Stoichiometry of Lead Iodide: A Mole Ratio Study

Objectives: To investigate the stoichiometry of the potassium iodide—lead nitrate system in water. The volumes of reagents will be varied, and the mass of product will be determined. Students will determine the stoichiometry of the precipitation reaction by graphical analysis.

Materials: 1.00 M potassium iodide, KI;, 0.500 M lead nitrate, $Pb(NO_3)_2$

Equipment: Test tubes; stirring rod; filtering funnel and quantitative filter paper (e.g., Whatman #42); iron ring and ring stand; watch glass

Safety: Lead compounds are toxic. Wear gloves when handling solutions of lead compounds. Safety goggles should be worn at all times.

Waste Disposal: The solid reaction product, filtrate and wash solutions should be placed in the inorganic waste container.

Review: You should be familiar with techniques for measuring masses and solution volumes, and for filtering solutions. You should be familiar with precipitation reactions and the general solubility rules.

INTRODUCTION

The composition of reaction products can often be verified by determining the **stoichiometry** of the reaction. Stoichiometry is the mole ratio of reactants that will combine in exact amounts to yield a given product, and is represented in the coefficients of a balanced chemical equation.

The stoichiometry of a reaction system can be examined using the **mole ratio** method. A series of reactions are carried out in which the amount of one reactant is varied while holding the amounts of other reactant(s) constant. Some property of the reacting system is monitored as the amounts of reactants are varied. For example, if a reactant or product of the reaction absorbs light of a given wavelength, then the absorbance of the reaction solutions can be examined. If the reaction forms an insoluble product, then the mass of this product be determined.

Consider the barium chloride-sodium sulfate-water system. Mixing aqueous solutions of barium chloride ($BaCl_2$) and sodium sulfate (Na_2SO_4) results in formation of an insoluble product, or **precipitate**. Such a system can be used to illustrate the mole ratio method to be used in this lab exercise. The volume of sodium sulfate solution is varied while the volume of barium chloride is held constant. The precipitate formed is carefully collected, washed and dried, and the mass of precipitate is measured. The mass of product is plotted vs the moles of sodium sulfate in each reaction mixture, and the **stoichiometric point** is determined graphically. The stoichiometric point occurs when the reactants are present in the correct mole ratio for complete reaction. The experimental details and mass of product obtained in this mole ratio study are summarized in the table below:

	Na_2SO_4 (1.00 M)		$BaCl_2$ (1.00 M)		
Reaction Mixture	Volume of solution (mL)	# of mmoles (10^{-3} mol)	Volume of solution (mL)	# of mmoles (10^{-3} mol)	Mass of precipitate (g)
1	1.00	1.00	6.00	6.00	0.25
2	2.00	2.00	6.00	6.00	0.45
3	3.00	3.00	6.00	6.00	0.70
4	4.00	4.00	6.00	6.00	0.90
5	5.00	5.00	6.00	6.00	1.15
6*	***6.00***	***6.00***	***6.00***	***6.00***	***1.38***
7	7.00	7.00	6.00	6.00	1.40
8	8.00	8.00	6.00	6.00	1.39
9	9.00	9.00	6.00	6.00	1.38

*stoichiometric point

A plot of the mass of precipitate vs moles of Na_2SO_4 added to each reaction mixture is provided below. We can see that the mass of product increases as the amount of Na_2SO_4 increases. Above 6.00 moles of added Na_2SO_4 the mass of product levels off. The stoichiometric point in the reaction is identified as the point of intersection of the trend lines. At this point, the molar ratio of $BaCl_2$ to Na_2SO_4 is 1:1. A review of the solubility rules indicates that the insoluble product is likely to be barium sulfate, $BaSO_4$. The balanced chemical equation for this reaction can be written as:

