N26 – Gases

Ideal Gases and Laws

Ideal Gas Law

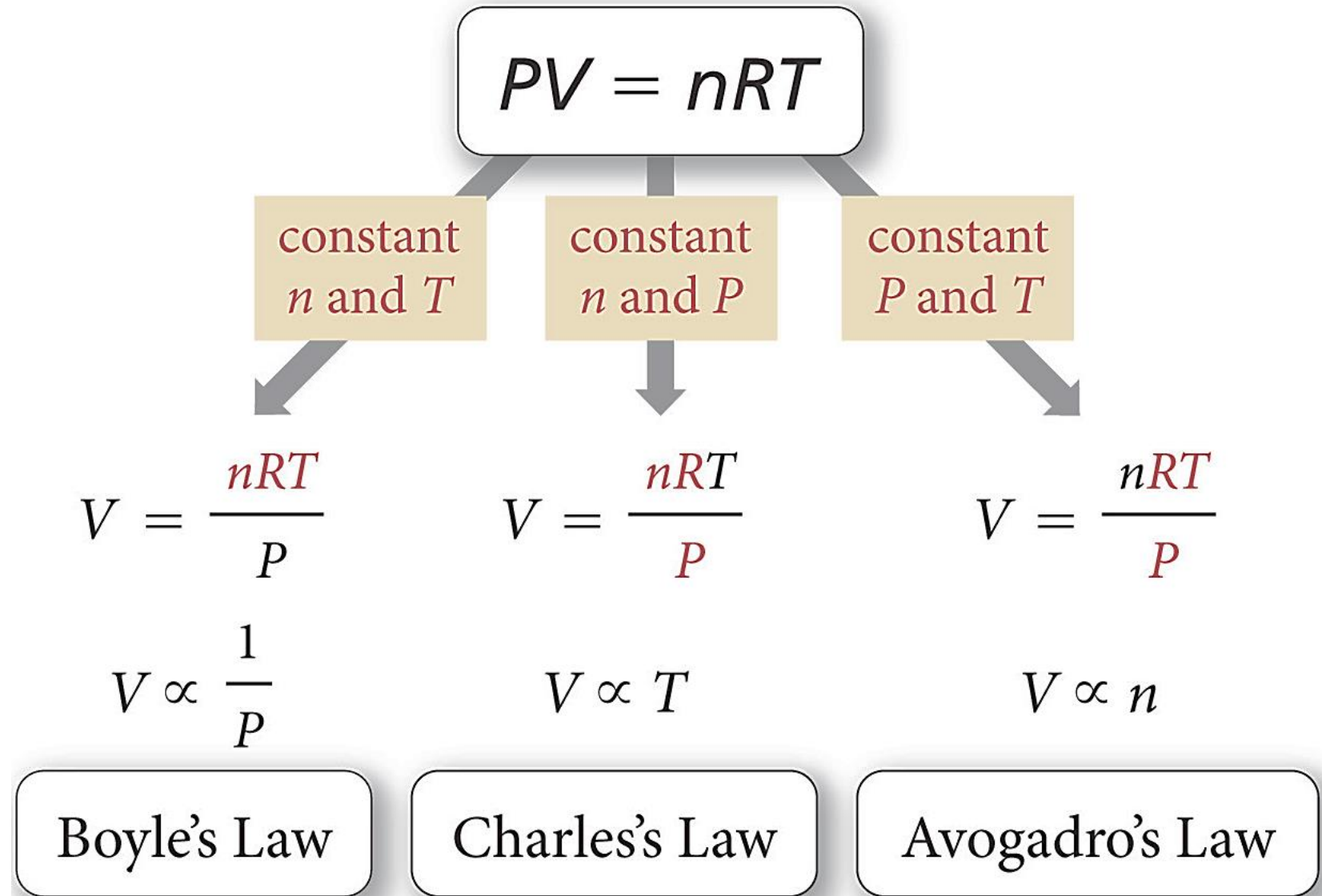## PV = nRT

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

- **P =** pressure in atm
- **V =** volume in liters
- **n =** moles
  - **=** m/M;   *m = mass, M = molar mass*
- **R =** proportionality constant
  - **=** 0.08206 L·atm/ mol·K
  - **=** 8.314 L·Kpa/ mol·K
  - **=** 62.4 L·mmHg/ mol·K
- **T =** temperature in Kelvins

