**Limiting & Excess Reactants Lab**

*Use this worksheet as a guideline for the lab. Fill in the blanks and complete the chart of colors based on the video. You may also need to use the class notes to answer some of the ten (10) questions. Once completed, go to Study Place and complete the Test.*

**Learning Objective:**

Use stoichiometry to determine the ratios of substances in a chemical reaction. Explain how the quantity of reactants limits the amount of product. Determine the substances that are limiting or excess in a reaction.

[Limiting Reactant & Excess Reactant](https://screencast-o-matic.com/watch/cqjiqXOMtI) (10:32)

Fill in the blanks for the worksheet below.

### 

Have you ever followed a recipe to make bread? If you have, you know that the final product is very different than the individual ingredients—flour, eggs, sugar—with which you started. You also know that the amount of ingredients that you mix together is very important to produce the desired results.

The recipe for the Kaiser rolls in **Figure 1** calls for four eggs and eight tablespoons of butter, among other things. Suppose you only have two eggs, six tablespoons of butter, and an unlimited supply of the other ingredients. Can you still bake the rolls?  Of course! You can simply make a smaller batch of rolls. In this case, you are limited by how many eggs you have, which is half of the number required in the original recipe. You can use both eggs, only four tablespoons of your butter, and half of the other listed ingredient amounts.

### **Material Amounts in Chemical Reactions**

Reactions occur according to the number of atoms and molecules that are available to react in a precise ratio. The Law of Conservation of **\_\_\_\_\_** states that matter can neither be created nor destroyed. Therefore, the **\_\_\_\_\_** of atoms of each **\_\_\_\_\_** on the reactants side must be the same as the number of atoms on the products side. This quantitative study of chemical reactions is called **\_\_\_\_\_** . The substances in a balanced reaction are related to each other by stoichiometric **\_\_\_\_\_** ratios. For example, magnesium reacts with hydrochloric acid in a 1:2 stoichiometric ratio in the balanced equation below.

Mg(s) + 2HCl(aq) → MgCl2(aq) + H2(g)

The molar ratios can be used as conversion factors to find the amount (in moles) of one substance given the amount of another.  For example, given the number of moles of HCl, the amount of MgCl2 can be determined as shown below.

begin mathsize 12px style n subscript MgCl subscript 2 end subscript space equals space n subscript HCl space cross times space fraction numerator 1 space mol space MgCl subscript 2 over denominator 2 space mol space HCl end fraction end style

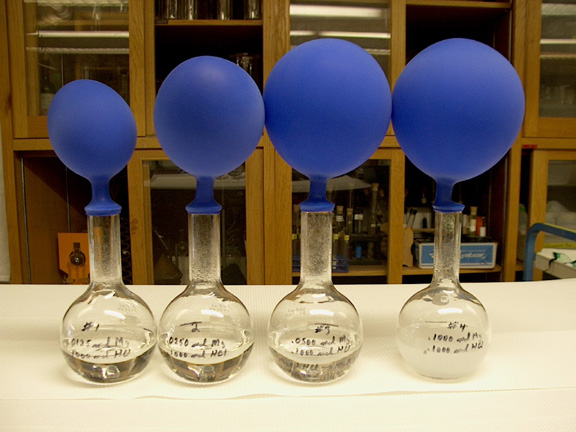
Using molar ratios, like shown above, determines the amount of MgCl2 in moles. However, the amount of reactant or product is often measured in grams. Mass can be converted to moles and vice versa as shown below.

begin mathsize 12px style n space equals space fraction numerator m over denominator M M end fraction
m space equals space n space cross times space M M end style

… where n is the amount of a substance (in mol), m is the mass of the reactant or product (in g), and MM is the molar mass (in g/mol).

### **Limiting Reactants**

Reactants are rarely mixed in exact stoichiometric ratios when performing reactions. The amount of product that can be obtained depends on the reactant that will be entirely consumed in the reaction. This reactant is called the **\_\_\_\_\_** reactant (reagent). The limiting reactant is determined either by calculating the maximum amount of **\_\_\_\_\_** that can be formed from each reactant or by comparing the reactants with each other. The reactant that will produce the least of amount of product is the limiting reactant, whereas the other reactant is present in **\_\_\_\_\_** . **Figure 2** shows how the amount of hydrogen gas produced in the reaction above depends on the amount of limiting reactant.



**Figure 2. Limiting Reactant Effects**

Flask 1 and 2 are limited by the amount of Mg present, flask 3 contains a stoichiometric ratio of Mg to HCl, whereas flask 4 is limited by the amount of HCl present.

#### Determine the Limiting Reactant through Calculations

Suppose you react 0.50 g of Mg with 4.00 g of HCl and you want to determine how many moles of hydrogen gas can be formed. To do this, you will first have to determine the limiting reactant.

