SECTION 9.1

Net Ionic Equations and Qualitative Analysis

Key Terms

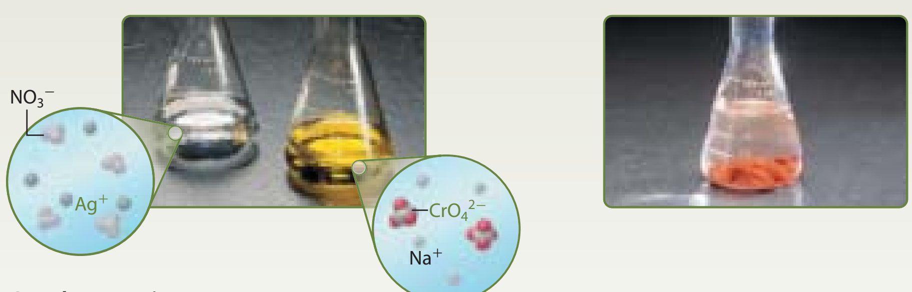
spectator ion
ionic equation
net ionic equation
precipitate
qualitative analysis
flame test

Flowerpot Island, shown in **Figure 9.1**, is a tourist attraction off the Bruce Peninsula in Ontario. The island is composed of a rock called dolomite, which is a mixture of calcium carbonate, $CaCO_3(s)$, and magnesium carbonate, $MgCO_3(s)$. How dolomite rock forms is not well understood. It could be the product of reactions with calcium, magnesium, and carbonate ions, which are commonly present in water. Adding a solution of sodium carbonate to any solution that contains calcium ions and magnesium ions will precipitate calcium carbonate and magnesium carbonate.

Figure 9.1 The dolomite on Flowerpot Island was probably formed from ions in an aqueous solution.

spectator ion an ion that is present in a solution but not involved in a chemical reaction

As shown in **Figure 9.2**, some reactions in aqueous solutions cause spectacular colour changes. The reaction shown in **Figure 9.2** is a double displacement reaction between silver nitrate and sodium chromate. A chemical reaction between two aqueous solutions that contain ions is *always* a double displacement reaction. Water dissociates ionic substances into their component ions, allowing reactant ions to mix and react more readily. However, water is not a reactant in the chemical equation, and neither are some of the ions in the solution. Non-reacting ions in an aqueous solution are called **spectator ions**. Spectator ions are usually ions that form soluble compounds. As described in Section 8.2, these ions often have a single charge and a large radius.



Complete Equation

$$\underset{\text{silver nitrate}}{2AgNO_3(aq)} + \underset{\text{sodium chromate}}{Na_2CrO_4(aq)} \rightarrow \underset{\text{silver chromate}}{Ag_2CrO_4(s)} + \underset{\text{sodium nitrate}}{2NaNO_3(aq)}$$

Ionic Equation

$$2Ag^+(aq) + 2NO_3^-(aq) + 2Na^+(aq) + CrO_4^{2-}(aq) \rightarrow Ag_2CrO_4(s) + 2Na^+(aq) + 2NO_3^-(aq)$$

Net Ionic Equation

$$2Ag^+(aq) + CrO_4^{2-}(aq) \rightarrow Ag_2CrO_4(s)$$

Figure 9.2 In the reaction shown here, the reactants are a colourless solution of silver nitrate, $AgNO_3(aq)$, and a yellow solution of sodium chromate , $Na_2CrO_4(aq)$. The products are a red precipitate of silver chromate, $Ag_2CrO_4(s)$, and a colourless solution of sodium nitrate, $NaNO_3(aq)$.

Writing Ionic and Net Ionic Equations

The following equation represents the reaction shown in **Figure 9.2** in terms of intact compounds:

$$2AgNO_3(aq) + Na_2CrO_4(aq) \rightarrow Ag_2CrO_4(s) + 2NaNO_3(aq)$$

This representation is not fully accurate because soluble ionic substances dissociate into ions in water.

