NAMING WORKSHEET 1
Naming Ionic Compounds

Type I: Diatomic

Writing Names from Formulas

1. Identifying the cation as a Group I metal , Group II metal, Aluminum, Zinc, or Silver
2. Identify the anion as a nonmetal
3. Name the cation (the metal) with its full name
4. Name the anion (the nonmetal) by changing the ending to -ide

Example: NaCl

cation: sodium & anion: chlorine
Name: sodium chlor*ide*

NaCl	Sodium chloride	BeO	beryllium oxide	$AlCl_3$	aluminum chloride
KBr	potassium bromide	CaF_2	calcium fluoride	Zn_2O	zinc oxide
MgI_2	magnesium iodide	Cs_2S	cesium sulfide	AgP	silver phosphide

Writing Formulas from Names

1. Identify charge of cation (1+, 2+, 3+)
2. Identify charge of anion (1-, 2-, 3-)
3. Balance the charges
4. The charge of the cation becomes the subscript of the anion
5. The charge of the anion becomes the subscript of the cation
6. Reduce subscripts if necessary

Aluminum Sulfide	Al_2S_3	Potassium Oxide	K_2O	Sodium Nitride	$NaNO_3$
Barium Carbide	BaC	Zinc Chloride	$ZnCl_2$	Potassium Iodide	KI
Lithium Sulfide	Li_2S	Silver Fluoride	AgF	Calcium Oxide	CaO

Type I: Polyatomic

Writing Names from Formulas

1. Identifying the cation as a Group I metal , Group II metal, Aluminum, Zinc, or Silver
2. Identify the anion as a polyatomic ion
3. Name the cation (the metal) with its full name
4. Name the anion (the polyatomic) with its full name

Example: KOH

cation: potassium & anion: hydroxide
Name: potassium hydroxide

KCN	potassium cyanide	$LiSO_3$	Lithium sulfite	$FrClO_2$	francium chlorite
NaOH	sodium hydroxide	$CsPO_4$	cesium phosphate	$MgSiO_3$	magnesium silicate
$CaCO_3$	calcium carbonate	NH_4Cl	ammonium chloride	BaC_2O_4	barium oxalate

Writing Formulas from Names (polyatomics)

silver nitrate	$AgNO_3$	strontium chlorate	$Sr(ClO_3)_2$	aluminum dichromate	$K_2Cr_2O_7$
magnesium sulfate	$MgSO_4$	barium cyanide	$Ba(CN)_2$	ammonium sulfate	$(NH_4)_2SO_4$
calcium hydroxide	$Ca(OH)_2$	zinc silicate	$ZnSiO_3$	potassium permanganate	$KMnO_4$

1

Type II: Transition Metals

Writing Names from Formulas

1. Identify the cation as a transition metal
2. Identify the anion
3. Identify the charge of the cation
4. Name the cation (the transition metal) with its full name and the charge of the ion in roman numerals

5a. Name the anion (the nonmetal) by changing the ending to –ide

5b. Name the anion (the polyatomic) with its full name

Example: $CoBr_2$

Cation: cobat 2+ & anion: 2 bromine

Name: cobalt (II) bromide

CuI	copper(I) iodide	$Co_2(CO_3)_3$	cobalt(III) carbonate	$HgBr_2$	Mercury (II) bromide
CuI_2	copper(II) iodide	SnO	tin(II) oxide	Hg_2Br_2	Mercury (I) bromide
$CoCO_3$	cobalt (II) carbonate	SnO_2	tin(IV) oxide	SnS	tin (II) sulfide

Writing Formulas from Names (transitional metals)

iron(II) oxide	FeO	chromium(III) phosphate	$CrPO_4$	iron(III) hydroxide	$Fe(OH)_3$
iron(III) oxide	Fe_2O_3	manganese (II) fluoride	MnF_2	lead(IV) sulfite	$Pb(SO_3)_2$
chromium(II) phosphate	$Cr_3(PO_4)_2$	manganese (III) fluoride	MnF_3	mercury(I) sulfide	Hg_2S

Naming Worksheet 2

Naming Molecular Compounds

Writing Names from Formulas

1. Both cation and anion are nonmetals
2. Use prefixes to indicate how many atoms are present
3. Name the first element: prefix with its full name
4. Name the second element: prefix element name and change the ending to -ide
5. Do not use "mono" when naming the first element

Example: CS_2

Elements: carbon & 2 sulfur

Name: carbon *di*sulf*ide*

Prefixes:

1: mono 2: di 3: tri 4: tetra 5: penta
6: hexa 7: hepta 8: octa 9: nona 10: deca

CO	carbon monoxide	PCl_3	phosphorus trichloride	N_2O	dinitrogen monoxide
CO_2	carbon dioxide	SO_3	sulfur trioxide	$P2O_5$	diphosphorus pentoxide
NO_2	nitrogen dioxide	SF_6	sulfur hexafluoride	NF_3	nitrogen trifluoride

