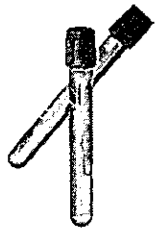
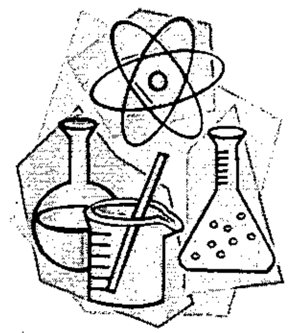
Stoichiometry





NAME____

TEACHER ____________________________________

Chemistry

What You Need to Know for Moles & Stoichiometry

Content Objectives

- Match the elements of compounds with the symbols of their atoms & ions
- Write compound formulas using symbols and valences of atoms and ions
- Select the number of atoms and ions in a compound from the given formula
- Name a given compound according to its given formula
- Compare the differences between an empirical formula and a molecular formula.
- Solve for the empirical formula based on the molecular formula; visa-versa
- Identify and write formulas of a binary compound
- Select and label products and reactants in a given chemical reaction
- Given the formulas for reactants and products, balance a chemical equation
- Deduce a missing reactant or product in a given chemical equation
- Correctly use the Law of Conservation
- Distinguish between the following
  - Decomposition
  - Double Replacement
  - Single Replacement
  - Synthesis

Key Subject Competencies

- Define stoichiometry
- Understand the concept of balance in chemical reactions
- Find the atomic mass of elements
- Use atomic mass to determine molecular mass and formula mass
- Define a Mole
- Determine mole from formula mass
- Calculate the percent composition by mass of each element in a compound or hydrate
- Name the four types of chemical reactions and give an example of each.
- Identify molecular formulas of substances
- Use molecular formulas to determine empirical formulas
- Use molecular formulas to represent structural formulas
- Define an empirical formula
- Determine which formulas are empirical
- Calculate the empirical formula of a substance from % composition
- Determine the molecular formula of a compound
- Distinguish between an empirical formula and a molecular formula
- Determine the empirical formula of any molecular formula

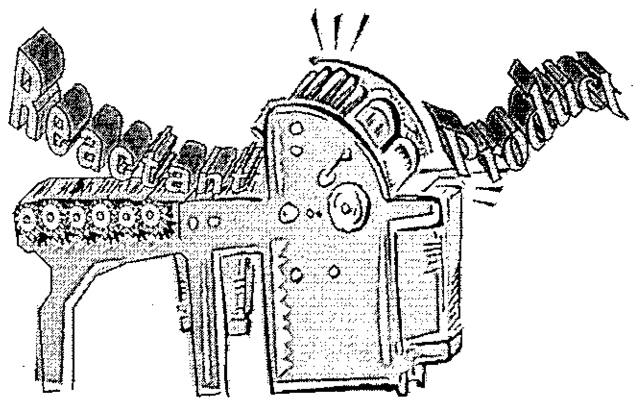
Vocabulary

- Moles
- Formula Mass
- Synthesis
- Stoichiometry
- Gram Formula Mass
- Percent Composition
- Hydrates
- Molar Ratio
- Oxidation Number
- Coefficients
- Molecular Formula
- Yield
- Product
- Decomposition
- Reactant
- Polyatomic
- Double Replacement
- Single Replacement
- Molar Mass
- Empirical Formula
- Subscript
- Avogadro's Number

Chemistry: Form WS5.3.1A Name ______________________

CHEMICAL FORMULAS AND EQUATIONS Date ______________ Period ______

Understanding Chemical Equations



Chemical reactions are like mini-factories. Reactants go in, and products come out. Chemical equations provide a shorthand way to easily describe what occurs during a chemical reaction. In a typical chemical equation, the reactants are written on the left, while the products are written on the right. The reactants and products are separated by an arrow, or yield sign, which indicates that reactants yield products. (**REACTANTS** → **PRODUCTS**) There are other symbols as well that show the state of the chemicals involved in the reaction. They are: (*s*) or ↓ for a solid precipitate; (ℓ) for a liquid; (*g*) or ↑ for a gas; and (*aq*) for dissolved in water or aqueous. Symbols can also be used to show other factors involved in the reaction such as sources of energy used. These include: Δ for heat or ↑| for light. These symbols are written above or below the yield sign because they are neither reactants nor products. The complete equation shows the identity of the reactants and products using chemical formulas and symbols, the phases of the reactants and products, any energy changes involved in the reaction, and the mole ratios of all the substances indicated by the coefficients. Equations may occasionally be written omitting information about phases or energy changes. The example below shows a complete chemical equation with all the components.

$$2KClO_3(s) \xrightarrow[\Delta]{\mathbf{MnO_2}(s)} 2KCl(s) + 3O_2(g)$$

In the above reaction, the equation shows that the reactant is solid potassium chlorate, the products are solid potassium chloride and oxygen gas, manganese dioxide is a catalyst, and the reaction is endothermic. Symbols for manganese dioxide and heat are shown above and below the yield sign because they are neither reactants nor products.

For each of the chemical equations below, identify the reactants and the products, state what phase each is in, and state the mole ratios of all the products and reactants. See the sample below.

Chemical Equation	Reactants		Products		Ratio
	Identity	Phase	Identity	Phase	
Sample: • $2H_2(g) + O_2(g) \rightarrow 2H_2O(\ell)$	H_2 O_2	gas gas	H_2O	liquid	2:1:2
[A] $3Ca(NO_3)_2(aq) + 2Na_3PO_4(aq) \rightarrow 6NaNO_3(aq) + Ca_3(PO_4)_2(s)$					

Chemical Equation	Reactants		Products		Ratio
	Identity	Phase	Identity	Phase	
[B] $CO_2(g) + H_2O(\ell) \rightarrow H_2CO_3(aq)$					
[C] $Zn(s) + 2HCl(aq) \rightarrow ZnCl_2(aq) + H_2(g)$					
[D] $Cu(s) + 2AgNO_3(aq) \rightarrow$ $2Ag(s) + Cu(NO_3)_2(aq)$					
[E] $2Mg(s) + O_2(g) \rightarrow 2MgO(s)$					
[F] $2Fe(OH)_2(s) + H_2O_2(aq) \rightarrow 2Fe(OH)_3(s)$					
[G] $3Cu(s) + 8HNO_3(aq) \rightarrow$ $2NO(g) + 3Cu(NO_3)_2(g) + 4H_2O(\ell)$					
[H] $2Li(s) + 2H_2O(\ell) \rightarrow 2LiOH(aq) + H_2(g)$					
[I] $H_2O(\ell) + N_2O_5(g) \rightarrow 2HNO_3(aq)$					
[J] $2Al(s) + 3Zn(NO_3)_2(aq) \rightarrow$ $3Zn(s) + 2Al(NO_3)_3(aq)$					

Name ______________________

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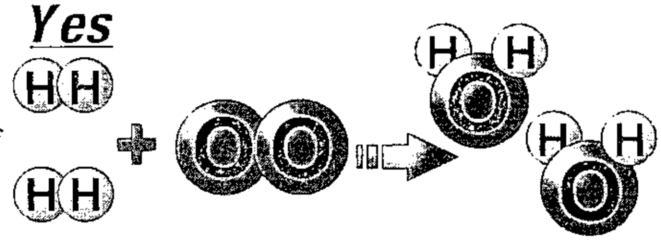
Balancing Equations

During a chemical change, there is no change in mass. A properly written chemical equation shows this. The equation below is not properly written. It does not show conservation of mass.

$$H_2 + O_2 \rightarrow H_2O$$
$$2 + 32 \neq 18$$

No

Yes



$$2H_2 + O_2 \rightarrow 2H_2O$$
$$2(2) + 32 = 2(18)$$

The reason the equation doesn't work is simple. There are two atoms of oxygen in the reactants, but only one in the product. If two molecules of hydrogen react with a molecule of oxygen to form two molecules of water, there are no atoms missing and mass is conserved. The number of molecules is shown with a number to the left of the formula known as a coefficient. A coefficient behaves like a multiplier. It's not necessary to check the mass to get a properly written equation. Counting atoms is sufficient. When the equation for the formation of water is written properly, $2H_2 + O_2 \rightarrow 2H_2O$, there are 4 hydrogen atoms and two oxygen atoms on both sides of the equation and the mass of the reactants is the same as the mass of the products. Making the number of atoms equal on both sides of the equation is all that is needed. The process is called balancing.

Balance the equations below by writing the correct coefficient in the space before each formula. Coefficient "1" need not be written.

1. ____ H_2 + ____ $Cl_2 \rightarrow$ ____ HCl
2. ____ $Ca(NO_3)_2$ + ____ $H_2SO_4 \rightarrow$ ____ $CaSO_4$ + ____ HNO_3
3. ____ Fe + ____ $Cl_2 \rightarrow$ ____ $FeCl_3$
4. ____ Fe + ____ $O_2 \rightarrow$ ____ Fe_2O_3
5. ____ Zn + ____ HCl $\rightarrow$ ____ $ZnCl_2$ + ____ H_2
6. ____ Cu + ____ $AgCH_3COO \rightarrow$ ____ $Cu(CH_3COO)_2$ + ____ Ag
7. ____ H_2SO_4 + ____ NaOH $\rightarrow$ ____ Na_2SO_4 + ____ H_2O
8. ____ N_2 + ____ $H_2 \rightarrow$ ____ NH_3
9. ____ CH_4 + ____ $O_2 \rightarrow$ ____ CO_2 + ____ H_2O
10. ____ S + ____ $O_2 \rightarrow$ ____ SO_3

BALANCING CHEMICAL EQUATIONS

Name ______________________

Rewrite and balance the equations below.

1. $N_2 + H_2 \rightarrow NH_3$ ______________________
2. $KClO_3 \rightarrow KCl + O_2$ ______________________
3. $NaCl + F_2 \rightarrow NaF + Cl_2$ ______________________
4. $H_2 + O_2 \rightarrow H_2O$ ______________________
5. $AgNO_3 + MgCl_2 \rightarrow AgCl + Mg(NO_3)_2$ ______________________
6. $AlBr_3 + K_2SO_4 \rightarrow KBr + Al_2(SO_4)_3$ ______________________
7. $CH_4 + O_2 \rightarrow CO_2 + H_2O$ ______________________
8. $C_3H_8 + O_2 \rightarrow CO_2 + H_2O$ ______________________
9. $C_8H_{18} + O_2 \rightarrow 1O_2 + H_2O$ ______________________
10. $FeCl_3 + NaOH \rightarrow Fe(OH)_3 + NaCl$ ______________________
11. $P + O_2 \rightarrow P_2O_5$ ______________________
12. $Na + H_2O \rightarrow NaOH + H_2$ ______________________
13. $Ag_2O \rightarrow Ag + O_2$ ______________________
14. $S_8 + O_2 \rightarrow SO_3$ ______________________
15. $CO_2 + H_20 \rightarrow C_6H_{12}O_6 + O_2$ ______________________
16. $K + MgBr_2 \rightarrow KBr + Mg$ ______________________
17. $HCl + CaCO_3 \rightarrow CaCl_2 + H_2O + CO_2$ ______________________

WORD EQUATIONS

Name ____________________

Write the word equations below as chemical equations and balance.

