Name Filled in Notes Hour

CHM CON B Unit 11 Packet: Chemical Reactions

Learning Goals:

1. I can explain the difference between a coefficient and a subscript.
2. I can count the number of atoms in a compound.
3. I can classify the five types of reactions.
4. I can predict the products of reactions and finish the equation.
5. I can write chemical equations including the heat term as a part of equation or using ΔH notation.
6. I can draw enthalpy diagrams for reactants and products in endothermic and exothermic reactions
7. I can balance a chemical equation.
8. I can explain how the Law of Conservation of Mass relates to balancing equations.

VOCABULARY (I can define/describe the following terms in my own words)

- Activity series
- Aqueous
- Coefficient
- Combustion
- Decomposition
- Diatomic molecules
- Double replacement
- Enthalpy
- Law of Conservation of Matter
- Products
- Reactants
- Single replacement
- Subscript
- Synthesis
- Yields

Chemical Equation Notes

Prior Knowledge – 5 pieces of evidence of a chemical reaction:

1. Heat/Temperature Change
2. Color Change
3. Precipitate (Solid) forms
4. Gas Produced (bubbles)
5. Light Produced

Formatting of chemical equations:

Reactants ⟶ Products

Notation within a chemical equation:

Symbol	Meaning:
+	elements/compounds are combined
→	"yields" (Result of chemical reaction)
↑	gas escapes
↓	precipitate (solid) - falls out of solution
(aq)	aqueous = solid is dissolved in water
(s)	solid
(l)	liquid
(g)	gas
ΔH	a change in heat energy

Factors that affect the rate of chemical reactions:

1) Temperature

2) Reactivity of elements

3) Concentration

4) Surface Area

5) Catalyst - extra substance that speeds up a reaction

POGIL #1 – Shall We Dance? Classifying Types of Chemical Reactions

Why?

Chemical reactions can be classified into different categories. Five common types are synthesis, decomposition, combustion, single replacement, and double replacement. Specific reactions corresponding to these general types are associated with health issues, environmental problems, and manufacturing processes. In order to use chemical reactions or evaluate their effects, you need to be able to identify the type of reaction.

New Concepts

Types of Chemical Reactions:

Synthesis	Elements or less complex compounds come together to form a single, more complex compound.
Decomposition	A compound breaks apart into either elements or less complex compounds
Combustion	A hydrocarbon combines with oxygen, releasing energy, forming carbon dioxide and water.
Single Replacement	A single element replaces another one in a compound.
Double Replacement	Ions in a compound switch places with ions in another compound to form two new compounds.

Model 1: Analogy – Dancing with Reactants

The Dance...

Adam and Barbara were both single. No one was talking about "Adam and Barbara" being together before the dance. They each go to the dance alone. However, they meet up at just the perfect time when a song they both adore is playing. They end up holding hands the entire dance. After that fateful meeting, no one ever sees Adam without Barbara; they are forever referred to as "Adam and Barbara."

1. Represent the drama of Adam and Barbara as a chemical equation. Use A to represent Adam and B to represent Barbara. Use the reactant side of the equation to represent Adam and Barbara before the dance and the product side of the equation to represent Adam and Barbara after the dance.

   $A + B \rightarrow AB$

2. If A and B represent elements, can you describe what has happened?

   A and B combine

3. How would you classify the reaction between A and B using the words from the New Concepts section above?

   Synthesis

The dance continues...

Later that same evening, Xavier and Yasmine, who have been 'the couple' forever, have a heated quarrel and break up.

4. Represent the drama of Xavier and Yasmine as a chemical equation. Use X to represent Xavier and Y to represent Yasmine. Use the reactant side of the equation to represent Xavier and Yasmine before the dance and the product side of the equation to represent Xavier and Yasmine after the dance.

   $XY \rightarrow X + Y$

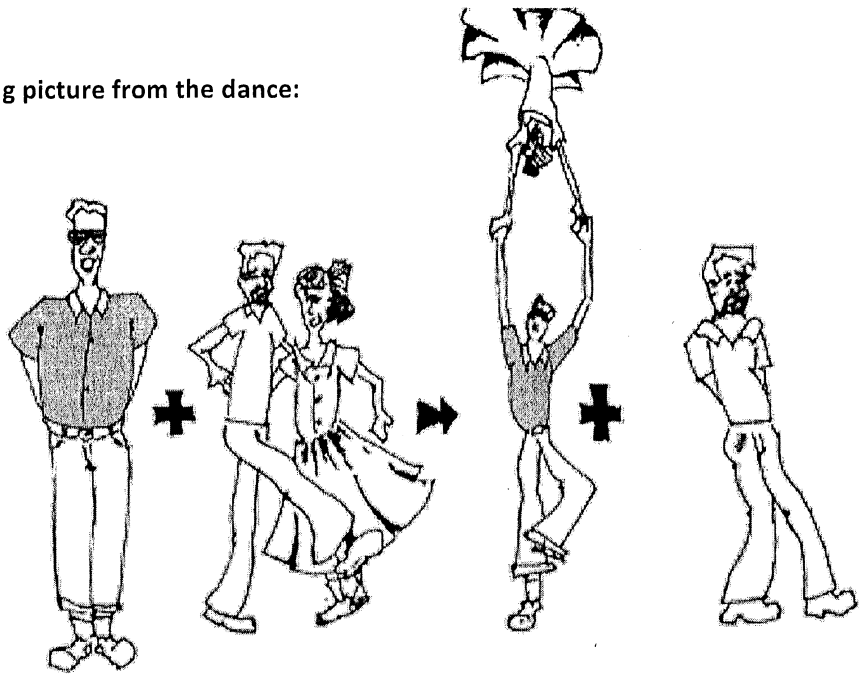
5. If X and Y represent elements, can you describe what has happened?