Writing Formulas from Names

1. Identify the elements
2. Identify prefixes for each element
3. Charges do not matter for molecular formulas!!

diphosphorous monosulfide	P_2S	carbon monoxide	CO	diphosphorous trioxide	P_2O_3
sulfur tetrafluoride	SF_3	nitrogen triiodide	NI_3	carbon tetrabromide	CBr_4
nitrogen monoxide	NO	phosphorous hexabromide	PBr_6	dichlorine heptoxide	Cl_2O_7

4)

Naming Acids

Writing Names from Formulas

1. Identify the cation as hydrogen
2. Identify the anion, does the anion contain oxygen or not?

3a. Anion with oxygen (polyatomic)

Change –ate ending to –ic acid

Change –ite ending to -ous acid

Example: H_2SO_4

cation: hydrogen & anion: sulfate

name: sulfuric acid

3b. Anion without oxygen (diatomic)

Hydro- element root –ic acid

Example: HCl

cation: hydrogen & anion: chlorine

name: *hydro*chlor*ic acid*

HF	hydrofluoric acid	H_3PO_4	phosphoric acid	HNO_3	nitric acid
HI	hydroiodic acid	$HC_2H_3O_2$	acetic acid	H_2SO_3	sulfurous acid
HBr	hydrobromic acid	H_2CO_3	carbonic acid	HCN	hydrocyanic acid

Writing Formulas from Names

1. Identify elements
2. Identify type of anion

3a. Hydro : there is no oxygen in the formula

3b. –ic acid : look for the polyatomic with –ate ending

3c. –ous acid: look for polyatomic with –ite ending

hydrobromic acid	HBr	hydrocyanic acid	HCN	nitrous acid	HNO_2
hydrofluoric acid	HF	carbonic acid	H_2CO_3	nitric acid	HNO_3

Naming & Formula Practice

Ionic Compounds Type I, Diatomic

CsBr	cesium bromide	BaF_2	barium fluoride	NaF	sodium fluoride
$CaBr_2$	Calcium Bromide	ZnS	Zinc Sulfide	Al_4C_3	Aluminum Carbide

Ionic Compounds Type I, Polyatomic

NH_4NO_2	ammonium nitrite	$Al_2(CrO_4)_3$	aluminum chromate	$ZnSO_3$	zinc sulfite
$K_2Cr_2O_7$	Potassium dichromate	RbCN	Rubidium cyanide	$AgClO_2$	Silver chlorite

Ionic Compounds Type II, Transition Metals

CuCl	copper (I) chloride	$Mn_2(SO_4)_3$	manganese(III) sulfate	$MnSO_4$	manganese (II) sulfate
$CuCl_2$	copper (II) chloride	SnO	Tin(II) oxide	SnO_2	Tin(IV) oxide

Molecular Compounds

BCl_3	Boron trichloride	$SeBr_2$	selenium dibromide	P_4O_6	tetraphosphorus hexoxide
PF_3	Phosphorus trifluoride	CO	Carbon monoxide	N_2O_5	Dinitrogen pentoxide

Acids

HCl	hydrochloric acid	H_2PO_3	phosphorous acid	HI	hydroiodic acid
HF	Hydrofluoric acid	H_2SO_3	Sulfurous acid	$HC_2H_3O_2$	Acetic acid

Mixed Practice

Hint: List the type of compounds you are naming, *then* name the compounds!

formula	name	type
K_2S	potassium sulfide	I
HgI_2	mercury (II) iodide	I
H_2SO_4	sulfuric acid	A
$NaC_2H_3O_2$	sodium acetate	I
Fe_2O_3	Iron (III) oxide	I
HBr	hydrobromic acid	A
H_2CO_3	carbonic acid	A
SI_2	sulfur ~~[illegible]~~ diiodide	C
AgCl	Silver Chloride	I
$Ca(OH)_2$	Calcium hydroxide	I
$CoPO_4$	Cobalt (III) phosphate	I
C_4N_3	Tetracarbon trinitride	C
NH_4Cl	Ammonium chloride	I
MgO	Magnesium Oxide	I

formula	name	type
$MgCO_3$	magnesium carbonate	I
N_2H_4	dinitrogen tetrahydride	C
Ga_2O_3	gallium oxide	I
$KMnO_4$	potassium permanganate	I
CO_2	carbon dioxide	C
Mg_2S	magnesium sulfide	I
Ag_3N	silver nitride	I
$BeBr_2$	beryllium bromide	I
N_2S_3	Dinitrogen trisulfide	C
HI	Hydroiodic acid	A
HgI	Mercury(I) iodide	I
$SrSiO_3$	Strontium silicate	I
CCl_4	Carbon tetrachloride	C
Cs_3P	Cesium phosphide	I

Name ______________________________ Date ____________ Period ________

Theoretical and Percent Yield Worksheet

Hon chem; coleman

1. Write the equations for calculating % yield and % error in the boxes below:

% yield: actual / theoretical x100	% error: |actual - theoretical| / theoretical x100

2. What does a % yield tell you?

how much product you collect based off the total amount you could have produced

3. What does a % error tell you?

how far off your yield was from how much could have been produced

Worked example:

Given the following equation, determine the percent yield of KCl if you react 34.5 g of K_2CO_3 with excess HCl and you are able to actually isolate 36.1 g of KCl. Also Calculate the % error.

K_2CO_3 + 2HCl --------> H_2O + CO_2 + 2KCl

Steps:

a) Balance the equation.
b) Determine the theoretical yield of KCl if you start with 34.5 g of K_2CO_3.
c) Starting with 34.5 g of K_2CO_3, and you isolate 36.1 g of KCl, what is the percent yield?
d) Calculate the percent error for this reaction.

a) Balanced equation: K_2CO_3 + 2HCl --------> H_2O + CO_2 + 2KCl

b) $34.5\text{ g } K_2CO_3 \times \frac{1\text{ mole } K_2CO_3}{138.21\text{ g } K_2CO_3} \times \frac{2\text{ mol KCl}}{1\text{ mol } K_2CO_3} \times \frac{74.55\text{ g KCl}}{1\text{ mol KCl}} = 37.2\text{ g KCl}$

c) $\%\text{ yield} = \frac{\text{actual yield}}{\text{theoretical yield}} \times 100$ so... $\%\text{ yield of KCl} = \frac{36.1\text{ g KCl}}{37.2\text{ g KCl}} \times 100 = 97.0\%$

d) $\%\text{ error} = \frac{|(\text{theoretical} - \text{actual})|}{\text{theoretical yield}} \times 100$ so... $\%\text{ error} = \frac{|(37.2-36.1)|}{37.2} \times 100 = 2.96\%$

Now you try... **Show all your work with correct sig figs. ☺**

1. What is the % yield and % error if when 16.22 g of NH_3 is reacted with excess K_2PtCl_4, 129.1 g of $Pt(NH_3)_2Cl_2$ is produced according to the following equation:

$$\_\_ K_2PtCl_4 + \underline{2}\ NH_3 \dashrightarrow \_\_ Pt(NH_3)_2Cl_2 + \underline{2}\ KCl$$

a) Balance the equation.
b) Determine the theoretical yield of $Pt(NH_3)_2Cl_2$ if you start with 16.22 grams of NH_3.
c) Starting with 16.22 g of NH_3, and you isolate 129.1 g of $Pt(NH_3)_2Cl_2$, what is the percent yield?
d) Calculate the percent error for this reaction.

b) $16.22\,g\ NH_3 \times \frac{1\ mol\ NH_3}{17.034\ g\ NH_3} \times \frac{1\ mol\ Pt(NH_3)_2Cl_2}{2\ mol\ NH_3} \times \frac{300.048\ g\ Pt(NH_3)_2Cl_2}{1\ mol\ Pt(NH_3)_2Cl_2} = 142.9\,g\ Pt(NH_3)_2Cl$

c) $\frac{129.1\,g}{142.9} \times 100 = 90.34\%$

d) $\frac{|129.1 - 142.9|}{142.9} \times 100 = 9.657\%$

2. Given the following equation:

$$H_3PO_4 + 3\,KOH \dashrightarrow K_3PO_4 + 3H_2O$$

a) If 53.0 g of H_3PO_4 is reacted with excess KOH, determine the percent yield of K_3PO_4 if you isolate 87.6 g of K_3PO_4.
b) Calculate the percent error for this reaction.

a) $53.0\,g\ H_3PO_4 \times \frac{1\ mol\ H_3PO_4}{97.994\ g\ H_3PO_4} \times \frac{1\ mol\ K_3PO_4}{1\ mol\ H_3PO_4} \times \frac{212.27\ g\ K_3PO_4}{1\ mol\ K_3PO_4} = 115\,g\ K_3PO_4$

$\frac{87.6\,g}{115\,g} \times 100 = 76.2\%$

b) $\frac{|87.6 - 115|}{115} \times 100 = 23.8\%$

3. Given the following equation:

$$Al_2(SO_3)_3 + 6NaOH \text{ ------> } 3Na_2SO_3 + 2Al(OH)_3$$

a) If you start with 389.04 g of $Al_2(SO_3)_3$ and you isolate 212.60 g of Na_2SO_3, what is your percent yield for this reaction?
b) Calculate the percent error for this reaction.

a) $\frac{389.04 g\ Al_2(SO_3)_3}{} \Big| \frac{1\ mol\ Al_2(SO_3)_3}{294.14\ g\ Al_2(SO_3)_3} \Big| \frac{3\ mol\ Na_2SO_3}{1\ mol\ Al_2(SO_3)_3} \Big| \frac{126.04\ g\ Na_2SO_3}{1\ mol\ Na_2SO_3}$

$= 500.11 g\ Na_2SO_3$

$\frac{212.60 g}{500.11 g} \times 100$ = 42.511 %

b) $\frac{|212.60 - 500.11|}{500.11} \times 100$ = 57.489 %

4. Given the following equation:

$$Al(OH)_3\ (s) + 3\ HCl\ (aq) \text{ -------> } AlCl_3\ (aq) + 3\ H_2O\ (l)$$

a) If you start with 50.3 g of $Al(OH)_3$ and you isolate 39.5 g of $AlCl_3$, what is the percent yield and percent error?

$\frac{50.3 g\ Al(OH)_3}{} \Big| \frac{1\ mol\ Al(OH)_3}{78.004\ g\ Al(OH)_3} \Big| \frac{1\ mol\ AlCl_3}{1\ mol\ Al(OH)_3} \Big| \frac{133.33\ g\ AlCl_3}{1\ mol\ AlCl_3}$

$= 86.0 g\ AlCl_3$

% yield

$\frac{39.5}{86.0} \times 100$ = 45.9 %

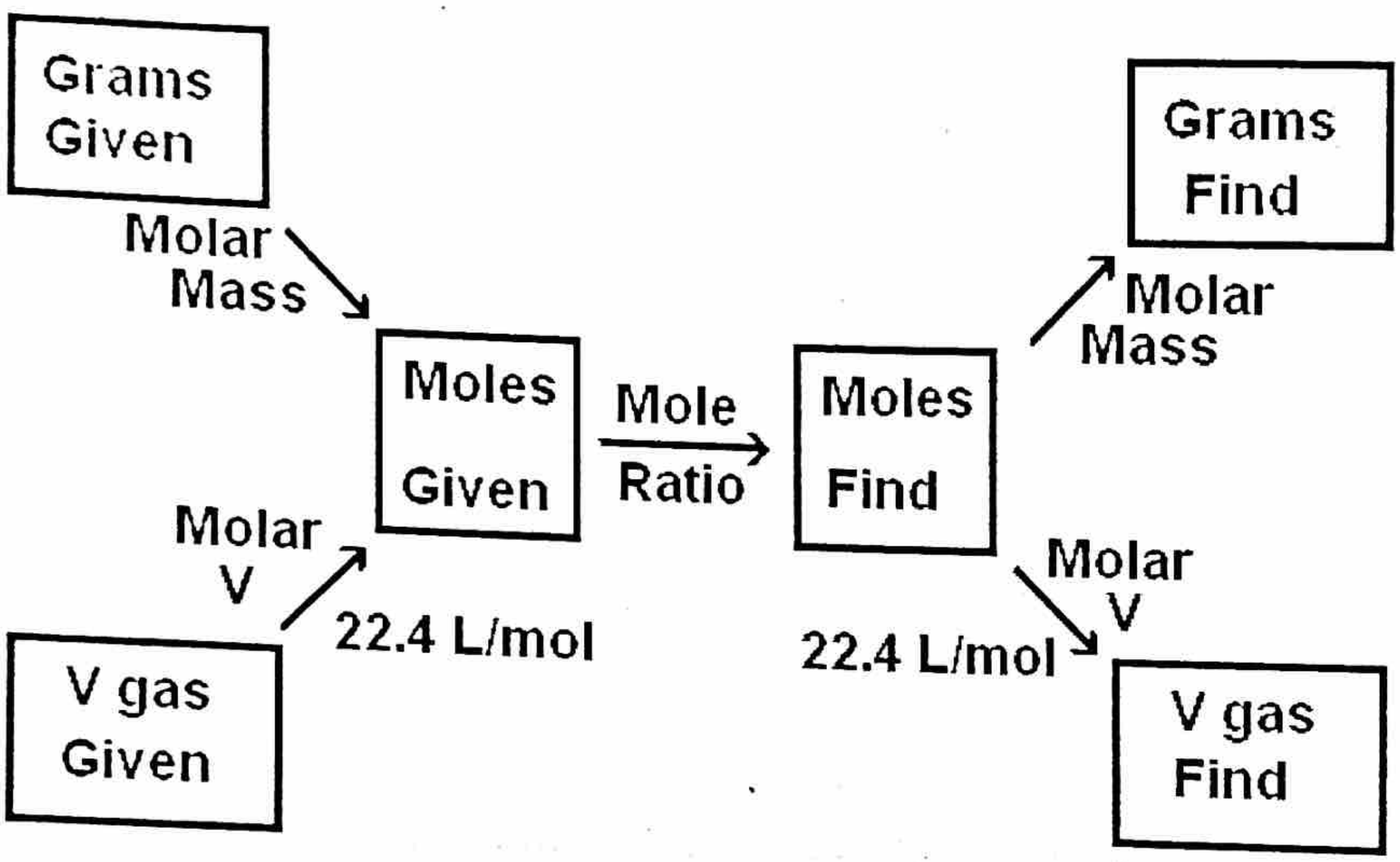
% error

$\frac{|39.5 - 86.0|}{86.0} \times 100$ = 54.1 %

8

CHM 130 Stoichiometry Worksheet

The following flow chart may help you work stoichiometry problems. Remember to pay careful attention to what you are given, and what you are trying to find.



1. Fermentation is a complex chemical process of making wine by converting glucose into ethanol and carbon dioxide:

$$C_6H_{12}O_6(s) \rightarrow 2\ C_2H_5OH\ (l) + 2\ CO_2(g)$$

A. Calculate the mass of ethanol produced if 500.0 grams of glucose reacts completely.

$$\frac{500.0\ g\ C_6H_{12}O_6}{} \cdot \frac{1\ mol\ C_6H_{12}O_6}{180.156\ g\ C_6H_{12}O_6} \cdot \frac{2\ mol\ C_2H_5OH}{1\ mol\ C_6H_{12}O_6} \cdot \frac{46.068\ g\ C_2H_5OH}{1\ mol\ C_2H_5OH} = 255.7\ g\ C_2H_5OH$$

B. Calculate the volume of carbon dioxide gas produced at STP if 100.0 grams of glucose reacts.

$$\frac{100.0\ g\ C_6H_{12}O_6}{} \cdot \frac{1\ mol\ C_6H_{12}O_6}{180.156\ g\ C_6H_{12}O_6} \cdot \frac{2\ mol\ CO_2}{1\ mol\ C_6H_{12}O_6} \cdot \frac{22.4\ L\ CO_2}{1\ mol\ CO_2} = 24.87\ L\ CO_2$$

C. If 17.5 moles of ethanol were produced, how many moles of glucose were there in the beginning?

$$\frac{17.5\ mol\ C_2H_5OH}{} \cdot \frac{1\ mol\ C_6H_{12}O_6}{2\ mol\ C_2H_5OH} = 8.75\ mol\ C_6H_{12}O_6$$

2. Consider the reaction of zinc metal with hydrochloric acid, HCl(aq).

   A. Write the equation for this reaction, then balance the equation.

   $Zn + 2HCl \rightarrow H_2 + ZnCl_2$

   B. Calculate the moles of HCl needed to react completely with 8.25 moles of zinc.

   $8.25\ mol\ Zn \times \frac{2\ mol\ HCl}{1\ mol\ Zn} = 16.5\ mol\ HCl$

   C. Calculate the grams of zinc chloride produced if 0.238 grams of zinc react completely.

   $0.238\ g\ Zn \times \frac{1\ mol\ Zn}{65.39\ g\ Zn} \times \frac{1\ mol\ ZnCl_2}{1\ mol\ Zn} \times \frac{136.29\ g\ ZnCl_2}{1\ mol\ ZnCl_2} = 0.496\ g\ ZnCl_2$

   D. Calculate the volume of hydrogen gas produced at STP if 25.0 grams of HCl react completely.

   $25.0\ g\ HCl \times \frac{1\ mol\ HCl}{36.458\ g\ HCl} \times \frac{1\ mol\ H_2}{2\ mol\ HCl} \times \frac{22.4\ L\ H_2}{1\ mol\ H_2} = 7.68\ L\ H_2$

3. If you dissolve lead(II) nitrate and potassium iodide in water they will react to form lead(II) iodide and potassium nitrate.

   A. Write the equation for this reaction, then balance the equation.

   $Pb(NO_3)_2 + 2KI \rightarrow 2KNO_3 + PbI_2$

   B. Calculate the grams of lead(II) iodide that can be produced from 5.00 moles of potassium iodide.

   $5.00\ mol\ KI \times \frac{1\ mol\ PbI_2}{2\ mol\ KI} \times \frac{461.02\ g}{1\ mol\ PbI_2} = 1150\ g\ PbI_2$

   C. Calculate the grams of lead(II) iodide that can be produced from 75.00 grams of potassium iodide.

   $75.00\ g\ KI \times \frac{1\ mol\ KI}{166.01\ g\ KI} \times \frac{1\ mol\ PbI_2}{2\ mol\ KI} \times \frac{461.02\ g\ PbI_2}{1\ mol\ PbI_2} = 104.1\ g\ PbI_2$

4. Write then balance the combustion reaction for propane gas, C_3H_8.

   $C_3H_8 + 5O_2 \rightarrow 3CO_2 + 4H_2O$

   A. If 5.00 grams of propane burn completely, what volume of carbon dioxide is produced at STP?

   $5.00\ g\ C_3H_8 \times \frac{1\ mol\ C_3H_8}{44.094\ g\ C_3H_8} \times \frac{3\ mol\ CO_2}{1\ mol\ C_3H_8} \times \frac{22.4\ L\ CO_2}{1\ mol\ CO_2} = 7.62\ L\ CO_2$

   B. If 75.0 L of steam are produced at STP, what mass of propane must have burned?

   $75.0\ L\ H_2O \times \frac{1\ mol\ H_2O}{22.4\ L\ H_2O} \times \frac{1\ mol\ C_3H_8}{4\ mol\ H_2O} \times \frac{44.094\ g\ C_3H_8}{1\ mol\ C_3H_8} = 36.9\ g\ C_3H_8$

   C. If 34.2 grams of propane are completely combusted, how many moles of steam will that produce?

   $34.2\ g\ C_3H_8 \times \frac{1\ mol\ C_3H_8}{44.094\ g\ C_3H_8} \times \frac{4\ mol\ H_2O}{1\ mol\ C_3H_8} = 3.10\ mol\ H_2O$

Worksheet - Law of Definite Proportions

Name______________
Period______
Date_______

Directions: SHOW ALL WORK!!!!

1. A 78.0 g sample of an unknown compound contains 12.4 g of hydrogen. What is the percent by mass of hydrogen in the compound?

$$\frac{12.4g}{78.0g} \times 100 = 15.9\% \text{ H}$$

2. If 1.0 g of hydrogen reacts completely with 19.0 g of fluoride. What is the mass of the compound formed? What is the percent by mass of hydrogen in the compound formed?

$$1.0g + 19.0g = 20.0g$$

$$\frac{1.0g}{20.0g} \times 100 = 5.0\% \text{ H}$$

3. A 134.50 g sample of aspirin is made up of 6.03 g of hydrogen, 80.70 g of carbon, and 47.77 g of oxygen. What is the percent by mass of each element in aspirin?

$$\frac{6.03g \text{ H}}{134.50g} \times 100 = 4.48\% \text{ H}$$

$$\frac{47.77g \text{ O}}{134.50g} \times 100 = 35.52\% \text{ O}$$

$$\frac{80.70g \text{ C}}{134.50g} \times 100 = 60.0\% \text{ C}$$

4. A 2.89 g sample of sulfur reacts with 5.72 g of copper to form a black compound. What is the percentage composition of the compound?

↳ total mass = 8.61 g

$\frac{2.89\,g\,S}{8.61\,g} \times 100 = 33.6\%\ S$

$\frac{5.72\,g}{8.61\,g} \times 100 = 66.4\%\ Cu$

5. Aluminum oxide has a composition of 52.9% aluminum and 47.1% oxygen by mass. If 16.4 g of aluminum reacts with oxygen to form aluminum oxide, what mass of oxygen reacts?

$4Al + 3O_2 \rightarrow 2Al_2O_3$

$\frac{16.4\,g\,Al}{52.9\%} = \frac{x}{47.1\%}$

$x = 14.6\,g\ O$

6. Two unknown compounds are tested. Compound I contains 15.0 g of hydrogen and 120.0 g of oxygen. Compound II contains 2.0 g of hydrogen and 32.0 g of oxygen. Are the compounds the same?

$\frac{120.0}{15} = 8$ $\frac{32}{2} = 16$

NO

~~Not not~~

Not in the same ratio

CHEM 1A: Law of Multiple Proportion Practice Problems

1. **A.** The mass composition data for two compounds containing phosphorus and chlorine is shown below. Show that this experimental data follows the law of multiple proportions.

Substance	Mass of Phosphorus (g)	Mass of Chlorine (g)
Compound 1	3.097	10.63
Compound 2	1.548	8.863

Compound 1

$\frac{10.63}{3.097} = 3.43$

Compound 2

$\frac{8.863}{1.548} = 5.725$

B. If **Compound 1** above was found to have a formula of PCl_3, propose a reasonable formula for **Compound 2.**

Assuming a fixed amount of phosphorus, **Compound 2** must have 5/3 more Cl than **Compound 1.** So if **Compound 1** is PCl_3, than **Compound 2** could be PCl_5.

2. Iron forms multiple different compounds with oxygen. Data from mass composition studies is reported below for three unique iron oxides.

Substance	Mass of Iron (g)	Mass of Oxygen (g)
FeO	4.654	1.333
Fe_2O_3	9.308	4.000
UNKNOWN	13.963	5.333

A. Show that the mass data above for iron (II) oxide and iron (III) oxide follows the Law of Multiple Proportions.

FeO $\frac{4.654}{1.333} = 3.49$ Fe_2O_3 $\frac{9.308}{4.000} = 2.327$

B. Propose a reasonable formula for the **unknown compound.**

$13.963\text{ g Fe} \times \frac{1\text{ mol Fe}}{55.85\text{ g Fe}} = 0.2500 / .2500 = 1 \times 3 = 3$

$5.333\text{ g O} \times \frac{1\text{ mol O}}{16\text{ g O}} = .333 / .2500 = 1.33 \times 3 = 4$

Fe_3O_4

Combustion Analysis

How can burning a substance help determine the substance's chemical formula?

Why?

Scientists have many techniques to help them determine the chemical formula or structure of an unknown compound. One commonly used technique when working with carbon-containing compounds is combustion analysis. Any compound containing carbon and hydrogen will burn. With an ample oxygen supply, the products of the combustion will be carbon dioxide and water. Analyzing the mass of CO_2 and H_2O that are produced allows chemists to determine the ratios of elements in the compound.

Model 1 – Combustion Reactions

$CH_4 + 2\ O_2 \rightarrow CO_2 + 2\ H_2O$

$C_2H_6 + 7/2\ O_2 \rightarrow 2\ CO_2 + 3\ H_2O$

$C_2H_4 + 3\ O_2 \rightarrow 2\ CO_2 + 2\ H_2O$

$C_3H_8 + 5\ O_2 \rightarrow 3\ CO_2 + 4\ H_2O$

1. According to Model 1, what reactant is always required for combustion?

   hydrocarbons + O_2

2. Balance the reactions in Model 1 while keeping the hydrocarbon coefficient a "1." This may require the use of fractions in other places.

3. How is the coefficient of CO_2 in the chemical reactions in Model 1 related to the chemical formula of the hydrocarbon being analyzed?

   always the same number as the number of carbons in the hydrocarbon

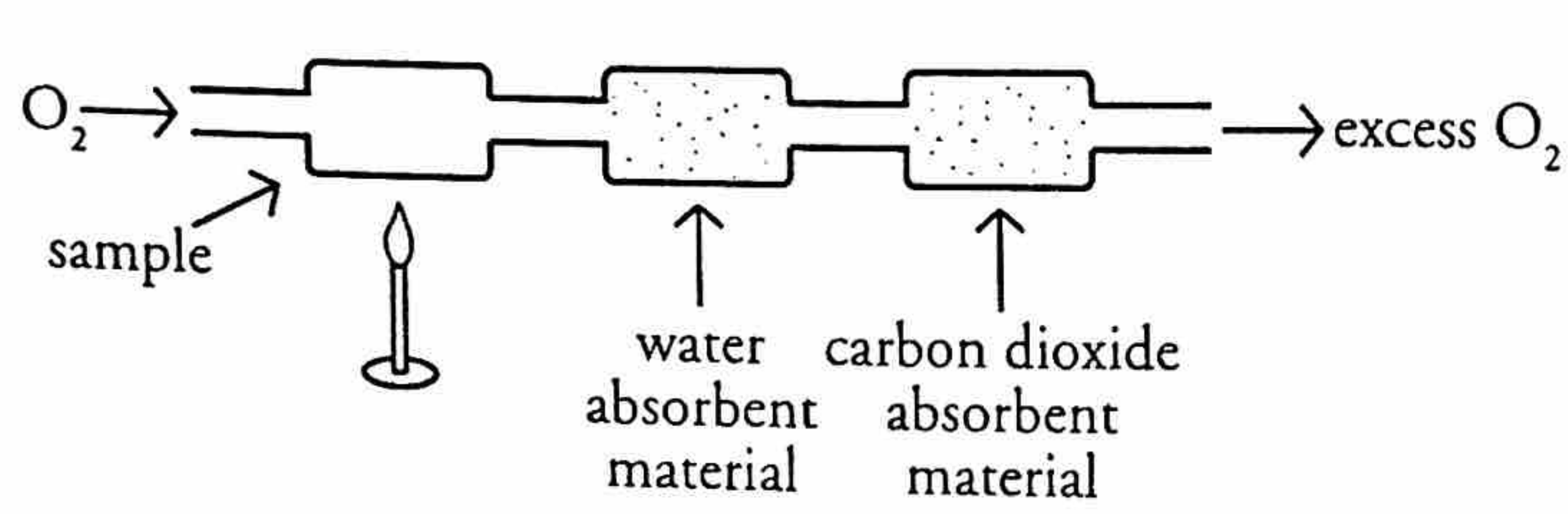
4. How is the coefficient of the H_2O in the chemical reactions in Model 1 related to the chemical formula of the hydrocarbon being analyzed?

   half the number of hydrogens in the hydrocarbon

STOP

14

Read This!



In a combustion analysis experiment, a hydrocarbon sample is heated in a stream of oxygen gas. As the sample burns, water and carbon dioxide is pushed through a series of chambers with materials that absorb each of the respective products. The chambers are each weighed before and after the combustion to determine the mass of each product.

Model 2 – Combustion Analysis of C_xH_y Unknowns

10.00-g Sample	Mass of CO_2 Produced	Moles of CO_2	Moles of Carbon Atoms	Mass of H_2O Produced	Moles of H_2O	Moles of Hydrogen Atoms	Sample's Empirical Formula	Total Mass of C and H Atoms	found mass
1	27.42 g	0.6230	0.6230	22.46 g	1.247	2.493	CH_4	[illegible]	10.00g
2	29.26 g	0.6648	0.6648	17.97 g	.9974	1.995	CH_3	[illegible]	10.00g

30.00-g Sample	Mass of CO_2 Produced	Moles of CO_2	Moles of Carbon Atoms	Mass of H_2O Produced	Moles of H_2O	Moles of Hydrogen Atoms	Sample's Empirical Formula	Total Mass of C and H Atoms	found mass
3	94.11 g	2.138	2.138	38.53 g	2.139	4.277	CH_2	[illegible]	30.00g
4	89.80 g	2.040	2.040	49.03 g	2.721	5.443	C_3H_8	[illegible]	30.00g

5. Discuss with your group how the data in Model 2 could be used to calculate the following quantities:

   Moles of CO_2 Moles of C atoms

   Moles of H_2O Moles of H atoms

   Divide the work among group members to complete those four columns in Model 2. Show work for your calculations below.

