Gases
Ideal Gas
And Laws

Ideal Gas Law

$$PV = nRT \qquad PV = \frac{m}{M}RT$$

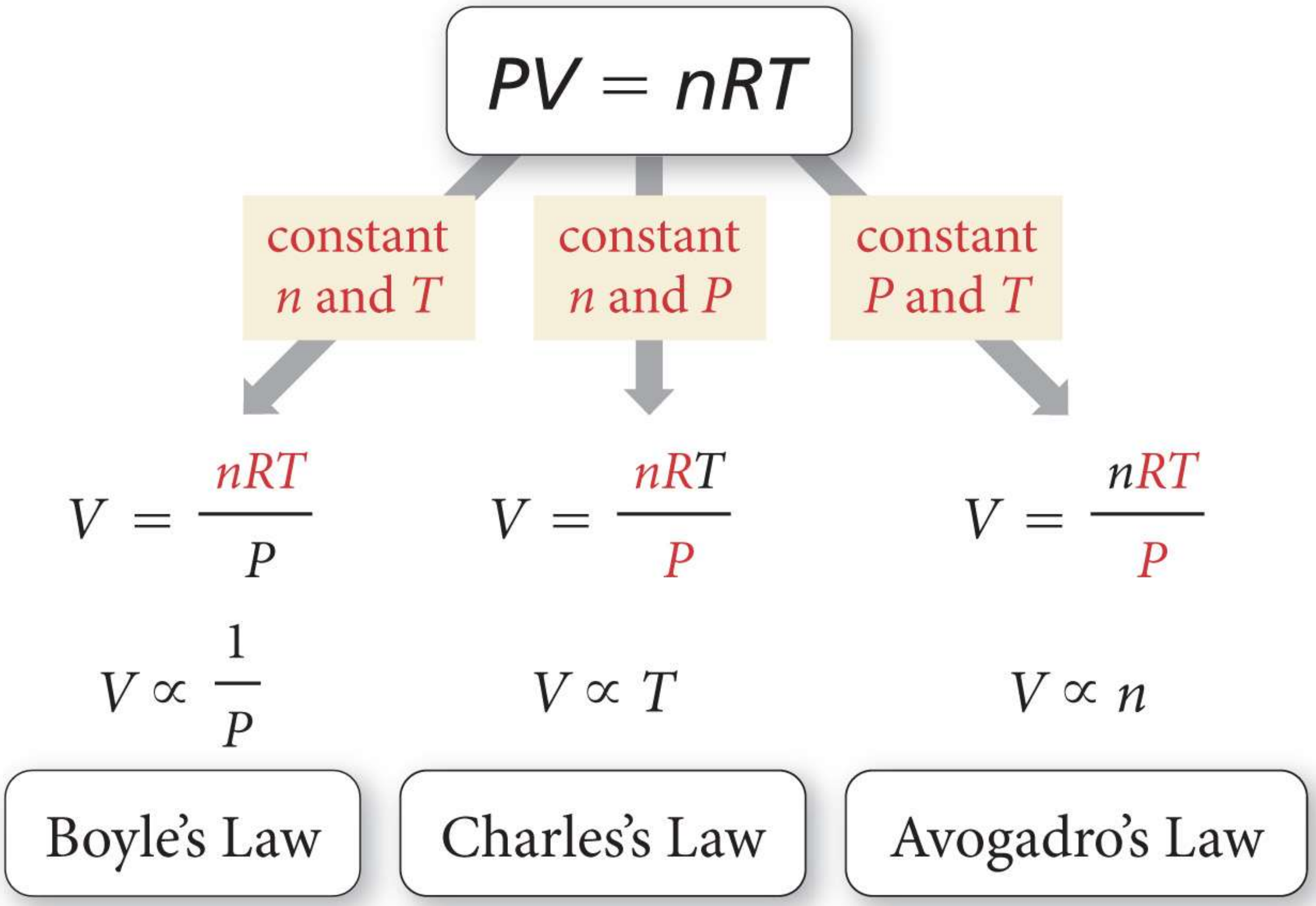
- P = pressure in atm
- V = volume in liters
- n = moles = m/M; m = mass, M = molar mass
- R = proportionality constant
  - = 0.08206 $\text{L}\cdot\text{atm}/\text{mol}\cdot\text{K}$
  - = 8.314 $\text{L}\cdot\text{Kpa}/\text{mol}\cdot\text{K}$
  - = 62.4 $\text{L}\cdot\text{mmHg}/\text{mol}\cdot\text{K}$

