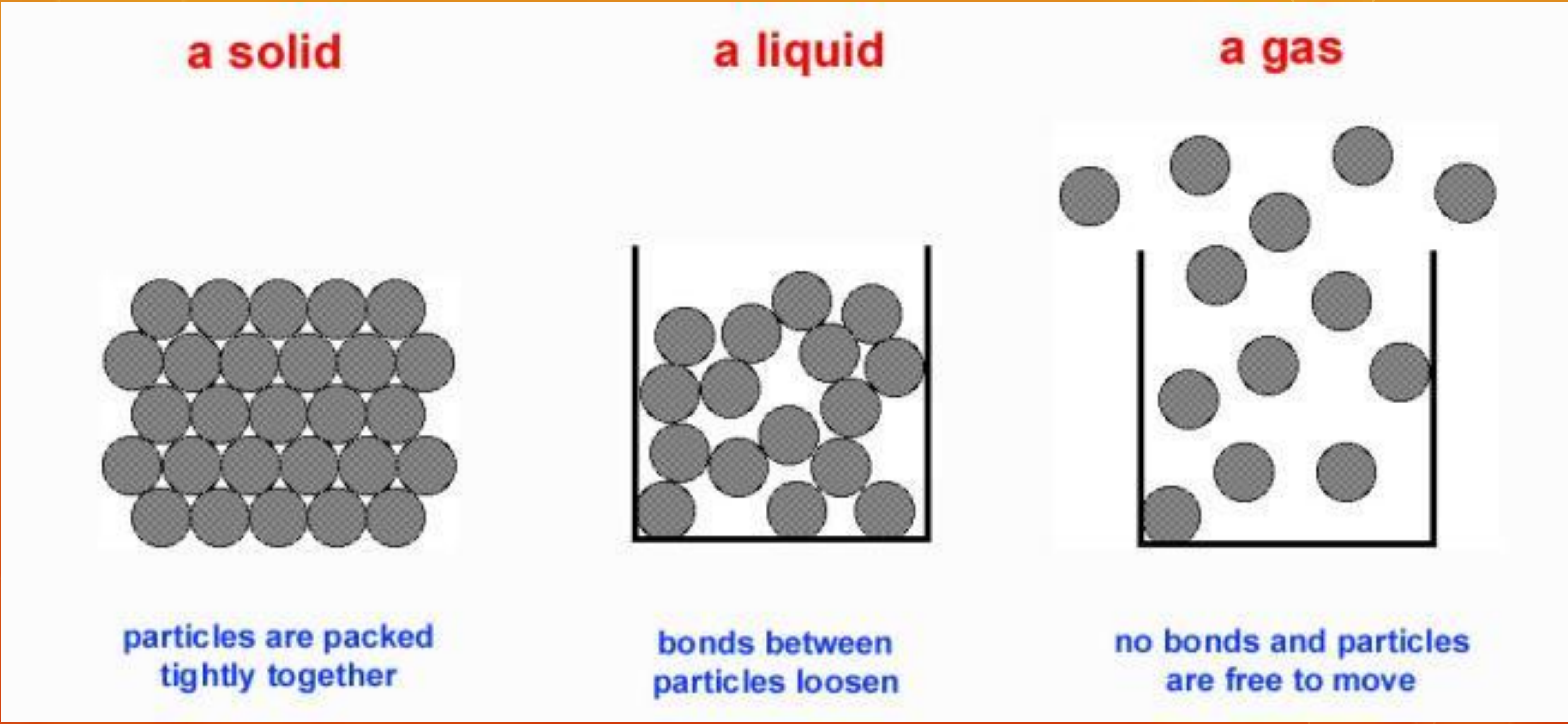
The Behavior of Gases

Chapter 14

Gases

- Unlike solids and liquids, gases can be compressed easily.
- The reason for this is that the atoms or molecules in a gas are relatively far apart from one another.

Particles in Each Phase



A Quick Reminder

- Recall that one mole of a gas…any gas…takes up 22.4 L of volume.
  - One mole of H_2 has a molar mass of approximately 2 g/mol. It takes up 22.4 Liters.
  - One mole of CH_4 has a molar mass of approximately 16 g/mol. It takes up 22.4 Liters.
- 1 atm = 101.3 kPa = 760 torr = 760 mm Hg

Variables

- Gas laws and equations use a lot of variables.
  - P = Pressure
    - Units: kpa, mm Hg, torr, atm
  - V = Volume
    - Units: L, mL, cm^3
  - n = Number of Moles
  - T = Temperature
    - Units: Kelvin
    - K = ◦C + 273

