

Key!

Chapter 10: Gases

What Gas law has these conditions?

Boyle's Law: For a given mass of gas at a constant temperature, the volume of a gas varies inversely with pressure.

$$P_1 V_1 = P_2 V_2$$

(Constants: moles (n)
+
temperature (T))

Gay-Lussac's Law: The volume of a fixed mass of gas is directly proportional to its Kelvin temperature if the pressure is kept constant.

$$\frac{P_1}{T_1} = \frac{P_2}{T_2}$$

(Constants: moles (n)
+
volume (V))

Charles' Law: The volume of a fixed mass of a gas is directly proportional to its absolute temperature.

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

(Constants: moles (n)
+
Pressure (P))

Avogadro's Law: The volume of a gas at constant temperature and pressure is directly proportional to the number of moles of the gas.

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

(Constants: temperature (T)
+
Pressure (P))

What is the Combined Gas Law formula?

Boyle's + Charles' + Gay-Lussac's

$$\frac{P_1 V_1}{n_1 T_1} = \frac{P_2 V_2}{n_2 T_2}$$

What's the mole fraction of F_2 ? Given: $0.35 \text{ mol } F_2 + 0.25 \text{ mol } H_2 + 0.65 \text{ mol } CO_2 = 1.25 \text{ mol}$

$\frac{\text{Part}}{\text{Whole}}$

$\frac{0.35 \text{ mol } F_2}{1.25 \text{ mol}}$
symbol
for
mole fraction

$$= \frac{0.35 \text{ mol } F_2}{1.25 \text{ mol}} = \boxed{0.28}$$

no units!

Always convert °C to K!

A submarine with a volume of $1.2 \times 10^5 \text{ L}$ has an internal pressure of 1.0 atm and an internal temperature of 15°C . If the submarine descends to a depth where the pressure is 150 atm and the temperature is 3.0°C , what will the volume of the gas inside be if the hull of the submarine breaks?

$$\begin{aligned} V_1 &= 1.2 \times 10^5 \text{ L} \\ P_1 &= 1.0 \text{ atm} \\ T_1 &= 15^\circ \text{C} \\ P_2 &= 150 \text{ atm} \\ T_2 &= 3.0^\circ \text{C} \\ V_2 &= ? \end{aligned}$$

$$\begin{aligned} C + 273.15 &= K \\ T_1 &= 15^\circ \text{C} + 273.15 = 288.15 \text{ K} \\ T_2 &= 3.0^\circ \text{C} + 273.15 = 276.15 \text{ K} \end{aligned}$$

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

$$V_2 = \frac{P_1 V_1 T_2}{T_1 P_2} = \frac{(1.0 \text{ atm})(1.2 \times 10^5 \text{ L})(276.15 \text{ K})}{(288.15 \text{ K})(150 \text{ atm})}$$

$$= 766,684,0157 \text{ L}$$

$$V_2 = 7.7 \times 10^2 \text{ L}$$

sig figs!

At what temperature will 5.00 g of Cl_2 exert a pressure of 900. Torr at a volume of 750. mL? 3 sig figs

$$\begin{aligned} T &= ? \\ V &= 750 \text{ mL} \\ P &= 900 \text{ torr} \\ n &= 5.00 \text{ g Cl}_2 \end{aligned}$$

$$750 \text{ mL} \cdot \frac{1 \text{ L}}{1000 \text{ mL}} = 0.750 \text{ L}$$

$$900 \text{ torr} \cdot \frac{1.0 \text{ atm}}{760 \text{ torr}} = 1.18 \text{ atm}$$

$$R = (0.0821 \frac{\text{atm} \cdot \text{L}}{\text{mol} \cdot \text{K}})$$

$$5.00 \text{ g Cl}_2 \cdot \frac{1 \text{ mol}}{70.9 \text{ g Cl}_2} = 0.0705 \text{ mol}$$

Ideal Gas Law

$$PV = nRT$$

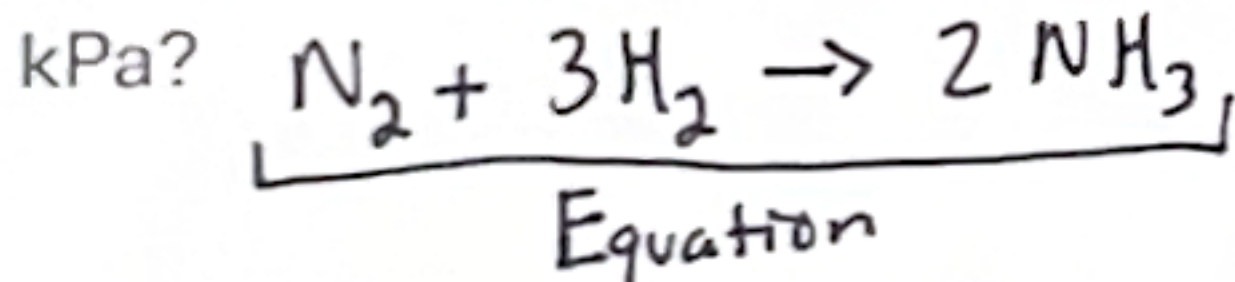
↓
constant

$$T = \frac{PV}{nR} = \frac{(1.18 \text{ atm})(0.750 \text{ L})}{(0.0705 \text{ mol})(0.0821 \frac{\text{atm} \cdot \text{L}}{\text{mol} \cdot \text{K}})}$$

$$= 152.901$$

$$T = 152 \text{ K}$$

Ammonia is often formed by reacting nitrogen and hydrogen gases. How many liters of ammonia gas can be formed from 24.5 L of hydrogen gas at 93.0°C and a pressure of 33.9 kPa?



$$V_{\text{NH}_3} = ?$$

$$V_{\text{Hydrogen}} = 24.5 \text{ L}$$

$$PV = nRT$$

* rearrange to find moles
* Plug in values with units

$$n = \frac{PV}{RT} = \frac{(0.335 \text{ atm})(24.5 \text{ L})}{(0.0821 \frac{\text{atm} \cdot \text{L}}{\text{mol} \cdot \text{K}})(366.15 \text{ K})}$$

$$n = 0.273 \text{ mol H}_2$$

$$\begin{aligned} T &= 93.0^\circ \text{C} + 273.15 = 366.15 \text{ K} \\ P &= 33.9 \text{ kPa} \cdot \frac{1 \text{ atm}}{101.3 \text{ kPa}} = 0.335 \text{ atm} \end{aligned}$$

$$0.273 \text{ mol H}_2 \cdot \frac{2 \text{ mol NH}_3}{3 \text{ mol H}_2} \cdot \frac{22.4 \text{ L}}{1 \text{ mol NH}_3} = 4.0768 \rightarrow 4.08 \text{ L NH}_3$$

(STP) * got from Mole roadmap

Empirical formula: % changes to decimal

A container with two gases, helium and argon, is 30.0% helium. Calculate the partial pressure of helium and argon if the total pressure inside the container is 4.00 atm

$$P_{\text{total}} = P_{\text{gas}} + P_{\text{gas}} + P_{\text{gas}} \dots$$

$$4.00 \text{ atm} \times 0.30 = 1.2 \text{ He}$$

$$\text{He} = 1.2 \text{ partial pressure}$$

$$\text{Ar} = (4.00 \text{ atm} - 1.2 \text{ atm})$$

$$\text{Ar} = 2.8 \text{ partial pressure}$$

% = out of hundred

$$n_{\text{He}} = 30.0\% \rightarrow 0.30 \text{ mol He}$$

$$n_{\text{Ar}} = 70.0\% \rightarrow 0.70 \text{ mol Ar}$$

solve this way

solve this way

$$P_{\text{He}} = \left(\frac{0.30 \text{ mol}}{1 \text{ mol}} \right) (4.00 \text{ atm}) = 1.20 \text{ atm He}$$

$$P_{\text{Ar}} = \left(\frac{0.70 \text{ mol}}{1 \text{ mol}} \right) (4.00 \text{ atm}) = 2.8 \text{ atm Ar}$$

A sample of nitrogen gas (N_2) is contained in a 5.00 L container at a temperature of 300 K and a pressure of 2.00 atm. Calculate the density of the nitrogen gas.

$$mm = \frac{dRT}{P}$$

*rearrange formula

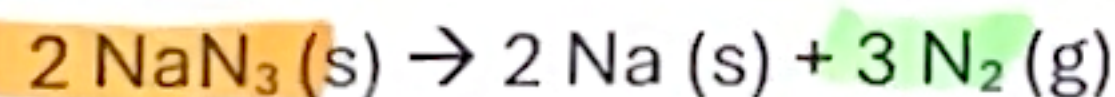
$$d = \frac{P \cdot mm}{RT}$$

$$mm \cdot \text{N}_2 = 14.007 \times 2 = 28.014 \text{ g/mol}$$

$$d = \frac{(2.00 \text{ atm})(28.014 \text{ g/mol})}{(0.0821 \frac{\text{atm} \cdot \text{L}}{\text{mol} \cdot \text{K}})(300 \text{ K})}$$

$$d = 2.27 \text{ g/L}$$

Automobile air bags are inflated by nitrogen gas generated by the rapid decomposition of sodium azide, NaN_3 :



If an air bag has a volume of 36 L and is to be filled with nitrogen gas at 1.15 atm and 26.0°C, how many grams of NaN_3 must be decomposed?

$$PV = nRT$$

$$n_{\text{N}_2} = \frac{PV}{RT} = \frac{(1.15 \text{ atm})(36 \text{ L})}{(0.0821 \frac{\text{atm} \cdot \text{L}}{\text{mol} \cdot \text{K}})(299.15 \text{ K})}$$

$$= 1.69 \text{ mol N}_2 \quad \text{sig figs}$$

$$= 1.7 \text{ mol N}_2 \cdot \frac{2 \text{ mol NaN}_3}{3 \text{ mol N}_2} \cdot \frac{65.01 \text{ g NaN}_3}{1 \text{ mol NaN}_3} = 73.67 \text{ g} \rightarrow 74 \text{ g NaN}_3 \quad \text{sig figs}$$