Holds closely at $P < 1$ atm

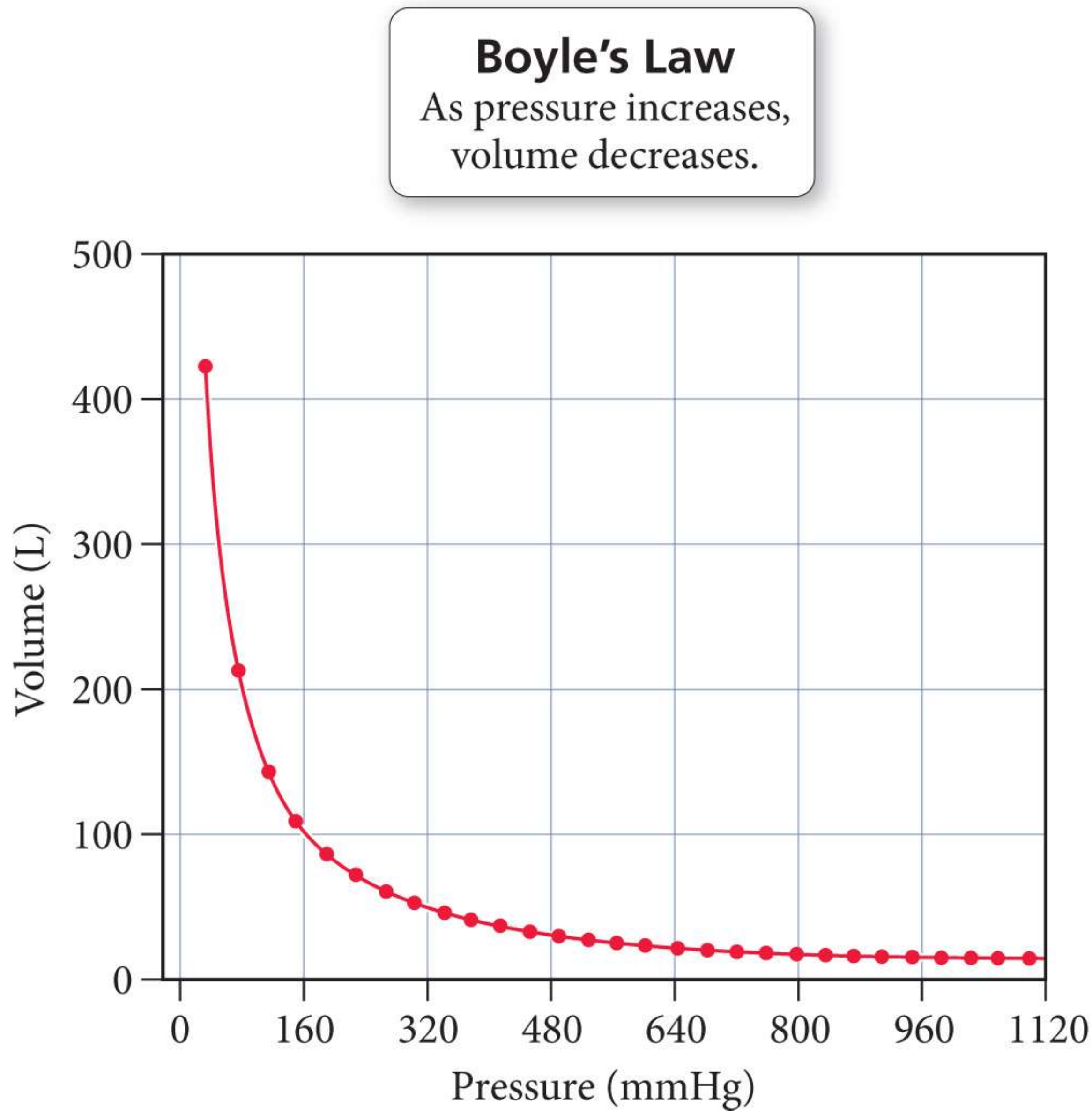
- T = temperature in Kelvins

Ideal Gas Law

Ideal Gas Law

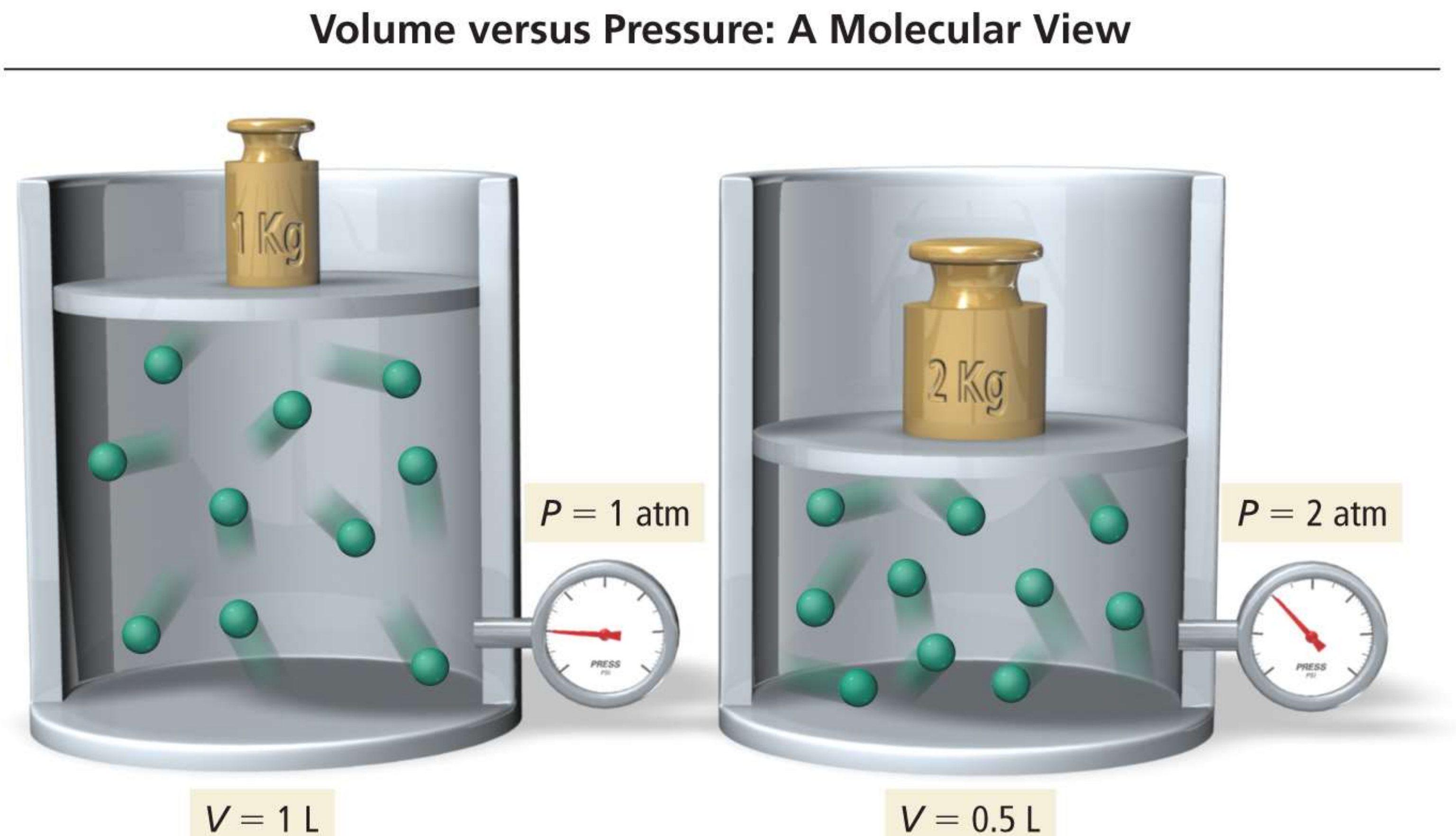


Boyle's Law