R holds closely at P < 1 atm

Getting Other Gas Laws from Ideal Gas Law

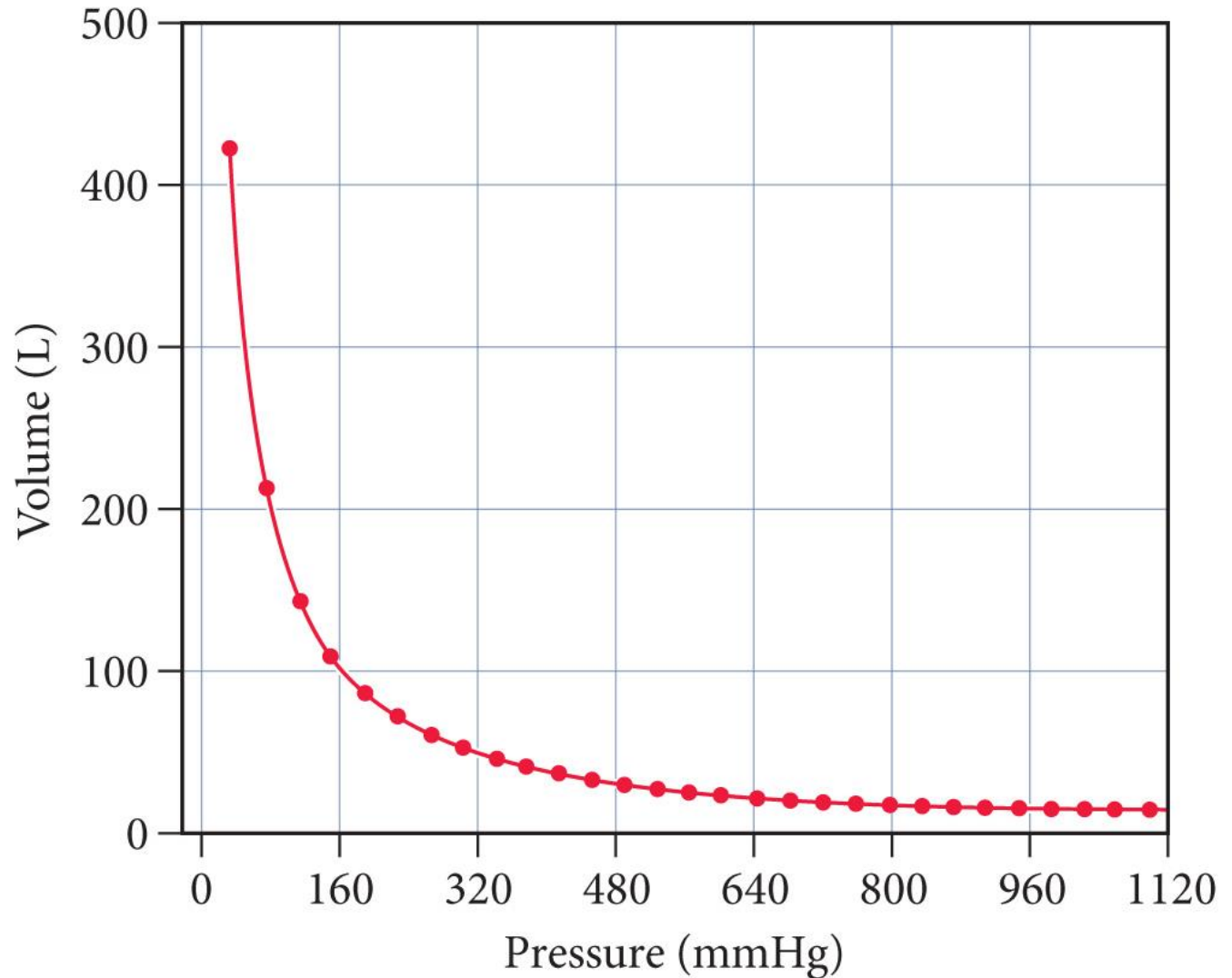**If some variables are held constant then PV=nRT reduces into the other laws.**