An **ionic equation** replaces the formulas of soluble ionic compounds with the ions that these compounds form in water. Recall that the solubility guidelines in **Table 8.3** indicate whether a substance is soluble in water. Silver nitrate, sodium chromate, and sodium nitrate are all soluble. Each of these compounds dissociates into its respective ions in water. Since silver chromate is insoluble, it is shown as an intact compound in the ionic equation:

$$2Ag^+(aq) + 2NO_3^-(aq) + 2Na^+(aq) + CrO_4^{2-}(aq) \rightarrow Ag_2CrO_4(s) + 2Na^+(aq) + 2NO_3^-(aq)$$

Note that the total charge on the left side of the ionic equation equals the total charge on the right side. Also note that sodium ions, $Na^+(aq)$, and nitrate ions, $NO_3^-(aq)$, appear on both sides of the equation. These ions are spectator ions in the reaction. You can cancel any term that appears on both sides of an equation:

$$2Ag^+(aq) + \cancel{2NO_3^-(aq)} + \cancel{2Na^+(aq)} + CrO_4^{2-}(aq) \rightarrow Ag_2CrO_4(s) + \cancel{2Na^+(aq)} + \cancel{2NO_3^-(aq)}$$

$$2Ag^+(aq) + CrO_4^{2-}(aq) \rightarrow Ag_2CrO_4(s)$$

Cancelling the spectator ions leaves the **net ionic equation**. A net ionic equation shows only the ions that react and the insoluble product(s), or **precipitates**, of the reaction.

ionic equation a chemical equation in which soluble ionic substances are written in dissociated form

net ionic equation an ionic equation that does not include spectator ions

precipitate an insoluble product in a reaction

Benefits of Net Ionic Equations

In the example above, the net ionic equation shows that silver ions react with chromate ions to form silver chromate. A solution of an ionic compound always contains both cations and anions. However, the net ionic equation indicates that the source of the silver ions does not matter. The silver ions could be from silver nitrate or from any other soluble silver salt, such as silver acetate, $AgCH_3COO(aq)$. Similarly, sodium chromate could be replaced with ammonium chromate, $(NH_4)_2CrO_4(aq)$. Mixing aqueous solutions of silver acetate and ammonium chromate would produce the same precipitate as the mixture shown in **Figure 9.2**. Changing the spectator ions, from sodium to ammonium or from nitrate to acetate, does not change the reaction because these ions do not participate in the chemical reaction, just as the spectators in **Figure 9.3** do not participate in the game they are watching.

Figure 9.3 Spectators are present at a sporting event but do not take part in the event, just as spectator ions are present in a reaction but do not take part in it.

Writing Net Ionic Equations

Use the following rules to write a net ionic equation for a reaction in an aqueous solution.

Rules for Writing a Net Ionic Equation

1. Write the complete chemical equation for the reaction.
2. Rewrite the soluble ionic compounds as ions. For example, show ammonium chloride as $NH_4^+(aq)$ and $Cl^-(aq)$, instead of $NH_4Cl(aq)$.
3. Leave insoluble ionic compounds as formula units. For example, zinc sulfide is insoluble, so you write it as $ZnS(s)$, not $Zn^{2+}(aq)$ and $S^{2-}(aq)$.
4. Leave molecular compounds as molecular formulas since these compounds produce relatively few ions in an aqueous solution. For example, write aqueous carbon dioxide as $CO_2(aq)$ and water as $H_2O(\ell)$.
5. Write all acids as formula units, except for the six strong acids listed below. Since these strong acids ionize almost completely in water, write them as ions:
   - Write hydrochloric acid, HCl, as $H^+(aq)$ and $Cl^-(aq)$.
   - Write hydrobromic acid, HBr, as $H^+(aq)$ and $Br^-(aq)$.
   - Write hydroiodic acid, HI, as $H^+(aq)$ and $I^-(aq)$.
   - Write sulfuric acid, H_2SO_4, as $2H^+(aq)$ and $SO_4^{2-}(aq)$.
   - Write nitric acid, HNO_3, as $H^+(aq)$ and $NO_3^-(aq)$.
   - Write perchloric acid, $HClO_4$, as $H^+(aq)$ and $ClO_4^-(aq)$.
6. Cancel out the spectator ions. Keep only covalent compounds, the ions that react, and the precipitates that form in the reaction. Any gas that is involved in the reaction must appear in the net ionic equation.
7. Check that both the charges and the atoms are balanced in the net ionic equation.

As you learned in Section 4.2, a double displacement reaction always produces a precipitate, a gas, or water. The next two Sample Problems describe how to write net ionic equations for reactions that produce a precipitate and for reactions that produce water. A reaction between an acid and a base that produces water is called a *neutralization reaction*.

Writing net ionic equations is helpful for distinguishing the important reactants and products in a reaction. Read the Sample Problems and then use what you learned to complete the Practice Problems on page 410.

Sample Problem

Net Ionic Equation for a Reaction That Forms a Precipitate

Problem

What substance will precipitate when an aqueous solution of sodium sulfide, $Na_2S(aq)$, is mixed with an aqueous solution of silver nitrate, $AgNO_3(aq)$? Write the net ionic equation for the reaction.

What Is Required?

You need to identify the precipitate in the reaction between an aqueous solution of sodium sulfide and an aqueous solution of silver nitrate. Then you need to write the net ionic equation for the reaction.

What Is Given?

You know that a precipitate forms when sodium sulfide reacts with silver nitrate.

Solubility guidelines are listed in **Table 8.3** in Section 8.2.

Plan Your Strategy	Act on Your Strategy
Use the solubility guidelines to identify the precipitate.	The exchange of ions in the reaction gives two possibilities for the precipitate: $NaNO_3(s)$ or $Ag_2S(s)$. According to the solubility guidelines, all ionic compounds that contain either sodium or nitrate ions are soluble. However, most sulfides are insoluble. Thus, the precipitate must be silver sulfide, $Ag_2S(s)$.
Write the complete chemical equation for the reaction.	$Na_2S(aq) + 2AgNO_3(aq) \rightarrow 2NaNO_3(aq) + Ag_2S(s)$
Write $Na_2S(aq)$, $AgNO_3(aq)$, and $NaNO_3(aq)$ as ions. Leave $Ag_2S(s)$ as a formula unit since this ionic compound is insoluble.	$2Na^+(aq) + S^{2-}(aq) + 2Ag^+(aq) + 2NO_3^-(aq) \rightarrow 2Na^+(aq) + 2NO_3^-(aq) + Ag_2S(s)$
Cancel the spectator ions on both sides of the equation.	$\cancel{2Na^+(aq)} + S^{2-}(aq) + 2Ag^+(aq) + \cancel{2NO_3^-(aq)} \rightarrow \cancel{2Na^+(aq)} + \cancel{2NO_3^-(aq)} + Ag_2S(s)$
Write the net ionic equation.	$2Ag^+(aq) + S^{2-}(aq) \rightarrow Ag_2S(s)$

Check Your Solution

The net ionic equation is balanced, including the charges on the ions. The solubility guidelines indicate that silver sulfide is insoluble in water.

Sample Problem

Net Ionic Equation for a Neutralization Reaction

Problem

Write the net ionic equation for the double displacement reaction between aqueous hydrobromic acid, $HBr(aq)$, and aqueous potassium hydroxide, $KOH(aq)$.

What Is Required?

You need to write the net ionic equation for the reaction.

What Is Given?

You know that the reaction between hydrobromic acid and potassium hydroxide is a double displacement reaction.