   X and Y break apart

6. How would you classify the reaction between X and Y using the words from the New Concepts section above?

   Decomposition

Observe the following picture from the dance:



7. Write your own analogy for the reaction listed above using the names Albert, Bobby, and Cindy.

Albert steals Bobby's girl replacing him.

8. What type of reaction is represented in the picture above?

Single Replacement

9. Write a chemical reaction for this scenario using the first letters of the characters' names.

$A + BC \rightarrow AC + B$

The dance continues...

In their blissful state, Adam and Barbara (AB) try to help Xavier and Yasmine (XY) reconcile their differences. After everyone agrees to stop quarreling, Adam asks Yasmine to dance. Xavier and Barbara decide that they will dance together as well.

10. Represent Adam and Barbara's attempt to reconcile Xavier and Yasmine's differences as a chemical equation.

$AB + XY \rightarrow AY + XB$

11. What type of reaction does this scenario represent? (Based on the New Concepts table)

Double Replacement

Reaction Type Notes

Synthesis (Composition) (means to make or build)

Skeleton Equation: $A + B \rightarrow AB$

Example: $Na^{+1} + S^{-2} \rightarrow Na_2S$

Hint: Only 1 product

Decomposition (means to replace or breakdown)

Skeleton Equation:

$AB \rightarrow A + B$

Example: $H_2O_2 \rightarrow H_2 + O_2$

Hint: Only 1 reactant

Single Replacement

Skeleton Equation: $AB + C \rightarrow AC + B$

Example: $NaCl + Li \rightarrow LiCl + Na$

Hint: one element and one compound

Double Replacement

Skeleton Equation: $AB + CD \rightarrow AD + CB$

Example: $Na^{+1}OH^{-1} + K^{+1}Cl^{-1} \rightarrow Na^{+1}Cl^{-1} + K^{+1}OH^{-1}$

Hint: 2 compounds on both sides (outsides combine, insides switch.)

Combustion

Skeleton Equation: $C_xH_z + O_2 \rightarrow CO_2 + H_2O$

Example: $C_2H_6 + O_2 \rightarrow CO_2 + H_2O$

* do not look up charges *

Hint:

Classifying Concept Check

Classify the reactions below as synthesis, decomposition, single replacement (cationic or anionic) or double replacement.

1) $C_8H_4 + 2O_2 \rightarrow 8CO_2 + 2H_2O$ _____

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

3) $Zn + H_2SO_4 \rightarrow ZnSO_4 + H_2$ _____

4) $AgNO_3 + NaCl \rightarrow AgCl + NaNO_3$ _____

5) $2KBr + Cl_2 \rightarrow 2KCl + Br_2$ _____

6) $CaO + H_2O \rightarrow Ca(OH)_2$ _____

Types of Reactions Sorting Activity

Below you will find multiple examples of each of the 5 types of chemical reactions. Use one highlighter color to highlight all of the reactions of one type. Then switch colors and highlight another reaction type. The color key is listed to the right.

Key:
Synthesis= Yellow
Decomposition= Green
Single Replacement= Orange
Double Replacement= Blue
Combustion= Purple or Pink

