OXIDATION-REDUCTION EXPERIMENT

INTRODUCTION

An oxidation-reduction (redox) reaction involves the movement of electrons from one reactant to another. Many reactions that you have already studied are redox reactions; these include single replacement, combustion, and combination. **Oxidation** is the loss of electrons. **Reduction** is the gain of electrons. The loss and gain of electrons occur simultaneously in the reaction. For example, in the reaction of elemental calcium and oxygen to produce calcium oxide:

$$Ca(s) + ½\ O_2(g) \rightarrow CaO(s)$$

Calcium loses two electrons and oxygen gains two electrons. Although the two events occur simultaneously, they may be written as two separate half-reactions:

Reduction half-reaction: $2\ e^- + ½\ O_2 \rightarrow O^{2-}$

Oxidation half-reaction: $Ca \rightarrow Ca^{2+} + 2\ e^-$

In this reaction, O_2 is the oxidizing agent. The **oxidizing agent** is the species that is being reduced (gaining electrons). The **reducing agent** is the species that is being oxidized (losing electrons). The reducing reagent in this reaction is Ca.

An oxidation-reduction reaction may be thought of as a competition between two substances for electrons. Consider the two reactions below, which are the reverse of each other:

Reaction (1) $Cu(NO_3)_2(aq) + Zn(s) \rightarrow Cu(s) + Zn(NO_3)_2(aq)$

net ionic equation: $Cu^{2+}(aq) + Zn(s) \rightarrow Cu(s) + Zn^{2+}(aq)$

reduction half-reaction: $Cu^{2+}(aq) + 2\ e^- \rightarrow Cu(s)$

oxidation half-reaction: $Zn(s) \rightarrow Zn^{2+}(aq) + 2\ e^-$

oxidizing agent = Cu^{2+}
reducing agent = Zn

Reaction (2) $Zn(NO_3)_2(aq) + Cu(s) \rightarrow Zn(s) + Cu(NO_3)_2(aq)$

net ionic equation: $Zn^{2+}(aq) + Cu(s) \rightarrow Zn(s) + Cu^{2+}(aq)$

reduction half-reaction: $Zn^{2+}(aq) + 2\ e^- \rightarrow Zn(s)$

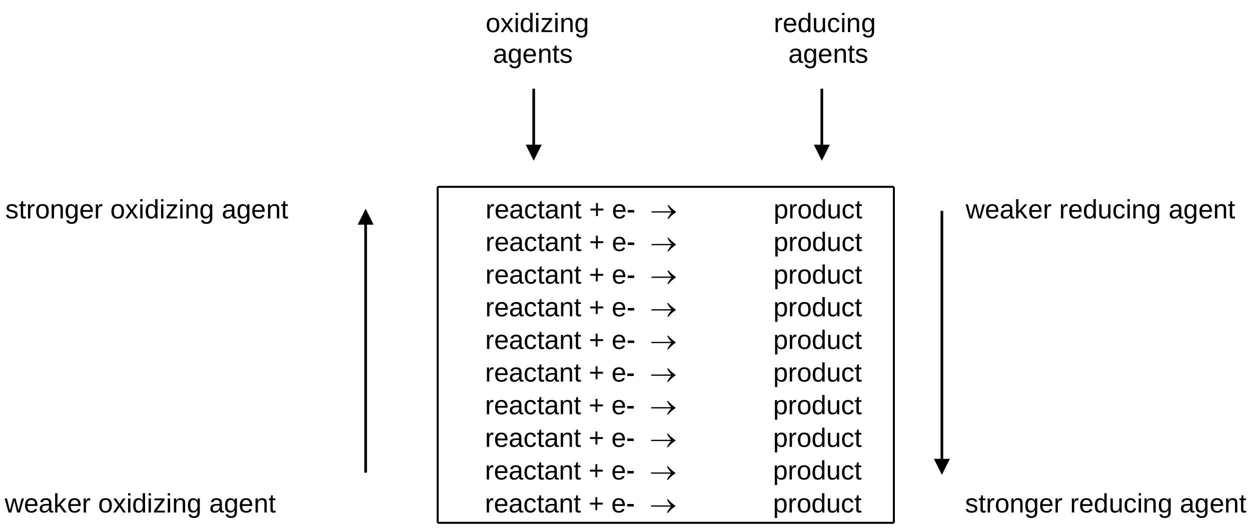
oxidation half-reaction: $Cu(s) \rightarrow Cu^{2+}(aq) + 2\ e^-$

