Reversible and Irreversible Processes (Modified from an SWH laboratory by Thomas Greenbowe and Kathy Burke)

Introduction (No Change)
Safety (Comment about the seriousness of chromate/dichromate compounds)

Objective
In this laboratory you will investigate four (five so one can be an irreversible reaction) chemical systems.

Concepts (Prior Knowledge)
During your first semester of chemistry you investigated several types of chemical reactions including; precipitation reactions, neutralization reactions, synthesis/formation reactions, and combustion reactions. While these reactions are all very different from each other in many respects, in one respect they are similar. These reactions were used during the discussion of stoichiometry, limiting reagents and excess reagents. Consider the reaction of glucose with oxygen,

$$C_6H_{12}O_6(s) + 6O_2(g) \rightarrow 6CO_2(g) + 6H_2O(l)$$

This is an example of a combustion reaction that occurs in the body to produce energy, glucose reacting with oxygen to produce carbon dioxide and water. We can talk about how for respiration oxygen is the excess reagent and glucose is the limiting reagent. For a particular amount of glucose we can calculate the amounts of carbon dioxide and water that would be produced in the presence of excess oxygen. These are the types of questions we can answer using stoichiometry.

What about the reverse reaction?

$$6CO_2(g) + 6H_2O(l) \rightarrow C_6H_{12}O_6(s) + 6O_2(g)$$

Would you expect a mixture of carbon dioxide gas and water liquid in a container in the laboratory to produce glucose and oxygen?

This is an example of a chemical reaction that proceeds in only one direction. Are all reactions like this?

Procedure
Part 1:

Work in pairs to perform this activity. As a class, decide how you want to divide the work to conduct your analyses and share your results.

Materials Available

13 x 100 mm test tubes	0.10 M $Mg(NO_3)_2$

Plastic dropper pipets 0.10 M Na_2CO_3
Small test tubes
Test tube holder
Distilled Water

Obtain a solution of magnesium nitrate and a solution of sodium carbonate. Describe each solution. Transfer 40 drops of the magnesium nitrate solution to a small test tube. Add 10 drops of sodium carbonate to the solution of magnesium nitrate. (Note: you may prefer to try a different combination of drops of each reagent. If you elect to do that be sure to record the number of drops of each reactant.) Describe what you observe happening.

(Get the students to try different combinations of 50 drops. 40 drops of magnesium nitrate and 10 drops of sodium carbonate, 30 drops of magnesium nitrate and 20 drops of sodium carbonate, 25 drops of magnesium nitrate and 25 drops of sodium carbonate, 20 drops of magnesium nitrate and 30 drops of sodium carbonate, 10 drops of magnesium nitrate and 40 drops of sodium carbonate as possible examples.)

Write a chemical equation (write the molecular, ionic and net ionic equations) to represent the reaction that occurred when magnesium nitrate and sodium carbonate were mixed.

(Teacher Note: Before mixing the $Mg(NO_3)_2$ solution and the Na_2CO_3 solution, ask the students to predict the products of the reaction. To help the students write the reactants in the molecular form:

$Mg(NO_3)_{2(aq)} + Na_2CO_{3(aq)} \rightarrow$

Then get the students to tell you to write the reactants as an ionic equation and then as a net ionic equation;

$Mg^{2+}(aq) + 2NO_3^-(aq) + 2Na^+(aq) + CO_3^{2-}(aq) \rightarrow MgCO_{3(s)} + 2NO_3^-(aq) + 2Na^+(aq)$

$Mg^{2+}(aq) + CO_3^{2-}(aq) \rightarrow MgCO_{3(s)}$

Whether you ask the students to write the equation before or after doing the reaction is up to you.

For your combination of drops of each reactant, predict which compound is the limiting reagent and which compound is the compound in excess. Explain the basis of your prediction.

