Lab 24. Identification of Reaction Products: What Are the Products of the Chemical Reactions?

Introduction

Chemical reactions are the result of a rearrangement of the molecular or ionic structure of a substance. It is important to remember that the *law of conservation of mass* states that mass is conserved in ordinary chemical changes. The total amount of mass before and after the reaction is therefore the same, even though there are new substances with different properties than the original substances. Additionally, the *law of definite proportions* states that atoms combine in specific ways when they form compounds; therefore, a given compound always contains the same proportion of elements by mass. These two laws allow us to predict the rearrangement of atoms during chemical reactions, with no atoms being destroyed and no new atoms being produced. Balanced chemical equations are used to show the relative amounts of substances that react with each other and how the structures are rearranged during a chemical reaction.

One specific type of chemical reaction is a double replacement reaction or a *precipitation reaction*. Precipitation reactions typically occur when two solutions are mixed together and a nonsoluble product—the precipitate—is formed. Figure L24.1 shows an example of a precipitation reaction involving potassium iodide and lead nitrate. The balanced chemical equation is

FIGURE L24.1

An example of a precipitate reaction

$$2KI(aq) + Pb(NO_3)_2(aq) \rightarrow 2KNO_3(aq) + PbI_2(s)$$

In this example clear potassium iodide (KI) and clear lead nitrate ($Pb(NO_3)_2$) solutions are mixed together, producing a bright yellow precipitate, lead iodide (PbI_2). The other product, potassium nitrate (KNO_3), is soluble and remains dissolved in the solution.

TABLE L24.1

Solubility rules for ionic compounds in water

Ion	Soluble?	Exceptions
NO_3^-	Yes	None
ClO_4^-	Yes	None
Cl^-	Yes	Ag^+, Hg_2^{2+}, Pb^{2+}
I^-	Yes	Ag^+, Hg_2^{2+}, Pb^{2+}
SO_4^{2-}	Yes	Ca^{2+}, Ba^{2+}, Sr^{2+}, Ag^+, Hg^{2+}, Pb^{2+}
CO_3^{2-}	No	Group IA and NH_4^+
PO_4^{3-}	No	Group IA and NH_4^+
OH^-	No	Group IA, Ca^{2+} (slightly soluble), Ba^{2+}, Sr^{2+}
S^{2-}	No	Groups IA and IIA and NH_4^+
Na^+	Yes	None
NH_4^+	Yes	None
K^+	Yes	None

To predict the products during a precipitation reaction, you must know the ion charges for the substances dissolved into the solutions and understand which types of substances are soluble in water. There are some general rules that can help you determine if an ionic compound will dissolve in water. Table L24.1 lists some basic solubility rules for ionic compounds; the table shows common *anions* (negatively charged ions) and *cations* (positively charged ions) along with their solubility. General solubility rules do not hold

true in every case; therefore, exceptions to the solubility rules are also noted in Table L24.1.

Understanding how ions may rearrange during a chemical reaction and understanding the general solubility rules will go a long way in helping you predict the products of a precipitation reaction and identify the actual precipitate. However, depending on the chemicals involved, there may be no obvious way to identify the precipitate using qualitative observations. In those cases it may be necessary to use stoichiometric procedures to determine the precipitate based on a balanced chemical equation.

Your Task

Four partial chemical equations are provided below. Your task is to identify the products of the four chemical reactions, including the precipitate in each reaction.

$$AgNO_3(aq) + NaCl(aq) \rightarrow ?$$

$$Na_2CrO_4(aq) + Ca(NO_3)_2(aq) \rightarrow ?$$

$$CaCl_2(aq) + Na_3PO_4(aq) \rightarrow ?$$

$$NaOH(aq) + NiCl_2(aq) \rightarrow ?$$

The guiding question of this investigation is, **What are the products of the chemical reactions?**

Materials

You may use any of the following materials during your investigation:

Consumables	**Equipment**
• Calcium chloride, $CaCl_2$ • 1 M calcium nitrate, $Ca(NO_3)_2$ • 1 M nickel(II) chloride, $NiCl_2$ • 1 M silver nitrate, $AgNO_3$ • 1 M sodium chloride, NaCl • 1 M sodium chromate, Na_2CrO_4 • 1 M sodium hydroxide, NaOH • 1 M sodium phosphate, Na_3PO_4 • Distilled water	• Toothpicks • Filter paper • 4 test tubes • Well plate • Electronic or triple beam balance • Graduated cylinder (10 ml) • Vacuum filtration kit

Safety Precautions

Follow all normal lab safety rules. Silver nitrate is toxic by ingestion, is corrosive to body tissues, and stains clothes and skin. Your teacher will explain relevant and important information about working with the chemicals associated with this investigation. In addition, take the following safety precautions:

- Wear indirectly vented chemical-splash goggles and chemical-resistant gloves and apron while in the laboratory.
- Handle all glassware with care.
- Wash your hands with soap and water before leaving the laboratory.

Investigation Proposal Required? ☐ Yes ☐ No

Getting Started

To answer the guiding question, you will need to determine what type of data you need to collect, how you will collect the data, and how you will analyze the data.

To determine *what type of data you need to collect*, think about the following questions:

- How much of each chemical will you need to use?
- What masses will you need to measure during the investigation?
- What observations will you need to make?

To determine *how you will collect the data*, think about the following questions:

- How long will you need to allow the chemicals to react?

- How will you reduce error?

To determine *how you will analyze the data*, think about the following questions:

- What type of calculations will you need to make (if any)?
- How will you determine the precipitate in each reaction?

Connections to Crosscutting Concepts, the Nature of Science, and the Nature of Scientific Inquiry

As you work through your investigation, be sure to think about

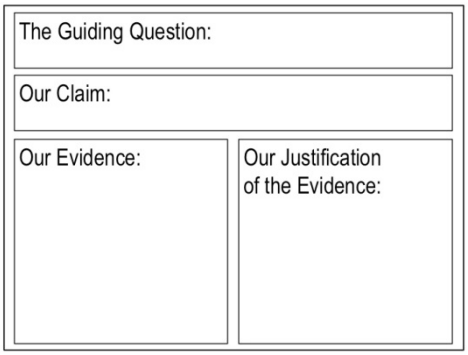
- the importance of patterns in science,
- the importance of the flow of matter and energy within systems,
- the difference between observations and inferences in science, and
- the difference between laws and theories in science.

Initial Argument

Once your group has finished collecting and analyzing your data, you will need to develop an initial argument. Your argument must include a *claim*, which is your answer to the guiding question. Your argument must also include *evidence* in support of your claim. The evidence is your analysis of the data and your interpretation of what the analysis means. Finally, you must include a *justification* of the evidence in your argument. You will therefore need to use a scientific concept or principle to explain why the evidence that you decided to use is relevant and important. You will create your initial argument on a whiteboard. Your whiteboard must include all the information shown in Figure L24.2.

FIGURE L24.2

Argument presentation on a whiteboard



Argumentation Session

The argumentation session allows all of the groups to share their arguments. One member of each group stays at the lab station to share that group's argument, while the other members of the group go to the other lab stations one at a time to listen to and critique the arguments developed by their classmates. The goal of the argumentation session is not to convince others that your argument is the best one; rather, the goal is to identify errors or instances of faulty reasoning in the initial arguments so these mistakes can be fixed. You will therefore need to evaluate the content of the claim, the quality of the evidence used to support the claim, and the strength of the justification of the evidence included in each argument that you see. To critique an argument, you might need more information than what is included on the whiteboard. You might, therefore, need to ask the presenter one or more follow-up questions, such as:

- What did your group do to analyze the data, and why did you decide to do it that way?
- Is that the only way to interpret the results of your group's analysis? How do you know that your interpretation of the analysis is appropriate?
- Why did your group decide to present your evidence in that manner?
- What other claims did your group discuss before deciding on that one? Why did you abandon those alternative ideas?
- How confident are you that your group's claim is valid? What could you do to increase your confidence?

Once the argumentation session is complete, you will have a chance to meet with your group and revise your original argument. Your group might need to gather more data or design a way to test one or more alternative claims as part of this process. Remember, your goal at this stage of the investigation is to develop the most valid or acceptable answer to the research question!

Report

Once you have completed your research, you will need to prepare an *investigation report* that consists of three sections that provide answers to the following questions:

- What question were you trying to answer and why?
- What did you do during your investigation and why did you conduct your investigation in this way?
- What is your argument?

Your report should answer these questions in two pages or less. The report must be typed and any diagrams, figures, or tables should be embedded into the document. Be sure to write in a persuasive style; you are trying to convince others that your claim is acceptable or valid!