

EXPERIMENT 8: Activity Series (Single Displacement Reactions)

PURPOSE

- Reactions of metals with acids and salt solutions
- Determine the activity of metals
- Write a balanced molecular equation, complete ionic equation, and net ionic equation for single replacement reaction.

Materials:

Equipment: 2 well-plates (Spot plates) or small test tubes

Stirring rod or toothpicks

Chemicals and solutions : a tray containing the metals Mg, Pb, Cu, Zn, Fe, 1.0 M HCl and 0.25 M nitrate salt solutions of each of these metals such as;



Note - Before you begin this lab, you should be familiar with types of reactions found in chapter 4 of the text. Wear appropriate clothing, shoes and safety glasses for this lab.



Stirring rod



Spot plate

INTRODUCTION

One of the most important characteristics of a metal is its activity (reactivity). The activity of a metal is its ability to react with nonmetals. In such reaction a metal typically loses electrons to the nonmetal to form cations and the product is an ionic compound.

Different metals have different activities. Some metals are very active such as lithium, sodium, potassium, and cesium; some are slowly active such as tin, lead, and iron; and some are not active at all (inactive) such as copper, silver, and mercury. Inactive metals are those which resist oxidation (reaction with oxygen in air). These are often called the noble metals.

An activity series is the ranking of metals according to their reactivity. In an activity series metals are arranged in order of decreasing ability to lose electrons. Generally, the more reactive metals are placed at the top of the list. Any metal above hydrogen will displace hydrogen gas, H₂ (g), from an acid, and any metal below hydrogen will not displace hydrogen from an acid.

For example:

Active metals (above H); $\text{Zn}_{(s)} + 2\text{HCl}_{(aq)} \rightarrow \text{ZnCl}_{2(aq)} + \text{H}_{2(g)}$

Inactive metals (below H); $\text{Cu}_{(s)} + \text{HCl}_{(aq)} \rightarrow \text{no reaction (NR)}$

In performing this experiment, you will observe and compare the reaction of some common metals with acids and salt solutions and establish an order of reactivity, from most active to least active.

This activity list is called ‘**activity series**’

Li
K
Ba
Ca
Na
Mg
Al
Mn
Zn
Cr
Fe
Co
Ni
Sn
Pb
H
Cu
Ag
Hg
Pt
Au



Activity Series

I. Reactivity of metals with HCl

Very active metals will react with strong acids such as hydrochloric acid. An example considers magnesium:

Molecular equation: $\text{Mg}_{(s)} + 2\text{HCl}_{(aq)} \rightarrow \text{MgCl}_{2(aq)} + \text{H}_{2(g)}$

Ionic equation: $\text{Mg}_{(s)} + 2\text{H}^{+}_{(aq)} + 2\text{Cl}^{-}_{(aq)} \rightarrow \text{Mg}^{2+}_{(aq)} + 2\text{Cl}^{-}_{(aq)} + \text{H}_{2(g)}$

Net-ionic equation: $\text{Mg}_{(s)} + 2\text{H}^{+}_{(aq)} \rightarrow \text{Mg}^{2+}_{(aq)} + \text{H}_{2(g)}$

Somewhat **less reactive metals** will slowly react with a strong acid such as hydrochloric acid. An example considers aluminum:

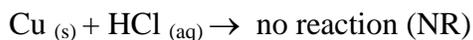
Molecular equation: $2\text{Al}_{(s)} + 6\text{HCl}_{(aq)} \rightarrow 2\text{AlCl}_{3(aq)} + 3\text{H}_{2(g)}$

Ionic equation: $2\text{Al}_{(s)} + 6\text{H}^{+}_{(aq)} + 6\text{Cl}^{-}_{(aq)} \rightarrow 2\text{Al}^{3+}_{(aq)} + 3\text{Cl}^{-}_{(aq)} + 3\text{H}_{2(g)}$

Net-ionic equation: $2\text{Al}_{(s)} + 6\text{H}^{+}_{(aq)} \rightarrow 2\text{Al}^{3+}_{(aq)} + 3\text{H}_{2(g)}$

In the previous cases the hydrogen is displaced as hydrogen gas from the acid.

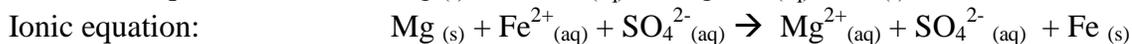
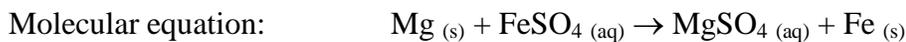
Metals of low activity such as Cu do not react with hydrochloric acid.



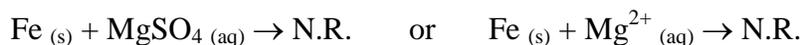
Note: Very active metals react vigorously and even explosively in acid. Thus Li, K, and Na should not be tested with hydrochloric acid.

II. Reactivity of metal with aqueous salt solution

The reaction of a metal with a solution of salts of another metal is also revealing. The relative activities of the less active metals can be determined by observing reactions in which a more reactive metal (higher activity), such as magnesium, Mg, displaces ions of a less reactive metal, such as iron sulfate, FeSO₄, as a typical metallic salt or aqueous solutions.



In this example, magnesium is said to be **more active** than iron because in the activity series magnesium is higher than iron. The reverse of the reaction will not occur because Fe is **less reactive** and cannot displace ions of a more reactive metal, such as magnesium sulfate, MgSO₄, as aqueous solution.



In this experiment, you will examine relative activities of common metals and compare your initial and final observations of the metals and the solutions. Based on these observations, you will determine whether or not a reaction has occurred, and, if so, with what intensity, slowly or rapidly. Using these results, you will arrange the metals in decreasing or increasing order of reactivity.

PROCEDURE:

Part A. Appearance of Metals and Reaction of Each with 1.0 M HCl.

Write a brief description of each metal on **Date Sheet 1**.

Place a small piece of each metal, such as Mg, Pb, Cu, Zn, and Fe, in each of the holes in a clean spot test plate and add 5 to 10 drops of 6M HCl. Watch for evidence of the reaction by noting evolution of gas bubbles (Hydrogen gas) and any changes in the color or size of the metal. Record your observations in Data Sheet 2. Based on these observations, you will determine whether or not a reaction has occurred, and, if so, with what intensity, slowly or rapidly. Write balanced equations for all occurred reactions.

Part B. Reaction of Metals with Metal Ion Solutions.

Place a small piece of each metal, such as Mg, Pb, Cu, Zn, and Fe in each of the holes in a clean spot test plate and add 5 to 10 drops 0.25M aqueous solution of Mg(NO₃)₂, Pb(NO₃)₂, Cu(NO₃)₂, Zn(NO₃)₂, and Fe(NO₃)₃. Watch for evidence of the reaction by noting changes in the color or size of the metal. Record your observations in Data Sheet 3. Based on these observations, you will determine whether or not a reaction has occurred, and, if so, with what intensity, slowly or rapidly. Write balanced equations for all occurred reactions.

Because a solution of many metal ions is colorless, often we must examine the reaction of a mixture carefully to establish whether or not a reaction has occurred. Changes in the appearance of the metal, a solution-color change, or the formation of precipitate all indicate that a reaction of this type has occurred. Sometimes, because metallic salt solutions are acidic, hydrogen gas, H₂, is produced when the metal is added. In such cases, the formation of hydrogen gas does not indicate a reaction between the metal and the salt solution. The fact that a metal does or does not react with a solution of another metallic salt can be used to establish the comparative reactivities of several metals.

NOTE-YOU MAY OMIT PUTTING METAL INTO ITS OWN SALT SOLUTION, SEE DATA SHEET 3.

EXPERIMENT 8 – Activity Series (Single Displacement Reactions)

REPORT FORM

Name _____

Instructor _____

Date _____

DATA SHEET 1

METAL/SOLUTION	APPEARANCE (Metal: silver, gray,...) (Solution: color, blue, colorless)
Magnesium metal, Mg	
Lead metal, Pb	
Copper metal, Cu	
Zinc metal, Zn	
Iron metal, Fe	
Magnesium nitrate solution	
Lead(II) nitrate solution	
Copper(II) nitrate solution	
Zinc nitrate solution	
Iron(II) nitrate solution	

DATA SHEET 2

Metal	Reaction with HCl Initially	Reaction with HCl After 20 minutes	Balanced Molecular Equation**
Mg			
Pb			
Cu			
Zn			
Fe			
Al	Yes Slow Reaction	Yes Completely Reacted	$2\text{Al} + 6\text{HCl} \rightarrow 2\text{AlCl}_3 + 3\text{H}_2$

****Bubbles must appear for there is be displacement of the hydrogen as gas.**

DATA SHEET 3

Metal	Mg(NO ₃) ₂	Pb(NO ₃) ₂	Cu(NO ₃) ₂	Zn(NO ₃) ₂	Fe(NO ₃) ₂	Al(NO ₃) ₃
Mg	X					Yes Mg dissolves
Pb		X				N.R.
Cu			X			N.R.
Zn				X		N.R.
Fe					X	N.R.

***INCLUDE INITIAL OBSERVATIONS AFTER 20 MINUTES. RECORD IF ANY GAS IS PRODUCED, IF THERE ARE ANY COLOR CHANGES OF METAL OR SOLUTION.**

EXPERIMENT 8: Activity Series (Single Displacement Reactions)

Name: _____

Pre-laboratory Questions and Exercises

Due before lab begins. Answer in separate sheet of paper.

- List the three metals, Mg, Pb, Cu, Zn, and Fe in order of increasing activity (least to highest).
- Define the following terms; a) oxidation b) reduction
- Which is more active (a) iron or copper, (b) iron or silver, (c) silver or copper? Arrange the three metals in order of decreasing activity.
- Complete and balance the following reactions (if no reaction, write NR):
(a) $\text{Cr (III)} + \text{HCl} \rightarrow$ (b) $\text{Fe (II)} + \text{HCl} \rightarrow$
(c) $\text{Fe (III)} + \text{Zn(NO}_3)_2 \rightarrow$ (d) $\text{Zn} + \text{H}_2\text{SO}_4 \text{ (dilute)} \rightarrow$
- Write an equation for the reaction if one occurs.
(a) Iron (III) with CuSO_4 solution
(b) Copper (I) with FeSO_4 solution
(c) Tin (IV) with $\text{Cu (NO}_3)_2$ solution
- Complete and balance the following reactions:
a. $\text{Zn} + \text{Cu}^{2+} \rightarrow$ (b) $\text{Fe} + \text{H}^+ \rightarrow$ (c) $\text{Ca} + \text{Mg}^{2+} \rightarrow$ (d) $\text{Na} + \text{Ca}^{2+} \rightarrow$
- Why is Cu^{2+} more active than Cu^+ ?
- For each of the following reactions, identify:
a. oxidized species b. reduced species c. oxidizing agent d. reducing agent
I) $2 \text{Fe}_{(s)} + 3 \text{Cl}_{2(g)} \rightarrow 2 \text{FeCl}_{3(s)}$
II) $\text{Mg}_{(s)} + 2 \text{H}_2\text{SO}_{4(aq)} \rightarrow \text{MgSO}_{4(aq)} + \text{SO}_{2(g)} + 2 \text{H}_2\text{O}_{(l)}$
III) $2 \text{Mg}_{(s)} + \text{O}_{2(g)} \rightarrow 2 \text{MgO}_{(s)}$

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Post-Laboratory Questions and Exercises

Due after completing the lab. Answer in the space provided.

1. Rank Sn, Cu, H, Zn, Cu, Fe, Mg, Ag, Pb, and Na according to their activity.



2. Define the following terms and give an example of each.

a) Cation -

b) Anion -

3. Complete and balance the following reactions (if no reaction, write NR): 7

a) $\text{Co(II)} + \text{HCl} \rightarrow$

b) $\text{Hg} + \text{HCl} \rightarrow$

c) $\text{Zn} + \text{Ni}(\text{NO}_3)_3 \rightarrow$

d) $\text{Cu} + \text{H}_2\text{SO}_4$ (concentrated) \rightarrow

4. What observations will you look for to determine if a metal undergoes reaction?

5. What cautions and/or hazardous techniques must you observe in this experiment?

Complete the following equations and balance. If no reaction occurred, mark it as NR for no reaction. All salts are in aqueous solution and all metals are +2 in the salts.