$C_3H_8 + O_2 \rightarrow H_2O + CO_2$

$C_2H_4 + O_2 \rightarrow CO_2 + H_2O$

$KOH + H_3PO_4 \rightarrow K_3PO_4 + H_2O$

$Pb(OH)_2 \rightarrow PbO + H_2O$

$ZnBr_2 + AgNO_3 \rightarrow Zn(NO_3)_2 + AgBr$

$NaOH + Fe(NO_3)_3 \rightarrow Fe(OH)_3 + NaNO_3$

$C_6H_{12}O_6 + O_2 \rightarrow CO_2 + H_2O$

$Al + CuCl_2 \rightarrow AlCl_3 + Cu$

$CH_2O_2 + O_2 \rightarrow CO_2 + H_2O$

$CaO + H_2O \rightarrow Ca(OH)_2$

$Cl_2 + KBr \rightarrow KCl + Br_2$

$Fe + Pb(NO_3)_2 \rightarrow Fe(NO_3)_2 + Pb$

$H_2SO_4 + NaOH \rightarrow Na_2SO_4 + H_2O$

$Ag_2O \rightarrow Ag + O_2$

$Ba(NO_3)_2 + H_3PO_4 \rightarrow Ba_3(PO_4)_2 + HNO_3$

$CH_4 + O_2 \rightarrow H_2O + CO_2$

$AgNO_3 + NaCl \rightarrow AgCl + NaNO_3$

$H_2SO_4 + Al(OH)_3 \rightarrow Al_2(SO_4)_3 + H_2O$

$Zn + H_2SO_4 \rightarrow ZnSO_4 + H_2$

$Ca + H_2O \rightarrow Ca(OH)_2 + H_2$

$Sr + Br_2 \rightarrow SrBr_2$

$Sr + S \rightarrow SrS$

$SrBr_2 \rightarrow Sr + Br_2$

$Hg + O_2 \rightarrow HgO$

$H_2 + O_2 \rightarrow H_2O$

$HgO \rightarrow Hg + O_2$

$C_7H_{16} + O_2 \rightarrow CO_2 + H_2O$

$C_{12}H_{22}O_{11} \rightarrow C + H_2O$

$HBr \rightarrow H_2 + Br_2$

$Li + N_2 \rightarrow Li_3N$

$Li_3N \rightarrow Li + N_2$

$Mg + Fe_2O_3 \rightarrow Fe + MgO$

$Cl_2 + NaI \rightarrow NaCl + I_2$

$C_2H_6 + O_2 \rightarrow H_2O + CO_2$

$Mg + N_2 \rightarrow Mg_3N_2$

POGIL #2 – Predicting Products of Chemical Reactions

Information: Introduction to Reactions

During a chemical reaction, new substances are formed. Reactants are transformed into different products. **Atoms are never created nor destroyed, but they are rearranged** (Law of Conservation of Matter). A chemical equation represents what happens during a reaction. The following is an example of a chemical equation:

Example Equation: $Ca + HNO_3 \rightarrow Ca(NO_3)_2 + H_2$

This equation describes the reaction of calcium (Ca) with nitric acid (HNO_3) to produce calcium nitrate ($Ca(NO_3)_2$) and hydrogen gas (H_2). You may notice that there are more total atoms on the right side than there are on the left side of the equation. If this seems strange to you, don't worry about it now; we'll fix this later.

Note in the above equation that hydrogen gas is written as H_2 and not simply as H. There are a few elements that exist as diatomic molecules. If a substance is diatomic then the substance must always be bonded to something. A hydrogen atom is diatomic so it must be bonded to something else like in HCl or HNO_3. If nothing is available for it to bond to, it will bond to itself by forming H_2. All the diatomic substances are listed below:

H O F Br I N Cl

Written by themselves these elements exist as H_2, O_2, F_2, Br_2, I_2, N_2, and Cl_2. By the way, you can remember these diatomic molecules by recalling the made-up word **HOFBrINCl**.

Hint- If you notice there are 7 diatomic elements. F, Br, I, and Cl are all halogens. Hydrogen and oxygen and nitrogen are not, but when you connect these 7 elements with a line it makes a 7!

Critical Thinking Questions

1. What are the **reactants** in the example equation in the above information section?

2. Consider the bromine atoms in this reaction: $LiBr + P \rightarrow Li_3P + Br_2$.
   a. Why is bromine written as Br_2 on the right side?

   b. Why is it not necessary for LiBr to be written as $LiBr_2$?

3. Answer the questions that follow based on this chemical equation: $Na + MgCl_2 \rightarrow NaCl + Mg$
   a. Why can't NaMg be produced?

   b. Why can't $NaCl_2$ be produced?

   c. Are NaCl and Mg the only products that can be produced?

4. Given the following equation: $Li + Ca_3(PO_4)_2 \rightarrow Li_3PO_4 + Ca$.
   a. Why can't $CaLi_2$ be produced?

   b. Why can't Li_3P be produced?

   c. Are Li_3PO_4 and Ca the only substances that can be produced?

5. Write chemical equations for the following reactions: (Use your ion sheet to look up the charges!)
   a. Aluminum sulfate reacts with barium to produce barium sulfate and aluminum.

   b. Magnesium reacts with copper(I) nitrate to produce magnesium nitrate and copper metal.

   c. Sodium reacts with calcium phosphide to produce sodium phosphide and calcium.

   d. Phosphorus reacts with sodium chloride to produce sodium phosphide and chlorine.

6. Each of the reactions you wrote in question 5 follow a similar pattern. The pattern is also followed by the equations in questions 3 and 4. Describe this pattern.

7. Compare the reactions in 5c and 5d.
   a. How are they different?

   b. How are the similar?

8. Use what you have observed about the pattern to complete the following reactions.

   a. $NaCl + Ag \rightarrow$

   b. $Li + Ca_3(PO_4)_2 \rightarrow$

Information: Single and Double Replacement Reactions

Each of the equations you looked at in the above section is called a single replacement reaction. Notice that in each of them, a single atom replaces an ion from another reactant. Study what happens in the following reactions. They are called double replacement reactions.

$$MgCl_2 + NaF \rightarrow NaCl + MgF_2$$
$$Al_2S_3 + Na_2O \rightarrow Al_2O_3 + Na_2S$$
$$Ca(NO_3)_2 + Na_3P \rightarrow NaNO_3 + Ca_3P_2$$

Critical Thinking Questions

9. What is the difference between single replacement reactions and double replacement reactions?

10. Complete the following reactions by providing the formulas for the missing compound(s).
    a. $Cu(NO_3)_2 +$ _____ $\rightarrow NaNO_3 + CuCl_2$

    b. $ZnI_2 +$ _____ $\rightarrow ZnSO_4 + AlI_3$

    c. $K_2O + MgBr_2 \rightarrow$ _____ + _____

11. Name the two products in the reaction between calcium phosphate and sodium iodide.

12. Explain why when you mix the following reactants, no reaction (NR) occurs: $Na_2SO_4 + NaCl \rightarrow NR$

Information: Combustion, Synthesis, and Decomposition Reactions

Another type of reaction is a combustion reaction. During combustion, a hydrocarbon reacts with oxygen. The products for complete combustion are always the same – water and carbon dioxide and energy. The following is an example equation of the combustion of a hydrocarbon:

$$C_3H_8 + O_2 \rightarrow CO_2 + H_2O$$

Two other types of reactions are synthesis and decomposition. During a synthesis reaction, several reactants combine to make a single product. During decomposition, one reactant *decomposes* into two or more products. The following table shows some examples of these types of reactions.