oxidizing agent = Zn^{2+}
reducing agent = Cu

Reaction (1) will occur spontaneously and (2) will not if Cu^{2+} is a stronger oxidizing agent than Zn^{2+}. Conversely, reaction (2) will occur and (1) will not if Zn^{2+} is a stronger oxidizing agent than Cu^{2+} (and Cu is a stronger reducing agent than Zn). That is, a redox reaction will occur spontaneously to produce the weaker oxidizing and reducing agents.

A standard oxidation-reduction potential series (standard potential series) is a list of reduction half-reactions. The half-reactions are listed such that the reduction half-reaction for the strongest oxidizing agent is written first, followed by the next strongest, and so on. Since the strongest oxidizing agent produces the weakest reducing agent, as you proceed down the right side (product side) of the series, the reducing agents will be progressively stronger, as shown on the next page.

Oxidation-Reduction Potential Series



reduction half-reactions

In this experiment you will use experimental evidence and additional information to write a potential series for some cations, halogens, and hydrogen ion.

EXPERIMENT

A. Potential Series for metals and Hydrogen

The reactions you will carry out to determine a potential series for metals and hydrogen will be done in the separate wells of a spot plate. In each case a single piece of metal will be added to approximately 5 drops of solution in a spot plate well. Use a paper towel under the spot plate to label the separate reactions. In some cases, the reaction mixtures must be disposed of in special waste containers, therefore, those reactions should be carried out separately from others – that is – only one well of the spot plate should be used if that well contains material that requires special disposal. Read carefully and plan ahead!

NOTE: Some reactions are slow. If a reaction does not occur immediately, do another part of the experiment and then go back and examine the well after ten to fifteen minutes.

1. Copper and Zinc

Safety Caution:
COPPER (II) NITRATE Solution: STRONG OXIDIZER. HARMFUL IF SWALLOWED. CAUSES IRRITATION TO SKIN, EYES AND RESPIRATORY TRACT.
ZINC NITRATE Solution: CAUSES IRRITATION. HARMFUL IF SWALLOWED. STRONG OXIDIZER.

Place a piece of each metal into 0.1 M aqueous solutions of the nitrates of the other metal . That is, place copper in aqueous zinc nitrate; place zinc in aqueous copper (II) nitrate in separate wells in a spot plate.

Examine each reaction mixture and record your observations on the Report Sheet. If you conclude from your observations that a reaction has occurred, write its net ionic equation. If no reaction occurs, do not write an equation, write N.R.

DISPOSAL: Dispose of reaction mixtures (pieces of unreacted metals plus solutions) on spot plate by pouring them all into the waste container labeled "Ag and metals."

On your report sheet, indicate for each pair of ions given which is the stronger oxidizing agent.

2. Silver, Copper, and Zinc

SAFETY CAUTION:
SILVER NITRATE: WARNING! CAUSES SEVERE EYE IRRITATION. HARMFUL IF SWALLOWED OR INHALED. CAUSES IRRITATION TO SKIN AND RESPIRATORY TRACT. AFFECTS EYES, SKIN AND RESPIRATORY TRACT. FURTHERMORE, SILVER NITRATE WILL STAIN YOUR SKIN AND CLOTHING.

Add a piece of each metal, copper and zinc, to aqueous silver nitrate solution in separate wills of a spot plate.

Examine each reaction mixture and record your observations on the Report Sheet. If you conclude from your observations that a reaction has occurred, write its net ionic equation. If no reaction occurs, do not write an equation, write N.R.

