Name __________________ HONORS CHEMISTRY ___/___/___

Oxide Reactions & Net Ionic Reactions

The first type of reactions we will look at today are reactions between an oxide (a compound with oxygen as its anion) and water. There are two such types of reactions. In the first type, a **metal oxide (also known as a base anhydride)** reacts with water and a **base** is formed. All bases, for now, **end in hydroxide (OH)**. In the second type, a **non-metal oxide (also known as an acid anhydride)** reacts with water and an **acid** is formed. All acids, for now, **begin with hydrogen (H)**. These reactions take the form of a **synthesis reaction**, even though their setup is similar to that of a double displacement reaction. The best way to identify these particular reactions is to look for water as a reactant. If water is one of your reactants, check the other reactant. If it is either a metal oxide or a non-metal oxide, your product will be either a base or an acid. Take a look at the examples below.

Example #1 Metal oxide + water
Calcium oxide + water →
$CaO + HOH \rightarrow Ca(OH)_2$

Note in the above reaction that the product is formed by taking the metal, calcium, and combining it with hydroxide (OH^-). To form their compound you MUST cross charges. Let's go through one step by step.

Determine the product for the following reactants: sodium oxide + water

Description of Action	Action
1. Write the formulas of the reactants. Remember, if it has more than one word, it is a compound and you MUST cross charges. Also, write water as HOH.	**1.** $Na_2O + HOH \rightarrow$ (Note: In the above formulas the charges have already been crossed. Sodium's 1+ went to oxygen and oxygen's 2- went to sodium. Hydrogen is 1+ and hydroxide is 1-, so their charges cancel each other out.)
2. Examine your formula…and if you spot water as a reactant, a bell should go off in your head. Check out the other formula. If that other formula is an oxide (meaning oxygen is the anion) determine which kind.	**2.** $Na_2O + HOH \rightarrow$ Ding, ding, ding!!! **Water is a reactant.** The other reactant is an oxide. Since sodium is a metal, sodium oxide is a metal oxide.
3. Write your product. The product will always begin with the metal and end in hydroxide. Since you are forming a compound, you must cross charges.	**3.** $Na_2O + HOH \rightarrow Na^{1+}\ (OH)^{1-}$
4. Write your product with the charges crossed. Do not write + signs, - signs, ones and if there is no number written outside of the parenthesis, eliminate them.	**4.** $Na_2O + HOH \rightarrow NaOH$
5. Balance the equation.	**5.** $Na_2O + HOH \rightarrow$ **2** $NaOH$

Now, you try it with: magnesium oxide + water

Description of Action	Action
1.	**1.**
2.	**2.**
3.	**3.**
4.	**4.**
5.	**5.**

Non-metal oxides work in much the same way. The difference between metal oxides and non-metal oxides however is that instead of ending in hydroxide, non-metal oxides begin with hydrogen. Lets look at an example below.

Example #2 Non-metal oxide + water
Sulfur trioxide (SO_3) + water $\rightarrow$
$SO_3 + HOH \rightarrow H_2SO_4$

Note above that the product begins with hydrogen and then the other elements are listed in order of appearance (first sulfur and then oxygen). These reactions always work out such that the subscript of each element is equal to the number. The product is formed by adding the oxygen from water to SO_3, making it SO_4. The compound is written by crossing the charges of H and SO_4. See below.

$SO_3 + HOH \rightarrow$
The O from HOH changes SO_3 to SO_4.
SO_4 is the anion. Look on the back of your periodic table and you will see that SO_4 has a charge of 2-.
Hydrogen's charge is 1+, making it the cation. Put the cation first, cross the charges and the product is formed.
$H^{1+}\ (SO_4)^{2-}$ becomes H_2SO_4
The complete reaction is: **$SO_3 + HOH \rightarrow H_2SO_4$**

Go through one step by step. Determine the product of dinitrogen pentoxide (N_2O_5) and water.

