Reactions

Word	Definition
Coefficient	A number placed in front of a formula to balance a chemical reaction.
Decomposition	A redox reaction in which a compound breaks up to form two elements.
Double replacement	A solution reaction in which the positive ion of one compound combines with the negative ion of the other compound to form a precipitate, and the other ions remain dissolved in solution.
Law of conservation of charge	Charge cannot be created or destroyed by physical or chemical change. This is the basis for writing chemical formulas and half-reactions, and balancing redox ionic reactions.
Law of conservation of energy	Energy cannot be created or destroyed by physical or chemical change. This is the basis for calculating the heat of reaction.
Law of conservation of mass	Matter cannot be created or destroyed by physical or chemical change. This is the basis for balancing chemical reactions.
Mole ratio	The whole-number ratio between components of a balanced chemical reaction.
Oxidation	The loss of electron(s), causing the oxidation number of a species to become more positive.
Precipitate	An insoluble solid that is formed either in a double-replacement reaction or as excess solute added to a saturated solution.
Product	The substances that are formed by a chemical reaction, designated as the right side of a chemical equation.
Reactant	The substances that are reacted together, designated as the left side of a chemical equation.
Reaction	A chemical change where reactants are turned into products.
Redox reaction	A reaction in which one element is oxidized and another element is reduced.
Reduction	The gain of electron(s), causing the oxidation number of a species to become more negative.
Single replacement	A redox reaction in which an element replaces an ion in a compound.
Spectator ion	An ion that does not participate in the chemical reaction. In a redox reaction, it is the ion whose charge does not change. In a double replacement reaction, they are the ions that remain dissolved in solution.
Stoichiometry	The mathematics of mole relationships.
Synthesis	A redox reaction in which two elements combine to form a compound.

1) What is a Chemical Equation? (HW: p. 16, 17)

Essential Question: How is the Law Of Conservation of mass applied during chemical changes?

CHEMICAL EQUATION: symbolic representation of a chemical reaction. Includes the substances being reacted (reactants), the substances being formed (products), the phases of each of the substances, the number of moles of each substance, and the resultant energy change.

Reactants → Products

Coefficients are placed in front of the substance symbols to denote a mole ratio that is in accordance with the Law of Conservation of Mass.

$$\mathbf{HCl\ (aq) + Zn\ (s) \rightarrow H_2\ (g) + ZnCl_2\ (aq)}$$

(reactants) (products)

This says that hydrochloric acid reacts with zinc metal to form hydrogen gas and zinc chloride.

<u>THE LAW OF CONSERVATION OF MASS</u> – mass cannot be created or destroyed by physical or chemical change. The elements found in the reactants can be the only elements found in the products, and there must be equal numbers of moles of those elements on both sides.

$$\mathbf{HCl\ (aq) + Zn\ (s) \rightarrow H_2\ (g) + ZnCl_2\ (aq)}$$

(reactants) (products)

This equation breaks the **Law of Conservation of Mass**, there are unequal moles of moles of H and Cl on both sides.

Balancing equations involves placing coefficients that act as multipliers in front of a substance's formula.

$$\underline{\mathbf{2}}\ HCl\ (aq) + Zn\ (s) \rightarrow H_2\ (g) + ZnCl_2\ (aq)$$

This shows that 2 moles of HCl are required to react with 1 mole of Zn. H_2 is formed because hydrogen exists in diatomic form (BrINClHOF).

RULES FOR WRITING CHEMICAL EQUATIONS (given the names)

1) Write the formulas of the compounds

2) Balance the equation.

- **a) Write in pencil**
- **b) Write coefficients one element at a time**
- **c) Only coefficients may be used…you may not change chemical formulas in order to balance.**
- **d) Revise where necessary**

SOMETHING TO REMEMBER - the difference between coefficients and subscripts (2 Cl vs Cl_2)

2 Cl means that there are **TWO ATOMS of chlorine**. **Cl_2** means that there is **one molecule of diatomic chlorine**. Diatomic molecules (Br_2, I_2, N_2, Cl_2, H_2, O_2, F_2) exist whenever these elements are not in a compound with another element. In NaCl, there is one Cl^{-1} ion (since Na is charged +1), but if that chlorine is separated from that compound:

$$\mathbf{NaCl \rightarrow Na + Cl}$$

Then the Cl's thus formed will pair up diatomically, which throws off the balancing:

$$\mathbf{NaCl \rightarrow Na + Cl_2}$$

How do we balance this reaction? Look at the next page!

$NaCl \rightarrow Na + Cl_2$

* There is one Na on the left and one Na on the right. Na is balanced…for now.
* There is one Cl on the left and one Cl on the right. Multiply them together: 1 X 2 = 2. This means that when balanced, there should be two chlorine atoms on each side. There are already two on the right, so put a 2 coefficient in front of NaCl:

$2\ NaCl \rightarrow Na + Cl_2$

* This messes up the balancing of Na, so place a 2 in front of the Na on the right side to balance this off:

$2\ NaCl \rightarrow 2\ Na + Cl_2$

* There are now 2 Na's on both sides and 2 Cl's on both sides. This reaction is balanced.

$H_2 + O_2 \rightarrow H_2O$

* There are two H's on the left and two H's on the right. H is balanced…for now.
* There are two O's on the left and only one on the right. Multiply: 2 X 1 = 2. There should be two O's on either side to be balanced. Put a 2 in front of H_2O to accomplish this:

$H_2 + O_2 \rightarrow 2\ H_2O$

* This messes up the balancing of H. To remedy this, put a 2 in front of the H_2 on the left:

$2\ H_2 + O_2 \rightarrow 2\ H_2O$

* There are now 4 H's on both sides and 2 O's on both sides. This reaction is balanced.

$Al + O_2 \rightarrow Al_2O_3$

* There is one Al on the left and two on the right. Multiply 1 X 2 = 2. There should be 2 on each side, so put a 2 in front of Al on the left:

$2\ Al + O_2 \rightarrow Al_2O_3$

* There are two O's on the left and three on the right. Multiply 2 X 3 = 6. When balanced, there should be six O's on each side. On the left, there are two O's. Two times what equals six? Three! Put a 3 in front of the O_2 on the left. Three times what is six? Two! Put a 2 in front of the Al_2O_3 on the right. The reaction now looks like:

$2\ Al + 3\ O_2 \rightarrow 2\ Al_2O_3$

* But this now throws off the Al! There are now 2 Al on the left and four on the right! Easily fixed…Put a 4 in front of the Al on the left. Now it looks like:

$4\ Al + 3\ O_2 \rightarrow 2\ Al_2O_3$

* There are now 4 Al's on each side and 6 O's on both sides. Bravo! It's balanced.

$SO_3 \rightarrow SO_2 + O_2$

* This one is strange, because you find O in two places on the left. No problem, follow!
* There is one S on either side. S is balanced for now…but it won't stay that way for long.
* There are three O's on the left, but FOUR on the right! Two in the SO_2 and two in the O_2. Multiply: 3 X 4 = 12. There should be 12 O's on each side when balanced. There are three on the left. 3 times what equals 12? FOUR! Place a 4 in front of the SO_3. The reaction now looks like

$4\ SO_3 \rightarrow SO_2 + O_2$

* Now place a 4 in front of the SO_2 to balance off the S:

$4\ SO_3 \rightarrow 4\ SO_2 + O_2$

* Now, there are 8 O's in the SO_2 and two in the O_2. Remember, we need twelve O's on each side. What We need two more O's on the right side. How can we do that without messing up S again? Right! Put a 2 in front of the O_2.

$4\ SO_3 \rightarrow 4\ SO_2 + 2\ O_2$

* Now there are 4 S's on both sides and 12 O's. It's balanced! Note, however, that the coefficients can be simplified to

$2\ SO_3 \rightarrow 2\ SO_2 + 1\ O_2$

* If a reaction's coefficients can be simplified in this way, you have to do it…otherwise, the Balancing Police will come and drag you away in handcuffs (well, covalent bonds, really…but you get the point).

$Ca + HNO_3 \rightarrow Ca(NO_3)_2 + H_2$

* Now we have a reaction with a polyatomic ion! Treat the whole ion like one element. To make it easier, put parentheses around the polyatomic ion if it doesn't already have them:

$Ca + H(NO_3) \rightarrow Ca(NO_3)_2 + H_2$

* There is one Ca on either side. Ca is good. Will it stay that way? The suspense is killing me!

* There is one H on the left and two on the right. 1 X 2 = 2, so there should be 2 H's on either side. Place a 2 in front of $H(NO_3)$:

$Ca + 2\ H(NO_3) \rightarrow Ca(NO_3)_2 + H_2$

* There are two NO_3's on the left and also two on the right! No balancing of NO_3 is necessary

Let's see…1 Ca on both sides, 2 H's on both sides and 2 NO_3's on both sides? I'd say this sucker is balanced! ☺

$Al + CuSO_4 \rightarrow Al_2(SO_4)_3 + Cu$

* Again, put parentheses around any polyatomic ion that doesn't have them already:

$Al + Cu(SO_4) \rightarrow Al_2(SO_4)_3 + Cu$

* There is one Al on the left, two on the right. 1 X 2 = 2, so there should be two Al's on both sides. Place a 2 in front of the Al on the left:

$2\ Al + Cu(SO_4) \rightarrow Al_2(SO_4)_3 + Cu$

* There is one Cu on both sides. Leave it alone…for now.
* There's one sulfate on the left and three on the right! 1 X 3 = 3, so place a 3 in front of the $CuSO_4$ on the left:
$2\ Al + 3\ Cu(SO_4) \rightarrow Al_2(SO_4)_3 + Cu$

* Now there are three sulfates on both sides, but now the Cu is messed up. No biggie…there are 3 Cu's on the left, one on the right, so slap a 3 in front of the Cu on the right:

$2\ Al + 3\ Cu(SO_4) \rightarrow Al_2(SO_4)_3 + 3\ Cu$

* There are now 2 Al's on each side, 3 Cu's on each side and 3 SO_4's on each side. The reaction is now balanced!

$FeCl_3 + Pb(NO_3)_2 \rightarrow Fe(NO_3)_3 + PbCl_2$

* This is the nastiest it will get for you. There are four things that have to be balanced. Be patient and do on at a time.
* There is one Fe on each side. Let it be for now.
* There's one Pb on each side. Let that be for now as well.
*There are three Cl's on the left and two on the right. 2 X 3 = 6, so there has to be six Cl's on each side. On the left, three times what equals six? Two! Put a 2 in front of $FeCl_3$. On the right, two times what equals six? Three! Put a 3 in front of $PbCl_2$. The reaction should now look like:

$2\ FeCl_3 + Pb(NO_3)_2 \rightarrow Fe(NO_3)_3 + 3\ PbCl_2$

* Now let's deal with the nitrate. There are two NO_3's on the left and three on the right. 2 X 3 = 6, so there should be six on each side. On the left, 2 X 3 = 6, so put a 3 in front of the $Pb(NO_3)_2$. On the right, 3 X 2 = 6, so put a 2 in front of the $Fe(NO_3)_3$. Now there are six nitrates on each side:

$2\ FeCl_3 + 3\ Pb(NO_3)_2 \rightarrow 2\ Fe(NO_3)_3 + 3\ PbCl_2$

* Now check out what happened to Fe and Pb! There are now 2 Fe's on both sides and 3 Pb's on each side. Balancing the chloride and the nitrate automatically balanced the Fe and the Pb! Nice, how things work out sometimes. This baby be balanced!!!!

Writing Equations given the names

If you are given names of the compounds instead of the formulas, use the rules for writing formulas in the previous unit to write the formulas, and then balance the reaction.

Magnesium + lead (IV) nitrate → magnesium nitrate + lead

$Mg \quad Pb(NO_3)_4 \rightarrow Mg(NO_3)_2 + Pb$

Then balance!

$2\ Mg + Pb(NO_3)_4 \rightarrow 2\ Mg(NO_3)_2 + Pb$

Copper + oxygen gas → copper (I) oxide

$Cu + O_2 \rightarrow Cu_2O$

Then balance!

