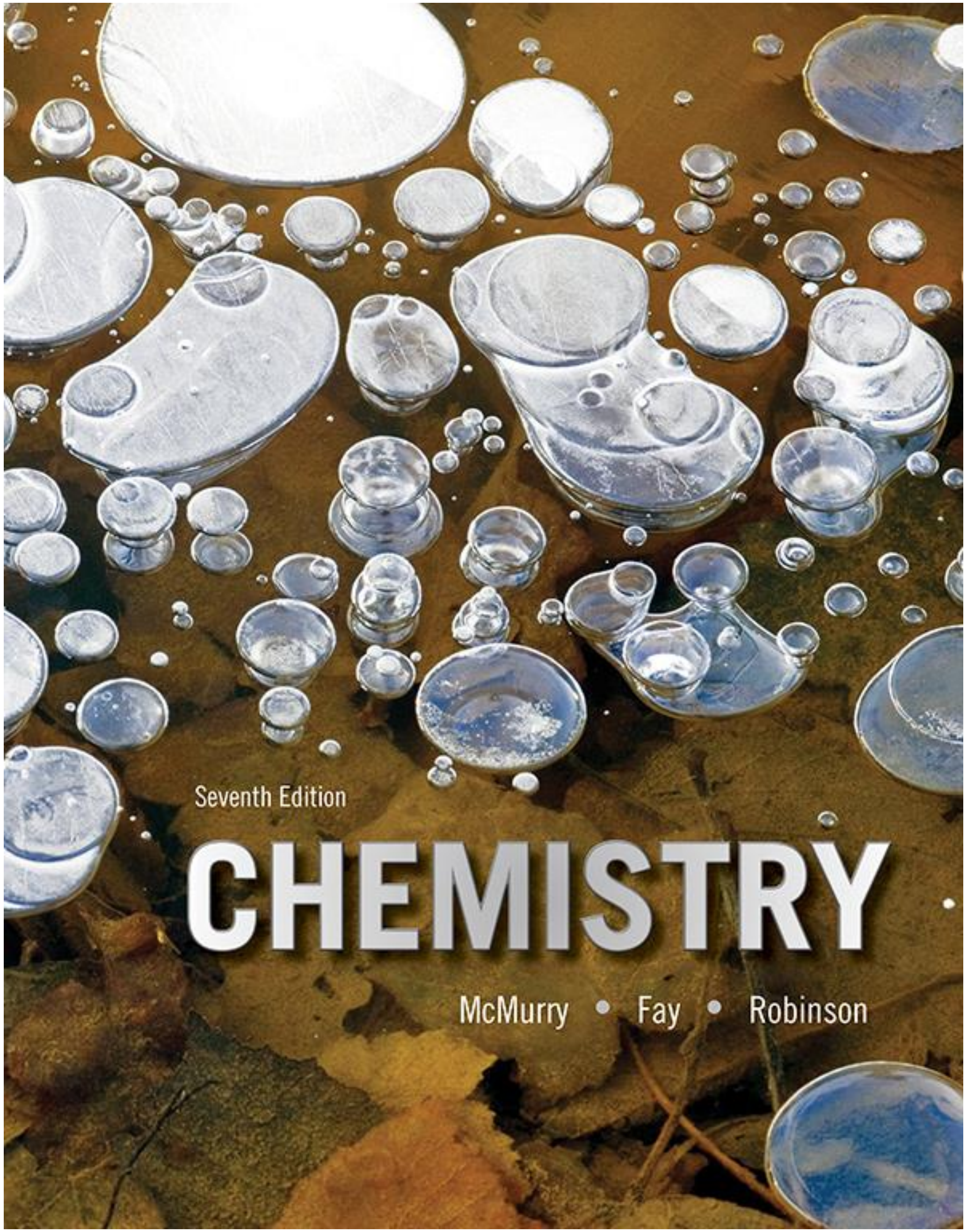

Lecture Presentation

Chapter 10

Gases: Their Properties and Behavior

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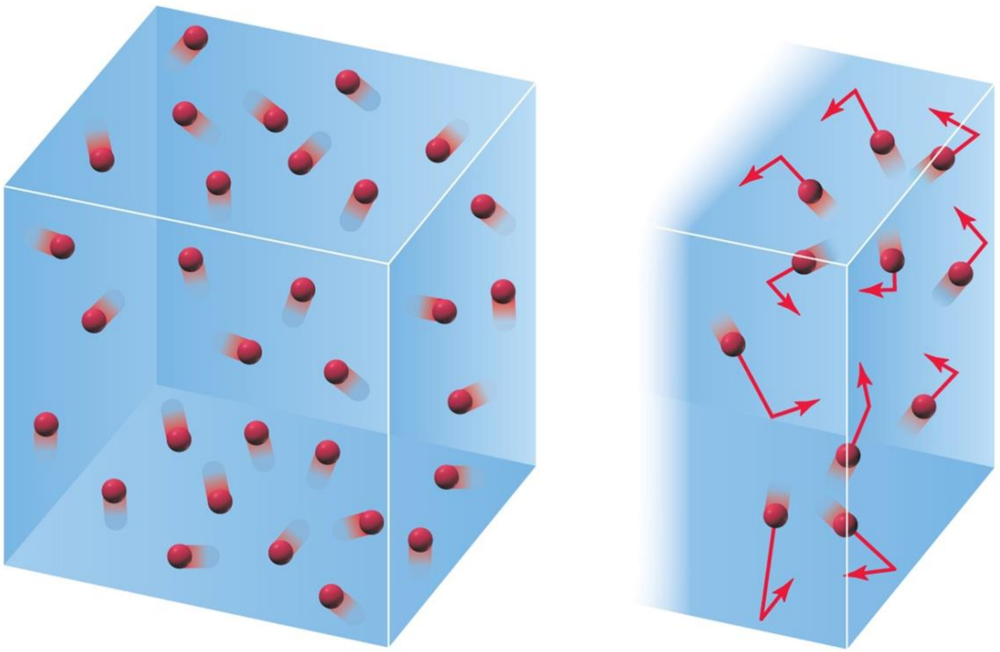
Robert C. Fay

Instructor's Resource Materials (Download only) for *Chemistry,* 7e
John E. McMurry, Robert C. Fay, Jill Robinson

Gases and Gas Pressure

Gas mixtures are **homogeneous** and **compressible**.

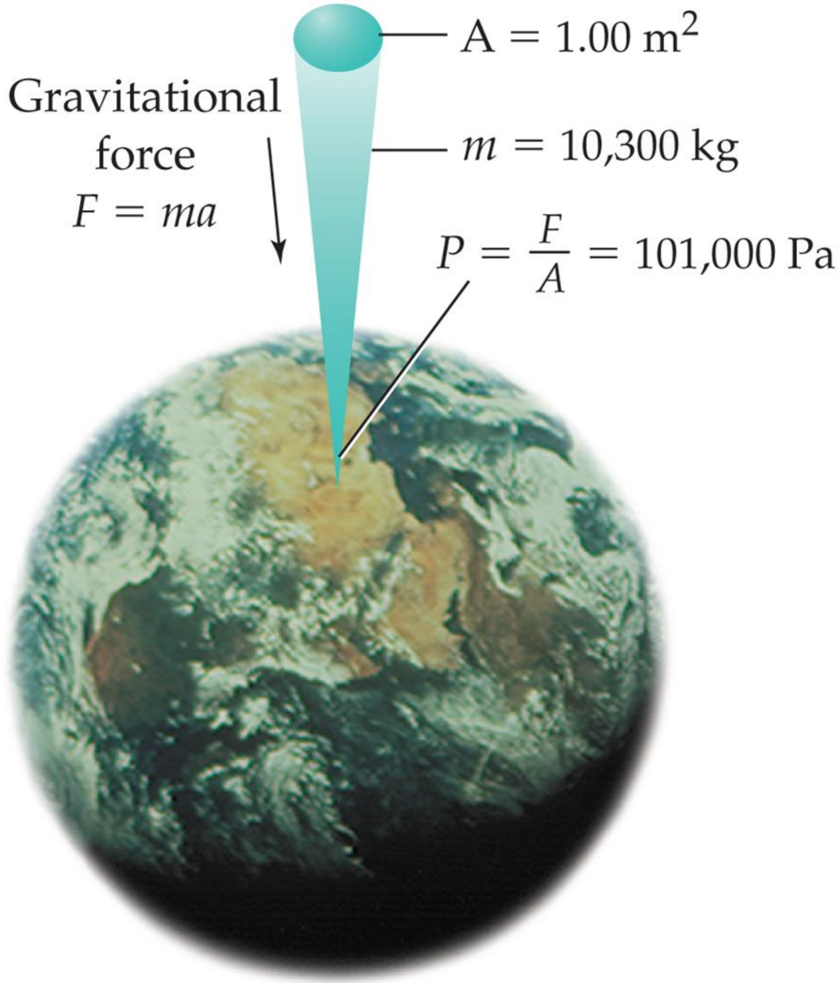


A gas is a large collection of particles moving at random through a volume that is primarily empty space.