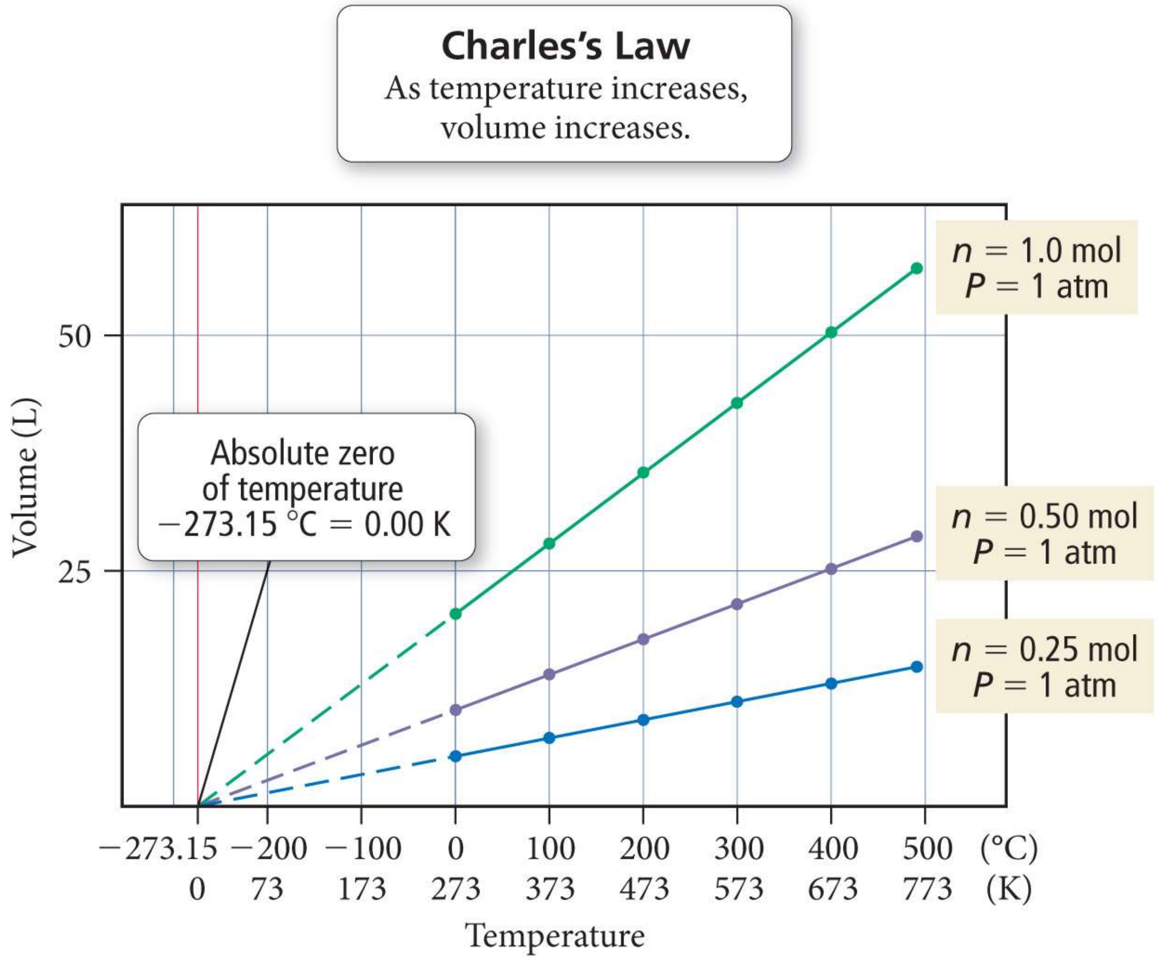
Boyle's Law
As pressure increases,
volume decreases.
500
400
300
200
100
0
Volume (L)
0
160
320
480
640
800
960
1120
Pressure (mmHg)

Molecular Interpretation of Boyle's Law



As the volume of a gas sample is decreased, gas molecules collide with surrounding surfaces more frequently, resulting in greater pressure.