$$PV = nRT$$

constant n and T	constant n and P	constant P and T
$V = \dfrac{nRT}{P}$	$V = \dfrac{nRT}{P}$	$V = \dfrac{nRT}{P}$
$V \propto \dfrac{1}{P}$	$V \propto T$	$V \propto n$
Boyle's Law	Charles's Law	Avogadro's Law

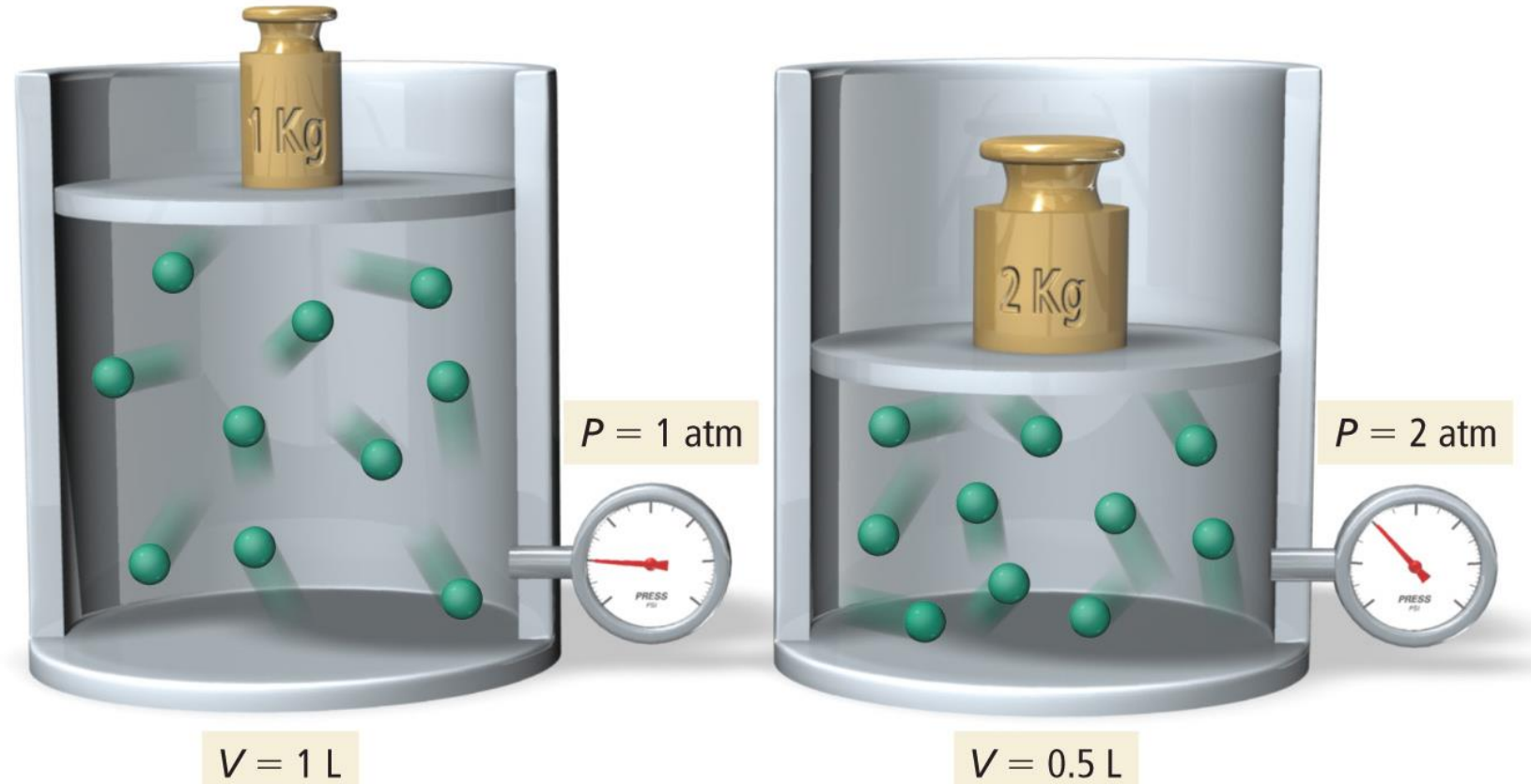# Boyle's Law

$$P_1V_1 = P_2V_2$$

As pressure increases, volume decreases.

Indirect relationship.

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.
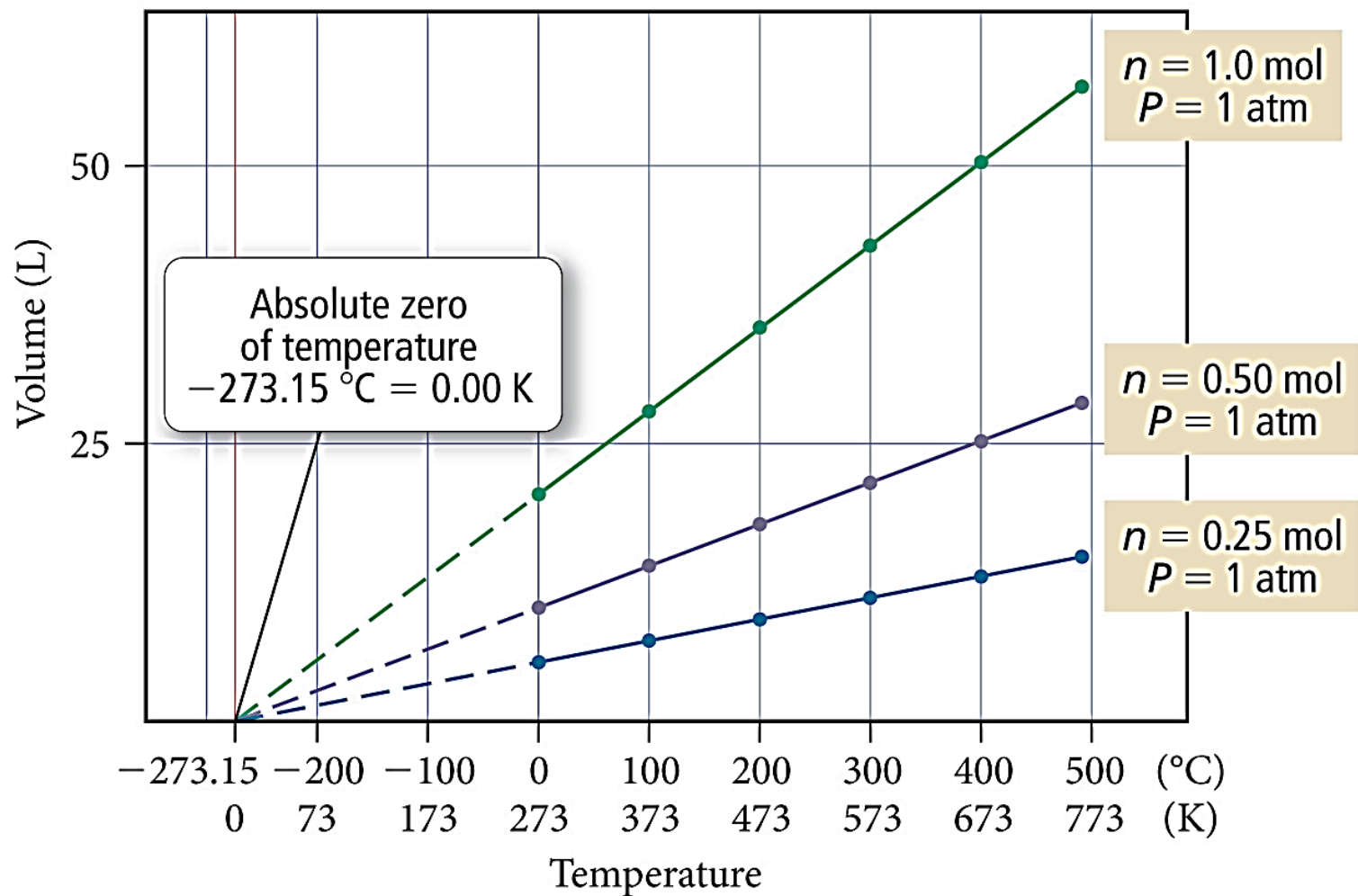

