The Properties of Gases

– importance in atmospheric phenomena, gas phase reactions, combustion engines, etc.

5.1 The Nature of Gases

- Molecular model of the gaseous state
  - gases fill their containers entirely → molecules in constant, rapid, random motion
  - gases are compressible → molecules are widely separated

5.2 Pressure

- Gas molecules collide with each other an the walls of the container → molecules exert force on the walls

$$\text{Pressure} = \frac{\text{Force}}{\text{Area}}$$

$$P = \frac{F}{A}$$

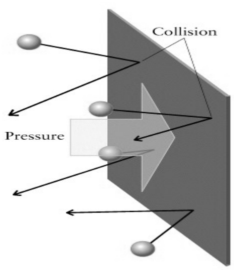

Fig. 5.4

- Measurements of $\boldsymbol{P}$
  - manometers
  - barometers - measure the atmospheric pressure (Torricelli)
    - no pressure above the mercury column (vacuum)
    - the weight of the Hg column balances $\boldsymbol{P_{atm}}$
    - the height of the Hg column is proportional to $\boldsymbol{P_{atm}}$

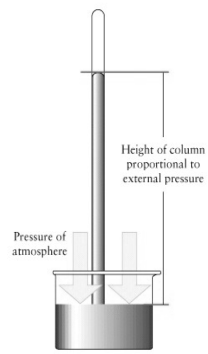

Fig. 5.5

- – ***g*** - acceleration of free fall (**9.81 m/s^2**)
- – ***d*** - density of Hg (**13546 kg/m^3**)
- – ***V*** - volume of Hg column
- – ***h*** - height of Hg column (**0.760 m** at sea level)
- – ***A*** - area of Hg column base

$$P_{atm} = P_{Hg} = \frac{F}{A} \qquad F = m_{Hg} g$$

$$m_{Hg} = dV = dhA \qquad \Rightarrow \qquad F = dhAg$$

$$\Rightarrow P_{atm} = \frac{dhAg}{A} = dhg$$

$$P_{atm} = 13546 \times 0.760 \times 9.81 = 1.01 \times 10^5 \text{ kg / m} \cdot \text{s}^2$$

5.3 Units of Pressure

- SI unit → pascal (Pa) → **1 Pa = 1 kg/m·s^2**

  $\boldsymbol{P_{atm} = 1.01 \times 10^5}$ **Pa** (at sea level)
- Conventional units:

  atm → **1 atm = 101325 Pa** (exactly)

  bar → **1 bar = 100000 Pa** (exactly)

  torr → **760 Torr = 1 atm** (exactly)

  mm Hg → **1 mmHg = 1 Torr**

  lb/in^2 → **14.7 lb/in^2 = 1 atm**

- **Example:** Convert **630.0 Torr** in pascals and atmospheres.

$$630.0\ \text{Torr} \times \left(\frac{1\ \text{atm}}{760\ \text{Torr}}\right) = 0.8289\ \text{atm}$$

$$630.0\ \text{Torr} \times \left(\frac{1\ \text{atm}}{760\ \text{Torr}}\right) \times \left(\frac{101325\ \text{Pa}}{1\ \text{atm}}\right) = 8.399 \times 10^{4}\ \text{Pa}$$

The Gas Laws

5.4 Boyle's Law

- At constant temperature (T) the pressure (P) of a fixed amount of gas is inversely proportional to its volume (V)

$$P = \frac{k}{V} \qquad k \rightarrow \text{ constant (depends on } T)$$

$$PV = k = \text{constant} \qquad V\downarrow \Leftrightarrow P\uparrow$$

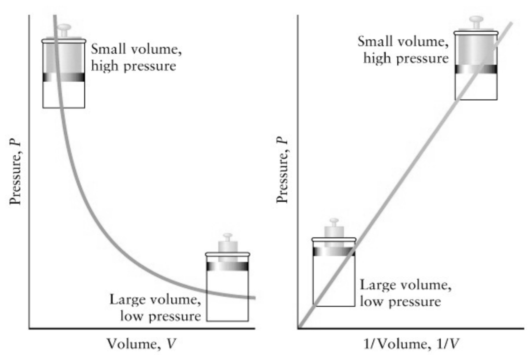

Fig. 5.7, 5.8

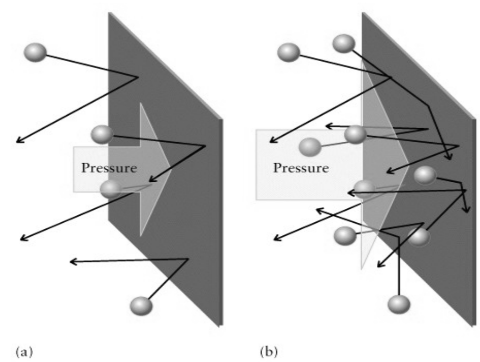

Fig. 5.9

- Assume two states of a gas at constant T
  - state 1 $\rightarrow$ P_1, V_1
  - state 2 $\rightarrow$ P_2, V_2

$$P_1V_1 = k \qquad P_2V_2 = k$$

$$P_1V_1 = P_2V_2$$

Example: A 2.0 L sample of oxygen at 10 atm is transferred to a 15.0 L container at constant temperature. What is the new pressure.

$V_1 = 2.0$ L $P_1 = 10$ atm $V_2 = 15.0$ L $P_2 = ?$

$$P_2 = \frac{P_1V_1}{V_2} = \frac{10\ \text{atm} \times 2.0\ \text{L}}{15.0\ \text{L}} = 1.3\ \text{atm}$$