Collisions of randomly moving particles with the walls of the container exert a force per unit area that we perceive as gas pressure.

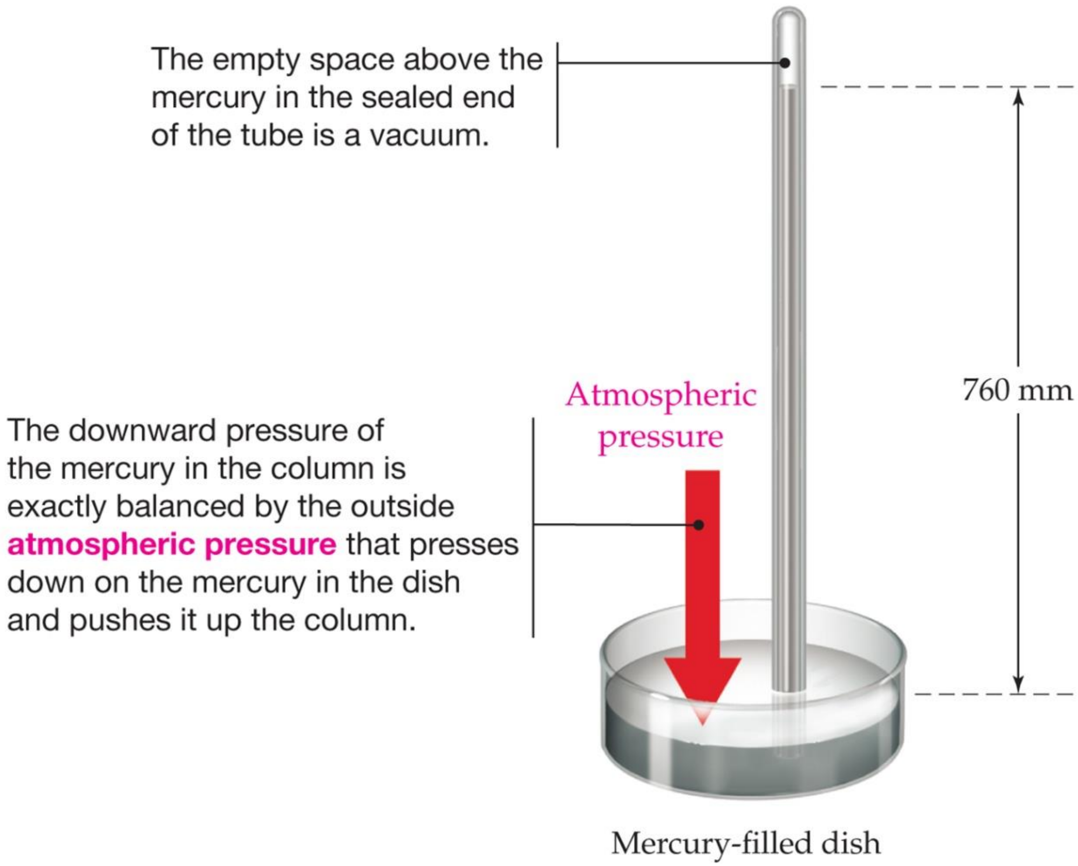
Gases and Gas Pressure

$$\textbf{Pressure} = \frac{\text{Force}}{\text{Unit area}}$$



Gases and Gas Pressure

Barometer

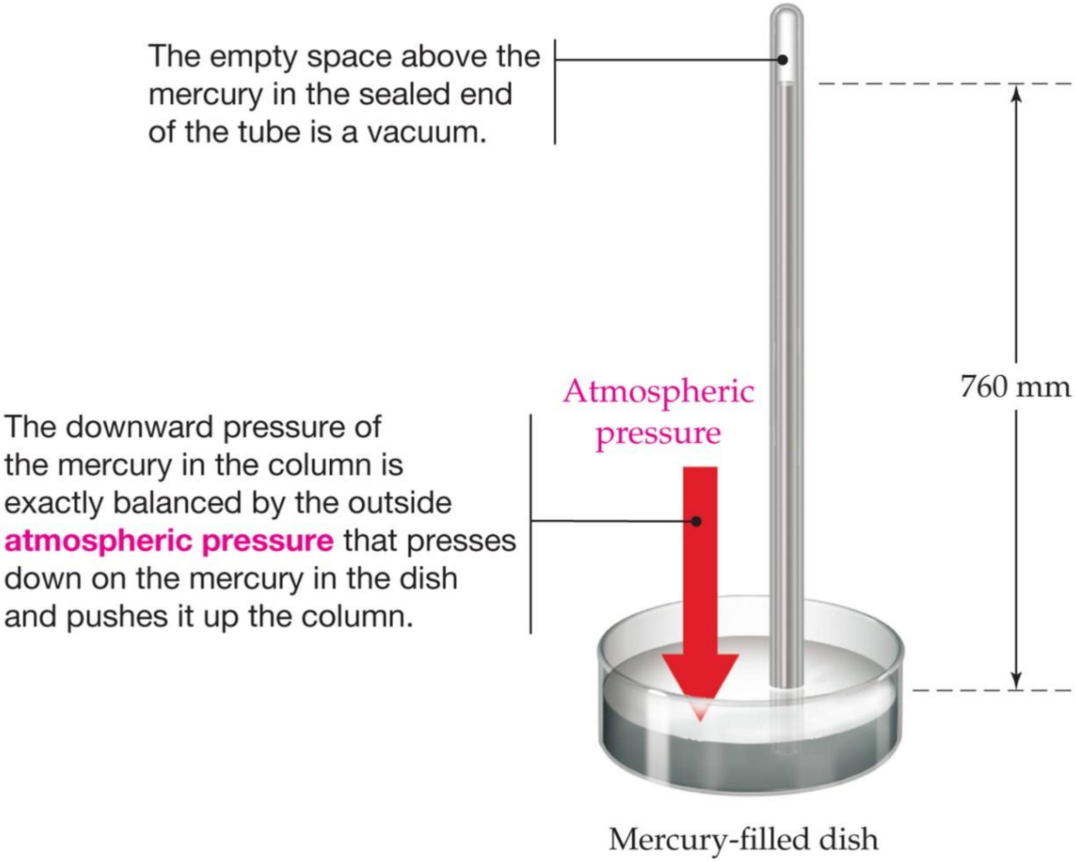


Gases and Gas Pressure

Barometer

Units

Pa
torr
mm Hg
atm
bar

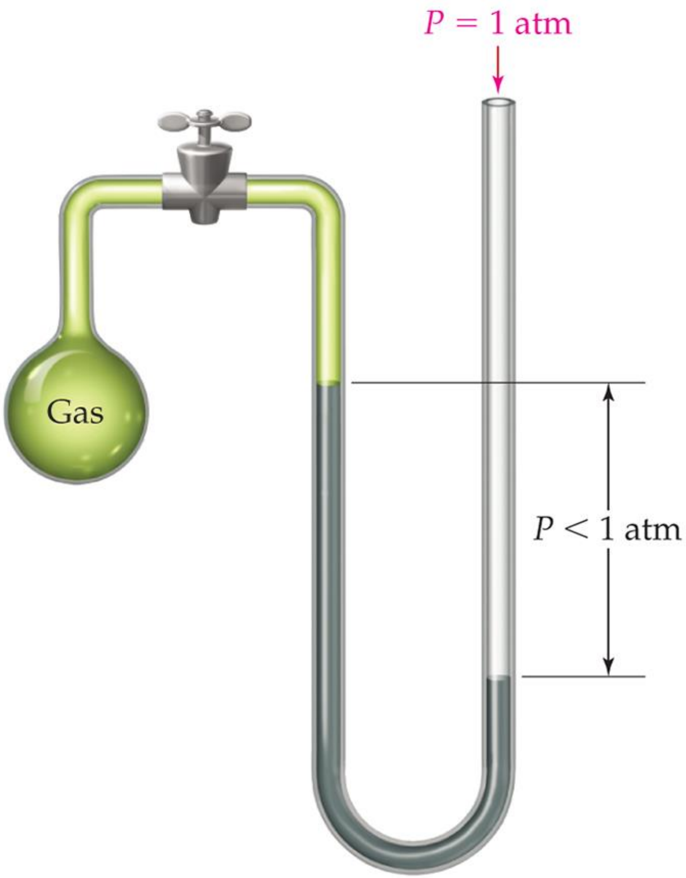


Gases and Gas Pressure

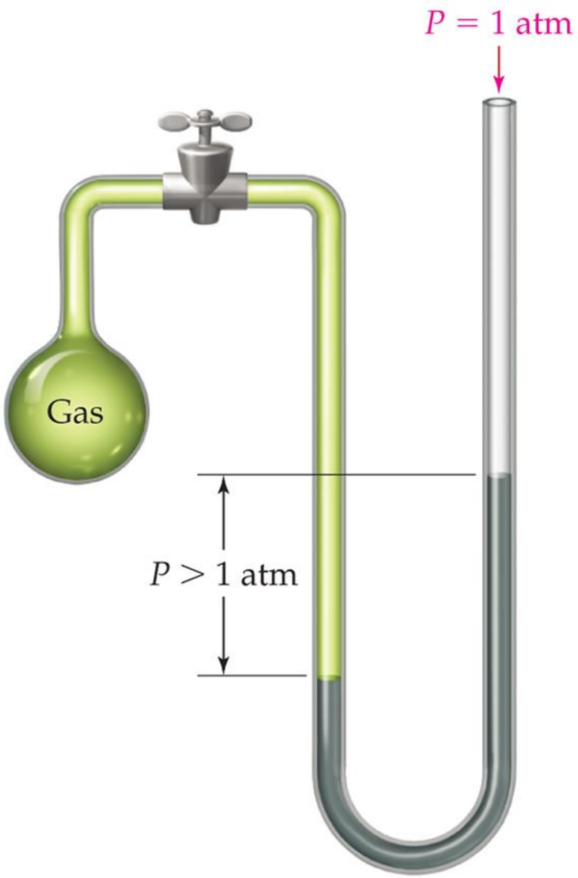
Conversions

1 atm = 760 mm Hg	(exact)
1 torr = 1 mm Hg	(exact)
1 bar = 1×10^5 Pa	(exact)
1 atm = 101 325 Pa	

Gases and Gas Pressure



(a) The mercury level is higher in the arm open to the bulb because the pressure in the bulb is lower than atmospheric.



(b) The mercury level is higher in the arm open to the atmosphere because the pressure in the bulb is higher than atmospheric.

The Gas Laws

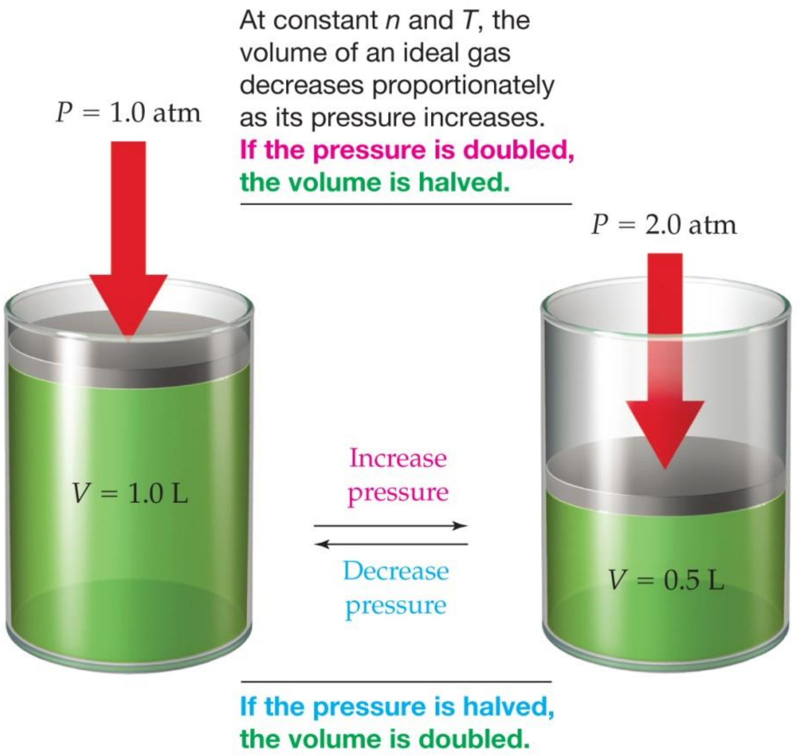
The physical properties of a gas can be defined by four variables:

P	pressure
T	temperature
V	volume
n	number of moles

The Gas Laws

Boyle's Law

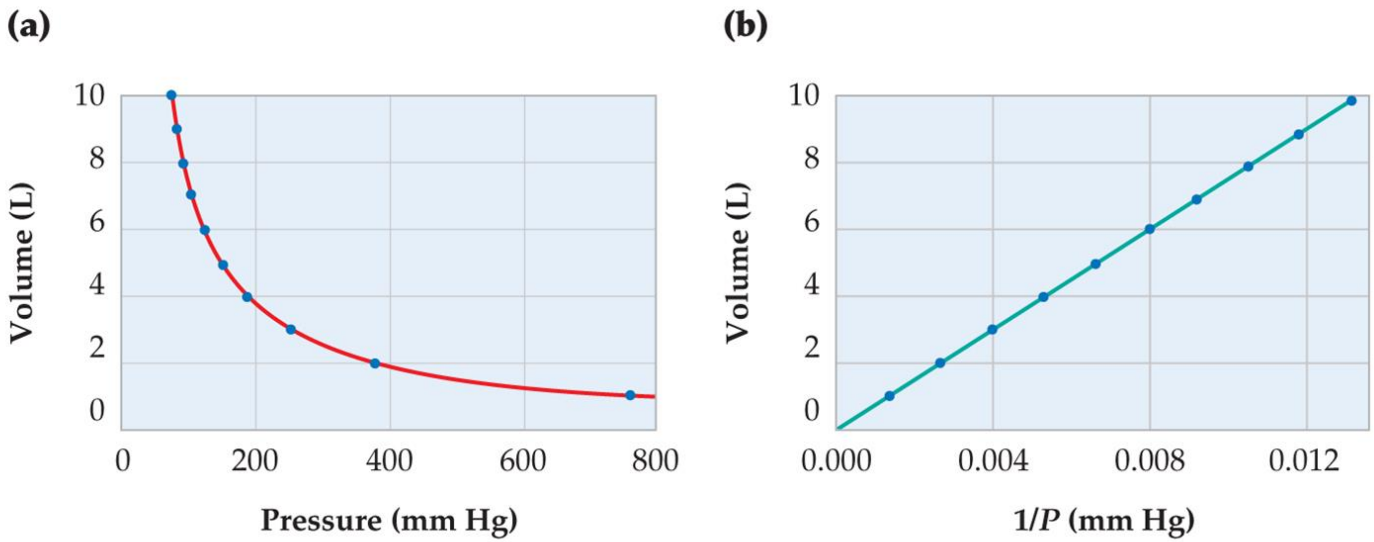
$$V \propto \frac{1}{P} \quad \text{(constant } n \text{ and } T\text{)}$$



The Gas Laws

Boyle's Law

$$V \propto \frac{1}{P} \quad (\text{constant } n \text{ and } T)$$



A plot of *V* versus *P* for a gas sample is a **hyperbola**.

A plot of *V* versus 1/*P* is a **straight line**. Such a graph is characteristic of equations having the form $y = mx + b$.