Synthesis	Decomposition
$H_2 + O_2 \rightarrow H_2O$	$H_2O \rightarrow H_2 + O_2$
$Na + Cl_2 \rightarrow NaCl$	$NaCl \rightarrow Na + Cl_2$

Critical Thinking Questions

13. Write an equation for the combustion of C_3H_6.

14. Write an equation for the decomposition of calcium oxide.

Practice Problems

1. Complete the following reactions:

   a. $Na_2CO_3 + AlN \rightarrow$

   b. $BaCl_2 + F_2 \rightarrow$

   c. $CuNO_3 + Ag \rightarrow$

2. Fill in the blanks for the missing reactant or product and then in the blank to the left of each equation, indicate whether the reaction is a single replacement (SR), double replacement (DR), synthesis (S), decomposition (D), or combustion (C) reaction.

   a. _____ $LiCl +$ _____ $\rightarrow ZnCl_2 + LiNO_3$

   b. _____ $CaBr_2 +$ _____ $\rightarrow NaBr + Ca$

   c. _____ $K + Cl_2 \rightarrow$ _____

Classifying Reactions Practice

Classify the type of reaction shown in each of the following chemical equation:

1) $KClO_3(s) \rightarrow 2KCl(s) + 3O_2(g)$ _____

2) $AgNO_3(aq) + KCl(aq) \rightarrow AgCl(s) + KNO_3(aq)$ _____

3) $2AgNO_3(aq) + Cu(s) \rightarrow CuNO_3(aq) + Ag(s)$ _____

When finished with questions 1-3 CIRCLE, the compounds that are dissolved in water, UNDERLINE the solids and put BOXES around the gases.

4) For the reaction between zinc metal and hydrochloric acid (aqueous) producing zinc chloride (aqueous) and hydrogen gas....

a) write an unbalanced equation for this reaction

b) classify this reaction _____

5) Nitrogen molecules and hydrogen molecules react to form ammonia gas (NH_3).

a) write an unbalanced equation for this reaction

b) classify this reaction _____

For question 6-16 finish the following reactions:

Synthesis

6) $Na + O_2 \rightarrow$ _____

7) $Cu^{+1} + S \rightarrow$ _____

8) $Fe^{+3} + O_2 \rightarrow$ _____

Single Replacement

9) $Br_2 + KI \rightarrow$ _____ + _____

10) $Na + H_2O \rightarrow$ _____ + _____

11) $Cl_2 + KBr \rightarrow$ _____ + _____

Double Replacement

12) $NaOH + FeCl_3 \rightarrow$ _____ + _____

13) $H_2SO_4 + Al(OH)_3 \rightarrow$ _____ + _____

14) $CaCl_2 + KBr \rightarrow$ _____ + _____

15) $CuBr_2 + H_2SO_4 \rightarrow$ _____ + _____

16) $AgNO_3 + K_2CrO_4 \rightarrow$ _____ + _____

Reactivity Activity – Who is the Most Reactive of Them All?

Element	Reactivity
Li Rb K Ba Sr Ca Na	React with cold water and acids, replacing hydrogen; react with oxygen, forming oxides
Mg Al Mn Zn Cr Fe Cd	React with steam(but not cold water) and acids, replacing hydrogen; react with oxygen, forming oxides
Co Ni Sn Pb	Do not react with water; react with acids, replacing hydrogen; react with oxygen, forming oxides
H_2 Sb Bi Cu Hg	React with oxygen, forming oxides
Ag Pt Au	Fairly unreactive; form oxides only indirectly

Information: The activity series ranks reactivity

To know if single replacement reactions will occur (and the speed of double replacement reactions), you must consult the activity series shown in the table to the right. The activity series is a list of the elements organized according to their tendency to react (their "activity"). The more readily an element reacts with other substances the greater its activity.

The more active elements tend to be more stable as cations (positive ions) in aqueous solutions than in elemental form. If a more active element, such as potassium, and a compound containing a less active element such as H_2O (which contains hydrogen), are brought together, **the more active element will replace the less active element in the compound as shown below**.

$$2\ K(s) + 2\ HOH(l) \rightarrow 2KOH + H_2(g)$$

In the activity series, elements are arranged according to their activity, with the most active elements at the top. ***In general, an element can displace those below it from compounds in solution but NOT those above it.***

Along with predicting whether a reaction will occur, the activity series provides indications of how easily or quickly the reaction will proceed. ***In general, the farther apart two elements are on the activity series, the more likely it is that the higher one will quickly displace the lower one in compounds.***

Follow your teacher's instructions to write down the equations.

1. Sr + $CoNO_3$ → $SrNO_3$ + Co
2. Fe + $MnPO_4$ → NR + _____
3. Pt + $RbSO_4$ → NR + _____
4. Rb + $PtSO_4$ → Pt + $RbSO_4$
5. Zn + $CuNO_3$ → $ZnNO_3$ + Cu
6. N_2 + $MgPO_4$ → NR + _____

After the activity is done, answer the questions that follow.