$P = 1$ atm

$V = 1$ L

$P = 2$ atm

$V = 0.5$ L

Charles's Law

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

As temperature increases, volume increases.
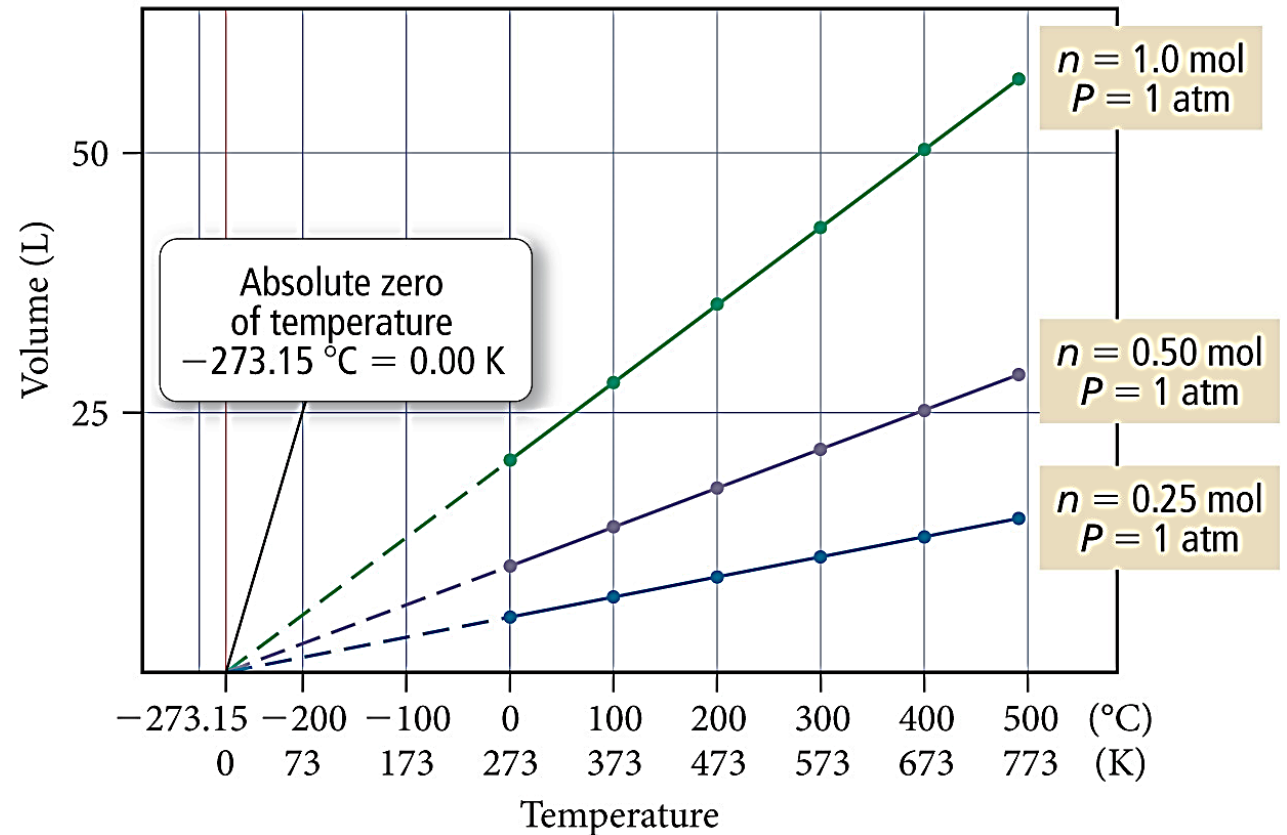
Direct relationship.

Charles's Law
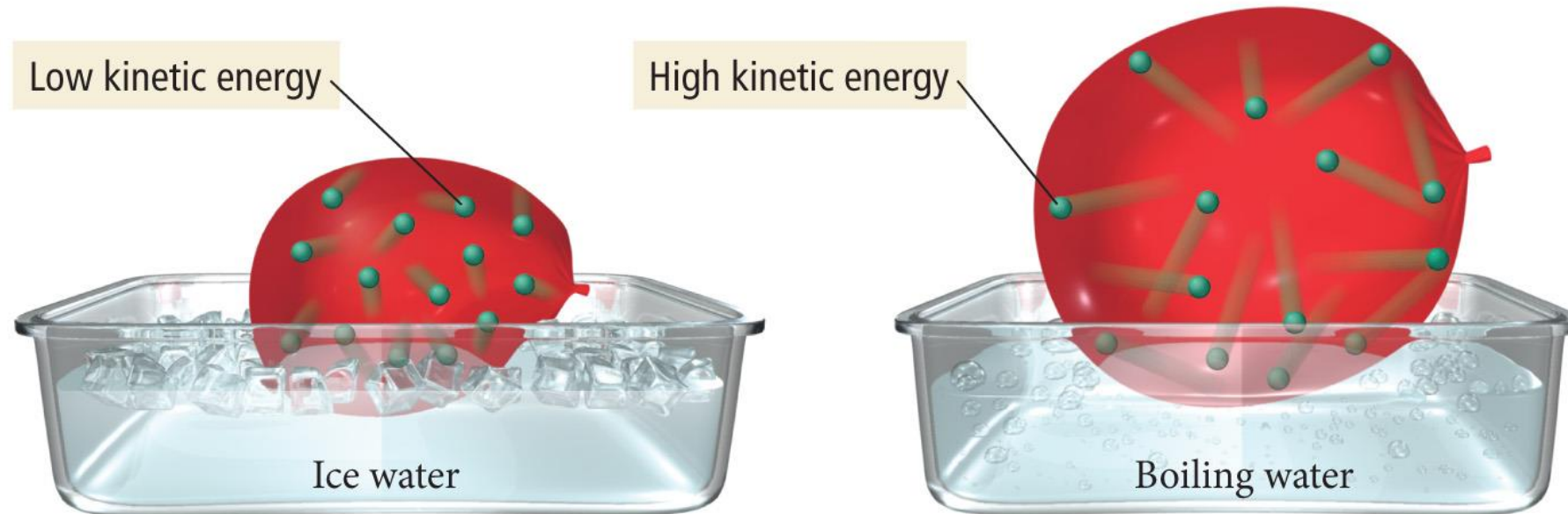
$$\frac{V_1}{T_1} = \frac{V_2}{T_2}$$

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.

