Chemistry 132.L4. Introduction to Chemical Reactions - Part 2

Prelaboratory Exercises

1. Define the terms homogeneous and heterogeneous. Give an example of a homogeneous mixture and an example of a heterogeneous mixture.

5. The Iron Test

Add 1 mL iron (III) chloride (FeCl₃) solution to a test tube. Add 2 mL of distilled water to the tube. Add 2 drops of ammonium thiocyanide (NH₄SCN) solution and mix thoroughly. Record all observations including any solution color and/or precipitate formation.

→Observations:

→Is the mixture homogeneous or heterogeneous?

The reaction you have just observed is:

\[
\text{FeCl}_3(\text{aq}) + \text{NH}_4\text{SCN}(\text{aq}) \rightarrow \text{Fe(SCN)Cl}_2(\text{aq}) + \text{NH}_4\text{Cl}(\text{aq})
\]

where the colored species is Fe(SCN)Cl₂(\text{aq}).

To a second test tube, add 1 mL iron (III) chloride (FeCl₃) solution. Now add 2 mL of sodium monohydrogen phosphate (Na₂HPO₄) solution and mix thoroughly. Record all observations including any solution color and/or precipitate formation.

→Observations:

→Is the mixture homogeneous or heterogeneous?

→The reaction that you have observed is:

\[
\text{FeCl}_3(\text{aq}) + \text{Na}_2\text{HPO}_4(\text{aq}) \rightarrow \text{FePO}_4(\text{s}) + 2\text{NaCl}(\text{aq}) + \text{HCl}(\text{aq})
\]

Now add 2 drops of ammonium thiocyanide (NH₄SCN) solution to this test tube and mix thoroughly. Record all observations including any solution color and/or precipitate formation.

→Observations:

→Is the mixture homogeneous or heterogeneous?
Compared to your last experiment, is there very much iron in solution available to react with the ammonium thiocyanide? Explain your reasoning.

6. How Fast is the Gas Evolved?

In this experiment we will observe the dissolution of magnesium metal (Mg) by nitric acid (HNO₃), according to the chemical equation below:

\[
\text{Mg(s)} + 2 \text{HNO}_3(\text{aq}) \rightarrow \text{H}_2(\text{g}) + \text{Mg(NO}_3)_2(\text{aq})
\]

Here we will investigate the amount of time that is required to dissolve the magnesium versus the volume of nitric acid added to the solution. Warning: nitric acid is a corrosive substance. Wear your safety goggles. In case of skin contact, wash thoroughly with water. Take 3 test tubes and add 2 mL of nitric acid to tube #1, 3 mL of nitric acid to tube #2, and 4 mL of nitric acid to tube #3. Now add water to tubes #1 and #2 so that the level is the same as tube #3 (do not add any water to tube #3). Mix the solutions with a clean stirring rod (clean the stirring rod before each transfer to a new test tube!). You should see that tube #1 contains 50% nitric acid, tube #2 contains 75% nitric acid, and tube #3 contains 100% nitric acid. The relative amount of a chemical per unit volume is called the concentration of that chemical.

Now obtain three 1 cm pieces of magnesium ribbon. Be sure that the three pieces of Mg are equal in length. Using a clock or watch with a second hand, add a piece of magnesium to test tube #1, making sure the ribbon is submerged in the nitric acid, and record the time for the reaction to be complete in the table below. Repeat this step for tube #2 and tube #3 (you can do them simultaneously if you are careful).

Observations during these reactions:

What is the chemical identity of the bubbles that are produced during the reaction?

We wish to calculate the rate of the reaction. The rate (R) is equal to the amount of material divided by the time required for completion of the reaction (t). In this case we have used 1 cm of magnesium in each case, so the rate is given by

\[
R = \frac{1 \text{ cm}}{\text{Time for Complete Reaction in sec}}
\]
Calculate the reaction rate for each tube and insert the value into the table below.

<table>
<thead>
<tr>
<th>Tube #</th>
<th>Volume of HNO₃, mL</th>
<th>Total Volume, mL</th>
<th>Concentration of HNO₃, %</th>
<th>Time for Complete Reaction, sec</th>
<th>Rate, cm/sec</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>4</td>
<td>50</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>3</td>
<td>4</td>
<td>75</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>4</td>
<td>4</td>
<td>100</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Now graph the concentration of HNO₃ on the x-axis versus the rate of reaction on the graph coordinates below.

How is the rate of the reaction effected by the concentration of nitric acid?
7. The Many Colors of Copper

Copper is an example of a transition metal. Transition metals are characterized by the formation of brightly colored compounds. Here we will investigate various reactions of copper. Obtain a large test tube and place it in a beaker. Tare the test tube and beaker and weigh 0.5 g of solid copper (II) carbonate (CuCO₃(s)) into the test tube. Add 1 mL of water.

→ Observations

→ Based on your observations, would you consider the CuCO₃ to be soluble in water? Explain.