The Gas Laws

Boyle's Law

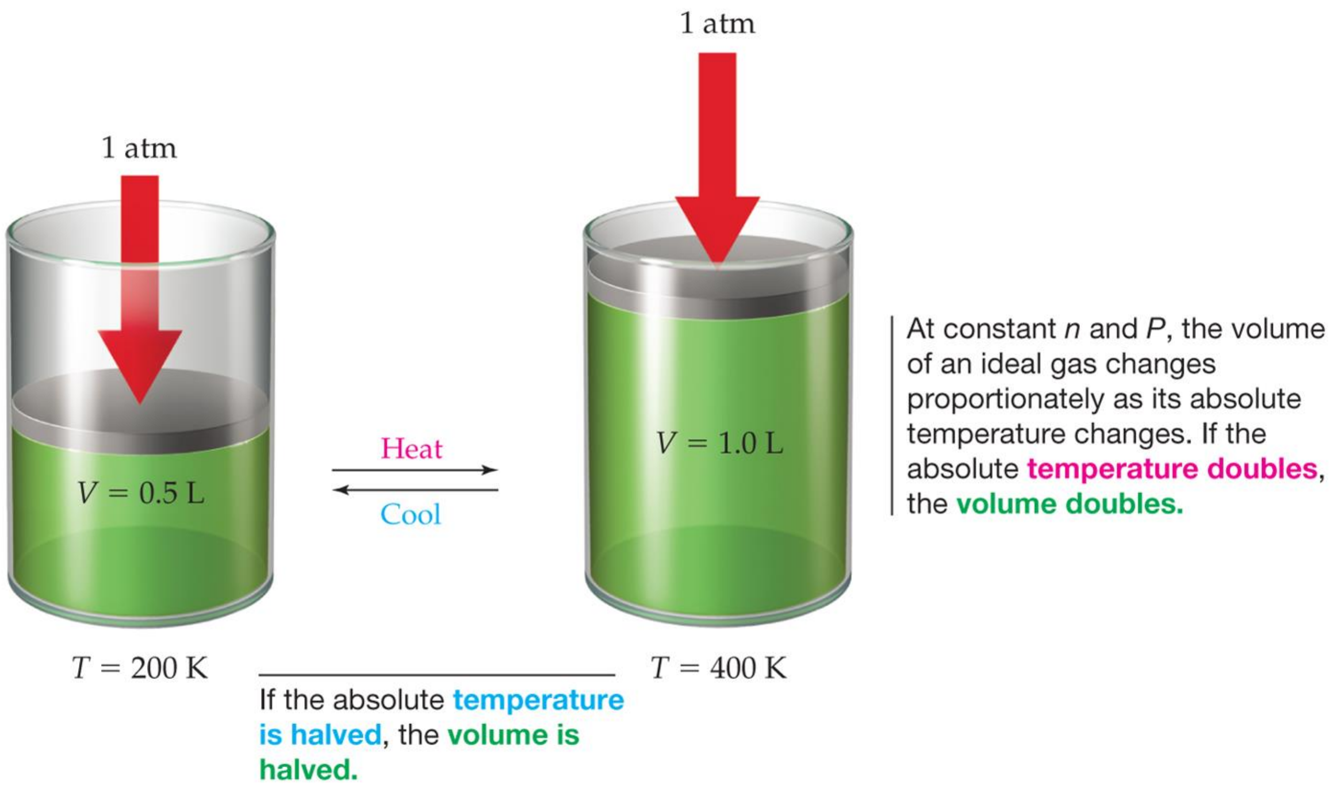
$$V \propto \frac{1}{P} \quad \text{(constant } n \text{ and } T\text{)}$$

$$PV = k$$

$$P_{\text{initial}}V_{\text{initial}} = P_{\text{final}}V_{\text{final}}$$

Charles's Law

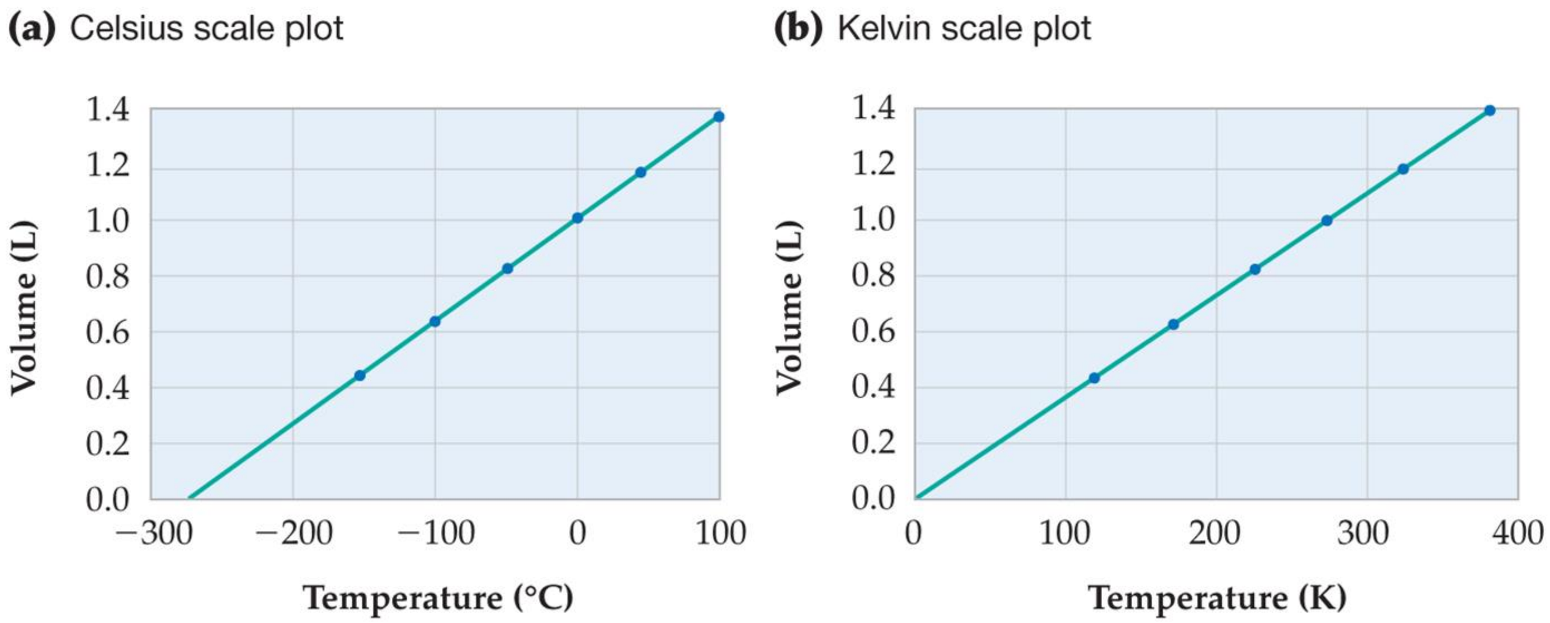
$V \propto T$ (constant n and P)



The Gas Laws

Charles's Law

$V \propto T$ (constant n and P)



A plot of V versus T for a gas sample is a straight line that can be extrapolated to absolute zero, 0 K = −273.15 °C.

The Gas Laws

Charles's Law

$V \propto T$ (constant n and P)

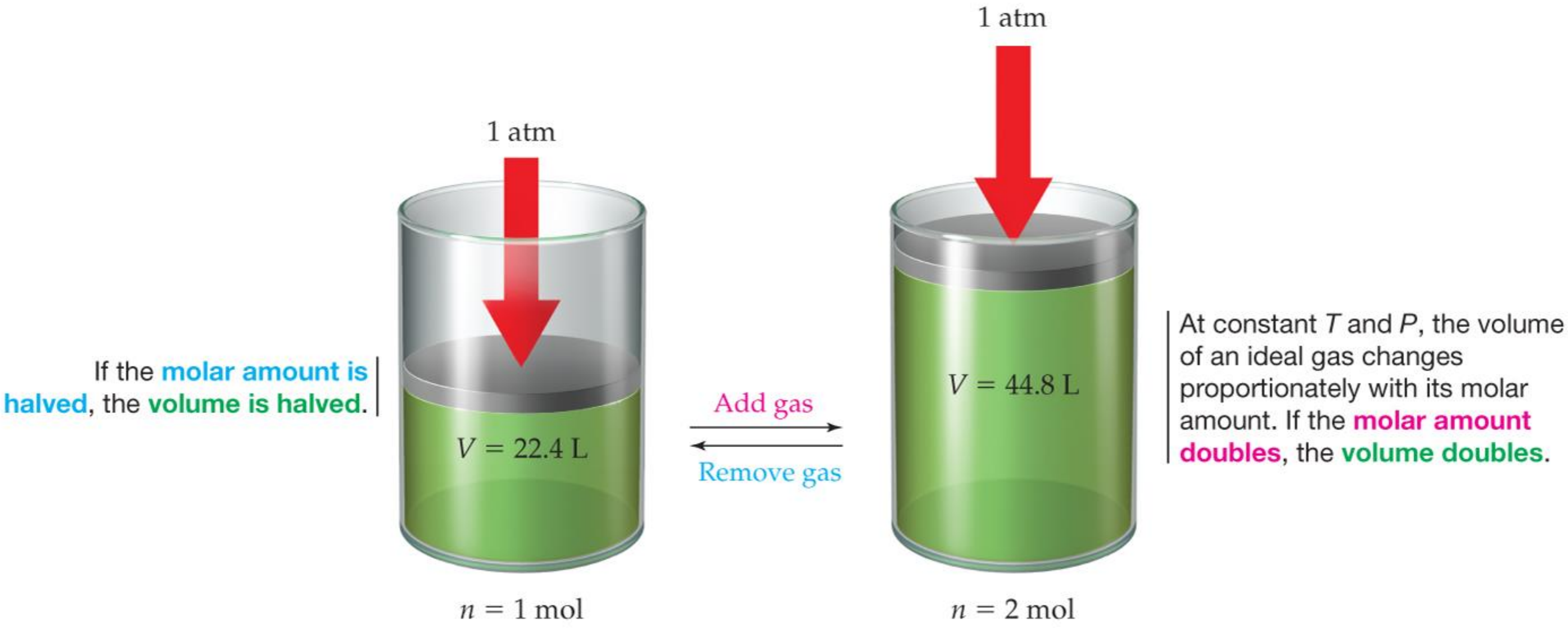
$$\frac{V}{T} = k$$

$$\frac{V_{\text{initial}}}{T_{\text{initial}}} = \frac{V_{\text{final}}}{T_{\text{final}}}$$

