CHEM110 – Chapter 6
Gases

Dr Daniel Keddie

Room 2.02 – Riggs Building C23

daniel.keddie@une.ede.au

University of New England

6.1 The States of Matter

- Matter exists in three common states
  - Solid
  - Liquid
  - Gas

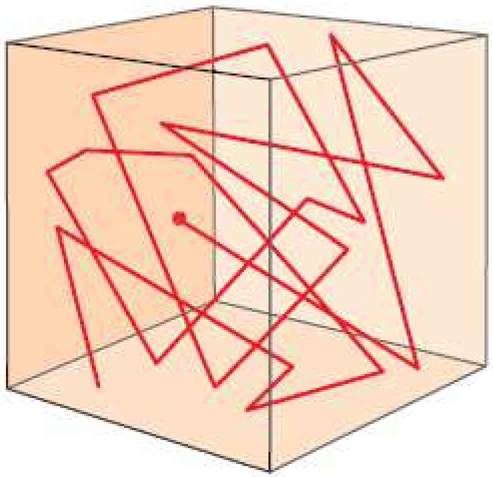
- The most stable state of a particular substance can be changed by varying the temperature and/or pressure

6.2 Describing Gases

- Gases expand to occupy all of the space of their container

- Individual gas atoms or molecules are free to move anywhere within their container

- Therefore the forces between them must be very weak



6.2 Describing Gases

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- The defining characteristic of gases is the pressure (p) they exert

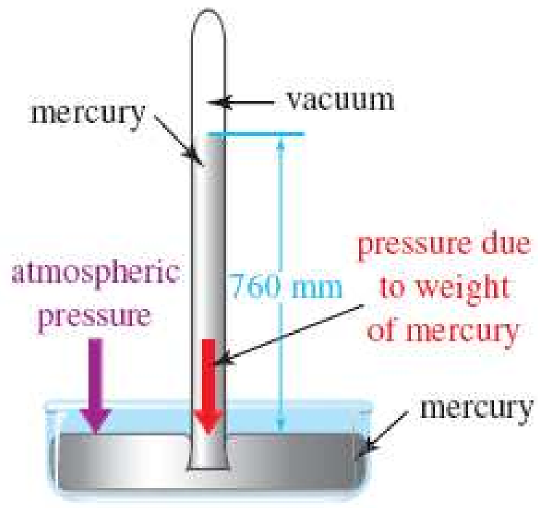
- Changes in pressure (p), temperature (T) and amount of gas (n) affects the volume (V) occupied by a gas

6.2 Describing Gases

- Pressure (*p*) - defined
  - At any temperature above absolute zero (0 K), atoms/molecules are always in motion
  - Atoms/molecules exert forces through never-ending collisions with each other and with the walls of their container
  - Pressure is the collective result of these collisions

6.2 Describing Gases

- Pressure (*p*)
  - Atmospheric pressure - the atmosphere exerts pressure on the Earth's surface
  - The pressure of the atmosphere can be measured with a barometer



6.2 Describing Gases

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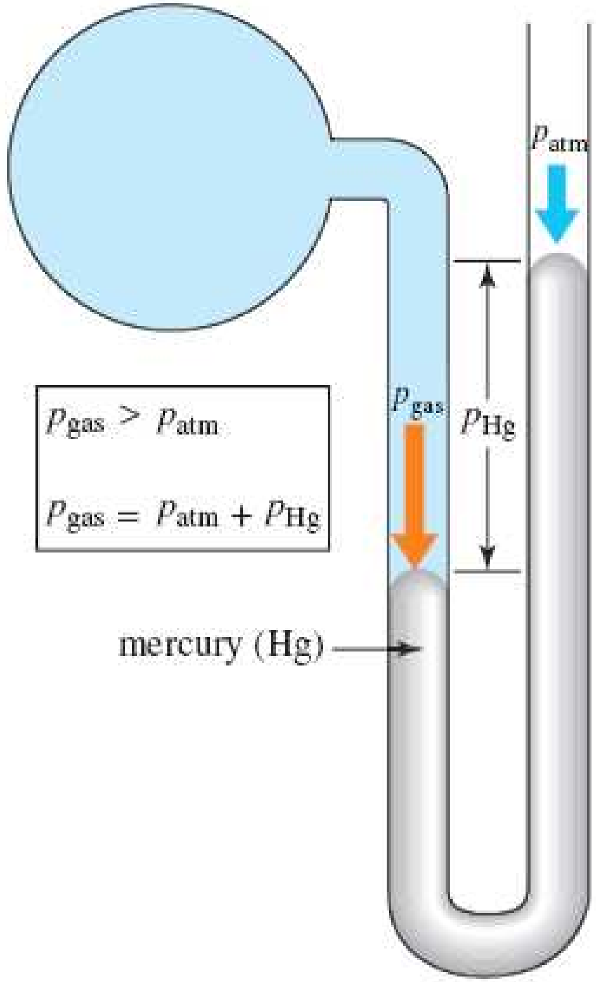
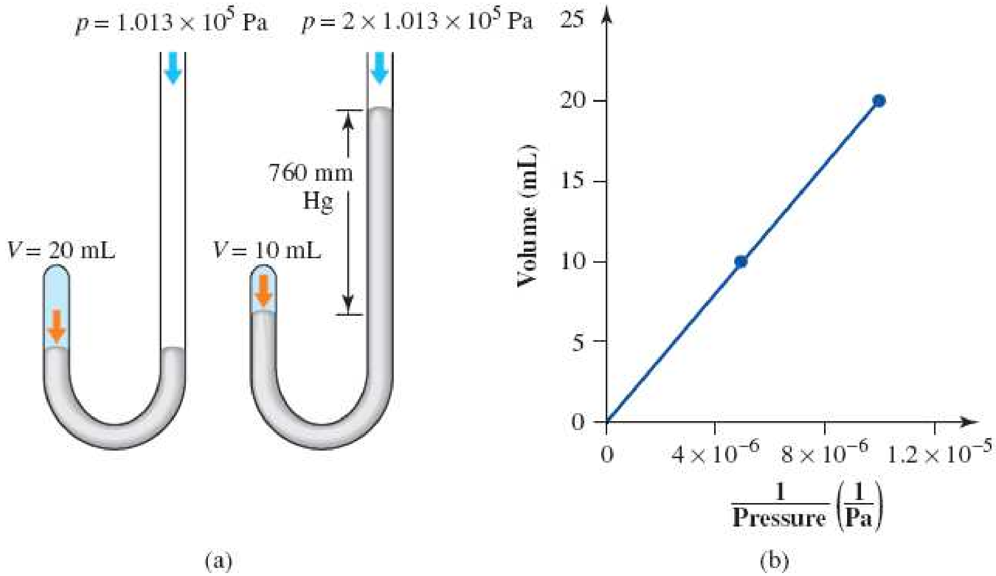
- Pressure (*p*)
  - A manometer measures the difference in pressures exerted by two gases
  - The SI unit for pressure is the pascal (Pa)
  - Pressure is force per unit area: 1 Pa = 1 N m^{-2}
  - 1 atm = 1.013×10^5 Pa



6.2 Describing Gases: Boyle's Law

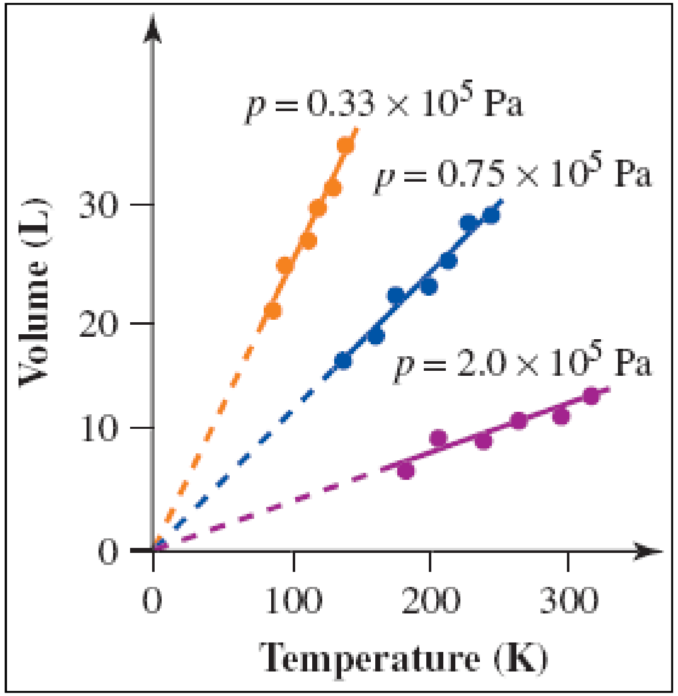
- The gas laws: Boyle's Law
  - Boyle investigated gases in a J-shaped tube



  - Determined that volume was inversely proportional to pressure: $p = \frac{k}{V}$

6.2 Describing Gases: Charle's Law

- The gas laws: Charles' Law:
  - Gas volume is directly proportional to its temperature:
  - $V_{gas} = k' T_{gas}$



6.2 Describing Gases: Avogadro's Law

Avogadro's Law:

- Gas volume is directly proportional to the amount of gas:
- V_{gas} = k'' n_{gas}

6.2 Describing Gases: The Ideal Gas Equation

- The gas laws: The ideal gas equation
  - All four variables (*p*, *V*, *T* and *n*) can be related using a single constant
  - This is known as the gas constant (R)
  - In SI units, R = 8.314 J mol^{-1} K^{-1}

    note that 1 J = 1 N m

$$pV = nRT$$

6.2 Describing Gases: The Ideal Gas Equation

- The gas laws: The ideal gas equation
  - Known as the ideal gas equation, as it describes the behaviour of an ideal gas

    (an idealised system with no molecular interactions)

  - Real gases act as ideal gases when their pressure is relatively low

  - Note SI units:

    T is in K (T(K) = T (°C) + 273.15);

    V = m^3

    p = Pa (pascals) = 1 N m^{-2}

6.2 Describing Gases: Calculation of Gas Pressure

- Worked Example 6.1 (page 216)

A 1.000×10^3 L steel storage tank contains 88.5 kg of methane, CH_4. If the temperature is 25°C, what is the pressure inside the tank?

6.2 Describing Gases: Pressure-Volume Variations

- <u>Worked Example 6.2 (page 217)</u>

A sample of helium gas is held at constant temperature inside a cylinder with a volume of 0.8 L when a piston exerts a pressure of 1.5×10^5 Pa. If the external pressure on the piston is increased to 2.1×10^5 Pa, what will the new volume be?

6.3 Molecular View of Gases

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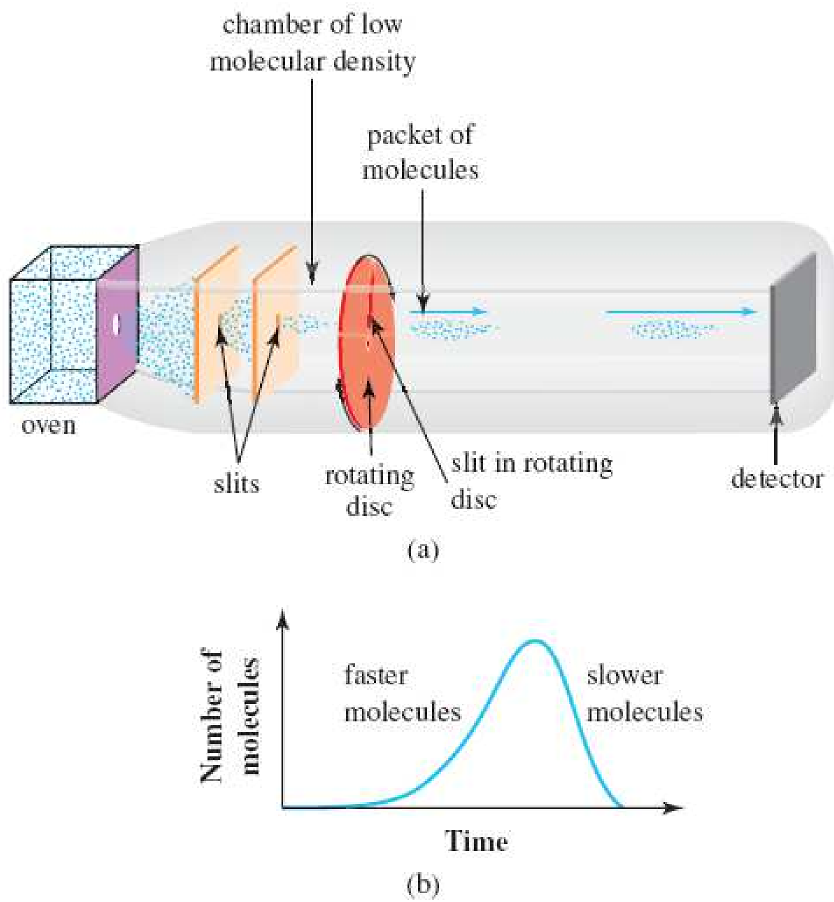
- Gases are characterised by rapid motion of their constituent atoms or molecules,
- The most important energy component to consider is their kinetic energy, E_{kinetic}
- The kinetic energy of an object is given by the equation:

$$E_{\text{kinetic}} = \frac{1}{2} m u^2$$

m = mass, u= velocity

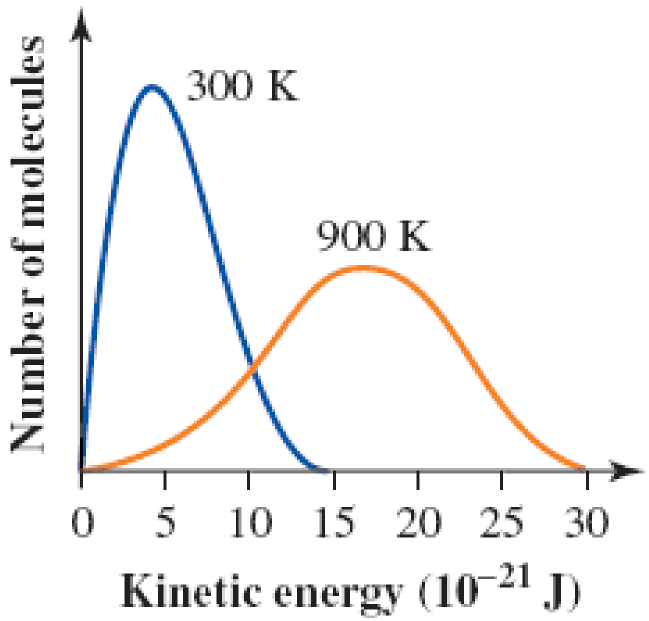
6.3 Molecular View of Gases

- Molecular speeds
  - A molecular beam apparatus measures the speeds of molecules in a gas
  - Molecules in a gas have a distribution of speeds
  - Molecules with small masses move, on average, faster



6.3 Molecular View of Gases

- Speed and energy
  - The energy of a molecule is related to its speed
  - At a given temperature, all gases have the same molecular
    kinetic energy
    distribution



6.3 Molecular View of Gases

- Average kinetic energy and temperature
  - The most probable kinetic energy is not the same as the average kinetic energy
  - The average kinetic energy of gas molecules depends on the temperature of the gas:

$$E_{\text{kinetic, molar}} = N_A \frac{3RT}{2N_A} = \frac{3}{2}RT$$

6.3 Molecular View of Gases: Molecular Kinetic Energies

- Worked Example 6.4 (page 222)

Determine the average molecular kinetic energy and molar kinetic energy of gaseous sulfur hexafluoride, SF_6, at 150°C.

