{1} = \frac{31.998}{x}$$

$$\frac{31.998 = .126025x}{.126025}$$

$$x = 253.9020036$$

$$\boxed{x = 254\ g/mol}$$

iodine gas I_2 is unknown

$H_2, O_2, N_2, F_2, Br_2, I_2, Cl_2$

More Practice

diatomic H_2

- A sample of ① hydrogen effuses through a porous container about nine times faster than an ② unknown gas. Calculate the molar mass of the unknown gas.

$$\frac{9}{1}^2 = \sqrt{\frac{X}{2.0158}}^2$$

$$\frac{81}{1} = \frac{X}{2.0158}$$

$$X = 163.2798 \text{ g/mol}$$

HOMEWORK

- A sample of oxygen gas (O_2) was found to effuse at a rate equal to two times that of an unknown gas. The molar mas of the unknown gas is ____________________ g/mol.

More Practice

$$\frac{r_1}{r_2} = \sqrt{\frac{M_2}{M_1}}$$

- Calculate the ratio of the effusion rates of N_2 gas to the rate O_2 gas.

$$\frac{N_2}{O_2} = \sqrt{\frac{31.998}{28.014}}$$

$x = 1.068744407$

N_2 effuses at a rate of 1.068744407 times faster than O_2

HOMEWORK

- A tank containing both HF and HBr gases developed a leak. The ratio of the rate of effusion of HF to the rate of effusion of HBr is ______________________.

More Practice

- If a molecule of ①neon gas travels at an average speed of 400.0 m/s at a given temperature. Find the average speed of a molecule of bu②tane gas, C_4H_{10}, at the same temperature.

$$\frac{400}{x} = \sqrt{\frac{58.123}{20.179}}$$

$$\frac{400}{x} = \frac{1.697165485}{1}$$

$$\frac{1.697165485x}{1.697} = \frac{400}{1.697}$$

$$x = 235.68709 33$$

$$x = 235.7 \text{ m/s}$$

HOMEWORK

- If a molecule of CH_4 gas travels at an average speed of 0.5300 m/s at a given temperature. Find the average speed of a molecule of nitrogen gas, N_2, at the same temperature.