Gas Stoichiometry

Read from **Lesson 3: Gas Stoichiometry** in the **Chemistry Tutorial Section, Chapter 10** of **The Physics Classroom**:

Part a: Stoichiometry Revisited Part b: Gas Stoichiometry at Standard Conditions

Part c: Gas Stoichiometry at Non-Standard Conditions

Chemistry students study the relationship between gases and their behavior under various conditions of temperature and pressure. By combining gas laws with stoichiometry, they can solve problems involving gas reactions, such as calculating the volume of gas produced or consumed in a chemical reaction. Coefficients in chemical equations indicate molar amounts, mole ratios, and volume ratios. Volumes can be compared ONLY if all gases are measured at the same temperature and pressure. While stoichiometry establishes the relationship between the quantities of reactants and products in a balanced equation, the ideal gas law and other gas laws link these quantities to the physical properties of gases.

Solving Gas Stoichiometry Problems

A methodical approach is so important in chemistry problem-solving! The process should always be as *slow* as necessary to ensure accuracy and understanding.

1. **Use Paper and a Plan** – Chemistry problems aren't mental math. Write everything down. Your calculator is only useful when you have a clear strategy.
2. **Develop a Solution Strategy** – Use tools like Mole Island to map out your steps. Determine how many steps are needed and what information is required at each stage.
3. **Set Up Conversion Factors Correctly** – Place units first so they cancel properly. Only plug in numbers once you know where they belong. Use your calculator last.
4. **Approach PV = nRT Methodically** – List known values, rearrange the equation, substitute, then solve. The calculator is only for the final step.

Strategizing may seem time-consuming at first, but with practice, it becomes second nature.

Example 1: Aluminum metal reacts with fluorine gas to produce aluminum fluoride. What volume of F_2 (at STP) is required to make 16.4 g of aluminum fluoride?

Answer: Write the balanced equation. Then use the Mole Island (with molar volume of 22.4 L at STP) to set up a solution.

$$2\ Al\ (s) + 3\ F_2\ (g) \rightarrow 2\ AlF_3\ (s)$$

$$16.4\ g\ AlF_3 \bullet \frac{1\ mol\ AlF_3}{83.98\ g\ AlF_3} \bullet \frac{3\ mol\ F_2}{2\ mol\ AlF_3} \bullet \frac{22.4\ L\ F_2}{1\ mol\ F_2} = \boxed{6.56\ L\ F_2}$$

Example 2: Aluminum metal reacts with fluorine gas to produce aluminum fluoride. What volume of F_2 is needed to react with 56.3 g aluminum at 25°C and 0.937 atm?

Answer: Write the balanced equation. $\mathbf{2\ Al\ (s) + 3\ F_2\ (g) \rightarrow 2\ AlF_3\ (s)}$

Then use the Mole Island to do the stoichiometry part and find moles of F_2 needed:

$$56.3\ g\ Al \bullet \frac{1\ mol\ Al}{26.98\ g\ Al} \bullet \frac{3\ mol\ F_2}{2\ mol\ Al} = 3.13\ mol\ F_2$$

Now use the ideal gas equation to find the volume of F_2 at 25°C and 0.937 atm.

P = 0.937 atm

V = ?

n = 3.13 mol F_2

T =25°C + 273.15 = 298.15 K

R = 0.08206 L•*atm*/mol/K since P is in atm.

$$PV = nRT$$

$$(0.937)^* V = (3.13)(0.08206)(298.15)$$

$$V = 81.7\ L$$

Gases and Gas Laws

Gas Stoichiometry Problems

Solve the following problems using the method described above. Remember to balance all equations before you do any stoichiometry math. And please show your work on a separate piece of paper.

1. Sulfurous acid (H_2SO_3) is formed when sulfur dioxide gas reacts with water. To produce 164 g of sulfurous acid at STP, how many liters of sulfur dioxide gas are needed?

2. 256 g of ammonium nitrite decomposes into nitrogen gas and water vapor. If this reaction occurs at STP, what is the total number of liters of products formed? (Hint: calculate the volume of both products!)

3. Difluoromethane, CH_2F_2 (g), is used in refrigeration and air conditioning. It is produced from chlorofluorocarbon and hydrogen: CCl_2F_2 (g) + H_2 (g) → CH_2F_2 (g) + HCl (g) If 50 L of CCl_2F_2 and 50 L of H_2 react at STP, what volume of CH_2F_2 will be produced? (Hint: this is a gas limiting reactant problem.)

4. Earl N. Meyer is working in the chem lab. He heats 10.0 g of calcium carbonate, and it decomposes into solid calcium oxide and carbon dioxide gas. The 1.00 L flask containing the reaction is sealed. What is the pressure of the carbon dioxide in the flask if the reaction occurred at 22°C?

5. Blaze Bolt, the record-breaking cross-country runner oxidizes a lot of glucose when she runs. What volume of oxygen does she need to oxidize the 14.0 g of glucose that she consumed when she ate a banana before her run? This reaction $C_6H_{12}O_6$ (aq) + O_2(g) → CO_2(g) + H_2O(l) will occur at 29°C and 100 kPa.

6. Saucy Sam is barbequing for his family. Using a propane grill, he prepares the perfect steak by combusting 50.6 g of C_3H_8 (the propane). If this combustion reaction occurred at 1.00 atm of pressure and 260°C, what volume of water vapor was produced in the combustion reaction?

7. Ellie Ment is making a type of "lava lamp" for a chemistry demonstration. She reacts sodium hydrogen carbonate with acetic acid in the following reaction:
$NaHCO_3$ (s) + $HC_2H_3O_2$ (aq) → $NaC_2H_3O_2$ (aq) + H_2O (l) + CO_2(g)
If Ellie wants to produce 500 mL of CO_2 gas at 25°C and 0.99 atm, how many grams of sodium hydrogen carbonate will she need?

8. Marsha Mellow is interested in the chemical reaction that occurs when air bags inflate. (Marsha is concerned about safety!) An airbag is inflated by the decomposition of sodium azide into nitrogen gas and sodium metal. NaN_3(s)→ Na (s) + N_2 (g) To produce 15.9 liters of nitrogen gas at 92.4 kPa and 30.0°C, how many grams of sodium azide must decompose?

9. Potassium chlorate is a key ingredient in fireworks as it acts as an oxidizer to support combustion. The decomposition of solid potassium chlorate produces solid potassium chloride and oxygen gas. What volume of oxygen gas could be generated from the decomposition of 180 g of potassium chlorate at 1.00 atm and 50°C?