Objective 7. Single replacement reactions: balancing, apply Activity Series, write net ionic equations to predict whether a reaction occurs, perform mole-mass and mole ratio calculations

Quiz Practice problems:

Key ideas:

In a single replacement reaction, an element reacts with an ionic compound or acid to form a new element and new ionic compound. The element in the reactant becomes an ion and replaces an ion in the ionic compound; the ion that is replaced becomes an element.

A + BC ---> B + AC

A single replacement reaction is also an oxidation-reduction reaction.

If Element A is a metal,

- Metal A loses electrons (it is oxidized) to become a cation (charge or oxidation number increases).
- Ion B gains electrons (it is reduced) to become an element (charge or oxidation number decreases).
- Metal A, which is oxidized, is also called a reducing agent because it is reducing another substance.
- Ion B, which is reduced, is also called an oxidizing agent because it is oxidizing another substance.

If Element A is a non-metal,

- Non-metal A gains electrons (it is reduced) to become an anion (charge or oxidation number decreases).
- Ion C loses electrons (it is oxidized) to become an element (charge or oxidation number increases).
- Non-metal A, which is reduced, is also called an oxidizing agent because it is oxidizing another substance.
- Ion C, which is oxidized, is also called a reducing agent because it is reducing another substance.

Oxidation-reduction reactions are like acid-base reactions, except electrons are transferred instead of H^+.

Skills: Use Table of common monoatomic and polyatomic ions.
Given reactants, predict the product (write chemical formulas) of products.
Balance single replacement reactions.
Use Activity Series – identify more active metal, determine whether a reaction occurs.
Write a net ionic equation to predict whether a reaction occurs.
Perform chemical calculations involving an acid-base reaction.

1. a. Determine the oxidation number of each element in the following substances: $CuSO_4$, $NiCl_2$, $FeSO_4$, $Al(NO_3)_3$, $SnCl_2$, $AgNO_3$, HCl, Cu, Zn, Al.
b. Heavy metals are considered toxic and hazardous. What makes a metal "heavy"?
c. Does an oxidizing agent give or take electrons? Does a reducing agent give or take electrons?

2. You can gold plate a piece of iron by placing the iron in a gold ion solution.

$Fe\ (s) + AuCl_3\ (aq) \rightarrow Au\ (s) + FeCl_3\ (aq)$

a. What is being oxidized? Fe because it loses electrons (Fe^0 ---> Fe^{3+}). Fe is the reducing agent.
b. Write an ionic equation: $Fe\ (s) + Au^{3+}\ (aq) + 3\ Cl^-\ (aq) \rightarrow Au\ (s) + Fe^{3+}\ (aq) + 3\ Cl^-\ (aq)$
c. Write a net ionic equation.
d. ID the spectator ions.

3. When rust reacts with Al, molten iron is produced. This reaction is known as the thermite process (go to YouTube to see this reaction).
a. Write a chemical equation that represents this reaction. Identify the oxidizing agent and reducing agent. What is it about this reaction that makes iron molten?
b. Write a net ionic equation.

4. Different metals have a different ability to lose electrons. A metal that loses electrons easily is called an active metal. The Activity Series of Metals ranks the ability of metals to lose electrons.
Lithium is the most active metal (best reducing agent), which means it very easily loses its electron to form Li^+. Li^+ does not want to gain an electron to re-form Li metal and is the worst oxidizing agent.
Gold is the least active metal (worst reducing agent), which means it does not easily lose its electrons to form Au^{3+}. Au^{3+} wants to gain electrons to re-form Au metal and is the best oxidizing agent.
The Activity Series is used to predict which metal reduces which metal ion. A metal will reduce any metal ion below it in the Activity Series.
Examples: Fe is above Au^{3+} so Fe reacts with Au^{3+} (see Problem 2).
Fe is below Cr^{3+} so Fe will not react with Cr^{3+}.

TABLE 4.5 Activity Series of Metals in Aqueous Solution

Metal	Oxidation Reaction				
Lithium	$Li(s)$	$\longrightarrow$	$Li^+(aq)$	+	e^-
Potassium	$K(s)$	$\longrightarrow$	$K^+(aq)$	+	e^-
Barium	$Ba(s)$	$\longrightarrow$	$Ba^{2+}(aq)$	+	$2e^-$
Calcium	$Ca(s)$	$\longrightarrow$	$Ca^{2+}(aq)$	+	$2e^-$
Sodium	$Na(s)$	$\longrightarrow$	$Na^+(aq)$	+	e^-
Magnesium	$Mg(s)$	$\longrightarrow$	$Mg^{2+}(aq)$	+	$2e^-$
Aluminum	$Al(s)$	$\longrightarrow$	$Al^{3+}(aq)$	+	$3e^-$
Manganese	$Mn(s)$	$\longrightarrow$	$Mn^{2+}(aq)$	+	$2e^-$
Zinc	$Zn(s)$	$\longrightarrow$	$Zn^{2+}(aq)$	+	$2e^-$
Chromium	$Cr(s)$	$\longrightarrow$	$Cr^{3+}(aq)$	+	$3e^-$
Iron	$Fe(s)$	$\longrightarrow$	$Fe^{2+}(aq)$	+	$2e^-$
Cobalt	$Co(s)$	$\longrightarrow$	$Co^{2+}(aq)$	+	$2e^-$
Nickel	$Ni(s)$	$\longrightarrow$	$Ni^{2+}(aq)$	+	$2e^-$
Tin	$Sn(s)$	$\longrightarrow$	$Sn^{2+}(aq)$	+	$2e^-$
Lead	$Pb(s)$	$\longrightarrow$	$Pb^{2+}(aq)$	+	$2e^-$
Hydrogen	$H_2(g)$	$\longrightarrow$	$2H^+(aq)$	+	$2e^-$
Copper	$Cu(s)$	$\longrightarrow$	$Cu^{2+}(aq)$	+	$2e^-$
Silver	$Ag(s)$	$\longrightarrow$	$Ag^+(aq)$	+	e^-
Mercury	$Hg(l)$	$\longrightarrow$	$Hg^{2+}(aq)$	+	$2e^-$
Platinum	$Pt(s)$	$\longrightarrow$	$Pt^{2+}(aq)$	+	$2e^-$
Gold	$Au(s)$	$\longrightarrow$	$Au^{3+}(aq)$	+	$3e^-$

Ease of oxidation increases

Reference: https://www.pinterest.com/pin/572520171356648614

a. Al is above Fe^{2+} so the thermite reaction occurs. What metal other than Al could you use to make molten iron? Give reasons. Write a chemical equation to support your answer.
b. Use the Activity Series of Metals to explain why Reaction (i) does not occur but Reaction (ii) does.
(i) Au (s) + $AgNO_3$ (aq) → no reaction
(ii) 3 Ag (s) + $AuCl_3$ (aq) → Au + 3 AgCl
Identify the oxidizing agent and reducing agent.
Could you silver plate gold or gold plate silver? Give reasons.
c. One of the reactions occurs but the other does not. Predict which reaction occurs. If a reaction occurs, write a net ionic equation. Identify the oxidizing agent and reducing agent.
(i) $CuSO_4$ (aq) + Zn (s) →
(ii) $ZnCl_2$ (aq) + Cu (s) →

5. You are trying to prevent an iron drain pipe from rusting. Your high school chemistry teacher, who usually teaches PE, suggests wrapping the iron pipe in copper foil whereas your grandmother tells you to wrap the iron pipe in magnesium foil. Which person's advice will you follow? Give reasons. (Pick one or the other. Do not say neither.)

6. When exposed to air, silver tarnishes because the silver reacts with hydrogen sulfide in the air to form a layer of black silver sulfide. The tarnish can be chemically removed by using a solution of baking soda and aluminum foil. In this electrochemical process, electrons move from the aluminum atoms to the silver ions in the tarnish, reducing the silver ions to silver atoms while the aluminum atoms are oxidized to aluminum ions. The baking soda provides an electrolyte solution for the flow of electrons and also helps remove the aluminum oxide coating from the surface of the aluminum foil. This method of cleaning silverware is better than using polish because the tarnish is restored to silver on the silverware. Polish removes the Ag_2S, including the silver it contains. (Reference: Moore et al., "The Chemical World", 2nd ed., p. 840) Write a balanced chemical equation that represents the tarnish removing reaction. Explain why aluminum is used in this reaction. What other metal could be used besides aluminum? Give reasons.

Another type of oxidation-reduction reaction is a combustion reaction. For a carbon based fuel:

Fuel + O_2 ---> CO_2 + H_2O

7. Natural gas is methane, CH_4, which is burned in a Bunsen burner:

CH_4 + 2 O_2 --> CO_2 + 2 H_2O

a. Identify the reactant that is oxidized.
b. Identify the reducing agent.

8. Butane (C_4H_{10}) is used in lighter fluid:

___ C_4H_{10} + ___ O_2 --> ___ CO_2 + ____ H_2O

a. Balance the chemical equation.
b. (i) 1 mole of butane reacts with ____ moles of oxygen.
(ii) How many moles of CO_2 are produced? (What is the conversion factor?)
c. 1.0 g of butane reacts.
(i) Calculate the moles of butane.
(ii) How many moles of H_2O are produced? (Answer: between 0.08 and 0.09 moles)
d. 1.0 g of butane reacts. How many g of O_2 reacts with 1.0 g of butane? (Answer: between 3.5 and 3.7 g)