Table J — Activity Series

Overview:

You have probably noticed that if iron is not painted or coated, it starts to rust in days, especially if moisture is present. But silver, and especially gold, seem to be unaffected by substances in the environment and keep their brilliant luster. The reason for this is that different metals exhibit different chemical activity. In other words, some metals are very reactive, while other metals are less reactive. By studying the chemical activities of elements (metals and nonmetals), chemists have been able to arrange them based upon chemical reactivity.

The Table:

This table shows the relative chemical activity of metals and nonmetals, both arranged in order of decreasing chemical activity. Although H_2 is not a metal, it is listed on the metallic side because the table is based on the hydrogen standard.

In a chemical reaction, a more active metal (higher up on Table J) will replace a less active metal when placed in an aqueous solution containing the ion of the less active metal. For example, lithium (Li), being the most active metal, will replace any metallic ion found below it from a solution of its salt. Rubidium (Rb) will replace any metal found below it from a solution of its salt, but because it is under Li, indicating that it is less active than Li, it will not replace Li from a solution of its salt.

Metals found above H_2 are more active than hydrogen. Therefore, it will replace the H^+ in an aqueous acidic solution, producing hydrogen gas and a solution of a salt containing that metal. Those metals below H_2 will not react with acids in this fashion.

Most Active	Metals	Nonmetals	Most Active
	Li	F_2	
	Rb	Cl_2	
	K	Br_2	
	Cs	I_2	
	Ba		
	Sr		
	Ca		
	Na		
	Mg		
	Al		
	Ti		
	Mn		
	Zn		
	Cr		
	Fe		
	Co		
	Ni		
	Sn		
	Pb		
	H_2		
	Cu		
	Ag		
Least Active	Au		Least Active

**Activity Series is based on the hydrogen standard. H_2 is *not* a metal.

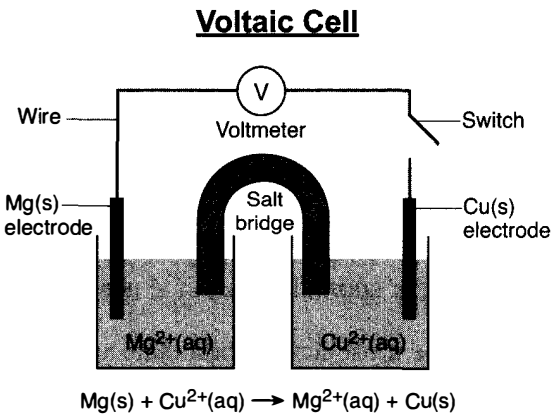
For example: $Mg + 2HCl \rightarrow MgCl_2 + H_2\uparrow$ reacted, because Mg is more active (being above H_2) than H_2, as shown on Table J.

$Ag + HCl \rightarrow$ no reaction, because Ag is less active (being lower than H_2) than H_2, as shown on Table J.

In a similar fashion, in a chemical reaction, a nonmetal will replace a less active nonmetal when interacting with a solution containing the ion of the less active nonmetal. For example, fluorine (F_2) will replace Cl^-, Br^- and I^- in solutions containing those ions, but chlorine (Cl_2) cannot replace F^- from a solution containing the F^- ion; however, chlorine will replace Br^- and I^- in solutions containing these ions.

Voltaic Cell:

An electrochemical or voltaic cell uses a spontaneous redox reaction to produce an electric current. It consists of two different metals, called electrodes, immersed in a solution of that metals salt, called an electrolyte. The electrodes are connected by a wire conductor. The electrolytes are connected by a salt bridge. The more active metal, higher up on Table J, undergoes oxidation and is called the anode (the negative electrode). The electrons flow through the wire to the less active metal, lower down on Table J, where they reduce that metals ions in the electrolyte. This electrode is called the cathode (the positive electrode).



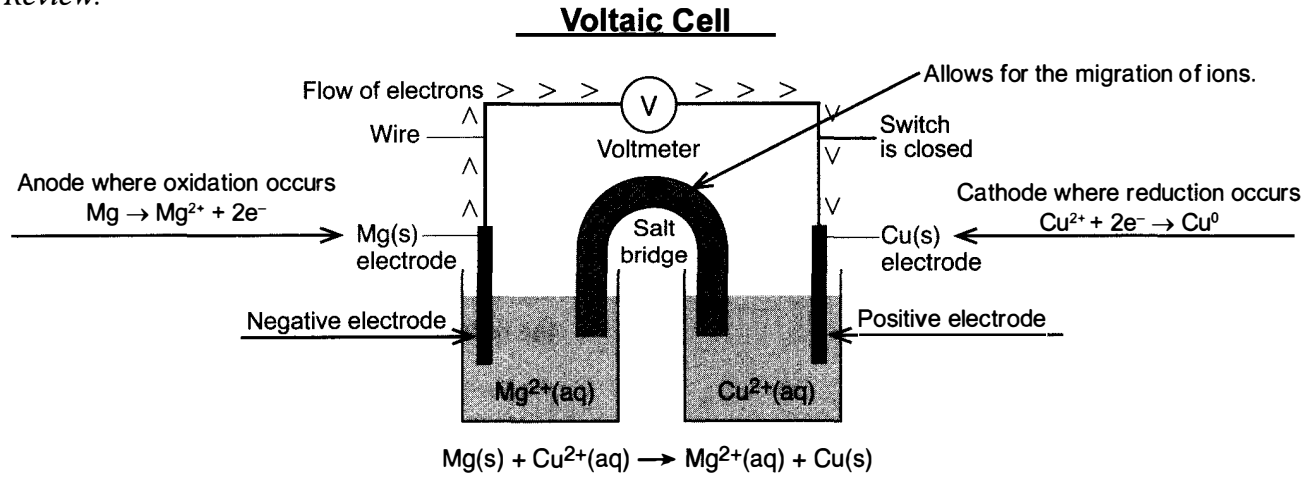
Example:

A voltaic cell with magnesium and copper electrodes is shown in the above diagram. The copper electrode has a mass of 15.0 grams. Below the diagram is the balanced ionic equation for the reaction in the cell.

When the switch is closed, the salt bridge allows ions to flow between the half-cells and the reaction in the cell begins. The more active metal, Mg being higher up on Table J, will undergo oxidation (acting as a reducing agent) and the less active metal, Cu will undergo reduction (acting as an oxidizing agent). The electrons flow from the Mg electrode (losing electrons during oxidation) to the copper electrode where they will be used in the reduction of the Cu^{2+} ions found in the electrolyte. As Cu^{2+} ions become reduced to Cu^{0} (a neutral copper atom), the atoms become part of the copper electrode, increasing its mass.

In an electrolytic cell, an electric current is used to cause a nonspontaneous redox reaction to occur. It needs a power source, such as a battery, to begin and sustain the reaction. In this reaction, electrical energy is converted to chemical energy. In the voltaic cell, chemical energy is converted to electrical energy.

Review:



Additional Information:

- In the single replacement reaction $A + BC \rightarrow B + AC$ where A is a metal, the reaction will occur spontaneously if A is above B on Table J. If A is below B, the reaction will not occur.
- The most active metals are those that readily lose an electron, thus are easily oxidized. They tend to be the strongest reducing agents. Typically, they are Group 1 and Group 2 elements.
- In the single replacement reaction $A + BC \rightarrow C + BA$ where A is a nonmetal, the reaction will occur spontaneously if A is above C on Table J. If A is below C, the reaction will not occur.
- The most active nonmetals are those that more readily gain an electron, thus most easily reduced. They tend to be the strongest oxidizing agents. Typically, they are Group 17 elements.
- Fluorine is the most active of all the elements.
- Gold (Au) a very inactive metal, which is why it keeps its brilliant luster. Being inactive, it is used in electrical connections that are exposed to hostile conditions, such as those found in space vehicles.