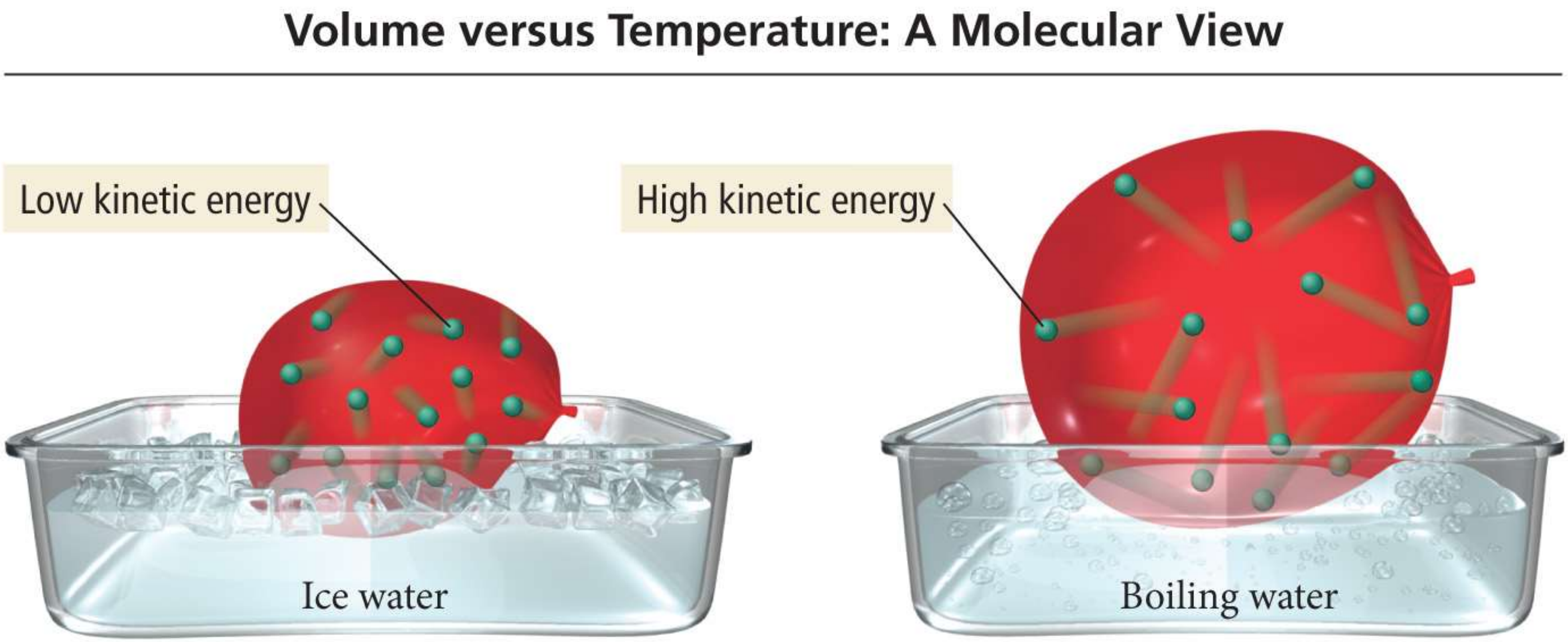
Charles's Law



If the lines are extrapolated back to a volume of "0," they all show the same temperature, −273.15 °C = 0 K, called **absolute zero**

