16.5: The Activity Series- Predicting Spontaneous Redox Reactions

Learning Objectives

- Use the activity series to predict if a reaction will occur.

We see two metals below that can be exposed to water. The picture on the left is of sodium, which gives a violent reaction when it comes in contact with water. The picture on the right is of silver, a metal so unreactive with water that it can be made into drinking vessels.

Figure 16.5.1: On the left, sodium reacts with water. On the right, silver in the form of cups do not react with water.

The Activity Series

Single-replacement reactions only occur when the element that is doing the replacing is more reactive than the element that is being replaced. Therefore, it is useful to have a list of elements in order of their relative reactivities. The **activity series** is a list of elements in decreasing order of their reactivity. Since metals replace other metals, while nonmetals replace other nonmetals, they each have a separate activity series. The table below is an activity series of most common metals and of the halogens.

Table 16.5.1: Activity Series of Metals in Aqueous Solutions

Most Active (Easily Oxidized—Readily Lose Electrons)		
lithium	Li	These metals displace hydrogen from water $Ca_{(s)} + 2H_2O_{(l)} \rightarrow Ca(OH)_2 + H_{2\,(g)}$. These elements are very reactive and react readily to form compounds.
potassium	K	
barium	Ba	
calcium	Ca	
sodium	Na	
magnesium	Mg	These metals displace hydrogen from acids $Zn_{(s)} + HCl_{(aq)} \rightarrow ZnCl_2 + H_{2(g)}$
aluminum	Al	
zinc	Zn	
chromium	Cr	
iron	Fe	
cadmium	Cd	
nickel	Ni	
tin	Sn	
lead	Pb	
hydrogen	H	
copper	Cu	These metals do not displace hydrogen from acids or water. These elements are more stable,
silver	Ag	

Most Active (Easily Oxidized—Readily Lose Electrons)		
mercury	Hg	and form compounds less readily than do those higher in the table.
platinum	Pt	
gold	Au	
Least Active		

For a single-replacement reaction, a given element is capable of replacing an element that is below it in the activity series. This can be used to predict if a reaction will occur. Suppose that small pieces of the metal nickel were placed into two separate aqueous solutions: one of iron (III) nitrate and one of lead (II) nitrate. Looking at the activity series, we see that nickel is below iron, but above lead. Therefore, the nickel metal will be capable of replacing the lead in a reaction, but will not be capable of replacing iron.

$$\mathrm{Ni}\,(s) + \mathrm{Pb(NO_3)_2}\,(aq) \rightarrow \mathrm{Ni(NO_3)_2}\,(aq) + \mathrm{Pb}\,(s)$$

$$\mathrm{Ni}\,(s) + \mathrm{Fe(NO_3)_3}\,(aq) \rightarrow \mathrm{NR\ (no\ reaction)}$$

In the descriptions that accompany the activity series of metals, a given metal is also capable of undergoing the reactions described below that section. For example, lithium will react with cold water, replacing hydrogen. It will also react with steam and with acids, since that requires a lower degree of reactivity.

Steps for Problem Solving	**Example 16.5.1** Use the activity series to predict if the reaction below will occur. If not, write NR. If the reaction does occur, write the products of the reaction and balance the equation. $\mathrm{Al}(s) + \mathrm{Zn(NO_3)_2}\,(aq) \rightarrow$	**Example 16.5.2** Use the activity series to predict if the reaction below will occur. If not, write NR. If the reaction does occur, write the products of the reaction and balance the equation. $\mathrm{Ag}\,(s) + \mathrm{HCl}\,(aq) \rightarrow$
Plan the problem.	Compare the placements of aluminum (the element doing the replacing) and zinc (the element being replaced) on the activity series.	Compare the placements of silver (the element doing the replacing) and hydrogen (the element being replaced) on the activity series.
Solve.	Since aluminum is above zinc, it is capable of replacing it and a reaction will occur. The products of the reaction will be aqueous aluminum nitrate and solid zinc. Take care to write the correct formulas for the products before balancing the equation. Aluminum adopts a $+3$ charge in an ionic compound, so the formula for aluminum nitrate is $\mathrm{Al(NO_3)_3}$. The balanced equation is: $$\mathbf{2}\mathrm{Al}(s) + \mathbf{3}\mathrm{Zn(NO_3)_2}\,(aq) \rightarrow \mathbf{2}\mathrm{Al(NO_3)_3}\,(aq) + \mathbf{3}\mathrm{Zn}(s) \quad (16.5.1)$$	Since silver is below hydrogen, it is not capable of replacing hydrogen in a reaction with an acid. $$\mathrm{Ag}\,(s) + \mathrm{HCl}\,(aq) \rightarrow \mathrm{NR} \quad (16.5.2)$$

? Exercise 16.5.1

Use the activity series to predict if the following reactions will occur. If not, write NR. If the reaction does occur, write the products of the reaction and balance the equation.

a. Would it be possible to store a silver spoon in a zinc nitrate solution? That is, will the following reaction occur?

$$\backslash\mathrm{Ag\_\{(s)\}} + \mathrm{Zn(NO\_3)\_\{2\ (aq)\}} \rightarrow$$

b. Would it be possible to store a silver nitrate solution in a copper container? That is, will the following reaction occur?

$$\backslash[\mathrm{Cu\_\{(s)\}} + \mathrm{AgNO\_\{3\ (aq)\}} \rightarrow$$

Summary

- Metals and halogens are ranked according to their ability to displace other metals or halogens below them in the activity series.
