Section 3.2 The Gas Laws

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Math Skills *The Combined Gas Law*

Content and Vocabulary Support

Charles's Law

Charles's law describes how the volume of a gas is affected by a change in temperature. The law states that the volume of a gas is directly proportional to its temperature if its pressure and number of particles remain constant. Charles's law can be written as:

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

V_1 and T_1 represent the volume and temperature of the gas before a change in temperature occurs. V_2 and T_2 represent the volume and temperature of the gas after the temperature changes. Temperatures must be expressed in degrees Kelvin (K) for the formula to apply.

Boyle's Law

Boyle's law describes how the volume of a gas is affected by a change in pressure. The law states that the volume of a gas is inversely proportional to its pressure if its temperature and number of particles remain constant. Boyle's law can be written as:

$$P_1V_1 = P_2V_2$$

P_1 and V_1 are the pressure and volume of the gas before a change in pressure occurs. P_2 and V_2 are the pressure and volume of the gas after the pressure changes. Pressure is usually measured in kilopascals (kPa), and kPa = 0.0102 kg/cm^2.

The Combined Gas Law

Charles's law and Boyle's law can be combined into a single law called the combined gas law. The combined gas law describes the relationship among temperature, volume, and pressure of a gas when the number of particles is constant. The combined gas law can be written as:

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

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Solved Examples

Example 1: A 0.50-L container of air has a pressure of 200 kPa. If the pressure increases to 250 kPa, while the temperature remains the same, what is the new volume of air?

Given: $V_1 = 0.50$ L $P_1 = 200$ kPa $P_2 = 250$ kPa $T_1 = T_2$

Unknown: V_2 *Equation:* $\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$

Solution: Solving the equation for V_2 gives:

$$V_2 = \frac{P_1V_1T_2}{T_1P_2}$$

Because T_1 and T_2 are equal, they cancel each other out, leaving:

$$V_2 = \frac{P_1V_1}{P_2}$$

Substituting the given values into this equation yields:

$$V_2 = \frac{(200 \text{ kPa}) \times (0.50\text{L})}{(250 \text{ kPa})} = 0.4 \text{ L}$$

Example 2: At a temperature of 200 K, a closed cylinder contains gas at a pressure of 400 kPa. If the temperature increases to 280 K, what is the new pressure?

Given: $T_1 = 200$ K $P_1 = 400$ kPa $T_2 = 280$ K $V_1 = V_2$

Unknown: P_2 *Equation:* $\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$

Solution: Solving the equation for P_2 gives:

$$P_2 = \frac{P_1V_1T_2}{T_1V_2}$$

Because V_1 and V_2 are equal, they cancel each other out, leaving:

$$P_2 = \frac{P_1V_1T_2}{T_1V_2}$$

Substituting the given values into this equation yields:

$$P_2 = \frac{(400 \text{ kPa}) \times (280 \text{ K})}{(200 \text{ K})} = 560 \text{ kPa}$$

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Practice Exercises

Exercise 1: At a given temperature, gas with a pressure of 150 kPa has a volume of 0.8 L. If the pressure decreases to 75 kPa and the temperature remains the same, what will be the volume of the gas?

Exercise 2: A liter of gas has a pressure of 200 kPa. If the gas is put into 2-L container, what will be its pressure, assuming its temperature does not change?

Exercise 3: A given volume of gas at a temperature of 100 K has a pressure of 225 kPa. At a higher temperature, the same volume of gas has a pressure of 450 kPa. At what temperature does the gas have this higher pressure?

Exercise 4: Gas under 200 kPa of pressure at a temperature of 120 K fills a 0.5-L container. If the temperature decreases to 80 K but the pressure stays the same, what volume will the gas have?

Exercise 5: A volume of 1.5 L liters of a gas at a temperature of 150 K has a pressure of 340 kPa. If the temperature of the gas increases to 200 K and the volume decreases to 1 L, what is the new pressure of the gas?