6.3 Molecular View of Gases

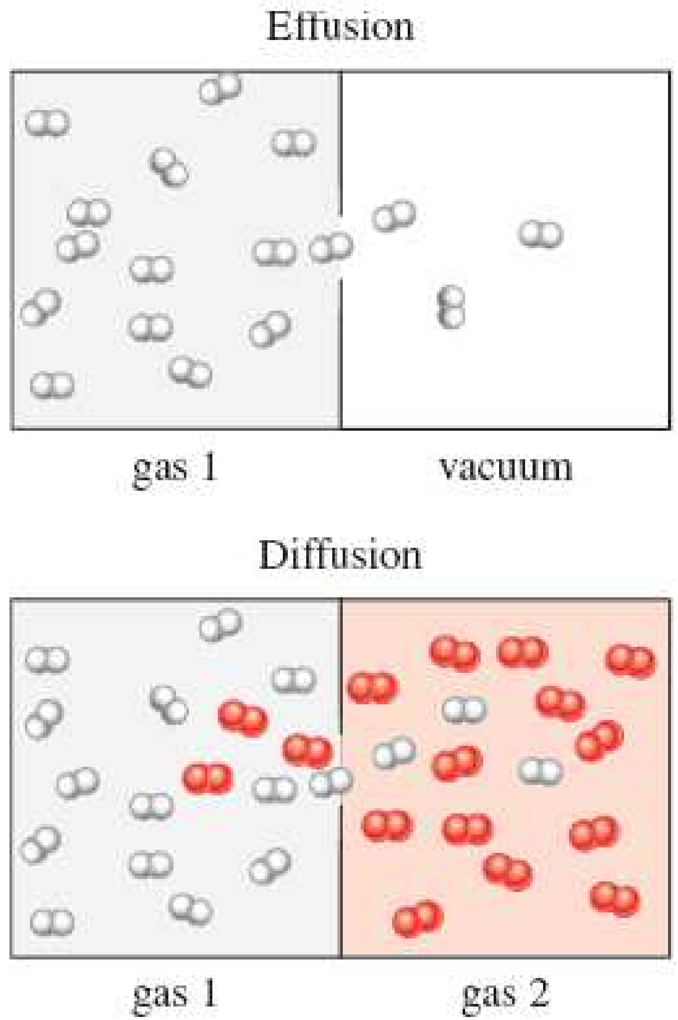
- Rates of gas movement
  - The average speed of the molecules in a gas determines its temperature
  - To state this dependence quantitatively:

$$\overline{u}^2 = \frac{3RT}{mN_\mathrm{A}} = \frac{3RT}{M} \qquad \text{so} \qquad \overline{u} = \left(\frac{3RT}{M}\right)^{\frac{1}{2}}$$

  - This is called the root-mean-square speed

6.3 Molecular View of Gases

- Rates of gas movement
  - Effusion: The movement of molecules escaping from a container into a vacuum
  - Diffusion: The movement of one type of molecule through molecules of another type



6.3 Molecular View of Gases

Ideal gases definition:

- *A gas for which both the volume of molecules and the forces between the molecules are so small that they have no effect on the behaviour of the gas*

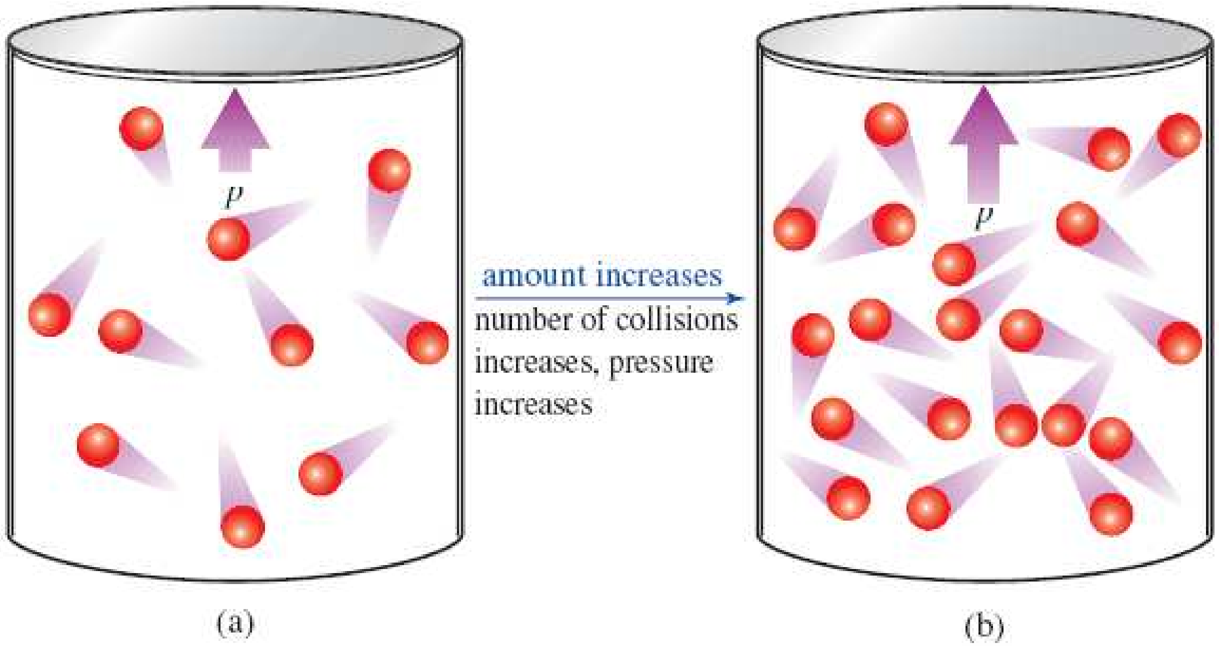
- The volume occupied by the molecules of an ideal gas is negligible compared with the volume of its container