The Gas Laws

Avogadro's Law

$V \propto n$ (constant T and P)



Avogadro's Law

$V \propto n$ (constant T and P)

$$\frac{V}{n} = k$$

$$\frac{V_{\text{initial}}}{n_{\text{initial}}} = \frac{V_{\text{final}}}{n_{\text{final}}}$$

The Ideal Gas Law

Summary

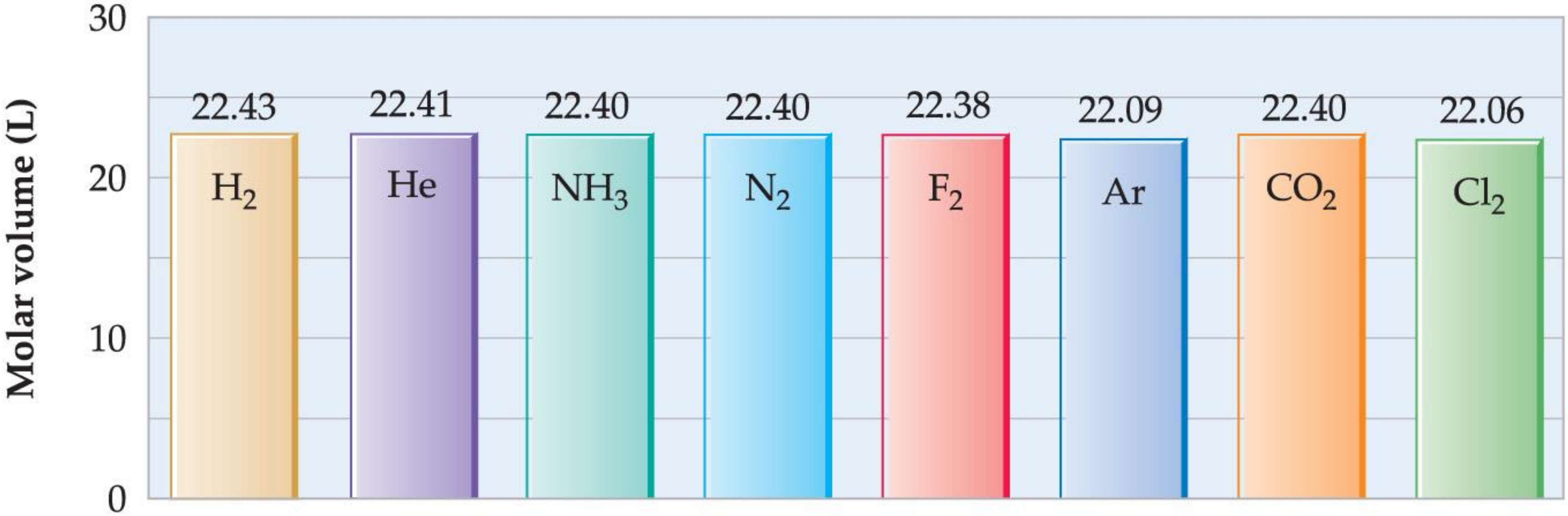
Boyle's Law: $P_{\text{initial}}V_{\text{initial}} = P_{\text{final}}V_{\text{final}}$

Charles' Law: $$\frac{V_{\text{initial}}}{T_{\text{initial}}} = \frac{V_{\text{final}}}{T_{\text{final}}}$$

Avogadro's Law: $$\frac{V_{\text{initial}}}{n_{\text{initial}}} = \frac{V_{\text{final}}}{n_{\text{final}}}$$

The Ideal Gas Law

TABLE 9.4 Molar Volumes of Some Real Gases at 0 °C and 1 atm



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The Ideal Gas Law

Ideal Gas Law: $PV = nRT$

R is the gas constant and is the same for all gases.

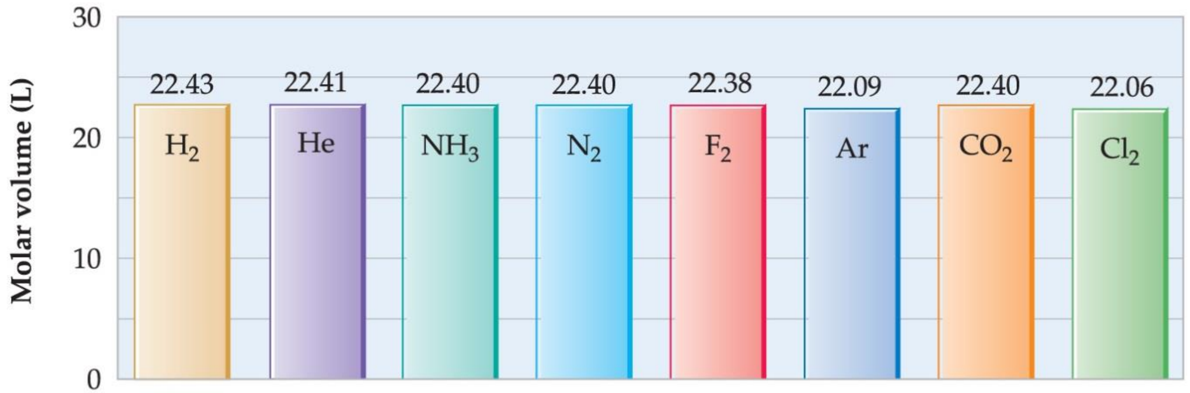
$$R = 0.08206 \frac{\text{L atm}}{\text{K mol}}$$

Standard Temperature and Pressure (STP) for Gases

- $T = 0$ °C (**273.15 K**)
- $P = 1$ atm

The Ideal Gas Law

TABLE 9.4 Molar Volumes of Some Real Gases at 0 °C and 1 atm



What is the volume of 1 mol of gas at STP?

$$V = \frac{nRT}{P} = \frac{(1\ \text{mol})\left(0.08206\frac{\text{L atm}}{\text{K mol}}\right)(273.15\ \text{K})}{(1\ \text{atm})} = 22.41\ \text{L}$$

Stoichiometric Relationships with Gases

The reaction used in the deployment of automobile airbags is the high-temperature decomposition of sodium azide, NaN_3, to produce N_2 gas. How many liters of N_2 at 1.15 atm and 30.0 °C are produced by decomposition of 45.0 g NaN_3?

$$2NaN_3(s) \longrightarrow 2Na(s) + 3N_2(g)$$

Stoichiometric Relationships with Gases

$$2NaN_3(s) \longrightarrow 2Na(s) + 3N_2(g)$$

Moles of N_2 produced:

$$45.0 \text{ g } NaN_3 \times \frac{1 \text{ mol } NaN_3}{65.0 \text{ g } NaN_3} \times \frac{3 \text{ mol } N_2}{2 \text{ mol } NaN_3} = 1.04 \text{ mol } N_2$$

Volume of N_2 produced:

$$V = \frac{nRT}{P} = \frac{(1.04 \text{ mol})\left(0.08206 \frac{\text{L atm}}{\text{K mol}}\right)(303.2 \text{ K})}{(1.15 \text{ atm})} = 22.5 \text{ L}$$

Mixtures of Gases: Partial Pressure and Dalton's Law

Dalton's Law of Partial Pressures: The total pressure exerted by a mixture of gases in a container at constant *V* and *T* is equal to the sum of the pressures of each individual gas in the container.

$$P_{\text{total}} = P_1 + P_2 + \ldots + P_N$$

$$\textbf{Mole fraction } (X) = \frac{\text{Moles of component}}{\text{Total moles in mixture}}$$

$$X_i = \frac{n_i}{n_{\text{total}}} \quad \text{or} \quad X_i = \frac{P_i}{P_{\text{total}}}$$

