Experiment 4: Limiting Reactant and Percent Yield

Lab report structure:

Part A: Zinc Coupon Reaction

Part B: Zinc Granules Reaction

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1 Introduction

The aim of this lab report is to study the effects of stoichiometry and how the limiting and excess reactant work in a chemical reaction. First off stoichiometry is the study of the proportions in where compounds or elements react with each other. For example, comparing stoichiometry to making sandwiches, to make one sandwich, requires two breads and one slice of meat. Suppose there are only 6 breads and 2 meats. Making the greatest number of sandwiches would leave one bread left and zero meats so the limit on making the most sandwiches is the meat. The limiting reactant would be equivalent to the meat in the sandwich example and the excess reactant would be the zero-bread left. For both experiments will include this reaction equation, $Zn(s) + CuCl_2(aq) \rightarrow ZnCl_2(aq) + Cu(s)$. Where solid zinc combines in an aqueous solution of copper (II) Chloride and turns into zinc (II) Chloride and copper as a solid. This reaction called a single displacement reaction happens because the zinc metal 2 charged ion replaces the copper 2 charged ion from the Chloride. There are two cases in the experiment one where the zinc is the limiting reactant and, in this case, there would be Copper (II) Chloride and zinc (II) Chloride in the solution and the solution's color does not completely go away as copper (II) Chloride is blue in a solution, but the zinc would disappear. The second case, where the Copper (II) Chloride is the limiting reactant, and all the copper would be absorbed with the Chloride and there would be some zinc but a clear solution. To calculate the theoretical yield of how much solid zinc would be left in the experiment, the limiting reactant must be calculated. To calculate it we must go through every reactant and calculate the amount of product it produces based on the chemical equation, and the lowest amount is the limiting reactant. Using the chemical equation above to find the amount of copper that is being produced, first we start off with the amount of moles in the reaction there is. Next, we multiply amount of that moles of

reactant is needed for the product is being received. In this case there is one zinc for every copper that is being produced and every copper chloride for one copper. Lastly is to multiply that value by the atomic mass of the product in this case copper is 63.55 u which will get the theoretical amount that will be made in grams and the least of the two would be the limiting reactant. The theoretical amount is maximum amount that can be produced. However, the theoretical amount may not be the real value the is made in the experiment. So, the percent yield exists to determine how off the theoretical is to the real value. To calculate the percent yield is by dividing the actual yield by theoretical yield and multiply it by 100%. One of the ingredients needed for the experiment is not in a solid nor a liquid state it is in an aqueous state, how do we determine the amount of moles that are in a volume of liquid. The amount of solute in a container is in the form of Molarity (M) which is the moles divided by the liters of solution. Knowing this to calculate the amount of moles we must multiply the molarity with the liters of solution.

2 Experimental

2.1 Materials

The materials needed in this experiment are two vials one containing 10.00 mL 0.200 M CuCl2 and the other containing 10.00 mL 0.100 M CuCl2. A weigh boat with a zinc coupon, 50 mL beaker, watch glass, filter paper, glass funnel, 125 mL Erlenmeyer flask, glass stir rod with a rubber policeman, weigh boat with zinc granules, glass funnel, and a stir bar.

2.2 Safety

For safety of this experiment proper lab attire and PPE is needed which includes eyewear, lab coat and latex gloves. When removing the latex gloves, make sure not to touch the outside of the gloves with your hands and dispose of it is the waste containers. Copper (II) chloride is

dangerous and handle it carefully, it can damage eyes skin, toxic, corrosive. Store in a tightly closed container. Wash thoroughly after handling, if exposed to skin take clothes off immediately and rinse with water, if in eyes rinse with water for several minutes. For the hydrochloric acid, it is colorless and pungent, it can cause severe burns, store in a sealed container, wash thoroughly after handling, if exposed to skin take clothes off immediately and rinse with water, if in eyes rinse with water for several minutes. Disposal of these chemicals cannot be drained in the sink it needs to be discarded in the proper waste containers.

2.3 Methods (Exp A)

The purpose of part a experiment is to accurately determine the amount of copper that is being produced in the reaction above with the reactants being 10.00 mL of 0.200 M copper (II) chloride solution and a zinc coupon. Starting off first record the mass of the zinc coupon using the weight balance. Next empty the copper chloride solution into the 50 mL beaker and rinse it with distilled water to make sure all the solution is gone, next add the zinc into the 50 mL beaker. Stir it mixture using the stir rod for 5 to 10 minutes until the solution is completely clear and make sure to scrape the zinc to make a better reaction. Next pre-weight the filler paper and the watch glass. Prepare the filter paper into the glass funnel to be able to filter out the copper. Using the glass funnel and the Erlenmeyer flask, dump the 50 mL beaker into the funnel and use the distilled water on the beaker and the paper filter to make sure all the solution is filtered into the flask. Using the tweezers carefully remove the zinc coupon and dispose of it in the waste in the proper accumulation area. Now transfer the filter paper into the glass funnel and place the glass funnel on the square wire mesh and move the whole thing to dry under the infrared lamp to evaporate to remaining water for 5 minutes. Next weight the glass funnel and the paper filter together. Repeat the drying process and weighing of the glass funnel for two more times. The

third weigh in minus the prerecorded glass funnel and paper filter should be the amount of solid copper that is made in the experiment.

