Creating a Redox Reactivity Series

This week you and a partner will develop a redox reactivity series that ranks a variety of chemical species in terms of how easily they are reduced.

Pre-lab Assignment
Before coming to lab, review your notes from class on oxidation-reduction chemistry.

Preliminary Experiment
Place 3 mL of 0.1 M $AgNO_3$ in a clean test tube. Add a small piece of copper wire to the test tube and observe the reaction for at least five minutes. Do you see any change in the copper wire? Do you see any change in the solution? Record your observations in your lab notebook.

This reaction between $AgNO_3$ and Cu is one example of an oxidation–reduction reaction in which the oxidation of Cu to Cu^{2+} provides the electrons that reduce Ag^+ to Ag

$$Cu(s) \rightarrow Cu^{2+}(aq) + 2e^-$$

$$Ag^+(aq) + e^-(aq) \rightarrow Ag(s)$$

Because each Cu atom produces two electrons and each Ag^+ ion consumes one electron, two silver ions are reduced for each copper atom that is oxidized; thus, the overall balanced reaction is

$$2Ag^+(aq) + Cu(s) \rightarrow Cu^{2+}(aq) + 2Ag(s)$$

It is easy to verify that Ag^+ has been reduced to Ag because it appears on the copper wire as a feathery solid. It is more difficult to verify that Cu has been oxidized because the copper metal is coated with silver; however, you may notice that the solution turns a faint blue, which provides evidence for the presence of Cu^{2+} in solution. We can confirm the presence of Cu^{2+} by adding NH_3 to form the deep-blue $Cu(NH_3)_4{}^{2+}$ complex, a reaction you observed several times this semester. We call this a qualitative test for Cu^{2+}. To confirm the presence of Cu^{2+}, transfer 10 drops of the reaction's solution to a clean test-tube and add 10 drops of 6 M NH_3. Record your observations in your lab notebook.

A Redox Reactivity Series
The oxidized and reduced form of a species form a redox couple, which we write by listing the species' oxidized form followed by its reduced form, separating the two with a slash (/). For the reaction in the preliminary experiment, the redox couples are Ag^+/Ag and Cu^{2+}/Cu. Because Cu reduces Ag^+ we know that Ag will not reduce Cu^{2+}, which means the Ag^+/Ag redox couple is easier to reduce than the Cu^{2+}/Cu redox couple. A redox reactivity series simply lists two or more redox couples, one per line, from the from the redox couple that is easiest-to-reduce, to the redox couple that is hardest-to-reduce; thus, for silver and copper the redox reactivity series is

easiest to reduce: Ag^+/Ag

hardest to reduce: Cu^{2+}/Cu

In this experiment you will create a redox reactivity series for the following seven redox couples:

Br_2/Br^- Cu^{2+}/Cu Fe^{2+}/Fe Fe^{3+}/Fe^{2+} H^+/H_2 I_2/I^- Zn^{2+}/Zn

Additional Qualitative Tests

As noted in the preliminary experiment, it is not always easy to tell if a redox reaction is taking place. When this is the case, a simple qualitative test can help us discern what is happening. To help with identifying the presence of some of the species in these redox couples, complete these additional qualitative tests, recording your observations in your lab notebook.

Qualitative Test for Fe^{3+}: Place 10 drops of 0.1 M $FeCl_3$ in a clean test tube. Add several drops of 0.2 M KSCN and record your observations.

Qualitative Test for Fe^{2+}: Dissolve 0.1 g of $FeSO_4$•$7H_2O$ in about 3 mL of deionized water. Add several drops of 0.2 M $K_3Fe(CN)_6$ and record your observations.

Qualitative Test for Zn^{2+}: Place 10 drops of 0.1 M $Zn(NO_3)_2$ in a clean test tube. Add several drops of 0.2 M $K_3Fe(CN)_6$ and record your observations.

Qualitative Test for Br^-: Place 10 drops of 0.1 M KBr in a clean test tube. Add several drops of 0.1 M $AgNO_3$ and record your observations.

Qualitative Test for I^-: Place 10 drops of 0.1 M KI in a clean test tube. Add several drops of 0.1 M $AgNO_3$ and record your observations.

Caution: complete the next two tests in a hood and dispose the reagents in the waste jar when the test is complete; do not bring these reagents to your bench.

Qualitative Test for Br_2: Add several drops of the Br_2 solution and 3 mL of deionized water to a clean test tube; mix and record your observations. Add 1 mL of hexane to the test tube, mix, and record your observations.