Start by calculating the moles of each reactant.

Mg(s) + 2HCl(aq) → MgCl2(aq) + H2(g)

begin mathsize 12px style n subscript Mg space end subscript equals space fraction numerator m subscript Mg over denominator M M subscript Mg end fraction space equals space fraction numerator 0.50 space straight g over denominator 24.31 space straight g divided by mol end fraction space equals space 0.021 space mol space Mg space space
n subscript HCl space equals space straight m subscript HCl over MM subscript HCl space equals space fraction numerator 4.00 space straight g over denominator 36.46 space straight g divided by mol end fraction space equals space 0.110 space mol space HCl end style

Pick one reactant and calculate how many moles of the other reactant are needed to completely react with it. Suppose you choose Mg. The number of moles of HCl needed to completely react with it can be calculated as shown below.

Mg(s) + 2HCl(aq) → MgCl2(aq) + H2(g)

The mole ratio of Mg:HCl = 1:2. Therefore, 0.021 mol Mg / 1 mol = ? mol MgCl2 / 2 mol or

begin mathsize 12px style 0.021 space mol space Mg space cross times fraction numerator 2 space mol space HCl over denominator 1 space mol space Mg end fraction space equals space 0.042 space mol space HCl end style

Only  **\_\_\_\_\_** mol of HCl is required to react with all the Mg present (0.021 mol), yet there is **\_\_\_\_\_** mol of HCl available. This is more than what is needed. Thus, **\_\_\_\_\_** is the excess reactant, making **\_\_\_\_\_** the limiting reactant.

One can determine the limiting and excess reagents another way as well … by calculating the amount of product (e.g. H2) that each reactant can form.

begin mathsize 12px style n subscript straight H subscript 2 end subscript space equals space 0.021 space mol space Mg space cross times space fraction numerator 1 space mol space straight H subscript 2 over denominator 1 space mol space Mg end fraction space space equals space 0.021 space mol space straight H subscript 2 space space space
n subscript straight H subscript 2 end subscript space equals space 0.110 space mol space HCl space cross times space fraction numerator 1 space mol space straight H subscript 2 over denominator 1 space mol space HCl end fraction space space equals space 0.055 space mol space straight H subscript 2 end style

2

OR

0.021 mol Mg / 1 mol = ? mol H2 / 1 mol

0.110 mol HCl / 2 mol = ? mol H2 / 1 mol

Mg forms **\_\_\_\_\_** mol H2 while HCl forms **\_\_\_\_\_** mol H2 (more than twice as much), indicating that Mg is the **\_\_\_\_\_** reactant and HCl is present in **excess**.

#### Determine the Limiting Reactant through Experimentation

In this lab, copper (II) sulfate reacts with sodium sulfide to produce copper (II) sulfide as a black precipitate. Notice that all reagents are in a **\_\_\_\_\_** mole ratio:

CuSO4 (aq) + Na2S (aq) 🡪 CuS ↓ + Na2SO4 (aq)

By using a zinc sulfate and ammonia test solution, one can determine if there is an excess of either CuSO4 or Na2S in the above reaction. The test solution contains [Zn(NH3)4]2+ and NH3, which allows testing for excess CuSO4 or excess Na2S according to the following two reactions:

### Cu2+(aq) + 4NH3(aq) → [Cu(NH3)4]2+(aq)

### For the first reaction, when excess Copper is present (via CuSO4(aq)), one will observe a BLUE solution above the black precipitate.

### S2–(aq)  + Zn2+(aq) → ZnS(s)

For the second reaction, when excess Sulfide is present (via Na2S (aq)), one will observe a **\_\_\_\_\_** in a clear solution.

Use the video to collect data and complete the chart and questions.

<http://somup.com/cqjiq6eFpJ>

Record the color of the CuSO4(aq) solution in the first test tube: \_\_\_\_\_

Record the color of the Na2S(aq) solution in the second test tube: \_\_\_\_\_

Fill in the table below with the results from the video experiment. Be sure to subtract out the mass of the empty test tube when determining the “Mass of Precipitate”.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Trial #** | **Amounts of**  **CuSO4 : 1 mL Na2S**  **added to test solution** | **Color of liquid and precipitate (if present)** | **Reagent in Excess** | **Mass of precipitate (g)** |
| **1** | **5 mL CuSO4 : 1 mL Na2S** |  |  |  |
| **2** | **4 mL CuSO4 : 2 mL Na2S** |  |  |  |
| **3** | **3 mL CuSO4 : 3 mL Na2S** |  |  |  |
| **4** | **2 mL CuSO4 : 4 mL Na2S** |  |  |  |
| **5** | **1 mL CuSO4 : 5 mL Na2S** |  |  |  |

Answer the following questions using the color of the liquid and mass of precipitate.

