

LIMITING REAGENT PROBLEMS BY TYPE:

This handout is designed to give you a flavor of the types Limiting Reagent (reactant) problems you might encounter in your sojourn through chemistry. Notice that I have broken down the parts for you. Breaking a problem into bite size amounts is key to solving the problem. You can see that the problems break into smaller parts in similar manner.

1) MASS/MASS:

Problems such as these have one of three forms, mass/mass, mass/mole, or mole/mole. After you have solved this problem, try starting with the moles represented by the two reagents, and by the mass of reagent one and the moles of reagent two (your choice). These were covered in Chapter 3, chemical Reactions and Reaction Stoichiometry.

The problem reads: How many grams of carbon dioxide can be produced from the reaction of 1.00 kg of Octane (C_8H_{18}) with 1.00 kg of oxygen?

Broken down into parts:

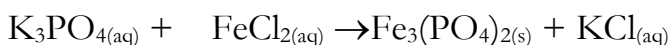
- i. Write the balanced equation.
- ii. What is the molar mass of octane?
- iii. What is the molar mass of oxygen?
- iv. What is the limiting reagent?
- v. How many grams of carbon dioxide is produced by the reaction?

2) SOLUTION/SOLUTION YIELDING A SOLID OR A LIQUID

Formation of a solid:

Problems of this nature are often precipitation type reactions. However, as we have learned in lecture, mixing two solutions together can produce a solid, a liquid (neutralization), or a gas. Double displacement in nature, they often include writing the molecular (ME), ionic (IC), and net ionic (NIE) equations. For these types of problems, consider that the volumes are additive. This type of problem tends to be easier, in my opinion, to solve using the balanced ionic equation.

Consider the following *unbalanced* reaction:



- a. The problem reads: If 125.0 mL of 0.1100 M $\text{K}_3\text{PO}_{4(\text{aq})}$ and 150.0 mL of 0.09500 M $\text{FeCl}_{2(\text{aq})}$ are combined, what **mass** of $\text{Fe}_3(\text{PO}_4)_{2(\text{s})}$ can potentially be recovered from the reaction mixture after the reaction is complete? In your answer, clearly indicate which is the **limiting reagent**, and which is in **excess**.
- b. What is the concentration of the excess reagent from part (a) that **remains** in solution when the reaction is complete?

Broken into parts:

- i. What is the ionic and net ionic equation for the reaction?
- ii. How many moles of phosphate ions are in 125.0mL of 0.1100 M $\text{K}_3\text{PO}_{4(\text{aq})}$ solution?
- iii. How many moles of potassium ions are in 125.0 mL of 0.1100 M $\text{K}_3\text{PO}_{4(\text{aq})}$ solution?
- iv. How many moles of iron(II) ions are in 150.0mL of 0.09500 M $\text{FeCl}_{2(\text{aq})}$
- v. How many moles of chloride ions are in 150.0 mL of 0.09500 M $\text{FeCl}_{2(\text{aq})}$
- vi. What is the limiting reagent?
- vii. What mass of iron(II) phosphate is produced? [HINT: Start with your limiting reagent moles]
- viii. What is the concentration of the potassium ion, phosphate ion, iron(II) ion, and chloride ion that remains after the reaction is completed? [hint: you need to find the moles of excess reagent in the form of an ion for this part]

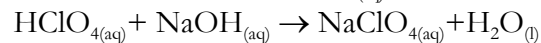
Now solve these:

1. A solution of 100.0 mL of 0.200 M sodium chromate is mixed with a solution of 200.0 mL of 0.150 M strontium nitrate.
 - a. What is the limiting reagent or reacting?
 - b. How many grams of precipitate form?
What is the concentration of spectator ions in the final mixture?
 - c. What is the concentration of the excess ion?

2. 25.0 mL of 0.235 M $\text{Mg}(\text{NO}_3)_2$ are combined with 30.0 mL of 0.260 M KOH . How many grams of magnesium hydroxide form?

Formation of a liquid: Problems of this nature are generally titration reactions. The product is usually an aqueous salt and water.

What is the molarity of sodium perchlorate produced and the molarity of the excess reagent that remains when 25.00 mL of 0.230 M $\text{HClO}_{4(\text{aq})}$ reacts with 50.00-mL of 0.1750 M $\text{NaOH}_{(\text{aq})}$?



Broken into parts:

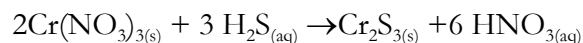
- i. What is the ionic and net ionic equation for the reaction?
- ii. How many moles of NaOH are present?
- iii. How many moles of perchloric acid are present?
- iv. What is the limiting reagent?
- v. How many moles of sodium perchlorate are produced?
- vi. What is the final volume of the mixture after the reaction?
- vii. What mass of molarity of sodium perchlorate produced?
- viii. What molarity of excess remains after the reaction is finished?
- ix. Is the remaining solution acidic or basic?

3) SOLUTION/SOLID PRODUCING A SOLID, LIQUID, GAS, OR AQUEOUS PRODUCT

Formation of a solid:

Still a double displacement, as above, but now one of the reactants is a solid. Because one of the reactants is a solid, these types of problems can also be worked in the mole. The unit the mmol (No, this is not a typo!) is often used for solution work because when divided, $\text{mmol/mL} = M$.

What is the mass of chromium(III) sulfide produced and the mass of the excess reactant remains in a reaction mixture consisting of 1.54 g of $\text{Cr}(\text{NO}_3)_3$ dissolved in 120. mL of 0.10 M $\text{H}_2\text{S}_{(\text{aq})}$.



Broken into parts:

- What is the ionic and net ionic equation for the reaction?
- How many moles of chromium (III) ions are in 1.54 g of $\text{Cr}(\text{NO}_3)_3$?
- How many moles of nitrate ions are in 1.54 g of $\text{Cr}(\text{NO}_3)_3$?
- How many moles of hydrosulfuric acid are in 120. mL of 0.10 M $\text{H}_2\text{S}_{(\text{aq})}$?
- What is the limiting reagent?
- What mass of chromium(III) sulfide produced?
- What mass of excess remains after the reaction is finished?

Now solve this one:

3. A solution of 100.0 mL of 0.200M KOH is mixed with a 46.4 g NiSO_4 .

Solve the following to complete the problem:

- Write the balanced equation for the reaction. Include correct state suspects and coefficients.
- How many moles of precipitate form?
- What is the final volume of the solution?
- What are the moles of the spectator ions remaining?
- What is the concentration of the spectator ions remaining?
- One of the ions involved in the reaction is in excess. What is the concentration of this remaining ion?

Formation of a gas:

Still a double displacement, as above, but now one of the reactants is a gas. Because one of the reactants is a solid, these types of problems can also be worked in the mole. The unit the mmol (No, this is not a typo!) is often used for solution work because when divided, mmol/mL=M.

What is the mass of carbon dioxide produced and the mass of the excess reactant remains in a reaction mixture consisting of 1.54 g of KHCO_3 is dissolved in 120. mL of 0.10 M H_2SO_4 .



Broken into parts:

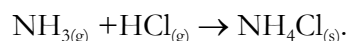
- i. What is the ionic and net ionic equation for the reaction?
- ii. How many moles of sulfuric acid?
- iii. How many moles of carbon dioxide are produced?
- iv. What is the limiting reagent?
- v. What mass (if solid) or molarity (if aqueous) of excess remains after the reaction is finished?

4) GAS/GAS PRODUCING SOLID, LIQUID, GAS, OR AQUEOUS PRODUCT

Save this problem for Chapter 10, Gases. We will solve it then.

Gases react on the mole level in these problems. If you are given the mass of the gases, see the first example. In these problems we are interested in the variables that control the behavior of gases: P,V, n, T. You will use the ideal gas equation to solve for moles here.

- a) The problem reads: A 15.0 mL sample of ammonia gas at 100 torr and 30. °C is mixed with 25 mL of hydrogen chloride at 150. torr and 25°C and the reaction



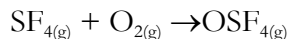
Calculate the mass of ammonium chloride that forms. Identify the gas in excess and determine its pressure (in the combined volume of the original two flasks) at 27°C.

Broken down into parts:

- i. Convert pressures to atmospheres
- ii. Convert milliliters to liters
- iii. Convert temperatures from Celsius to kelvin
- iv. Use the ideal gas law to find the individual moles of reactants

Now you solve this:

1. Sulfur tetrafluoride (SF_4) reacts slowly with oxygen to form sulfur tetrafluoride monoxide (OSF_4) according to the following unbalanced reaction:



What is the mass of the OSF_4 produced after a reaction of 100.0 mL of oxygen at 25.7°C and 200.00 torr is mixed and reacted with 150. mL of sulfur tetrafluoride at 28.5°C and 300.0 torr.

Are there other types of limiting reagent problems? To give you an answer with no hedging, “Maybe, maybe not”. Without overwhelming you, these examples should help you navigate many of your limiting reagent problems.