- The energies generated by forces among ideal gas molecules are negligible compared with molecular kinetic energies;

  i.e. small gas molecules are not attracted to one another

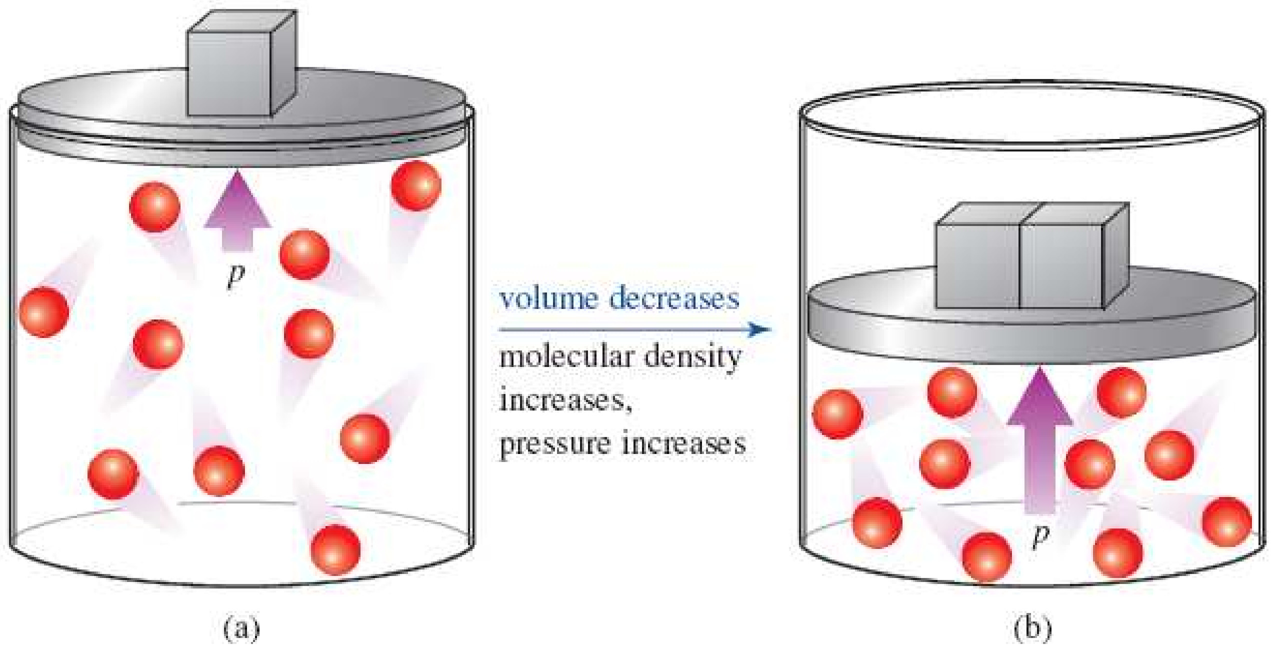
6.3 Molecular View of Gases

- Ideal gases
  - Increasing the amount of gas:
    - Pressure is directly proportional to the amount of gas in agreement with $pV = nRT$



6.3 Molecular View of Gases

- Ideal gases
  - Changing the volume of the gas:
    - Pressure is inversely proportional to volume in agreement with $pV = nRT$



6.3 Molecular View of Gases

- Ideal gases
  - Changing the temperature:
    - Pressure is directly proportional to temperature in agreement with $pV = nRT$