$$BaCl_2(aq) + Na_2SO_4(aq) \rightarrow BaSO_4(s) + 2\,NaCl(aq)$$

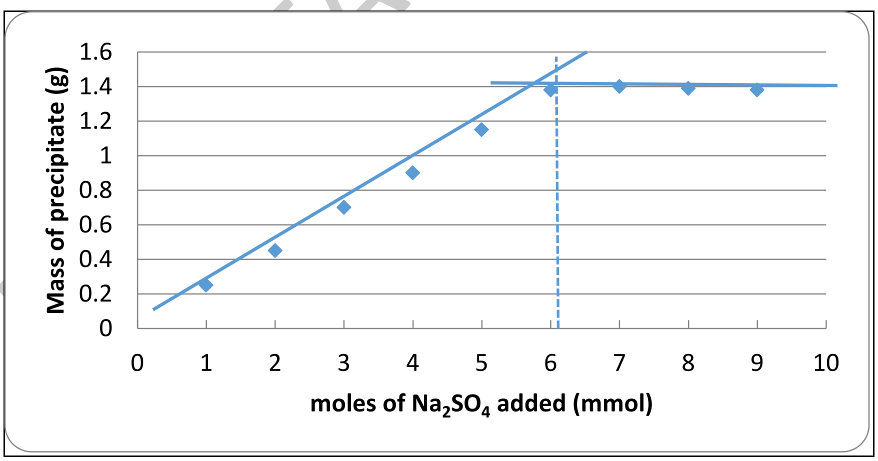

Figure 1. Identification of stoichiometric point for $BasSO_4$ mole ratio study.

Pre-Lab Questions

1. Outline the appropriate techniques for weighing, filtering, and drying a precipitate.

2. A student investigated the stoichiometry of the silver nitrate—sodium sulfide—water system using experimental procedures similar to those described in this lab. The reagent concentrations and volumes used are included in the table below.

	1.00 M $AgNO_3$		1.00 M Na_2S		
Reaction mixture	Volume (mL)	# of moles	Volume (mL)	# of moles	Mass of residue (g)
1	2.00		6.00		0.2420
2	4.00		6.00		0.5013
3	6.00		6.00		0.7433
4	8.00		6.00		1.054
5	10.00		6.00		1.252
6	12.00		6.00		1.4862
7	14.00		6.00		1.5012
8	16.00		6.00		1.4961
9	18.00		6.00		1.4882

(a) Complete the table by performing the appropriate calculations as outlined in the lab module.

(b) On graph paper, plot the mass of residue vs. the number of moles of silver nitrate added to each reaction mixture. Draw the best straight lines between the data points on the left and on the right-hand sides of the plot.

(c) What is the number of moles of $AgNO_3$ and Na_2S at the point of intersection of the two lines on the graph?

Moles of $AgNO_3$:___________ Moles of Na_2S:_______________

(d) Based on these data write a chemical equation to represent the precipitation reaction between $AgNO_3$ and Na_2S showing the correct stoichiometry.

(e) If 7.00 mL of 1.00 M $AgNO_3$ is added to 6.00 mL of Na_2S, what mass of precipitate would you expect to recover based on the plot you prepared?

PROCEDURE

Observe all safety precautions when working with sample components and reagents. Each student will be assigned one of the ten reaction mixtures listed in Table 2. Students will share data obtained from their individual experiments, and perform graphical analysis on the compiled data set.

1. Clean and dry two test tubes. Label the test tubes with numbers corresponding to your assigned reaction mixture.

2. Dispense 6.00 mL of 1.00 M KI solution into each of the test tubes. From a second buret, add the volume of 0.500 M $Pb(NO_3)_2$ indicated in Table 1 for your assigned mixture. Stir the contents of the test tube thoroughly with a glass stirring rod. Wash the stirring rod with a small amount of distilled water, collecting the wash water in the test tube to avoid loss of product. Set the test tube aside and allow contents to settle.

Table 1. Reaction mixture volumes for potassium iodide—lead nitrate—water system.

Reaction Mixture	1	2	3	4	5	6	7	8	9	10
mL of 1.00 M KI	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00
mL of 0.500 M $Pb(NO_3)_2$	1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.00

3. Obtain a piece of filter paper. Weigh the filter paper to the nearest milligram. Record this mass on your Data Sheet.

4. Place the filter paper in the filter funnel and moisten with distilled water. Once the precipitate in your reaction mixture has settled, filter the precipitate.

5. Wash the precipitate on the filter paper with two 5 mL portions of ice-cold distilled water.

6. Weigh a watch glass to the nearest milligram, and record this mass on your Data Sheet. Carefully remove the filter paper and residue from the filter funnel and place them on the tared watch glass.

7. Place the watch glass with filter paper and residue in an oven at 90^{o}C and allow to dry for 1 hour.

8. Remove the watch glass from the oven and allow to cool. Once cooled, weigh the watch glass, filter paper and residue and record this mass on your Data Sheet.

9. Return the watch glass, filter paper and residue to the oven and dry for an additional 15 minutes.

10. Remove the watch glass from the oven and allow to cool. Once cooled, weigh the watch glass, filter paper and residue and record this mass on your Data Sheet. Repeat this step until you obtain a constant mass (within ± 0.002 g). Report the results of your determination to your lab TA.

11. If time permits, perform a second determination for your reaction mixture by repeating Steps 2–10.

12. BE SURE TO RECORD THE RESULTS FOR ALL REACTION MIXTURES REPORTED BY OTHER STUDENTS BEFORE YOU LEAVE LAB! RECORD THESE MASSES IN TABLE 2 ON YOUR DATA SHEET.

CALCULATIONS AND GRAPHING

1. Calculate the number of moles of KI in your reaction mixture:

   # moles KI = (volume KI, liters) (molarity of KI)

   Record this number of moles on your Data Sheet.

2. Calculate the number of moles of $Pb(NO_3)_2$ in each of the reaction mixtures in Table 1 using the following equation:

   # moles $Pb(NO_3)_2$ = (volume $Pb(NO_3)_2$, liters) x (molarity of $Pb(NO_3)_2$)

3. Record these values in the appropriate locations in Table 2 on your Data Sheet.

4. Plot the masses of residues in Table 2 vs. the number of moles of $Pb(NO_3)_2$ in each reaction mixture on graph paper. The scale of the ordinate (y-xis) should extend from 0.0 g to 0.5 g more than the largest mass of product recorded in Table 2. The scale of the abscissa (x-axis) should extend from 0.0 mol to 5.00×10^{-3} mol of $Pb(NO_3)_2$. Label the axes with appropriate titles and units.

5. Using a straight edge, draw the best straight line through the plotted points on the left side of the graph. Draw another straight line through the plotted points on the right side of the graph. The stoichiometric point for the reaction between potassium iodide and lead nitrate will be the point where these two lines intersect. Record this point on your Data Sheet.

Data Sheet

Assigned reaction mixture: ________________

	Determination 1	2
Volume of 1.00 M KI solution (mL)	__________	__________
Number of moles of KI	__________	__________
Volume of 0.500 M $Pb(NO_3)_2$ solution (mL)	__________	__________
Number of moles of $Pb(NO_3)_2$	__________	__________
Mass of watch glass, filter paper + residue (g)		
First weighing:	__________	__________
Second weighing:	__________	__________
Third weighing (if needed):	__________	__________
Mass of filter paper (g)	__________	__________
Mass of watch glass (g)	__________	__________
Mass of residue (g)	__________	__________
Mole Ratio (moles KI : moles $Pb(NO_3)_2$)	__________	__________

Table 2. Compilation of Class Data

Reaction Mixture	Moles of KI	Volume of $Pb(NO_3)_2$ solution (mL)	Moles of $Pb(NO_3)_2$	Mass of residue (g)
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				

Post-Lab Questions

1. How would each of the following modifications to the experimental procedure used in this investigation affect the mass of product obtained? Indicate if the mass of product would be greater, less, or unchanged. Explain your reasoning.

(a) The KI solution is added to the $Pb(NO_3)_2$ solution instead of adding the $Pb(NO_3)_2$ solution to the KI solution.

(b) The temperature of the reactant solutions is 40^{o}C instead of room temperature.

(c) The residue is washed with hot distilled water instead of cold distilled water.

(d) The residue is not washed with distilled water at all.

(e) The reactions were performed using 6.00 mL of 2.00 M KI instead of 6.00 mL of 1.00 M KI.