The Kinetic-Molecular Theory of Gases

1. A gas consists of tiny particles, either atoms or molecules, moving about at random.

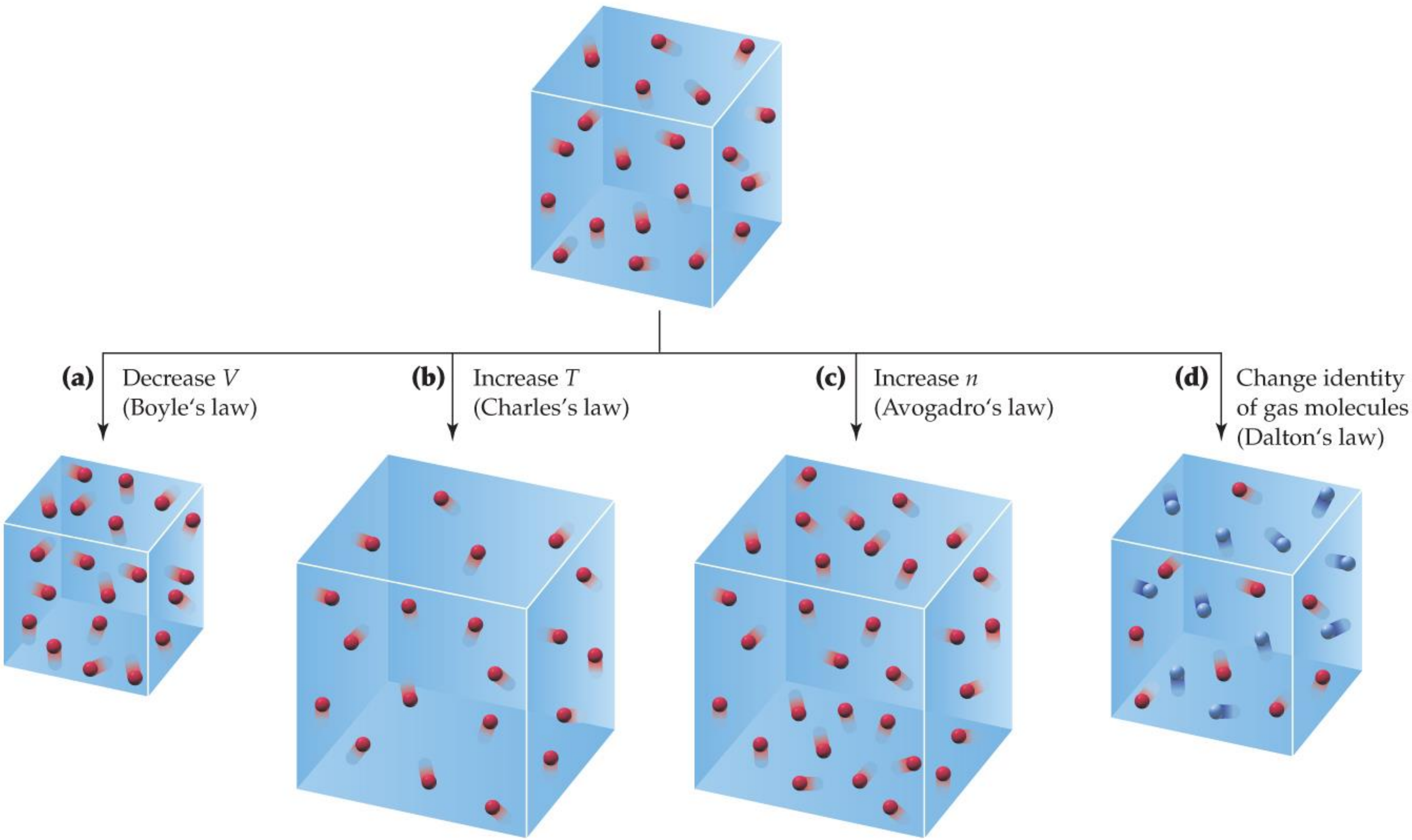
2. The volume of the particles themselves is negligible compared with the total volume of the gas. Most of the volume of a gas is empty space.

3. The gas particles act independently of one another; there are no attractive or repulsive forces between particles.

The Kinetic-Molecular Theory of Gases

4. Collisions of the gas particles, either with other particles or with the walls of a container, are elastic (constant temperature).

5. The average kinetic energy of the gas particles is proportional to the Kelvin temperature of the sample.



Decreasing the volume of the gas at constant *n* and *T* increases the frequency of collisions with the container walls and thus increases the pressure **(Boyle's law)**.

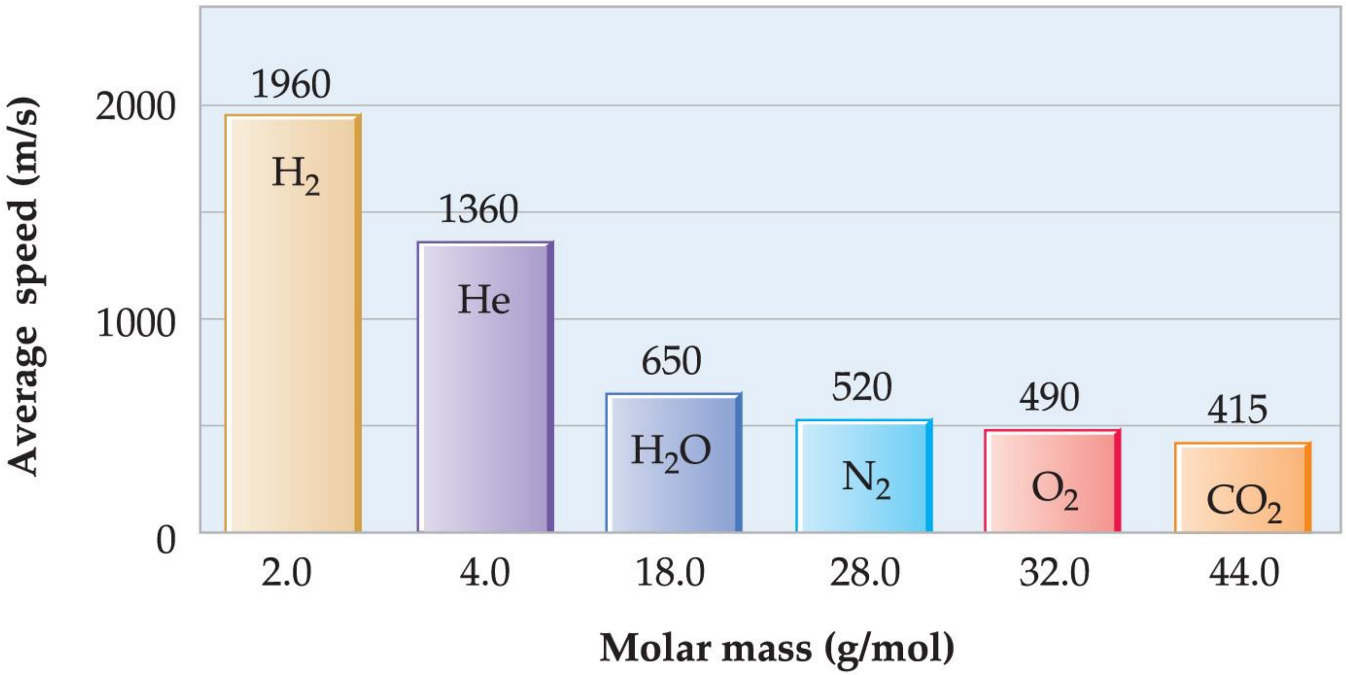
Increasing the temperature (kinetic energy) at constant *n* and *P* increases the volume of the gas **(Charles's law)**.

Increasing the amount of gas at constant *T* and *P* increases the volume of the gas **(Avogadro's law)**.

Changing the identity of some gas molecules at constant *T* and *V* has no effect on the pressure **(Dalton's law)**.