(Students should base their prediction on the concentration of each reagent/reactant and the number of drops of each reagent/reactant that is added. Since the

concentration of each reagent/reactant is the same students should explain that the limiting reagent is the reagent/reactant that the fewest number of drops were added. The excess reagent is the reagent/reactant that the largest. number of drops were added.
You may wish to stop the students after they have mixed their specific combination and ask for their explanation for their prediction.

Describe experiments that could be done to produce evidence to support your claim (prediction above) of which compound is the LR and which is in excess.

This may be a difficult question for students to answer. You may want to give the students a few minutes to discuss the question in small groups. What you are looking to hear is that students plan to separate their samples into two test tubes and then add one of the reactants to each sample see whether a precipitate is formed or not. If there is a centrifuge it would be useful to centrifuge the test tube to get the precipitate to the bottom of the test tube so it is easy to decant or siphon off the supernatant solution. Place the supernatant solution into two similar sized test tubes and then add one reactant to one of the solutions and the other reactant to the other test tube. The important logic must be that the reactant that produces a precipitate when added must be the limiting reagent. The reactant that does not produce a precipitate is the excess reagent. Not that for the combination of 25 drops of each reactant solution, this test should result in not precipitate after either addition. NOTE:If the drops are not counted right, results may vary.

This experiment is critical for the Part 2 portion of this activity, as will be discussed later.
It is important to note what is going on in this reaction. One of the reactants (the one present in the smallest amount) must be completely used up in the reaction

Perform the experiments, describe your observations and explain how accurate your prediction turned out.

For this reaction place a sample of the solid product in a sample test tube, and add 20 – 40 drops of distilled water. Do you expect the solid to dissolve? Explain. What experiments could you do to provide evidence to support or refute your prediction?

Procedure
Part 2:

Work in pairs to perform this activity. As a class, decide how you want to divide the work to conduct your analyses and share your results.

Materials Available

Small test tubes	0.050 M $Fe(NO_3)_3$
Plastic dropper pipets	0.050 M NH_4SCN
Distilled Water	solid NaF
Test tube holder	
Beaker for water baths	
Hot Plate for hot water bath	
Ice for cold water bath	

Mix 4 drops of 0.050 *M* $Fe(NO_3)_3$ with 4 drops of 0.050 *M* KSCN in 5 to 10 mLs of distilled water. Describe what you observe. Can you detect any changes in temperature of the test tube and its contents. Record your observations.

(Teacher Note: Before mixing the $Fe(NO_3)_3$ solution and the NH_4SCN solution, ask the students to predict the products of the reaction. To help the students write the reactants in the molecular form:

$Fe(NO_3)_{3(aq)} + NH_4SCN_{(aq)} \rightarrow$

Then get the students to tell you to write the reactants as an ionic equation and then as a net ionic equation;

$Fe^{3+}(aq) + 3NO_3^-(aq) + NH_4^+(aq) + SCN^-(aq) \rightarrow$

$Fe^{3+}(aq) + SCN^-(aq) \rightarrow$

I think most students will predict the product of the reaction will be $Fe(SCN)_{3(aq)}$. This is the most likely product that will be predicted based on the reaction between magnesium nitrate and sodium carbonate. Ask the students if they think this product is a solid or not. There will possibly be a variety of responses; yes, no, I do not know, I'm not sure. Then have the students do the experiment and ask them what they think the product might be.

Most students should be 'surprised' that a solid was not formed and might not be sure what the product is. That is OK, I recommend telling the students that this is a 'complex' reaction, and the product does not follow from most double displacement reactions. Students should accept this since they know most double displacement reactions produce a precipitate and since this did not happen there should be some confusion. Simply indicate that since this reaction is 'complex' that the product is a 'complex ion'.

The product of mixing $Fe(NO_3)_3$ and NH_4SCN is the complex ion $Fe(SCN)^{2+}$. Write a net ionic equation that represents the reaction that occurs.

Predict which compound is the limiting reagent and which compound is the compound in excess.