Slowly add hydrochloric acid (HCl) drop by drop mixing thoroughly after each drop. Continue adding HCl dropwise until all of the solid has dissolved. Warning: hydrochloric acid is a corrosive substance. Wear your safety goggles. In case of skin contact, wash thoroughly with water.

→ Observations:

→ Did you observe a chemical change or a physical change?

→ The copper (II) carbonate dissolved in HCl according to the following reaction:

CuCO₃(s) + 2HCl(aq) + 3H₂O(l) → CO₂(g) + Cu(H₂O)₄Cl₂(aq)

→ Which of the products in the reaction above is responsible for the observed color?

Add 20 drops of water and then ammonia (NH₃) dropwise to the test tube, shaking the tube well to mix the solution. Continue to add drops of ammonia until you see a change.

→ Observations:

Ammonia is a weak base, which means it produces hydroxide ions OH⁻ when added to water,

NH₃(aq) + H₂O(l) → NH₄⁺(aq) + OH⁻(aq)
The formation of \(\text{OH}^-\) ions allows formation of copper hydroxide \((\text{Cu(OH)}_2)\) according to the following equation:

\[
\text{Cu(H}_2\text{O)}_4\text{Cl}_2(\text{aq}) + 2 \text{NH}_4\text{OH}(\text{aq}) \rightarrow \text{Cu(OH)}_2(\text{s}) + 4 \text{H}_2\text{O}(\text{l})
\]

Now add more ammonia \((\text{NH}_3)\) dropwise until the solid dissolves. Mix thoroughly. Continue to add until the solution turns a deep blue color. As we discussed above in section 1 (Lab#2), copper reacts with excess ammonia to form a brightly colored soluble product according to the following equation:

\[
\text{Cu(OH)}_2(\text{s}) + 4\text{NH}_3(\text{aq}) \rightarrow [\text{Cu(NH}_3)\text{)}_4^{2+}(\text{aq}) + 2\text{OH}^-(\text{aq})
\]

Which of the products in the reaction above is responsible for the observed color?

To the tube add 1 g of powdered zinc \((\text{Zn(s)})\), and make all observations.

Observations:

Zinc \((\text{Zn(s)})\) reacts with the copper ammonia complex to give copper \((\text{Cu(s)})\) and a soluble zinc ammonia complex according to the following equation:

\[
[\text{Cu(NH}_3)\text{)}_4^{2+}(\text{aq}) + \text{Zn(s)} \rightarrow [\text{Zn(NH}_3)\text{)}_4^{2+}(\text{aq}) + \text{Cu(s)}
\]

Was this reaction exothermic or endothermic?

Which of the products above is the dark solid produced when zinc was added?

8. Soap on a Rope

Tap water may be classified by its “hardness.” Hard water contains trace amounts of dissolved calcium \((\text{Ca}^{2+})\), magnesium \((\text{Mg}^{2+})\), and iron \((\text{Fe}^{3+})\) salts. These metal cations react with soap to form insoluble products (precipitates). When these precipitates are formed, the soap is no longer available for cleaning. Soap is produced by adding a base (typically sodium hydroxide) to animal fat. Here we will look at the properties of soft (distilled) and hard (to which calcium, magnesium, or iron had been added) water, and evaluate the hardness of our tap water. Detergents, which are alternative cleaning products to soap, are derived from petroleum products and have some advantages over soap in hard water which will be observed in this section of the experiment.
Soap and detergent clean using the same idea. They are relatively long molecules, with one side charged so it is polar and soluble in water, and the other side uncharged and non-polar, so it can dissolve non-polar materials like dirt, oil, etc. Water is relatively polar, and hence it can not dissolve dirt and oil very well. Consequently, soaps and detergents clean because they are soluble in both water and nonpolar things, and therefore can dissolve most stains better than pure water.

Obtain the following solutions: soap, detergent, calcium chloride (CaCl₂), magnesium chloride (MgCl₂), distilled water and tap water. Obtain four test tubes, number them 1-4 and add five drops of soap solution to each. Add five drops of distilled water to tube #1, 5 drops of MgCl₂ to tube #2, 5 drops of CaCl₂ to tube #3, and 5 drops of tap water to tube #4. Mix thoroughly. Record your results in the table below. Clean these four test tubes thoroughly and add five drops of detergent to each. Add distilled water, MgCl₂, CaCl₂, and tap water as above and record your results in the table below.

<table>
<thead>
<tr>
<th>Solution</th>
<th>Soap</th>
<th>Detergent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Distilled water</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Calcium chloride</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Magnesium chloride</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tap water</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

What happens when soap is mixed with hard water (water containing calcium or magnesium)? How would this effect the ability of soap to get things clean?

What happens when detergent is mixed with hard water? What advantage do detergents have over soaps?

Which would be more appropriate for use in hair shampoo, soap or detergent?

Is our tap water hard or soft?