Plan Your Strategy	Act on Your Strategy
Write the complete chemical equation for the reaction.	$HBr(aq) + KOH(aq) \rightarrow KBr(aq) + H_2O(\ell)$
Write $HBr(aq)$, $KOH(aq)$, and $KBr(aq)$ as ions. Leave $H_2O(\ell)$ as a formula unit since very few water molecules ionize.	$H^+(aq) + Br^-(aq) + K^+(aq) + OH^-(aq) \rightarrow K^+(aq) + Br^-(aq) + H_2O(\ell)$
Identify the spectator ions, and cancel them on both sides of the equation.	$H^+(aq) + \cancel{Br^-(aq)} + \cancel{K^+(aq)} + OH^-(aq) \rightarrow \cancel{K^+(aq)} + \cancel{Br^-(aq)} + H_2O(\ell)$
Write the net ionic equation.	$H^+(aq) + OH^-(aq) \rightarrow H_2O(\ell)$

Check Your Solution

The net ionic equation is balanced, including the charges on the ions.

This net ionic equation can also be used to represent all neutralization reactions between other strong acids and strong bases. These reactions are discussed in detail in Chapter 10.

Practice Problems

1. Write the net ionic equation for this reaction:
$Ba(ClO_3)_2(aq) + Na_3PO_4(aq) \rightarrow Ba_3(PO_4)_2(s) + NaClO_3(aq)$
2. Write the net ionic equation for this reaction:
$Na_2SO_4(aq) + Sr(OH)_2(aq) \rightarrow SrSO_4(s) + NaOH(aq)$
3. Write the net ionic equation for this reaction:
$MgCl_2(aq) + NaOH(aq) \rightarrow Mg(OH)_2(s) + NaCl(aq)$
4. Barium sulfate, $BaSO_4(s)$, is used in some types of paint as a white pigment and as a filler. Barium sulfate precipitates when an aqueous solution of barium chloride, $BaCl_2(aq)$, is mixed with an aqueous solution of sodium sulfate, $Na_2SO_4(aq)$. Write the complete chemical equation and the net ionic equation for this reaction.
5. Identify the precipitate and the spectator ions in the reaction that occurs when an aqueous solution of sodium sulfide is mixed with an aqueous solution of iron(II) sulfate. Write the net ionic equation.
6. Identify the spectator ions in the reaction between each pair of aqueous solutions. Then write the net ionic equation for the reaction.
   a. ammonium phosphate and zinc sulfate
   b. lithium carbonate and nitric acid
   c. sulfuric acid and barium hydroxide
7. When aqueous solutions of sodium iodide and lead(II) nitrate are mixed, a bright yellow precipitate of lead(II) iodide forms. Write a net ionic equation to represent this reaction.
8. A chemical reaction can be represented by the following net ionic equation:
$2Al^{3+}(aq) + 3Cr_2O_7^{2-}(aq) \rightarrow Al_2(Cr_2O_7)_3(s)$
Suggest two aqueous solutions that could be mixed to cause this reaction.
9. Iron(III) ions, $Fe^{3+}(aq)$, can be precipitated from a solution by adding potassium hydroxide, $KOH(aq)$. Write the net ionic equation for the reaction between iron(III) nitrate, $Fe(NO_3)_3(aq)$, and potassium hydroxide. Identify the spectator ions.
10. Complete and balance each equation. Then write the corresponding net ionic equation.
   a. $Pb(NO_3)_2(aq) + Na_2CO_3(aq) \rightarrow$
   b. $Co(CH_3COO)_2(aq) + (NH_4)_2S(aq) \rightarrow$

Activity 9.1 Reactions in Aqueous Solutions

Observe three reactions between aqueous solutions, and write the net ionic equation for each reaction.

Safety Precautions

- Wear chemical safety goggles throughout this activity.
- Wear a lab coat or apron throughout this activity.
- Hydrochloric acid and sodium hydroxide are corrosive. Flush any spills off skin or clothing immediately.
- Wash your hands after completing this activity.

