

# Metal/Metal Ion Reactions

## Laboratory Simulation

Name \_\_\_\_\_ Lab Section \_\_\_\_\_

Lab Partner \_\_\_\_\_

Problem Statement: How do metals and metal ions react?

### I. Data Collection: Eight Solutions

A. The simulation is located at

<http://intro.chem.okstate.edu/1515F01/Laboratory/ActivityofMetals/home.html>. Open the software and go to the opening activity. You should see a graphic that appears in part like figure A.

B. Hold the magnifier over each beaker and "click" to view it's submicroscopic contents. Record what you see on the beakers in Figure A.

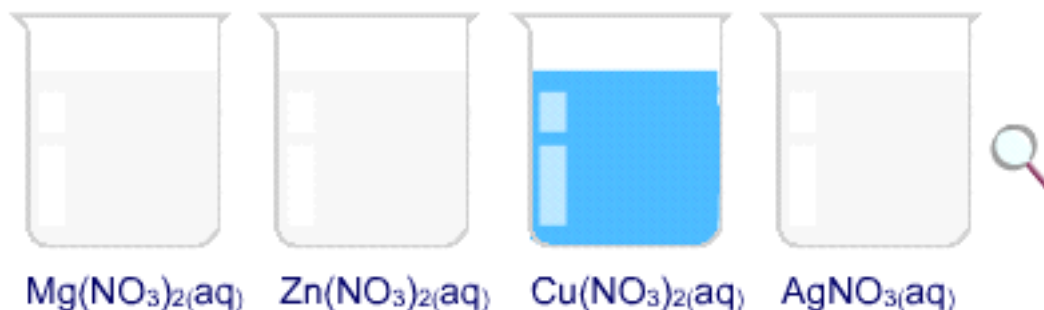


Figure A

**Mg<sup>2+</sup> and NO<sub>3</sub><sup>-</sup> ions : Zn<sup>2+</sup> and NO<sub>3</sub><sup>-</sup> ions : Cu<sup>2+</sup> and NO<sub>3</sub><sup>-</sup> ions :  
Ag<sup>+</sup> and NO<sub>3</sub><sup>-</sup> ions**

C. In your own words describe why H<sub>2</sub>O molecules are not displayed when the magnifier shows the submicroscopic contents of each beaker.

**There are too many water molecules to depict at the molecular level. If they were shown it would not be possible to see the metal ions or the nitrate ions since there are so few of them compared to the water molecules.**

## II. Data Analysis

Record the number of each species in each beaker. How are these numbers related to the formula of the compound?

**The ratio of the ions in the solution is the same as the ratio of the ions in the formula for each system.**

**Mg(NO<sub>3</sub>)<sub>2</sub> : 1 Mg<sup>2+</sup> ion for every 2 NO<sub>3</sub><sup>-</sup> ions.      Cu(NO<sub>3</sub>)<sub>2</sub> : 1 Cu<sup>2+</sup> ion for every 2 NO<sub>3</sub><sup>-</sup> ions.**

**Zn(NO<sub>3</sub>)<sub>2</sub> : 1 Zn<sup>2+</sup> ion for every 2 NO<sub>3</sub><sup>-</sup> ions.      AgNO<sub>3</sub> : 1 Ag<sup>+</sup> ion for every 1 NO<sub>3</sub><sup>-</sup> ions.**

## III. Interpretation

- A. List three characteristics that are the same for all of these solutions and three characteristics that make them different.

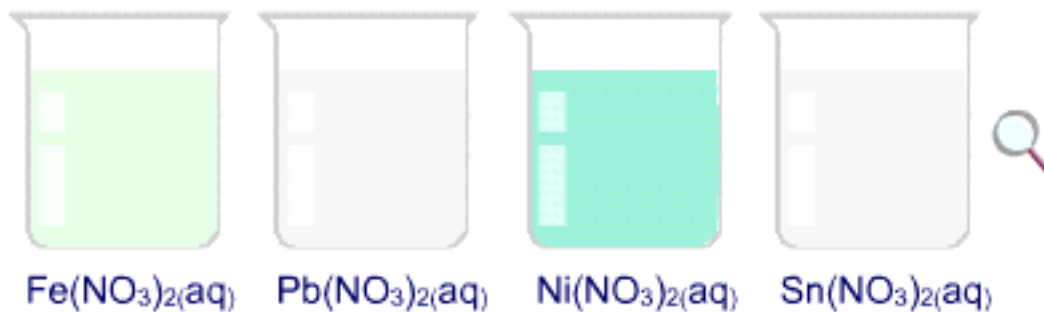
**All four solutions contain metal ions and nitrate anions, the compounds that are dissolved are ionic compounds, all have the same volume of solution.**

**For three of the solution the cation is divalent, while one of the cations is monovalent, one of the solutions has a different color, two of the cations are in the 4<sup>th</sup> period, one from the 3<sup>rd</sup> period and one from the 5<sup>th</sup> period.**

- B. Identify the species that accounts for the color of each of the four solutions. What evidence did you use to arrive at your conclusions?

**Since all of the solutions contain water and the same anion, the color can not be due to the anion. The metal ions are different, so the color must be due to the different cations.**

C. Predict and record in Figure B what you would expect to see with the magnifier in the other beakers.



**Figure B**

**The ratio of the ions in the solution is the same as the ratio of the ions in the formula for each system.**

**$\text{Fe}(\text{NO}_3)_2$  : 1  $\text{Fe}^{2+}$  ion for every 2  $\text{NO}_3^-$  ions.**

**$\text{Pb}(\text{NO}_3)_2$  : 1  $\text{Pb}^{2+}$  ion for every 2  $\text{NO}_3^-$  ions.**

**$\text{Ni}(\text{NO}_3)_2$  : 1  $\text{Ni}^{2+}$  ion for every 2  $\text{NO}_3^-$  ions.**

**$\text{Sn}(\text{NO}_3)_2$  : 1  $\text{Sn}^{2+}$  ion for every 2  $\text{NO}_3^-$  ions.**

IV. Data Collection: Activity One

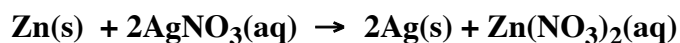
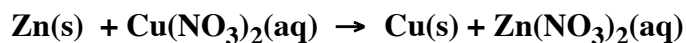
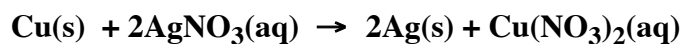
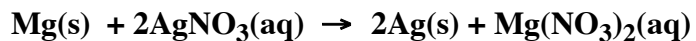
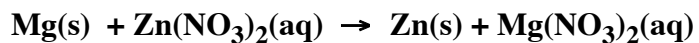
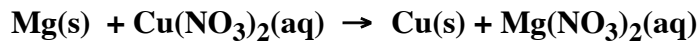
- A. Go to Activity One in the simulation, pick one of the metals and follow the instructions to test its interaction with each of the solutions. Record your observations in Table 1 below. Describe any evidence you see for a chemical reaction. What changes do you see in the metal? What changes do you see in the solutions?
- B. Repeat this process with each of the metals.

	Mg <sup>2+</sup>	Cu <sup>2+</sup>	Zn <sup>2+</sup>	Ag <sup>+</sup>
Mg	No reaction	<b>Solid plates out on the magnesium strip and the intensity of the blue color in the solution is reduced in intensity</b>	<b>Solid plates out on the magnesium strip, no color change in the solution.</b>	<b>Solid plates out on the magnesium strip, no color change in the solution.</b>
Cu	No reaction	No reaction	No reaction	<b>Solid plates out on the copper strip and the solution's color changes from colorless to greenish blue.</b>
Zn	No reaction	<b>Solid plates out on the zinc strip and the intensity of the color in the solution is reduced after the strip is removed</b>	No reaction	<b>Solid plates out on the zinc strip, no color change in the solution.</b>
Ag	No reaction	No reaction	No reaction	No reaction

Table 1

## V. Data Analysis

A. Write a chemical equation for each chemical reaction you observed.



B. Rank the metal ions in order of reactivity using Table 2a below. Rank the metals in reverse order of reactivity using table 2b below. What criteria did you use for your rankings?

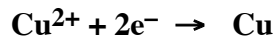
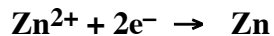
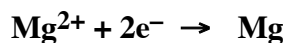
The order was based on the reactivity demonstrated when strips of the metal were immersed in the solutions. Magnesium reacted with three of the solutions, zinc reacted with two, copper with one and silver did not react with any of the solutions.

	Metal Ion Table		Metal Table									
	<table border="1"><tr><td>Ag<sup>+</sup></td></tr><tr><td>Cu<sup>2+</sup></td></tr><tr><td>Zn<sup>2+</sup></td></tr><tr><td>Mg<sup>2+</sup></td></tr></table>	Ag <sup>+</sup>	Cu <sup>2+</sup>	Zn <sup>2+</sup>	Mg <sup>2+</sup>		<table border="1"><tr><td>Ag</td></tr><tr><td>Cu</td></tr><tr><td>Zn</td></tr><tr><td>Mg</td></tr></table>	Ag	Cu	Zn	Mg	
Ag <sup>+</sup>												
Cu <sup>2+</sup>												
Zn <sup>2+</sup>												
Mg <sup>2+</sup>												
Ag												
Cu												
Zn												
Mg												
↑ Most Reactive				↓ Most Reactive								
	<b>Table 2a</b>			<b>Table 2b</b>								

## Interpretation

- A. How are Tables 2a and 2b in the previous section related to each other? Write a balanced equation relating each metal ion to its corresponding metal.

**The reactivity of the metals is exactly opposite the reactivity of the corresponding cation. While solid magnesium was the most reactive metal, its ion,  $\text{Mg}^{2+}$ , was the least reactive.**



- B. Pick one of the metals in Table 2b. Using the reactivity data you collected (Table 1), mark the metal ions in Table 2a that chemically reacted with it. Note the position of these reacting ions in relation with the position of those that don't react. Repeat this process for each of the metals. Summarize your findings concerning the combination of reacting metals and metal ions in Tables 2a and 2b.

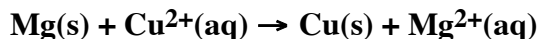
**Any particular metal in Table 2b reacts with the metal ion in Table 2a that is to the left and above itself. For example, Mg metal will react with  $\text{Zn}^{2+}(\text{aq})$ ,  $\text{Cu}^{2+}(\text{aq})$ , and  $\text{Ag}^{+}(\text{aq})$ .**

Summarize your findings concerning the combination of non-reacting metals and metal ions in Tables 2a and 2b.

**Any particular metal in Table 2b will not react with the metal ion in Table 2a that is to the left and below itself. For example, Ag metal will not react with  $\text{Cu}^{2+}(\text{aq})$ ,  $\text{Zn}^{2+}(\text{aq})$ , or  $\text{Mg}^{2+}(\text{aq})$ .**

- C. "Click" on the molecular scale button in the laboratory simulation to view the metal/metal ion interactions at the submicroscopic level. Follow the instructions in the software. Describe your observations of reacting combinations and non-reacting combinations. Write a chemical equation for one of the reacting combinations. Relate your submicroscopic observation with your macroscopic observations for one example of a reacting and one example of a non-reacting combination.

**For a reacting combination such as  $\text{Mg}(\text{s})$  and  $\text{Cu}^{2+}(\text{aq})$  the molecular level animation showed the  $\text{Cu}^{2+}(\text{aq})$  ions approaching the Mg strip. When the ions were almost in contact with the metal strip electron appeared in the metal moving towards the  $\text{Cu}^{2+}(\text{aq})$  ions. The  $\text{Cu}^{2+}(\text{aq})$  ions gained the electrons and formed  $\text{Cu}(\text{s})$ , while the  $\text{Mg}(\text{s})$  lost the electrons forming  $\text{Mg}^{2+}(\text{aq})$  ions.**



**At the macroscopic level for the above reaction we saw a brownish-red material that must be  $\text{Cu}(\text{s})$  plated on the magnesium strip. Since copper metal had plated out**

there were fewer  $\text{Cu}^{2+}(\text{aq})$  in solution and the intensity of the solution's color decreased.

In the nonreacting combination such as  $\text{Cu}(\text{s})$  and  $\text{Zn}^{2+}(\text{aq})$  the zinc ions approached the copper strip but no reaction occurred. At the macroscopic level nothing plated out on the copper strip immersed in the  $\text{Zn}^{2+}(\text{aq})$  solution, nor was there any color change in the solution.

VII. Data Collection: Activity Two

Go to Activity Two and repeat what you did in sections IV, V, and VI with a new set of metal/metal ions.

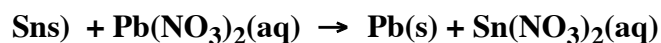
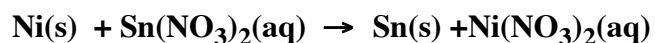
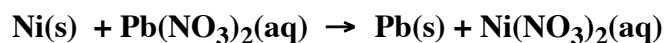
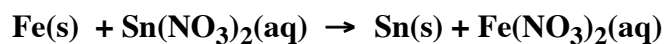
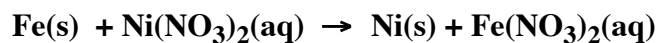
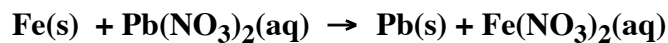
	$\text{Fe}^{2+}$	$\text{Pb}^{2+}$	$\text{Ni}^{2+}$	$\text{Sn}^{2+}$
Fe	No reaction	Solid plates out on the iron strip and the color in the solution changes from colorless to a greenish color.	Solid plates out on the iron strip and the color in the solution changes slightly, although it is difficult to tell.	Solid plates out on the iron strip and the color in the solution changes from colorless to a greenish color.
Pb	No reaction	No reaction	No reaction	No reaction
Ni	No reaction	Solid plates out on the nickel strip and the color in the solution changes from colorless to a greenish color.	No reaction	Solid plates out on the nickel strip and the color in the solution changes from colorless to a greenish color.
Sn	No reaction	Solid plates out on the tin strip	No reaction	No reaction

Table 3

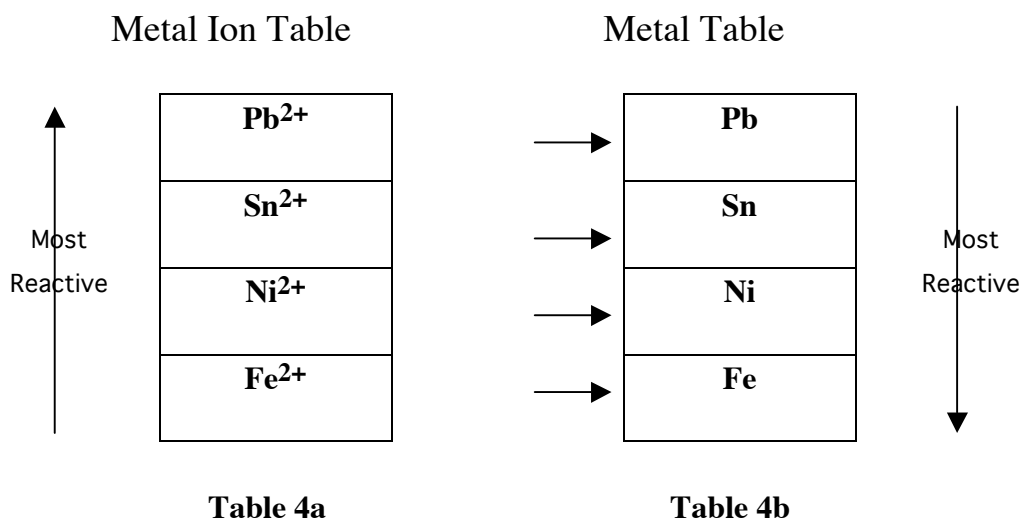


### VIII. Data Analysis and Interpretation

D. Write chemical equations for the chemical reactions you observed.



E. Rank the metal ions and metals as you did in section V.B. Write balanced equations relating the metal ion/metal combinations.



IX. Data Collection: Activity Three

A. Go to Activity Three and repeat what you did in sections IV, V, and VI with a combination of metal/metal ions taken from Activities One and Two.

	$Zn^{2+}$	$Cu^{2+}$	$Fe^{2+}$	$Pb^{2+}$
Zn	No reaction	Solid plates out on the zinc strip and the intensity of the blue color in the solution is reduced.	Solid plates out on the zinc strip and the intensity of the greenish color in the solution is reduced.	Solid plates out on the zinc strip, no color change in the solution.
Cu	No reaction	No reaction	No reaction	No reaction
Fe	No reaction	Solid plates out on the zinc strip and the blue color in the solution is reduced in intensity	No reaction	Solid plates out on the zinc strip and the solution's color changes from colorless to a greenish color
Pb	No reaction	Solid plates out on the zinc strip and the intensity of the blue color in the solution is reduced.	No reaction	No reaction

Table 5

## X. Data Analysis and Conclusions

Use the data you collected in Activities One, Two, and Three (Tables 1,3 and 5) to rank the eight metal ion and metals you have studied. Write balanced equations relating the metal/metal ion combinations.

