A Partial Pressure and Stoichiometry Problems

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Partial Pressure Problem

A Sample of zinc metal reacts completely with hydrochloric acid:

$$Zn(s) + 2HCl(aq) \rightarrow ZnCl_2(aq) + H_2(g)$$

The hydrogen gas is collected over water at 25^{o}C. The gas volume is found to be 7.80L and the atmospheric pressure is 0.980atm. Calculate the mass of zinc metal that reacted.

Partial Pressure Problem

A Sample of zinc metal reacts completely with hydrochloric acid:

$$Zn(s) + 2HCl(aq) \rightarrow ZnCl_2(aq) + H_2(g)$$

$$\text{Moles } H_2 \rightarrow \text{Moles Zn}$$

$$\text{Moles Zn} \rightarrow \text{Mass Zn}$$

Partial Pressure Problem

A Sample of zinc metal reacts completely with hydrochloric acid:

$$Zn(s) + 2HCl(aq) \rightarrow ZnCl_2(aq) + H_2(g)$$

298K

How do we get moles of H_2?

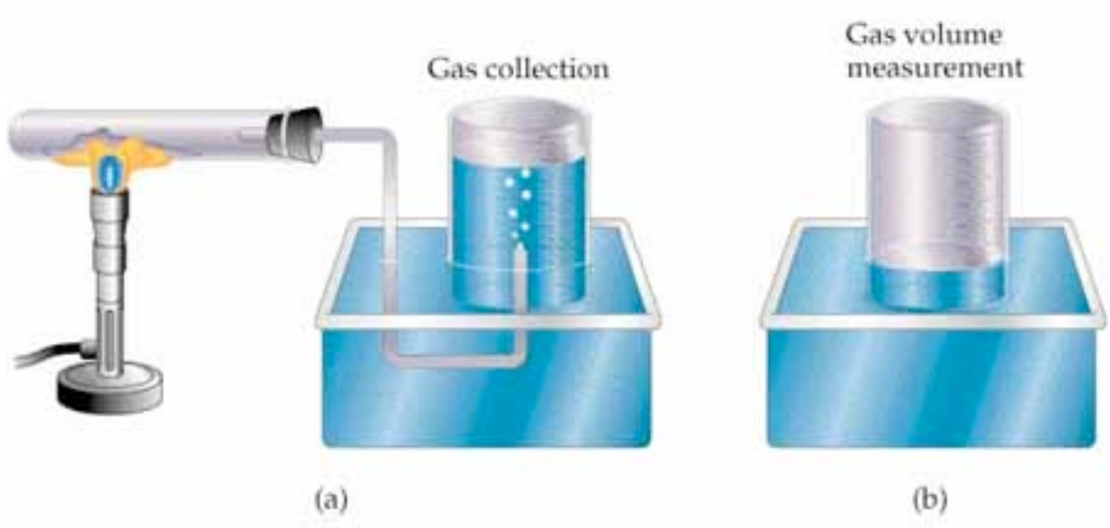
7.80L

PV=nRT

0.980atm

But first look at the experiment

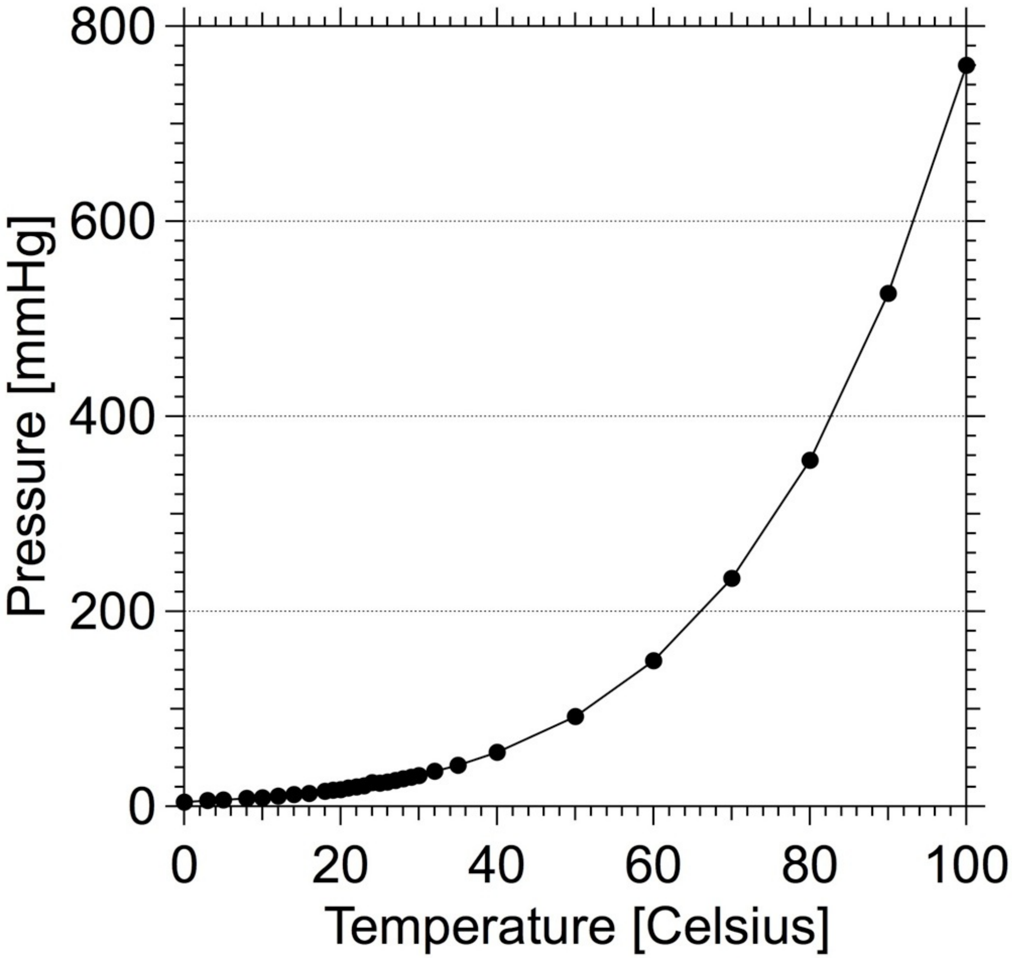
Partial Pressure Problem



Gas is collected over water so that the atmosphere is not present. Water levels made equal so pressure inside is equal to that outside

But is the pressure inside due to hydrogen gas only?

Vapor Pressure Curve for Water



At 25°C:

P_{H2O} = 23.8mmHg

Or

P_{H2O} = 0.0313atm

Partial Pressure Problem

A Sample of zinc metal reacts completely with hydrochloric acid:

$$Zn(s) + 2HCl(aq) \rightarrow ZnCl_2(aq) + H_2(g)$$

298K

7.80L

$P_{H2} = 0.980atm - 0.313atm$

$P_{H2} = 0.949atm$

Partial Pressure Problem

A Sample of zinc metal reacts completely with hydrochloric acid:

$$Zn(s) + 2HCl(aq) \rightarrow ZnCl_2(aq) + H_2(g)$$

$\mathbf{P_{H2}V=n_{H2}RT}$ $T = 298K$ $V = 7.80L$

$P_{H2} = 0.949atm$ $R = 0.08206 \frac{L \bullet atm}{K \bullet mol}$

$$(0.949)(7.80)=n(0.08206)(298)$$

$$n_{H2} = 0.303moles$$

Partial Pressure Problem

A Sample of zinc metal reacts completely with hydrochloric acid:

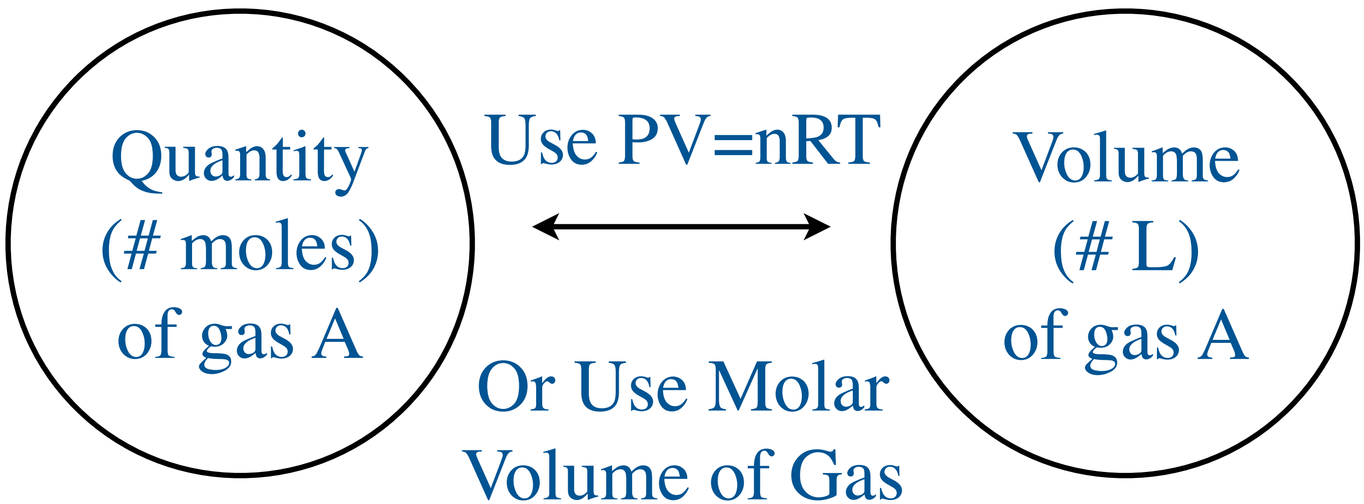
$$Zn(s) + 2HCl(aq) \rightarrow ZnCl_2(aq) + H_2(g)$$