Materials

- 0.1 mol/L sodium hydroxide, NaOH(aq), in a dropper bottle
- 0.1 mol/L ammonium chloride, $NH_4Cl(aq)$, in a dropper bottle
- 0.1 mol/L magnesium chloride, $MgCl_2(aq)$, in a dropper bottle
- 0.1 mol/L hydrochloric acid, HCl(aq), in a dropper bottle
- phenolphthalein indicator in a dropper bottle
- six-well plate
- toothpicks

Procedure

1. Add a few drops of ammonium chloride to one of the wells in the six-well plate. Then add a few drops of sodium hydroxide to the same well. Stir the mixture with a toothpick. Cautiously smell the liquid mixture by wafting the air that is just above the mixture toward your nose. Record your observations.
2. Add a few drops of magnesium chloride to another well. Then add a few drops of sodium hydroxide to the same well. Stir the mixture with a clean toothpick. Record your observations.
3. Add five drops of hydrochloric acid to one of the wells. Add one drop of phenolphthalein to the same well. Then add sodium hydroxide, drop by drop, until you observe a change.
4. Dispose of the solutions as instructed by your teacher.

Questions

1. Write a chemical equation for the reaction you observed in step 1. Identify the spectator ions in this reaction and write the net ionic equation for this reaction. Finally, explain how the net ionic equation corresponds to your observations.
2. Repeat question 1 for the reaction you observed in step 2.
3. Repeat question 1 for the reaction you observed in step 3.

Qualitative Analysis

Qualitative analysis identifies substances in a sample. You can often identify whether certain ions are in a sample by observing the colour in a flame test, the colour of a solution, or the formation of a precipitate. Qualitative analysis can tell you what ions are present in a solution. Quantitative analysis, which you will learn about in the next section, tells you *how much* of a given ion is present in a solution.

qualitative analysis analysis that identifies elements, ions, or compounds in a sample

flame test qualitative analysis that uses the colour that a sample produces in a flame to identify the metal ion(s) in the sample

Flame Tests

As you saw in Chapter 1, many metal ions produce a distinctive colour when they are heated. Thus, one way to test for the presence of metal ions is to heat a small sample of a solid, or a drop of a solution, in a flame and observe the colour. This type of qualitative analysis is called a **flame test**. The flame colours of some common ions are listed in **Table 9.1**. Fireworks, shown in **Figure 9.4**, are a dramatic demonstration of the various colours that are produced when metal ions are heated.

Figure 9.4 Fireworks are a spectacular demonstration of the different colours of light that are given off by metal ions when they are heated.

Analyze *Which metal ions could produce the colours in this fireworks display?*

Table 9.1 Flame Colours of Some Metal Ions

Ion	Symbol	Colour
lithium	Li^{+}	Crimson red
sodium	Na^{+}	Yellow-orange
potassium	K^{+}	Lavender
cesium	Cs^{+}	Blue
calcium	Ca^{2+}	Reddish-orange
strontium	Sr^{2+}	Bright red
barium	Ba^{2+}	Yellowish-green
copper	Cu^{2+}	Bluish-green
lead	Pb^{2+}	Bluish-white

The Bunsen burner was invented by the German chemist Robert Wilhelm Eberhard Bunsen (1811–1899). It produces a clean, hot flame that can be used to heat samples of chemicals. Flame tests can be performed using a Bunsen burner and a clean wire loop, made from either platinum or an alloy of nickel and chromium. To test an aqueous solution, the wire is dipped into the solution. To test a solid, the wire can be moistened with hydrochloric acid or nitric acid to help the solid stick to the wire.

As shown in **Figure 9.5**, the wire is placed in the flame of the Bunsen burner. The electrons in the atoms of the sample absorb energy from the flame. The electrons then re-emit some of the energy as visible light. Since the arrangement of the electrons within the atoms determines the colours of the light that the electrons emit, some elements produce characteristic colours. The bright yellow-orange light that is emitted by some streetlights comes from sodium atoms heated by an electric current. Bunsen used light from heated samples to discover the elements cesium and rubidium. The wavelengths of light emitted by different elements are so unique that astronomers analyze light from distant stars to determine which elements are present in those stars.