The Kinetic-Molecular Theory of Gases

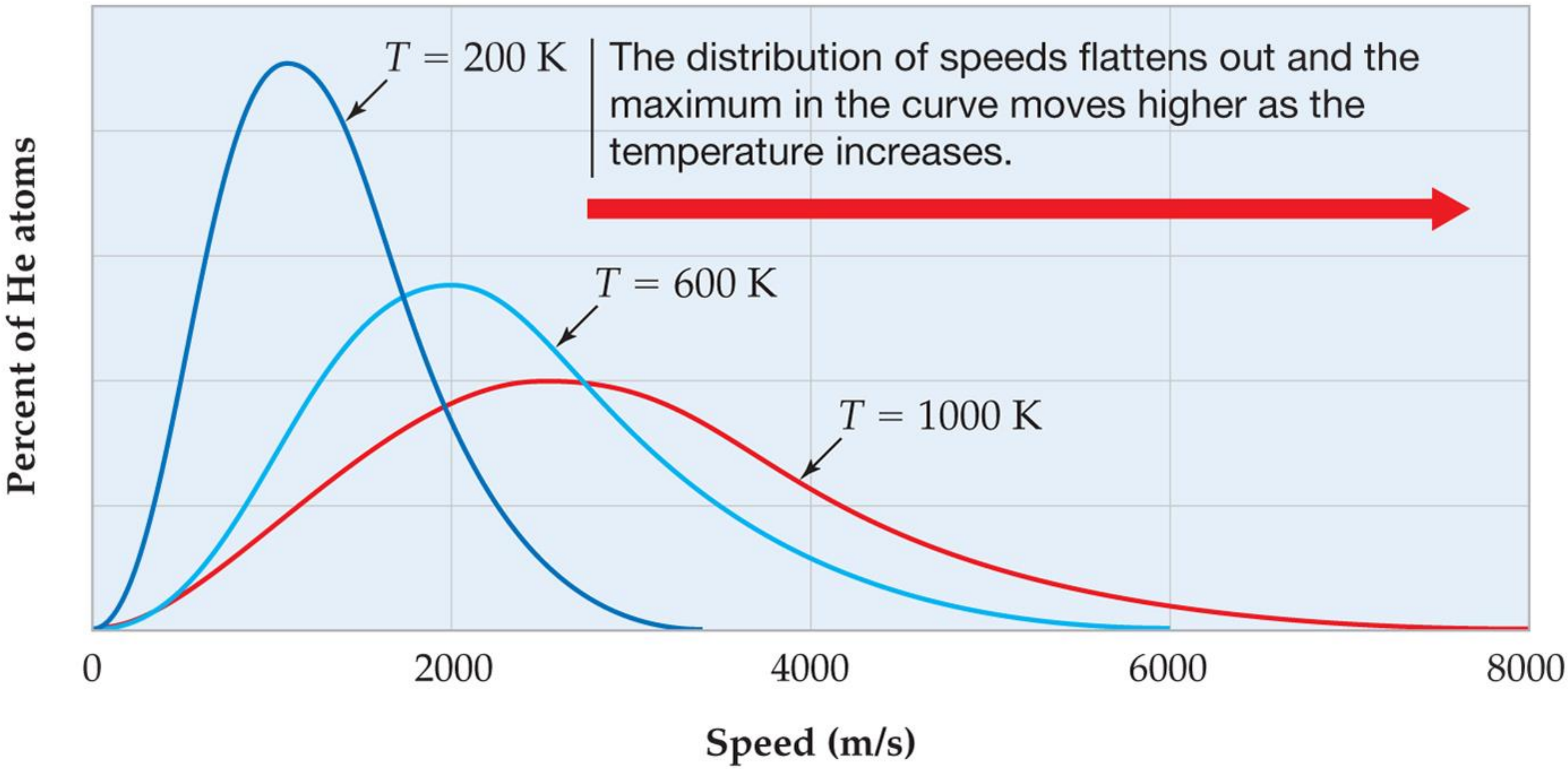
TABLE 9.5 Average Speeds (m/s) of Some Gas Molecules at 25 °C



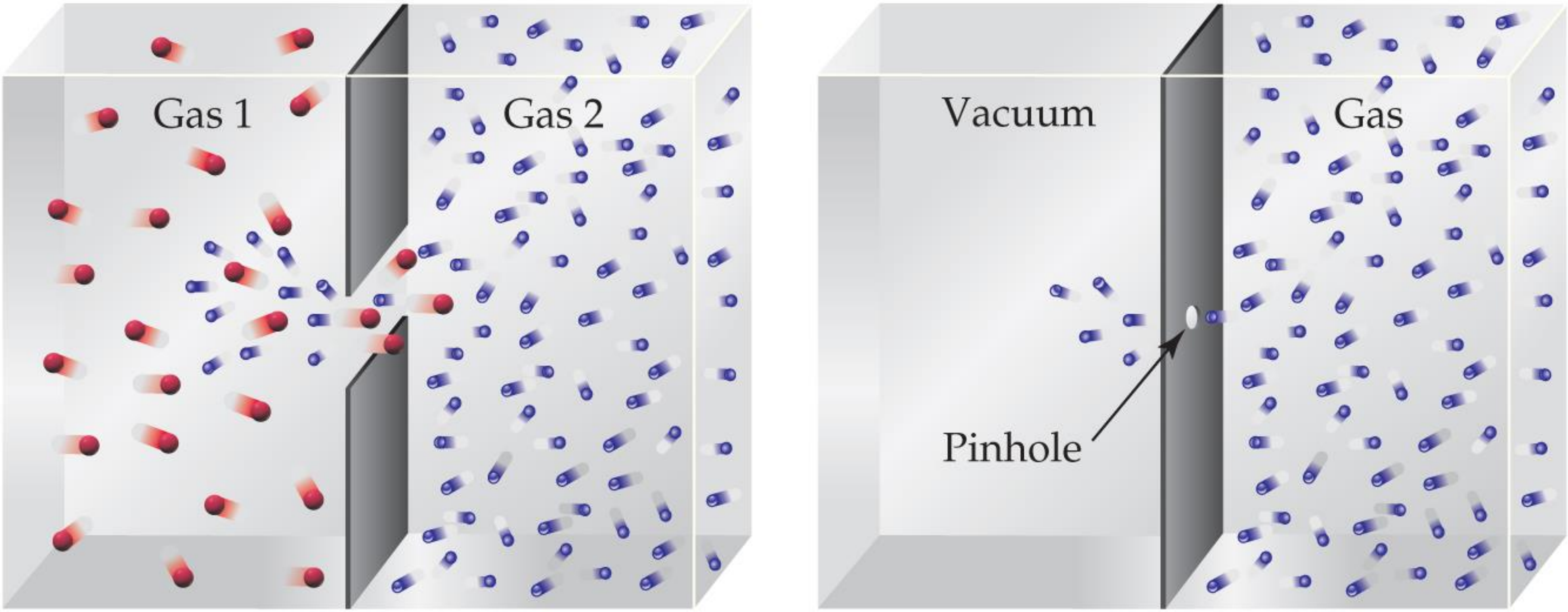
Molar mass ↑

Average speed ↓

The Kinetic-Molecular Theory of Gases



Diffusion and Effusion of Gases: Graham's Law



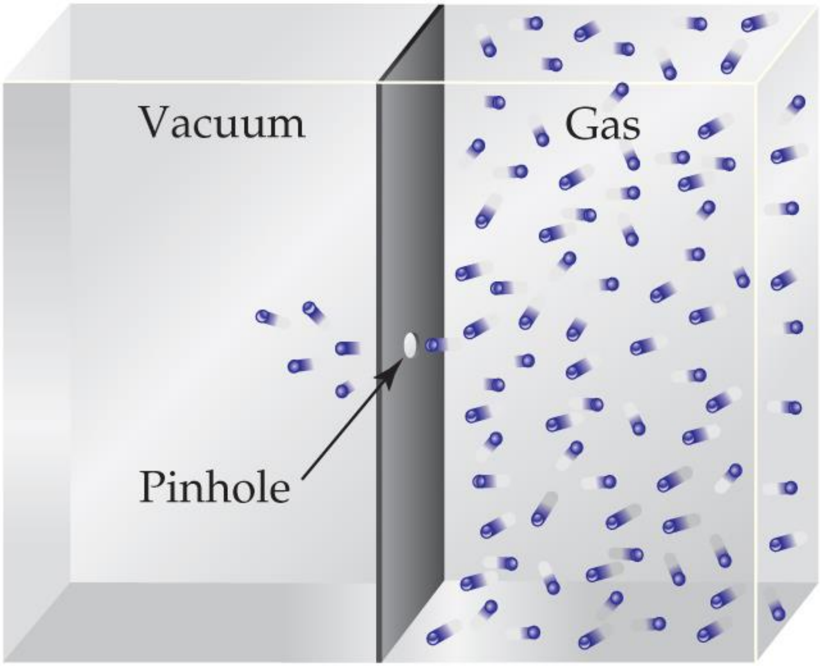
Diffusion is the mixing of gas molecules by random motion under conditions where molecular collisions occur.

Effusion is the escape of a gas through a pinhole into a vacuum without molecular collisions.

Diffusion and Effusion of Gases: Graham's Law

Graham's Law

$$\text{Rate} \propto \frac{1}{\sqrt{m}}$$



Effusion is the escape of a gas through a pinhole into a vacuum without molecular collisions.

