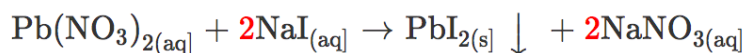


## Unit 4: Solutions and solubility

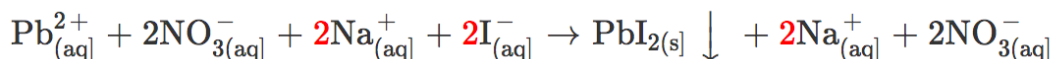
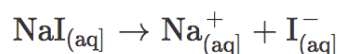
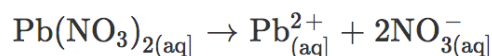
### Lesson 5: Net ionic equations & Qualitative analysis (chapter 9)

Consider the double displacement reaction between lead (II) nitrate solution and sodium iodide solution.

- Write the balanced chemical equation
- Determine states of the products



Due to each of the **high-solubility ionic reactants** and products dissociate in aqueous solution to form separate cations and anions. So the reaction could be written as:



This is the **Total Ionic Equation** – shows all high-solubility ionic compounds in their dissociated form.

Note: The nitrate and sodium ions present on the reactant side also appear unchanged on the product side = **Spectators** – any ion, atom, molecule that does not change during the chemical reaction.

A **Net Ionic Equation** represents a chemical reaction by writing only those ions specifically involved in the overall chemical reaction.

The net ionic equation for the above reaction is:  $\text{Pb}_{(\text{aq})}^{2+} + 2\text{I}_{(\text{aq})}^{-} \rightarrow \text{PbI}_{2(\text{s})} \downarrow$

### Steps for writing Net Ionic Equations:

1. Write the balanced chemical equation include state (using solubility table)
2. Rewrite the formulas for all aqueous ionic compounds as dissociated ions to show the total net ionic equation.
3. Cancel identical amounts of identical entities appearing on both reactant and product sides.
4. write the net ionic equation, reducing coefficients if necessary.

**Practice:** Write the net ionic and state spectator ions for the following examples

1. Aqueous barium chloride and aqueous sodium sulfate.

Balanced equation:

Total ionic equation:

Net ionic equation:

Spectator ion(s):

2. Zinc Metal and aqueous copper (II) sulfate.

Balanced equation:

Total ionic equation:

Net ionic equation:

Spectator ion(s):

## Qualitative Analysis:

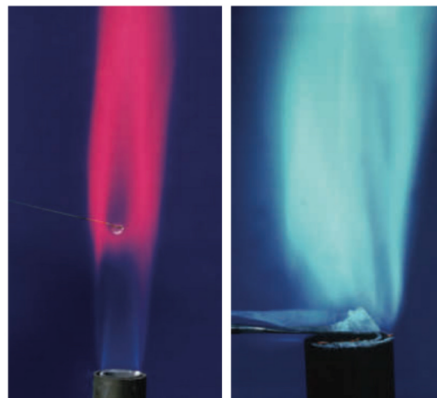
- Identities elements, ions, or compounds in a sample
- We will look at 3 type of qualitative analysis:
  - 1) Flame tests
  - 2) Color of a solution
  - 3) Formation of precipitate

## Flame Tests:

- 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 color
- Fireworks are a dramatic demonstration of the various colours that are produced when metal ions are heated.

**Table 9.1** Flame Colours of Some Metal Ions

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



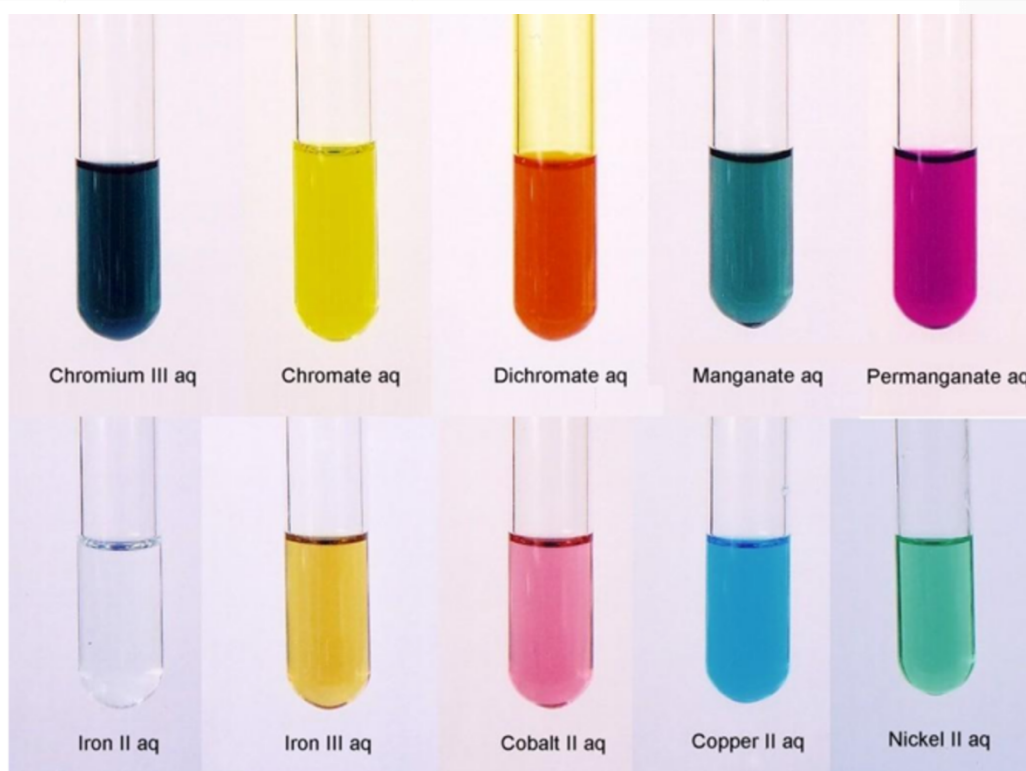
**Figure 9.5** These photographs show flame tests of strontium and copper. Notice that the colour of the copper flame is greener than a typical Bunsen burner flame.

### Colors of Ions in solutions:

- 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** Colours of Some Common Ions in Aqueous Solutions

|                | Ion           | Symbol                                  | Colour      |
|----------------|---------------|-----------------------------------------|-------------|
| <b>Cations</b> | chromium(II)  | $\text{Cr}^{2+}(\text{aq})$             | Blue        |
|                | copper(II)    | $\text{Cu}^{2+}(\text{aq})$             | Blue        |
|                | chromium(III) | $\text{Cr}^{3+}(\text{aq})$             | Green       |
|                | copper(I)     | $\text{Cu}^{+}(\text{aq})$              | Green       |
|                | iron(II)      | $\text{Fe}^{2+}(\text{aq})$             | Green       |
| <b>Anions</b>  | nickel(II)    | $\text{Ni}^{2+}(\text{aq})$             | Pale yellow |
|                | iron(III)     | $\text{Fe}^{3+}(\text{aq})$             | Pink        |
|                | cobalt(II)    | $\text{Co}^{2+}(\text{aq})$             | Yellow      |
|                | manganese(II) | $\text{Mn}^{2+}(\text{aq})$             | Pink        |
|                | chromate      | $\text{CrO}_4^{2-}(\text{aq})$          | Yellow      |
| <b>Anions</b>  | dichromate    | $\text{Cr}_2\text{O}_7^{2-}(\text{aq})$ | Orange      |
|                | permanganate  | $\text{MnO}_4^{-}(\text{aq})$           | Purple      |



### Formation of Precipitate:

- You can add a known reactant to the solution and observe whether a precipitate forms.

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, $\text{NaOH(aq)}$ , 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, $\text{Na}_2\text{SO}_4\text{(aq)}$ , 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.                     |

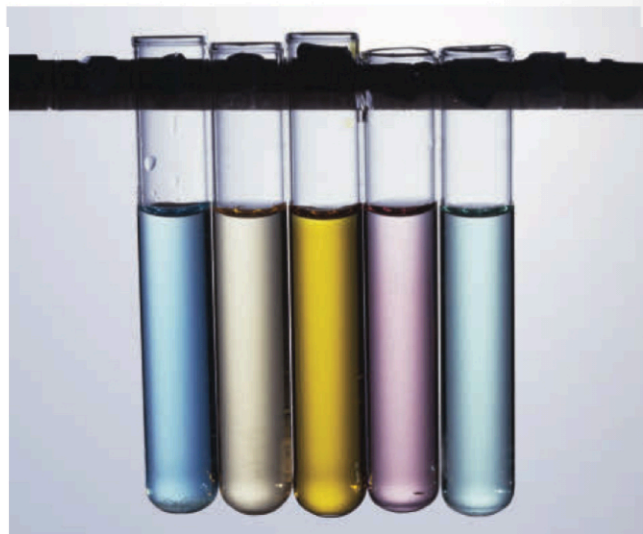
### Questions

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.  $\text{Na}^+\text{(aq)}$  only
  - b.  $\text{Cu}^{2+}\text{(aq)}$  only
  - c.  $\text{Na}^+\text{(aq)}$  and  $\text{Ag}^+\text{(aq)}$
  - d.  $\text{Cu}^{2+}\text{(aq)}$  and  $\text{Ag}^+\text{(aq)}$



## 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.**  $3\text{CuCl}_2(\text{aq}) + 2(\text{NH}_4)_3\text{PO}_4(\text{aq}) \rightarrow \text{Cu}_3(\text{PO}_4)_2(\text{s}) + 6\text{NH}_4\text{Cl}(\text{aq})$
  - b.**  $2\text{Al}(\text{NO}_3)_3(\text{aq}) + 3\text{Ba}(\text{OH})_2(\text{aq}) \rightarrow 2\text{Al}(\text{OH})_3(\text{s}) + 3\text{Ba}(\text{NO}_3)_2(\text{aq})$
  - c.**  $2\text{NaOH}(\text{aq}) + \text{MgCl}_2(\text{aq}) \rightarrow 2\text{NaCl}(\text{aq}) + \text{Mg}(\text{OH})_2(\text{s})$
- 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.**  $3\text{Ba}^{2+}(\text{aq}) + 2\text{PO}_4^{3-}(\text{aq}) \rightarrow \text{Ba}_3(\text{PO}_4)_2(\text{s})$
  - b.**  $\text{Mg}^{2+}(\text{aq}) + 2\text{OH}^{-}(\text{aq}) \rightarrow \text{Mg}(\text{OH})_2(\text{s})$
  - c.**  $2\text{Al}^{3+}(\text{aq}) + 3\text{Cr}_2\text{O}_7^{2-}(\text{aq}) \rightarrow \text{Al}_2(\text{Cr}_2\text{O}_7)_3(\text{s})$
- 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,  $\text{Li}_2\text{CO}_3(\text{s})$ , in a tablet?
- 11. T/I** Limewater is a solution of calcium hydroxide,  $\text{Ca}(\text{OH})_2(\text{aq})$ . 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,  $\text{NaI}(\text{aq})$ , 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  $\text{Pb}^{2+}(\text{aq})$  ions but not  $\text{Cu}^{+}(\text{aq})$  or  $\text{Mg}^{2+}(\text{aq})$  ions?
  - b.** What aqueous solution will precipitate  $\text{Cu}^{+}(\text{aq})$  ions but not  $\text{Mg}^{2+}(\text{aq})$  ions?
  - c.** Using your answers to parts a and b, outline a procedure that would allow you to precipitate the  $\text{Pb}^{2+}(\text{aq})$  ions, followed by  $\text{Cu}^{+}(\text{aq})$  ions, and then  $\text{Mg}^{2+}(\text{aq})$  ions.

### **Solution Stoichiometry:**

Example 1: What volume of 15.0 M  $\text{NH}_{3(\text{aq})}$  would be required to react completely with 1.5 L of 12.9 M  $\text{H}_3\text{PO}_{4(\text{aq})}$ ?

Example 2: In an experiment, a 5.00 mL sample of sulfuric acid reacts completely with 15.9 mL of 0.150M potassium hydroxide solution. Calculate the molar concentration of sulfuric acid.

Example 3: 50.0mL of 0.75 M potassium iodide is reacted with excess lead (II) nitrate. What mass of precipitate would you expect to recover?

Example 4: In a lab experiment, 125mL of 0.70 M potassium iodide is poured into a beaker containing 90.0 mL of 0.65 M lead (II) chloride solution. If 17.5 g of precipitate is recovered at the end of this experiment, what is the percent yield of this reaction?

## **Unit 4: Solutions and solubility**

### **Lesson 5: Arrhenius Acids and Bases (chapter 10)**

#### **The Arrhenius Theory of Acids and Bases**

- Acid: a substance that dissociates in water to produce hydrogen ions ( $H^+$ )  
Example:  $HCl$ ,  $H_2SO_4$ , Carbonated drinks
- Base: A substance dissolved in water to produce hydroxide ions ( $OH^-$ )  
Example:  $NaOH$ ,  $Ca(OH)_2$ , baking soda

#### **Properties of Acids:**

1. sour taste
2. changes the colour of litmus paper from blue to red
3. reacts with:
  - **Metal, such as Zinc and Magnesium to produce hydrogen gas**
  - **Strong bases to produce water and an ionic compound**
  - **carbonate salt, such as  $CaCO_3$  to produce**