$4\ Cu + O_2 \rightarrow 2\ Cu_2O$

Lead (II) nitrate + sodium phosphate → lead (II) phosphate + sodium nitrate

$Pb(NO_3)_2 + Na_3PO_4 \rightarrow Pb_3(PO_4)_2 + NaNO_3$

Then balance!

$3\ Pb(NO_3)_2 + 2\ Na_3PO_4 \rightarrow Pb_3(PO_4)_2 + 6\ NaNO_3$

Missing Mass In Equations

The mass on the reactants side and products side have to equal each other because the Law of Conservation of Mass states that mass cannot be created or destroyed in a physical or chemical change.

If 35.0 grams of nitrogen gas are reacted with hydrogen gas to produce 42.5 grams of ammonia gas. How many grams of hydrogen gas were reacted?

35.0 + X = 42.5, so X = **7.5 grams of hydrogen gas**

How many grams of aluminum are formed when 45.0 grams of aluminum oxide are decomposed into aluminum and 21.1 grams of oxygen?

45.0 = X + 21.1, so X = **23.9. grams of aluminum are formed**

How many grams of iron (II) sulfide must be decomposed to form 33.0 grams of iron and 19.0 grams of sulfur?

X = 33.0 + 19.0, so **52.0 grams of iron (II) sulfide must be decomposed.**

2) Oxidation and Reduction Reactions (HW: p. 18, 19)

Essential Question: How do we make the chemical products that we use every day?

Driving Force: The "motivation" of a reaction to occur: In nature, changes that require the least amount of energy will be the ones that happen. After all, when you let go of a bowling ball, it falls down. The motivation is gravity. It would take more energy to make the ball go up than down, so the ball falls. In order to get the ball to go up, energy has to be added. This motivation is called a driving force.

Redox Reactions: driven by the loss of electrons (oxidation) and the gain of electrons (reduction).

In a redox reaction, one species gains electrons and one species loses them. Any ions that are not involved in this process are called "spectator ions".

Redox (oxidation-reduction) - a reaction prompted by an exchange in electrons between two elements, resulting in a change of oxidation number of the two elements.

a) The more electronegative element (usually a nonmetal atom) gains the electron, resulting in a decrease in oxidation number (going more negative). This is called **reduction**.

b) The less electronegative element (usually a metal atom) loses the electron, resulting in an increase in oxidation number. This is called **oxidation**.

TYPES OF REDOX REACTIONS

1) Synthesis (synthesizer, synthetic, to make something from individual parts)
Two elements combine to form a compound. **This is the easiest way to make a compound, and is often used in industry for that purpose.**

a) A + B → AB

b) $A^0 + B^0 \rightarrow A^+B^-$ (A^0 gives up its electron to B^0. A^0 is oxidized, B^0 is reduced)

Reaction: $K + Br_2 \rightarrow 2\ KBr$ With charges: $K^0 + Br_2^0 \rightarrow 2\ K^{+1}Br^{-1}$

K^0 goes from 0 to +1, so it is oxidized. K^0 gives electrons to Br^0. Br^0 goes from 0 to –1, so it is reduced

2) Decomposition (reverse of synthesis), a compound decomposes into its original elements.

This reaction is very rare to occur on its own. It takes less energy for most compounds to form than to decompose. Water forms on its own from hydrogen and oxygen gas, but it takes a constant supply of energy to get water to decompose into hydrogen and oxygen. Imagine if the water in your glass suddenly decomposed into hydrogen and oxygen! Or if the salt on your plate decomposed suddenly into sodium (explosive metal) and chlorine (poisonous, corrosive gas)! Compounds exist because it requires less energy to exist in compound form. This is why the diatomic molecules exist…hydrogen has less energy as H_2 than as just H…so whenever H atoms are hanging around, they will form diatomic molecules. **This reaction is used to get highly reactive elements out of compounds and into a pure form. It is often done using electric current in a process called electrolytic decomposition.**

a) AB → A + B

b) $A^+B^- \rightarrow A^0 + B^0$ (B^- gives up its electron to A^+, so A^+ is reduced, B^- is oxidized)

Reaction: $2\ AgCl \rightarrow 2\ Ag + Cl_2$ With charges: $2\ Ag^{+1}Cl^{-1} \rightarrow 2\ Ag^0 + Cl_2^0$

Ag^{+1} goes from +1 to 0, so it is reduced. It gains electrons from Cl^{-1}, which goes from –1 to 0 and is oxidized.

3) Single Replacement: this reaction has one element and on compound on each side.

Two possibilities.

A) A metal plus a compound. The metal replaces the positive ion in the compound. **This reaction can be used to create electricity, and so is often found in batteries. This reaction can also be used to get less reactive elements out of compounds. React a more active metal with a compound containing the less active metal, and the more active metal will drive the less active metal out, leaving the less active metal in its pure form. This is also called extraction from ore.**

1) A + BC → AC + B

2) $A^0 + B^+C^- \rightarrow A^+C^- + B^0$ (A^0 gives its electron to B^+, so A^0 is oxidized and B^+ is reduced. C^- does not undergo a change in charge, so it is a spectator ion.)

Reaction: $Zn + Cu(NO_3)_2 \rightarrow Zn(NO_3)_2 + Cu$ With Charges: $Zn^0 + Cu^{+2}(NO_3)_2^{-1} \rightarrow Zn^{+2}(NO_3)_2^{-1} + Cu^0$

Zn^0 goes from 0 to +2, so it is oxidized. It loses electrons to Cu^{+2}, which goes from +2 to 0 and is reduced. NO_3^{-1} does not change charge, so it is the **spectator ion.**

B) A nonmetal plus a compound. The nonmetal replaces the negative ion in the compound. **This is a very rare reaction, and is a less economical way to produce a pure nonmetal than electrolytic decomposition.**.

1) A + BC → BA + C

2) $A^0 + B^+C^- \rightarrow B^+A^- + C^0$ (C^- gives its electrons to A^0, so C^- is oxidized and A^0 is reduced. B^+ does not undergo any change in charge, so it is a spectator ion.)