1. How does one know that a chemical reaction took place in all of these tests?

2. Which trial(s) indicated no limiting or excess reagents? Explain.

3. In question 2, what would the mole ratio of CuSO4 : Na2S be?

4. Which trial(s) indicated that CuSO4 is in excess? Explain.

5. Which trial(s) indicated that Na2S is in excess? Explain.

Answers for Discussion Section

Reactions occur according to the number of atoms and molecules that are available to react in a precise ratio. The Law of Conservation of **Mass** states that matter can neither be created nor destroyed. Therefore, the **number** of atoms of each **element** on the reactants side must be the same as the number of atoms on the products side. This quantitative study of chemical reactions is called **stoichiometry**. The substances in a balanced reaction are related to each other by stoichiometric **molar** ratios. For example, magnesium reacts with hydrochloric acid in a 1:2 stoichiometric ratio in the balanced equation below.

Mg(s) + 2HCl(aq) → MgCl2(aq) + H2(g)

The molar ratios can be used as conversion factors to find the amount (in moles) of one substance given the amount of another.  For example, given the number of moles of HCl, the amount of MgCl2 can be determined as shown below.

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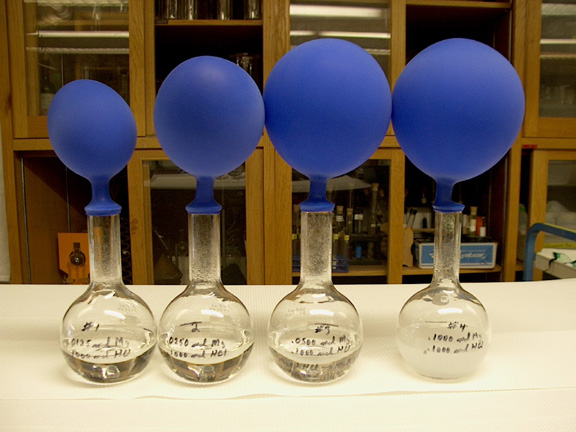
Using molar ratios, like shown above, determines the amount of MgCl2 in moles. However, the amount of reactant or product is often measured in grams. Mass can be converted to moles and vice versa as shown below.

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m space equals space n space cross times space M M end style

… where n is the amount of a substance (in mol), m is the mass of the reactant or product (in g), and MM is the molar mass (in g/mol).

### **Limiting Reactants**

Reactants are rarely mixed in exact stoichiometric ratios when performing reactions. The amount of product that can be obtained depends on the reactant that will be entirely consumed in the reaction. This reactant is called the **limiting** reactant (reagent). The limiting reactant is determined either by calculating the maximum amount of **product** that can be formed from each reactant or by comparing the reactants with each other. The reactant that will produce the least of amount of product is the limiting reactant, whereas the other reactant is present in **excess**. **Figure 2** shows how the amount of hydrogen gas produced in the reaction above depends on the amount of limiting reactant.



**Figure 2. Limiting Reactant Effects**

Flask 1 and 2 are limited by the amount of Mg present, flask 3 contains a stoichiometric ratio of Mg to HCl, whereas flask 4 is limited by the amount of HCl present.

#### Determine the Limiting Reactant through Calculations

Suppose you react 0.50 g of Mg with 4.00 g of HCl and you want to determine how many moles of hydrogen gas can be formed. To do this, you will first have to determine the limiting reactant.

Start by calculating the moles of each reactant.

Mg(s) + 2HCl(aq) → MgCl2(aq) + H2(g)

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n subscript HCl space equals space straight m subscript HCl over MM subscript HCl space equals space fraction numerator 4.00 space straight g over denominator 36.46 space straight g divided by mol end fraction space equals space 0.110 space mol space HCl end style

Pick one reactant and calculate how many moles of the other reactant are needed to completely react with it. Suppose you choose Mg. The number of moles of HCl needed to completely react with it can be calculated as shown below.

Mg(s) + 2HCl(aq) → MgCl2(aq) + H2(g)

The mole ratio of Mg:HCl = 1:2. Therefore, 0.021 mol Mg / 1 mol = ? mol MgCl2 / 2 mol or

begin mathsize 12px style 0.021 space mol space Mg space cross times fraction numerator 2 space mol space HCl over denominator 1 space mol space Mg end fraction space equals space 0.042 space mol space HCl end style

Only **0.042** mol of HCl is required to react with all the Mg present (0.021 mol), yet there is **0.110** mol of HCl available. This is more than what is needed. Thus, **HCl** is the excess reactant, making **Mg** the limiting reactant.

