Name:______________________________Class: _________________ Date: _________________

Skills Worksheet

Sample Problem Set

Teacher Notes and Answers

LIMITING REACTANTS

1. $2ZnS + 3O_2 \rightarrow 2ZnO + 2SO_2$; ZnS is limiting
2. a. Al is limiting
   b. 4.25×10^{-3} mol Al_2O_3
   c. O_2 is limiting
3. a. CuS is limiting
   b. 15.6 g CuO
4. Fe is limiting; 0.158 mol Cu
5. 54 g $Ba(NO_3)_2$
6. a. 38 g Br_2
   b. 510 g I_2
7. a. Ni is in excess
   b. 60.2 g $Ni(NO_3)_2$
8. $CS_2(g) + 3O_2(g) \rightarrow 2SO_4(g) + CO_2(g)$
   0.80 mol O_2 remain
9. a. 0.84 g $Hg(NH_2)Cl$
   b. 0.84 g
10. a. $2Al(s) + 2NaOH(aq) + 2H_2O(l)$
    $\rightarrow 2NaAlO_2(aq) + 3H_2(g)$
    b. NaOH is limiting; 0.56 mol H_2
    c. Al should be limiting because you would not want aluminum metal remaining in the drain.
11. a. 0.0422 mol Cu; 0.169 mol HNO_3
    b. Cu is in excess
    c. 3.32 g H_2O
12. a. 2.90 mol NO;
    4.35 mol H_2O
    b. NH_3 is limiting
    c. NH_3 is limiting; 1.53×10^3kg NO
13. 565 g CH_3CHO;
    29 g CH_3CH_2OH remains
14. 630 g HBr
15. 12.7 g SO_2
16. a. 18.4 g Tb
    b. 2.4 g TbF_3

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Sample Problem Set

Limiting Reactants

At the beginning of Chapter 8, a comparison was made between solving stoichiometry problems and making turkey sandwiches. Look at the sandwich recipe once more:

2 bread slices + 2 turkey slices + 1 lettuce leaf + 1 cheese slice→ 1 turkey-and-cheese sandwich

If you have 24 slices of turkey, you can make 12 sandwiches at 2 slices per sandwich *if you have enough of all the other ingredients.* If, however, you have only 16 slices of bread, you can make only 8 sandwiches, even though you may an ample supply of the other ingredients. The bread is the *limiting* ingredient that prevents you from making more than 8 sandwiches.

The same idea applies to chemical reactions. Look at a reaction used to generate hydrogen gas in the laboratory:

