

## Reactions

<b>Word</b>	<b>Definition</b>
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.

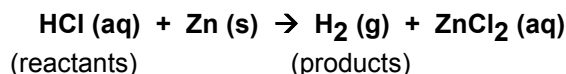
# 1) What is a Chemical Equation? (HW: p. 16, 17)

**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.

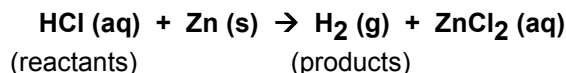
**Reactants → Products**

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.



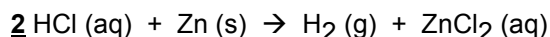
This says that hydrochloric acid reacts with zinc metal to form hydrogen gas and zinc chloride.

**THE LAW OF CONSERVATION OF MASS** – 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.



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

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



This shows that 2 moles of HCl are required to react with 1 mole of Zn. H<sub>2</sub> 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<sub>2</sub>)

**2 Cl** means that there are **TWO ATOMS of chlorine**. **Cl<sub>2</sub>** means that there is **one molecule of diatomic chlorine**.

Diatomic molecules (Br<sub>2</sub>, I<sub>2</sub>, N<sub>2</sub>, Cl<sub>2</sub>, H<sub>2</sub>, O<sub>2</sub>, F<sub>2</sub>) exist whenever these elements are not in a compound with another element. In NaCl, there is one Cl<sup>-1</sup> ion (since Na is charged +1), but if that chlorine is separated from that compound:



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

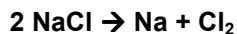


How do we balance this reaction? Look at the next page!



\* There is one Na on the left and one Na on the right. Na is balanced...for now.

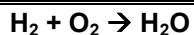
\* There is one Cl on the left and one Cl on the right. Multiply them together:  $1 \times 2 = 2$ . This means that when balanced, there should be two chlorine atoms on each side. There are already two on the right, so put a 2 coefficient in front of NaCl:



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

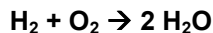


\* There are now 2 Na's on both sides and 2 Cl's on both sides. This reaction is balanced.

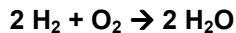


\* There are two H's on the left and two H's on the right. H is balanced...for now.

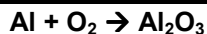
\* There are two O's on the left and only one on the right. Multiply:  $2 \times 1 = 2$ . There should be two O's on either side to be balanced. Put a 2 in front of H<sub>2</sub>O to accomplish this:



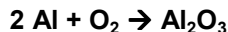
\* This messes up the balancing of H. To remedy this, put a 2 in front of the H<sub>2</sub> on the left:



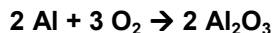
\* There are now 4 H's on both sides and 2 O's on both sides. This reaction is balanced.



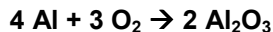
\* There is one Al on the left and two on the right. Multiply  $1 \times 2 = 2$ . There should be 2 on each side, so put a 2 in front of Al on the left:



\* There are two O's on the left and three on the right. Multiply  $2 \times 3 = 6$ . 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<sub>2</sub> on the left. Three times what is six? Two! Put a 2 in front of the Al<sub>2</sub>O<sub>3</sub> on the right. The reaction now looks like:



\* 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:



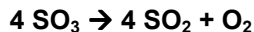
\* There are now 4 Al's on each side and 6 O's on both sides. Bravo! It's balanced.



- \* 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  $\text{SO}_2$  and two in the  $\text{O}_2$ . Multiply:  $3 \times 4 = 12$ . 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  $\text{SO}_3$ . The reaction now looks like



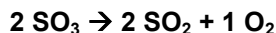
- \* Now place a 4 in front of the  $\text{SO}_2$  to balance off the S:



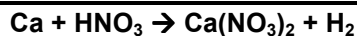
- \* Now, there are 8 O's in the  $\text{SO}_2$  and two in the  $\text{O}_2$ . Remember, we need twelve O's on each side. What We need two more O's on the right side. How can we do that without messing up S again? Right! Put a 2 in front of the  $\text{O}_2$ .



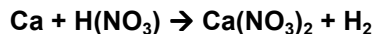
- \* Now there are 4 S's on both sides and 12 O's. It's balanced! Note, however, that the coefficients can be simplified to



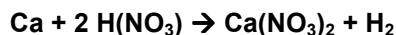
- \* If a reaction's coefficients can be simplified in this way, you have to do it...otherwise, the Balancing Police will come and drag you away in handcuffs (well, covalent bonds, really...but you get the point).



- \* 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:

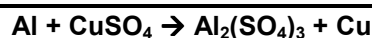


- \* There is one Ca on either side. Ca is good. Will it stay that way? The suspense is killing me!
- \* There is one H on the left and two on the right.  $1 \times 2 = 2$ , so there should be 2 H's on either side. Place a 2 in front of  $\text{H}(\text{NO}_3)$ :

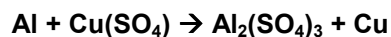


- \* There are two  $\text{NO}_3$ 's on the left and also two on the right! No balancing of  $\text{NO}_3$  is necessary

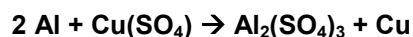
Let's see...1 Ca on both sides, 2 H's on both sides and 2  $\text{NO}_3$ 's on both sides? I'd say this sucker is balanced! ☺



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

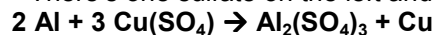


\* There is one Al on the left, two on the right.  $1 \times 2 = 2$ , so there should be two Al's on both sides. Place a 2 in front of the Al on the left:

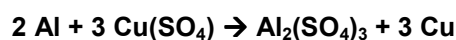


\* There is one Cu on both sides. Leave it alone...for now.

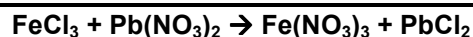
\* There's one sulfate on the left and three on the right!  $1 \times 3 = 3$ , so place a 3 in front of the  $\text{CuSO}_4$  on the left:



\* 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:



\* There are now 2 Al's on each side, 3 Cu's on each side and 3  $\text{SO}_4$ 's on each side. The reaction is now balanced!

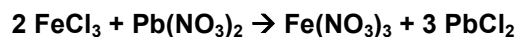


\* This is the nastiest it will get for you. There are four things that have to be balanced. Be patient and do on at a time.

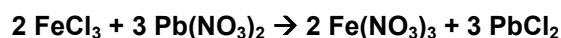
\* There is one Fe on each side. Let it be for now.

\* 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.  $2 \times 3 = 6$ , 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  $\text{FeCl}_3$ . On the right, two times what equals six? Three! Put a 3 in front of  $\text{PbCl}_2$ . The reaction should now look like:



\* Now let's deal with the nitrate. There are two  $\text{NO}_3$ 's on the left and three on the right.  $2 \times 3 = 6$ , so there should be six on each side. On the left,  $2 \times 3 = 6$ , so put a 3 in front of the  $\text{Pb}(\text{NO}_3)_2$ . On the right,  $3 \times 2 = 6$ , so put a 2 in front of the  $\text{Fe}(\text{NO}_3)_3$ . Now there are six nitrates on each side:



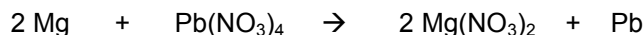
\* Now check out what happened to Fe and Pb! There are now 2 Fe's on both sides and 3 Pb's on each side. Balancing the chloride and the nitrate automatically balanced the Fe and the Pb! Nice, how things work out sometimes. This baby be balanced!!!!

## 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  
 $\text{Mg} \quad \text{Pb}(\text{NO}_3)_4 \rightarrow \text{Mg}(\text{NO}_3)_2 + \text{Pb}$

Then balance!



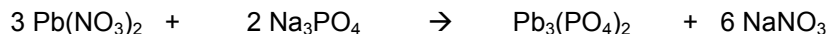
Copper + oxygen gas → copper (I) oxide  
 $\text{Cu} + \text{O}_2 \rightarrow \text{Cu}_2\text{O}$

Then balance!



Lead (II) nitrate + sodium phosphate → lead (II) phosphate + sodium nitrate  
 $\text{Pb}(\text{NO}_3)_2 + \text{Na}_3\text{PO}_4 \rightarrow \text{Pb}_3(\text{PO}_4)_2 + \text{NaNO}_3$

Then balance!



## 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?

$$35.0 + X = 42.5, \text{ so } X = \mathbf{7.5 \text{ grams of hydrogen gas}}$$

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

$$45.0 = X + 21.1, \text{ so } X = \mathbf{23.9 \text{ grams of aluminum are formed}}$$

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

$$X = 33.0 + 19.0, \text{ so } \mathbf{52.0 \text{ grams of iron (II) sulfide must be decomposed.}}$$

## 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”.

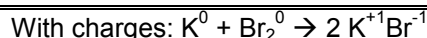
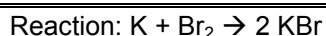
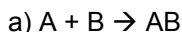
Redox (oxidation-reduction) - a reaction prompted by an exchange in electrons between two elements, resulting in a change of oxidation number of the two elements.

