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Calculating Percentage Yield using Molar Quantities

The Single Displacement of Copper(ii) Sulfate and Iron

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Introduction:

The yield for a chemical reaction, the relationship between that yield, and the balanced

equation representing the reaction are very important to chemists. Not only does a laboratory

chemistry investigation require an understanding of such concepts, but the chemical industry also

depends on percent yield principle in manufacturing of chemical products.

Stoichiometry is the study of quantities in chemical reactions. The Stoichiometry of a reaction is

based on the mole. The coefficients in the balanced equation represent the relative number of moles of

substances that react or are formed in the reaction.

For practical reasons, the quantities of the reactants used in a reaction are generally not in the

same mole proportions as the balanced chemical equation. It is important to be able to predict how

much product will form under certain conditions.

Purpose:

In this experiment, you will use iron wool and an aqueous solution of copper (II) sulfate in order to

synthesize Cu(s). A single displacement reaction will take place, the products being iron(III)sulfate and

copper metal. The balanced equation for this reaction is:

3CuSO4 ●5H2O (aq) + 2Fe(s) + H2O(aq) → 3Cu(s) + Fe2(SO4)3●5H2O  (aq) + H2O(aq)

## Background Information

Copper is a substance

## Calculations

### 1. Write the balanced chemical equation for the reaction.

Copper(ii) sulfate pentahydrate + iron wool + water → copper metal + iron(iii) sulfate pentahydrate + water

CuSO4 (aq) ●5H2O + Fe(s) + H2O→ Cu(s) + Fe2(SO4)3 ●5H2O  (aq) + H2O

3CuSO4 ●5H2O (aq) + 2Fe(s) + H2O(aq) → 3Cu(s) + Fe2(SO4)3●5H2O  (aq) + H2O(aq)

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### 2. What mass of Cu(s) can be prepared by the reaction of iron wool

3CuSO4 : 3Cu

2g  / (63.55 + 32.66 + 4 \* 16 + 5 \* 18.02)g/mol = 0.008mol CuSO4

1 : 1

0.008mol CuSO4 : 0.008mol Cu

0.008mol Cu = m/63.55

0.008mol\*63.55= m

m=0.5g of Cu

Estimated percentage yield ~95%

0.5g \* 95% = 0.48g

∴ My goal is to synthesize 0.75g of Cu (s) to have an expected yield of

95%

# Materials List

1. 1 pair of safety goggles
2. 1 stirring rod
3. 2 250ml beakers
4. 100ml of distilled water
5. 2g of copper(ii) sulfate
6. 0.46g of iron wool
7. 1 sheet of filter paper
8. 1 sheet of paper towel
9. 1 funnel
10. 1 metric scale
11. 1 pair of crucible tongs

# Procedure:

1. Gather materials
2. Put on safety goggles
3. Pour 100ml of distilled water into the beaker
4. Pour 2g of copper(ii) sulfate into the test tube
5. Using the crucible tongs place 0.46g of iron wool in the solution of copper(ii) sulfate
6. Stir the solution for approximately 5 minutes or until the iron wool appears to be broken up
7. Measure the mass of the filter paper
8. Form the filter paper into a funnel shape
9. Place the filter paper into the funnel
10. Place the funnel over the second beaker
11. Slowly pour the solution from the beaker into the funnel
12. Wait while the solution filters through the paper
13. Remove the filter paper from the funnel and place on a sheet of paper towel
14. Record Observations of the remaining liquid solution
15. Record Observations of the substance left on the filter paper
16. Dispose of liquid solution
17. Let the filter paper dry for 1 day
18. Record the mass of the substance
19. Dispose of Remaining Materials

# Experimental Results

|  |  |  |
| --- | --- | --- |
| Fe | CuSO4 (Limiting Reactant) | Cu |
| 0.5g | 1.5g | 0.5g |
| 1g | 2g | 0.7g |
| 1.5g | 1.5g | 0.7g |
| 0.5g | 1.5g | 0.6g |
| 0.46g | 2g | 0.6g |
| 0.46g | 2g | 0.59g |
| 1g | 2g | 0.43g |
| 0.8g | 2g | 0.9g |

Table 1. Mass of limiting reactant (g) vs. Mass of Cu (g)

|  |  |  |
| --- | --- | --- |
| Fe | CuSO4 (Limiting Reactant) | Cu |
| 0.009mol | 0.006mol | 0.008mol |
| 0.018mol | 0.008mol | 0.011mol |
| 0.027mol | 0.006mol | 0.011mol |
| 0.009mol | 0.006mol | 0.009mol |
| 0.008mol | 0.008mol | 0.009mol |
| 0.008mol | 0.008mol | 0.009mol |
| 0.018mol | 0.008mol | 0.007mol |
| 0.014mol | 0.008mol | 0.014mol |

Table 2. Moles of limiting reactant (mol) vs. Moles of Cu (mol)

|  |  |  |  |
| --- | --- | --- | --- |
| H2O | Fe | CuSO4 ●5H2O | Solid Product |
| Clear Liquid | Lustrous, silver coloured, made up of thin strands of wire, wrapped into a small ball. | Small lustrous solid blue crystals. | Brown hard |

Table 3. Qualitative observations of the reaction between Fe and CuSO4●5H2O

Figure 1. Moles of limiting reactant vs Moles of Cu

Figure 1. represents the number of moles of the limiting reactant compared to the resulting product of Copper.