DISPOSAL: Dispose of reaction mixtures (pieces of unreacted metals plus solutions) on spot plate by pouring them all into the proper waste container.

On your report sheet incorporate silver ion, copper (II), and zinc ion into a potential series ions so that your oxidation-reduction potential series consists of reduction half-reactions for all three metal cations listed in order such that the reaction of the strongest oxidizing agent is written first and the weakest last.

3. Hydrogen, Silver, Copper, and Zinc

SAFETY CAUTION:
<u>HYDROCHLORIC ACID SOLUTION:</u> POISON! CORROSIVE. LIQUID AND MIST CAUSE SEVERE BURNS TO BODY TISSUE. MAY BE FATAL IF SWALLOWED OR INHALED.

Add a piece of each metal, silver, copper, and zinc, to 6 <u>M</u> hydrochloric acid solution in separate wells of a spot plate.

Examine each reaction mixture and record your observations on the Report Sheet. If you conclude from your observations that a reaction has occurred, write its net ionic equation.

DISPOSAL: Dispose of reaction mixtures (pieces of unreacted metals plus solutions) on spot plate by pouring them all into the proper waste container labeled “Ag and metals.”

On your report sheet incorporate hydrogen ion into the potential series for silver ion, copper (II) ion, and zinc ion, so that your oxidation-reduction potential series consists of reduction half-reactions for all five species listed in order such that the reaction of the strongest oxidizing agent is written first and the weakest last.

B. Potential Series for Halogens and Iron

1. Chlorine, Bromine, and Iodine

In this section of the experiment water or an aqueous solution will be added cyclohexane, a nonpolar solvent. (The cyclohexane is not a reactant, just another solvent like water). From your observations of the colors of the halides and the halogens in the two solvent layers, you will determine whether a reaction has occurred or not.

SAFETY CAUTION:
<u>CYCLOHEXANE:</u> EXTREMELY FLAMMABLE LIQUID AND VAPOR. VAPOR MAY CAUSE FLASH FIRE. HARMFUL OR FATAL IF SWALLOWED. HARMFUL IF INHALED. CAUSES IRRITATION TO SKIN, EYES, AND RESPIRATORY TRACT.
<u>CHLORINE WATER</u>: CORROSIVE. CAUSES EYE AND SKIN BURNS. CAUSES DIGESTIVE AND RESPIRATORY TRACT BURNS.
<u>BROMINE WATER:</u> CORROSIVE. CAUSES EYE AND SKINBURNS. CAUSES DIGESTIVE AND RESPIRATORY TRACT BURNS.
<u>IODINE WATER:</u> POISON! CAUSES SEVERE IRRITATION OR BURNS TO EVERY AREA OF CONTRACT. MAY BE FATAL IF SWALLOWED OR INHALED. VAPORS CAUSE SEVERE IRRITATION TO SKIN, EYES, AND RESPIRATORY TRACT. OXIDIZER. MAY CAUSE ALLERGIC SKIN OR RESPIRATORY REACTION.
<u>POTASSIUM BROMIDE</u>: HARMFUL IF SWALLOWED OR INHALED. MAY CAUSE IRRITATION TO SKIN, EYES, AND RESPIRATORY TRACT.
<u>POTASSIUM IODIDE:</u> MAY CAUSE IRRITATION TO SKIN, EYES, AND RESPIRATORY TRACT.

PART B IS TO BE CARRIED OUT <u>IN THE HOOD</u>.