1. How do you use the activity series to predict single replacement reactions? If the element is very reactive and is listed higher in activity series then the element in the compound
2. Use the activity series to predict if the following reactions will occur.
   a. Will gold replace tin in a compound? No lower on series
   b. Will rubidium replace lithium in a compound? No lower on series
   c. With copper replace hydrogen in a compound? No lower on series
3. Why are gold, silver, and platinum used for jewelry? (Hint: Use the activity series to help you figure out the answer to this question.) They are not very reactive, won't change, jewerly will stay intact/the same.

Reactivity Concept Check

Single Replacement Reactions-Use your activity series to determine if the reaction will occur. If no reaction will occur, write NR on the first line. If the reaction does not involve a metal ion as A, then assume the reaction will occur.

1) Zn + HCl → _____ + _____

2) Ag + H_2SO_4 → _____ + _____

3) Ag + NaCl → _____ + _____

4) Cu^{2+} + HNO_3 → _____ + _____

5) Cl_2 + KI → _____ + _____

Heat in Reactions Notes

You have learned the words **exothermic** and **endothermic** in the second unit of our class. Remind yourself what each term means:

- Exothermic reactions... heat energy is released by reaction
- Endothermic reactions... heat energy is absorbed by reaction

So these terms relate to the heat energy associated with a reaction. When we want to know how heat energy is changing in a reaction chemists measure **enthalpy**. Enthalpy is defined as: *a thermodynamic quantity equivalent to the total heat content of a system*. The letter associated with enthalpy is H and when H has changed we put a delta symbol (Δ) in front - ΔH (pronounced "delta H").

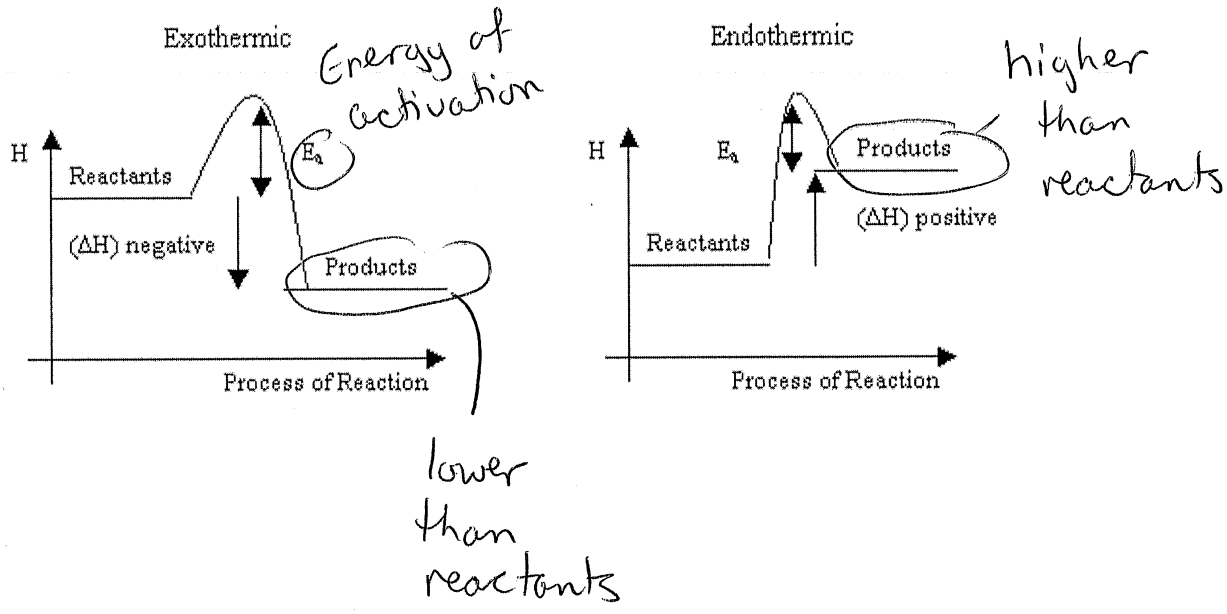
When energy is released by a reaction the change in heat energy is **negative**, because heat is **escaping** the reaction and going **into the environment**. exothermic reactions = - ΔH values

When a reaction **absorbs energy from the surrounding** atmosphere in order to occur, it is **gaining** heat energy; therefore the ΔH will be positive. endothermic reactions = + ΔH values

Classify the following reactions as ENDOTHERMIC or EXOTHERMIC based on their ΔH values

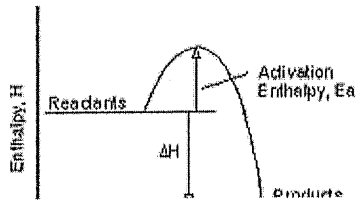
$C_{diamond}(s) + O_2(g) \rightarrow CO_2(s)$	ΔH = -396 kJ	exothermic
$N_2(g) + O_2(g) \rightarrow 2\ NO(g)$	ΔH = 180 kJ	endothermic
$2\ Al(s) + 3/2\ O_2(g) \rightarrow Al_2O_3(s)$	ΔH = -1669.8 kJ	
$2\ Fe(s) + 3/2\ O_2(g) \rightarrow Fe_2O_3(s)$	ΔH = -824.2 kJ	
$2\ NO_2(g) \rightarrow 2NO(g) + O_2(g)$	ΔH = 112 kJ	
$C_{graphite}(s) + O_2(g) \rightarrow CO_2(g)$	ΔH = -394 kJ	