Flame tests are usually very sensitive—the characteristic colours of metal cations can be seen using tiny samples. Because platinum is very expensive and nickel-chromium alloys produce a trace of orange colour in the flame, a wooden splint is sometimes used instead of the wire loop.

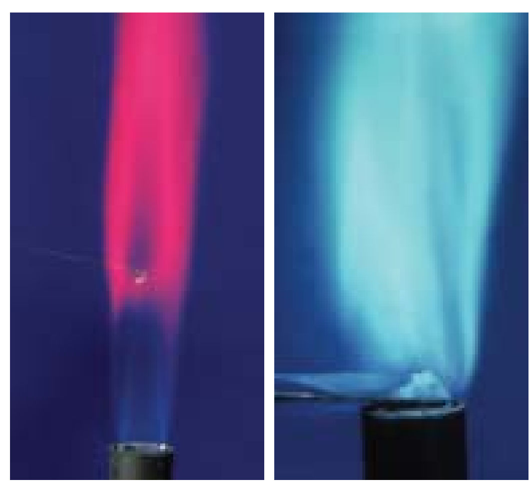


Figure 9.5 These photographs show flame tests of strontium and copper. Notice that the colour of the copper flame is greener than a typical Bunsen burner flame.

Go to **scienceontario** to find out more

Colours of Ions in Solutions

Flame tests can be used to identify only certain metallic ions. However, aqueous solutions of the ionic compounds of certain cations and anions also have characteristic colours. Therefore, the colour of a solution can help to identify some of the ions in the solution. For example, most aqueous solutions that contain aqueous copper(II) ions are blue. **Table 9.2** lists the colours of aqueous solutions of some common ions.

Table 9.2 Colours of Some Common Ions in Aqueous Solutions

	Ion	Symbol	Colour
Cations	chromium(II) copper(II)	$Cr^{2+}(aq)$ $Cu^{2+}(aq)$	Blue
	chromium(III) copper(I) iron(II) nickel(II)	$Cr^{3+}(aq)$ $Cu^{+}(aq)$ $Fe^{2+}(aq)$ $Ni^{2+}(aq)$	Green
	iron(III)	$Fe^{3+}(aq)$	Pale yellow
	cobalt(II) manganese(II)	$Co^{2+}(aq)$ $Mn^{2+}(aq)$	Pink
Anions	chromate	$CrO_4{}^{2-}(aq)$	Yellow
	dichromate	$Cr_2O_7{}^{2-}(aq)$	Orange
	permanganate	$MnO_4{}^{-}(aq)$	Purple

Suggested **Investigation**

Inquiry Investigation 9-A, Qualitative Analysis

Precipitation Reactions

Another way to identify an unknown ion in a solution is to add a known reactant to the solution and observe whether a precipitate forms. Then the solubility guidelines can be used to infer which ion must have been present in the unknown solution. **Figure 9.6** shows how a series of precipitation reactions can be used to identify different ions in a solution. Each time a precipitate forms, ions are removed from the solution. After a precipitate has been filtered out, other reactants can be added to the *filtrate* (the filtered solution). The colour of the solution after each reaction can help to identify the ions that are still present. A flame test may also be used on a precipitate after it has been rinsed.

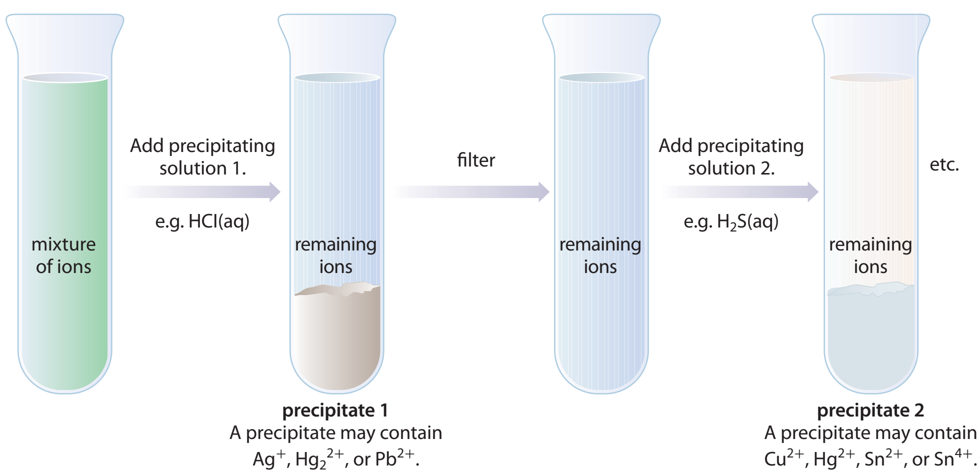


Figure 9.6 A series of precipitation reactions can be used to identify ions in a solution.

Explain *Why could a precipitate caused by adding hydrochloric acid, HCl(aq), contain silver ions but not copper ions?*

Learning Check

1. Give two specific examples of substances that are never shown as ions in a net ionic equation.
2. Explain how a chemical equation differs from an ionic equation.
3. After you have written a net ionic equation, why should you check to make sure that it is balanced for charges as well as for atoms?
4. When an aqueous solution of ammonium phosphate is mixed with an aqueous solution of sodium carbonate, all the ions are spectator ions. Explain why.
5. Describe three different qualitative analysis tests.
6. If an aqueous solution is a certain colour, will a sample of the solution cause the same colour in a flame test? Explain your answer.

Activity 9.2 Identifying Unknown Aqueous Solutions

In this activity, you will interpret observations of flame tests, solution colours, and precipitation reactions to identify dissolved metal ions.

Procedure

Examine the observations listed in the table below, and then answer the questions.

Observations from Testing a Solution of Unknown Metal Ions

Test	Observation
1. Solution colour	The solution is colourless.
2. Addition of sodium hydroxide, $NaOH(aq)$, to the solution	A white precipitate is produced. When the mixture is filtered, the filtrate is colourless.
3. Flame test on the precipitate from test 2	The flame colour is red.
4. Addition of sodium sulfate, $Na_2SO_4(aq)$, to the filtrate from test 2	A second white precipitate is produced. When the mixture is filtered, the filtrate is colourless.
5. Flame test on the precipitate from test 4	The flame colour is red, but a different red than the flame colour in test 3.

Questions

1. List all the ions that cause a red flame and produce a precipitate in the presence of hydroxide ions.
2. List all the cations that could cause a red flame and produce a precipitate in the presence of sulfate ions.
3. If all traces of the two metal cations are removed from the solution in test 4, what might the flame colour be when a sample of the solution is tested? Explain your prediction.
4. List the solution colours and precipitation reactions you would expect to observe in tests to identify the metal ions in solutions that contain the following cations:
   a. $Na^{+}(aq)$ only
   b. $Cu^{2+}(aq)$ only
   c. $Na^{+}(aq)$ and $Ag^{+}(aq)$
   d. $Cu^{2+}(aq)$ and $Ag^{+}(aq)$

Qualitative Analysis and Quantitative Analysis

Qualitative analysis is only useful for determining which ions are present in a solution. Sometimes, the identity of the ions is all the information that a chemist needs. But other times, chemists want to know the amount or concentration of the ions present. To find the concentration of the ions, chemists need to perform quantitative analysis, which is described in the next section.

If chemists need to perform both qualitative analysis and quantitative analysis on the same solution, they often do qualitative analysis first. However, they can do both kinds of analysis at the same time when doing precipitation reactions. To do so, they must keep accurate records of the amounts of unknown solution and reagent used and carefully measure the amount of precipitate formed by the reaction.