- 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)

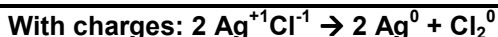
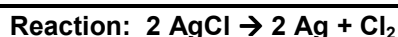
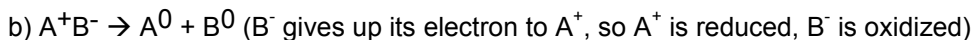
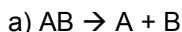
Two elements combine to form a compound. **This is the easiest way to make a compound, and is often used in industry for that purpose.**



**$K^0$  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.**

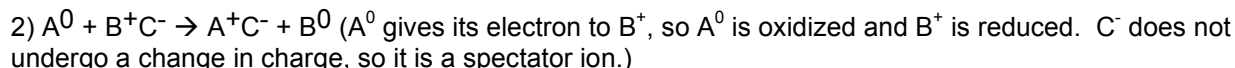
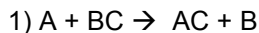


$Ag^+$  goes from +1 to 0, so it is reduced. It gains electrons from  $Cl^-$ , which goes from -1 to 0 and is oxidized.

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

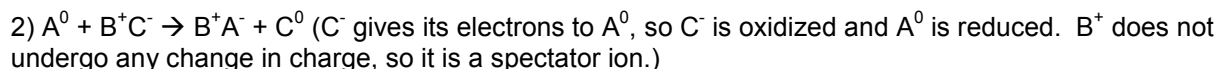
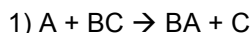
Two possibilities.

**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.**



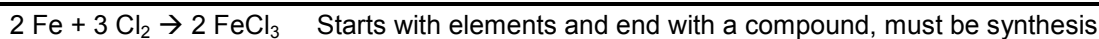
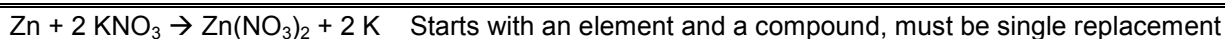
$Zn^0$  goes from 0 to +2, so it is oxidized. It loses electrons to  $Cu^{+2}$ , which goes from +2 to 0 and is reduced.  $NO_3^{-1}$  does not change charge, so it is the **spectator ion**.

**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..**



$F^0$  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?



### WHAT YOU HAVE TO BE ABLE TO DO:

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

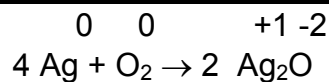
a) **Elements by themselves have no charge.**  $Al^0$ ,  $Cl_2^0$ ,  $Fe^0$

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.

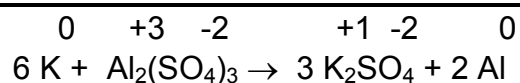


$Fe_3(PO_4)_2$ : Fe has 2 charges listed (+2 and +3).  $PO_4$  is listed on Table E as being -3. To make the charges add up to zero, Fe must have a +2 charge:  $Fe_3^{+2}(PO_4)_2^{-3}$ . For Fe:  $3 \times +2 = +6$ . For  $PO_4$ :  $2 \times -3 = -6$ . +6 and -6 add up to ZERO.

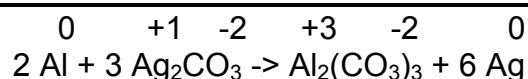
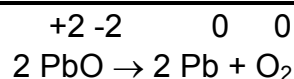
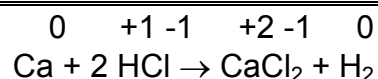
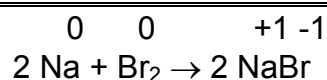
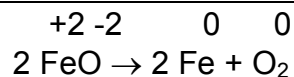




Note the elements that are by themselves have a charge of **0**



Note that the sum of the ion charges in each of the compounds is ZERO.

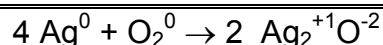


## **2) Ho Do You Determine Which Species Is Oxidized And Which Is Reduced And Which Is The Spectator Ion?**

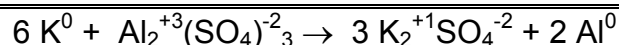
The species that is OXIDIZED has lost electrons, and its oxidation number has become more POSITIVE

The species that is REDUCED has gained electrons, and its oxidation number has become more NEGATIVE

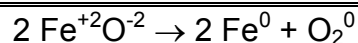
The species that is the SPECTATOR ION neither gains nor loses electrons, and its charge REMAINS THE SAME.



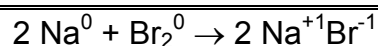
OX (charge more +):  $\text{Ag}^0$       RD (charge more -):  $\text{O}_2^0$       SI (no change): none



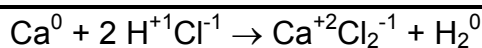
OX (charge more +):  $\text{K}^0$       RD (charge more -):  $\text{Al}^{+3}$       SI (no change):  $\text{SO}_4^{-2}$



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



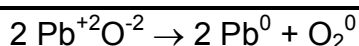
OX (charge more +):  $\text{Na}^0$       RD (charge more -):  $\text{Br}_2^0$       SI (no change): none



OX (charge more +):  $\text{Ca}^0$

RD (charge more -):  $\text{H}^{+1}$

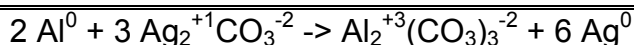
SI (no change):  $\text{Cl}^{-1}$



OX (charge more +):  $\text{O}^{-2}$

RD (charge more -):  $\text{Pb}^{+2}$

SI (no change): none



OX (charge more +):  $\text{Al}^0$

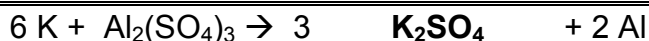
RD (charge more -):  $\text{Ag}^{+1}$

SI (no change):  $\text{CO}_3^{-2}$

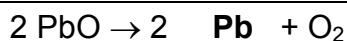
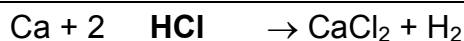
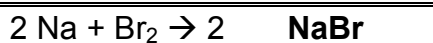
### 3) How Do You Find The Missing Species?

1) If the missing species is an **ELEMENT**, just write its symbol. If it diatomic ( $\text{Br}_2$ ,  $\text{I}_2$ ,  $\text{N}_2$ ,  $\text{Cl}_2$ ,  $\text{H}_2$ ,  $\text{O}_2$ ,  $\text{F}_2$ ), 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.



The missing species are 6 K's and 3  $\text{SO}_4$ 's. Since there is a 3 coefficient, the compound contains 2 K's ( $3 \times 2 = 6$  K's) and 1  $\text{SO}_4$  ( $3 \times 1 = 3$   $\text{SO}_4$ 's).



The missing species are 6 Ag's and 3  $\text{CO}_3$ 's. Since there is a 3 coefficient, the compound contains 2 Ag's ( $3 \times 2 = 6$  Ag's) and 1  $\text{CO}_3$  ( $3 \times 1 = 3$   $\text{CO}_3$ '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 ( $\delta +$ ) attaches to the  $-$  ion. The oxygen end of the water molecule ( $\delta -$ ) 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	Ions That Form Insoluble Compounds	Exceptions
Group 1 ions ( $\text{Li}^+$ , $\text{Na}^+$ , etc.)		carbonate ( $\text{CO}_3^{2-}$ )	when combined with Group 1 ions or ammonium ( $\text{NH}_4^+$ )
ammonium ( $\text{NH}_4^+$ )		chromate ( $\text{CrO}_4^{2-}$ )	when combined with Group 1 ions, $\text{Ca}^{2+}$ , $\text{Mg}^{2+}$ , or ammonium ( $\text{NH}_4^+$ )
nitrate ( $\text{NO}_3^-$ )		phosphate ( $\text{PO}_4^{3-}$ )	when combined with Group 1 ions or ammonium ( $\text{NH}_4^+$ )
acetate ( $\text{C}_2\text{H}_3\text{O}_2^-$ or $\text{CH}_3\text{COO}^-$ )		sulfide ( $\text{S}^{2-}$ )	when combined with Group 1 ions or ammonium ( $\text{NH}_4^+$ )
hydrogen carbonate ( $\text{HCO}_3^-$ )		hydroxide ( $\text{OH}^-$ )	when combined with Group 1 ions, $\text{Ca}^{2+}$ , $\text{Ba}^{2+}$ , $\text{Sr}^{2+}$ , or ammonium ( $\text{NH}_4^+$ )
chlorate ( $\text{ClO}_3^-$ )			
perchlorate ( $\text{ClO}_4^-$ )			
halides ( $\text{Cl}^-$ , $\text{Br}^-$ , $\text{I}^-$ )	when combined with $\text{Ag}^+$ , $\text{Pb}^{2+}$ , and $\text{Hg}_2^{2+}$		
sulfates ( $\text{SO}_4^{2-}$ )	when combined with $\text{Ag}^+$ , $\text{Ca}^{2+}$ , $\text{Sr}^{2+}$ , $\text{Ba}^{2+}$ , and $\text{Pb}^{2+}$		

**Table F**  
**Solubility Guidelines for Aqueous Solutions**

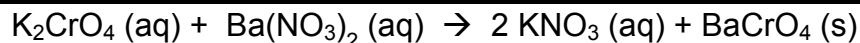
Compound	Soluble or Insoluble?	Why?
$\text{Li}_2\text{CO}_3$	Soluble	$\text{Li}^{+1}$ is a group 1 ion, and Group 1 ions are always soluble, with no exceptions.
$\text{Pb}(\text{NO}_3)_2$	Soluble	$\text{NO}_3^{-1}$ is listed as being always soluble, no exceptions.
$\text{ZnCl}_2$	Soluble	$\text{Cl}^{-1}$ is a halide, which are listed as being soluble, with a few exceptions. However, $\text{Zn}^{+2}$ is not one of those exceptions.
$\text{BaSO}_4$	Soluble	$\text{SO}_4^{-2}$ is listed as being soluble, with a few exceptions. However, $\text{Ba}^{+2}$ is not one of those exceptions.
$\text{Ca}(\text{HCO}_3)_2$	Soluble	$\text{HCO}_3^{-1}$ is listed as being soluble, with a few exceptions. However, $\text{Ca}^{+2}$ is not one of those exceptions.
$\text{CuCO}_3$	Inoluble	$\text{CO}_3^{-2}$ is listed as being insoluble, with a few exceptions. However, $\text{Cu}^{+2}$ is not one of those exceptions, because it is not a Group 1 ion.
$\text{Pb}(\text{CrO}_4)_2$	Inoluble	$\text{CrO}_4^{-2}$ is listed as being insoluble, with a few exceptions. However, $\text{Pb}^{+2}$ is not one of those exceptions, because it is not a Group 1 ion.
$\text{Na}_3\text{PO}_4$	Soluble	$\text{Na}^{+1}$ is a group 1 ion, and Group 1 ions are always soluble, with no exceptions.
$\text{NH}_4\text{OH}$	Soluble	$\text{NH}_4^{+1}$ is listed as being always soluble, no exceptions.
$\text{Mg}(\text{OH})_2$	Inoluble	$\text{OH}^{-1}$ is listed as being insoluble, with a few exceptions. However, $\text{Mg}^{+2}$ is not one of those exceptions, because it is not a Group 1 ion.

## Double Replacement reaction

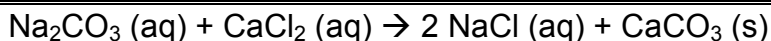
The positive ion of one compound swaps places with the negative ion from the other compound. This reaction is carried out with aqueous solutions of each reactant so that the ions can more easily mix and react.



Solution AB (which is made of separated ions  $\text{A}^+$  and  $\text{B}^-$ ) is mixed into solution CD (which is made of separated ions  $\text{C}^+$  and  $\text{D}^-$ ). Instantly upon mixing, the  $\text{A}^+$  ions of the first solution seek out and bond very tightly to the  $\text{D}^-$  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.



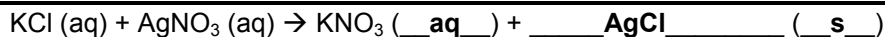
Taking a look at the two products on Table F:  $\text{K}^{+1}$  is a Group 1 ion, so it is always soluble, no exceptions.  $\text{NO}_3^{-1}$  is also always soluble, no exceptions. On the other hand,  $\text{CrO}_4^{-2}$  is listed as being insoluble with exceptions, but  $\text{Ba}^{+2}$  is not one of those exceptions.  $\text{BaCrO}_4$  is the precipitate in this reaction.



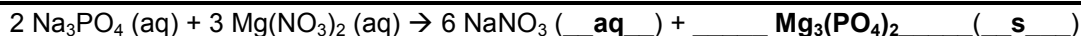
Taking a look at the two products on Table F:  $\text{Na}^{+1}$  is a Group 1 ion, so it is always soluble, no exceptions.  $\text{Cl}^{-1}$  is usually soluble, and  $\text{Na}^{+1}$  is not an exception. On the other hand,  $\text{CO}_3^{-2}$  is listed as being insoluble with exceptions, but  $\text{Ca}^{+2}$  is not one of those exceptions.  $\text{CaCO}_3$  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!

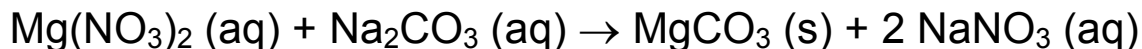


The missing compound will contain Ag and Cl. Since no coefficient is given, the formula is AgCl. Based on Reference F,  $\text{KNO}_3$  is soluble (aq), and the AgCl is the insoluble precipitate (s).