The Behavior of Real Gases

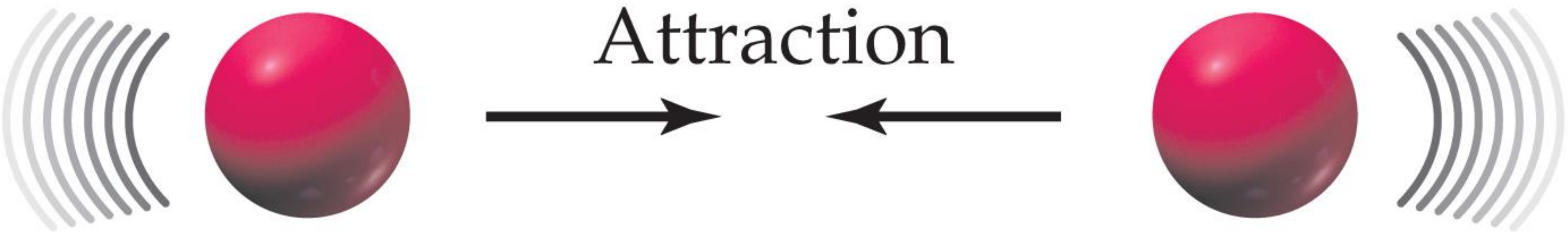
The volume of a real gas is larger than predicted by the ideal gas law.

At lower pressure, the volume of the gas particles is negligible compared to the total volume.

At higher pressure, the volume of the gas particles is more significant compared to the total volume. As a result, the volume of a real gas at high pressure is somewhat larger than the ideal value.

The Behavior of Real Gases

Attractive forces between particles become more important at higher pressures.



The Behavior of Real Gases

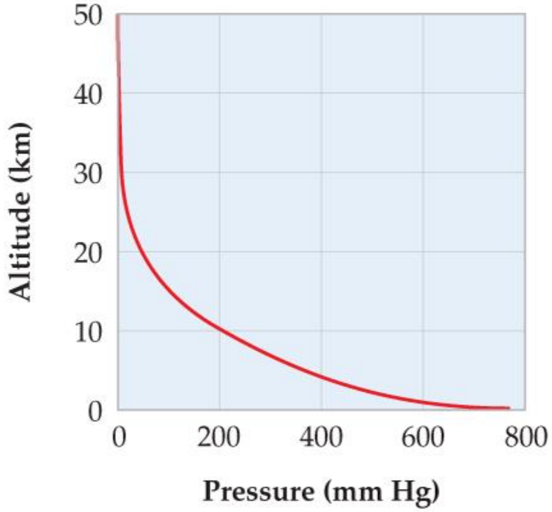
Van der Waals Equation

Correction for intermolecular attractions

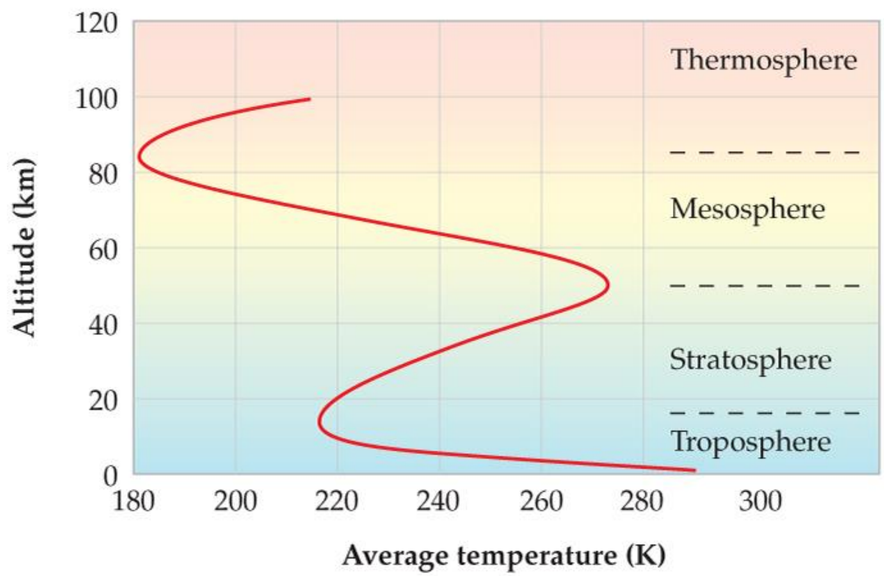
$$\left(P + \frac{an^2}{V^2}\right)\left(V - nb\right) = nRT$$

Correction for molecular volume

The Earth’s Atmosphere and Pollution



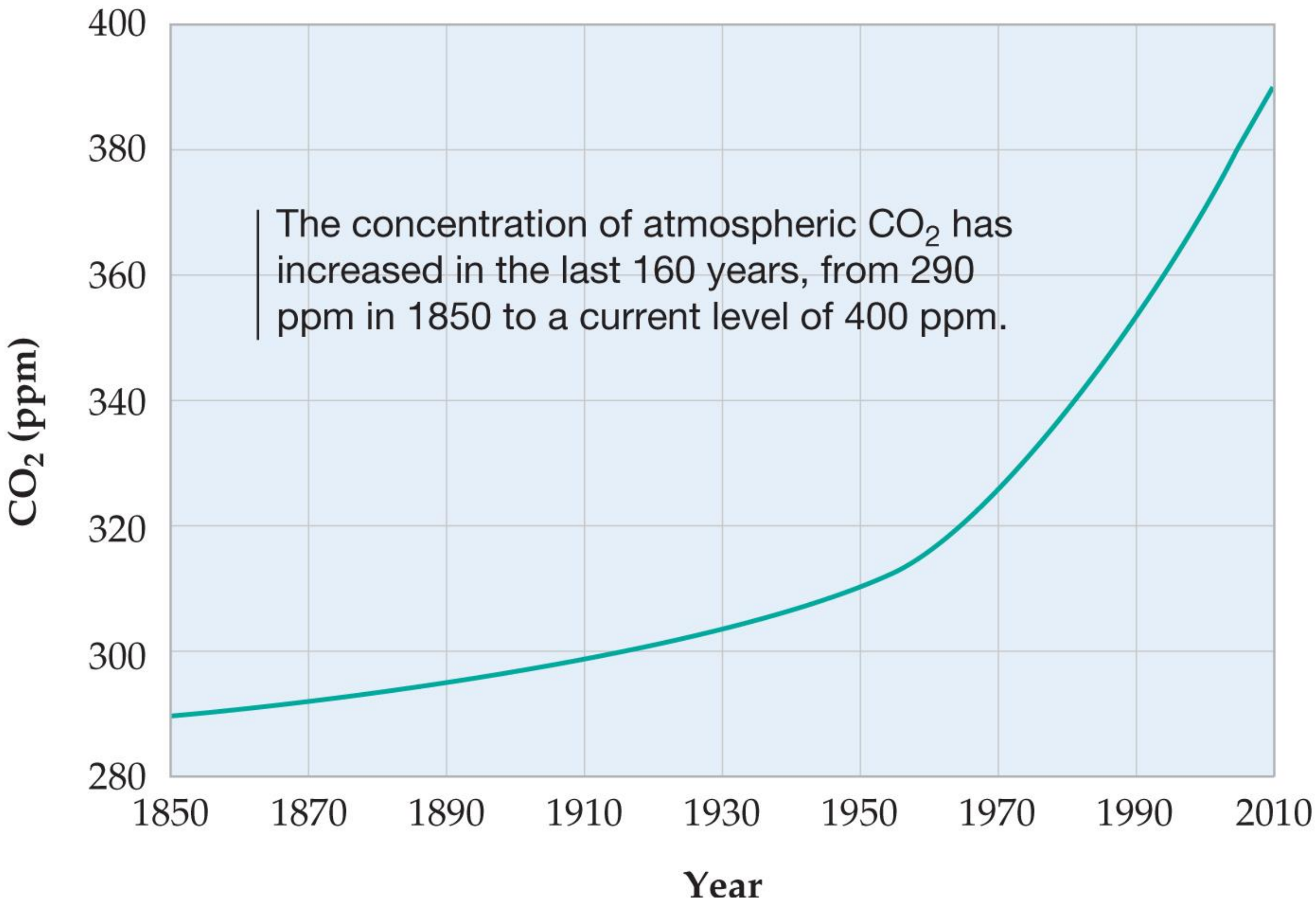
Atmospheric pressure decreases as altitude increases.



Four regions of the atmosphere are defined based on the temperature variations.

Average temperature varies irregularly with altitude.

The Earth's Atmosphere and Pollution



The Greenhouse Effect

- The greenhouse effect is caused by the absorption of heat radiation in the Earth's atmosphere.
  - CO_2 and CH_4, gases with bonds that can bend, forming temporary dipoles, are greenhouse gases.
  - O_2 and N_2, gases that can't form a dipole, do not contribute to the greenhouse effect.

Climate Change

- The term denotes warming on a global scale, but greater extremes of hot and cold in seasonal storms.

Climate Change

- Carbon dioxide is emitted through numerous industrial, chemical processes.
- The amount of CO_2 emitted is referred to as a carbon footprint.