

## Limiting Reactant

**Unit:** Stoichiometry

**NGSS Standards/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:

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         | <b>Have 51</b>   | need at least 8.5 | <b>could make 8.5</b> |
| B         | need at least 24 | <b>Have 4</b>     | <b>could make 4</b>   |

X



As you can see, we have only enough of both 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         | <b>have 15</b>   | need at least 2.5 | <b>could make 2.5</b> |
| D         | need at least 24 | <b>have 4</b>     | <b>could make 6</b>   |



X

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:



If we had 27.5 moles of copper and 1.4 moles of  $\text{S}_8$ , how much  $\text{Cu}_2\text{S}$  would we make?

A: Determine how many moles of  $\text{Cu}_2\text{S}$  we could make from each reactant:

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

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

We can make 11.2 mol of  $\text{Cu}_2\text{S}$  and then we run out of  $\text{S}_8$ . This means  $\text{S}_8$  is the limiting reactant.

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

A:  $\text{S}_8$  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:

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

Use this space for summary and/or additional notes:

**Homework Problems****Set #1: Scaffolded**

1. Consider the reaction:  $2 \text{Si}_2\text{H}_2 + 5 \text{O}_2 \rightarrow 4 \text{SiO}_2 + 2 \text{H}_2\text{O}$

- a. If you had 8 mol  $\text{Si}_2\text{H}_2$ , how many moles of  $\text{O}_2$  would you need for the above reaction?

Answer: 20 moles  $\text{O}_2$

- b. If you had 15 mol  $\text{O}_2$ , how many moles of  $\text{Si}_2\text{H}_2$  would you need for the above reaction?

Answer: 6 mol  $\text{Si}_2\text{H}_2$

- c. If you had 8 mol  $\text{Si}_2\text{H}_2$  and 15 mol  $\text{O}_2$ , which reactant would be limiting?

Answer:  $\text{O}_2$

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

Answer: 2 mol  $\text{Si}_2\text{H}_2$  left over

- e. What is the theoretical yield of  $\text{SiO}_2$ , in moles? (*i.e.*, how many moles of  $\text{SiO}_2$  would you make?)

Answer: 12 mol  $\text{SiO}_2$

Use this space for summary and/or additional notes:

## Limiting Reactant

Big Ideas

Details

Unit: Stoichiometry

2. Consider the reaction:  $3 \text{Ca (s)} + 2 \text{AlCl}_3 \text{(aq)} \rightarrow 3 \text{CaCl}_2 \text{(aq)} + 2 \text{Al (s)}$

- a. If you had 6 mol Ca, how many moles of  $\text{AlCl}_3$  would you need for the above reaction?

Answer: 4 mol  $\text{AlCl}_3$

- b. If you had 8 mol  $\text{AlCl}_3$ , 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  $\text{AlCl}_3$ , which reactant would be limiting?

Answer: Ca

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

Answer: 4 mol  $\text{AlCl}_3$  left over

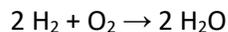
- e. What is the theoretical yield of  $\text{CaCl}_2$ , in moles? (*I.e.*, how many moles of  $\text{CaCl}_2$  would you make?)

Answer: 6 mol  $\text{CaCl}_2$

Use this space for summary and/or additional notes:

**Homework Problems****Set #2: Unscaffolded**

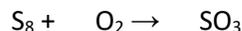
1. How many moles of H<sub>2</sub>O would be produced if 3.5 mol H<sub>2</sub> react with 1.5 mol O<sub>2</sub> in the reaction:



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

Answer: 3.0 mol H<sub>2</sub>O

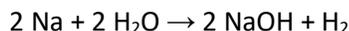
2. If 12.0 mol S<sub>8</sub> reacted with 100. mol O<sub>2</sub> in the *unbalanced* equation:



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

Answer: O<sub>2</sub> is limiting; there will be 3.7 mol S<sub>8</sub> left over.

3. 325 g of H<sub>2</sub>O is poured onto a 450. g block of sodium metal. The equation for this reaction is:



- a. What is the limiting reactant?

Answer: H<sub>2</sub>O

- b. If the reaction temperature is 227 °C (500. K) at a pressure of 1 atm, how many liters of H<sub>2</sub> gas are produced?

(Hint: find the moles of H<sub>2</sub> produced and use the ideal gas law to calculate the volume.)

Answer: 369 L H<sub>2</sub>

Use this space for summary and/or additional notes:

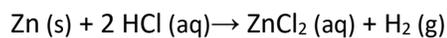
## Limiting Reactant

Big Ideas

Details

Unit: Stoichiometry

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



- a. Determine which reactant is limiting.

Answer: HCl

- b. Determine the number of *grams* of  $\text{ZnCl}_2$  that will be produced.

Answer: 6.82 g  $\text{ZnCl}_2$

- c. If the reaction conditions are 177 °C (*remember to convert to Kelvin!*) and 1 atm pressure, determine the number of liters of  $\text{H}_2$  gas that will be produced.

Answer: 1.85 L  $\text{H}_2$

- 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: