Reactivity of Metals with HCl: Creating an Experimental Activity Series

Introduction

Metals do not have the same reactivity towards the same reagents. Indeed, a whole series, called the activity series, of metals has been assembled in tabular form in the order of most reactive metal to least reactive metal. This table is based upon the reactivity of metals with different reagents. Additionally, **in theory, metals higher up in the table ought to reduce metal ions below that metallic element (e.g., $Zn + Cu^{2+} \rightarrow Zn^{2+} + Cu$).** There are 5 different levels of reduction reactivity of metals with different reagents. These activities are summarized in the activity series, below (note: "M" represents the metallic element in the table, below):

Abbreviated Activity Series [1]						
Reduction Potential	Relative degree of metallic activity	Element	Kind of Reactivity			
Most negative -- worst oxidizer -- best reducing agent	Most metallic -- most active	K	M + cold water $\rightarrow H_2$	M + steam $\rightarrow H_2$	M + H+ $\rightarrow H_2$	M + $O_2 \rightarrow$ Direct Oxide
		Na				
		Mg				
		Zn				
		Fe				
		Ni				
		Pb				
		H				
		Cu				
		Ag				M + Rx$\rightarrow$ Indirect oxide
		Pt				
Most positive -- best oxidizer -- worst reducing agent	Least metallic -- least reactive	Au				

"Rx" = reagent, BTW.

The reactions typifying acid reactivity with metals are of a general type ("HA" and variations thereof simply indicate an acid):

$$M + HA \rightarrow MA + H_2$$

$$M + HA_2 \rightarrow MA_2 + H_2$$

$$M + HA_3 \rightarrow MA_3 + H_2$$

These reactions are obviously not balanced. The rate of hydrogen generation depends upon the reactivity of the metal, i.e., metals higher up the activity series generates more hydrogen and faster than metals lower down the activity series.

The purpose of this experiment is threefold:

1) To set up your own experimentally determined activity series,

2) Determine if a metal that is above another metal [ion] in the activity series will reduce the lower metal ion while the higher metal is oxidized, and

3) to "hone" your skills of observation in preparation for performing an introduction to qualitative analysis, i.e., to observe subtle changes for identification purposes, e.g., you may have to look at a change in color of a piece of nichrome wire, you may have to observe bubbles emanating from lead shot, etc.

<u>Experimental</u>

Supplies

Obtain the following:

Mg ribbon (about 1 cm)	Mossy Zn -- 2-3 pieces	Chromel wire (small pieces)
Staples (Fe -- 2 each-- 1 for each part of the experiment)	Al wire -- about 0.5 cm	Pb shot (about 3 pcs)
Sn foil -- same size as Mg	Cu wire -- about a cm	Disposable pipets
Disposable test tubes -- 8 each	Test tube rack	Concentrated HCl
Scissors		

<u>Part 1 -- Activity series</u>

Set up 8 test tubes in your test tube rack. Label each tube (in pencil on the label side) with the element you are going to add to it. Put about 1 mL (20 gtts) concentrated HCl in each tube. One at a time, add the small pieces of metals to the appropriate tube and observe the reaction (if there is any) and the rate of hydrogen production. Let the tubes stand for 20 minutes and observe, again. Record your observations in the table below. Give a 4+ score for the metal that had the greratest reaction and a 0+ for the metal that had the lowest reaction. The other reactions will subjectively fit in between 0+ and 4+ for reactivity. Add this information to your table, below, as well. For clarification purposes, examine the sample data table, below, before you enter your data in the real data table coming up:

Sample Activity Series Record Table		
Metal	Zn	Cu
Observations immediately	Rapid bubbling; exothermic	No reaction (NR)
Observations after 20 minutes	No reaction	No reaction
Reactivity	4+	0+
Order of reactivity	1	2

Below is your data table split in two:

Activity Series Record Table -- Part 1				
Metal	Mg	Zn	Cu	NiCr
Observations immediately				
Observations after 20 minutes				
Reactivity				
Order of reactivity				

Activity Series Record Table -- Part 2				
Metal	Pb	Fe	Sn	Al
Observations immediately				
Observations after 20 minutes				
Reactivity				
Order of reactivity				

Based upon your results, construct a table of the metals in an activity series, most reactive on the left, least reactive on the right in the table, below:

Part 2 -- Redox Capability

To the tubes from Part 1 (the original 8 tubes, above) add elemental metals (use the same dimensions as before) as shown in the table, below. Proceed as before, i.e., one at a time, and note your observations -- you do NOT have to add more HCl, so do not.

Activity Series Record Table -- Part 1				
Metal	Mg	Zn	Cu	NiCr
Add	NOTHING-	Mg ribbon	Sn foil	Al wire
Observations before reaction	NONE			
Observations immediately	NONE			
Observations after 20 minutes	NONE			
M^+ reduced?	NO!!!			

Activity Series Record Table -- Part 1				
Metal	Pb	Fe	Sn	Al
Add	Cu wire	Mossy Zn	Mg ribbon	1 Staple
Observations before reaction				
Observations immediately				
Observations after 20 minutes				
M^+ reduced?				

NOTE: "M^+ reduced?" means was there bubbling? If so, put a "Y" for yes in the box; if there was no bubbling, put an "N" for no in the box.

Questions

Complete the questions on a separate piece of paper and attach it to this experiment for turn-in.

1) Based upon your observations, does the metal above the metal ion reduce the metal ion? How do you know this?

2) Given the following series of “ reactions”, create an activity series beginning with the most reactive and ending with the least reactive "element" -- NOTE: these are NOT real elements -- this is a concept question. Remember that elements higher in the series will reduce the ion lower in the series.

$$C + H^+ \rightarrow C^+ + H^\circ$$

$$C + E^+ \rightarrow C^+ + E^\circ$$

$$C + I^+ \rightarrow C^+ + I^\circ$$

$$C + T^+ \rightarrow C^+ + T^\circ$$

$$C + Y^+ \rightarrow C^+ + Y^\circ$$

$$H + E^+ \rightarrow H^+ + E^\circ$$

$$I + S^+ \rightarrow I^+ + S^\circ$$

$$M + I^+ \rightarrow M^+ + I^\circ$$

$$M + S^+ \rightarrow M^+ + S^\circ$$

$$E + M^+ \rightarrow E^+ + M^\circ$$

$$T + R^+ \rightarrow T^+ + R^\circ$$

$$S + T^+ \rightarrow S^+ + T^\circ$$

$$Y + R^+ \rightarrow NR$$

$$Y + I^+ \rightarrow NR$$

$$Y + C^+ \rightarrow NR$$

<u>Source</u>

[1]. Holtzclaw, HF, Robinson, WR and Odom, JD: **General Chemistry with Qualitative Analysis, 9th Edition** (DC Heath and Co.: Lexington) © 1991, p. 381.

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