0.303mol

$$0.303 \text{ mol } H_2 \left(\frac{1 \text{ mol Zn}}{1 \text{ mol } H_2}\right)\left(\frac{65.39\text{g Zn}}{1 \text{ mol Zn}}\right) = 19.8\text{g Zn}$$

Stoichiometry with Gases

Moles and Volumes of Gas



At STP, 1 mol of a gas has a volume of 22.4L

If you know the molar volume at other pressure and temperature conditions then you can use that.

Stoichiometry Problem With 2 Gases

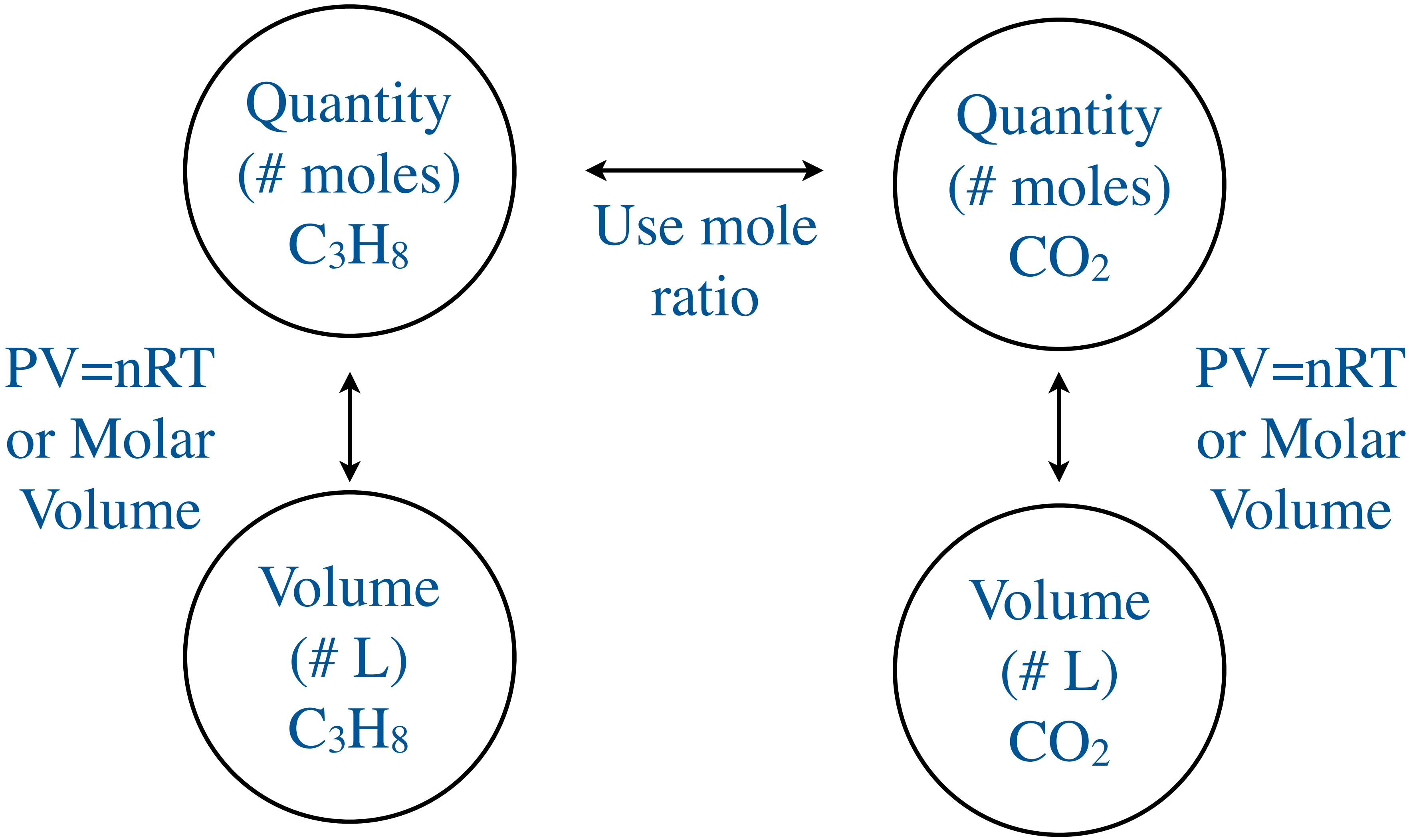
For example: The combustion of propane

$$C_3H_8(g) + 10O_2(g) \rightarrow 3CO_2(g) + 4H_2O(g)$$

What volume of carbon dioxide is produced at STP if 0.500L of propane at 50.0psi and 25.0^{o}C is combusted?

Combustion of Propane

$C_3H_8(g) + 10O_2(g) \rightarrow 3CO_2(g) + 4H_2O(g)$



Combustion of Propane

Volume → moles of propane: PV=nRT

$$C_3H_8(g) + 10O_2(g) \rightarrow 3CO_2(g) + 4H_2O(g)$$

25.0^{o}C

0.500L

50.0psi

$T_{prop} = 298K$ $V_{prop} = 0.500L$ $P_{prop} = 3.40atm$