Description of Action	Action
1. Write the formulas of the reactants. Since all non-metal oxides are covalent compounds and we have not yet studied them, I will provide you with the formula for these compounds. Write water as HOH.	**1.** $N_2O_5 + HOH \rightarrow$ (NO_2 is a covalent compound. We have not studied them yet, so I will provide the formula for you.)
2. Examine your formula…and if you spot water as a reactant, a bell should go off in your head. Check out the other formula. If that other formula is an oxide (meaning oxygen is the anion) determine which kind.	**2.** $N_2O_5 + HOH \rightarrow$ Ding, ding, ding!!! (There is that bell again.) **Water is a reactant.** The other reactant is an oxide. Since nitrogen is a non-metal, nitrogen dioxide is a non-metal oxide.
3. Write hydrogen as your cation with its charge. Add the oxygen from water to the non-metal oxide. Reduce if necessary. Look the ion up on the back of your periodic table to find its charge. This is your anion.	**3.** N_2O_5 becomes N_2O_6. N_2O_6 can be reduced to NO_3. NO_3 has a 1- charge. H has a 1+ charge. Write H first, NO_3 second, and cross their charges. $N_2O_5 + HOH \rightarrow H^{1+}\ (NO_3)^{1-}$
4. Write your equation eliminating any + signs, - signs, ones and parenthesis.	**4.** $N_2O_5 + HOH \rightarrow HNO_3$
5. Balance if necessary.	**5.** $N_2O_5 + HOH \rightarrow 2HNO_3$

Now you do these same with carbon dioxide (CO_2) and water.

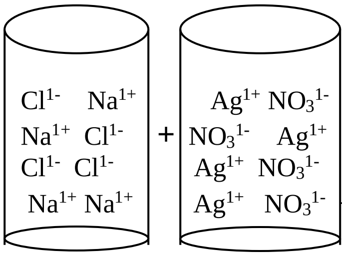
Description of Action	Action
1.	**1.**
2.	**2.**
3.	**3.**
4.	**4.**
5.	**5.**

Complete Ionic Equations & Net Ionic Equations

The last of chemical equations we will study are variations on double and single displacement reactions in solution. Below I have written a regular double displacement reaction.

$AgNO_3$ (aq) + NaCl (aq) → AgCl (s) + $NaNO_3$ (aq)

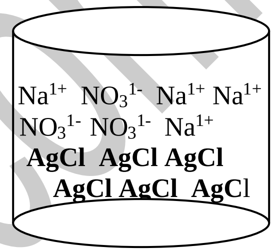
In the above reaction **aqueous** silver nitrate reacts with **aqueous** sodium chloride to yield **solid** silver chloride and **aqueous** sodium nitrate. The term aqueous means dissolved in water. When most ionic compounds are dissolved in water they dissociate or break into ions. So, when we say aqueous silver nitrate, what we have is silver ions and nitrate ions dissolved in water. Perhaps the diagram below will show you what I mean.



In the beaker to the left I have drawn diagrams to represent the reactants, aqueous silver nitrate and aqueous sodium chloride. The aqueous compounds dissociate or break into their individual ions: silver ions, nitrate ions, sodium ions and chloride ions.

Reactants

Products



Now in the beaker to the right I have represented the products after the reactants are combined. Note that sodium nitrateis aqueous, but silver chloride is solid. Solids remain bonded even when placed in a liquid (they do not dissociate). See the diagram to the right. Note: silver chloride remains bonded because it is a solid. A solid that forms in a solution is called a **precipitate**.

Anyway, let's get to the point at hand. When you are asked to write a **complete ionic equation** you must write aqueous compounds as if they are dissociated ions. Remember solids stay bonded, so they can be written as compounds. I took our original double displacement equation and rewrote it as a complete ionic equation. See below.

Ag^{1+}(aq) + NO_3^{1-}(aq) + Na^{1+}(aq) + Cl^{1-}(aq) → AgCl(s) + Na^{1+}(aq) + NO_3^{1-}(aq)

Aqueous compounds are written as individual ions. Since solids do not dissociate they can be written as compounds.

A **net ionic equation** is a simplified version of a complete ionic equation. In a net ionic compound particles that do not take part in the reaction are not written. These ions that are not directly involved in a reaction are called **spectator ions.** When writing net ionic equations any ion that does not combine to form a solid, liquid (water only) or gas is not written. Basically we eliminate unnecessary aqueous ions. The net ionic compound for the above reaction would be:

Ag^{1+}(aq) + Cl^{1-}(aq) → AgCl(s)

The spectator ions that were not included in the net ionic equation are: Na^{1+} & NO_3^{1-}
The precipitate that formed in the above reaction is AgCl.

Solubility Rules for Salts	
Usually Soluble	Insoluble
• Alkali Metal Salts	• Hydroxides (except alkali metals and ammonium)
• Ammonium Salts	• Phosphates (except alkali metals and ammonium)
• Nitrates	• Carbonates (except alkali metals and ammonium)
• Chlorates	• Oxalates (except alkali metals and ammonium)
• Perchlorates	• Sulfites (except alkali metals and ammonium)
• Acetates	• Sulfides (except alkali metals and ammonium)
• I, Br, Cl (except Ag^+, Hg_2^{2+}, Pb^{2+}, Cu^+)	
• Sulfates (except Ba^{2+}, Sr^{2+}, Ca^{2+}, Pb^{2+}, Ag^+)	

The solubility rules you need to know: All alkali, ammonium, acetate and nitrate salts are soluble in water.

Homework

Part I: Oxides + Water: For each of the following, write the complete balanced equation.

1. cesium oxide + water → **$Cs_2O + H_2O \rightarrow 2CsOH$**
2. dinitrogen pentoxide (N_2O_5) + water → **$N_2O_5 + H_2O \rightarrow 2HNO_3$**
3. potassium oxide + water → **$K_2O + H_2O \rightarrow 2KOH$**
4. barium oxide + water → **$BaO + H_2O \rightarrow Ba(OH)_2$**
5. sulfur dioxide (SO_2) + water → **$SO_2 + H_2O \rightarrow H_2SO_3$**
6. sodium oxide + water → **$Na_2O + H_2O \rightarrow 2NaOH$**
7. rubidium oxide + water → **$Rb_2O + H_2O \rightarrow 2RbOH$**
8. sulfur trioxide (SO_3) + water → **$SO_3 + H_2O \rightarrow H_2SO_4$**
9. magnesium oxide + water → **$MgO + H_2O \rightarrow Mg(OH)_2$**
10. carbon dioxide (CO_2) + water → **$CO_2 + H_2O \rightarrow H_2CO_3$**

Part II: Double Displacement Complete Ionic & Net Ionic Equations. For each of the following, write the double displacement, complete and net ionic equations and indicate the spectator ions.

1. A **solution** of ammonium carbonate is added to **a solution** of lead(II) nitrate.

Double Displacement: **$(NH_4)_2CO_3 + Pb(NO_3)_2 \rightarrow PbCO_3 + 2NH_4NO_3$**

Complete Ionic: **$2NH_4^{1+} + CO_3^{2-} + Pb^{2+} + 2NO_3^{1-} \rightarrow PbCO_3 + 2NH_4^{1+} + 2NO_3^{1-}$**

Net Ionic: **$CO_3^{2-} + Pb^{2+} \rightarrow PbCO_3$**

Spectator ions: **$NH_4^{1+} + NO_3^{1-}$**

2. A **solution** of barium oxide is added to **a solution** of potassium phosphate

Double Displacement: **$3BaO + 2K_3PO_4 \rightarrow 3K_2O + Ba_3(PO_4)_2$**

Complete Ionic: **$3Ba^{2+} + 3O^{2-} + 6K^{1+} + 2PO_4^{3-} \rightarrow 6K^{1+} + 3O^{2-} + Ba_3(PO_4)_2$**

Net Ionic: **$3Ba^{2+} + 2PO_4^{3-} \rightarrow Ba_3(PO_4)_2$**

Spectator ions: **$O^{2-} + K^{1+}$**

3. A solution of silver acetate is added to a solution of iron(III) bromide

Double Displacement: **$3AgC_2H_3O_2 + FeBr_3 \rightarrow 3AgBr + Fe(C_2H_3O_2)_3$**

Complete Ionic: **$3Ag^{+} + 3C_2H_3O_2^{1-} + Fe^{3+} + 3Br^{1-} \rightarrow 3AgBr + Fe^{3+} + 3C_2H_3O_2^{1-}$**

Net Ionic: **$Ag^{+} + Br^{1-} \rightarrow AgBr$**

Spectator ions: **$Fe^{3+} + C_2H_3O_2^{1-}$**

4. A solution of silver chlorate is added to a solution of barium oxide

Double Displacement: **$2AgClO_3 + BaO \rightarrow Ag_2O + Ba(ClO_3)_2$**

Complete Ionic: **$2Ag^{1+} + 2ClO_3^{1-} + Ba^{2+} + O^{2-} \rightarrow Ag_2O + Ba^{2+} + 2ClO_3^{1-}$**

Net Ionic: **$2Ag^{1+} + O^{2-} \rightarrow Ag_2O$**

Spectator ions: **$ClO_3^{1-} + Ba^{2+}$**

5. A solution of zinc acetate is added to a solution of sodium hydroxide

Double Displacement: **$Zn(C_2H_3O_2)_2 + 2NaOH \rightarrow Zn(OH)_2 + 2NaC_2H_3O_2$**

Complete Ionic: **$Zn^{2+} + 2C_2H_3O_2^{1-} + 2Na^{1+} + 2OH^{1-} \rightarrow Zn(OH)_2 + 2Na^{+} + 2C_2H_3O_2^{1-}$**

Net Ionic: **$Zn^{2+} + 2OH^{1-} \rightarrow Zn(OH)_2$**

Spectator ions: **$Na^{+} + C_2H_3O_2^{1-}$**

Part III: Single Displacement Complete Ionic & Net Ionic Equations. For each of the following, write the single displacement, complete and net ionic equations and indicate the spectator ion.

1. Lead foil is immersed in silver nitrate solution.

Single Displacement: **$Pb + 2AgNO_3 \rightarrow Pb(NO_3)_2 + 2Ag$**

Complete Ionic: **$Pb + 2Ag^{1+} + 2NO_3^{1-} \rightarrow Pb^{2+} + 2NO_3^{1-} + 2Ag$**

Net Ionic: **$Pb + 2Ag^{1+} \rightarrow Pb^{2+} + 2Ag$**

Spectator ion: **NO_3^{1-}**

2. Liquid bromine is shaken with a sodium iodide solution.

Single Displacement: **$Br_2 + 2NaI \rightarrow 2NaBr + I_2$**

Complete Ionic: **$Br_2 + 2Na^{1+} + 2I^{1-} \rightarrow 2Na^{1+} + 2Br^{1-} + I_2$**

Net Ionic: **$Br_2 + 2I^{1-} \rightarrow 2Br^{1-} + I_2$**

Spectator ion: **Na^{1+}**

3. Chlorine gas is bubbled into a solution of potassium iodide.

Single Displacement: **$Cl_2 + 2KI \rightarrow 2KCl + I_2$**

Complete Ionic: **$Cl_2 + 2K^{1+} + 2I^{1-} \rightarrow 2K^{1+} + 2Cl^{1-} + I_2$**

Net Ionic: **$Cl_2 + 2I^{1-} \rightarrow 2Cl^{1-} + I_2$**

Spectator ion: **K^{1+}**

4. A strip of magnesium is added to a solution of silver nitrate.

Single Displacement: **$Mg + 2AgNO_3 \rightarrow Mg(NO_3)_2 + 2Ag$**

Complete Ionic: **$Mg + 2Ag^{1+} + 2NO_3^{1-} \rightarrow Mg^{2+} + 2NO_3^{1-} + 2Ag$**

Net Ionic: **$Mg + 2Ag^{1+} \rightarrow Mg^{2+} + 2Ag$**

Spectator ion: **NO_3^{1-}**