Describe experiments that could be done to produce evidence to support your claim of which compound is the LR and which is in excess.

Perform the experiments and describe your observations and how accurate your prediction turned out. (NOTE: In your experiment separate the solution equally into three test tubes.)

Explain what you observed using the chemical reaction you had written earlier.

Obtain a small amount of NaF. Add some NaF to a test tube containing 10 drops of 0.20 M $Fe(NO_3)_3$. Describe what you observe happening.

Obtain a small amount of NaF. Add some NaF to a test tube containing 10 drops of 0.20 M NH_4SCN. Describe what you observe happening.

Obtain a small amount of NaF. Add some NaF to the third test tube containing the mixture of 0.20 M $Fe(NO_3)_3$ and 0.20 M NH_4SCN. Predict what might happen?

Describe what you observe happening.

Explain what you observed using the chemical reaction you had written earlier.

How does the original system respond to being heated or cooled in a water bath?

Part 3:
Work in pairs to perform this activity. As a class, decide how you want to divide the work to conduct your analyses and share your results.

Materials Available

Small test tubes	6.0 M HCl
Plastic dropper pipets	solid $CoCl_2$
Distilled Water	95% ethanol
Test tube holder	0.10 M $CoCl_2$ (in distilled water)
Beaker for water baths	
Hot Plate for hot water bath	
Ice for cold water bath	

Begin by adding solid $CoCl_2$ to approximately 20 mLs of 95% ethanol. Describe what you observed.

Pour equal amount of the solution into three other test tubes. Add 2 drops of water to one of the test tubes, add 4 drops of water to another test tube.

How does the mixture of $CoCl_2$ with respond to being heated or cooled in a water bath?

Analysis:

Summarizing the findings using the four parts of this activity.

1a) Explain the difference between a reversible and an irreversible reaction.

1b) In a reversible reaction, adding a reactant shifts the reaction to which side?

1c) In a reversible reaction, adding a product shifts the reaction to which side?

1d) In a reversible reaction, removing a reactant shifts the reaction to which side?

1e) In a reversible reaction, removing a product shifts the reaction to which side?

1f) In a reversible reaction, how does adding or removing heat shift the reaction?

2. For each reagent you added in Parts 1 – 3 write a chemical equation to identify the chemical reaction that is occurring.

3. Write a general statement to summarize what you have learned about these reaction systems.

Procedure
Part 3:

Work in pairs to perform this activity. As a class, decide how you want to divide the work to conduct your analyses and share your results.

Materials Available

13 x 100 mm test tubes	1.0 M HCl
Plastic dropper pipets	1.0 M NaOH
Small test tubes	0.10 M CrO_4^{2-} (as $K_2CrO_{4(aq)}$)
Test tube holder	0.10 M $Cr_2O_7^{2-}$ (as $K_2Cr_2O_{7(aq)}$)
Distilled Water	
Beaker for water baths	
Hot Plate for hot water bath	
Ice for cold water bath	

Add 10 – 20 drops of 0.10 M CrO_4^{2-} and 10 – 20 drops of 0.10 M $Cr_2O_7^{2-}$ in to small test tubes and place in the test tube rack. Observe the difference between these two reagents. To the solution of chromate (CrO_4^{2-}) add 1.0 M HCl dropwise until you observe a change. Save the solution in this test tube.

What did you observe?

Write a chemical reaction to describe what you observed.

Repeat this process using 1.0 M NaOH dropwise instead. Keep track of the number of drops. Observe. How can you reverse the effect of adding the drops of NaOH? Try to see whether your prediction is correct.

As a class design a series of experiments to determine other combinations from the reagents above. Add reagents dropwise in order to minimize waste.

How does the original solution that contained CrO_4^{2-} and HCl respond to being heated or cooled in a water bath? How does a solution after NaOH addition behave? When you perform this investigation be sure the solution in the test tube is fully immersed in the water baths. You may want a large amount of solution for this investigation. Record your observations.