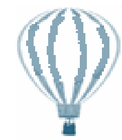
Combined Gas Law and other Variations

Read from **Lesson 2: Gas Laws** in the **Chemistry Tutorial Section, Chapter 10** of **The Physics Classroom**:
Part b: [Volume and Temperature] **Part d:** [Volume and the Number of Moles]
Part f: [Combined Gas Law]

Charles' Law



Jacques Charles (a French scientist and balloonist) determined that for a sample of gas with a constant pressure and a constant number of moles, the volume of the gas is directly proportional to its Kelvin temperature. If you keep the pressure and amount of gas constant, the volume of a gas increases linearly with the temperature of the gas (and vice versa).
This proportionality statement is often written in equation form as **V = k•T** or $\frac{V}{T} = k$
where **V** is the volume measured in milliliters (mL) or Liters (L) and **T** is the Kelvin temperature, and **k** is a proportionality constant.

Charles' Law

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

V = Volume
T = Temperature (K)
P and n are constant.

Avogadro's Law

Italian scientist Amedeo Avogadro (also of the mole fame!) determined that for a sample of gas with a constant pressure and absolute temperature (K), the volume of the gas is directly proportional to the number of moles of gas.
This proportionality statement is often written in equation form as **V = k•n** or $\frac{V}{n} = k$
where **V** is the volume measured in milliliters (mL) or Liters (L) and **n** is the number of moles of gas., and **k** is a proportionality constant.

Avogadro's Law

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

V = Volume
n = Number of Moles
P and T are constant.

Also, at STP, one mole of any type of gas has a volume of 22.4L.

STP = Standard Temperature and Pressure
(T = 273.15 K and P = 1.00 atm)

At STP, 1.00 mole of a gas occupies 22.4 L.

Combined Gas Law

We can combine all previous gas laws into one formula. (You don't have to memorize all of them!) The combined gas law relates the pressure, volume, and temperature of a gas. This allows us to study the changes in three properties of a gas for a fixed amount (or moles) of gas. Temperature must be in K, and units for P_1 and P_2 must be identical, as well as V_1 and V_2.

Combined Gas Law

$$\frac{P_1 \cdot V_1}{T_1} = \frac{P_2 \cdot V_2}{T_2}$$

P = Pressure
V = Volume
T = Temperature (K)
n is constant.

Gases and Gas Laws

Part 1: Charles' Law Problems Show all work as you solve these problems.

Example: A gas has a volume of 65 mL and a temperature of 25°C. If the pressure is held constant, what is the new volume when the temperature is increased to 145 °C?

First, assign values to the variables in the equation

V_1 = 65 mL

T_1 = 25 °C + 273.15 = 298.15 K

V_2 = ?

T_2 =145 °C + 273.15 = 418.15 K

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

$$V_1 * T_2 = T_1 * V_2$$

$$(65)(418.15) = (298.15) * V_2$$

$$V_2 = 92 \text{ mL}$$

1. A 5.0 L sample of I_2 is generated at STP. If the pressure remains constant, what temperature is needed to double the volume? Report your answer in both Kelvin and Celsius.

V_1 =

T_1 =

V_2 =

T_2 =

2. Ellie Ment is riding a hot air balloon at the local summer festival. Initially, the air inside of the balloon has a volume of 2000. L and a temperature of 27°C. A gust of wind carries the balloon to a higher elevation where the temperature of the balloon's air changes to 60°C. What is the volume of the balloon at this temperature?

V_1 =

T_1 =

V_2 =

T_2 =

Part 2: Avogadro's Law Problems Show all work as you solve these problems.

Example: A 375 mL can of soda contains 0.050 mole of CO_2 gas as carbonation. How many moles of CO_2 would be in a 2.0 L bottle of soda under the same temperature and pressure?

First, assign values to the variables in the equation

V_1 = 375 mL =0.375 L

n_1 = 0.050 mol

V_2 = 2.0

n_2 =?

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

$$V_1 * n_2 = n_1 * V_2$$

$$(0.375) * n_2 = (0.050) * (2.0)$$

$$n_2 = 0.27 \text{ mol}$$

1. A flexible fuel tank contains 14.4 mol of a gas that has an initial volume of 10.0 L. More gas is added, and the final volume of the gas is 27.5 L even while keeping the temperature and pressure constant. How many moles of gas were added to the fuel tank?

V_1 =

n_1 =

V_2 =

n_2 =

2. Earl E. Bird arrives to help set up his friend's birthday party. Earl's job is to fill the birthday balloons with helium. Initially he adds 4.00 g of helium to fill a balloon to a volume of 0.98 L. What is the total mass of the helium in the balloon when Earl fills it to a volume of 2.0 L?

V_1 =

n_1 =

V_2 =

n_2 =

Gases and Gas Laws

Part 3: Combined Gas Law Problems Show all work as you solve these problems.

Example: A gas originally at a pressure of 5.0 atm and a temperature of 37°C changes to a volume of 34.2 liters when conditions change to 2.5 atm and 10°C. What was its original volume?

First, assign values to the variables in the equation

P_1 =5.0 atm

V_1 = ?

T_1 = 37 °C + 273.15 = 310.15 K

P_2 = 2.5 atm

V_2 = 34.2 L

T_2 =10 °C + 273.15 = 283.15 K

$$\frac{P_1 \cdot V_1}{T_1} = \frac{P_2 \cdot V_2}{T_2}$$

$$P_1 * V_1 * T_2 = T_1 * P_2 * V_2$$

$$(5) * V_1 * (283.15) = (310.15) * (2.5) * (34.2)$$

$$V_1 = 18.7 \text{ L}$$

1. 23 Liters of nitrogen has a pressure of 120 kPa at a temperature of 200 K. What is the new volume of the nitrogen gas if the pressure is raised to 240 kPa and the temperature is increased to 300 K?

P_1 =

V_1 =

T_1 =

P_2 =

V_2 =

T_2 =

2. A piston contains one mole of water vapor. The initial volume is 840 mL at a pressure of 3.4 atm and a temperature of 20°C. If the piston is heated to 75°C and the volume expands to 1.2 Liters, what is the new pressure inside of the piston?

V_1 =

T_1 =

P_2 =

V_2 =

T_2 =

3. The pressure of 12.0 L of nitrous oxide contained in a flexible container is decreased to one-third of its original pressure and its Kelvin temperature is decreased by one-half. What is the new volume of this gas?

P_1 =

V_1 =

T_1 =

P_2 =

V_2 =

T_2 =