Molecular Interpretation of Charles's Law

Low kinetic energy

High kinetic energy
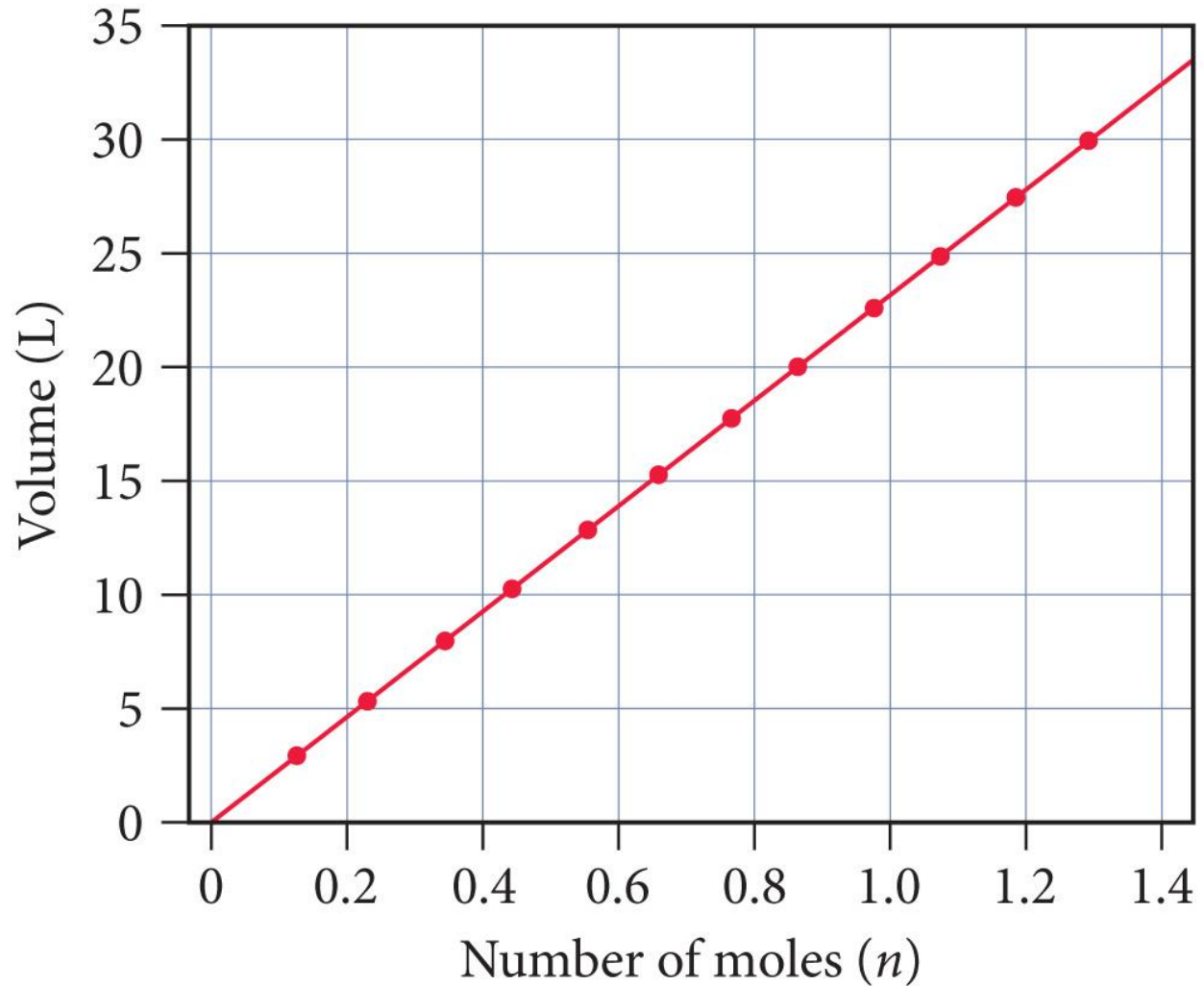
Ice water

Boiling water

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

$$\frac{V_1}{n_1} = \frac{V_2}{n_2}$$

As number of moles of gas increases, volume increases.
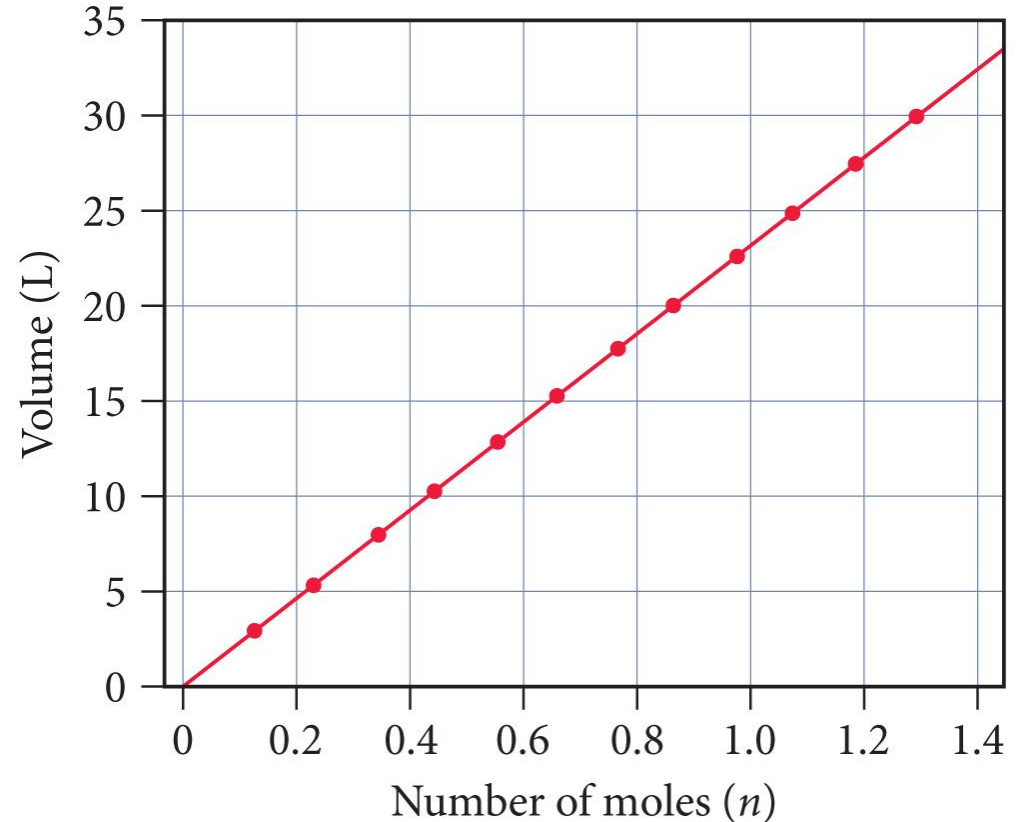
Direct relationship.

Avogadro's Law

$$\frac{V_1}{n_1} = \frac{V_2}{n_2}$$

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

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

P_{total} is the total pressure and P_1, P_2, P_3 or P_a, P_b, P_c, . . . are the partial pressures of the components.

$$= n_a \frac{RT}{V} + n_b \frac{RT}{V} + n_c \frac{RT}{V} + \cdots$$

$$= (n_a + n_b + n_c + \ldots) \frac{RT}{V}$$

$$= (n_{total}) \frac{RT}{V}$$

Mole Fraction

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

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

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

Mole Fraction

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

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

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

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

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

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.**

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

$$P_{total} = P_{N_2} + P_{O_2} + P_{Ar}$$

$$P_{total} = 0.78 \text{ atm} + 0.21 \text{ atm} + 0.01 \text{ atm}$$

$$= 1.00 \text{ atm}$$