$$Zn(s) + H_2SO_4(aq) \rightarrow ZnSO_4(aq) + H_2(g)$$

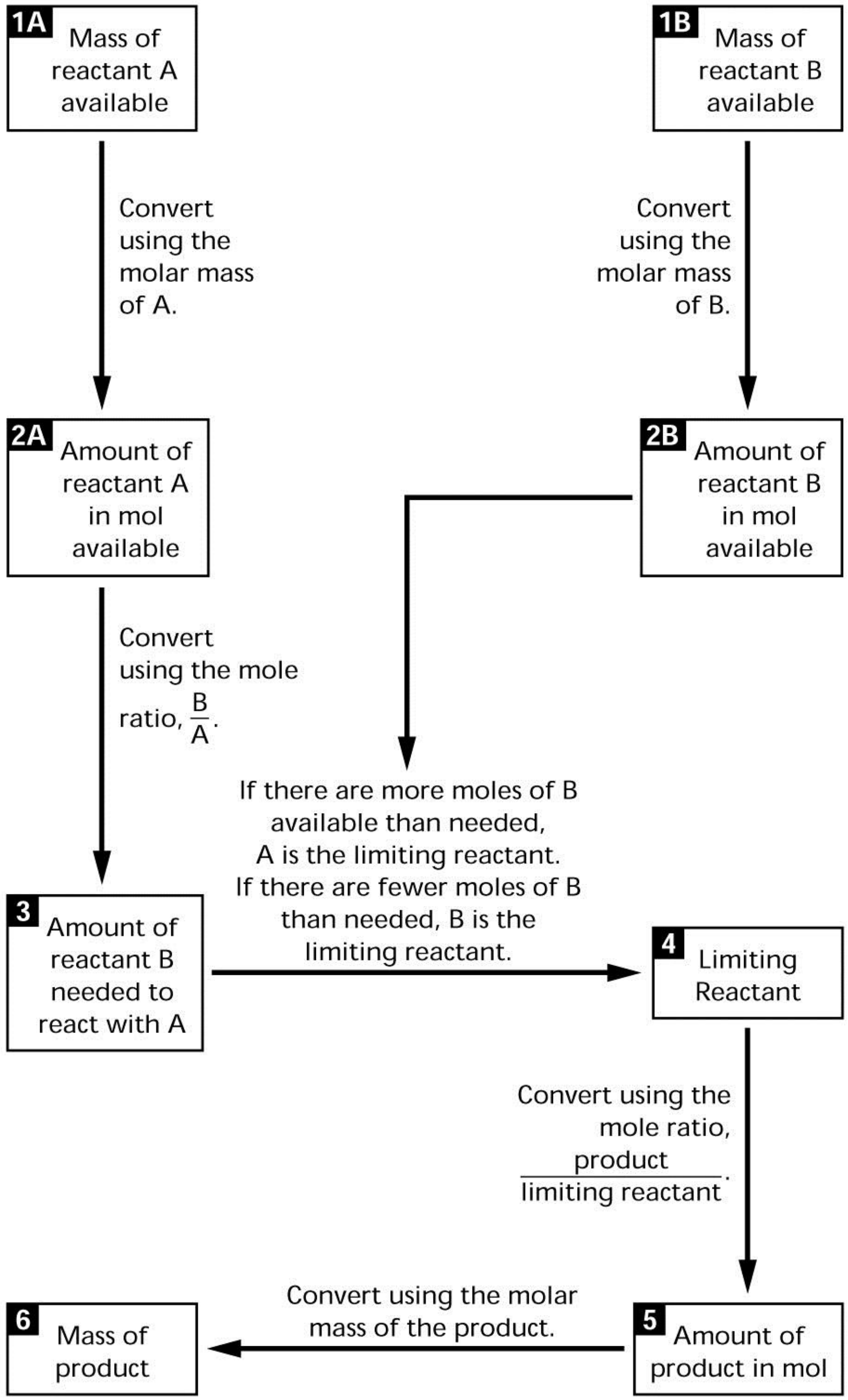
The balanced equation tells you that 1 mol Zn reacts with 1 mol H_2SO_4 to produce 1 mol $ZnSO_2$ and 1 mol H_2. Suppose you have 1 mol Zn and 5 mol H_2SO_4. What will happen, and what will you get? Only 1 mol of H_2SO_4 will react and only 1 mol of each of the products will be produced because only 1 mol Zn is available to react. In this situation, zinc is the limiting reactant. When it is used up the reaction stops even though more H_2SO_4 is available.

It is difficult to directly observe molar amounts of reactants as they are used up. It is much easier to determine when a certain mass of a reactant has been completely used. Use molar masses to restate the equation in terms of mass, as follows:

$$65.39 \text{ g Zn} + 98.09 \text{ g } H_2SO_4 \rightarrow 161.46 \text{ g } ZnSO_4 + 2.02 \text{ g } H_2$$

This version of the equation tells you that zinc and sulfuric acid will *always* react in a mass ratio of 65.39 g of Zn:98.09 g of H_2SO_4 or 0.667 g of Zn:1.000 g of H_2SO_4. If you have 65.39 g of Zn but only 87.55 g of H_2SO_4, you will not be able to make 2.02 g of hydrogen. Sulfuric acid will be the limiting reactant, preventing the zinc from reacting completely. Suppose you place 20 g of zinc and 100 g of sulfuric acid into a flask. Which would be used up first? In other words, is the limiting reactant zinc or sulfuric acid? How much of each product will be produced? The sample problems in this chapter will show you how to answer these questions.

