The Law of Combining Volumes

- The ***law of combining volumes*** states that, when gases react, the volumes of the gaseous reactants and products, measured at constant temperature and pressure, are always in whole number ratios
- The law of combining volumes is also closely related to *Avogadro's law*
  - ***Avogadro's gas law*** states the volume of a gas is proportional to the number of moles of gas present when temperature and pressure are held constant.
  - Avogadro's law is used to determine the volume of a gas when more gas is added to the system or when gases are mixed together to undergo a reaction
    - To use Avogadro's gas law to determine the volume of a gas, the initial volume is simply multiplied by a ratio that compares the moles of the gas we want to find to the moles of the gas that we already have
      - We call this a "want over have" ratio

↳ $V_f = V_i\left(\frac{n_{want}}{n_{have}}\right)$

EXAMPLES:

1. A 6.0 L sample of methane gas at 25 °C and 2.00 atm of pressure contains 0.50 moles of a methane. If an additional 0.25 moles of methane gas at the same pressure and temperature are added, what is the final total volume of the methane gas?

$V_i = 6.0L$

$V_f = ?$

$n_{have} = 0.50\,mol$

$n_{want} = 0.50\,mol + 0.25\,mol$

$n_{want} = 0.75\,mol$

$V_f = (6.0L)\left(\frac{0.75mol}{0.50mol}\right)$

$\boxed{V_f = 9.0L}$

2. Sample #1 contains 2.98 moles of hydrogen at 35.1 degrees C and 2.3atm in a 32.8 L container. How many moles of hydrogen are in a 45.3 liter container under the same conditions?

$V_i = 32.8L$

$V_f = 45.3L$

$n_{have} = 2.98\,mol$

$n_{want} = ?$

$V_f = V_i\left(\frac{n_{want}}{n_{have}}\right)$

$n_{want} = \frac{V_f n_{have}}{V_i} = \frac{(45.3L)(2.98mol)}{32.8L}$

$n_{want} = 4.11567\ldots\,mol$

$\boxed{n_{want} = 4.12mol}$

* • When comparing volumes of gases involved in a chemical reaction, it is crucial to start with the balanced chemical reaction because the balancing coefficients are a representation of the moles

EXAMPLES:

1. Calculate the volume of oxygen required for the complete combustion of 120mL of butane ($C_4H_{10(g)}$) as shown by the following chemical reaction.

"have" "want"

$2\ C_4H_{10(g)} + 13\ O_{2(g)} \rightarrow 8\ CO_{2(g)} + 10\ H_2O_{(g)}$

$V = 120mL \quad V = ?$

$$120mL \times \left(\frac{13}{2}\right) = \boxed{780mL} \leftarrow V_{O_2}$$

↑ #'s from balancing coefficients

2. What volume of nitrogen is used if 100mL of ammonia is formed from its elements in a formation reaction? → NH_3

$N_{2(g)} + 3H_{2(g)} \longrightarrow 2\ NH_{3(g)}$

"want" "have"

$V = ?$ $V = 100mL$

$$100mL \times \left(\frac{1}{2}\right) = \boxed{50.0mL} \leftarrow V_{N_2}$$

↑ #'s from balanced equation

*****Now try Practice Problems #1-7*****

Practice Problems

1. Say you have 5.00 L of a gas which contains 0.965 mol of molecules. What will be the new volume of the gas if the quantity is increased to 1.80 mol, assuming pressure and temperature are held constant?

2. A 25.5 liter balloon holding 3.5 moles of carbon dioxide leaks. If we are able to determine that 1.9 moles of carbon dioxide escaped before the container could be sealed, what is the new volume of the container?

3. Sally adds 3.13 moles of argon to a 5.29 liter balloon that already contained 2.51 moles of argon. What is the volume of the balloon after the addition of the extra gas?

4. What volume of water vapour forms when 250mL of hydrogen gas combines with 125mL of gas oxygen according to the following equation?

$$2H_{2(g)} + O_{2(g)} \rightarrow 2H_2O_{(g)}$$

5. What volume of nitrogen gas forms when the decomposition of ammonia gas produces 15mL of hydrogen gas?

$$2NH_{3(g)} \rightarrow N_{2(g)} + 3H_{2(g)}$$

6. Hydrogen gas ($H_{2(g)}$) combines with chlorine gas ($Cl_{2(g)}$) to form hydrogen chloride gas ($HCl_{(g)}$). What volume of hydrogen gas is required to produce 6.0L of hydrogen chloride gas?

7. A chemist performed an experiment and determined that 125mL of nitrogen gas reacted with 250mL of oxygen gas and formed 250mL of nitrogen dioxide gas. What volume of nitrogen dioxide gas is formed when 350mL of nitrogen gas reacts with an excess of oxygen gas?

Answers:

1. 9.33 L
2. 12 L
3. 11.9 L
4. 250 mL
5. 5.0 mL
6. 3.0 L
7. 700 mL