The enthalpy of a reaction can be graphed. First the enthalpy of the reactants is graphed separately from the products. Those are the two horizontal lines you see below in each graph. The energy change during the reaction is graphed with the curve. **If the product line ends up <u>lower</u> than the reactant line, then energy was lost to the surroundings and the reaction was <u>exothermic</u>. If the product line is <u>higher</u> than the reactant line, it means energy was absorbed from the surrounding and the reaction was <u>endothermic</u>.**

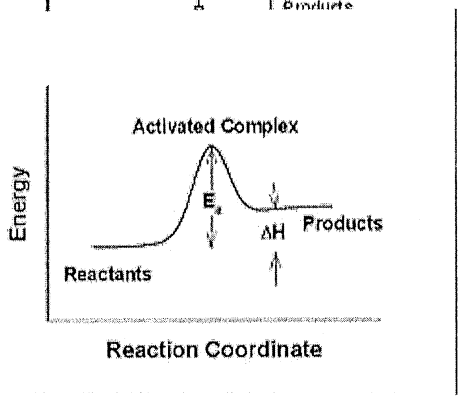


Classifying Heat Reactions Concept Check

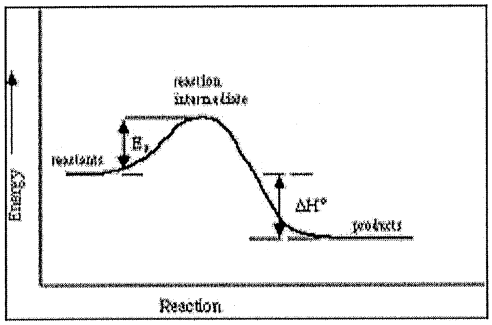
Classify the following reactions as endothermic or exothermic based on their enthalpy diagrams:



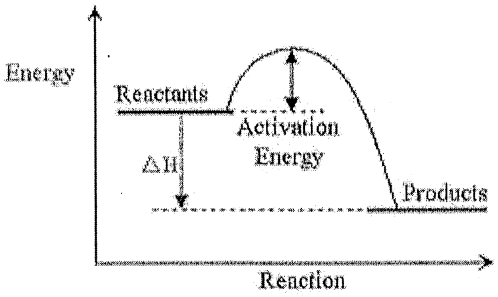
_____



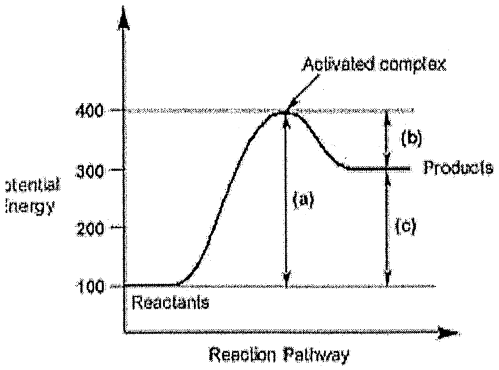
_____



_____



_____



_____

POGIL #3 – Balancing Equations

Introduction Questions

1. Write the equation for the reaction of sodium and chlorine (diatomic) to form sodium chloride.

$Na + Cl_2 \rightarrow NaCl$

2. Write the equation for the reaction of calcium nitride and sodium chloride to produce calcium chloride and sodium nitride.

$Ca_3N_2 + NaCl \rightarrow Na_3N + CaCl_2$

Information: Subscripts and Coefficients

A subscript is a small number that tells you how many atoms are in a compound. For example, in $CaCl_2$ the two is the subscript and it tells us that there are two chloride ions bonded to one calcium.

A coefficient tells us how many atoms or compounds there are, but in a different way. For example, in the expression "3 H_2O" the three is the coefficient. The three tells us that there are three molecules of water present. In the expression "3 H_2O" there are a total of 6 hydrogen atoms and 3 oxygen atoms.

Critical Thinking Questions

3. Verify that in 4 $Ca_3(PO_4)_2$ there are 32 oxygen atoms present.

4. How many TOTAL atoms are in each of the following:

_____ a) Al_2O_3 _____ b) 3 Na_2O _____ c) 4 Na_2SO_4 _____ d) 5 $Mg(NO_3)_2$

Information: How to Balance Equations

Consider the reaction of sodium and chlorine to produce sodium chloride from question one:

	Na +	Cl_2 →	NaCl	
How many of each atom?	Na____		Na____	Are they equal?
	Cl____		Cl____	

Remember that when chlorine is by itself it is always written as Cl_2. On the reactant side of the reaction (left side) there are a total of two atoms of chlorine, but on the product side there is only one atom of chlorine. **Atoms cannot simply disappear** (Law of Conservation of Matter). In order for the equation to make sense, we need to balance the equation. This can be done, first, by adding a "2" to the product side:

	Na +	Cl_2 →	2 NaCl	
How many of each atom?	Na____		Na____	Are they equal?
	Cl____		Cl____	

Now the equation reads that one atom of Na reacts with one molecule of Cl_2 to produce two units of NaCl. However, how the Na atoms are not balanced because there is one atom on the reactant side, but two atoms of Na on the product side. **Atoms also cannot simply appear** (Law of Conservation of Matter). This can be fixed by adding another two:

	2 Na +	Cl_2 →	2 NaCl	
How many of each atom?	Na____		Na____	Are they equal
	Cl____		Cl____	

Let us consider another example, the equation you wrote in question two above:

How many of each atom?

$Ca_3N_2 + NaCl \rightarrow CaCl_2 + Na_3N$

Are they equal?