Genaral Plan for Solving Limiting Reactant Problems



Sample Problem 1

Calcium hydroxide, used to neutralize acid spills, reacts with hydrochloric acid according to the following equation:

$$Ca(OH)_2 + 2HCl \rightarrow CaCl_2 + 2H_2O$$

If you have spilled 6.3 mol of HCl and put 2.8 mol of $Ca(OH)_2$ on it, which substance is the limiting reactant?

Solution

ANALYZE

What is given in the problem? **the balanced equation, the amounts of $Ca(OH)_2$ and HCl in moles**

What are you asked to find? **the limiting reactant**

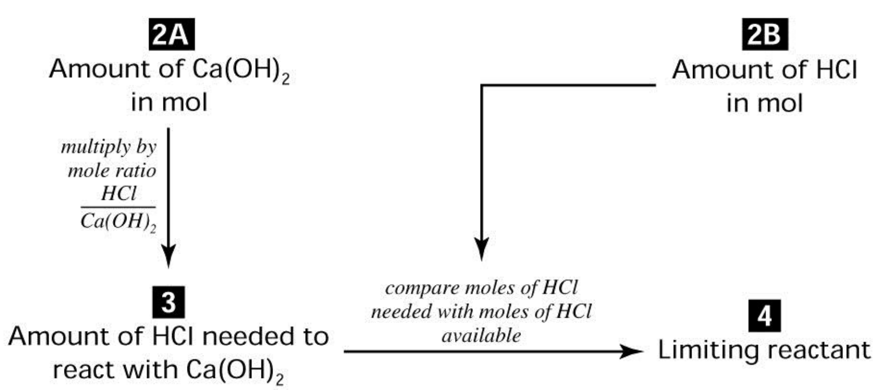
Items	**Data**	
Reactant	$Ca(OH)_2$	HCl
Coefficient in balanced equation	1	2
Molar mass	NA*	NA
Amount of reactant	2.8 mol	6.3 mol
Mass of reactant	NA	NA
Limiting reactant	?	?

*not applicable to the problem

PLAN

What steps are needed to determine the limiting reactant?

Choose one of the reactants. Use the mole ratio between the two reactants to compute the amount of the other reactant that would be needed to react with it. Compare that amount with the amount available.



Choose one of the reactants, for instance, $Ca(OH)_2$

$$\text{mol}\ \overset{\text{given}}{\text{Ca(OH)}_2} \times \overset{\textit{mole ratio}}{\frac{2\ \text{mol HCl}}{1\ \text{mol Ca(OH)}_2}} = \text{mol HCl needed}$$

COMPUTE

$$2.8\ \text{mol Ca(OH)}_2 \times \frac{2\ \text{mol HCl}}{1\ \text{mol Ca(OH)}_2} = 5.6\ \text{mol HCl needed}$$

The computation shows that more HCl (6.3 mol) is available than is needed (5.6 mol) to react with the 2.8 mol $Ca(OH)_2$ available. Therefore, HCl is present in excess, making $Ca(OH)_2$ the limiting reactant.

EVALUATE

Is the answer reasonable?
Yes; you can see that 6.3 mol HCl is more than is needed to react with 2.8 mol $Ca(OH)_2$.

Practice

1. Aluminum oxidizes according to the following equation:

$$4Al + 3O_2 \rightarrow 2Al_2O_3$$

Powdered Al (0.048 mol) is placed into a container containing 0.030 mol O_2. What is the limiting reactant? **ans: O_2**

Sample Problem 2

Chlorine can replace bromine in bromide compounds forming a chloride compound and elemental bromine. The following equation is an example of this reaction.

$$2KBr(aq) + Cl_2(aq) \rightarrow 2KCl(aq) + Br_2(l)$$

When 0.855 g of Cl_2 and 3.205 g of KBr are mixed in solution, which is the limiting reactant? How many grams of Br_2 are formed?

Solution

ANALYZE

What is given in the problem? **the balanced equation, and the masses of Cl2 and KBr available**

What are you asked to find? **which reactant is limiting, and the mass of Br2 produced**

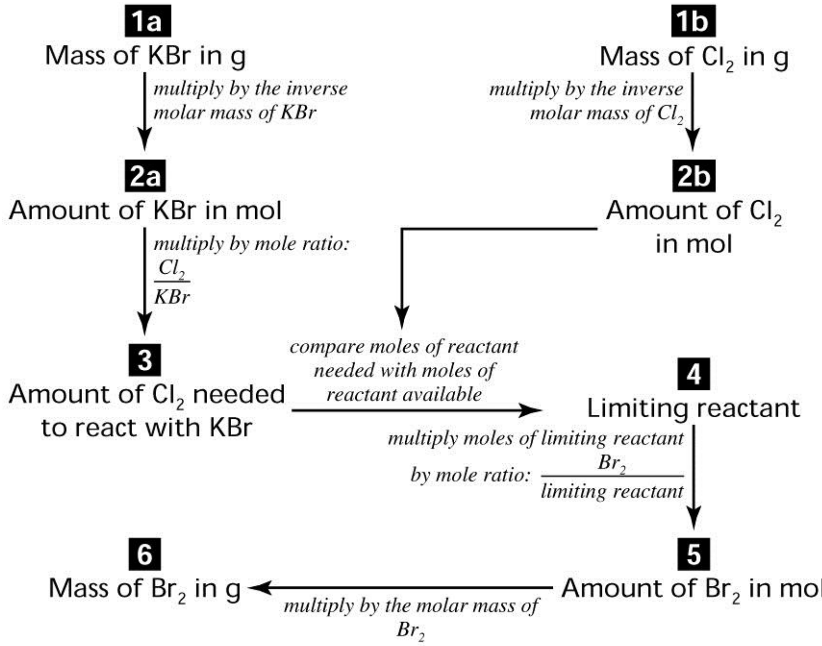
Items	**Data**		
Substance	KBr	Cl_2	Br_2
Coefficient in balanced equation	2	1	1
Molar mass*	119.00 g/mol	70.90 g/mol	159.80 g/mol
Amount of substance	? mol	? mol	? mol
Mass of substance	3.205 g	0.855 g	? g
Limiting reactant	?	?	NA

*determined from the periodic table

PLAN

What steps are needed to determine the limiting reactant?
Convert mass of each reactant to amount in moles. Choose one of the reactants. Compute the amount of the other reactant needed. Compare that with the amount available.

What steps are needed to determine the mass of Br_2 produced in the reaction?
Use amount of the limiting reactant and the mole ratio given in the equation to determine the amount of Br_2. Convert the amount of Br_2 to the mass of Br_2 using the molar mass.



$$\overset{given}{\text{g KBr}} \times \overset{\frac{1}{\textit{molar mass KBr}}}{\frac{1 \text{ mol KBr}}{119.00 \text{ g KBr}}} = \text{mol KBr}$$

$$\overset{given}{\text{g } Cl_2} \times \overset{\frac{1}{\textit{molar mass } Cl_2}}{\frac{1 \text{ mol } Cl_2}{70.90 \text{ g } Cl_2}} = \text{mol } Cl_2$$

Choose one of the reactants, KBr for instance.

$$\overset{calculated\ above}{\text{mol KBr}} \times \overset{mole\ ratio}{\frac{1 \text{ mol} Cl_2}{1 \text{ mol KBr}}} = \text{mol } Cl_2 \text{ needed}$$

Determine the limiting reactant.

$$\overset{calculated\ above}{\text{mol limiting reactant}} \times \overset{mole\ ratio}{\frac{\text{mol} Br_2}{\text{mol limiting reactant}}} \times \overset{molar\ mass\ Br_2}{\frac{159.80 \text{ g } Br_2}{1 \text{ mol } Br_2}} = \text{g } Br_2$$

COMPUTE

$$3.205 \text{ g KBr} \times \frac{1 \text{mol KBr}}{119.00 \text{ g KBr}} = 0.02693 \text{ mol KBr}$$

$$0.855 \text{ g} Cl_2 \times \frac{1 \text{mol} Cl_2}{70.90 \text{ g} Cl_2} = 0.0121 \text{ mol } Cl_2$$

Choose one of the reactants, KBr, for instance.

$$0.02693 \text{ mol KBr} \times \frac{1 \text{ mol } Cl_2}{2 \text{ mol KBr}} = 0.01346 \text{ mol } Cl_2 \text{ needed}$$

Only 0.0121 mol Cl_2 is available. For all of the KBr to react, 0.0136 mol Cl_2 is needed. Therefore, Cl_2 is the limiting reactant.

$$0.0121 \text{ mol } Cl_2 \times \frac{1 \text{ mol } Br_2}{1 \text{ mol } Cl_2} \times \frac{159.80 \text{ g } Br_2}{1 \text{ mol } Br_2} = 1.93 \text{ g } Br_2$$

EVALUATE

Is the determination of limiting reactant reasonable?

Yes; the mass of 2 mol KBr is 238 g and the mass of 1 mol Cl_2 is about 71 g, so they react in roughly a 3:1 ratio by mass. 3.2 g KBr would require about 1 g of Cl_2, but only 0.855 g is available.

Are the units and significant figures of the mass of Br_2 correct?
The number of significant figures is correct because the mass of Cl_2 was given to three significant figures. Units cancel to give grams of Br_2.

Practice

1. A process by which zirconium metal can be produced from the mineral zirconium(IV) orthosilicate, $ZrSiO_4$, starts by reacting it with chlorine gas to form zirconium(IV) chloride.

$$ZrSiO_4 + 2Cl_2 \rightarrow ZrCl_4 + SiO_2 + O_2$$

What mass of $ZrCl_4$ can be produced if 862 g of $ZrSiO_4$ and 950. g of Cl_2 are available? You must first determine the limiting reactant.
ans: $ZrSiO_4$, 1.10×10^3 g $ZrCl_4$

Additional Problems

1. Heating zinc sulfide in the presence of oxygen yields the following:

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

If 1.72 mol of ZnS is heated in the presence of 3.04 mol of O_2, which reactant will be used up? Balance the equation first.

2. Use the following equation for the oxidation of aluminum in the following problems.

$$4Al + 3O_2 \rightarrow 2Al_2O_3$$

a. Which reactant is limiting if 0.32 mol Al and 0.26 mol O_2 are available?

b. How many moles of Al_2O_3 are formed from the reaction of 6.38×10^{-3} mol of O_2 and 9.15×10^{-3} mol of Al?

c. If 3.17 g of Al and 2.55 g of O_2 are available, which reactant is limiting?

3. In the production of copper from ore containing copper(II) sulfide, the ore is first roasted to change it to the oxide according to the following equation:

$$2CuS + 3O_2 \rightarrow 2CuO + 2SO_2$$

a. If 100 g of CuS and 56 g of O_2 are available, which reactant is limiting?

b. What mass of CuO can be formed from the reaction of 18.7 g of CuS and 12.0 g of O_2?

4. A reaction such as the one shown here is often used to demonstrate a single replacement reaction.

$$3CuSO_4(aq) + 2Fe(s) \rightarrow 3Cu(s) + Fe_2(SO_4)_3(aq)$$

If you place 0.092 mol of iron filings in a solution containing 0.158 mol of $CuSO_4$, what is the limiting reactant? How many moles of Cu will be formed?

5. In the reaction $BaCO_3 + 2HNO_3 \rightarrow Ba(NO_3)_2 + CO_2 + H_2O$, what mass of $Ba(NO_3)_2$ can be formed by combining 55 g $BaCO_3$ and 26 g HNO_3?

6. Bromine displaces iodine in magnesium iodide by the following process:

$$MgI_2 + Br_2 \rightarrow MgBr_2 + I_2$$

a. Which is the excess reactant when 560 g of MgI_2 and 360 g of Br_2 react, and what mass remains?

b. What mass of I_2 is formed in the same process?