Set 1 — Activity Series

1. According to Reference Table J, which of these metals will react most readily with 1.0 M HCl to produce $H_2(g)$?

   (1) Ca (3) Mg
   (2) K (4) Zn 1 _____

2. Which metal is more active than H_2?

   (1) Ag (3) Cu
   (2) Au (4) Pb 2 _____

3. According to Reference Table J, which metal will react with Zn^{2+} but will not react with Mg^{2+}?

   (1) Al(s) (3) Ni(s)
   (2) Cu(s) (4) Ba(s) 3 _____

4. Which metal reacts spontaneously with a solution containing zinc ions?

   (1) strontium (3) copper
   (2) nickel (4) silver 4 _____

5. Which of the following metals is most active?

   (1) Ag (3) Sn
   (2) Zn (4) Li 5 _____

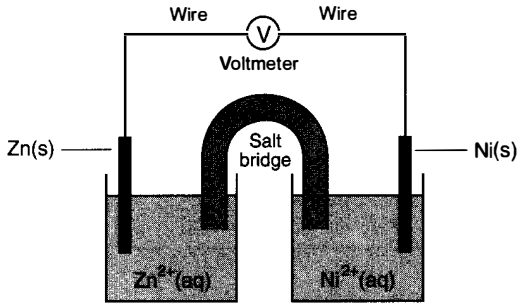
6. Which metal is more active than Ni and less active than Zn?

   (1) Cu (3) Cr
   (2) Mg (4) Pb 6 _____

7. Which half-reaction equation represents the reduction of an iron(II) ion?

   (1) $Fe^{2+} \rightarrow Fe^{3+} + e^-$
   (2) $Fe^{2+} + 2e^- \rightarrow Fe$
   (3) $Fe^{3+} + e^- \rightarrow Fe^{2+}$
   (4) $Fe \rightarrow Fe^{2+} + 2e^-$ 7 _____

8. The diagram below represents an operating electrochemical cell and the balanced ionic equation for the reaction occurring in the cell.



$Zn(s) + Ni^{2+}(aq) \longrightarrow Zn^{2+}(aq) + Ni(s)$

Which statement identifies the part of the cell that conducts electrons and describes the direction of electron flow as the cell operates?

(1) Electrons flow through the salt bridge from the Ni(s) to the Zn(s).
(2) Electrons flow through the salt bridge from the Zn(s) to the Ni(s).
(3) Electrons flow through the wire from the Ni(s) to the Zn(s).
(4) Electrons flow through the wire from the Zn(s) to the Ni(s). 8 _____

9. Which statement is true for any electrochemical cell?

(1) Oxidation occurs at the anode, only.
(2) Reduction occurs at the anode, only.
(3) Oxidation occurs at both the anode and the cathode.
(4) Reduction occurs at both the anode and the cathode. 9 _____

10. Which energy conversion occurs during the operation of an electrolytic cell?

(1) chemical energy to electrical energy
(2) electrical energy to chemical energy
(3) nuclear energy to electrical energy
(4) electrical energy to nuclear energy 10 _____

11. Which process occurs at the anode in an electrochemical cell?

(1) the loss of protons
(2) the loss of electrons
(3) the gain of protons
(4) the gain of electrons 11 _____

12. Given the balanced ionic equation representing the reaction in an operating voltaic cell:

$Zn(s) + Cu^{2+}(aq) \rightarrow Zn^{2+}(aq) + Cu(s)$

The flow of electrons through the external circuit in this cell is from the

(1) Cu anode to the Zn cathode
(2) Cu cathode to the Zn anode
(3) Zn anode to the Cu cathode
(4) Zn cathode to the Cu anode 12 _____

13. A student collects the materials and equipment below to construct a voltaic cell.

- two 250-mL beakers
- wire and a switch
- one strip of magnesium
- one strip of copper
- 125 mL of 0.20 M $Mg(NO_3)_2(aq)$
- 125 mL of 0.20 M $Cu(NO_3)_2(aq)$

Which additional item is required for the construction of the voltaic cell?

(1) an anode
(2) a battery
(3) a cathode
(4) a salt bridge 13 _____