$n_{prop} = PV/RT = 0.0695mol$

Combustion of Propane

Moles Propane → Moles Carbon dioxide

$$C_3H_8(g) \ + \ 10O_2(g) \ \rightarrow \ 3CO_2(g) \ + \ 4H_2O(g)$$

$n_{prop} = 0.0695 mol$

$$0.0695 \ \cancel{\text{mol } C_3}H_8 \left(\frac{3 \text{ mol } CO_2}{1 \ \cancel{\text{mol } C_3}H_8} \right) = 0.209 \text{ mol } CO_2$$

Combustion of Propane

Volume → moles of carbon dioxide:

$$C_3H_8(g) + 10O_2(g) \rightarrow 3CO_2(g) + 4H_2O(g)$$

$$n_{CO2} = 0.209\text{mol}$$

$$T = 273\text{K}$$

STP

$$P = 1.00\text{atm}$$

Could use PV = nRT:

$$T = 273\text{K}$$

$$n = 0.209\text{mol}$$

$$P = 1.00\text{atm}$$

Combustion of Propane

Volume → moles of carbon dioxide:

$$C_3H_8(g) + 10O_2(g) \rightarrow 3CO_2(g) + 4H_2O(g)$$

$$n_{CO2} = 0.209\text{mol}$$

Could also use the molar volume at STP (22.4L/mol):

$$0.209 \text{ mol } CO_2 \left(\frac{22.4 \text{ L } CO_2}{1 \text{ mol } CO_2} \right) = 4.68 \text{ L } CO_2$$

Volume Ratios of Gases

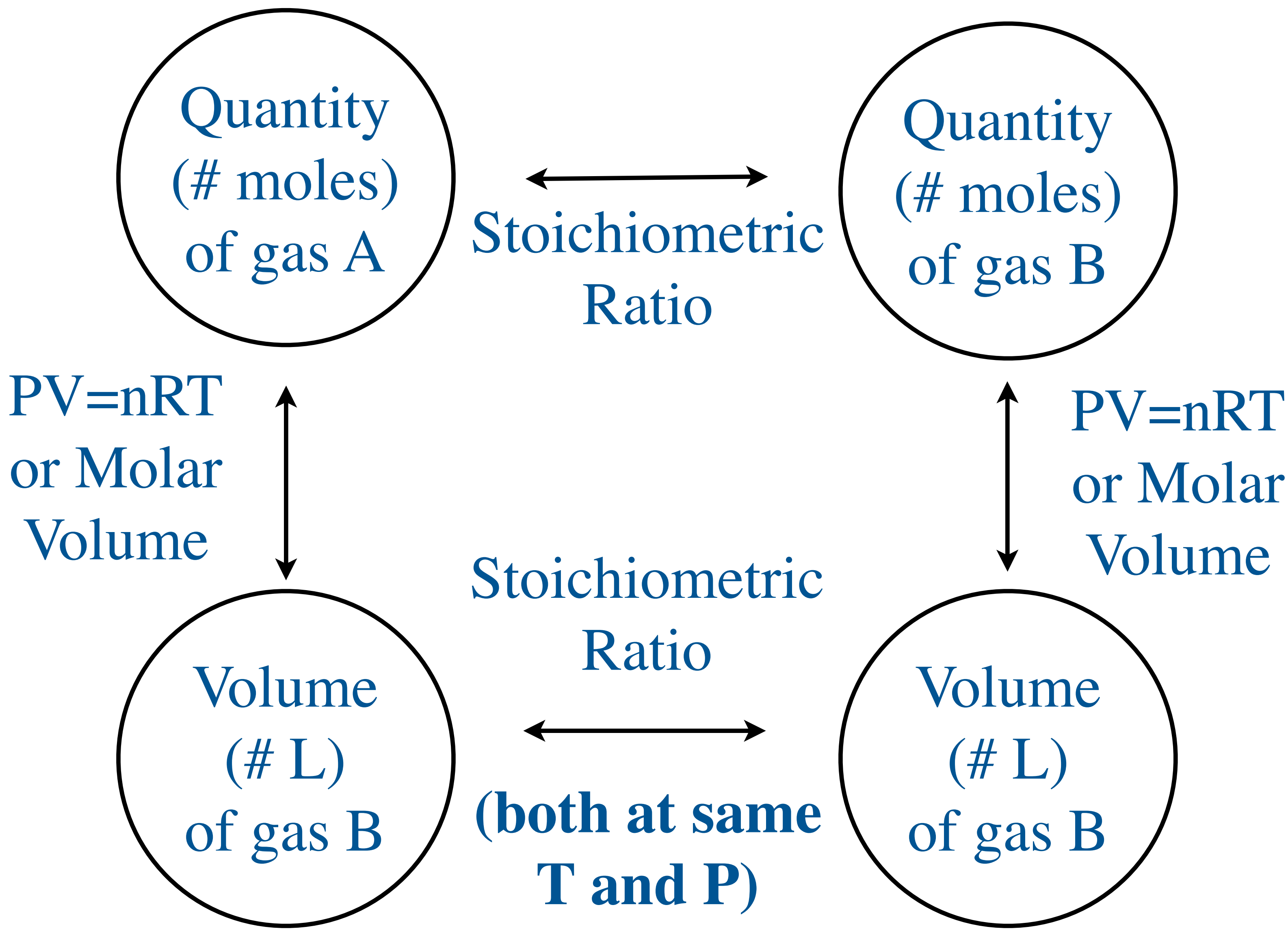
The stoichiometric ratio applies to gas volumes if the gases are at the same temperature and pressure. This is the law of Guy-Lusaac.

$$C_3H_8(g) + 10O_2(g) \rightarrow 3CO_2(g) + 4H_2O(g)$$

What volume of carbon dioxide gas at STP is produced if 0.500L (measured at STP) of propane are combusted?

$$0.500 \cancel{\text{L } C_3H_8} \left(\frac{3 \text{ L } CO_2}{1 \text{ L } \cancel{C_3H_8}} \right) = 1.50 \text{ L } CO_2$$

Volume Ratios of Gases



Volume Ratios of Gases

Back to this problem: The combustion of propane

$$C_3H_8(g) + 10O_2(g) \rightarrow 3CO_2(g) + 4H_2O(g)$$

What volume of carbon dioxide is produced at STP if 0.500L of propane at 50.0psi and 25.0^{o}C is combusted?

Can we use volume ratios instead of mole ratios?

Volume Ratios of Gases

Back to this problem: The combustion of propane

$$C_3H_8(g) + 10O_2(g) \rightarrow 3CO_2(g) + 4H_2O(g)$$

298K	273K
3.40atm	1atm
0.500L	V=?

Can we use volume ratios instead of mole ratios?

Yes - first calculate volume of propane if at STP!

Volume Ratios of Gases

Volume (298K, 3.40atm) → Volume (STP) of propane:

$$\frac{P_1V_1}{n_1T_1} = \frac{P_2V_2}{n_2T_2}$$

For propane:

$T_1 = 298K$ $P_1 = 3.40atm$

$T_2 = 273K$ $P_2 = 1atm$

$V_1 = 0.500L$

$n_1 = n_2$

$V_2 = ??$

$$\frac{(3.40atm)(0.500L)}{298K} = \frac{(1atm)V_2}{273K}$$

$V_2 = 1.56L$

Volume Ratios of Gases

Volume propane (STP) → Volume CO_2 (STP):

$$C_3H_8(g) + 10O_2(g) \rightarrow 3CO_2(g) + 4H_2O(g)$$

1.55L
STP

V=??
STP

$$1.56 \text{ L } \cancel{C_3H_8}\left(\frac{3 \text{ L } CO_2}{1 \text{ L } \cancel{C_3H_8}}\right) = 4.68 \text{ L } CO_2$$