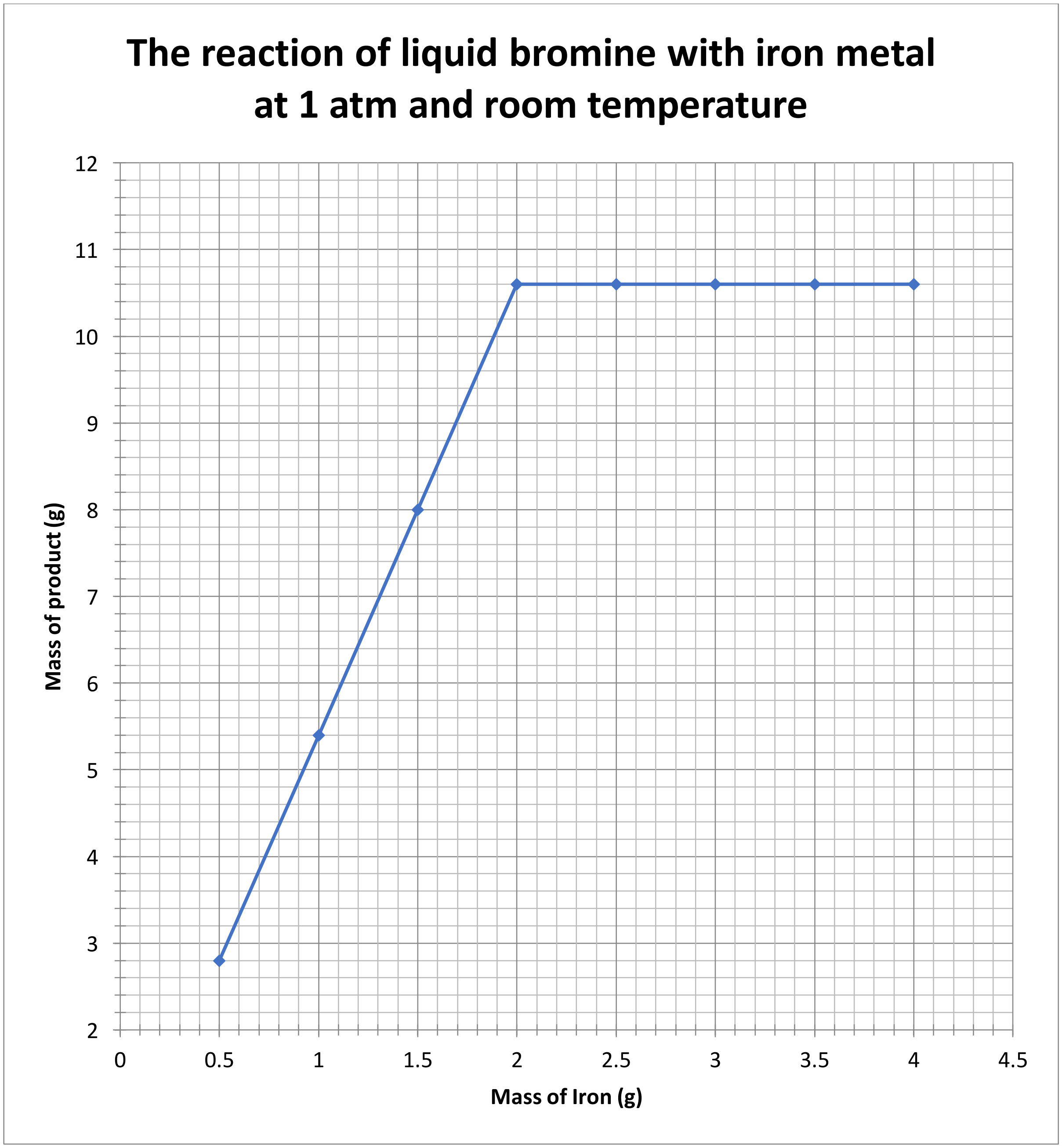
Dry Lab I: Graphing and Problems in Limiting Reagent Involving Mass Relationships

Part 1: Interpreting Limiting Reagent from a Graph

A weighed sample of iron is added to liquid bromine and allowed to react completely. The reaction produces a single product, which can be isolated and weighed. The experiment is repeated several times with different masses of iron but the same mass of bromine.