All volumes are to be **approximated**.

a. Colors of Bromine, Chlorine, and Iodine in Both Cyclohexane and Water

Add 1 mL of cyclohexane to 2 mL of water in a 4-inch test tube. To the same test tube, add 1 mL bromine water (aqueous solution of bromine). Mix well. On your report sheet record the colors of both solvent layers.
To a second 4-inch test tube, add 2 mL of water, 1 mL of cyclohexane, and 1 mL chlorine water (aqueous solution of chlorine). Mix well and record the colors of both solvent layers.
To a third 4-inch test tube, add 2 mL of water, 1 mL of cyclohexane, and 1 mL iodine water (0.05 M I_2 in dropper bottle). Mix well and record the color of the cyclohexane layer.
Now you will be able to identify any of these three halogens in the cyclohexane layer.

b. Potassium Bromide and Chlorine

Put 2 mL of 0.1 M aqueous potassium bromide solution in a 4-inch test tube and add 1 mL of cyclohexane. Mix well. Observe the colors of the two layers and record them on your report sheet.

To the test tube with aqueous potassium bromide/cyclohexane add 1 mL of Cl_2 water. Mix well Mix well and record the color of the cyclohexane layer. Now you will be able to identify any of these three halogens in the cyclohexane layer If you conclude from your observations that a reaction has occurred, write its net ionic equation.

c. Potassium Bromide and Iodine

Put 2 mL of 0.1 M aqueous potassium bromide solution in a 4-inch test tube and add 1 mL of cyclohexane. Mix well.

To the test tube with of aqueous potassium bromide/cyclohexane add 1 mL of I_2 water. Mix well. Mix well and record the color of the cyclohexane layer. Now you will be able to identify any of these three halogens in the cyclohexane layer If you conclude from your observations that a reaction has occurred, write its net ionic equation.

d. Potassium Iodide and Bromine

Write your observations on your report sheet. If a reaction occurred, write its net ionic equation.

Put 2 mL of 0.1 M aqueous potassium iodide solution in a 4 inch test tube and add 1 mL of cyclohexane. Mix well. To the test tube with aqueous KI/cyclohexane add 1 mL of Br_2 water. Mix well. Mix well and record the color of the cyclohexane layer. Now you will be able to identify any of these three halogens in the cyclohexane layer. If you conclude from your observations that a reaction has occurred, write its net ionic equation.

e. Potassium Iodide and Chlorine

Put 2 mL of 0.1 M aqueous potassium iodide solution in a 4 inch test tube and add 1 mL of cyclohexane. Mix well.

To the test tube with aqueous potassium iodide/cyclohexane add 1 ml of Cl_2 water. Mix well Mix well and record the color of the cyclohexane layer. Now you will be able to identify any of these three halogens in the cyclohexane layer. If you conclude from your observations that a reaction has occurred, write its net ionic equation.

DISPOSAL: Dispose of all mixtures that contain cyclohexane in the specially labeled "halogenated hydrocarbons" bottle located in the hood. DO NOT THROW THEM IN THE SINK!!!

On your report sheet, write the oxidation-reduction potential series for the three halogens, listing the reduction half-reactions such that the reaction of the strongest oxidizing agents is written first and the weakest last.

2. Bromine, Iodine, and Iron

You will be determining whether Fe^{3+} ion is a stronger or weaker oxidizing agent than I_2 or Br_2. You will be able to determine if I_2 or Br_2 are produced by observing the colors of the water & cyclohexane layers. If the Fe^{3+} is reduced, it does not go to Fe, rather to Fe^{2+}. You will determine if Fe^{2+} is produced by testing with potassium ferricyanide, $K_3(CN)_6$, solution. **If Fe^{2+} is present, a dark blue precipitate of $Fe_3[Fe(CN)_6]_2$ will form.**

SAFETY CAUTION:
FERRIC CHLORIDE SOLUTION: DANGER! STRONG OXIDIZER. HARMFUL IF SWALLOWED. CAUSES IRRITATION TO SKIN, EYES AND RESPIRATORY TRACT.
POTASSIUM FERRICYANIDE: CAUTION! MAY BE HARMFUL IF SWALLOWED OR INHALED. MAY CAUSE IRRITATION TO SKIN, EYES, AND RESPIRATORY TRACT.