Section 9.1 REVIEW

Section Summary

- A net ionic equation omits the spectator ions and shows only the ions that react and the product(s) of the reaction.
- You can use observations of flame tests, solution colours, and the formation of precipitates to identify ions in a sample.

Review Questions

1. K/U What is a spectator ion? What characteristics does a spectator ion often have?
2. K/U Identify the spectator ions in each reaction.
   a. $3CuCl_2(aq) + 2(NH_4)_3PO_4(aq) \rightarrow Cu_3(PO_4)_2(s) + 6NH_4Cl(aq)$
   b. $2Al(NO_3)_3(aq) + 3Ba(OH)_2(aq) \rightarrow 2Al(OH)_3(s) + 3Ba(NO_3)_2(aq)$
   c. $2NaOH(aq) + MgCl_2(aq) \rightarrow 2NaCl(aq) + Mg(OH)_2(s)$
3. T/I Write a net ionic equation for each reaction in question 2.
4. T/I An aqueous solution of copper(II) sulfate is mixed with an aqueous solution of sodium carbonate.
   a. State the name and formula for the precipitate that forms.
   b. Write the net ionic equation for the reaction.
   c. Identify the spectator ions.
5. T/I For each of the following net ionic equations, list two soluble ionic compounds that can be mixed together in solution to produce the reaction represented by the equation. (**Note:** There are many correct answers.)
   a. $3Ba^{2+}(aq) + 2PO_4^{3-}(aq) \rightarrow Ba_3(PO_4)_2(s)$
   b. $Mg^{2+}(aq) + 2OH^-(aq) \rightarrow Mg(OH)_2(s)$
   c. $2Al^{3+}(aq) + 3Cr_2O_7^{2-}(aq) \rightarrow Al_2(Cr_2O_7)_3(s)$
6. K/U Explain why there are many correct answers for question 5.
7. C Draw a flowchart that summarizes how to write net ionic equations for double displacement reactions.
8. K/U What is the difference between qualitative analysis and quantitative analysis?
9. A Why might a chemist need to carry out qualitative analysis on a solution?
10. A Lithium carbonate is the active ingredient in some anti-depression medications. What tests could you perform to confirm the presence of lithium carbonate, $Li_2CO_3(s)$, in a tablet?
11. T/I Limewater is a solution of calcium hydroxide, $Ca(OH)_2(aq)$. It can be used to test for the presence of carbon dioxide. When carbon dioxide is bubbled through limewater, a milky-white precipitate is produced.
    a. Write a chemical equation and a net ionic equation to show what happens when carbon dioxide is bubbled through limewater.
    b. Is this test an example of qualitative or quantitative analysis? Explain your answer.
12. T/I An ion in a solution forms a yellow precipitate when sodium iodide, $NaI(aq)$, is added to the solution. The precipitate produces a blue-white colour when it is heated in a flame.
    a. Suggest a formula for the ion and a formula for the precipitated compound.
    b. Write a net ionic equation to represent the reaction.
13. T/I All the solutions below have the same concentration. Use **Table 9.2** to infer what ion causes the colour in each solution. How much confidence do you have in your inferences? How could you check your inferences?

14. A To answer the following questions, refer to the solubility guidelines in Section 8.2.
    a. What aqueous solution will precipitate $Pb^{2+}(aq)$ ions but not $Cu^+(aq)$ or $Mg^{2+}(aq)$ ions?
    b. What aqueous solution will precipitate $Cu^+(aq)$ ions but not $Mg^{2+}(aq)$ ions?
    c. Using your answers to parts a and b, outline a procedure that would allow you to precipitate the $Pb^{2+}(aq)$ ions, followed by $Cu^+(aq)$ ions, and then $Mg^{2+}(aq)$ ions.