Reaction: $F_2 + ZnCl_2 \rightarrow ZnF_2 + Cl_2$ With Charges: $F_2^0 + Zn^{+2}Cl_2^{-1} \rightarrow Zn^{+2}F_2^{-1} + Cl_2^0$

F^0 goes from 0 to –1, so it is reduced. It gains electrons from Cl^{-1}, which goes from –1 to 0 and is oxidized. Zn^{+2} does not change charge, so it is the **spectator ion.**

How Do You Identify The Type Of Reaction?

$Zn + 2\ KNO_3 \rightarrow Zn(NO_3)_2 + 2\ K$ Starts with an element and a compound, must be single replacement

$2\ Fe + 3\ Cl_2 \rightarrow 2\ FeCl_3$ Starts with elements and end with a compound, must be synthesis

$2\ NaNO_2 \rightarrow 2\ Na + N_2 + 2\ O_2$ Starts with a compound, ends with elements, must be decomposition.

WHAT YOU HAVE TO BE ABLE TO DO:

1) How Do You Determine The Charge Of Each Species?

a) Elements by themselves have no charge. Al^0, Cl_2^0, Fe^0

b) The charge of the ions in the compound can be looked up on Table E (for polyatomic ions) or the Periodic Table (for element ions). If the element has more than one charge listed, use the negative ion's charge to determine the charge of the positive ion.

$Al_2(SO_4)_3$: Al is listed as +3, SO_4 is listed on Table E as being -2: $\mathbf{Al_2^{+3}(SO_4)_3^{-2}}$

$Fe_3(PO_4)_2$: Fe has 2 charges listed (+2 and +3). PO_4 is listed on Table E as being -3. To make the charges add up to zero, Fe must have a +2 charge: $\mathbf{Fe_3^{+2}(PO_4)_2^{-3}}$. For Fe: 3 X +2 = +6. For PO_4: 2 X -3 = -6. +6 and -6 add up to ZERO.

0 0 +1 -2 $4\ Ag + O_2 \rightarrow 2\ Ag_2O$ Note the elements that are by themselves have a charge of **0**

0 +3 -2 +1 -2 0 $6\ K + Al_2(SO_4)_3 \rightarrow 3\ K_2SO_4 + 2\ Al$ Note that the sum of the ion charges in each of the compounds is ZERO.

+2 -2 0 0 $2\ FeO \rightarrow 2\ Fe + O_2$

0 0 +1 -1 $2\ Na + Br_2 \rightarrow 2\ NaBr$

0 +1 -1 +2 -1 0 $Ca + 2\ HCl \rightarrow CaCl_2 + H_2$

+2 -2 0 0 $2\ PbO \rightarrow 2\ Pb + O_2$

0 +1 -2 +3 -2 0 $2\ Al + 3\ Ag_2CO_3$ -> $Al_2(CO_3)_3 + 6\ Ag$

2) Ho Do You Determine Which Species Is Oxidized And Which Is Reduced And Which Is The Spectator Ion?

The species that is OXIDIZED has lost electrons, and its oxidation number has become more POSITIVE
The species that is REDUCED has gained electrons, and its oxidation number has become more NEGATIVE
The species that is the SPECTATOR ION neither gains nor loses electrons, and its charge REMAINS THE SAME.

$4\ Ag^0 + O_2^0 \rightarrow 2\ Ag_2^{+1}O^{-2}$

OX (charge more +): Ag^0 RD (charge more -): O_2^0 SI (no change): none

$6\ K^0 + Al_2^{+3}(SO_4)^{-2}_3 \rightarrow 3\ K_2^{+1}SO_4^{-2} + 2\ Al^0$

OX (charge more +): K^0 RD (charge more -): Al^{+3} SI (no change): SO_4^{-2}

$2\ Fe^{+2}O^{-2} \rightarrow 2\ Fe^0 + O_2^0$

OX (charge more +): O^{-2} RD (charge more -): Fe^{+2} SI (no change): none

$2\ Na^0 + Br_2^0 \rightarrow 2\ Na^{+1}Br^{-1}$

OX (charge more +): Na^0 RD (charge more -): Br_2^0 SI (no change): none

$Ca^0 + 2\ H^{+1}Cl^{-1} \rightarrow Ca^{+2}Cl_2^{-1} + H_2^0$

OX (charge more +): Ca^0 RD (charge more -): H^{+1} SI (no change): Cl^{-1}

$2\ Pb^{+2}O^{-2} \rightarrow 2\ Pb^0 + O_2^0$

OX (charge more +): O^{-2} RD (charge more -): Pb^{+2} SI (no change): none

$2\ Al^0 + 3\ Ag_2^{+1}CO_3^{-2}$ -> $Al_2^{+3}(CO_3)_3^{-2} + 6\ Ag^0$

OX (charge more +): Al^0 RD (charge more -): Ag^{+1} SI (no change): CO_3^{-2}

3) How Do You Find The Missing Species?

1) If the missing species is an ELEMENT, just write its symbol. If it diatomic Br_2, I_2, N_2, Cl_2, H_2, O_2, F_2), write it as being diatomic. The reaction will balance that way.

2) If the missing species is a COMPOUND, write the positive ion first and the negative ion second. Write the formula in such a way that you have the same numbers of atoms of each element on both sides of the balanced reaction.

$4\ Ag + O_2 \rightarrow 2$ __**Ag_2O**_____ This way, there are 4 Ag on both sides and 2 O.

$6\ K + Al_2(SO_4)_3 \rightarrow 3$ ____**K_2SO_4**____ + 2 Al

The missing species are 6 K's and 3 SO_4's. Since there is a 3 coefficient, the compound contains 2 K's (3 X 2 = 6 K's) and 1 SO_4 (3 X 1 = 3 SO_4's).

$2\ FeO \rightarrow 2\ Fe +$ __**O_2**___ Since O is diatomic, putting O_2 balances the oxygen on both sides.

$2\ Na + Br_2 \rightarrow 2$ ___**NaBr**____

Ca + 2 __**HCl**___ $\rightarrow CaCl_2 + H_2$

$2\ PbO \rightarrow 2$ __**Pb**_ + O_2

2 Al + 3 __**Ag_2CO_3**_____ -> $Al_2(CO_3)_3 + 6\ Ag$

The missing species are 6 Ag's and 3 CO_3's. Since there is a 3 coefficient, the compound contains 2 Ag's (3 X 2 = 6 Ag's) and 1 CO_3 (3 X 1 = 3 CO_3's).

3) Double Replacement (HW: p. 20, 21)

Essential Question: How do we make the chemical products that we use every day?

Ionic compounds generally ionize in water. When the soluble ionic compound is placed into water, the molecule-ion interaction rips the ionic compound into its component ions. The hydrogen end of the water molecule (δ +) attaches to the – ion. The oxygen end of the water molecule (δ-) attaches to the + ion. The water molecules, which are in constant motion, tear the ions off of the crystal and keep them apart, floating forever in solution.

Insoluble ions remain together. This is because the attractions between the ions are too strong for water molecules to tear apart. The ions come together and form crystals, which make the solution cloudy. The crystals are pulled to the bottom of the solution by gravity, forming a **PRECIPITATE**.

Which ionic compounds dissociate (dissolve)? Refer to Reference Table F:

Ions That Form *Soluble* Compounds	Exceptions
Group 1 ions (Li^+, Na^+, etc.)	
ammonium (NH_4^+)	
nitrate (NO_3^-)	
acetate ($C_2H_3O_2^-$ or CH_3COO^-)	
hydrogen carbonate (HCO_3^-)	
chlorate (ClO_3^-)	
perchlorate (ClO_4^-)	
halides (Cl^-, Br^-, I^-)	when combined with Ag^+, Pb^{2+}, and Hg_2^{2+}
sulfates (SO_4^{2-})	when combined with Ag^+, Ca^{2+}, Sr^{2+}, Ba^{2+}, and Pb^{2+}

Ions That Form *Insoluble* Compounds	Exceptions
carbonate (CO_3^{2-})	when combined with Group 1 ions or ammonium (NH_4^+)
chromate (CrO_4^{2-})	when combined with Group 1 ions, Ca^{2+}, Mg^{2+}, or ammonium (NH_4^+)
phosphate (PO_4^{3-})	when combined with Group 1 ions or ammonium (NH_4^+)
sulfide (S^{2-})	when combined with Group 1 ions or ammonium (NH_4^+)
hydroxide (OH^-)	when combined with Group 1 ions, Ca^{2+}, Ba^{2+}, Sr^{2+}, or ammonium (NH_4^+)

Table F
Solubility Guidelines for Aqueous Solutions

Compound	Soluble or Insoluble?	Why?
Li_2CO_3	Soluble	Li^{+1} is a group 1 ion, and Group 1 ions are always soluble, with no exceptions.
$Pb(NO_3)_2$	Soluble	NO_3^{-1} is listed as being always soluble, no exceptions.
$ZnCl_2$	Soluble	Cl^{-1} is a halide, which are listed as being soluble, with a few exceptions. However, Zn^{+2} is not one of those exceptions.
$BaSO_4$	Soluble	SO_4^{-2} is listed as being soluble, with a few exceptions. However, Ba^{+2} is not one of those exceptions.
$Ca(HCO_3)_2$	Soluble	HCO_3^{-1} is listed as being soluble, with a few exceptions. However, Ca^{+2} is not one of those exceptions.
$CuCO_3$	Inoluble	CO_3^{-2} is listed as being insoluble, with a few exceptions. However, Cu^{+2} is not one of those exceptions, because it is not a Group 1 ion.
$Pb(CrO_4)_2$	Inoluble	CrO_4^{-2} is listed as being insoluble, with a few exceptions. However, Pb^{+2} is not one of those exceptions, because it is not a Group 1 ion.
Na_3PO_4	Soluble	Na^{+1} is a group 1 ion, and Group 1 ions are always soluble, with no exceptions.
NH_4OH	Soluble	NH_4^{+1} is listed as being always soluble, no exceptions.
$Mg(OH)_2$	Inoluble	OH^{-1} is listed as being insoluble, with a few exceptions. However, Mg^{+2} is not one of those exceptions, because it is not a Group 1 ion.

Double Replacement reaction

The positive ion of one compound swaps places with the negative ion from the other compound. This reaction is carried out with aqueous solutions of each reactant so that the ions can more easily mix and react.

General Formula: A^+B^- (aq) + C^+D^- (aq) → A^+D^- (s) + C^+B^- (aq)

Solution AB (which is made of separated ions A^+ and B^-) is mixed into solution CD (which is made of separated ions C^+ and D^-). Instantly upon mixing, the A^+ ions of the first solution seek out and bond very tightly to the D^- ions of the second solution, so tightly that water molecules cannot separate them. They form small crystals of compound AD, which turn the solution cloudy. Finally, gravity pulls the crystals of AD down and they settle to the bottom as a precipitate.

K_2CrO_4 (aq) + $Ba(NO_3)_2$ (aq) → 2 KNO_3 (aq) + $BaCrO_4$ (s)

Taking a look at the two products on Table F: K^{+1} is a Group 1 ion, so it is always soluble, no exceptions. NO_3^{-1} is also always soluble, no exceptions. On the other hand, CrO_4^{-2} is listed as being insoluble with exceptions, but Ba^{+2} is not one of those exceptions. $BaCrO_4$ is the precipitate in this reaction.

Na_2CO_3 (aq) + $CaCl_2$ (aq) → 2 NaCl (aq) + $CaCO_3$ (s)

Taking a look at the two products on Table F: Na^{+1} is a Group 1 ion, so it is always soluble, no exceptions. Cl^{-1} is usually soluble, and Na^{+1} is not an exception. On the other hand, CO_3^{-2} is listed as being insoluble with exceptions, but Ca^{+2} is not one of those exceptions. $CaCO_3$ is the precipitate in this reaction.

How Can Double Replacement Reactions be Completed?

The same way redox reactions are completed! For the missing compound, write the positive ion first and the negative ion second. Write the formula in such a way that you have the same numbers of atoms of each element on both sides of the balanced reaction. Then use Table F to identify the precipitate!

KCl (aq) + $AgNO_3$ (aq) → KNO_3 (__**aq**__) + _____**AgCl**________ (__**s**__)

The missing compound will contain Ag and Cl. Since no coefficient is given, the formula is AgCl. Based on Reference F, KNO_3 is soluble (aq), and the AgCl is the insoluble precipitate (s).

2 Na_3PO_4 (aq) + 3 $Mg(NO_3)_2$ (aq) → 6 $NaNO_3$ (__**aq**__) + _____ **$Mg_3(PO_4)_2$**_____(__**s**___)

The missing compound contains Mg and PO_4. The reactants side contains 2 PO4's and 3 Mg's. There is no coefficient given for the missing product, so the formula is $Mg_3(PO_4)_2$. Based on Reference Table F, $NaNO_3$ is soluble and $Mg_3(PO_4)_2$ is the insoluble precipitate.

The spectator ions in a double replacement reaction are the two that remain dissolved in water on both sides of the reaction. In the following double replacement reaction, identify the spectator ions:

$$Mg(NO_3)_2 \text{ (aq)} + Na_2CO_3 \text{ (aq)} \rightarrow MgCO_3 \text{ (s)} + 2\ NaNO_3 \text{ (aq)}$$

Mg^{+2}: is found in the precipitate
NO_3^{-1}: is in (aq) compounds on both sides
Na^{+1}: is in (aq) compounds on both sides
CO_3^{-2}: is found in the precipitate

Therefore, NO_3^{-1} and Na^{+1} are the spectator ions for this reaction. They are not involved in the formation of the precipitate.

4) Stoichiometry of Equations (HW: p. 22-23)

Essential Question: How do we make the amount of chemical product that we need for the job?

It's time to make pancakes! The recipe calls for 1 egg, 1 cup of mix, 1 cup of milk, 2 tablespoons of oil, 1 ½ tablespoons of vanilla extract and 1/3 teaspoon of nutmeg. This will make sixteen 4" diameter pancakes. This will serve four people quite nicely, and make for a delicious breakfast. I recommend real maple syrup, as it is delicious and actually has some nutritional value.

But wait! Your grandparents and an aunt and uncle are coming to visit! You now have 8 people coming to breakfast, and the recipe only gives you instructions for four servings!!! Whatever shall you do? Easy! Use RATIOS to double the recipe and make enough to satisfy everyone's morning hunger!

Original recipe (serves four, makes 16 pancakes)	Doubled recipe (serves 8, makes 32 pancakes)
1 egg	2 eggs
1 cup mix	2 cups of mix
1 cup milk	2 cups of milk
2 tablespoons of oil	4 tablespoons of oil
1 ½ tablespoon of vanilla extract	3 tablespoons vanilla extract
1/3 teaspoon of nutmeg	2/3 teaspoon of nutmeg

Notice how the proportions of the ingredients AND the pancakes are preserved? Eat hearty!

This is also true of chemical reactions. The coefficients in front of each species lets you know what the proportional number of moles of reactant needed is to make a proportional number of moles of product. For example, in the manufacture of ammonia (called the Haber Process), a simple synthesis reaction is used:

$$N_2 + 3\ H_2 \rightarrow 2\ NH_3$$

What this means is that if nitrogen and hydrogen are reacted in a 1:3 mole ratio, the amount of ammonia you will produce from the reaction is 2 moles. This is important to know, because if your company gets a call for 10 moles of ammonia, you can use that 1:3 → 2 proportion to determine how many moles of nitrogen and hydrogen you have to react together in order to make the 10 moles of ammonia. Let's see how this scales up:

5 moles 15 moles 10 moles are needed!

$$1\ N_2 + 3\ H_2 \rightarrow 2\ NH_3$$

If you scale the ratio up by a factor of five, you will see that to make 10 moles of ammonia, you will have to combine 5 moles of nitrogen with 15 moles of hydrogen. This maintains the 1:3 → 2 ratio that the coefficients give you!

What if you needed 34.338 moles of NH_3? Is there an easy way to make use of the 1:3 → 2 ratio to figure that out? In fact, there is a very simple equation you can use:

How many moles of X are formed when n moles of Y are reacted?

$$\text{Moles of } \cancel{\text{given}} \times \frac{\text{Coefficient of target}}{\text{Coefficient of } \cancel{\text{given}}} = \text{Moles of target}$$

Notice that for each of the following problems, the given is written in ~~strikethrough mode~~, indicating that this unit cancels out to leave the target.

For the reaction N_2 (g) + 3 H_2 (g) → 2 NH_3 (g), how many moles of NH_3 will be formed if 6.0 moles of N_2 are completely reacted with H_2?

$$\text{Moles of } \cancel{\text{given}} \quad X \quad \frac{\text{Coefficient of target}}{\text{Coefficient of } \cancel{\text{given}}} = \text{Moles of target}$$

6.0 moles ~~N_2~~ X (2 NH_3 / 1 ~~N_2~~) = **12 moles of N_2**

For the reaction N_2 (g) + 3 H_2 (g) → 2 NH_3 (g), how many moles of H_2 are needed to completely react with N_2 to form 1000. moles of NH_3?

$$\text{Moles of } \cancel{\text{given}} \quad X \quad \frac{\text{Coefficient of target}}{\text{Coefficient of } \cancel{\text{given}}} = \text{Moles of target}$$

1000. moles ~~NH_3~~ X (3 H_2 / 2 ~~NH_3~~) = **1500. moles H_2**

For the reaction 2 Na + 2 H_2O → 2 NaOH + H_2, how many moles of Na are needed to make 4.0 moles of H_2?

$$\text{Moles of } \cancel{\text{given}} \quad X \quad \frac{\text{Coefficient of target}}{\text{Coefficient of } \cancel{\text{given}}} = \text{Moles of target}$$

4.0 moles ~~H_2~~ X (2 Na / 1 ~~H_2~~) = **8.0 moles Na**

For the reaction 4 Al + 3 O_2 → 2 Al_2O_3, how many moles of Al_2O_3 will form if 6.0 moles of Al are completely reacted with O_2?

$$\text{Moles of } \cancel{\text{given}} \quad X \quad \frac{\text{Coefficient of target}}{\text{Coefficient of } \cancel{\text{given}}} = \text{Moles of target}$$

6.0 moles ~~Al~~ X (2 Al_2O_3 / 4 ~~Al~~) = **3.0 moles Al_2O_3**

For the reaction 2 NaCl (aq)$^+$ $Pb(NO_3)_2$ (aq) → 2 $NaNO_3$ (aq) + $PbCl_2$ (s), how many moles of $PbCl_2$ precipitate will form when 5.0 moles of $Pb(NO_3)_2$ are completely reacted with NaCl?

$$\text{Moles of } \cancel{\text{given}} \quad X \quad \frac{\text{Coefficient of target}}{\text{Coefficient of } \cancel{\text{given}}} = \text{Moles of target}$$

5.0 moles ~~$Pb(NO_3)_2$~~ X (1 $PbCl_2$ / 1 ~~$Pb(NO_3)_2$~~) = **5.0 moles $PbCl_2$**

Student Name:________________________________ Grades: _____, _____, _____, _____
Balance Redox Dbl Repl Stoich

1) What is a Chemical Equation? Homework

A) Balance the following equations/reactions by placing small whole-number coefficients in front of the formulas. You may NOT change the formula of a compound. A number one (1) does not need to be written, but is helpful to do.

Reaction (fill in the coefficients)	Sum of Coefficients
____ C(s) + _____ H_2 (g) → _____ CH_4	
_____Fe (s) + _____ O_2 (g) → _____ Fe_2O_3	
____NaI (s) → _____ Na (s) + _____ I_2 (s)	
____ $C_6H_{12}O_6$ (s) → _____ C (s) + _____ H_2O (l	
_____ $AgNO_3$ (aq) + _____Cu (s) → _____Ag (s) + _____$Cu(NO_3)_2$ (aq)	
_____Na_2CO_3 (aq) + _____HCl (aq) → _____NaCl (aq) + _____H_2O (l) + _____CO_2 (g)	
_____H_2 (g) + _____Cl_2 (g) → _____HCl (g)	
_____N_2 (g) + _____O_2 (g) → _____N_2O_4 (g)	
_____CH_4 (g) + _____O_2 (g) → _____CO_2 (g) + _____H_2O (g)	
_____N_2 (g) + _____H_2 (g) → _____NH_3 (g)	
_____H_2O_2 (l) → _____H_2O (l) + _____O_2 (g)	
_____Al_2O_3 → _____Al (s)+ _____O_2 (g)	
_____C (g) + _____O_2 (g) → _____CO_2 (g)	
_____CuO (s) + _____C (s) → _____Cu (s) + _____CO_2 (g)	
_____$Ca(OH)_2$ (aq) + _____HCl (aq) → _____$CaCl_2$ (aq) + _____H_2O (l)	

B) What does the following mean in an equation?

(s)_________________ (l)___________________ (g)_________________ (aq)__________________

C) Write the formulas for the following compounds:

Name	Formula	Name	Formula
sodium oxide		lead (II) carbonate	
potassium sulfate		lead (IV) carbonate	
iron (II) chloride		zinc phosphate	
iron (III) chloride		zinc phosphide	

D) Write the formulas given the names below and balance the reactions:

1) iron + nitrogen gas → iron (II) nitride

2) lead + copper (II) nitrate → lead (II) nitrate + copper

3) calcium + dihydrogen monoxide → calcium hydroxide + hydrogen gas

4) potassium phosphate + iron (II) nitrate → potassium nitrate + iron (II) phosphate

E) Find the missing mass!

1) If 15.0 grams of nitrogen are reacted with 3.2 grams of hydrogen gas to form ammonia, how many grams of ammonia will be formed?

2) If 37.0 grams of zinc react with hydrochloric acid (HCl) to form 77.2 grams of zinc chloride and 1.1 grams of hydrogen gas, how many grams of HCl were reacted?

3) How many grams of aluminum oxide must decompose to form 112.0 grams of aluminum metal and 99.6 grams of oxygen gas?

2) Oxidation and Reduction Reactions Homework

MAKE SURE TO INCLUDE THE CHARGES WHEN IDENTIFYING ALL SPECIES

Al^{+3}, not Al	**Na^{0}, not Na**	**Cl^{-1}, not Cl**

A) Multiple Choice Questions: Place your answer in the space in front of each question.

_____1) In the reaction 2 Na + 2 HNO_3 → 2 $NaNO_3$ + H_2, which species is the spectator ion?
a) Na^{0} b) H^{+1} c) NO_3^{-1} d) Na^{+1}

Why is this the spectator ion? Explain, in terms of *ion charge*.

_____2) In the reaction Zn + 2 HNO_3 → _________ + H_2, the missing product is
a) $Zn(NO_3)_2$ b) $(NO_3)_2Zn$ c) $ZnNO_3$ d) NO_3Zn

_____3) In the reaction 2________ → 2 Pb + O_2, the missing product is
a) PbO b) OPb c) PbO_2 d) O_2Pb

B) Identify the type of reaction shown:

Reaction	What Type?	How Did You Know?
KBr + Na → NaBr + K		
2 $LiNO_3$ + Ca → $Ca(NO_3)_2$ + 2 Li		
2 Fe + 3 Cl_2 → 2 $FeCl_3$		
2 Li_2O → 4 Li + O_2		

C) Write the charges of each species, then identify which species are oxidized, reduced and spectator ions in the following reactions:

1) Ag_2 S → 2 Ag + S

OXIDIZED:________________ Reduced:_________________ Spectator Ion:____________

2) K Br + Na → Na Br + K

OXIDIZED:________________ Reduced:_________________ Spectator Ion:____________

3) 2 Li NO_3 + Ca → Ca $(NO_3)_2$ + 2 Li
OXIDIZED:________________ Reduced:_________________ Spectator Ion:____________

4) 2 Fe + 3 Cl_2 → 2 Fe Cl_3
OXIDIZED:________________ Reduced:_________________ Spectator Ion:____________

5) 2 Li_2 O → 4 Li + O_2
OXIDIZED:________________ Reduced:_________________ Spectator Ion:____________

D) Complete the following reactions by writing the appropriate formula(s) and balancing:

a) 2 Na + Br_2 →2 _______________
b) 3 Zn + 2 $Fe(NO_3)_3$ → 3 _______________________ + 2Fe
c) 2 BaO → 2 Ba + ______________
d) 2 Sc + 3 $CuSO_4$ → $Sc_2(SO_4)_3$ + 3 ________________________
e) 2 NO_2 → ________________ + 2 O_2
f) 2______________ + S → Li_2S
g) Cu + 2 ______________________→ $Cu(NO_2)_2$ + 2 K
h) Mg + ____________________________ → $MgCl_2$
i) 2 __________________→ 6 Li + N_2
j) 2 Na + _____________________________ → Na_2CO_3 + Ca

3) Double Replacement Homework

A) Determine whether the following compounds are soluble or insoluble:

Compound	Soluble or Insoluble?	Why?
Na_2CO_3		
CaS		
$PbBr_2$		
$Al(OH)_3$		
$(NH_4)_2CrO_4$		

B) CIRCLE the precipitate (PRODUCT that is insoluble) in the following double replacement reactions:

Reaction (place a circle around the precipitate in each one)
$3\ Ca(NO_3)_2 + 2\ K_3PO_4 \rightarrow 6\ KNO_3 + Ca_3(PO_4)_2$
$AgNO_3 + NaOH \rightarrow NaNO_3 + AgOH$
$Na_2SO_4 + Ba(ClO_3)_2 \rightarrow 2\ NaClO_3 + BaSO_4$
$(NH_4)_2CO_3 + Ca(C_2H_3O_2)_2 \rightarrow CaCO_3 + 2\ NH_4C_2H_3O_2$
$2\ AgNO_3 + Li_2CrO_4 \rightarrow 2\ LiNO_3 + Ag_2CrO_4$

C) Find the missing product in each of the following balanced double-replacement reactions:

a) $CaCl_2 + Na_2CO_3 \rightarrow CaCO_3 + 2$ ________________

b) $(NH_4)_2CO_3 + Cu(NO_3)_2 \rightarrow CuCO_3 + 2$________________

c) $2\ Li_3PO_4 + 3\ Fe(NO_3)_2 \rightarrow 6\ LiNO_3 +$ __________________

d) $Pb(ClO_3)_2 + 2\ KBr \rightarrow PbBr_2 + 2$ ____________________

D) Circle the precipitate formed in each reaction in C), above.

E) Answer the following questions:

1) Explain why ion exchange reactions are not considered to be redox reactions.

2) Explain the difference between spectator ions in redox reactions and spectator ions in ion exchange reactions.

What is a spectator ion in a redox reaction?	
What is a spectator ion in a double replacement reaction?	

4) Hard water contains relatively high concentrations of magnesium and calcium ions from groundwater. When hard water comes into contact with soap (sodium stearate), it forms a precipitate called "soap scum". Using a water softener uses special beads called "resin". This resin is flushed with salt water and the sodium sticks to the resin. Then, when tap water is passed through it, the sodium ions are released into the water and the calcium and magnesium ions get stuck onto the resin in their place. During the recharge cycle, the calcium and magnesium are flushed into the sewage drain and new sodium takes their place.

a) Complete the reaction that produces soap scum precipitate:

$$CaCO_3\ (aq) + 2\ Na(C_{17}H_{35}COO)\ (aq) \rightarrow Ca(C_{17}H_{35}COO)_2 + \underline{\hspace{4cm}}$$

b) Calcium carbonate is mostly, but not entirely insoluble in water. It can dissolve to very small degrees. Over the period of years, it can build up precipitate (lime scale) on water pipes, sinks and bathtubs. You can clean limescale away with vinegar ($HC_2H_3O_2$), because acids react with carbonate compounds as follows. Fill in the blank with the formula of the missing substance. Note that the reaction is balanced…use the Law of Conservation of Mass to identify the ions in the compound and the charges of those ions to write the formula.

$$2\ HC_2H_3O_2\ (aq) + CaCO_3\ (s) \rightarrow \underline{\hspace{4cm}}(aq) + CO_2\ (g) + H_2O\ (l)$$

c) While not technically a double replacement reaction, why is this not considered to be a redox reaction?

4) Stoichiometry of Equations Homework

For ALL mole conversion problems, show ALL of your work, including showing which units cancel out by putting a slash through them.

A) For the reaction N_2 (g) + H_2 (g) → NH_3 (g):

1) Balance the reaction:
_____N_2 (g) + _____H_2 (g) → _____NH_3 (g)

2) How many moles of N_2 are needed to make 5.0 moles of NH_3?

3) How many moles of N_2 are needed to completely react with 10.0 moles of H_2?

4) How many moles of NH_3 should form if 6.0 moles of H_2 are completely reacted with N_2?

B) For the reaction Zn (s) + HBr (aq) → $ZnBr_2$ (aq) + H_2 (g)

1) Balance the reaction:
_____Zn (s) + _____HBr (aq) → _____$ZnBr_2$ (aq) + _____H_2 (g)

2) How many moles of Zn are needed to make 8.0 moles of $ZnBr_2$?

3) How many moles of HBr are needed to make 4.0 moles of H_2?

4) How many moles of $ZnBr_2$ should form if 5.0 moles of HBr are completely reacted with Zn?

C) For the reaction Ca (s) + N_2 (g) → Ca_3N_2 (s)

1) Balance the reaction:

_____Ca (s) + _____N_2 (g) → _____Ca_3N_2 (s)

2) How many moles of Ca are required to form 4.00 moles of Ca_3N_2?

3) How many moles of Ca_3N_2 will form if 2.50 moles of N_2 are reacted?

4) How many moles of Ca are needed to completely react with 5.00 moles of N_2?

D) For the reaction Al + $MgCl_2$ → $AlCl_3$ + Mg

1) Balance the reaction:

_____Al + _____$MgCl_2$ → _____$AlCl_3$ + _____Mg

2) How many moles of Mg will be formed if 35.0 moles of Al are reacted?

3) How many moles of $MgCl_2$ are required to completely react with 15.0 moles of Al?

4) How many moles of $AlCl_3$ will be formed if 13.0 moles of Mg are formed?