One can determine the limiting and excess reagents another way as well … by calculating the amount of product (e.g. H2) that each reactant can form.

begin mathsize 12px style n subscript straight H subscript 2 end subscript space equals space 0.021 space mol space Mg space cross times space fraction numerator 1 space mol space straight H subscript 2 over denominator 1 space mol space Mg end fraction space space equals space 0.021 space mol space straight H subscript 2 space space space
n subscript straight H subscript 2 end subscript space equals space 0.110 space mol space HCl space cross times space fraction numerator 1 space mol space straight H subscript 2 over denominator 1 space mol space HCl end fraction space space equals space 0.055 space mol space straight H subscript 2 end style

2

OR

0.021 mol Mg / 1 mol = ? mol H2 / 1 mol

0.110 mol HCl / 2 mol = ? mol H2 / 1 mol

Mg forms **0.021** mol H2 while HCl forms **0.055** mol H2 (more than twice as much), indicating that Mg is the **limiting** reactant and HCl is present in **excess**.

#### Determine the Limiting Reactant through Experimentation

In this lab, copper (II) sulfate reacts with sodium sulfide to produce copper (II) sulfide as a black precipitate. Notice that all reagents are in a **1:1** mole ratio:

CuSO4 (aq) + Na2S (aq) 🡪 CuS ↓ + Na2SO4 (aq)

By using a zinc sulfate and ammonia test solution, one can determine if there is an excess of either CuSO4 or Na2S in the above reaction. The test solution contains [Zn(NH3)4]2+ and NH3, which allows testing for excess CuSO4 or excess Na2S according to the following two reactions:

### Cu2+(aq) + 4NH3(aq) → [Cu(NH3)4]2+(aq)

### For the first reaction, when excess Copper is present (via CuSO4(aq)), one will observe a BLUE solution above the black precipitate.

### S2–(aq)  + Zn2+(aq) → ZnS(s)

For the second reaction, when excess Sulfide is present (via Na2S (aq)), one will observe a **precipitate** in a clear solution.

Answers for the Lab

Record the color of the CuSO4(aq) solution in the first test tube: **blue**

Record the color of the Na2S(aq) solution in the first test tube: **colorless**

Fill in the table below with the results from your experiment.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Trial #** | **Amounts of**  **CuSO4 : 1 mL Na2S**  **added to test solution** | **Color of liquid and precipitate (if present)** | **Reagent in Excess** | **Mass of precipitate** |
| **1** | **5 mL CuSO4 : 1 mL Na2S** | **Blue / Black** | **CuSO4** | **0.010 g** |
| **2** | **4 mL CuSO4 : 2 mL Na2S** | **Blue / Black** | **CuSO4** | **0.019 g** |
| **3** | **3 mL CuSO4 : 3 mL Na2S** | **Colorless with a precipitate** | **None** | **0.029 g** |
| **4** | **2 mL CuSO4 : 4 mL Na2S** | **Colorless with a precipitate** | **Na2S** | **0.019 g** |
| **5** | **1 mL CuSO4 : 5 mL Na2S** | **Colorless with a precipitate** | **Na2S** | **0.010 g** |

Answer the following questions using the color of the liquid and mass of precipitate.

1. How does one know that a chemical reaction took place in all of these tests?

**A precipitate (a black solid in a liquid) was formed.**

2. Which trial(s) indicated no limiting or excess reagents? Explain.

**Trial 3: adding 3 mL 0.1 M CuSO4 : 3 mL 0.1 M Na2S produced the most precipitate, but the liquid was colorless. This indicates that all of the reagents were used to make the precipitate and no excess was available. There was a precipitate based on BOTH the Copper II ions of CuSO4 (aq) and the Sulfide ions of Na2S (aq).**

3. In question 2, what would the mole ratio of CuSO4 : Na2S be?

**When the test solution was added, there was no color change. More precipitate was produced because trial 3 had the largest precipitate mass. Since neither reagent is in excess, the molar ratio of CuSO4 to Na2S is 1:1 for the reaction.**

4. Which trial(s) indicated that CuSO4 is in excess? Explain.

**Trials 1 and 2: adding 5 mL 0.1 M CuSO4 : 1 mL 0.1 M Na2S and 4 mL 0.1 M CuSO4 : 2 mL 0.1 M Na2S produced the black precipitate (CuS ↓) with a blue solution, indicating excess copper ions.**

5. Which trial(s) indicated that Na2S is in excess? Explain.

**Trials 4 and 5: adding 2 mL 0.1 M CuSO4 : 4 mL 0.1 M Na2S and 1 mL 0.1 M CuSO4 : 5 mL 0.1 M Na2S produced the white precipitate (CuS ↓) with a colorless solution, indicating excess Sulfide ions.**