Limiting Reagent & Percent Yields

9.4, 9.5

Getting Started

- Suppose a lemonade recipe calls for 1 cup sugar for every 6 lemons. You have 12 lemons + 3 cups sugar. Which ingredient is limiting the amount of lemonade that can be made, lemons or the sugar?

Objectives

- Describe the method for determining which of two reactants is a limiting reactant
- Calculate the amount in moles or mass in grams of a product, given the amounts in moles or masses in grams of two reactants, one of which is in excess
- Distinguish between theoretical yield, actual yield, and percent yield
- Calculate percent yield, given the actual yield and quantity of a reactant

Limiting Reagents

- Car companies and factories order parts in proportion to how they're are used to make their products.
- Ex. 4 wheels to each engine
- when chemicals are mixed together to undergo rxn, often mixed in stoichiometric quantities (exactly correct amount so all reactants "run out"/are used up at same time.

$$CH_4(g) + H_2O\,(g) \rightarrow 3H_2 + CO$$

- What mass H_2O is required to react exactly w/ 249g of methane? (How much H_2O will just use up all 249g methane?)

279

279.5

280 2.80×10^2

Limiting Reagents

- Means 249g methane mixed w/ 279g of H_2O both reactants run out at same point.
- But if 249g CH_4 mixed w/ 300g H_2O- CH_4 runs out first and water is in excess
  - Here quantities of products based on amount of methane present (once consumed no more products made)
  - Methane = limiting reactant/limiting reagent
- Limiting reactant/reagent: an insufficient quantity of any of the reactants will limit the amount of product that forms.
- Reactant not completely used up in rxn = excess reagent

Limiting Reagents

- In any problem when reactants not mixed in stoichiometric quantities- essential to determine which reactant is limiting to correctly calculate amounts of products formed.
- Can determine limiting reagent when comparing reactants in moles.

Practice

$$N_2 + 3H_2 \rightarrow 2NH_3$$

- Suppose 25.0 kg (2.50×10^4 g) of nitrogen gas and 5.00kg (5.00×10^3 g) of hydrogen gas are mixed and reacted to form ammonia. Calculate the mass of ammonia produced when this reaction is run to completion.

g NH_3 | mole ratio | molar mass

3.04×10^4 g N_2 | 2 mol NH_3 | 17.04 g NH_3

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1 mol N_2 | 1 mol NH_3

30,399.36

30,400 g NH_3

30.4 kg

Steps for Solving Stoichiometry Problems Involving Limiting Reagents

remember diatomic

1. Write and balance the equation for the reaction.
2. Convert know mass of reactants to moles.
3. Using the numbers of moles of reactants and the appropriate mole ratios, determine which reactant is limiting. (smaller #)
4. Using the amount of the limiting reactant and the appropriate mole ratios, compute the number of moles of the desired product.
5. Convert from moles of product to grams of product, using the molar mass (if required by problem)

Practice – Warm Up 4/4

- Nitrogen gas can be prepared by passing gaseous ammonia over solid copper(II)oxide at high temperatures. The other products of the reaction are solid copper and water vapor. How many grams of N_2 are formed when 18.1 g of NH_3 is reacted with 90.4 g of CuO?

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Quick LAB

Limiting Reagents

Purpose

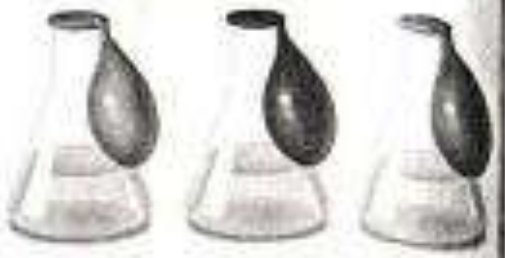
To illustrate the concept of a limiting reagent in a chemical reaction.

Materials

- graduated cylinder
- balance
- 3 250-mL Erlenmeyer flasks
- 3 rubber balloons
- 4.2 g magnesium ribbon
- 300 mL 1.0M hydrochloric acid

Procedure

1. Add 100 mL of the hydrochloric acid solution to each flask.
2. Weigh out 0.6 g, 1.2 g, and 2.4 g of magnesium ribbon, and place each sample into its own balloon.
3. Stretch the end of each balloon over the mouth of each flask. Do not allow the magnesium ribbon in the balloon to fall into the flask.
4. Magnesium reacts with hydrochloric acid to form hydrogen gas. When you mix the magnesium with the hydrochloric acid in the next step, you will generate a certain volume of hydrogen gas. How do you think the volume of hydrogen produced in each flask will compare?
5. Lift up on each balloon and shake the magnesium into each flask. Observe the volume of gas produced until the reaction in each flask is completed.



Analyze and Conclude

1. How did the volumes of hydrogen gas produced, as measured by the size of the balloons, compare? Did the results agree with your prediction?
2. Write a balanced equation for the reaction you observed.
3. The 100 mL of hydrochloric acid contained 0.10 mol HCl. Show by calculation why the balloon with 1.2 g Mg inflated to about twice the size of the balloon with 0.60 g Mg.
4. Show by calculation why the balloons with 1.2 g and 2.4 g Mg inflated to approximately the same volume. What was the limiting reagent when 2.4 g Mg was added to the acid?

Problems (Red Bk)

1. Copper reacts with sulfur to form copper(I) sulfide according to the following balanced equation. What is the limiting reagent when 80.0g Cu reacts with 25.0g S

   $2Cu(s) + S(s) \rightarrow Cu_2S(s)$

2. What is the maximum number of grams of Cu_2S that can be formed when 80.0g Cu reacts with 25.0g S?

   $2Cu(s) + S(s) \rightarrow Cu_2S(s)$

1. Percent Yield
    1. Theoretical yields: the maximum amount of product that can be produced from a given amount of reactant
        1. Product is often lost
            1. Side reactions
            2. Lost in purification process
    2. Actual yield: measured amount of a product obtained from a reaction
    3. Percent yield represents the efficiency of a reaction
        1. Ratio of the actual yield to the theoretical yield, multiplied by 100
        2. Percent yield = (actual yield / theoretical yield) X 100

Problem

What is the percent yield when the actual yield is 27.3 g and the theoretical yield is 44.6 g?

Huge quantities of sulfur dioxide are produced from zinc sulfide by means of the following reaction

$2ZnS + 3O_2 \rightarrow 2ZnO + 2SO_2$

If the typical yield is 86.78%, how much SO_2 should be expected if 4897 g of ZnS are used?