2.4 Methods (Exp B)

The purpose of part b like part a is to accurately determine the amount of copper that is being produced in the reaction above with the reactants being 10.00 mL of 0.100 M copper (II) chloride solution and zinc granules. First weigh the zinc granules. Next empty the zinc granules into the chloride solution's vial and add the magnetic stir bar into it and make sure to put the lid back. Put the entire thing into the magnetic stir plate and turn on the stirring function until the zinc is completely turned into the solution or the solution is completely clear. Next pre-weight the filler paper and the watch glass. Prepare the filter paper into the glass funnel to be able to filter out the copper. Using the glass funnel and the Erlenmeyer flask, dump the vial into the funnel and use the distilled water on the beaker and the paper filter to make sure all the solution is filtered into the flask. Now transfer the filter paper into the glass funnel and place the glass funnel on the square wire mesh and move the whole thing to dry under the infrared lamp to evaporate to remaining water for 5 minutes. Next weight the glass funnel and the paper filter together. Repeat the drying process and weighing of the glass funnel for two more times. The third weigh in minus the prerecorded glass funnel and paper filter should be the amount of solid copper that is made in the experiment.

3 Results

3.1 Part A:

The moles of zinc were calculated by dividing the mass of the zinc coupon 1.334 g by the atomic mass of zinc, 65.38 U, $\frac{1.334\ grams}{65.38\ U} = .002\ moles$. The moles of copper chloride were

calculated by multiplying the molarity by the amount of volume of solution, $\frac{.200\ moles}{1L} * .01L =$ $.002\ moles$. The final mass of copper was calculated by subtracting the mass of the 3rd drying by the mass of the watch glass and filter paper. The calculation of the theoretical yield of zinc to copper is $.20\ moles\ Zn * \frac{1\ moles\ copper}{1\ moles\ zinc} * \frac{65.55\ grams\ of\ copper}{1\ mol\ copper} = 1.297\ grams$. The calculation of the theoretical yield of copper chloride to copper is $.002\ moles * \frac{1\ moles\ copper}{1\ moles} *$ $\frac{65.55\ grams\ of\ copper}{1\ mol\ copper} = .127\ grams$. The actual yield is the lowest of the two which is .127 grams. Lastly the percent yield is the $\frac{final\ mass\ of\ copper\ .746g}{.127\ g\ theoretical} *$ 100% = 587%.

Name	Value
Mass of the Zinc Coupon (g)	1.334
Moles of Zinc (m)	0.020
Volume of Copper (II) chloride (mL)	10.000
Molarity of Copper (II) chloride (M)	0.200
Moles of Copper (II) chloride (m)	0.002
Atomic Mass of Copper (II) chloride (U)	134.450
Atomic Mass of Zinc (U)	65.380
Atomic Mass of Copper (U)	63.550
Mass of Watch Glass (g)	36.438
Mass of filter Paper (g)	0.295
Mass of Watch Glass + Filter Paper (g)	36.733
Mass of copper + watch glass + filter paper after 1st drying: (g)	36.839
Mass of copper + watch glass + filter paper after 2nd drying: (g)	38.435
Mass of copper + watch glass + filter paper after 3rd drying: (g)	37.479
Final mass of copper: (g)	0.746
Reaction	Zn(s) + CuCl2(aq) → ZnCl2(aq) + Cu(s)
Theoretical Yield Zinc to Copper (g)	1.297
Theoretical Yield Copper (II) chloride to copper (g)	0.127
Theoretical Yield of Copper (g)	0.127

Percent Yield (%)	587%

Observations: the zinc when mixing was turning into brown flakes, and the blue color completely disappeared around 5 minutes. The amount of copper flakes was not much. The copper in self was green and orange.

