**Activity Series**

**Purpose:** To become familiar with the relative activities of metals in chemical reactions.

**Materials:**

6 large test tubes

2 well plates

6 M HCl

0.2 M Ca(NO3)2

0.2 M Mg(NO3)2

0.2 M Zn(NO3)2

0.2 M Fe(NO3)3

0.2 M FeSO4

0.2 M Cu(NO3)2

0.2 M SnCl4

small pieces of calcium, magnesium, zinc, iron, tin and copper

Chemical elements are usually classified by their properties into three groups: metals, nonmetals, and metalloids. Most of the known elements are metals. Their physical properties include high thermal and electrical conductivity, high luster, malleability (ability to be pounded flat without shattering), and ductility (ability to be drawn out into a fine wire). All com­mon metals are solids at room temperature except mercury, which is a liq­uid. The periodic table shows the three classifica­tions of the elements.

All elements to the left of the lightly shaded area are metals except hydrogen; those to the right are nonmetals; and those in the lightly shaded area have interme­diate properties and are called semimetals or metalloids. Families or groups of elements consist of elements in vertical columns in the periodic table. Ele­ments within a group or family (called congeners) have similar chemical properties because they have similar valence electronic structures; that is, the number of valence electrons (electrons in the outermost shell) is the same for all members of a family or group. For historical reasons, most of the groups have names, and some are often referred to by them. These are

1. Group 1, called *alkali metals* because they react with oxygen to form bases;
2. Group 2, called *alkaline earth metals* because their presence makes soils alkaline;
3. Group 3, no common name;
4. Group 4, no common name;
5. Group 5, called *pnictides,* from the Greek word meaning choking suffo­cation;
6. Group 6, called *chalcogens,* from Greek roots meaning ore former;
7. Group 7, called *halogens,* from Greek roots meaning salt former;
8. Group 8, called *rare, noble,* or *inert gases* because they are rare and were thought to be unreactive.



Those most frequently referred to by group name are the alkali metals, the alkaline earth metals, the halogens, and the rare gases.

The three broad categories of the elements also have somewhat similar chemical properties. For example, metals, as compared with the other ele­ments, all have relatively low ionization potentials and enter into chemical combination with nonmetals by *losing* electrons to become cations.

This can be symbolized by the following equation: M → M*n+ + ne-*

Nonmetals, as compared with metals, have relatively high electron affinities and enter into chemical combination with metals by *gaining* electrons to become anions.

This can be symbolized by the following equation: X + *ne-* → X*n-*

Specific examples of these types of reactions can be divided into several use­ful categories, which will be illustrated by the following examples.

**Electron-Transfer Reactions**

**1 REACTIONS WITH OXYGEN (or other nonmetals)**

2Mg(*s*) + O2(*g*) →2MgO(*s*) *(synthesis redox reaction)*

In this reaction magnesium has been oxidized by oxygen which, in turn, has been reduced by magnesium. This can be better illustrated by breaking down the reaction into fictitious although helpful steps:

2(Mg → Mg+2 + 2e-) oxidation *(Mg acts as a reducing agent because it reduces the O2)*

O2 + 4e- → 2O2- reduction *(O2 acts as an oxidizing agent because it oxidizes the Mg)*

2Mg + O2 → 2MgO oxidation-reduction (redox) reaction

In *oxidation,* the oxidized element loses electrons and becomes more positive. In *reduction,* the reduced element gains electrons and becomes more nega­tive. Oxidation is always associated with a concomitant (accompanying) reduction.

**2 REACTIONS WITH WATER.**

2Na(*s*) + 2H2O(*l*) → 2NaOH(*aq*)+ H2(*g*) *(single replacement redox)*

Ca(*s*) + 2H2O(*l*) → Ca(OH)2(*aq*) + H2(*g*)

The *net ionic* equations for these reactions better illustrate the electron-transfer process:

2Na(*s*) + 2H2O(*l*) → 2Na+(*aq*)+ 2OH-(*aq*)+ H2(*g*)

Ca(*s*) + 2H2O(*l*) → Ca2+(*aq*)+ 2OH-(*aq*) + H2(*g*)