THE FOLLOWING IS PERFORMED IN THE HOOD:

a. Iron (III) Chloride and Potassium Bromide

Add 1 mL of 0.1 M aqueous ferric chloride solution to 2mL of 0.1 M KBr in a 6 inch test tube. Then add 1 mL of cyclohexane and mix well. Then add one drop of $K_3Fe(CN)_6$ to test for the presence of Fe^{2+}. Record your observations on your report sheet.

b. Iron (III) Chloride and Potassium Iodide

Add 1 mL of 0.1 M aqueous ferric chloride solution to 2 mL of 0.1 M KI in a 6 inch test tube. Then add 1 mL of cyclohexane and mix well. Then add one drop of $K_3Fe(CN)_6$ to test for the presence of $K_3Fe(CN)_6$ to test for the presence of Fe^{2+}. Record your observations on your report sheet.

DISPOSAL: Dispose of all mixtures that contain cyclohexane in the specially labeled "halogenated hydrocarbons" bottle located in the hood. DO NOT THROW THEM IN THE SINK!!!

On your report sheet, incorporate Fe^{3+} into the oxidation-reduction potential series for the Br_2, I_2, and Cl_2, listing the reduction half-reactions such that the reaction of the strongest oxidizing agent is written first and the weakest last.

C. Potential Series

On your report sheet, write a potential series of all the species studied, Zn^{2+}, Cu^{2+}, Ag^+, Fe^{3+}, H^+, I_2, Cl_2, and Br_2. to do this, use your experimental evidence plus the following information:
Other experiments have shown that I_2 and Fe^{3+} are both weaker oxidizing agents that Ag^+, but stronger than Cu^{2+}. On the other hand, Br_2 is a stronger oxidizing agent than Ag+.

Report - **OXIDATION-REDUCTION EXPERIMENT**
Chem 112

Name ___________________________

Date ______Lab Section___________

Instructor's Initials_________________

A. Potential Series for Metals and Hydrogen

1. Reactions of Copper and Zinc

a. Observations and reactions

(1) Copper + zinc nitrate

Observations: ____

Net ionic equation: ____

(2) Zinc + copper (II) nitrate

Observations: ____

Net ionic equation: ____

b. Relative oxidizing strengths

Which is the stronger oxidizing agent?

Cu^{2+} or Zn^{2+} __________

2. Reactions of Silver with Copper and Zinc

a. Observations and reactions

(1) Copper + silver nitrate

Observations: ____

Net ionic equation: ____

(2) Zinc + silver nitrate

Observations: ____

Net ionic equation: ____

b. Potential Series for Cu^{2+}, Zn^{2+}, and Ag^{+}

SOA		WRA
	________________________________	
	________________________________	
	________________________________	
	________________________________	
WOA		SRA