Questions for Part 1:Put the answers to these questions neatly in your lab book.

1. What mass of bromine is used when the reaction consumes 2.0 g of iron?
2. What are the moles of bromine used for the reaction?
3. Does it matter if one uses molecular or atomic bromine for the mass calculations? To test this,
    a. Calculate the moles of atomic bromine used for the reaction.
    b. Calculate the moles of molecular bromine used for the reaction.
    c. So, does it matter which one you use?
4. What is the mole ratio of bromine to iron in the reaction?
5. What is the empirical formula of the product?
6. Write the balanced chemical equation for the reaction of iron and bromine.
7. What is the name of the reaction product?
8. Which statement or statements best describe the experiments summarized by the graph? Explain your choice.
    a) When 1.00 g of iron is added to the bromine, iron is the limiting reagent.
    b) When 3.50 g of iron is added to the bromine, bromine is the excess reagent.
    c) When 2.50 g of iron is added to the bromine both reactants are used up completely.
    d) When 2.00 g of iron is added to the bromine, 10.0g of product is formed. The percent yield must there for be 20%.

Part 2: Graphing Limiting Reagent Data

Section 2A & B: Create graphs in your lab book using data from Data Table I & a graph from Data II (two different graphs!)

Show the calculations for your range, scale divisions, and starting points for each axis.
Follow good graphing procedures as presented in "Introduction to Graphing", a copy of which can be found on the web site.

Part 2A: Graph I Data

A Chemistry 1A class decided to do a group experiment to demonstrate the concept of limiting reagent. The reaction explored used varying amounts of magnesium metal reacting with a standard quantity of $HCl_{(aq)}$. The standard amount of $HCl_{(aq)}$ was 2.25 mmol/L.

The reaction is $Mg_{(s)} + 2HCl_{(aq)} \rightarrow MgCl_{2(aq)} + H_{2(g)}$

Data Table I: The change in the volume of hydrogen gas produced when Mg metal is reacted with a 2.25 mmol/L solution of $HCl_{(aq)}$ at 1 atm and 25°C

Length of the ribbon (cm)	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	5.0	6.0	7.0	8.0
Volume of H_2 gas produced (mL)	6.2	12.0	15.6	21.5	26.5	30.0	31.5	33.8	34.5	34.5	35.0	35.0

Questions for Section 2A: Answer the following questions that pertain to the graphs you made.

Graph I

1. Trace the data points to give the best smooth curve.
2. Draw a best-fit line that represents the maximum volume of hydrogen gas produced by this reaction.
3. Draw a best-fit line that follows the reaction amounts of magnesium as the reaction progresses.
    (a) These two lines should intersect, but don't be surprised if it does not look like the example in Part 1.
    (b) The two lines should represent a best-fit line
4. Indicate the region on the graph where the **hydrochloric acid** is the limiting reagent.
5. Indicate the region on the graph where the **magnesium metal** is the limiting reagent.
6. Indicate the region on the graph where **both reactants** are limiting reagents (in other words, perfect stoichiometric balance)
7. From the balanced equation and the graph, you can infer the limiting reagent to be hydrochloric acid. Explain.
8. Is volume of the solutions mixed an important factor?

Part 2B: Graph II Data

Graph I was so much fun, that the class decided to collect data on a second experiment. In this experiment, the temperature was measured as volumes of sodium hypochlorite solution and sodium sulfite solution were mixed. The class wanted to measure the ratio of moles of the reactants in a chemical reaction by the method of continuous variation using the temperature change of the reaction as a measure of the progress of the reaction.

In this method, the temperature is measured while different mole ratio of reactants is mixed, while the total volume of the reaction mixture is kept constant. The stoichiometric ratio (one in which there is no limiting reagent) would be the ratio in which the greatest amount of product is formed and the most heat is generating resulting in the highest temperature change, which indicated the intensity of the reaction.

Data was collected for both solutions. (see Data Table II) The students made two graphs, one comparing the change in temperature with the volume of sodium hypochlorite added, and a similar one with the volume of sodium sulfite. The molarity of all the solutions was the same. Since moles are directly related to the volume delivered, the smaller the volume, the smaller the moles added for the reactions. Although the class made two graphs, lucky you!! You are only making one (**1, ONE)** graph ΔT vs NaClO, because to get the corresponding amount of Na_2SO_3, one needs to subtract the volume of NaClO used by 50 mL.