Qualitative Test for I_2: Add several drops of the I_2 solution and 3 mL of deionized water to a clean test tube; mix and record your observations. Add 1 mL of hexane to the test tube, mix, and record your observations.

Redox Couple Set I: Metal Ion/Metal (M^{n+}/M) Redox Couples

Place 3 mL of 0.1 M $Zn(NO_3)_2$ in each of two clean test tubes. Place 3 mL of 0.1 M $CuSO_4$ in each of two clean test tubes. Place 0.1 g of $FeSO_4$•$7H_2O$ in each of two clean test tubes and dissolve each in 3 mL of deionized water. Using small pieces of Cu, Zn, and Fe (clean the iron wire with sandpaper before using), explore the redox systems below, using qualitative tests as needed to verify the products of any chemical reactions (to complete a test, first remove a small portion of your sample to a clean test tube). Record your observations in your lab notebook. If a reaction takes place, write a balanced reaction in your notebook; if a reaction does not occur, simply write NR for no reaction.

$Cu(s) + Zn^{2+}(aq) \rightarrow$

$Zn(s) + Cu^{2+}(aq) \rightarrow$

$Fe(s) + Cu^{2+}(aq) \rightarrow$

$Cu(s) + Fe^{2+}(aq) \rightarrow$

$Zn(s) + Fe^{2+}(aq) \rightarrow$

$Fe(s) + Zn^{2+}(aq) \rightarrow$

Redox Couple Set II: The H^+/H_2 Redox Couple

Place 3 mL of 6 M HCl in each of three clean test tubes. Add a small piece of Cu to one test tube, a small piece of Zn to the second test tube, and a small piece of Fe (clean the iron wire with sandpaper before using) to the third test tube. Use qualitative tests as needed to verify the products of any chemical reactions. Record your observations in your lab notebook. If a reaction takes place, write a balanced reaction in your notebook; if a reaction does not occur, simply write NR for no reaction.

$Cu(s) + H^+(aq) \rightarrow$ $Zn(s) + H^+(aq) \rightarrow$ $Fe(s) + H^+(aq) \rightarrow$

Redox Couple Set III: The Halogen/Halide (X_2/X^-) Redox Couple

Place 3 mL of 0.1 M KBr in a clean test tube and 3 mL of 0.1 M KI in a separate clean test tube. Add several drops of the Br_2 solution to the test tube containing KI, and several drops of the I_2 solution to the test tube containing KBr. Use qualitative tests as needed to verify the products of any chemical reactions. Record your observations in your lab notebook. If a reaction takes place, write a balanced reaction in your notebook; if a reaction does not occur, simply write NR for no reaction.

$Br^-(aq) + I_2(aq) \rightarrow$ $I^-(aq) + Br_2(aq) \rightarrow$

Redox Couple Set IV: The Fe^{3+}/Fe^{2+} Redox Couple

Place 1 mL of 0.1 M $FeCl_3$ in each of two clean test tubes. Add 2 mL of 0.1 M KI to the first test tube and 2 mL of 0.1 M KBr to the second test tube. Use qualitative tests as needed to verify the products of any chemical reactions. Record your observations in your lab notebook. If a reaction takes place, write a balanced reaction in your notebook; if a reaction does not occur, simply write NR for no reaction.

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

Redox Couple Set V: Reactions of Halogens with Copper Metal

Place 10 mL of the Br_2 solution in a clean test tube and 10 mL of the I_2 solution to a second clean test tube. Add a small piece of Cu to each test tube. Use qualitative tests as needed to verify the products of any chemical reactions. Record your observations in your lab notebook. If a reaction takes place, write a balanced reaction in your notebook; if a reaction does not occur, simply write NR for no reaction.

$Cu(s) + Br_2(aq) \rightarrow$ $Cu(s) + I_2(aq) \rightarrow$

Creating a Redox Reactivity Series

Based on your results, rank the seven redox couples explored in this lab

Br_2/Br^- Cu^{2+}/Cu Fe^{2+}/Fe Fe^{3+}/Fe^{2+} H^+/H_2 I_2/I^- Zn^{2+}/Zn

from the redox couple that is easiest to reduce, to the redox couple that is hardest to reduce. You may find it helpful to first construct separate redox reactivity series for redox couples in Sets I and II, and the redox couples in sets III–V, and then merge the two redox reactivity series.

Waste Disposal

Please dispose of your solutions in the appropriately labeled waste container in the hood.

Lab Report Write-up

Your lab report consists of your redox reactivity series, organized from the redox couple that is easiest to reduce, to the redox couple that is hardest to reduce. Include a well-written explanation that clearly explains how you arrived at this ranking. This report is due at our next laboratory period.