The missing compound contains Mg and  $\text{PO}_4$ . The reactants side contains 2  $\text{PO}_4$ 's and 3 Mg's. There is no coefficient given for the missing product, so the formula is  $\text{Mg}_3(\text{PO}_4)_2$ . Based on Reference Table F,  $\text{NaNO}_3$  is soluble and  $\text{Mg}_3(\text{PO}_4)_2$  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:**



$\text{Mg}^{+2}$ : is found in the precipitate

$\text{NO}_3^{-1}$ : is in (aq) compounds on both sides

$\text{Na}^{+1}$ : is in (aq) compounds on both sides

$\text{CO}_3^{-2}$ : is found in the precipitate

Therefore,  $\text{NO}_3^{-1}$  and  $\text{Na}^{+1}$  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?

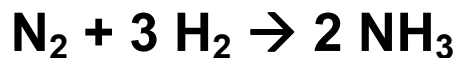
It's time to make pancakes! The recipe calls for 1 egg, 1 cup of mix, 1 cup of milk, 2 tablespoons of oil, 1 ½ tablespoons of vanilla extract and 1/3 teaspoon of nutmeg. This will make sixteen 4" diameter pancakes. This will serve four people quite nicely, and make for a delicious breakfast. I recommend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

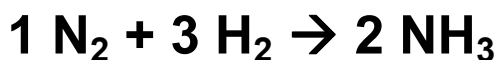
Notice how the proportions of the ingredients AND the pancakes are preserved? Eat hearty!

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:



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!



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<sub>3</sub>? 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?**

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

**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  $\text{N}_2 (\text{g}) + 3 \text{H}_2 (\text{g}) \rightarrow 2 \text{NH}_3 (\text{g})$ , how many moles of  $\text{NH}_3$  will be formed if 6.0 moles of  $\text{N}_2$  are completely reacted with  $\text{H}_2$ ?

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

$$6.0 \text{ moles } \text{N}_2 \times (2 \text{ NH}_3 / 1 \text{ N}_2) = \mathbf{12 \text{ moles of N}_2}$$

For the reaction  $\text{N}_2 (\text{g}) + 3 \text{H}_2 (\text{g}) \rightarrow 2 \text{NH}_3 (\text{g})$ , how many moles of  $\text{H}_2$  are needed to completely react with  $\text{N}_2$  to form 1000. moles of  $\text{NH}_3$ ?

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

$$1000. \text{ moles } \text{NH}_3 \times (3 \text{ H}_2 / 2 \text{ NH}_3) = \mathbf{1500. \text{ moles H}_2}$$

For the reaction  $2 \text{Na} + 2 \text{H}_2\text{O} \rightarrow 2 \text{NaOH} + \text{H}_2$ , how many moles of  $\text{Na}$  are needed to make 4.0 moles of  $\text{H}_2$ ?

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

$$4.0 \text{ moles } \text{H}_2 \times (2 \text{ Na} / 1 \text{ H}_2) = \mathbf{8.0 \text{ moles Na}}$$

For the reaction  $4 \text{Al} + 3 \text{O}_2 \rightarrow 2 \text{Al}_2\text{O}_3$ , how many moles of  $\text{Al}_2\text{O}_3$  will form if 6.0 moles of  $\text{Al}$  are completely reacted with  $\text{O}_2$ ?

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

$$6.0 \text{ moles } \text{Al} \times (2 \text{ Al}_2\text{O}_3 / 4 \text{ Al}) = \mathbf{3.0 \text{ moles Al}_2\text{O}_3}$$

For the reaction  $2 \text{NaCl} (\text{aq}) + \text{Pb}(\text{NO}_3)_2 (\text{aq}) \rightarrow 2 \text{NaNO}_3 (\text{aq}) + \text{PbCl}_2 (\text{s})$ , how many moles of  $\text{PbCl}_2$  precipitate will form when 5.0 moles of  $\text{Pb}(\text{NO}_3)_2$  are completely reacted with  $\text{NaCl}$ ?

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

$$5.0 \text{ moles } \text{Pb}(\text{NO}_3)_2 \times (1 \text{ PbCl}_2 / 1 \text{ Pb}(\text{NO}_3)_2) = \mathbf{5.0 \text{ moles PbCl}_2}$$