*Note: Only very reactive metals react with water to produce hydrogen gas.*

**3 REACTIONS WITH ACIDS.**

Zn(*s*) + 2HCl(*aq*)→ ZnCl2(*aq*)+ H2(*g*)  *(single replacement redox)*

*or*

Zn(*s*) + 2H+(*aq*) + 2Cl-(*aq*) → Zn2+(*aq*)+ 2Cl-(*aq*)+ H2(*g*)

Since the chloride ion is merely a spectator, that is, it does not participate in the reaction, it may be omitted, yielding the *net ionic equation:*

Zn(s) + 2H+(*aq*) → Zn2+(*aq*) + H2(*g*)

or simply Zn + 2H+ → Zn2+ + H2 *Note: only certain metals react with acids*

**4 ELECTRON TRANSFER AMONG METALS.**

Zn(s) + Cu(NO3)2(*aq*) → Zn(NO3)2(*aq*)+ Cu(s) *(single replacement redox)*

*or*

Zn(s) + Cu2+(*aq*)→ Zn2+(*aq*) + Cu(s) Zn is oxidized (reduces Cu2+) so it is the reducing agent

Cu2+ is reduced (oxidizes the Zn) so it is the oxidizing agent

or simply *reducing agents lose electrons oxidizing agents gain electrons*

Zn + Cu2+ → Zn2+ + Cu *The term reduction came from the idea that ore(rock) containing minerals was “reduced” to produce pure metals from the ore.*

Note once again that in the ionic equation the spectator ion (NO3-) has been omitted because it takes no active part in the reaction and serves only to pro­vide electrical neutrality. Therefore, any other soluble salt of copper (II), such as chloride, sulfate, or acetate, could perform the same function.

In this game of "musical electrons," there are only enough electrons for one atom of the system. In order to achieve the lowest energy level for the system, the more active metal of a pair will lose electrons to the more pas­sive metal or react more vigorously with water, acids, or oxygen. In some cases no reaction will occur at all. Without prior knowledge we have no way of predicting these events.

**Procedure**

**A. Reactions of Metals with Acid**

Place a ***small*** amount (enough so you can observe a reaction) of each metal Ca, Cu, Fe, Mg, Sn, and Zn into 6 different LARGE test tubes. Also prepare a 7th tube with Al in it. (Al is included in the next part of the procedure.) ***Slowly*** add 6 M HCl to each tube *drop by drop*. If a reaction immediately occurs only add about 5-6 drops. If no immediate reaction is visible, add enough drops to cover the piece of metal and allow the test tube to sit for several minutes. Some reactions are very slow and not easily noticed. Observe each test tube and note any changes that occur (such as the evolution of a gas, whether it is vigorous or not, color changes, speed of reaction, temperature changes). Enter your observations on the report sheet and write both complete and ionic equations for each reaction noted. Dispose of the contents of the test tubes into the waste container and clean the test tubes.

**B. Reactions of Metals with Solutions of Metal Ions**

Place 2 well plates side by side to form an 8 (across) by 6 (down) grid. Use the data table as a guide. Place a ***small*** amount of each metal sample in each corresponding ***row***. ***NOTE: It is not necessary to put samples in the shaded areas marked in the table (think why!)***  Next add enough drops of the Ca(NO3)2 solution cover each metal sample in the first ***column***. Note any reaction that occurs by observing whether a color change occurs on the sur­face of the metal or in the solution or whether a gas is evolved, as well as temperature changes (steam?). Some reactions may take much longer than others. If no reaction occurs in a particular well, write NR in the data table. Record your observations in the data table.

Repeat the process above for each of the other metal-cation solutions. Allow the well plate to sit for at least another 15-20 minutes and check for any changes. Note: The observations for Al are already filled in – the reactions for Al are very slow and are difficult to observe. The surface of Al oxidizes and produces a “protective” layer which prevents further oxidation.

**Relative-Activity Series**

From the information contained in the table you constructed in Part B, you can rank these five metals according to their relative chemical reactivities. (Count the number of reactions and note the speed of reaction that occurs for each metal.) List the metals (including Al) on your report sheet in terms of decreasing reactivity starting with the most reactive (1) and terminating with the least reactive (7).

**Reactions**

**A.** Write molecular, complete ionic and net ionic reactions for the metals marked with an asterisk in the data table.

**B.** Write molecular, complete ionic and net ionic reactions for the metals marked with an asterisk in the data table.