Limiting Reactant

Unit: Stoichiometry

MA Curriculum Frameworks (2016): HS-PS1-7

Mastery Objective(s): (Students will be able to…)

- Identify the limiting reactant in a stoichiometry problem.
- Perform stoichiometry calculations in a problem that involves a limiting reactant.
- Determine the amount(s) of the non-limiting reactant(s) left over.

Success Criteria:

- Limiting reactant correctly identified
- Stoichiometry calculations performed correctly (correct amount of desired compound in the desired units).
- Algebra and rounding to appropriate number of significant figures is correct.

Tier 2 Vocabulary: limiting

Language Objectives:

- Explain why a chemical reaction runs out of something.

Notes:

Q: What happens when a chemical reaction runs out of something?

A: The reaction stops.

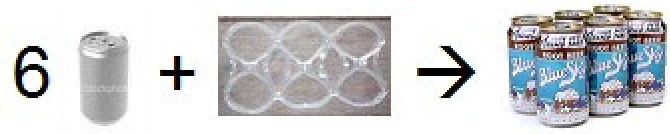
A reaction in which you run out of something is called a limiting reactant problem.

The reactant that you run out of is called the limiting reactant (or limiting reagent) because running out of it is what limits how much product you can make.

Use this space for summary and/or additional notes:

Limiting Reactant

Consider the following reaction:



Suppose you have 51 cans and four six-pack rings. There are two possibilities:

1. We use up all of the cans. (Situation A)
2. We use up all of the six-pack rings. (Situation B)

Situation	Cans	Six-Pack Rings	Six-Packs
A	**Have 51**	need at least 8.5	**could make 8.5**
B	need at least 24	**Have 4**	**could make 4**

As you can see, we have only enough of <u>*both*</u> reactants to make 4 six-packs. Once we have made 4 six-packs, we have used up all of the six-pack rings, and we cannot make any more.

This means six-pack rings are the limiting reactant, and we use all of them.

We used up 24 cans (the non-limiting reactant), and we had 27 cans left over.

On the other hand, suppose we have only 15 cans and 4 six-pack rings. Again, there are two possibilities:

1. We use up all of the cans. (Situation C)
2. We use up all of the six-pack rings. (Situation D)

Situation	Cans	Six-Pack Rings	Six-Packs
C	**have 15**	need at least 2.5	**could make 2.5**
D	need at least 24	**have 4**	**could make 6**

This time, we can make 2.5 six-packs and then we run out of cans, so now the limiting reactant is cans. If we make 2.5 six-packs, we would use 2.5 six-pack rings, which means we would have 1.5 six-pack rings left over.

Use this space for summary and/or additional notes:

The secret to solving limiting reactant problems is to do a stoichiometry problem on each reactant (using the factor-label method) to see how much of one of the products you make if you used it all up. The limiting reactant is the one that can make the least amount of product (gets used up first).

Steps for Solving Limiting Reactant Problems

1. Does the problem give you amounts for more than one reactant? (If not, it's not a limiting reactant problem.)
2. Convert the amount of each reactant to moles.
3. For each of the reactants, use stoichiometry to figure out how much of one of the products you could make if you used the reactant up.
4. The reactant that can make the *least* amount of product is the one that gets used up first—it is the ***limiting reactant***.
5. Perform *all* of your stoichiometry calculations using the number of moles of the limiting reactant that you identified in step 4 above.
6. If the problem asks how much of one of the non-limiting reactants is left over, use the moles of the limiting reactant to find out how many moles of the other reactant got used up. Subtract this number from the moles you started with to find out how much is left over.
7. If the problem is asking for a quantity other than moles (such as grams), convert from moles to the desired unit.

Use this space for summary and/or additional notes:

Sample Problem:

Q: Given the following reaction:

$$16\ Cu + S_8 \rightarrow 8\ Cu_2S$$

If we had 27.5 moles of copper and 1.4 moles of S_8, how much Cu_2S would we make?

A: Determine how many moles of Cu_2S we could make from each reactant:

$$\frac{27.5\ \text{mol Cu}}{1} \times \frac{8\ \text{mol Cu}_2\text{S}}{16\ \text{mol Cu}} = 13.75\ \text{mol Cu}_2\text{S} \leftarrow \text{more}$$

$$\frac{1.4\ \text{mol S}_8}{1} \times \frac{8\ \text{mol Cu}_2\text{S}}{1\ \text{mol S}_8} = 11.2\ \text{mol Cu}_2\text{S} \leftarrow \text{less}$$

We can make $\boxed{\text{11.2 mol of Cu}_2\text{S}}$ and then we run out of S_8. This means S_8 is the limiting reactant.