Metal Ion Table		Metal Table	
↑ Most Reactive	Ag <sup>+</sup>	→	Ag
	Cu <sup>2+</sup>	→	Cu
	Pb <sup>2+</sup>	→	Pb
	Sn <sup>2+</sup>	→	Sn
	Ni <sup>2+</sup>	→	Ni
	Fe <sup>2+</sup>	→	Fe
	Zn <sup>2+</sup>	→	Zn
	Mg <sup>2+</sup>	→	Mg

**Table 6a**                      **Table 6b**

↓  
Most  
Reactive

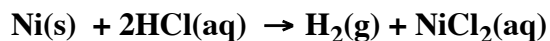
## XI. Data Collection – Activity Four

Go to Activity Four and follow the directions. Record your observation concerning the reaction of the five metals with HCl.

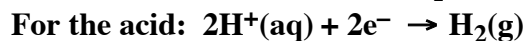
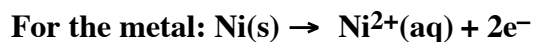
**Ni(s), Sn(s) and Pb(s) all react with the HCl, but Cu(s) and Ag(s) do not. Reaction was evident from the formation of bubbles of a gas. Neither Cu(s) or Ag(s) produced in bubbles of gas.**

## XII. Data Analysis

- A. Write a chemical equation for the reaction between one of the metals and HCl.



- B. Observe the reaction at the molecular scale. Write an equation for what is happening to the metal and a separate equation for what is happening to the acid. How are these equations related to each other and to the chemical equation you wrote in section XII.A.



**Adding the two equations together produces the overall equation in X11A. The electrons produced from the Ni(s) are picked up by the H<sup>+</sup> ions to form H<sub>2</sub>(g).**

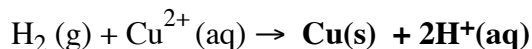
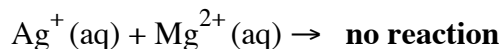
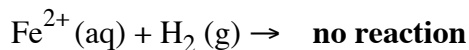
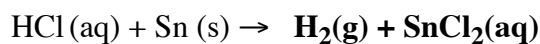
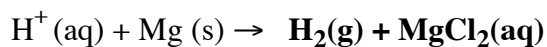
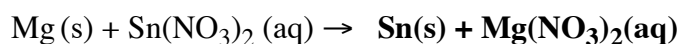
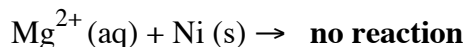
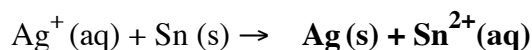
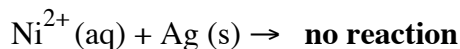
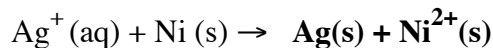
## XIII. Interpretation and Conclusions

- A. Add the hydrogen gas /hydrogen ion combination in the correct location in the tables from section X.

	Metal Ion Table		Metal Table	
	Ag <sup>+</sup>	→	Ag	
	Cu <sup>2+</sup>	→	Cu	
↑ Most Reactive	H <sup>+</sup>		H <sub>2</sub>	
	Pb <sup>2+</sup>	→	Pb	
	Sn <sup>2+</sup>	→	Sn	
	Ni <sup>2+</sup>	→	Ni	
	Fe <sup>2+</sup>	→	Fe	
	Zn <sup>2+</sup>	→	Zn	
	Mg <sup>2+</sup>	→	Mg	↓ Most Reactive

**Table 7a**                      **Table 7b**

B. Use the information in Tables 7a and 7b to predict the products of the following reactions.



F. Mental Model: Draw a picture(s) that illustrates what happens at the molecular level when  $\text{Ag}^+$  ion and Sn metal are mixed. In words explain what is happening in your picture(s).

G. An unknown metal, M, is found to react with  $\text{Ag}^+$  ion,  $\text{Pb}^{2+}$  ion and  $\text{Cu}^{2+}$  ion, but not with  $\text{Ni}^{2+}$  ion,  $\text{Mg}^{2+}$  ion or  $\text{Zn}^{2+}$  ion. Where does the unknown metal, M, appear in your activity series?

**The unknown metal has to appear between Pb(s) and Ni(s). There is not enough information to determine if the unknown metal is more reactive than Sn or less reactive.**