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 <sub>2</sub> (g) → _____ CH <sub>4</sub>	
_____ Fe (s) + _____ O <sub>2</sub> (g) → _____ Fe <sub>2</sub> O <sub>3</sub>	
_____ NaI (s) → _____ Na (s) + _____ I <sub>2</sub> (s)	
_____ C <sub>6</sub> H <sub>12</sub> O <sub>6</sub> (s) → _____ C (s) + _____ H <sub>2</sub> O (l)	
_____ AgNO <sub>3</sub> (aq) + _____ Cu (s) → _____ Ag (s) + _____ Cu(NO <sub>3</sub> ) <sub>2</sub> (aq)	
_____ Na <sub>2</sub> CO <sub>3</sub> (aq) + _____ HCl (aq) → _____ NaCl (aq) + _____ H <sub>2</sub> O (l) + _____ CO <sub>2</sub> (g)	
_____ H <sub>2</sub> (g) + _____ Cl <sub>2</sub> (g) → _____ HCl (g)	
_____ N <sub>2</sub> (g) + _____ O <sub>2</sub> (g) → _____ N <sub>2</sub> O <sub>4</sub> (g)	
_____ CH <sub>4</sub> (g) + _____ O <sub>2</sub> (g) → _____ CO <sub>2</sub> (g) + _____ H <sub>2</sub> O (g)	
_____ N <sub>2</sub> (g) + _____ H <sub>2</sub> (g) → _____ NH <sub>3</sub> (g)	
_____ H <sub>2</sub> O <sub>2</sub> (l) → _____ H <sub>2</sub> O (l) + _____ O <sub>2</sub> (g)	
_____ Al <sub>2</sub> O <sub>3</sub> → _____ Al (s) + _____ O <sub>2</sub> (g)	
_____ C (g) + _____ O <sub>2</sub> (g) → _____ CO <sub>2</sub> (g)	
_____ CuO (s) + _____ C (s) → _____ Cu (s) + _____ CO <sub>2</sub> (g)	
_____ Ca(OH) <sub>2</sub> (aq) + _____ HCl (aq) → _____ CaCl <sub>2</sub> (aq) + _____ H <sub>2</sub> O (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  $\rightarrow$  iron (II) nitride

2) lead + copper (II) nitrate  $\rightarrow$  lead (II) nitrate + copper

3) calcium + dihydrogen monoxide  $\rightarrow$  calcium hydroxide + hydrogen gas

4) potassium phosphate + iron (II) nitrate  $\rightarrow$  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

$\text{Al}^{+3}$ , not Al

$\text{Na}^0$ , not Na

$\text{Cl}^{-1}$ , not Cl

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

\_\_\_\_\_ 1) In the reaction  $2 \text{Na} + 2 \text{HNO}_3 \rightarrow 2 \text{NaNO}_3 + \text{H}_2$ , which species is the spectator ion?  
 a)  $\text{Na}^0$                       b)  $\text{H}^{+1}$                       c)  $\text{NO}_3^{-1}$                       d)  $\text{Na}^{+1}$

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

\_\_\_\_\_ 2) In the reaction  $\text{Zn} + 2 \text{HNO}_3 \rightarrow \text{_____} + \text{H}_2$ , the missing product is  
 a)  $\text{Zn}(\text{NO}_3)_2$                       b)  $(\text{NO}_3)_2\text{Zn}$                       c)  $\text{ZnNO}_3$                       d)  $\text{NO}_3\text{Zn}$

\_\_\_\_\_ 3) In the reaction  $2 \text{_____} \rightarrow 2 \text{Pb} + \text{O}_2$ , the missing product is  
 a) PbO                      b) OPb                      c)  $\text{PbO}_2$                       d)  $\text{O}_2\text{Pb}$

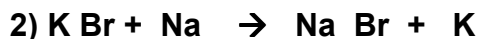
**B) Identify the type of reaction shown:**

Reaction	What Type?	How Did You Know?
$\text{KBr} + \text{Na} \rightarrow \text{NaBr} + \text{K}$		
$2 \text{LiNO}_3 + \text{Ca} \rightarrow \text{Ca}(\text{NO}_3)_2 + 2 \text{Li}$		
$2 \text{Fe} + 3 \text{Cl}_2 \rightarrow 2 \text{FeCl}_3$		
$2 \text{Li}_2\text{O} \rightarrow 4 \text{Li} + \text{O}_2$		

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



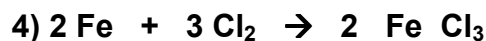
OXIDIZED: \_\_\_\_\_ Reduced: \_\_\_\_\_ Spectator Ion: \_\_\_\_\_



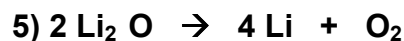
OXIDIZED: \_\_\_\_\_ Reduced: \_\_\_\_\_ Spectator Ion: \_\_\_\_\_



OXIDIZED: \_\_\_\_\_ Reduced: \_\_\_\_\_ Spectator Ion: \_\_\_\_\_

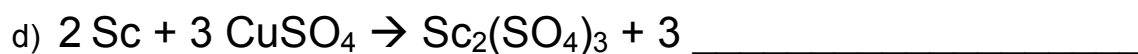
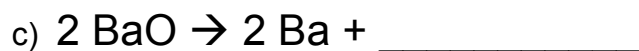
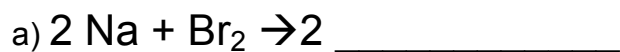


OXIDIZED: \_\_\_\_\_ Reduced: \_\_\_\_\_ Spectator Ion: \_\_\_\_\_



OXIDIZED: \_\_\_\_\_ Reduced: \_\_\_\_\_ Spectator Ion: \_\_\_\_\_

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



### 3) Double Replacement Homework

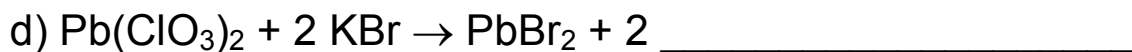
**A) Determine whether the following compounds are soluble or insoluble:**

Compound	Soluble or Insoluble?	Why?
$\text{Na}_2\text{CO}_3$		
$\text{CaS}$		
$\text{PbBr}_2$		
$\text{Al}(\text{OH})_3$		
$(\text{NH}_4)_2\text{CrO}_4$		

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

Reaction (place a circle around the precipitate in each one)
$3 \text{Ca}(\text{NO}_3)_2 + 2 \text{K}_3\text{PO}_4 \rightarrow 6 \text{KNO}_3 + \text{Ca}_3(\text{PO}_4)_2$
$\text{AgNO}_3 + \text{NaOH} \rightarrow \text{NaNO}_3 + \text{AgOH}$
$\text{Na}_2\text{SO}_4 + \text{Ba}(\text{ClO}_3)_2 \rightarrow 2 \text{NaClO}_3 + \text{BaSO}_4$
$(\text{NH}_4)_2\text{CO}_3 + \text{Ca}(\text{C}_2\text{H}_3\text{O}_2)_2 \rightarrow \text{CaCO}_3 + 2 \text{NH}_4\text{C}_2\text{H}_3\text{O}_2$
$2 \text{AgNO}_3 + \text{Li}_2\text{CrO}_4 \rightarrow 2 \text{LiNO}_3 + \text{Ag}_2\text{CrO}_4$

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



**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:



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 ( $\text{HC}_2\text{H}_3\text{O}_2$ ), 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.



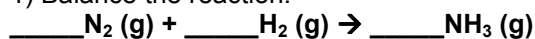
c) While not technically a double replacement reaction, why is this not considered to be a redox reaction?

## 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  $\text{N}_2 (\text{g}) + \text{H}_2 (\text{g}) \rightarrow \text{NH}_3 (\text{g})$ :**

1) Balance the reaction:



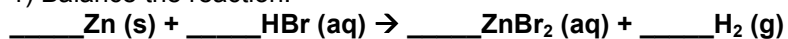
2) How many moles of  $\text{N}_2$  are needed to make 5.0 moles of  $\text{NH}_3$ ?

3) How many moles of  $\text{N}_2$  are needed to completely react with 10.0 moles of  $\text{H}_2$ ?

4) How many moles of  $\text{NH}_3$  should form if 6.0 moles of  $\text{H}_2$  are completely reacted with  $\text{N}_2$ ?

**B) For the reaction  $\text{Zn} (\text{s}) + \text{HBr} (\text{aq}) \rightarrow \text{ZnBr}_2 (\text{aq}) + \text{H}_2 (\text{g})$**

1) Balance the reaction:



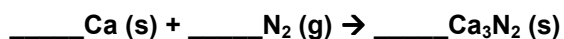
2) How many moles of  $\text{Zn}$  are needed to make 8.0 moles of  $\text{ZnBr}_2$ ?

3) How many moles of  $\text{HBr}$  are needed to make 4.0 moles of  $\text{H}_2$ ?

4) How many moles of  $\text{ZnBr}_2$  should form if 5.0 moles of  $\text{HBr}$  are completely reacted with  $\text{Zn}$ ?

**C) For the reaction  $\text{Ca (s)} + \text{N}_2 \text{(g)} \rightarrow \text{Ca}_3\text{N}_2 \text{(s)}$**

1) Balance the reaction:



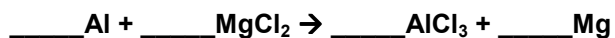
2) How many moles of Ca are required to form 4.00 moles of  $\text{Ca}_3\text{N}_2$ ?

3) How many moles of  $\text{Ca}_3\text{N}_2$  will form if 2.50 moles of  $\text{N}_2$  are reacted?

4) How many moles of Ca are needed to completely react with 5.00 moles of  $\text{N}_2$ ?

**D) For the reaction  $\text{Al} + \text{MgCl}_2 \rightarrow \text{AlCl}_3 + \text{Mg}$**

1) Balance the reaction:



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

3) How many moles of  $\text{MgCl}_2$  are required to completely react with 15.0 moles of Al?

4) How many moles of  $\text{AlCl}_3$  will be formed if 13.0 moles of Mg are formed?