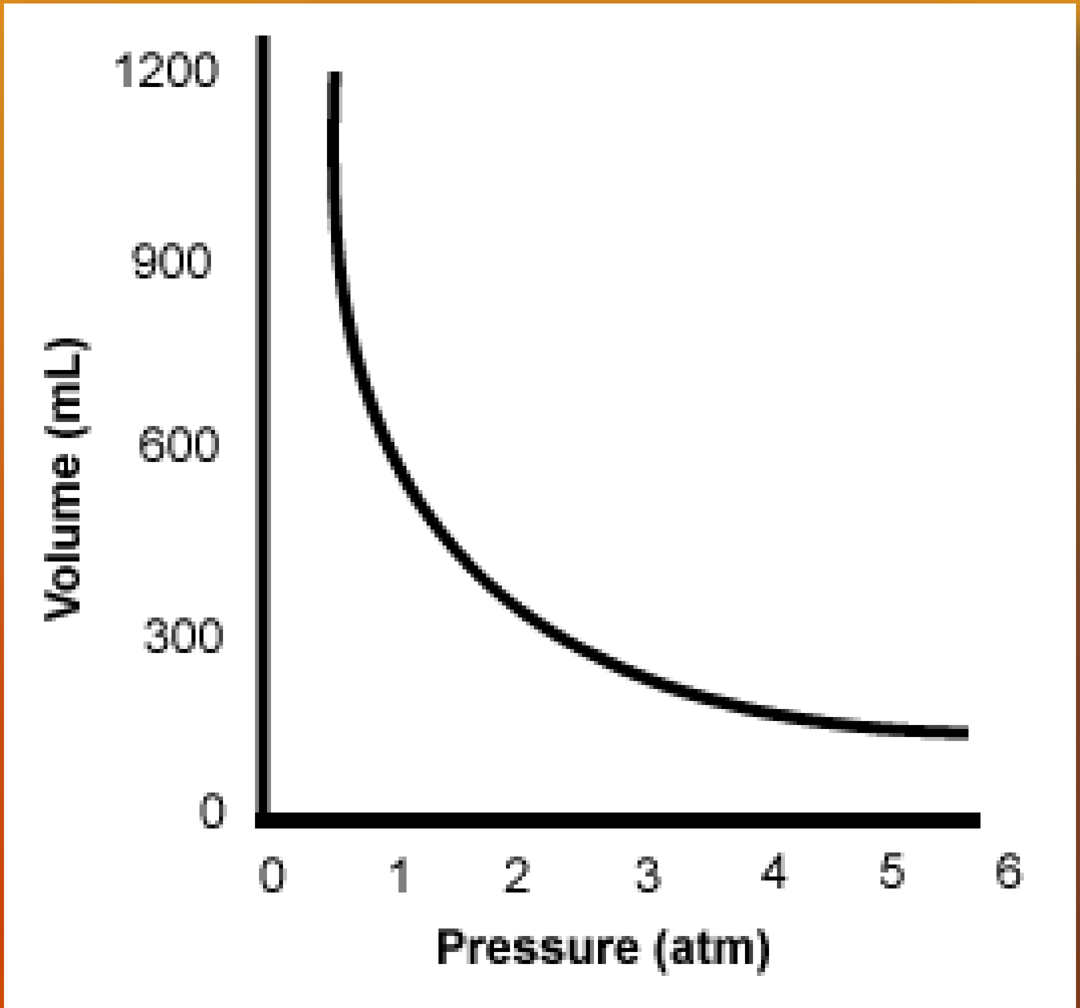
Boyle's Law

- *Proposed by Robert Boyle, 1662:*
- Pressure is inversely proportional to volume when temperature is held constant:

$$P_1V_1 = P_2V_2$$

- P_1 is like "pressure before."
- V_1 is like "volume before."
- P_2 is like "pressure after."
- V_2 is like "volume after."

Boyle's Law Graph



Boyle's Law Practice

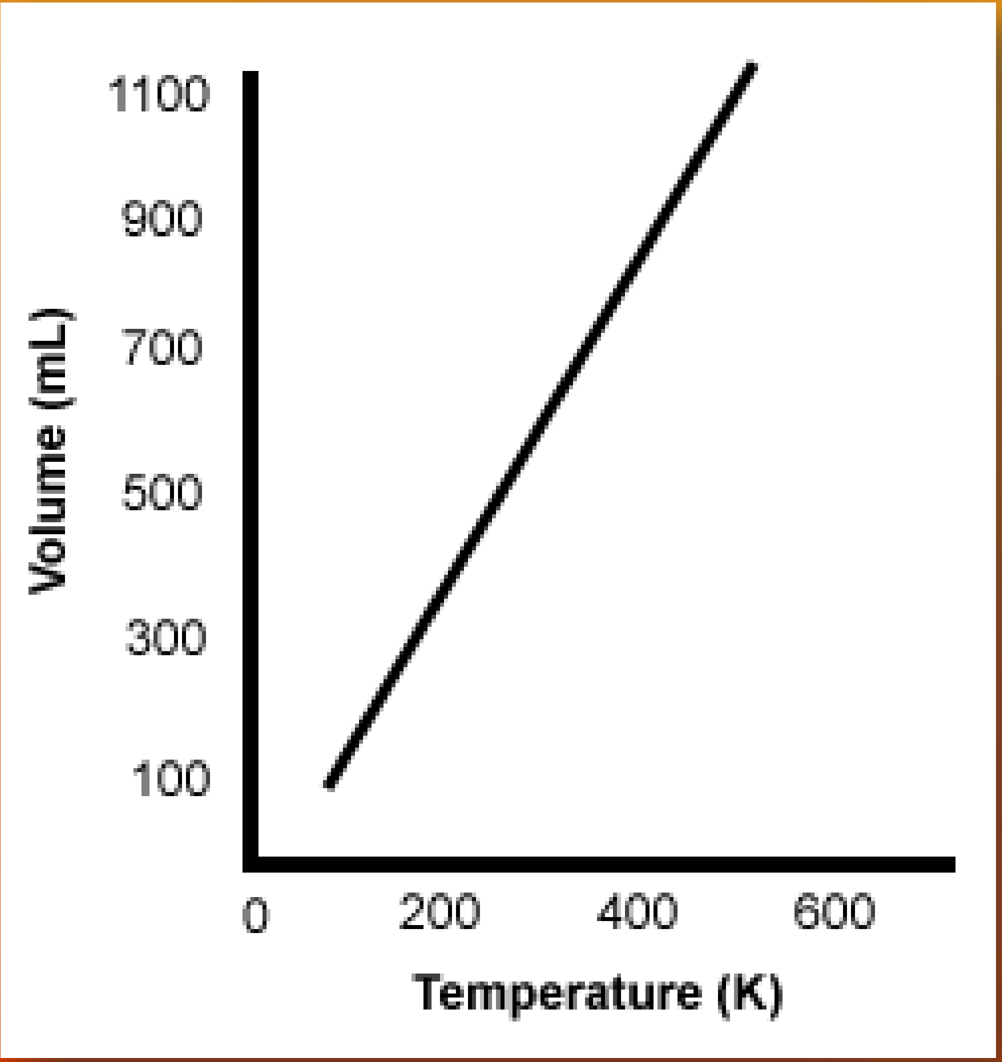
- 30.6 mL of carbon dioxide at 740 torr is expanded at constant temperature to 750 mL. What is the final pressure in kPa?

Charles' Law

- *Proposed by Jacques Charles, 1787:*
- The volume of a gas is directly proportional to temperature when pressure is held constant (volume is zero at 0 K).
- Temperature **<u>must</u>** be in Kelvin!

$$\frac{V_1}{T_1} = \frac{V_2}{T_2}$$

Charles' Law Graph



Charles' Law Practice

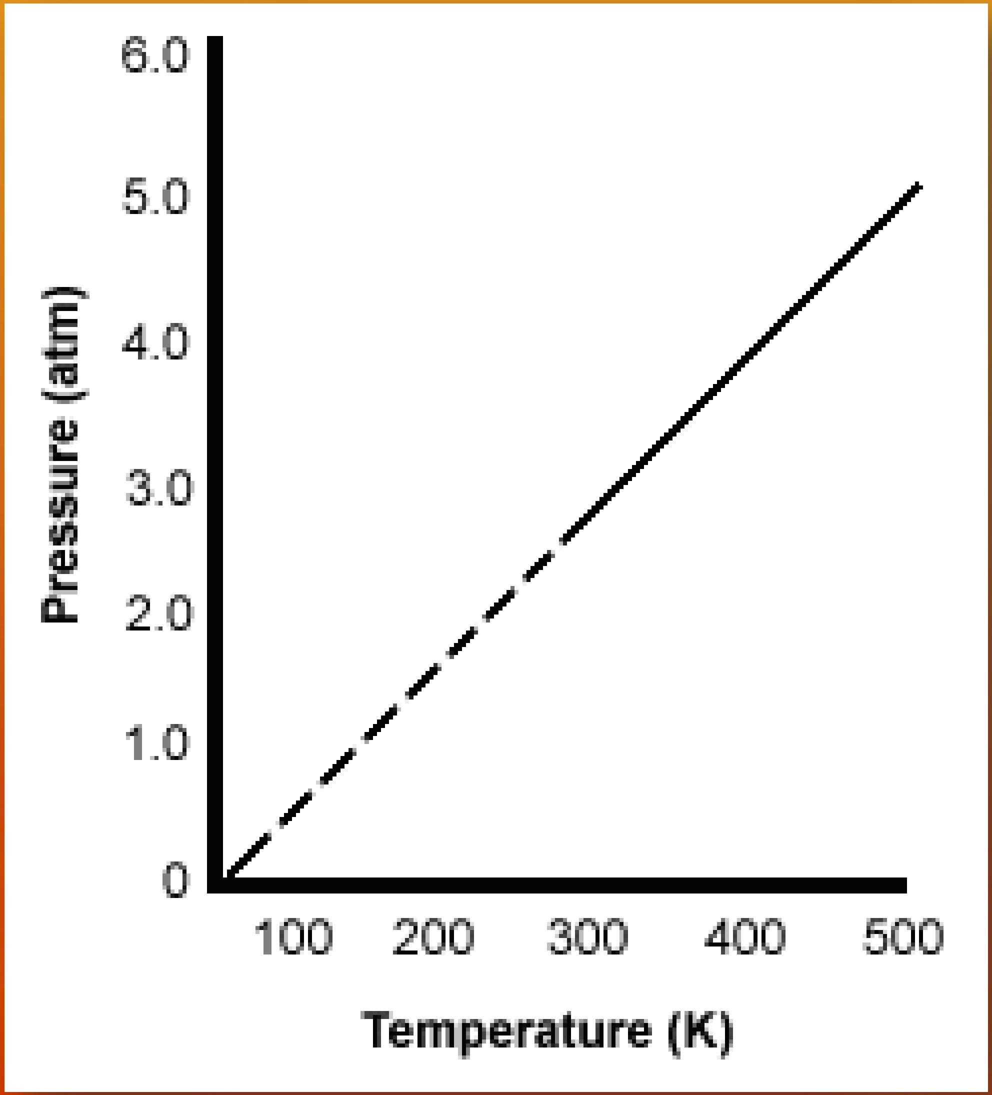
- What would the final volume be if 247 mL of gas at 22 °C is heated to 98 °C , if the pressure is held constant?

Gay-Lussac's Law

- *Proposed by Joseph Gay-Lussac, 1802:*
- The pressure and temperature of a gas are directly related when volume is held constant.
- Temperature **must** be in Kelvin!

$$\frac{P_1}{T_1} = \frac{P_2}{T_2}$$

Gay-Lussac's Law Graph



Gay-Lussac's Law Practice

- A sample of nitrogen gas has a pressure of 6.58 kPa at 539 K. If the volume does not change, what will the pressure be at 211 K?

Combined Gas Law

- The combined gas law expresses the relationship between pressure, volume and temperature of a fixed amount of gas.
- Temperature **<u>must</u>** be in Kelvin.

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$$

Combined Gas Law Practice

- A deodorant can has a volume of 175 mL and a pressure of 3.8 atm at 22 °C. What volume of gas could the can release at 22 °C and 743 torr?

Ideal Gases

- Ideal gases are imaginary gases that perfectly fit all of the assumptions of the kinetic molecular theory.
- Real gases, however, don't always behave that way.
- Nevertheless, it's still useful to perform calculations as if they were ideal.

Ideal Gas Law

- **PV = nRT**
- P – pressure (in <u>kPa</u> *or atm or mm Hg/torr*)
- V – volume (L)
- n – moles
- T – temperature (K)
- R – Ideal Gas Constant – *depends on pressure unit:*
  - <u>R = 8.314 L•kPa / K•mol</u>
  - *R = 0.0821 L•atm / K•mol*
  - *R = 62.38 L•torr / K•mol*

Ideal Gas Law Practice

- A 47.3 L container containing 1.62 mol of He is heated until the pressure reaches 1.85 atm. What is the temperature?

Dalton’s Law of Partial Pressures

- *Proposed by John Dalton, 1803:*
- For a mixture of gases in a container, the total pressure equals the sum of the individual gases’ pressures.
  - Useful for calculating pressure of gases collected over water.
- For each, P = (nRT)/V:

$$P_{total} = P_1 + P_2 + P_3 \ldots$$

Dalton's Law Practice

- A mixture of gases at total pressure 120 kPa contains N_2, CO_2, and O_2. The partial pressure of the nitrogen is 43 kPa and the partial pressure of the CO_2 is 34 kPa. What is the partial pressure of the O_2?