7. Nickel displaces silver from silver nitrate in solution according to the following equation:

$$2AgNO_3 + Ni \rightarrow 2Ag + Ni(NO_3)_2$$

a. If you have 22.9 g of Ni and 112 g of $AgNO_3$, which reactant is in excess?

b. What mass of nickel(II) nitrate would be produced given the quantities above?

8. Carbon disulfide, CS_2, is an important industrial substance. Its fumes can burn explosively in air to form sulfur dioxide and carbon dioxide.

$$CS_2(g) + O_2(g) \rightarrow SO_2(g) + CO_2(g)$$

If 1.60 mol of CS_2 burns with 5.60 mol of O_2, how many moles of the excess reactant will still be present when the reaction is over?

9. Although poisonous, mercury compounds were once used to kill bacteria in wounds and on the skin. One was called “ammoniated mercury” and is made from mercury(II) chloride according to the following equation:

$$HgCl_2(aq) + 2NH_3(aq) \rightarrow Hg(NH_2)Cl(s) + NH_4Cl(aq)$$

a. What mass of $Hg(NH_2)Cl$ could be produced from 0.91 g of $HgCl_2$ assuming plenty of ammonia is available?

b. What mass of $Hg(NH_2)Cl$ could be produced from 0.91 g of $HgCl_2$ and 0.15 g of NH_3 in solution?

10. Aluminum chips are sometimes added to sodium hydroxide-based drain cleaners because they react to generate hydrogen gas which bubbles and helps loosen material in the drain. The equation follows.

$$Al(s) + NaOH(aq) + H_2O(l) \rightarrow NaAlO_2(aq) + H_2(g)$$

a. Balance the equation.

b. How many moles of H_2 can be generated from 0.57 mol Al and 0.37 mol NaOH in excess water?

c. Which reactant should be limiting in order for the mixture to be most effective as a drain cleaner? Explain your choice.

11. Copper is changed to copper(II) ions by nitric acid according to the following equation:

$$4HNO_3 + Cu \rightarrow Cu(NO_3)_2 + 2NO_2 + 2H_2O$$

a. How many moles each of HNO_3 and Cu must react in order to produce 0.0845 mol of NO_2?

b. If 5.94 g of Cu and 23.23 g of HNO_3 are combined, which reactant is in excess?

12. One industrial process for producing nitric acid begins with the following reaction:

$$4NH_3 + 5O_2 \rightarrow 4NO + 6H_2O$$

a. If 2.90 mol NH_3 and 3.75 mol O_2 are available, how many moles of each product are formed?

b. Which reactant is limiting if 4.20×10^4 g of NH_3 and 1.31×10^5 g of O_2 are available?

c. What mass of NO is formed in the reaction of 869 kg of NH_3 and 2480 kg O_2?

13. Acetaldehyde CH_3CHO is manufactured by the reaction of ethanol with copper(II) oxide according to the following equation:

$$CH_3CH_2OH + CuO \rightarrow CH_3CHO + H_2O + Cu$$

What mass of acetaldehyde can be produced by the reaction between 620 g of ethanol and 1020 g of CuO? What mass of which reactant will be left over?

14. Hydrogen bromide can be produced by a reaction among bromine, sulfur dioxide, and water as follows.

$$SO_2 + Br_2 + H_2O \rightarrow 2HBr + H_2SO_4$$

If 250 g of SO_2 and 650 g of Br_2 react in the presence of excess water, what mass of HBr will be formed?

15. Sulfur dioxide can be produced in the laboratory by the reaction of hydrochloric acid and a sulfite salt such as sodium sulfite.

$$Na_2SO_3 + 2HCl \rightarrow 2NaCl + SO_2 + H_2O$$

What mass of SO_2 can be made from 25.0 g of Na_2SO_3 and 22.0 g of HCl?

16. The rare-earth metal terbium is produced from terbium(III) fluoride and calcium metal by the following displacement reaction:

$$2TbF_3 + 3Ca \rightarrow 3CaF_2 + 2Tb$$

a. Given 27.5 g of TbF_3 and 6.96 g of Ca, how many grams of terbium could be produced?

b. How many grams of the excess reactant are left over?