Charles' Law

Charles' Law states that the volume of a gas varies directly with the Kelvin temperature, assuming that pressure is constant. We use the following formulas:

$$\frac{V_1}{T_1} = \frac{V_2}{T_2} \quad \text{or} \quad V_1 \times T_2 = V_2 \times T_1$$

$$K = °C + 273$$

Solve the following problems assuming a constant pressure.

1. A sample of nitrogen occupies a volume of 250 mL at 25° C. What volume will it occupy at 95° C? 309 mL
2. Oxygen gas is at a temperature of 40° C when it occupies a volume of 2.3 liters. To what temperature should it be raised to occupy a volume of 6.5 liters? 611.6°C
3. Hydrogen gas was cooled from $1\bar{5}0$° C to $5\bar{0}$° C. Its new volume is 75 mL. What was its original volume? 98.2ml
4. Chlorine gas occupies a volume of 25 mL at $3\bar{0}0$ K. What volume will it occupy at 600 K? 50 ml
5. A sample of neon gas at $5\bar{0}$° C and a volume of 2.5 liters is cooled to 25° C. What is the new volume? 2.31 L
6. Fluorine gas at $30\bar{0}$ K occupies a volume of $50\bar{0}$ mL. To what temperature should it be lowered to bring the volume to $30\bar{0}$ mL? 180 K
7. Helium occupies a volume of 3.8 liters at -45° C. What volume will it occupy at 45° C? 5.3L
8. A sample of argon gas is cooled and its volume went from $38\bar{0}$ mL to $25\bar{0}$ mL. If its final temperature was -55° C, what was its original temperature? 58.4°C

Boyle's Law

Boyle's Law states that the volume of a gas varies inversely with its pressure if temperature is held constant. (If one goes up, the other goes down.) We use the formula:

$$P_1 \times V_1 = P_2 \times V_2$$

Solve the following problems (assuming constant temperature).

1. A sample of oxygen gas occupies a volume of 250. mL at 740. torr pressure. What volume will it occupy at 800. torr pressure? 231.3ml
2. A sample of carbon dioxide occupies a volume of 3.50 liters at 125 kPa pressure. What pressure would the gas exert if the volume was decreased to 2.00 liters? 291.7kPa
3. A 2.0 liter container of nitrogen had a pressure of 3.2 atm. What volume would be necessary to decrease the pressure to 1.0 atm? 6.4
4. Ammonia gas occupies a volume of 450. mL at a pressure of 720. mm Hg. What volume will it occupy at standard pressure? 426 ml
5. A 175 mL sample of neon had its pressure changed from 75 kPa to 150 kPa. What is its new volume? 87.5ml
6. A sample of hydrogen at 1.5 atm had its pressure decreased to 0.50 atm producing a new volume of 750 mL. What was its original volume? 250 ml
7. Chlorine gas occupies a volume of 1.2 liters at 720 torr pressure. What volume will it occupy at 1 atm pressure? 1.14 L
8. Fluorine gas exerts a pressure of 900. torr. When the pressure is changed to 1.50 atm, its volume is 250. mL. What was the original volume? 316.7ml

Dalton's Law of Partial Pressures

Dalton's Law says that the sum of the individual pressures of all the gases that make up a mixture is equal to the total pressure: $P_T = P_1 + P_2 + P_3 + \ldots$ The partial pressure of each gas is equal to the mole fraction of each gas x total pressure.

$$P_T = P_1 + P_2 + P_3 + \ldots \quad \text{or} \quad \frac{\text{moles gas}_x}{\text{total moles}} \times P_T = P_x$$

Solve the following problems.

1. A 250. mL sample of oxygen is collected over water at 25° C and 760.0 torr pressure. What is the pressure of the dry gas alone? (Vapor pressure of water at 25° C = 23.8 torr)
   $P_T = P_{O_2} + P_{H_2O}$ $P_{O_2} = 760 - 23.8$
   $P_{O_2} = P_T - P_{H_2O}$ $= 736.2$ torr
   736.2 torr
2. A 32.0 mL sample of hydrogen is collected over water at 20° C and 750.0 torr pressure. What is the volume of the dry gas at STP? (Vapor pressure of water at 20° C = 17.5 torr)
   $P_T = P_{H_2} + P_{H_2O}$ $P_{H_2} = 750 - 17.5 = 732.5$ torr $V_2 = \frac{P_1V_1T_2}{T_1P_2} = \frac{(732.5)(32)(273)}{(293)(760)}$
   $P_{H_2} = P_T - P_{H_2O}$
   28.7 ml
3. A 54.0 mL sample of oxygen is collected over water at 23° C and 770.0 torr pressure. What is the volume of the dry gas at STP? (Vapor pressure of water at 23° C = 21.1 torr)
   $P_{O_2} = P_T - P_{H_2O} = 770 - 21.1 = 748.9$ torr $V_2 = \frac{P_1V_1T_2}{T_1P_2} = \frac{(770)(54)(273)}{(296)(760)}$
   50.46 ml
4. A mixture of 2.00 moles of H_2, 3.00 moles of NH_3, 4.00 moles of CO_2 and 5.00 moles of N_2 exerts a total pressure of 800 torr. What is the partial pressure of each gas?
   $P_{H_2} = \frac{n_{H_2}}{n_{total}} \times P_T = \frac{2}{14}(800) = 114.3$ torr $P_{NH_3} = \frac{3}{14} \times 800 = 171.4$ torr $P_{CO_2} = \frac{4}{14} \times 800 = 228.6$ torr $P_{N_2} = \frac{5}{14} \times 800 = 285.7$ torr
5. The partial pressure of F_2 in a mixture of gases where the total pressure is 1.00 atm is 300. torr. What is the mole fraction of F_2?
   $300 \text{ torr} \times \frac{1 \text{ atm}}{760 \text{ torr}} = 0.395$ atm $\%F_2 = \frac{P_{F_2}}{P_T} \times 100 = \frac{0.395 \text{ atm}}{1.00 \text{ atm}} \times 100$
   = 39.5%

Combined Gas Law

In practical terms, it is often difficult to hold any of the variables constant. When there is a change in pressure, volume and temperature, the combined gas law is used.

$$\frac{P_1 \times V_1}{T_1} = \frac{P_2 \times V_2}{T_2} \quad \text{or} \quad P_1V_1T_2 = P_2V_2T_1$$

Complete the following chart.

	P_1	V_1	T_1	P_2	V_2	T_2
1	1.5 atm	3.0 L	20° C	2.5 atm	1.86L	30° C
2	720 torr	256 mL	25° C	799 torr	250 mL	50° C
3	600 mmHg	2.5 L	22° C	760 mmHg	1.8 L	-3.96°C
4	1.22atm	750 mL	0.0° C	2.0 atm	500 mL	25° C
5	95 kPa	4.0 L	295K 22°C	101 kPa	6.0 L	471 K or 198° C
6	650. torr	275ml	100° C	900. torr	225 mL	150° C
7	850 mmHg	1.5 L	15° C	537 torr	2.5 L	30° C
8	125 kPa	125 mL	271°C	100 kPa	100 mL	75° C