1. zinc + lead (II) nitrate yield zinc nitrate + lead

2. aluminum bromide + chlorine yield aluminum chloride + bromine

3. sodium phosphate + calcium chloride yield calcium phosphate + sodium chloride

4. potassium chlorate when heated yields potassium chloride + oxygen gas

5. aluminum + hydrochloric acid yield aluminum chloride + hydrogen gas

6. calcium hydroxide + phosphoric acid yield calcium phosphate + water

7. copper + sulfuric acid yield copper (II) sulfate + water + sulfur dioxide

8. hydrogen + nitrogen monoxide yield water + nitrogen

Answer the questions below by circling the number of the correct response

1. If 46 g of *X* combines with 16 g of *Y* to form *Z*, how much *Z* is formed? (1) 30 g (2) 2.9 g (3) 724 g (4) 62 g

2. The formula mass of sulfuric acid (H_2SO_4) is (1) 194 amu, (2) 98 amu, (3) 50 amu, (4) 192 amu

3. Which of the following equations does *NOT* show conservation of mass? (1) $C + O_2 \rightarrow CO_2$ (2) $Mg + S \rightarrow MgS$ (3) $H_2 + S \rightarrow H_2S$ (4) $H_2 + O_2 \rightarrow H_2O$

4. If 6 g of hydrogen burns to produce 54 g of water, how much oxygen was used? (1) 48 g (2) 60 g (3) 9 g (4) 324 g

5. During a chemical change, the total mass (1) increases, (2) decreases, (3) remains the same.

6. Which of the following is ***NOT*** a balanced equation?
   (1) $Cu + 2AgNO_3 \rightarrow 2Ag + Cu(NO_3)_2$
   (2) $3BaCl_2 + Fe_2(SO_4)_3 \rightarrow 2FeCl_3 + 3BaSO_4$
   (3) $4Na + 2H_2O \rightarrow 4NaOH + H_2$
   (4) $2KClO_3 \rightarrow 2KCl + 3O_2$

Balance each of the equations below and write the *SUM* of the coefficients in the appropriate place on the answer sheet.

7. $Al + HCl \rightarrow AlCl_3 + H_2$

8. $Li + H_2O \rightarrow LiOH + H_2$

9. $H_2 + N_2 \rightarrow NH_3$

10. In the equation $4Al + 3O_2 \rightarrow 2Al_2O_3$, the number 4 is a (1) subscript, (2) oxidation state, (3) formula mass, (4) coefficient.

11. When the equation $H2 + N_2 \rightarrow NH_3$ is completely balanced using smallest whole numbers, the sum of all the coefficients will be (1) 6 (2) 7 (3) 3 (4) 12

12. When the equation $H_2 + Fe_3O_4 \rightarrow Fe + H_2O$ is completely balanced using *smallest* whole numbers the coefficient of H_2 would be (1) 1 (2) 2 (3) 3 (4) 4

13. When the equation $C_2H_4 + O_2 \rightarrow CO_2 + H_2O$ is correctly balanced, using *smallest* whole-numbered coefficients, the sum of all the coefficients is (1) 16 (2) 12 (3) 8 (4) 4

14. When the equation $NH_3 + O_2 \rightarrow HNO_3 + H_2O$ is completely balanced using smallest whole numbers, the coefficient of O_2 would be (1) 1 (2) 2 (3) 3 (4) 4

15. When the equation $C_2H_4 + O_2 \rightarrow CO_2 + H_2O$ is balanced using smallest whole numbers, what is the coefficient of the O_2? (1) 1 (2) 2 (3) 3 (4) 4

16. When the equation $Na(s) + H_2O(\ell) \rightarrow NaOH(aq) + H_2(g)$ is correctly balanced using smallest whole numbers, the coefficient of the water is (1) 1 (2) 2 (3) 3 (4) 4

17. When the equation $Al(s) + O_2(g) \rightarrow Al_2O_3(s)$ is correctly balanced using the smallest whole numbers, the coefficient of Al(s) is (1) 1 (2) 2 (3) 3 (4) 4

Name ______________________

Date ______________ Period _____

Formula Mass

Compounds are either ionic or molecular. The formulas for ionic substances are always written with subscripts reduced to lowest terms. This is because we know the ratio of ions in a compound, but we don't necessarily know how many ions are in a crystal of the compound. Formulas written in lowest terms are called empirical formulas. Molecular substances can have formulas that are not in lowest terms. For example, the formula of glucose is $C_6H_{12}O_6$. All of the subscripts are divisible by six. This is acceptable, however, because we know exactly how many atoms of each type are in a molecule of glucose. The formula for glucose is called a molecular formula and its mass is called a molecular mass. Regardless of whether a compound has a molecular formula or an empirical formula, the mass of the compound is found the same way. The atomic masses of the elements in the compound and the formula are used to determine the mass. The mass determined from the formula is called a formula mass. A molecular mass is a type of formula mass. The terms are sometimes used interchangeably. Formula masses are determined by following the steps in the box to the right. The results are in *atomic mass units* (amu).

Finding the Formula Mass

Find the formula mass of $CuSO_4$

Step 1: Look up the mass of each element on the *Periodic Table* and round it off.
Step 2: Multiply each element's atomic mass by its subscript to get the product.
Step 3: Add the products together to get the total

Element	Atomic Mass		Subscript		Product
Cu	64	×	1	=	64
S	32	×	1	=	32
O	16	×	4	=	64
			TOTAL		160

Determine the formula masses of each of the substances below.

1. $CaCl_2$

2. NH_4OH

3. $AgCH_3COO$

4. $Ba_3(PO_4)_2$

5. $Al_2(CO_3)_3$

6. $Zn(NO_3)_2$

GRAM FORMULA MASS

Name ____________________

Determine the gram formula mass (the mass of one mole) of each compound below.

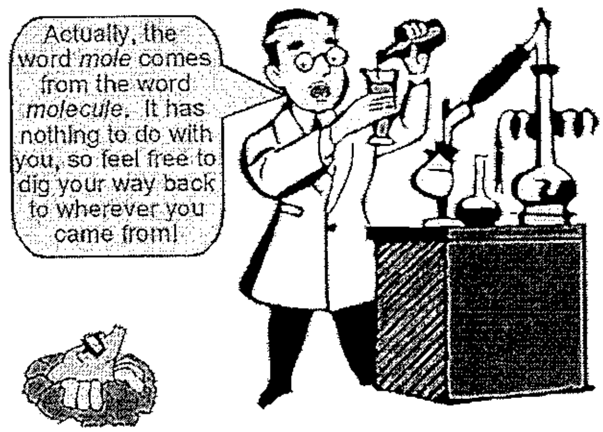
1. $KMnO_4$ ____________________
2. KCl ____________________
3. Na_2SO_4 ____________________
4. $Ca(NO_3)_2$ ____________________
5. $Al_2(SO_4)_3$ ____________________
6. $(NH_4)_3PO_4$ ____________________
7. $CuSO_4 \bullet 5H_2O$ ____________________
8. $Mg_3(PO_4)_2$ ____________________
9. $Zn(C_2H_3O_2)_2 \bullet 2H_2O$ ____________________
10. $Zn_3(PO_4)_2 \bullet 4H_2O$ ____________________
11. H_2CO_3 ____________________
12. $Hg_2Cr_2O_7$ ____________________
13. $Ba(ClO_3)_2$ ____________________
14. $Fe_2(SO_3)_3$ ____________________
15. $NH_4C_2H_3O_2$ ____________________

Chemistry: Form WS5.6.1A Name ______________________

CHEMICAL FORMULAS AND EQUATIONS Date ____________ Period ____

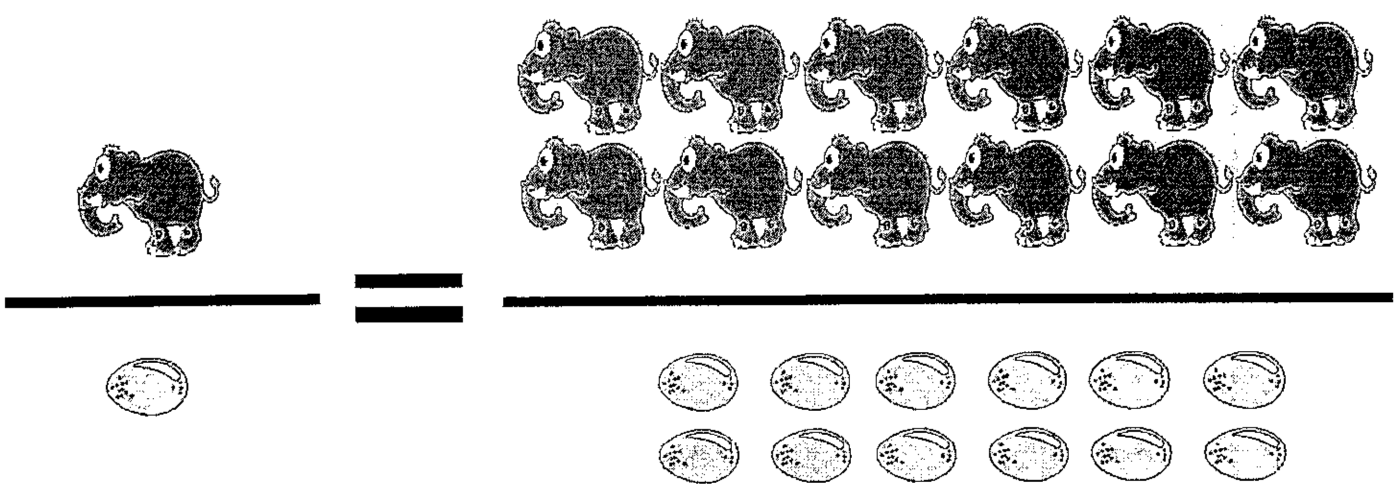
Working With Moles

The mole is a very useful concept in chemistry. It is a quantity, just as a dozen is a quantity, but it is much more than a dozen. The number of objects in a mole is 6.02×10^{23}. The importance of the mole as a quantity in chemistry comes from the fact that all moles, just like all dozens, have the same number of particles. The actual number of particles is not that important. There is a much simpler way to know when you have a mole. A mole is a formula mass expressed in grams. (1 mole = 1 gram formula mass)



Substance	Formula Mass	Gram Formula Mass
carbon	12 amu	12 g
sodium chloride (NaCl)	58 amu	58 g
glucose ($C_6H_{12}O_6$)	180 amu	180 g

Atomic mass units are too small to measure on a laboratory balance, but grams are not. An atom of carbon has a mass of 12 amu and a molecule of glucose has a mass of 180 amu. Each mass represents one particle. Since the mass ratios in formula masses and gram formula masses are the same (12 amu:180 amu::12 g:180 g), the ratio of particles must still be the same (1mole:1 mole). If you think in dozens, this is easy to understand. If we compare the mass of 1 egg to 1 elephant, it has the same mass ratio as 1 dozen eggs and 1 dozen elephants, because the ratio of objects is still 1 to 1.