3. Reactions of Hydrogen with Copper, and Zinc

a. Observations and reactions

(1) Copper + hydrochloric acid

Observations: ______________________________

Net ionic equation: ______________________________

(2) Zinc + hydrochloric acid

Observations: ______________________________

Net ionic equation: ______________________________

(3) Silver + hydrochloric acid

Observations: ______________________________

Net ionic equation: ______________________________

b. Potential Series for Cu^{2+}, Zn^{2+}, Ag^{+}, and H^{+}

SOA WRA

____

____

____

____

____

WOA SRA

Potential Series for Halogens and Iron

1. Chlorine, Bromine, and Iodine

a. Colors of Chlorine, Bromine and Iodine

Halogen	Color in Water	Color in Cyclohexane
Br_2		
I_2		
Cl_2		

b. Potassium Bromide and Chlorine

	Color in Cyclohexane
Potassium Bromide + Chlorine	

Observations: ____

Net ionic equation: ____

c. Potassium Bromide and Iodine

	Color in Cyclohexane
Potassium Bromide + Iodine	

Observations: ____

Net ionic equation: ____

d. Potassium Iodine and Bromine

	Color in Cyclohexane
Potassium Iodide + Bromine	

Observations: ____

Net ionic equation: ____

e. Potassium Iodide and Chlorine

	Color in Cyclohexane
Potassium Iodide + Chlorine	

Observations: ____

Net ionic equation: ____

Potential Series for Cl_2, Br_2, and I_2

SOA ______________________ WRA

____

____

____

WOA ______________________ SRA

2. Bromine, Iodine, and Iron

a. Iron (lll) Chloride and Potassium Bromide

Observations: ____

____

Net ionic equation: ____

b. Iron (lll) Chloride and Potassium Iodide

Observations: ____

____

Net ionic equation: ____

Potential Series for Cl_2, Br_2, I_2, and Fe^{3+}

SOA ______________________ WRA

____

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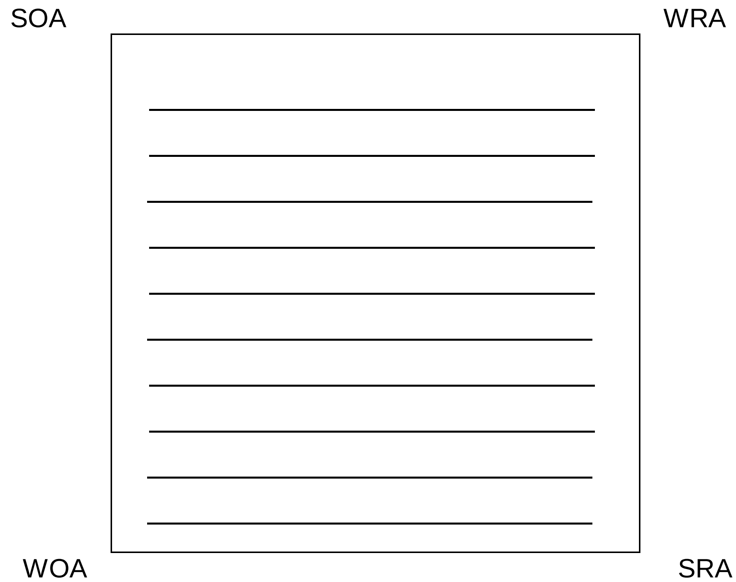
____

____

WOA ______________________ SRA

C. Potential Series



D. QUESTIONS

Use the standard potential table in your textbook, page 891, when answering the following.

1. Complete the following table. If the species listed can be used as an oxidizing agent, write YES in the Oxidizing Agent column and write its reduction half-reaction in the next column. If it cannot be used as an oxidizing agent, write NO in the oxidizing Agent column and leave the next column blank. If the species listed can be used as a reducing agent, write YES in the Reducing Agent column and write its oxidation half-reaction in the last column. If it cannot be used as a reducing agent, write NO in the Reducing Agent column and leave the last column blank.

	Oxidizing Agent?	Reduction Half-Reaction	Reducing Agent?	Oxidation Half-Reaction
K				
Fe^{2+}				
MnO_4^-				
Br_2				
H_2S				
HCl				

2. Indicate whether each of the following statements is true, **T**, or false, **F**. In each case, briefly explain your response.

_______ a. Chromium metal can dissolve in dilute HCl.
____

_______ b. Iron metal will reduce Fe^{3+} to Fe^{2+}.
____

_______ c. Silver metal will dissolve in nitric acid, liberating H_2 gas.
____

_______ d. Oxygen in moist air can oxidize Fe^{2+} to Fe^{3+}.
____

_______ e. Mercury metal will dissolve in HNO_3, but not in HCl.
____

_______ f. Tin metal will reduce Co^{2+}, but not Sn^{4+}.
____

3. Imagine that the hypothetical elements, A, B, C, and D, form the ions A^{2+}, B^{2+}, C^{2+}, and D^{2+}, respectively. The following equations indicate reactions which can, or cannot, occur. Use this information to write a potential series for the cations.

$B^{2+} + A \rightarrow A^{2+} + B$ $\quad$ $B^{2+} + D \rightarrow$ N.R. $\quad$ $A^{2+} + C \rightarrow C^{2+} + A$

4. Summarize the results of this experiment. Include the important principles and relationships that have been illustrated by this experiment.