The reaction is $NaClO_{(aq)} + Na_2SO_{3(aq)} \rightarrow NaHSO_{4(aq)} + NaCl_{(aq)}$

Data Table II: The temperature change of the reaction based on the volume of a 1.00M NaClO and corresponding volume of 1.00 MNa_2SO_3 solution at 1 atm.

NaClO (mL)	5.0	10.0	15.0	20.0	25.0	30.0	35.0	40.0	50.0
$Na_2SO_{3,(mL)}$	45.0	40.0	35.0	30.0	25.0	20.0	15.0	11.0	5.0
Temp °C	24.9	28.2	30.5	33.1	35.2	35.9	32.1	29.3	24.5
ΔT°C	2.75	6.05	8.65	10.95	13.05	13.75	9.95	6.15	2.35

Questions for Section 2B: Answer the following questions that pertain to the graphs you made.

Graph II

1. Trace a best-fit line that follows the increase in temperature with the increase of the volume of NaClO.
2. Trace a best–fit line that follows the increase in temperature with the decrease of the volume of NaClO.
   (c) These two lines should intersect,
   (d) The two lines should represent a best-fit line

3. Indicate the region on the graph where NaClO is **excess reagent.**
4. Indicate the region on the graph where the NaClO is the **limiting reagent.**
5. What is the data in the data table telling you about the reaction in terms of temperature changes?
6. Why is it more accurate to use the point of the two lines to find the mole to mole ratio, rather than the ratio associated with the greatest temperature change?
7. What does the intersection of the lines indicate about the reactants in the process?
8. Based on the graph, what is the stoichiometric point for this reaction?

Part 3: Questions

Answer the questions below. Show your work. Watch your significant figures. Put the answers to these questions in your lab book.

1. The compound SF_6 is made by burning sulfur in an atmosphere of fluorine. The balanced equation is:

$$S_{8(s)} + 24\ F_{2(g)} \rightarrow 8\ SF_6(g)$$

   If the reaction vessel contains 3.20 mole of sulfur and 70.0 mol of fluorine gas, determine the limiting reagent.

2. The reaction of methane and water is one way to prepare hydrogen for use as a fuel:

$$CH_{4(g)} + H_2O_{(g)} \rightarrow CO_{(g)} + 3\ H_{2(g)}$$

   If you begin with 995 g of methane and 2.150 kg water:
   (a) Determine the limiting reagent
   (b) What is the maximum mass of hydrogen produced?
   (c) What is the mass of the excess reactant that remains after the reaction is finished.

3. The deep blue compound $Cu(NH_3)_4SO_4$ is made by the reaction of copper(II) sulfate and ammonia

$$CuSO_{4(aq)} + 4\ NH_{3(aq)} \rightarrow Cu(NH_3)_4SO_{4(aq)}$$

   (a) If you use 10.0 g of $CuSO_4$ and 3.00 g NH_3, what is the theoretical yield of $Cu(NH_3)_4SO_{4(aq)}$?
   (b) If you obtained 9.60 g of $Cu(NH_3)_4SO_{4(}$, what is the percent yield?

4. Liquid phosphorus trichloride [PCl_3] reacts with water to form phosphorous acid [H_3PO_3] and hydrochloric acid.
   a. What is the balanced equation for the reaction?
   b. Which is the limiting reactant when 12.4 g of PCl_3 is mixed with 10.0g of H_2O?
   c. How many grams of hydrochloric acid are produced?
   d. How much excess reagent remains after the reaction is complete?

5. A mixture of 4.94 g of 85.0% pure phosphine, PH_3, and 0.110 kg of $CuSO_4 \bullet 5H_2O$ is placed in a reaction vessel. Calculate the mass of Cu_3P_2 with a 6.31% yield that would be produced in the reaction.

$$3\ CuSO_4 \bullet 5H_2O_{(s)} + 2PH_{3(g)} \rightarrow Cu_3P_{2(s)} + 3H_2SO_{4(aq)} + 15\ H_2O_{(l)}$$

SUGGESTION: DO THE WORK ON SCRATCH PAPER BEFORE YOU ENTER THE WORK IN YOUR LAB BOOK. THE WORK WILL BE BETTER SPACED, AND NEATER.