This is very useful for working with balanced equations. The equation for the formation of ammonia, $N_2(g) + 3H_2(g) \rightarrow 2NH_3(g)$, tells us that 1 molecule of nitrogen combines with 3 molecules of hydrogen to form 2 molecules of ammonia. This also means 1 mole of nitrogen combines with 3 moles of hydrogen to form 2 moles of ammonia. The mole amounts can be measured in the laboratory. Of course, it helps to understand the relationship between mass and moles. Based on the definition above, the gram formula mass (GFM) is the number of grams in 1 mole. This results in the mathematical relationships shown to the right.

1. $GFM = \dfrac{g}{mole}$
2. $g = GFM \times mole$
3. $mole = \dfrac{g}{GFM}$

MOLES AND MASS

Name ____________________

Determine the number of moles in each of the quantities below.

1. 25 g of NaCl ________
2. 125 g of H_2SO_4 ________
3. 100. g of $KMnO_4$ ________
4. 74 g of KCl ________
5. 35 g of $CuSO_4 \bullet 5H_2O$ ________

Determine the number of grams in each of the quantities below.

1. 2.5 moles of NaCl ________
2. 0.50 moles of H_2SO_4 ________
3. 1.70 moles of $KMnO_4$ ________
4. 0.25 moles of KCl ________
5. 3.2 moles of $CuSO_4 \bullet 5H_2O$ ________

THE MOLE AND VOLUME

Name ______________________

For gases at STP (273 K and 1 atm pressure), one mole occupies a volume of 22.4 L. What volume will the following quantities of gases occupy at STP?

1. 1.00 mole of H_2
2. 3.20 moles of O_2
3. 0.750 mole of N_2
4. 1.75 moles of CO_2
5. 0.50 mole of NH_3
6. 5.0 g of H_2
7. 100. g of O_2
8. 28.0 g of N_2
9. 60. g of CO_2
10. 10. g of NH_3

THE MOLE AND AVOGADRO'S NUMBER

Name ____________________

> One mole of a substance contains Avogadro's Number (6.02×10^{23}) of molecules.

How many molecules are in the quantities below?

1. 2.0 moles
2. 1.5 moles
3. 0.75 mole
4. 15 moles
5. 0.35 mole

How many moles are in the number of molecules below?

1. 6.02×10^{23}
2. 1.204×10^{24}
3. 1.5×10^{20}
4. 3.4×10^{26}
5. 7.5×10^{19}

STOICHIOMETRY: MOLE-MOLE PROBLEMS

Name ____________________

1. $N_2 + 3H_2 \rightarrow 2NH_3$
   How many moles of hydrogen are needed to completely react with two moles of nitrogen?

   ____

2. $2KClO_3 \rightarrow 2KCl + 3O_2$
   How many moles of oxygen are produced by the decomposition of six moles of potassium chlorate?

   ____

3. $Zn + 2HCl \rightarrow ZnCl_2 + H_2$
   How many moles of hydrogen are produced from the reaction of three moles of zinc with an excess of hydrochloric acid?

   ____

4. $C_3H_8 + 5O_2 \rightarrow 3CO_2 + 4H_2O$
   How many moles of oxygen are necessary to react completely with four moles of propane (C_3H_8)?

   ____

5. $K_3PO_4 + Al(NO_3)_3 \rightarrow 3KNO_3 + AlPO_4$
   How many moles of potassium nitrate are produced when two moles of potassium phosphate react with two moles of aluminum nitrate?

   ____

CHEMICAL FORMULAS AND EQUATIONS

Calculate the mass of each of the following as illustrated in the example below:

Example

What is the mass of 2 moles of sodium thiosulfate?

$Na_2S_2O_3$
Na = 23 × 2 = 46
S = 32 × 2 = 64
O = 16 × 3 = 48
158

g = GFM × moles

= 158 g/mole × 2 mole

= 316 g

1. What is the mass of 3 moles of potassium nitrate [KNO_3]?

2. What is the mass of 0.75 moles of aluminum oxide [Al_2O_3]?

3. What is the mass of 3.5 moles of silver acetate [$AgCH_3COO$]?

4. What is the mass of 0.25 moles of calcium sulfate [$CaSO_4$]?

Calculate the number of moles for each of the following as illustrated in the example below:

Example

How many moles are in 390g of calcium chloride?

$CaCl_2$
Ca = 40 × 1 = 40
Cl = 35 × 2 = 70
110

$$moles = \frac{g}{GFM}$$

$$moles = \frac{390}{110}$$

moles = 3.5 moles

5. How many moles are in 484.25 g of ammonium phosphate [$(NH_4)_3PO_4$]?

6. How many moles are in 75.46 g of sulfuric acid? [$H_2SO_4(aq)$]?

7. How many moles are in 270. g of dinitrogen pentoxide [N_2O_5]?

8. How many moles are in 546 g of tin IV fluoride [SnF_4]?

FORMULAS AND EQUATIONS

Answer the questions below by circling the number of the correct response

1. The gram molecular mass of CO_2 is the same as the gram molecular mass of (1) CO (2) SO_2 (3) C_2H_6 (4) C_3H_8

2. The number of molecules in 1.0 mole of SO_2 is the same as the number of molecules in
(1) 1.0 mole of N_2 (3) 0.25 mole of NO_2
(2) 2.0 moles of Ne (4) 0.50 mole of NH_3

3. What is the gram formula mass of $Ca(HCO_3)_2$?
(1) 101 (3) 202
(2) 162 (4) 324

4. What is the total mass of iron in 1.0 mole of Fe_2O_3?
(1) 160 g (3) 72 g
(2) 112 g (4) 56 g

5. What is the mass, in grams, of 1.0 mole of $(NH_4)_2S$?
(1) 50 (3) 64
(2) 54 (4) 68

6. The mass of two moles of sulfuric acid, expressed in grams, is equal to
(1) $\frac{98}{2}$ (3) $\frac{6.02 \times 10^{23}}{2}$
(2) 2×98 (4) $2 \times (6.02 \times 10^{23})$

7. Which quantity is equivalent to 39 grams of LiF?
(1) 1.0 mole (3) 0.30 mole
(2) 2.0 moles (4) 1.5 moles

8. What is the total number of moles contained in115 grams of C_2H_5OH?
(1) 1.00 (3) 3.00
(2) 1.50 (4) 2.50

9. How many moles of water are contained in 0.250 mole of $CuSO_4 \cdot 5H_2O$?
(1) 1.25 (3) 40.0
(2) 4.50 (4) 62.5

10. Which represents the greatest mass of chlorine
(1) 1 mole of chlorine (2) 1 atom of chlorine
(3) 1 gram of chlorine (4) 1 molecule of chlorine

11. What is the total mass of iron in 1.0 mole of Fe_2O_3?
(1) 160 g (3) 72 g
(2) 112 g (4) 56 g

12. What is the mass, in grams, of 1.0 mole of $(NH_4)_2S$?
(1) 50. (3) 64
(2) 54 (4) 68

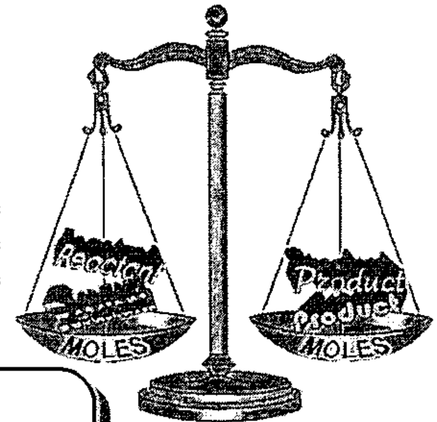
13. What is the gram atomic mass of the element chlorine?
(1) 17 g (3) 52 g
(2) 35 g (4) 70. g

14. The mass in grams of 1.00 mole of $CaSO_4 \cdot 2H_2O$ is
(1) 172 g (3) 136 g
(2) 154 g (4) 118 g

Chemistry: Form WS5.7.1A Name ____________________

CHEMICAL FORMULAS AND EQUATIONS Date ______________ Period ____

Stochiometric Relationships



Calculations based on quantitative relationships in a balanced chemical equation are called stoichiometry. Stoichiometric calculations are based on several assumptions. It is assumed that the reaction has no side reactions, the reaction goes to completion, and the reactants are completely consumed. One type of problem that can be solved stoichiometrically is based on the mole ratios of a balanced equation. A sample problem is shown below.

Sample Problem

How many moles of oxygen are consumed when 0.6 moles of hydrogen burns to produce water?

Step 1: Write a balanced equation and determine the mole ratios from the equation

Step 2: Identify the known and the unknown

	$2\,H_2(g)$	$+\ O_2(g)$	$\rightarrow 2\,H_2O$
mole ratio	2	1	2
moles	known 0.6	unknown x	

Step 3: Set up a proportion and solve for the unknown

- $\dfrac{2}{0.6mol} = \dfrac{1}{x}$
- $2x = 0.6mol$
- $x = 0.3mol$

Answer the questions below using the procedure described in the sample problem above.

1. How many moles of oxygen will be produced from the decomposition of 3 moles of $KClO_3$?

   $\_\_KClO_3 \rightarrow \_\_KCl + \_\_O_2$

2. How many moles of Zn will be needed to completely react with 0.4 moles of HCl?

   $\_\_Zn + \_\_HCl \rightarrow \_\_ZnCl_2 + \_\_H_2$

3. How many moles of oxygen will be needed to completely oxidize 4 moles of CH_4?

$$\_\_CH_4 + \quad \_\_O_2 \rightarrow \quad \_\_CO_2 + \quad \_\_H_2O$$

4. How many moles of hydrogen will be needed to react with 2 moles of nitrogen according to the following?

$$\_\_N_2 + \quad \_\_H_2 \rightarrow \quad \_\_NH_3$$

5. Using the above reaction how many moles of NH_3 will be formed if 18 moles of H_2 is used?

6. How many moles of sulfur will be needed to oxidize 3 moles of zinc to zinc sulfide?

$$\_\_Zn + \quad \_\_S \rightarrow \quad \_\_ZnS$$

7. How many moles of silver chloride will be produced if 2 moles of silver is allowed to react with an unlimited amount of chlorine?

$$\_\_Ag^+ + \quad \_\_Cl^- \rightarrow \quad \_\_AgCl(s)$$

MIXED MOLE PROBLEMS

Name ____________________

Solve the following problems.