Q: How much of the non-limiting reactant would be left over?

A: S_8 was limiting, and we had 1.4 moles of it. We need to find out how much Cu got used up.

$$\frac{1.4\ \text{mol S}_8}{1} \times \frac{16\ \text{mol Cu}}{1\ \text{mol S}_8} = 22.4\ \text{mol Cu}_2\text{S}$$

Now we subtract to find how much was left:

$$27.5\ \text{mol} - 22.4\ \text{mol} = \boxed{\text{5.1 mol Cu left over}}$$

Use this space for summary and/or additional notes:

Homework Problems

Set #1: Scaffolded

1. Consider the reaction: $2\ Si_2H_2 + 5\ O_2 \rightarrow 4\ SiO_2 + 2\ H_2O$

   a. If you had 8 mol Si_2H_2, how many moles of O_2 would you need for the above reaction?

      Answer: 20 moles O_2

   b. If you had 15 mol O_2, how many moles of Si_2H_2 would you need for the above reaction?

      Answer: 6 mol Si_2H_2

   c. If you had 8 mol Si_2H_2 and 15 mol O_2, which reactant would be limiting?

      Answer: O_2

   d. How many moles of the non-limiting reactant would be left over?

      Answer: 2 mol Si_2H_2 left over

   e. What is the theoretical yield of SiO_2, in moles? (*I.e.,* how many moles of SiO_2 would you make?)

      Answer: 12 mol SiO_2

Use this space for summary and/or additional notes:

2. Consider the reaction: $3\ Ca\ (s) + 2\ AlCl_3\ (aq) \rightarrow 3\ CaCl_2\ (aq) + 2\ Al\ (s)$

   a. If you had 6 mol Ca, how many moles of $AlCl_3$ would you need for the above reaction?

      Answer: 4 mol $AlCl_3$

   b. If you had 8 mol $AlCl_3$, how many moles of Ca would you need for the above reaction?

      Answer: 12 mol Ca

   c. If you had 6 mol Ca and 8 mol AlCl3, which reactant would be limiting?

      Answer: Ca

   d. How many moles of the non-limiting reactant would be left over?

      Answer: 4 mol $AlCl_3$ left over

   e. What is the theoretical yield of $CaCl_2$, in moles? (*I.e.,* how many moles of $CaCl_2$ would you make?)

      Answer: 6 mol $CaCl_2$

Use this space for summary and/or additional notes:

Homework Problems

Set #2: Unscaffolded

1. How many moles of H_2O would be produced if 3.5 mol H_2 react with 1.5 mol O_2 in the reaction:

$$2\ H_2 + O_2 \rightarrow 2\ H_2O$$

(*Note: because amounts were given for both reactants, this is a limiting reactant problem.*)

Answer: 3.0 mol H_2O

2. If 12.0 mol S_8 reacted with 100. mol O_2 in the *unbalanced* equation:

$$S_8 + \quad O_2 \rightarrow \quad SO_3$$

Which reactant is limiting, and how much of the other reactant would be left over?

Answer: $O_2$is limiting; there will be3.7 mol S_8 left over.

3. 325 g of H_2O is poured onto a 450. g block of sodium metal. The equation for this reaction is:

$$2\ Na + 2\ H_2O \rightarrow 2\ NaOH + H_2$$

   a. What is the limiting reactant?

   Answer: H_2O

   b. If the reaction temperature is 227 °C (500. K) at a pressure of 1 atm, how many liters of H_2 gas are produced?

   (*Hint: find the moles of H_2 produced and use the ideal gas law to calculate the volume.*)

   Answer: 369 L H_2

Use this space for summary and/or additional notes:

4. 5.00 g Zn are reacted with 100. mL of 1.00 M HCl in the reaction:

$$Zn\,(s) + 2\,HCl\,(aq) \rightarrow ZnCl_2\,(aq) + H_2\,(g)$$

a. Determine which reactant is limiting.

Answer: HCl

b. Determine the number of *grams* of $ZnCl_2$ that will be produced.

Answer: 6.82 g $ZnCl_2$

c. If the reaction conditions are 177 °C (*remember to convert to Kelvin!*) and 1 atm pressure, determine the number of liters of H_2 gas that will be produced.

Answer: 1.85 L H_2

d. Determine the mass in grams of the non-limiting reactant that will be left over.

Answer: 1.73 g Zn

Use this space for summary and/or additional notes: