

Lab 3. Activity Series

Prelab Assignment

Before coming to lab:

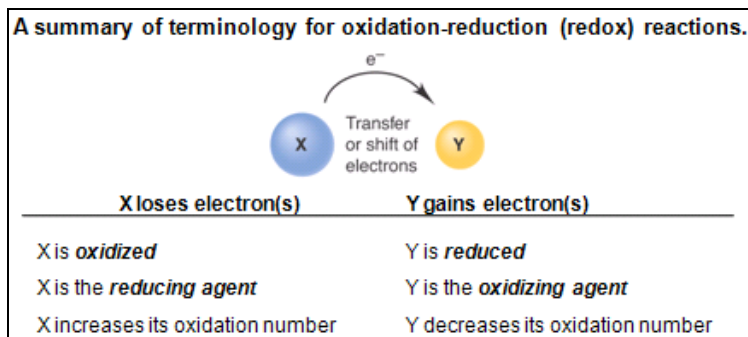
- After reading the "Chemistry Lab Notebook Policy" handout, complete the following sections of your report for this lab exercise *before* attending lab: Title, Introduction, Materials/Methods and Data Tables. An outline or flow chart of the procedure is appropriate for the Materials/Methods section. Simply copy and paste/tape (no staples!) into your notebook the data table on [page 5](#). Ensure that the table of contents of your lab notebook is current.
- Read the lab thoroughly and answer the pre-lab questions that appear at the end of this lab exercise.

Purpose

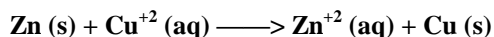
In this lab you will carry out a series of experiments and use your observations of the results to construct an activity series of several metals and then try to correlate the relative activity of each metal to the metal's electronic configuration, ionization energy and atomic radius.

Introduction

the *activity series* is a ranking of metals based on the ease with which they are oxidized. You will recall from our work in Chemistry 140 that **oxidation** involves the loss of one or more electrons, while **reduction** is the gain of one or more electrons—LEO (**L**oss of **E**lectrons = **O**xidation) the Lion said GER (**G**ain of **E**lectrons = **R**eduction) is a nifty way to remember the terms. For a review of oxidation and reduction, see [pp. 158–159, of Section 4.5 of your text](#). *Metals that are high on the activity series are easily oxidized and hence very reactive. Metals that are low on the activity series are not easily oxidized and hence not very reactive.* For a review of the activity series, see [pp. 170–172, of Section 4.6 of your text](#). Below is a summary of Redox terms.

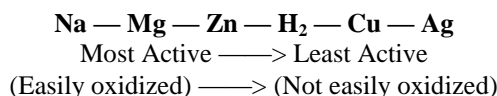


The activity series can be used to predict whether or not a redox reaction will take place. As an example, consider the following possible reaction:



Does this reaction take place? In other words, if zinc metal is placed in contact with aqueous copper ions, will zinc displace copper ions from solution? Another way to phrase this is, "Will Zn reduce Cu^{+2} ?" (Or, equivalently, "Will Cu^{+2} oxidize Zn?")

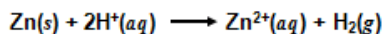
As a general rule, an element will be displaced from solution or its compounds by another element higher on the activity series. An abbreviated version of the activity series is given below, where the top of the series is to the left, and the bottom to the right.



We see that zinc is above (to the left in this list) copper. Thus, zinc metal will displace copper ions from solution since Zn is more easily oxidized than Cu.

Note that zinc is above hydrogen in the activity series and therefore is more easily oxidized than hydrogen. In the [example below](#), when zinc metal is placed in an acidic solution hydrogen gas (H_2) is produced as the solid zinc dissolves to form zinc ions in solution, $\text{Zn}^{2+}(\text{aq})$ —recall that acids (e.g. HCl , H_2SO_4 , etc.) are molecular compounds that dissociate in aqueous solution to produce hydrogen ions, $\text{H}^+(\text{aq})$. Would you expect copper or silver to react if placed in a solution of hydrochloric acid?

Redox Terminology applied to a reaction between Zinc and an Acid

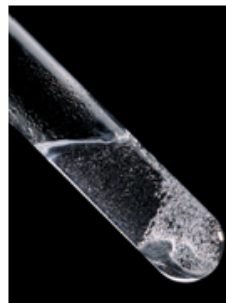


OXIDATION

One reactant loses electrons. Zn loses electrons.
 Reducing agent is oxidized. Zn is the reducing agent and becomes oxidized.
 Oxidation number increases. The oxidation number of Zn increases from x to $+2$.

REDUCTION

Other reactant gains electrons. Hydrogen ion gains electrons.
 Oxidizing agent is reduced. Hydrogen ion is the oxidizing agent and becomes reduced.
 Oxidation number decreases. The oxidation number of H decreases from $+1$ to 0 .



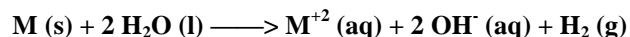
Some elements lose electrons (*i.e.*, are oxidized) readily. Are there any trends or regular patterns in the activity of the metals? How can these trends be explained? There are many factors that influence the activity of a metal. Below are [three](#) of the *many* factors that influence the activity of a metal:

1. The metal's **electron configuration** and the electron configuration of the *ion* formed when the metal is oxidized: What is it about the electron configuration that might influence the activity of a metal? Can we deduce any patterns or trends?
2. The metal's **ionization energy**: The **ionization energy** is the amount of energy required to remove an e^- from a neutral gaseous atom. Do you think there is a relationship between the activity of a metal and its ionization energy? How are the two related? Does the number of electrons lost influence the activity of the metal?
3. The metal's **atomic radius**: Is there a relationship between the activity of a metal and its atomic radius? If so, how are the two related?

You will answer these and other questions by observing the relative activity of several metals. You will use your results to generate an activity series and will compare your results to those in your text. Lastly, you will look for a relationship between electronic configuration, ionization energy and atomic radius and the activity of each metal.

Introduction to Part 1 — Metals Reacting With Water

When active metals react with water, hydrogen gas and the metal hydroxide are produced. The general reaction, where M is the metal, is



or

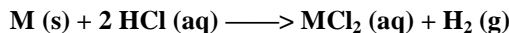


The resulting solution will be **basic**, due to the presence of the **hydroxide ion**, OH^- . One way to test if a reaction has occurred is to place a drop of **phenolphthalein**, an acid–base indicator, in the water. If the water turns **pink**, this is a signal that a reaction has occurred. Only the most active metals will react with water. The more vigorous the reaction, the more easily is the metal oxidized, and thus the higher it should be on the activity series.

The instructor will demonstrate the reaction of Li, Na, and K with water. Be sure to record your observations in your lab notebook. The activity of the remaining metals can be tested at your lab bench.

Introduction to Part 2 — Metals Reacting With Non-oxidizing Acids

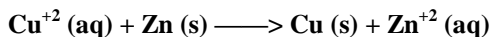
Metals that do not react with water may react with non-oxidizing acids like *hydrochloric acid*, HCl. The more vigorous the reaction, the more easily is the metal oxidized, and thus the higher it should be on the activity series. The general reaction is:



A *non-oxidizing acid* is an acid in which the anion is not a strong oxidizing agent. For example, in HCl, the Cl⁻ ion is not a strong oxidizing agent and will not oxidize a metal.

Introduction to Part 3 — Metals Reacting With Metallic Ions

The above set of reactions should allow you to rank each of the metals with respect to H⁺ ion. To rank metals relative to each other, you will need to see if one metal is more easily oxidized than another. As indicated above, a possible reaction might be:



If the reaction occurs as written, you would conclude that copper ion will oxidize zinc, indicating that zinc is more easily oxidized than Cu. Therefore, Zn should be placed above Cu in the activity series.

Materials and Methods

For this experiment you will work with a partner.

Collect the following materials from the lab cart:

- A well plate
- Strips of Cu, Al, Zn, Pb, Fe, and Mg
- Dropper bottles of 12 M HCl, 3 M HCl, 0.1 M Cu(NO₃)₂, 0.1 M Zn(NO₃)₂, 0.1 M Pb(NO₃)₂, 0.1 M Fe(NO₃)₃, 0.1 M AgNO₃
- A dropper bottle of phenolphthalein
- A small piece of steel wool or sandpaper

Observations for Parts 1-3. For each reaction in parts 1-3 use the key found in the caption of table 1 to indicate how vigorous each reaction, and record your observations about the reaction, e.g. gas produced, color changes of the metal and/or the solution, the color of the precipitate formed, etc.

Part I — Metals Reacting With Water

1. Boil some deionized water.
2. Clean the well plate carefully.
3. Clean each of the strips of metal with the steel wool or sandpaper.
4. Half fill 6 of the wells with boiling water.
5. Place a drop of phenolphthalein in each of the cells with boiling water. If the water turns pink, your well plate is contaminated and will need to be re-cleaned.
6. Place each of the metal strips into one of the cells with boiling water and look for signs of a reaction.
7. Remove the metal strips from the water, clean the well plate (the water can go down the drain) and proceed to Part II.

Part II — Metals Reacting With Non-oxidizing Acids

1. Remove from consideration any of the metals that reacted in Part I. These are the most active metals.
2. Add the remaining metals to the clean cells and add concentrated (12 M) HCl. **Caution: 12 M HCl is extremely corrosive. Goggles are essential.**
3. Watch for signs of a reaction and how vigorous the reaction is. The most obvious sign of a reaction will be bubbles forming and/or the metal “dissolving”. The more vigorous the bubbling, the more active the metal.

Part III — Metals Reacting With Metallic Ions

1. Clean and dry the well plate. Add a few drops of the $\text{Cu}(\text{NO}_3)_2$ solution to 6 of the cells.
2. Clean and dry the strips of metal. Place the strips in the cells, and watch for signs of a reaction. If a reaction occurs, you will observe a darkening or discoloration of the metal surface as the other metal “plates out”. You may need to take some special steps with aluminum. Aluminum normally forms an oxide coating on its surface that prevents it from reacting with air or solutions. Sandpaper may not remove this coating. Try dipping the aluminum in some 3 M HCl briefly to clean the surface.
3. Record your observations in your lab notebook.
4. Remove the metal strips. Clean, dry, and sand them if necessary.
5. Discard the $\text{Cu}(\text{NO}_3)_2$ solution and refill the cells with the $\text{Zn}(\text{NO}_3)_2$. Add the strips and watch for a reaction.
6. Repeat with the remaining solutions of lead, iron, and silver. Note that even though we don’t have strips of silver metal available (Oh, darn!), you should still be able to assess the activity of Ag based on the reactions of the metals with aqueous silver nitrate.
7. Wash your hands with soap before leaving the lab.

Analysis of Results

1. Your results section should contain neat recordings of all of your experimental observations in the data table provided on the next page.
2. Write balanced *net ionic equations* for each reaction that produced an observable result. Make sure that the reactions are balanced by mass (number of atoms) and charge.
3. Based on *your results*, rank each of the metals (including the Li, Na, K and Ag) from most active to least active, including the H^+ ion in your ranking. *Explain your reasoning in a paragraph below your ranking.*
4. Compare your activity series to the one in your text. Identify and try to explain any discrepancies if they exist
5. Below is a sample table for organizing the data involved in explaining and analyzing the results. Construct and complete a similar table in the analysis section of your lab note book, *arranging the elements in the table in order of their activity*—i.e. from most to least active. Take note that *transition metals* (e.g. Fe, Cu, Zn and Ag) lose their s-level electrons before losing their d-level electrons—e.g. Fe in the table below. *Post-transition metals* (e.g. Pb) lose their p-level electrons before losing their s-level electrons.

Atomic Number	Element	Atomic Radius (pm)	Ionization Energies (kJ/mol)			Condensed Electron Configuration of the element	Condensed Electron Configuration of the ion
			1 st	2 nd	3 rd		
1	H	37	1312			$\text{H} = 1s^1$	$\text{H}^+ = 1s^0$
3	Li	162	520				
11	Na	186	496				
12	Mg	160	738	1451			
13	Al	143	578	1870	2745		
19	K	227	419				
26	Fe	126	762	1562		$\text{Fe} = [\text{Ar}] 3d^6 4s^2$	$\text{Fe}^{2+} = [\text{Ar}] 3d^6$
29	Cu	128	746	1958			
30	Zn	134	906	1733			
47	Ag	144	731				
82	Pb	146	716	1450			

6. The *ionization energy* and *atomic radius* of each metal used in this experiment are given in the [table above](#). Is there a relationship between activity and ionization energy? If so, what is it? *Explain clearly* and thoroughly, including a discussion of the role(s) played by *electron configuration* and *atomic radius*.

Table 1. Results for parts 1-3.

Key: **3** = vigorous reaction; **2** = mild reaction; **1** = very mild reaction; **0** =no reaction observed

Metal	Part 1 Reaction with Water	Part 2 Reaction with 12 M HCl	Part 3 Reactions with metallic ions				
			0.1 M Cu ²⁺	0.1 M Zn ²⁺	0.1 M Pb ²⁺	0.1 M Ag ⁺	0.1 M Fe ²⁺
Na (teacher demo)	(Rm Temp)						
Li (teacher demo)	(Rm Temp)						
K (teacher demo)	(Rm Temp)						
Cu	(Boiling)						
Al	(Boiling)						
Zn	(Boiling)						
Pb	(Boiling)						
Fe	(Boiling)						
Mg	(Boiling)						

Lab Report Checklist

As indicated previously, when writing the report for this lab activity follow the guidelines found in the “*Lab Notebook Policy*” handout. Below is a checklist of what should appear in each of the 5 sections of your lab report.

Introduction

- Goal/purpose of the lab is stated clearly?
- Includes summary of background information
- Includes chemical equations for the following types of reactions
 - Metals Reacting With Water
 - Metals Reacting With Non-oxidizing Acids
 - Metals Reacting With Metallic Ions

Materials and Methods

- Procedures for parts 1-3 are detailed enough that a competent student could use it to replicate the experiment?

Results

- Data *neatly* recorded in table provided or in a ruled and easy to read table that are numbered consecutively and have an informative caption?
- Clearly indicates how vigorous each reaction was?
- Clear record of observations about each reaction?
 - Indicates if gas produced, color changes of the metal and/or the solution, the color of the precipitate formed, etc.?

Analysis of Results

- Work is clearly labeled, neat and easy to follow?
- Balanced net ionic equations for each reaction?
 - Includes physical states of all reactants and products
 - Correct charges for ions?
- Metals and H⁺ ranked from most active to least active
 - Uses the experimental observations to justify ranking?
 - Compares activity series to the one in the text and explains any discrepancies?
- Neatly organizes the activity series in a *ruled* table together with the ionization energy, atomic radius and electron configuration listed next to each metal?
- Correctly discusses relationship between activity of a metal and...
 - Ionization energy?
 - Electron configuration?
 - Atomic radius?

Conclusion

Uses “*bullets*” to state concisely the major conclusions:

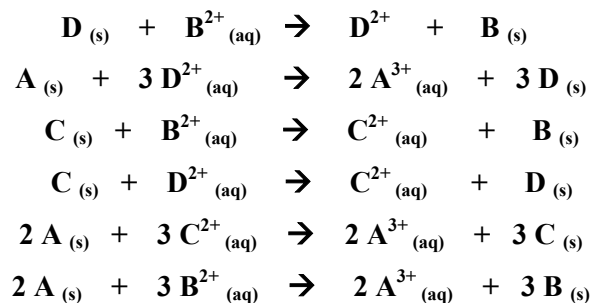
- Activity series: experimental vs. theoretical
- Summarizes major sources of error or uncertainty?

**Lab 3. Activity Series
Prelab Questions**

Name _____
Team _____ Date _____ Section _____

Instructions: Complete the following questions and hand in at the start of the lab period.

1. Use the information that follows to arrange the metals A, B, C, and D in order of decreasing ease of oxidation. Assume that all of the following reactions *do occur*.



Decreasing ease of oxidation →

Answer: _____

Use the activity series below to assist you in determining if the following reactions will occur. Write NR if no reaction will occur. Write balanced *molecular and net ionic equations* (Pages 139-141) for all reactions that do occur. Remember that equations must be balanced by both mass and charge.

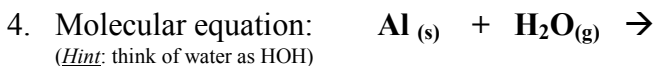
(Most easily oxidized) **Cs, Na, Mg, Al, Mn, Zn, Cr, H, Cu, Ag, Au** (least easily Oxidized)



Net ionic equation:



Net ionic equation:



Net ionic equation: