10.9.1: The Activity Series- Predicting Spontaneous Redox Reactions

Learning Objectives

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

We see below two metals that can be exposed to water. The picture on the left is of sodium, which has 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. Both metals have a single *s* electron in their outer shell, so you would predict a similar reactivity from each. However, we have a tool that allows us to make better predictions about how certain elements will react with others.

Figure 10.9.1.1: On the left, sodium reacts with water. On the right, silver in the form of cups does 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 reactivity. 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 10.9.1.1below is an activity series of most common metals, and the table 10.9.1.2is an activity series of the halogens.

Table 10.9.1.1: Activity Series of Metal Elements

Elements, from most to least reactive	Reaction Occurring
Li K Ba Sr Ca Na	React with cold water, replacing hydrogen.
Mg Al Zn Cr Fe Cd	React with steam, but not cold water, replacing hydrogen.
Co Ni Sn Pb	Do not react with water. React with acids, replacing hydrogen.
H_2	
Cu Hg Ag Pt Au	Unreactive with water or acids.

Table 10.9.1.2: Activity Series of Nonmetal elements

Elements, from most to least reactive
F_2
Cl_2
Br_2
I_2

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.

Examples 10.9.1.1

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. $\mathrm{Al}\,(s) + \mathrm{Zn(NO_3)_2}\,(aq) \rightarrow$
b. $\mathrm{Ag}\,(s) + \mathrm{HCl}\,(aq) \rightarrow$

Solution

Solutions to Example 7.11.1

Steps	**Example 10.9.1.1*A*** $\mathrm{Al}(s) + \mathrm{Zn(NO_3)_2}\,(aq) \rightarrow$	**Example 10.9.1.1*B*** $\mathrm{Ag}\,(s) + \mathrm{HCl}(aq) \rightarrow$
Plan the problem.	Compare the placements of aluminum and zinc on the activity series (Table 10.9.1.1)	Compare the placements of silver and hydrogen (Table 10.9.1.1)
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: $2\mathrm{Al}(s) + 3\mathrm{Zn(NO_3)_2}\,(aq) \rightarrow 2\mathrm{Al(NO_3)_3}\,(aq) + 3\mathrm{Zn}(s)$	Since silver is below hydrogen, it is not capable of replacing hydrogen in a reaction with an acid. $\mathrm{Ag}\,(s) + \mathrm{HCl}(aq) \rightarrow \mathrm{NR}$

Exercise 10.9.1.1

Use the activity series to predict the products, if any, of each equation.

a. $\mathrm{FeCl_2} + \mathrm{Zn} \rightarrow$
b. $\mathrm{HNO_3} + \mathrm{Au} \rightarrow$

Answer a

The products are $ZnCl_2$ + Fe.

Answer b

> No reaction.

Summary

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