1. How many grams are there in 1.5×10^{25} molecules of CO_2?

   ____

2. What volume would the CO_2 in Problem 1 occupy at STP?

   ____

3. A sample of NH_3 gas occupies 75.0 liters at STP. How many molecules is this?

   ____

4. What is the mass of the sample of NH_3 in Problem 3?

   ____

5. How many atoms are there in 1.3×10^{22} molecules of NO_2?

   ____

6. A 5.0 g sample of O_2 is in a container at STP. What volume is the container?

   ____

7. How many molecules of O_2 are in the container in Problem 6? How many atoms of oxygen?

   ____

   ____

Name ______________________

Date ______________ Period ______

Determining Percent Composition

Percentage composition is determined by finding the formula mass of a compound, multiplying the mass of each element by 100, and dividing the product by the formula mass of the compound. Use the periodic table to find the masses of individual elements. See the *Sample Problem* to the right.

Sample Problem: Find the percentage composition of $MgCO_3$.

Formula Mass	Percentage Composition
Mg = 24 × 1 = 24	% Mg = 24 × 100 ÷ 84 = 29
C = 12 × 1 = 12	% C = 12 × 100 ÷ 84 = 14
O = 16 × 3 = 48	% O = 48 × 100 ÷ 84 = 57
84	100

1. What is the percentage composition of: Na, O, and H in the compound NaOH?

   Na __________, O __________, H __________.

2. Calculate the percentage composition of baking soda ($NaHCO_3$).

   Na __________, H __________, C __________, O __________.

3. Calculate the percentage of each of the elements within acetic acid ($HC_2H_3O_2$), the substance found in vinegar.

   H __________, C __________, O __________.

4. What is the percentage composition of a soap ($C_{17}H_{35}COONa$)?

   C __________, H __________, O __________, Na __________.

5. Which of the following has the highest percentage of nitrogen? (✔)

   ___ $Ca(NO_3)_2$ __________ ___ $(NH_4)_2SO_4$ __________

Percentages can refer to different portions of a compound. In hydrated crystals, for example, it is possible to calculate the percentage of water. Find the formula mass of each portion of the compound separately. Add them together to get the mass of the compound. Then multiply the mass of the water by 100, and divide the product by the formula mass of the compound. See the ***Sample Problem*** to the right.

Sample Problem: What is the percentage of water in $CuSO_4 \cdot 5H_2O$?

Formula Mass of $CuSO_4$	Formula Mass of H_2O
Cu = 64 × 1 = 64	H = 1 × 2 = 2
S = 32 × 1 = 32	O = 16 × 1 = 16
O = 16 × 4 = 64	18
160	Mass of Water: 5 × 18 = 90 *TOTAL:* 160 + 90 =250

Percentage
$\%H_2O$ = 90 × 100 ÷ 250 = 36 %

6. Calculate the percentage of water in the compound $CaSO_4 \cdot 6H_2O$.

7. Calculate the percentage of water in the compound $CaCl_2 \cdot 10H_2O$.

Once you know the percentage composition of a compound, you can figure out the mass of any component of the compound in a sample of any mass simply by multiplying the sample mass by the percentage. See the ***Sample Problem*** to the right.

8. How many milligrams of iron are delivered from a 250. mg tablet of $FeSO_4 \cdot 7H_2O$?

Sample Problem: A 40.0 g sample of $CaCl_2 \cdot 2H_2O$ is heated to dryness. What is the mass of the remaining calcium chloride.

Formula Mass of $CuSO_4$	Formula Mass of H_2O
Ca = 40 × 1 = 40	H = 1 × 2 = 2
Cl = 35 × 2 = 70	O = 16 × 1 = 16
O = 16 × 4 = 110	18
	Mass of Water: 2 × 18 = 36 *TOTAL:* 110 + 36 = 146

Percentage
$\%CaCl_2$ = 110 × 100 ÷ 146 = 75 %

Mass
0.75 × 40.0 g = 30. g

9. What is the yield of uranium from 2.50 kg U_3O_8?

PERCENTAGE COMPOSITION

Name ____________

Determine the percentage composition of each of the compounds below.

1. $KMnO_4$

   K = ________

   Mn = ________

   O = ________

2. HCl

   H = ________

   Cl = ________

3. $Mg(NO_3)_2$

   Mg = ________

   N = ________

   O = ________

4. $(NH_4)_3PO_4$

   N = ________

   H = ________

   P = ________

   O = ________

5. $Al_2(SO_4)_3$

   Al = ________

   S = ________

   O = ________

Solve the following problems.

6. How many grams of oxygen can be produced from the decomposition of 100. g of $KClO_3$? ____________
7. How much iron can be recovered from 25.0 g of Fe_2O_3? ____________
8. How much silver can be produced from 125 g of Ag_2S? ____________

Name________________ **GFM, Balancing & % Composition** Date________________

Ms. Tintella **Practice** **Regents Chemistry**

1. What is the gram-formula mass of $Ca_3(PO_4)_2$?

   A) 248 g/mol B) 263 g/mol
   C) 279 g/mol D) 310. g/mol

2. The gram formula mass of NH_4Cl is

   A) 22.4 g/mole B) 28.0 g/mole
   C) 53.5 g/mole D) 95.5 g/mole

3. The gram-formula mass of $(NH_4)_2CO_3$ is

   A) 46.0 g B) 64.0 g
   C) 78.0 g D) 96.0 g

4. What is the gram formula mass of $CuSO_4 \cdot 5H_2O$?

   A) 160. g B) 178 g
   C) 186 g D) 250. g

5. Given the unbalanced equation:

   $\_\_Al_2(SO_4)_3 + \_\_Ca(OH)_2 \rightarrow \_\_Al(OH)_3 + \_\_CaSO_4$

   When the equation is correctly balanced with the smallest whole-number coefficients, the sum of the coefficients is

   A) 5 B) 7 C) 8 D) 9

6. A balanced equation representing a chemical reaction can be written using

   A) chemical formulas and mass numbers
   B) chemical formulas and coefficients
   C) first ionization energies and mass numbers
   D) first ionization energies and coefficients

7. Which chemical equation is correctly balanced?

   A) $H_2(g) + O_2(g) \rightarrow H_2O(g)$
   B) $N_2(g) + H_2(g) \rightarrow NH_3(g)$
   C) $2NaCl(s) \rightarrow Na(s) + Cl_2(g)$
   D) $2KCl(s) \rightarrow 2K(s) + Cl_2(g)$

8. Given the unbalanced equation:

   $\_\_Mg(ClO_3)_2(s) \rightarrow \_\_MgCl_2(s) + \_\_O_2(g)$

   What is the coefficient of O_2 when the equation is balanced correctly using the *smallest* whole number coefficients?

   A) 1 B) 2 C) 3 D) 4

9. Which equation is correctly balanced?

   A) $H_2 + O_2 \rightarrow H_2O$
   B) $Ca + Cl_2 \rightarrow CaCl$
   C) $2\ H_2 + O_2 \rightarrow 2\ H_2O$
   D) $Ca + Cl_2 \rightarrow Ca_2Cl$

10. Given the unbalanced equation:

    $\_\_Al + \_\_CuSO_4 \rightarrow \_\_Al_2(SO_4)_3 + \_\_Cu$

    When the equation is balanced using the *smallest* whole-number coefficients, what is the coefficient of Al?

    A) 1 B) 2 C) 3 D) 4

11. What is the percent composition by mass of hydrogen in NH_4HCO_3 (gram-formula mass = 79 grams/mole)?

    A) 5.1% B) 6.3%
    C) 10.% D) 50.%

12. What is the percent composition by mass of nitrogen in NH_4NO_3 (gram-formula mass = 80.0 grams/mole)?

    A) 17.5% B) 35.0%
    C) 52.5% D) 60.0%

13. What is the percent composition by mass of aluminum in $Al_2(SO_4)_3$ (gram-formula mass = 342 grams/mole)?

    A) 7.89% B) 15.8%
    C) 20.8% D) 36.0%

14. The percent by mass of hydrogen in NH_3 is equal to

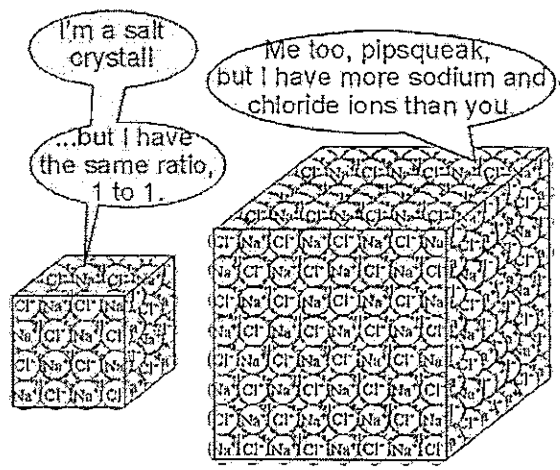
    A) $\frac{17}{1} \times 100$ B) $\frac{17}{3} \times 100$ C) $\frac{1}{17} \times 100$ D) $\frac{3}{17} \times 100$

15. What is the percent by mass of oxygen in $Ca(OH)_2$

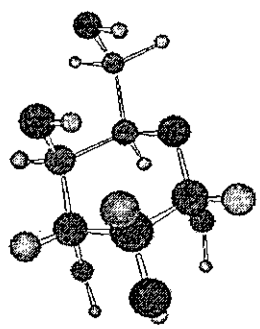
[formula mass = 47.1]

A) 21.6% B) 43.2%
C) 45.9% D) 54.1%

Empirical Formulas



The chemical formula for a molecular compound shows the number and type of atoms present in a molecule. Ionic crystals are a collections of ions. The chemical formula for an ionic compound shows the ratio ions in the compound. The ratio of ions in the formula for an ionic compound is always in lowest terms. A chemical formula in which the ratio of the elements are in lowest terms is called an empirical formula. For example, the formula for table salt, sodium chloride, is NaCl even though a salt crystal may have millions of ions and millions of ionic bonds. A glucose, molecule ($C_6H_{12}O_6$) such as the one pictured to the left, on the other hand, has exactly six carbon atoms, twelve hydrogen atoms, and six oxygen atoms per molecule. The molecular formula for glucose is not an empirical formula. All the subscripts are divisible by six. When the subscripts are divided by six, the empirical formula for glucose, CH_2O, is obtained. Some molecular formulas, such as the one for carbon dioxide, CO_2, are already empirical formulas without being reduced.



There are two skills you need to learn in order to work with empirical formulas. They are finding the empirical formula from the molecular formula and Finding the molecular formula from the empirical formula and the molecular mass:

- to find the empirical formula from the molecular formula

  divide all the subscripts by the greatest common factor

Determine the empirical formula, for each of the following molecular formulas.

1. C_8H_{18} .... ______________
2. H_2O_2 .... ______________
3. Hg_2Cl_2 ...... ______________
4. $C_3H_6O_3$ ..... ______________
5. $Na_2C_2O_4$ .... ______________
6. H_2O .... ______________
7. C_4H_8 .... ______________
8. C_4H_6 .... ______________
9. C_7H_{12} .... ______________
10. CH_3COOH .. ______________

NEXT PAGE ☞

- to find the molecular formula from the empirical formula and the molecular mass.

Step 1: Determine the empirical formula mass.
Step 2: Divide the molecular mass by the empirical formula mass to determine the multiple..
Step 3: Multiply the empirical formula by the by the multiple to find the molecular formula

Sample Problem

A compound with an empirical formula of CH_2O has a molecular mass of 90 amu. What is its molecular formula?

Step 1: Determine the empirical formula mass.

CH_2O
C = 12 × 1 = 12
H = 1 × 2 = 2
O = 16 × 1 = 16
30

Step 2: Divide the molecular mass by the empirical formula mass to determine the multiple.

$$\frac{90}{30} = 3$$

Step 3: Multiply the empirical formula by the by the multiple to find the molecular formula

$[CH_2O] \times 3 = C_3H_6O_3$

Determine the molecular formula for each of the following:

11. Find the molecular formula for a compound with a mass of 78 amu and the empirical formula CH.

12. Find the molecular formula for a compound with a mass of 82 amu and the empirical formula C_3H_5.

13. Find the molecular formula for a compound with a mass of 90 amu and the empirical formula HCO_2.

14. Find the molecular formula for a compound with a mass of 112 amu and the empirical formula CH_2.

15. Find the molecular formula for a compound with a mass of 40 amu and the empirical formula C_3H_4.

Name ______________________________

Classwork Review Activity

Show your work

$Ti_2(Cr_2O_7)_3$

1. Name the compound ______________________________

2. State the type of bond or bonds is in this compound

____

3. Give the number of moles of oxygen in the compound ____________________

4. Give the number of moles of atoms in the compound ____________________

5. Give the Gram Formulas Mass of the compound ____________________

6. Give the number of moles of oxygen in the compound ____________________

7. Give the percent by mass of oxygen in the compound ____________________

Name ______________________________

Classwork Review Activity

Show your work

$Fe_2(S_2O_3)_3$

1. Name the compound ______________________________

2. State the type of bond or bonds is in this compound ______________________

3. Give the Gram Formulas Mass of the compound ______________________

4. Give the number of moles of sulfer in the compound ____________________

5. Give the number of moles of atoms in the compound ____________________

6. Give the number of moles in 75 grams of the compound ____________________

7. Give the percent by mass of oxygen in the compound ____________________

DETERMINING EMPIRICAL FORMULAS

Name ____________________

What is the empirical formula (lowest whole number ratio) of the compounds below?

1. 75% carbon, 25% hydrogen

   ____

2. 52.7% potassium, 47.3% chlorine

   ____

3. 22.1% aluminum, 25.4% phosphorus, 52.5% oxygen

   ____

4. 13% magnesium, 87% bromine

   ____

5. 32.4% sodium, 22.5% sulfur, 45.1% oxygen

   ____

6. 25.3% copper, 12.9% sulfur, 25.7% oxygen, 36.1% water

   ____

DETERMINING MOLECULAR FORMULAS (TRUE FORMULAS)

Name ____________________

Solve the problems below.

1. The empirical formula of a compound is NO_2. Its molecular mass is 92 g/mol. What is its molecular formula?

   ____

2. The empirical formula of a compound is CH_2. Its molecular mass is 70 g/mol. What is its molecular formula?

   ____

3. A compound is found to be 40.0% carbon, 6.7% hydrogen and 53.5% oxygen. Its molecular mass is 60. g/mol. What is its molecular formula?

   ____

4. A compound is 64.9% carbon, 13.5% hydrogen and 21.6% oxygen. Its molecular mass is 74 g/mol. What is its molecular formula?

   ____

5. A compound is 54.5% carbon, 9.1% hydrogen and 36.4% oxygen. Its molecular mass is 88 g/mol. What is its molecular formula?

   ____

CHEMICAL FORMULAS AND EQUATIONS

Answer the questions below by circling the number of the correct response

1. An example of an empirical formula is (1) C_2H_2, (2) H_2O_2, (3) C_2Cl_2, (4) $CaCl_2$
2. A 10.0 gram sample of a hydrate was heated until all the water of hydration was driven off. The mass of anhydrous product remaining was 8.00 grams What is the percent of water in the hydrate? (1) 12.5% (2) 20.0% (3) 25.0% (4) 80.0%
3. A compound has the empirical formula NO_2. Its molecular formula could be (1) NO_2, (2) N_2O, (3) N_4O_2, (4) N_4O_4.
4. The percent by mass of oxygen in $Ca(OH)_2$ (formula mass = 74) is closest to (1) 16, (2) 22, (3) 43, (4) 74.
5. The empirical formula of a compound is CH. Its molecular mass could be (1) 21, (2) 40, (3) 51, (4) 78.
6. What is the percent by mass of oxygen in NaOH (formula mass = 40.)? (1) 80. (2) 40. (3) 32 (4) 16
7. A compound whose empirical formula is CH_2O could be (1) HCOOH, (2) CH_3OH, (3) CH_3COOH, (4) CH_3CH_2OH.
8. The percent by mass of oxygen in CO is approximately (1) 73%, (2) 57%, (3) 43%, (4) 17%.
9. A compound has an empirical formula of CH_2 and a molecular mass of 56. Its molecular formula is (1) C_2H_4, (2) C_3H_6, (3) C_4H_8, (4) C_5H_{10}.
10. What is the percent by mass of hydrogen in NH_3 (formula mass = 17.0)? (1) 5.9% (2) 17.6% (3) 21.4% (4) 82.4%
11. The empirical formula of a compound is CH_2 and its molecular mass is 70. What is the molecular formula of the compound? (1) C_2H_2 (2) C_2H_4 (3) C_4H_{10} (4) C_5H_{10}
12. The percent by mass of nitrogen in $Mg(CN)_2$ is equal to (1) $^{14}/_{76} \times 100$, (2) $^{14}/_{50} \times 100$, (3) $^{28}/_{76} \times 100$, (4) $^{28}/_{50} \times 100$.
13. What is the percent by mass of oxygen in Fe_2O_3 (formula mass = 160)? (1) 16% (2) 30.% (3) 56% (4) 70.%
14. Which formulas could represent the empirical formula and the molecular formula of a given compound? (1) CH_2O, $C_4H_6O_4$ (2) CHO $C_6H_{12}O_6$ (3) CH_4, C_3H_{12} (4) CH_2, C_3H_6
15. The percent by mass of carbon in CO_2 is equal to (1) $^{44}/_{12} \times 100$, (2) $^{12}/_{44} \times 100$, (3) $^{28}/_{12} \times 100$, (4) $^{12}/_{28} \times 100$
16. The percentage by mass of hydrogen in NH_3 is equal to (1) $^{1}/_{17} \times 100$ (2) $^{3}/_{17} \times 100$ (3) $^{17}/_{3} \times 100$ (4) $^{6}/_{17} \times 100$
17. The empirical formula of a compound is CH_4. The molecular formula of the compound could be (1) CH_4, (2) C_2H_6, (3) C_3H_8, (4) C_4H_{10}
18. A hydrocarbon has the empirical formula CH_3. The most probable molecular formula for this compound is (1) CH_3, (2) C_2H_6, (3) C_3H_8, (4) C_4H_6
19. A compound with an empirical formula of CH_2 has a molecular mass of 70. What is the molecular formula? (1) CH_2 (2) C_2H_4 (3) C_4H_8 (4) C_5H_{10}
20. What is the percent by mass of oxygen in CH_3OH? (1) 50.0 (2) 44.4 (3) 32.0 (4) 16.0
21. The approximate percent by mass of potassium in $KHCO_3$ is (1) 19 %, (2) 24 %, (3) 39 %, (4) 61 %
22. A compound has an empirical formula of CH_2 and a molecular mass of 56. What is its molecular formula?
    (1) CH_2 (3) C_3H_6
    (2) C_2H_4 (4) C_4H_8
23. What is the percent by mass of hydrogen in CH_3COOH (formula mass = 60.)?
    (1) 1.7% (3) 6.7%
    (2) 5.0% (4) 7.1%
24. What is the percentage by mass of oxygen in CuO?
    (1) 16% (3) 25%
    (2) 20% (4) 50%
25. What is the approximate percent composition by mass of $CaBr_2$ (formula mass = 200)? (1) 20% calcium and 80% bromine (2) 25% calcium and 75% bromine (3) 30% calcium and 70% bromine (4) 35% calcium and 65% bromine
26. A 60. gram sample of $LiCl{\cdot}H_2O$ is heated in an open crucible until all of the water has been driven off. What is the total mass of LiCl remaining in the crucible?
    (1) 18 g. (3) 42 g.
    (2) 24 g. (4) 60 g.
27. Which compound contains the greatest percentage of oxygen by mass?
    (1) BaO (3) MgO
    (2) CaO (4) SrO
28. The precent by mass of oxygen in MgO (formula mass = 40) is closest to
    (1) 16% (3) 40%
    (2) 24% (4) 60%

Identifying Reaction Types

Chemical reactions can be grouped into four basic types. They are direct combination or synthesis, decomposition, single replacement or substitution, and double replacement or exchange of ions.

An example of **synthesis** is shown below:

$$N_2(g) + 3H_2(g) \xrightarrow[\Delta]{catalyst} 2NH_3(g)$$

Synthesis often results in the formation of only one product from two reactants, but not always. Combustion, as in the following example, $CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O$, is also a form of synthesis because the oxygen combines with both the metal and the nonmetal to form two oxides.

Decomposition is the reverse of synthesis. One reactant breaks apart to form several products. This is what happens when hydrogen peroxide decomposes over time to leave behind plain, ordinary water [$2H_2O_2(aq) \rightarrow 2H_2O(\ell) + O_2(g)$].

During a **single replacement** reaction, a more active metal replaces a less active metal in a compound, or a more active nonmetal replaces a less active nonmetal in a compound. This is what happens when a metal becomes corroded by an acid [$2Fe(s) + 6HCl(aq) \rightarrow 2FeCl_3(aq) + 3H_2(g)$]. In single replacement reactions, an element is reacting with a compound.

Double replacement reactions occur between aqueous compounds. The cations and anions switch partners. If an insoluble precipitate forms, the reaction is an end reaction, otherwise the result is an aqueous mixture of ions. An example of a double replacement reaction is $AgNO_3(aq) + NaCl(aq) \rightarrow NaNO_3(aq) + AgCl(s)$.

Patterns of the Reaction Types

Legend:
- A and C = *metals*
- B and D = *nonmetals*

— ◆ —

Direct combination (synthesis)
A + B → AB *or*
AB + D → AD + BD

Decomposition
AB → A + B

Single Replacement (substitution)
AB + C → CB + A *or*
AB + D → AD + B

Double Replacement (Exchange of Ions)
AB + CD → AD + CB

For each of the reactions shown below, identify the type of reaction.

1. $Pb(NO_3)_2(aq) + 2KI(aq) \rightarrow PbI_2(s) + 2KNO_3(aq)$ .... ______________________
2. $Zn(s) + CuSO_4(aq) \rightarrow ZnSO_4(aq) + Cu(s)$ .... ______________________
3. $FeCl_3(aq) + 3NaOH(aq) \rightarrow Fe(OH)_3(s) + 3NaCl(aq)$ .... ______________________
4. $2Mg(s) + O_2(g) \rightarrow 2MgO(s)$ .... ______________________
5. $H_2CO_3(aq) \rightarrow H_2O(\ell) + CO_2(g)$ .... ______________________
6. $H_2O(\ell) + N_2O_5(g) \rightarrow 2HNO_3(aq)$ .... ______________________
7. $Cl_2(g) + 2NaBr(aq) \rightarrow 2NaCl(aq) + Br_2(\ell)$ .... ______________________
8. $2KClO_3(s) \rightarrow 2KCl(s) + 3O_2(g)$ .... ______________________
9. $2K(s) + 2H_2O(\ell) \rightarrow 2KOH(aq) + H_2(g)$ .... ______________________

 Name ____________________

 Date ______________ Period _____

Balancing Equations & Identifying Reaction Types

Balance the equations below by writing coefficients greater than one in front of the formulas where needed. Identify the reaction type in the answer space to the left of the equation [*Synthesis* (S), *Decomposition* (D), *Single Replacement* (SR), or *Double Replacement* (DR)].

_____ **1.** $Al + HCl \rightarrow AlCl_3 + H_2\uparrow$

_____ **2.** $Fe_2O_3 + C \rightarrow Fe + CO_2\uparrow$

_____ **3.** $S(s) + O_2(g) \rightarrow SO_3(g)$

_____ **4.** $N_2 + H_2 \rightarrow NH_3$

_____ **5.** $H_2O + P_2O_5 \rightarrow H_3PO_4$

_____ **6.** $NH_4NO_2 \xrightarrow[\Delta]{} H_2O + N_2\uparrow$

_____ **7.** $Ba(NO_3)_2 + Fe_2(SO_4)_3 \rightarrow BaSO_4\downarrow + Fe(NO_3)_3$

_____ **8.** $ZnCl_2 + AgNO_3 \rightarrow Zn(NO_3)_2 + AgCl\downarrow$

_____ **9.** $Na_2O + H_2O \rightarrow NaOH$

_____ **10.** $NiCO_3 + Al(OH)_3 \rightarrow Ni(OH)_2 + Al_2(CO_3)_3$

_____ **11.** $Ca(ClO_3)_2 \xrightarrow[\Delta]{} CaCl_2 + O_2\uparrow$

_____ **12.** $Mg + H_2O \rightarrow Mg(OH)_2 + H_2\uparrow$

CLASSIFICATION OF CHEMICAL REACTIONS

Name ____________________

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

1. $2H_2 + O_2 \rightarrow 2H_2O$ ____________________

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

3. $Zn + H_2SO_4 \rightarrow ZnSO_4 + H_2$ ____________________

4. $2CO + O_2 \rightarrow 2CO_2$ ____________________

5. $2HgO \rightarrow 2Hg + O_2$ ____________________

6. $2KBr + Cl_2 \rightarrow 2KCl + Br_2$ ____________________

7. $CaO + H_2O \rightarrow Ca(OH)_2$ ____________________

8. $AgNO_3 + NaCl \rightarrow AgCl + NaNO_3$ ____________________

9. $2H_2O_2 \rightarrow 2H_2O + O_2$ ____________________

10. $Ca(OH)_2 + H_2SO_4 \rightarrow CaSO_4 + 2H_2O$ ____________________

Chemistry: Form WS5.5.4A

CHEMICAL FORMULAS AND EQUATIONS

Name ______________________

Date ______________ Period ______

Everything about Equations

A chemical equation contains a lot of information. Many equations show evidence of a chemical change such as a change in temperature (exothermic – give off heat; endothermic – absorb heat), release of a gas, or formation of a precipitate. Other identifying characteristics of a chemical equation such as a change in color or a change in odor cannot be demonstrated in the equation. Some changes and/or conditions are shown using symbols such as [1] solid precipitate – (*s*) or ↓; [2] liquid – (*ℓ*); [3] gas – (*g*) or ↑; [4] dissolved in water or aqueous – (*aq*); [5] heat – Δ; [6] electricity – elec.; and [7] light – ↑↓. Symbols and formulas that are neither reactants nor products are written above or below the yield sign (→). Examine the equation below:

$$2KClO_3(s) \xrightarrow[\Delta]{MnO_2(s)} 2KCl(s) + 3O_2(g)$$

The equation tells us the following: [1] The reactant is $KClO_3$; [2] $KClO_3$ is a solid; [3] $KClO_3$ decomposes, particularly when heated (Δ) in the presence of the catalyst MnO_2; [4] One of the products is KCl, a solid; [5] The other product is O_2, a gas. [6] Conservation of mass is shown because the reactants contain 2 atoms of K, 2 atoms of Cl, and 6 atoms of O, and the products contain 2 atoms of K, 2 atoms of Cl, and 6 atoms of O also.

Sometimes a reaction results in the formation of a precipitate from dissolved reactants. Examine the equation below:

$$K_2SO_4(aq) + Ca(NO_3)_2(aq) \rightarrow 2KNO_3(aq) + CaSO_4(s)$$

The equation tells us the following: [1] The reactants are K_2SO_4 and $CaNO_3$; [2] Both reactants are dissolved; [3] A double-displacement reaction occurs resulting in the formation of a precipitate; [4] The precipitate is identified using *Table F–Solubility Guidelines*; [5] Conservation of mass is shown because the reactants contain 2 atoms of K, 1 sulfate ion, 1 atom of Ca, and 2 nitrate ions, and the products contain 2 atoms of K, 1 sulfate ion, 1 atom of Ca, and 2 nitrate ions; [6] The sum of the coefficients is 5 as in the example below.

Example

Unbalanced Equation:	$CuSO_4 + AgNO_3 \rightarrow Cu(NO_3)_2 + Ag_2SO_4$
Balanced Equation:	$CuSO_4 + 2AgNO_3 \rightarrow Cu(NO_3)_2 + Ag_2SO_4$
Sum of the Coefficients:	1 + 2 + 1 + 1 = 5

Examine the unbalanced equations in the table on the next page. Determine the following: [1] The sum of the coefficients of the balanced equation; [2] The type of reaction (*direct combination, decomposition, single displacement, double displacement*); [3] Identify the phase(s) of the product(s); and [4] The signs that a chemical change has occurred.

☞ Go on to the next page.

CHEMICAL FORMULAS AND EQUATIONS

Answer the questions below by circling the number of the correct response

1. The symbol (aq) after a chemical formula means (1) solid or precipitate, (2) liquid, (3) gas, (4) aqueous or dissolved.

2. In the reaction, $AgNO_3 + NaCl \rightarrow AgCl + NaNO_3$, the reactants are (1) AgCl and $NaNO_3$, (2) $AgNO_3$ and NaCl, (3) Ag and Na, (4) Cl and NO_3.

3. In the reaction, $AgNO_3 + NaCl \rightarrow AgCl + NaNO_3$, which of the four substances involved is a precipitate? [*HINT: Refer to Chart C*] (1) $AgNO_3$ (2) NaCl (3) AgCl (4) $NaNO_3$

Answer questions 4–5 by referring to the equation below:

$$2KClO_3(s) \xrightarrow[\Delta]{MnO_2(s)} 2KCl(s) + 3O_2(g)$$

4. The symbol Δ under the yield sign indicates that (1) the reaction is exothermic, (2) the reaction is endothermic, (3) a solid precipitate forms, (4) heat is a product of the reaction.

5. $MnO_2(s)$ is written above the yield sign because $MnO_2(s)$ is (1) a reactant, (2) a product, (3) neither a reactant nor a product, (4) both a reactant and a product.

CHEMICAL FORMULAS AND EQUATIONS

Unbalanced Equation	Sum of the Coefficients	Reaction Type	Phase	Evidence of Chemical Change
1. $FeCl_3(aq) + NaOH(aq) \rightarrow NaCl(?) + Fe(OH)_3(?)$				
2. $Al(s) + HCl(aq) \rightarrow AlCl_3(?) + H_2(?)$				
3. $Mg(s) + O_2(g) \rightarrow MgO(?)$				
4. $H_2O_2(aq) \xrightarrow{MnO_2} H_2O(?) + O_2(?)$				
5. $H_2CO_3(aq) \rightarrow H_2O(?) + CO_2(?)$				
6. $Pb(s) + CuSO_4(aq) \rightarrow PbSO_4(?) + Cu(?)$				
7. $H_2O(\ell) + N_2O_5(g) \rightarrow HNO_3(?)$				
8. $Na(s) + H_2O(\ell) \rightarrow NaOH(?) + H_2(?)$				
9. $K_2CrO_4(aq) + Al(NO_3)_3(aq) \rightarrow KNO_3(?) + Al_2(CrO_4)_3(?)$				
10. $NaOH(aq) + H_2SO_4(aq) \rightarrow Na_2SO_4(?) + H_2O(?)$				
11. $C_2H_6(g) + O_2(g) \rightarrow CO_2(?) + H_2O(?)$				
12. $Cu(s) + AgNO_3(aq) \rightarrow Cu(NO_3)_2(?) + Ag(?)$				
13. $N_2(g) + O_2(g) \rightarrow N_2O_5(?)$				
14. $O_3(g) \longrightarrow O_2(g)$				
15. $Ca(ClO_3)_2(aq) + Li_2SO_4(aq) \rightarrow CaSO_4(?) + LiClO_3(?)$				

For each of the reactions described in questions 1-7, write the correct number to indicate whether the reaction type is (1) DECOMPOSITION, (2) DIRECT COMBINATION, (3) SINGLE REPLACEMENT, or (4) DOUBLE REPLACEMENT

1. A reaction occurs in which only one reactant is present.
2. A metal reacts with an acid. ($2Fe + 6HCl \rightarrow 2FeCl_3 + 3H_2$)
3. Magnesium burns.
4. Two salt solutions react with each other.
5. Two elements unite to form a compound.
6. A compound breaks down.
7. $HCl + NaOH \rightarrow NaCl + H_2O$

---

8. Many sulfide ores are prepared for refinement by roasting. This reaction can BEST be described as (1) decomposition, (2) direct combination, (3) single displacement, (4) double displacement.
9. During smelting, oxide ores are reduced to pure metals by reacting with (1) oxygen, (2) hydrogen, () carbon, (4) nitrogen.

COMPOSITION OF HYDRATES

Name ____________________

A hydrate is an ionic compound with water molecules loosely bonded to its crystal structure. The water is in a specific ratio to each formula unit of the salt. For example, the formula $CuSO_4 \bullet 5H_2O$ indicates that there are five water molecules for every one formula unit of $CuSO_4$. Answer the questions below.

1. What percentage of water is found in $CuSO_4 \bullet 5H_2O$?

   ____

2. What percentage of water is found in $Na_2S \bullet 9H_2O$?

   ____

3. A 5.0 g sample of a hydrate of $BaCl_2$ was heated, and only 4.3 g of the anhydrous salt remained. What percentage of water was in the hydrate?

   ____

4. A 2.5 g sample of a hydrate of $Ca(NO_3)_2$ was heated, and only 1.7 g of the anhydrous salt remained. What percentage of water was in the hydrate?

   ____

5. A 3.0 g sample of $Na_2CO_3 \bullet H_2O$ is heated to constant mass. How much anhydrous salt remains?

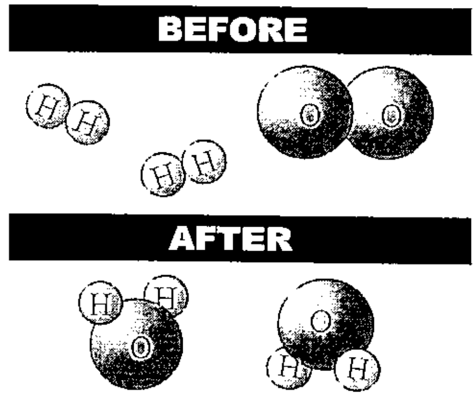
   ____

6. A 5.0 g sample of $Cu(NO_3)_2 \bullet nH_2O$ is heated, and 3.9 g of the anhydrous salt remains. What is the value of n?

   ____

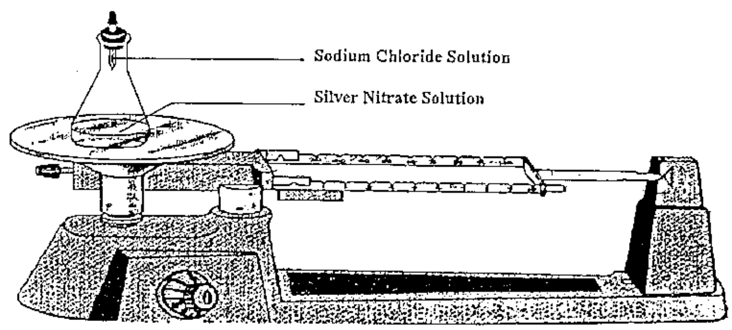
Conservation During Chemical Reactions

During a chemical reaction, new substances form with new properties. This means that during a chemical reaction there are both chemical changes and physical changes. Physical changes such as the formation of a solid precipitate, a liquid, or a gas, provide evidence that a chemical change has occurred. During a chemical change, the atoms of the reactants are rearranged to form new substances or products. No new atoms are created and none of the original atoms are destroyed. As a result, the mass of the reactants and the products is the same. This is called conservation of mass. When water (H_2O) forms from hydrogen (H_2) and oxygen (O_2), for example, the hydrogen and oxygen atoms are rearranged to form the new substance, but no new atoms are created and none of the original atoms are lost. Chemical reactions are described by chemical equations which show the reactants, the products, and conservation of mass.



Answer the questions below based on the reading above, your knowledge of chemistry, and the information provided below.

A student poured silver nitrate solution into a flask and put sodium chloride solution in a medicine dropper. Then the student put the medicine dropper through a one-hole stopper and sealed the flask with it. After that, the student measured the mass of the setup with a balance. Finally, the student squeezed the medicine dropper so the sodium chloride solution mixed with the silver nitrate in the sealed flask on the balance. A white precipitate formed.



1. What evidence is there that the reaction described above is a chemical change? ______________________

____

2. Did the mass of the contents of the flask change during this experiment? Support your answer. __________

____

____

3. Write the formulas for the reactants. Write the appropriate symbols to show the phase or state [(s) = solid; (ℓ) = liquid; (g) = gas; and (aq) = solution]. ______________________

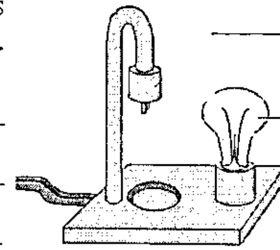
____

4. When the electrodes of the apparatus shown to the right are placed in solutions of silver nitrate, the light bulb lights. What does this show about the solution.

   What is the explanation for this? ______________________________

   ____

   ____



5. When ionic compounds such as silver nitrate and sodium chloride dissolve, the ions separate:

   $$AB(aq) \rightarrow A^{+}(aq) + B^{-}(aq)$$

   a. What ions will be present in solution when silver nitrate and sodium chloride dissolve? ______________________________

   ____

   b. What new combinations of ions could form? (*HINT:* Opposites attract!) ______________________________

   ____

6. Based on Table F (*Solubility Guidelines*), which of the products is the white precipitate? ______________________________

   ____

7. Write an equation for the reaction between silver nitrate solution and sodium chloride solution. ______________________________

   ____

8. The formula mass for silver nitrate ($AgNO_3$) is found as shown in the table to the right. Find the formula masses of all the reactants and products of this reaction.

Element	Atomic Mass		Subscript		Product
Ag	108	×	1	=	108
N	14	×	1	=	14
O	16	×	3	=	48
			TOTAL		170

<u>*REACTANTS*</u>

a. Silver nitrate 170

b. Sodium chloride .... ______

<u>*PRODUCTS*</u>

c. ______ .... ______

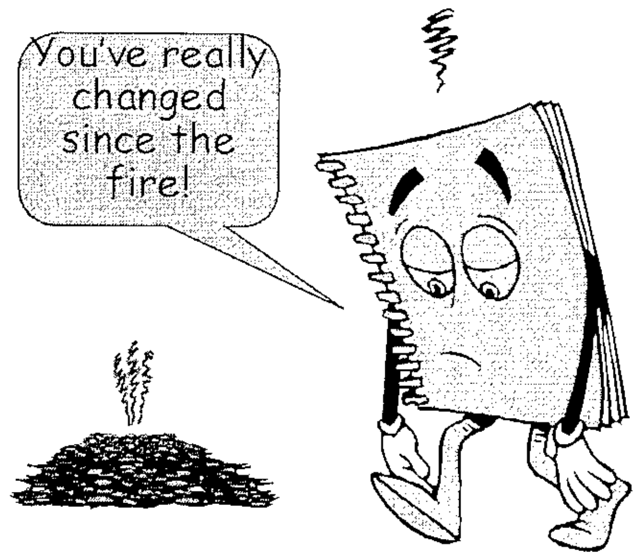
d. ______ .... ______

9. How does the total mass of the reactants compare to the total mass of the products? ______________________________

   ____

Chemical Change vs. Physical Change

When a piece of paper is ripped in half, it is still paper – only smaller! Since no new substances are formed, the change is only a physical change. When a piece of paper burns, heat is released, there may be some ash left behind, and two gases, carbon dioxide and water vapor, are released. These are not only physical changes. They are chemical changes as well. Carbon dioxide and water are new substances. They were not present before the change.



When new substances form, typically, there are a number of other changes that serve as evidence of the chemical change. They are: [1] energy changes, such as the heat released when paper burns; [2] the release of gases, such as carbon dioxide and water vapor; [3] the formation of a solid in solution (not in this reaction) or the formation of water; [4] a change in color – carbon dioxide and water are invisible, colorless gases while paper is opaque; and [5] a change in odor – the obvious smell of burning paper comes from the incompletely burned carbon which is left behind to form the ash. These five changes serve only as evidence of a chemical change. There is no rule that identifies chemical changes unequivocally except that new substances are formed. That takes a knowledge of chemistry.

Based on the reading above and your knowledge of chemistry state whether each of the following represents a *PHYSICAL CHANGE* only, or a *CHEMICAL CHANGE* as well.

1. Breaking glass .... ______________
2. Dissolving sugar [$C_{12}H_{22}O_{11}(s) + H_2O(\ell) \rightarrow C_{12}H_{22}O_{11}(aq) + H_2O(\ell)$] ..... ______________
3. Rusting iron [$4Fe(s) + 3O_2(g) \rightarrow 2Fe_2O_3(g)$] .... ______________
4. Boiling water [$H_2O(\ell) \rightarrow H_2O(g)$] .... ______________
5. Digesting sugar [$C_{12}H_{22}O_{11}(aq) + H_2O(\ell) \rightarrow 2C_6H_{12}O_6(aq)$] .... ______________
6. Burning gasoline [$2C_8H_{18}(g) + 25O_2(g) \rightarrow 16CO_2(g) + 18\ H_2O(g)$] .... ______________
7. Respiration [$C_6H_{12}O_6(aq) + 6O_2(g) + 6H_2O(g) \rightarrow 6CO_2(g) + 12H_2O(g)$] .. ______________
8. Forming ozone from oxygen [$3O_2(g) \rightarrow 2O_3(g)$] .... ______________
9. Dissolving salt [$NaCl(s) + H_2O(\ell) \rightarrow NaCl(aq) + H_2O(\ell)$] .... ______________
10. Exploding dynamite .... ______________

Chemistry Lab # ____ Name ______________________________

How many moles?

Purpose: Each chemical has a unique set of properties. One tool to help determine what a compound is, is its' Gram Formula Mass, or Molar Mass. You will, in this lab, use your knowledge of chemistry to determine how many moles of a substance is in a given sample.

Problem: ____

____

____

Hypothesis: ____

____

____

Vocabulary:

1. Mole - ____

   ____

   ____

2. Mass - ____

   ____

   ____

3. Gram - ____

   ____

   ____

4. Molecular Formula - ____

   ____

   ____

Chemistry Lab # ____ Name ______________________

5. Gram Formula Mass - ______________________

____

____

Procedure: ______________________

Chemistry Lab # ____ Name ______________________________

Observations:

Part 1: Moles of sucrose in a teaspoon of sugar

Mass of sucrose ____________________________

Molecular Formula for sucrose is $C_{12}H_{22}O_{11}$
Convert mass to moles. Show all work. Use significant figures.

Part 2: Moles of water is one sip

Mass of cup with water ____________________________

Mass of cup and water after drinking ____________________________

Mass of water swallowed ____________________________

Molecular formula for water ____________________________
Convert mass to moles. Show all work. Use significant figures.

Chemistry Lab # ____ Name ______________________________

Part 3: What's in a name? Calculate the number of moles of chalk needed to write your full name. The chemical name for chalk is Calcium Carbonate.

Mass a chalk before writing ________________________

Mass of chalk after writing ________________________

Mass of chalk used ________________________

Chemical formula for chalk is **$CaCO_3$**
Convert mass to moles. Show all work. Use significant figures.

Questions:
All questions are to be completed using significant figures and don't forget units.

1. How many moles does 80.0 grams of H_20 represent?

2. How many moles does 22.0 grams of CO_2 represent?

3. What is the mass of 5.0 moles of $Ba(CN)_2$?

Chemistry Lab # ____ Name ______________________

4. What is the mass of 0.75 moles of $CuSO_4$?

5. Calculate the mass of
   a) 2.00 moles of water, H_20

   b) 4.38 moles of chlorine, Cl_2

   c) 0.025 moles of ammonia, NH_3

   d) 1 .8 moles of oxygen, 0_2

6. Calculate the number of moles in
   a) 25 g of helium, He

b) 12.5 g of methane, CH_4

c) 0.364 g of iodine, I_2

d) 40.0 g of sodium, Na

Conclusion: ____

____

____

____

____

____

____

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Percentage of Sugar in Bubble Gum

Purpose
To determine the percentage of sugar in bubble gum.

Materials
balance, bubble gum

Procedure

Note: *Chewed gum cannot be placed directly on the balance pan; it must be wrapped in paper and the mass of the paper subtracted out. Most balances are not sensitive enough to measure the mass of one wrapper so all mass measurements will be of your entire group's wrappers and gum.*

1. Your teacher will give you one piece of bubble gum. Place the wrapped pieces of gum of everyone in your group on the balance. Record the combined mass of all the wrappers and all the unchewed gum.
2. Unwrap your piece of gum put the gum in your mouth. ***Do not throw the wrapper away!***
3. Place everyone's empty gum wrappers on the balance. Record the combined mass of all the wrappers. ***Do not throw the wrapper away!***
4. Chew your gum for 15 minutes.
5. After 15 minutes, put your wrapper up to your mouth and gently spit your gum into the wrapper. Try not to get too much saliva on the gum.
6. Place the wrapped, chewed gum of everyone in your group on the balance. Record the combined mass.
7. Throw away the gum and wrappers.

Data

	Mass (g)
Wrappers and unchewed gum	
Wrappers only	
Unchewed gum only	
Wrappers and chewed gum	
Chewed gum	
Number of people in group:	
Brand of gum:	

Percentage of Sugar in Bubble Gum (continued)

Analysis and Conclusions

1. Subtract the mass of the wrappers from the mass of the unchewed gum and wrappers. Record the mass of the unchewed gum in the data table.

2. Subtract the mass of the wrappers from the mass of the chewed gum and wrappers. Record the mass of the chewed gum in the data table.

3. What is the total mass of sugar dissolved by chewing?

4. What is the average mass of sugar dissolved by chewing in each piece of gum?

5. What is the percentage of sugar in a piece of gum?

6. Would your dentist recommend chewing this gum? Why or why not?

7. What assumption is made about the change in mass of the gum before and after chewing? Explain whether you think this is a valid assumption.

8. How would the results be affected if there was a lot of saliva on the chewed pieces of gum?

miniLAB 12
Baking Soda Stoichiometry

Predicting When baking soda is an ingredient in your recipe, its purpose is to make the batter rise and produce a product with a light and fluffy texture. That's because baking soda, or sodium hydrogen carbonate ($NaHCO_3$), decomposes upon heating to form carbon dioxide gas.

$$2NaHCO_3 \rightarrow Na_2CO_3 + CO_2 + H_2O$$

Predict how much sodium carbonate (Na_2CO_3) is produced when baking soda decomposes.

Materials ring stand, ring, clay triangle, crucible, crucible tongs, Bunsen burner, balance, 3.0 g baking soda ($NaHCO_3$)

Procedure

1. Measure the mass of a clean, dry crucible. Add about 3.0 g of $NaHCO_3$ and measure the combined mass of the crucible and $NaHCO_3$. Record both masses and calculate the mass of the $NaHCO_3$.

____

____

2. Use this starting mass of baking soda and the balanced chemical equation to calculate the mass of Na_2CO_3 that will be produced.

____

____

3. Set up a ring stand with a ring and clay triangle for heating the crucible.
4. Heat the crucible slowly at first and then with a stronger flame for 7–8 min. Use tongs to remove the hot crucible. Record your observations during the heating.
5. Allow the crucible to cool and then obtain the mass of the crucible and sodium carbonate.

____

Analysis

1. What were your observations during the heating of the baking soda?

____

____

2. How did your calculated mass of sodium carbonate compare with the actual mass you obtained from the experiment? If the two masses are different, suggest reasons for the difference.

____

____

Name ______________________ Date ____________ Class ____________

CHEMLAB 12

A Mole Ratio

Iron reacts with copper(II) sulfate in a single replacement reaction. By measuring the mass of iron that reacts and the mass of copper metal produced, you can calculate the ratio of moles of reactant to moles of product. This mole ratio can be compared to the ratio found in the balanced chemical equation.

Problem

Which reactant is the limiting reactant? How does the experimental mole ratio of Fe to Cu compare with the mole ratio in the balanced chemical equation? What is the percent yield?

Objectives

- **Observe** a single replacement reaction.
- **Measure** the masses of iron and copper.
- **Calculate** the moles of each metal and the mole ratio.

Materials

iron metal filings, 20 mesh
copper(II) sulfate pentahydrate ($CuSO_4 \cdot 5H_2O$)
distilled water
stirring rod
150-mL beaker
400-mL beaker
100-mL graduated cylinder
weighing paper
balance
hot plate
beaker tongs

Safety Precautions

- Always wear safety glasses and a lab apron.
- Hot objects will not appear to be hot.
- Do not heat broken, chipped, or cracked glassware.
- Turn off the hot plate when not in use.

Pre-Lab

1. Read the entire CHEMLAB.
2. Prepare all written materials that you will take into the laboratory. Be sure to include safety precautions and procedure notes. Use the data table on the next page.
3. Is it important that you know you are using the hydrated form of copper(II) sulfate? Would it be possible to use the anhydrous form? Why or why not?

____

____

____

____

____

____

____

____

Procedure

1. Measure and record the mass of a clean, dry 150-mL beaker.
2. Place approximately 12 g of copper(II) sulfate pentahydrate into the 150-mL beaker and measure and record the combined mass.
3. Add 50 mL of distilled water to the copper(II) sulfate pentahydrate and heat the mixture on the hot plate at a medium setting. Stir until all of the solid is dissolved, but do not boil. Using tongs, remove the beaker from the hot plate.
4. Measure approximately 2 g of iron metal filings onto a piece of weighing paper. Measure and record the exact mass of the filings.
5. While stirring, slowly add the iron filings to the hot copper(II) sulfate solution.
6. Allow the reaction mixture to stand, without stirring, for 5 minutes to ensure complete reaction. The solid copper metal will settle to the bottom of the beaker.

7. Use the stirring rod to decant (pour off) the liquid into a 400-mL beaker. Be careful to decant only the liquid.
8. Add 15 mL of distilled water to the copper solid and carefully swirl the beaker to wash the copper. Decant the liquid into the 400-mL beaker.
9. Repeat step 8 two more times.
10. Place the 150-mL beaker containing the wet copper on the hot plate. Use low heat to dry the copper.
11. Remove the beaker from the hot plate and allow it to cool.
12. Measure and record the mass of the cooled 150-mL beaker and the copper.

Cleanup and Disposal

1. Make sure the hot plate is off.
2. The dry copper can be placed in a waste container. Wet any residue that sticks to the beaker and wipe it out using a paper towel. Pour the unreacted copper(II) sulfate and iron(II) sulfate solutions into a large beaker in the fume hood.
3. Return all lab equipment to its proper place.
4. Wash your hands thoroughly after all lab work and cleanup is complete.

Data for the Reaction of Copper(II) Sulfate and Iron	
Mass of empty 150-mL beaker	
Mass of 150-mL beaker + $CuSO_4 \cdot 5H_2O$	
Mass of $CuSO_4 \cdot 5H_2O$	
Mass of iron filings	
Mass of 150-mL beaker and dried copper	
Mass of dried copper	
Observations	

Analyze and Conclude

1. **Observing and Inferring** What evidence did you observe that confirms that a chemical reaction occurred?

____

2. **Applying Concepts** Write a balanced chemical equation for the single-replacement reaction that occurred.

____

3. **Interpreting Data** From your data, determine the mass of copper produced.

____

4. **Using Numbers** Use the mass of copper to calculate the moles of copper produced.

____

5. **Using Numbers** Calculate the moles of iron used in the reaction.

6. **Using Numbers** Determine the whole number ratio of moles of iron to moles of copper.

7. **Comparing and Contrasting** Compare the ratio of moles of iron to moles of copper from the balanced chemical equation to the mole ratio calculated using your data.

8. **Evaluating Results** Use the balanced chemical equation to calculate the mass of copper that should have been produced from the sample of iron you used. Use this number and the mass of copper you actually obtained to calculate the percent yield.

9. **Error Analysis** What was the source of any deviation from the mole ratio calculated from the chemical equation? How could you improve your results?

10. **Drawing a Conclusion** Which reactant is the limiting reactant? Explain.

Real-World Chemistry

1. A furnace that provides heat by burning methane gas (CH_4) must have the correct mixture of air and fuel to operate efficiently. What is the mole ratio of air to methane gas in the combustion of methane? Hint: Air is 20% oxygen.

2. Automobile air bags inflate on impact because a series of gas-producing chemical reactions are triggered. To be effective in saving lives, the bags must not overinflate or underinflate. What factors must automotive engineers take into account in the design of air bags?