3.2 Part B:

The moles of zinc were calculated by dividing the mass of the zinc coupon by the atomic mass of zinc, 65.38 U, $\frac{.043\ grams}{65.38\ U} = .001\ moles$. The moles of copper chloride were calculated by multiplying the molarity by the amount of volume of solution, $\frac{.100\ moles}{1L} * .01L = .001\ moles$. The final mass of copper was calculated by subtracting the mass of the 3rd drying by the mass of the watch glass and filter paper. The calculation of the theoretical yield of zinc to copper is $.001\ moles\ Zn * \frac{1\ moles\ copper}{1\ moles\ zinc} * \frac{65.55\ grams\ of\ copper}{1\ mol\ copper} = .042\ grams$. The calculation of the theoretical yield of copper chloride to copper is $.001\ moles * \frac{1\ moles\ copper}{1\ moles} * \frac{65.55\ grams\ of\ copper}{1\ mol\ copper} = .064\ grams$. The actual yield is the lowest of the two which is .042 grams. Lastly the percent yield is the $\frac{final\ mass\ of\ copper\ 2.994g}{.042\ g\ theoretical} *$ 100% = 7163%.

Name	Value
Mass of Zinc Granules + Weigh Boat (g)	0.739
Mass of weigh boat (after transferring Zn) (g)	0.696
Mass of zinc granules (g)	0.043
Moles of zinc (m)	0.001
Volume of CuCl2 (mL)	10.000
Molarity of CuCl2 (M)	0.100
Moles of CuCl2 (m)	0.001
Atomic Mass of Copper (II) chloride (U)	134.450

Atomic Mass of Zinc (U)	65.380
Atomic Mass of Copper (U)	63.550
Mass of Watch Glass (g)	35.202
Mass of filter Paper (g)	0.290
Mass of Watch Glass + Filter Paper (g)	35.492
Mass of copper + watch glass + filter paper after 1st drying: (g)	39.139
Mass of copper + watch glass + filter paper after 2nd drying: (g)	38.602
Mass of copper + watch glass + filter paper after 3rd drying: (g)	38.486
Final mass of copper: (g)	2.994
Reaction	Zn(s) + CuCl2(aq) → ZnCl2(aq) + Cu(s)
Theoretical Yield Zinc to Copper (g)	0.042
Theoretical Yield Copper (II) chloride to copper (g)	0.064
Theoretical Yield of Copper (g)	0.042
Percent Yield (%)	7163%

Observations the zinc is being efficiently turned into copper and after a couple minutes. However, there was still some blue color left. The copper in self was green and orange. The amount of copper was even less that of part a.

4 Discussion / Analysis

4.1 Part A:

Part A, the objective was to determine the limiting reactant and calculate the theoretical and actual yield of copper in the reaction between zinc and copper (II) chloride. Based on the stoichiometry of the reaction: $Zn(s) + CuCl_2(aq) \rightarrow ZnCl_2(aq) + Cu(s)$. The reactants used in this part is 1.334 g of zinc and 10.00 mL of 0.200 M CuCl2. The calculated moles of zinc and copper chloride were 0.02 and 0.002 moles. Since both reactants have a 1:1 mole ratio the coper chloride would produce 10 times more copper than the zinc. The theoretical yield is .127

grams of copper however the actual yield came about .746 grams which is beyond expected from the experiment. The high percent yield of 587%, may have come from some sources off error. The most probable one is that the water did not completely dry off from the paper filter. Which would account for the huge error. Some other potential errors would be human error in weighing pouring and transporting the substance, which would make sense comparing the very small amount of mass that is worked with. During the observation the color of the copper also showed green and orange hues, which might be indicative of impurities or the formation of oxidized copper species, which might have added even more weight to it.

4.2 Part B:

In Part B, similar steps were followed, but this time with 10.00 mL of a more dilute 0.100 M CuCl2 solution and 0.043 g of zinc granules. The theoretical yield of copper based on zinc was 0.042 g, while the theoretical yield based on CuCl2 was 0.064 g. In this part, the limiting reactant was zinc, as the theoretical yield of copper should have been limited by the smaller quantity of zinc. The final mass of copper measured was a surprising 2.994 g. Which led to a very high percent yield of 7163%, which is far beyond the expected range for any reasonable experimental setup. This high percent yield may have been contributed because some error such as incomplete drying of the filter paper or glass funnel, or contamination of the sample during weighing, could have contributed to this inflated yield. Since the solution still retained some blue coloration at the end of the experiment, it is possible that not all copper (II) chloride had reacted, further complicating the outcome.

5 Conclusions

The experiments in Part A and Part B demonstrated the effects of stoichiometry through the chemical equation, of $Zn(s) + CuCl_2(aq) \rightarrow ZnCl_2(aq) + Cu(s)$, limiting reactants, and excess reactants in a chemical reaction. However, there were huge deviations between the actual value and the theoretical values. These discrepancies can be attributed to experimental errors such as incomplete drying, contamination, or impurities in the solution. Better refinement of the procedure, including more careful filtering, drying, and weighing techniques, would likely produce results that better align with theoretical predictions.

6 Acknowledgements

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7 References

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