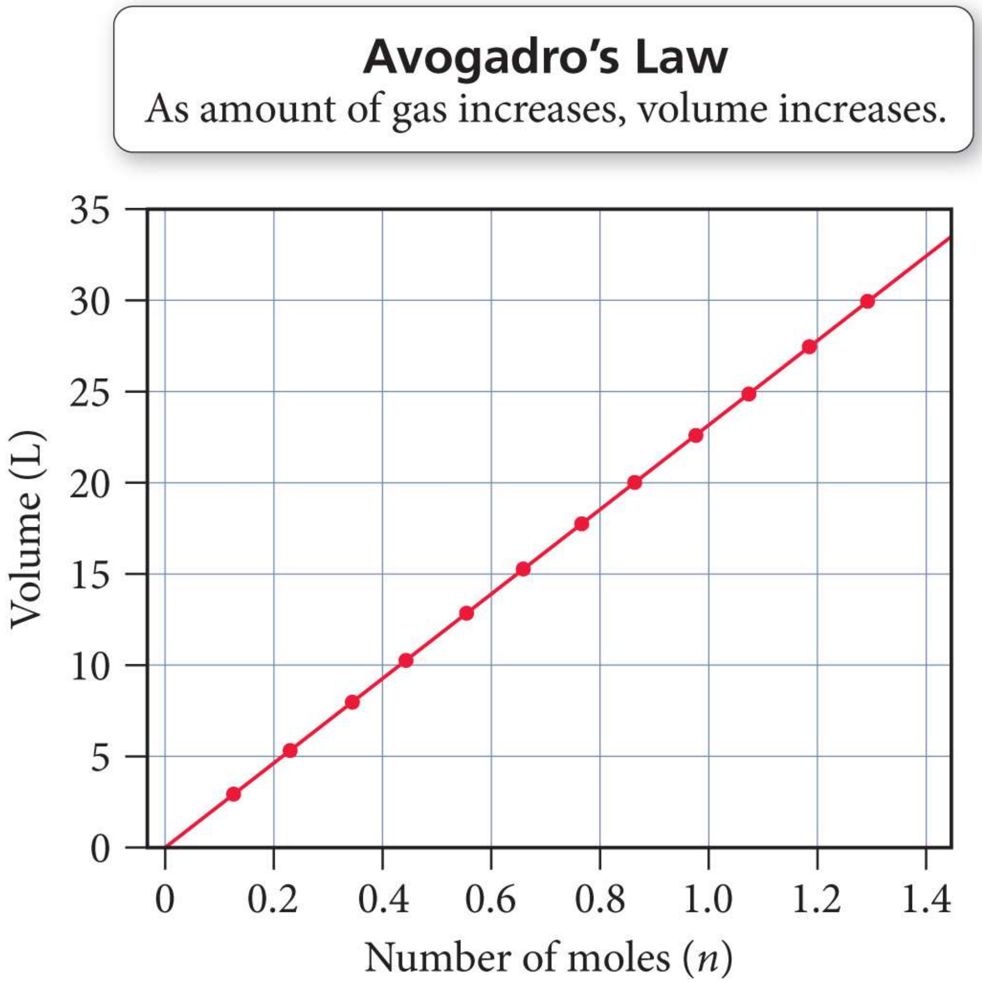
The extrapolated lines cannot be measured experimentally because all gases condense into liquids before –273.15 °C is reached.

Charles's Law – A Molecular View



If we move a balloon from an ice water bath to a boiling water bath, its volume expands as the gas particles within the balloon move faster (due to the increased temperature) and collectively occupy more space.

Avogadro's Law



When the amount of gas in a sample increases at constant temperature and pressure, its volume increases in direct proportion because the greater number of gas particles fill more space.

The volume of a gas sample increases linearly with the number of moles of gas in the sample.

Dalton's Law of Partial Pressures

P total is the total pressure and P_a, P_b, P_c, . . . are the partial pressures of the components. This relationship is known as Dalton's law of partial pressures.

$$
\begin{aligned}
P_{\text{total}} &= P_a + P_b + P_c + \ldots \\
&= n_a \frac{RT}{V} + n_b \frac{RT}{V} + n_c \frac{RT}{V} + \ldots \\
&= (n_a + n_b + n_c + \ldots) \frac{RT}{V} \\
&= (n_{\text{total}}) \frac{RT}{V}
\end{aligned}
$$

Mole Fraction

- **The ratio of the partial pressure a single gas contributes and total pressure is equal to the mole fraction.**

$$\frac{P_a}{P_{total}} = \frac{n_a(RT/V)}{n_{total}(RT/V)} = \frac{n_a}{n_{total}}$$

$$\chi_a = \frac{n_a}{n_{total}}$$

- **The number of moles of a component in a mixture divided by the total number of moles in the mixture, is the mole fraction.**

$$\frac{P_a}{P_{total}} = \frac{n_a}{n_{total}}$$

$$P_a = \frac{n_a}{n_{total}} P_{total} = \chi_a P_{total}$$

$$P_a = \chi_a P_{total}$$

Mole Fraction

- **The partial pressure of a component in a gaseous mixture is its mole fraction multiplied by the total pressure.**
- **For gases, the mole fraction of a component is equivalent to its percent by volume divided by 100%.**
  - ✓ **Nitrogen has a 78% composition of air; find its partial pressure.**

$$P_{N_2} = 0.78 \times 1.00 \text{ atm}$$
$$= 0.78 \text{ atm}$$

$$P_{total} = P_{N_2} + P_{O_2} + P_{Ar}$$
$$P_{total} = 0.78 \text{ atm} + 0.21 \text{ atm} + 0.01 \text{ atm}$$
$$= 1.00 \text{ atm}$$