Notice that none of the atoms are "balanced." There are three calcium atoms on one side and only one on the other. There are two nitrogen atoms on one side and one on the other. How can we fix this? **Begin by "balancing" <u>one atom at a time</u>.**

1. First, let's balance the calcium atoms by placing a three in front of $CaCl_2$:

How many of each atom?

$Ca_3N_2 + NaCl \rightarrow 3\ CaCl_2 + Na_3N$

Are they equal?

2. Next, let's balance the nitrogen atoms by placing a two in front of Na_3N:

How many of each atom?

$Ca_3N_2 + NaCl \rightarrow 3\ CaCl_2 + 2\ Na_3N$

Are they equal?

3. Now we will balance the sodium atoms by placing a 6 in front of NaCl:

How many of each atom?

$Ca_3N_2 + 6\ NaCl \rightarrow 3\ CaCl_2 + 2\ Na_3N$

Are they equal?

4. Finally, examine the chlorine atoms and notice that they are already balanced.

5. Double check each atom to make sure there are equal numbers of each on both sides of the equation.

When balancing equations you <u>NEVER</u> change <u>subscripts</u>. <u>ONLY</u> change the <u>coefficients</u>.

A HINT: *When trying to decide where to begin balancing, choose to start with the elements in the most complex formula. Ca_3N_2 is the most complex formula in the equation above because it has the largest numbers for subscripts. Complex formulas also can be identified as the ones that have the most atoms in the compound.*

<u>Critical Thinking Questions</u>

5. Which of the following equations are properly and completely balanced? (circle as many as apply)

   a. $2\ NaCl + Cu \rightarrow CuCl_2 + Na$

   b. $C_3H_8 + 3\ O_2 \rightarrow 3\ CO_2 + H_2O$

   c. $MgCl_2 + F_2 \rightarrow MgF_2 + Cl_2$

   d. $FeCl_2 + O_2 \rightarrow 2\ FeO + Cl_2$

6. Balance each of the following equations by inserting the correct coefficient in each blank. Remember to balance one atom at a time and to begin with atoms in the most complex formula. If the number "one" belongs in the blank you may either leave it blank or insert the number one.

   a. _____ $CaCl_2$ + _____ Li_2O → _____ CaO + _____ LiCl

   b. _____ Al_2S_3 + _____ Cu → _____ CuS + _____ Al

   c. _____ Na_3P + _____ $MgBr_2$ → _____ Mg_3P_2 + _____ NaBr

7. Here are the answers to question 6. Double check your answers to question 6:
   a. $CaCl_2 + Li_2O \rightarrow CaO + 2\ LiCl$
   b. $Al_2S_3 + 3\ Cu \rightarrow 3\ CuS + 2\ Al$
   c. $2\ Na_3P + 3\ MgBr_2 \rightarrow Mg_3P_2 + 6\ NaBr$

Information: Balancing Equations Containing Polyatomic Ions

When an equation contains polyatomic ions, it make look more difficult to balance. But balancing an equation containing polyatomic ions is really not much different from the ones you just did. In the equations above, you kept in mind that you must balance only one atom at a time. With polyatomic ions, keep in mind that you balance *one polyatomic ion* at a time. For example, consider the following unbalanced equation.

$$Na_2SO_4 + Ca_3(PO_4)_2 \rightarrow Na_3PO_4 + CaSO_4$$

The first thing you should do is take note of which atoms/ions are not balanced. Keep the polyatomic ions together. In other words, do not balance the phosphorus and oxygen atoms separately; instead, balance the phosphate ions on each side of the reaction. (*The only exception to this rule is if the polyatomic ion DOES not appear on both sides of the equation).* Follow these steps:

1. Identify the most complex formula as $Ca_3(PO_4)_2$. Balance the calcium so that that there are 3 calcium atoms on each side of the reaction:

   $$Na_2SO_4 + Ca_3(PO_4)_2 \rightarrow Na_3PO_4 + 3\ CaSO_4$$

2. Then balance the phosphate ions. There are two on the left and one on the right. Add a two to the right side of the equation.

   $$Na_2SO_4 + Ca_3(PO_4)_2 \rightarrow 2\ Na_3PO_4 + 3\ CaSO_4$$

3. Now there are three sulfate ions on the right and one on the left. Add a three to the left.

   $$3\ Na_2SO_4 + Ca_3(PO_4)_2 \rightarrow 2\ Na_3PO_4 + 3\ CaSO_4$$

4. Take inventory of all the atoms and ions to make sure they are balanced. The equation is now balanced.

Critical Thinking Questions

8. Which of the following equations are properly balanced?
   a. $Ba(NO_3)_2 + Fe_2SO_4 \rightarrow 2\ FeNO_3 + BaSO_4$

   b. $3\ SrCl_2 + Al(NO_3)_3 \rightarrow 3\ Sr(NO_3)_2 + AlCl_3$

   c. $Ca_3(PO_4)_2 + 3\ Na_2CO_3 \rightarrow 2\ Na_3PO_4 + 3\ CaCO_3$

   d. $Fe(NO_3)_2 + Mg \rightarrow Mg(NO_3)_2 + Fe$

9. Balance each of the following equations by inserting the correct coefficient in each blank. Remember to balance one atom/ion at a time. If the number "one" belongs in the blank you may either leave it blank or insert the number one.
   a. _____ $Ca(NO_3)_2$ + _____ $Na \rightarrow$ _____ $NaNO_3$ + _____ Ca

   b. _____ $Al_2(CO_3)_3$ + _____ $MgCl_2 \rightarrow$ _____ $AlCl_3$ + _____ $MgCO_3$

   c. _____ $Ba_3(PO_4)_2$ + _____ $Na_2CO_3 \rightarrow$ _____ Na_3PO_4 + _____ $BaCO_3$

10. Make sure you got the following answers for question 9:
    a. $Ca(NO_3)_2 + 2\ Na \rightarrow 2\ NaNO_3 + Ca$
    b. $Al_2(CO_3)_3 + 3\ MgCl_2 \rightarrow 2\ AlCl_3 + 3\ MgCO_3$
    c. $Ba_3(PO_4)_2 + 3\ Na_2CO_3 \rightarrow 2\ Na_3PO_4 + 3\ BaCO_3$

11. Complete AND balance the following equations. Be sure to check the metal activity chart for single replacement reactions.
    a. _____ HCl + _____ $Mg \rightarrow$ _____ + _____

    b. _____ Na_2S + _____ $Be(OH)_2 \rightarrow$ _____ + _____

    c. _____ BaF_2 + _____ $NaNO_3 \rightarrow$ _____ + _____

    d. _____ $Ca_3(PO_4)_2$ + _____ $K_2SO_4 \rightarrow$ _____ + _____

    e. _____ $Ba(NO_3)_2$ + _____ $Mg \rightarrow$ _____ + _____

    f. _____ $Ca(NO_3)_2$ + _____ $Al_2(CO_3)_3 \rightarrow$ _____ + _____

A couple of additional balancing hints: 1) *If there is more than ONE source of a element in an equation, balance this atom LAST.* 2) *Change H_2O to H(OH) if H and OH ions are found on the opposite side of the equation.*

Beady Balancing Activity

Color	Atom Represented
Purple	Hydrogen
Orange	Oxygen
Green	Nitrogen
White	Chlorine
Blue	Fluorine
Pink	Sodium

Use the beads on string to represent atoms and bonds between atoms to balance the equations.

1. ____ $H_2(g)$ + ____ $O_2(g)$ → ____ $H_2O(l)$

2. ____ $N_2(g)$ + ____ $H_2(g)$ → ____ $NH_3(g)$

3. ____ $H_2O(s)$ → ____ $H_2O(l)$

4. ____ $NF_3(g)$ → ____ $N_2(g)$ + ____ $F_2(g)$

5. ____ $H_2(g)$ + ____ $Cl_2(g)$ → ____ $HCl(g)$

6. ____ $NH_3(l)$ → ____ $NH_3(g)$

Now try to balance the following equations without using the beads. Check your answers with the beads.

7. ____ $Na(s)$ + ____ $Cl_2(g)$ → ____ $NaCl(s)$

8. ____ $Na(s)$ + ____ $H_2O(l)$ → ____ $NaOH(aq)$ + ____ $H_2(g)$

9. ____ $Na_3N(s)$ → ____ $Na(s)$ + ____ $N_2(g)$

10. ____ $O_2(g)$ + ____ $H_2(g)$ → ____ $H_2O(g)$

11. ____ $HCl(aq)$ → ____ $H_2(g)$ + ____ $Cl_2(g)$

Now try the following equation for which you have no beads.

12. ____ $CH_4(g)$ + ____ $O_2(g)$ → ____ $CO_2(g)$ + ____ $H_2O(g)$

Balance Chemical Equations Practice

1. _____ N_2 + _____ H_2 → _____ NH_3

2. _____ $KClO_3$ → _____ KCl + _____ O_2

3. _____ NaCl + _____ F_2 → _____ NaF + _____ Cl_2

4. _____ $AlBr_3$ + _____ K_2SO_4 → _____ KBr + _____ $Al_2(SO_4)_3$

5. _____ S_8 + _____ O_2 → _____ SO_3

6. _____ CO_2 + _____ H_2O → _____ $C_6H_{12}O_6$ + _____ O_2

7. _____Fe + _____O_2 → _____Fe_2O_3

8. _____Fe + _____H_2O → _____H_2 + _____Fe_3O_4

9. _____KCN + _____$Fe(OH)_2$→ _____KOH + _____$K_4Fe(CN)_6$

10. _____ C_8H_{18} + _____ O_2 → _____ CO_2 + _____ H_2O

11. _____Cu + _____H_2SO_4 → _____$CuSO_4$ + _____H_2O + _____SO_2

12. _____Al_2O_3 → _____O_2 + _____Al

13. _____P + _____O_2 → _____P_2O_5

14. _____Ag_2O → _____Ag + _____O_2

A reaction when elements or less complex compounds come together to form a single, more complex compound.	Elements or compounds that are transformed into different combinations of elements or compounds.	A reaction when a hydrocarbon combines with oxygen, releasing energy, forming carbon dioxide and water.	A reaction when ions in a compound switch places with ions in another compound to form two new compounds.
A reaction when a compound breaks apart into either elements or less complex compounds.	A substance or element that must always be bonded to something.	A small number that tells you how many atoms are in a compound	A reaction when a single element replaces another in one compound.
The law stating that atoms are never created nor destroyed, but they are rearranged.	A thermodynamic quantity equivalent to the total heat content of a system.	A number that tells you how many atoms or compounds there are (placed in front of your compound).	Results of a chemical reaction

The elements and/or compounds that are left at the end of a chemical reaction.	The term for a solution made up of a solid dissolved in water.	A list of elements organized according to their tendency to react.	