STOP

6. Discuss with your group how the data from Model 2 could be used to find the lowest whole number ratio between carbon and hydrogen atoms. This will give you the empirical formulas of the sample substances. Fill in the last column of Model 2.

7. Did you need balanced chemical combustion equations to find the empirical formulas of the unknowns in Model 2?

NO

8. Did you need to know the mass of the samples to find the empirical formulas of the unknowns in Model 2?

NO

9. What other information would you need to determine the molecular formulas?

the mass of each of the products and the mass of the sample

10. A 15.00-g sample of an unknown hydrocarbon is analyzed by combustion analysis. The sample produced 50.70 grams of carbon dioxide and 10.42 grams of water. Find the empirical formula of the unknown.

$\frac{50.70\text{ g } CO_2 \mid 1 \text{ mol } CO_2}{\mid 44.01 \text{ g } CO_2} = 1.152 / 1.152 = 1$

$\frac{10.42\text{ g } H_2O \mid 1 \text{ mol } H_2O \mid 2 \text{ mol H}}{\mid 18.016 \text{ g } H_2O \mid 1 \text{ mol } H_2O} = 1.1567 / 1.152 = 1$

CH

11. Calculate the total mass of carbon atoms and hydrogen atoms for each sample in Model 2. Divide the work among group members. Create a new column in Model 2 for these data.

a. How does the mass of carbon and hydrogen atoms compare to the mass of the original sample?

~~1) 0.6230 mol C / 0.6230 = 1; 2.493 mol H / 0.6230 = 4 CH4~~

~~2) 0.6648 mol C / 0.6648 = 1; 1.995 mol H / 0.6648 = 3 CH3~~

It is the same!

b. Name the scientific law that justifies your answer to part *a*

law of conservation of mass

c. Would part *a* be true if the original sample included atoms other than carbon and hydrogen? For example: C_2H_6O or $C_2H_5NH_2$. Justify your reasoning.

The masses of CH would be less than the total mass of the sample

110

Read This!

When the combustion analysis unknown is a compound containing only carbon and hydrogen, all of the atoms in the sample end up in either the CO_2 or H_2O products. However, if the unknown contains other elements, like oxygen or nitrogen, those atoms might end up in the CO_2 and H_2O products (in the case of oxygen) or they might form other gases that move through the apparatus without being captured. Additionally, O atoms may come from the atmosphere as opposed to the combusting sample. Moles of these atoms cannot be calculated by stoichiometry directly. Instead, we must use the law of conservation of mass.

Model 3 – Combustion Analysis of $C_xH_yO_z$ Unknowns (10.00-g samples)

Sample	Mass of CO_2 Produced	Moles of Carbon Atoms	Mass of H_2O Produced	Moles of Hydrogen Atoms	Total Mass of C and H Atoms	Mass of O Atoms	Moles of O Atoms	Sample's Empirical Formula
1	19.10 g	0.4340	11.73 g	1.302	6.525	3.475	0.2172	C_2H_6O
2	14.65 g	0.3329	6.00 g	0.6661	4.670	5.33	0.3331	CH_2O
3	21.96 g	0.4999	11.99 g	1.331	7.345	2.655	0.1659	C_3H_8O
4	28.05 g	0.6374	5.74 g	0.6372	8.297	1.703	0.1064	C_6H_6O

12. Four unknown hydrocarbons containing oxygen were analyzed by combustion analysis. The samples were 10.00 g each. The results are shown in Model 3. Discuss with your group what calculations would need to be performed to complete the table in Model 3. Divide the work among group members. Show work for your calculations below.

(1) 0.434 mol C / 0.2172 = 2
1.302 mol H / 0.2172 = 6
0.2172 mol O / 0.2172 = 1

(2) 0.3329 mol C / 0.3329 = 1
0.6661 mol H / 0.3329 = 2
0.3331 mol O / 0.3329 = 1

(3) 0.4999 mol C / 0.1659 = 3
1.331 mol H / 0.1659 = 8
0.1659 mol O / 0.1659 = 1

(4) 0.6374 mol C / .1064 = 6
0.6372 mol H / .1064 = 6
0.1064 mol O / .1064 = 1

STOP

17

13. Did you need balanced chemical combustion equations to find the empirical formula of your unknowns in Model 3?

NO

14. Did you need to know the mass of the samples to find the empirical formulas of your unknowns in Model 3?

yes

15. A 15.00-g sample of a compound containing carbon, hydrogen and nitrogen is analyzed by combustion analysis. The sample produced 29.3 grams of carbon dioxide and 20.8 grams of water. Find the empirical formula of the unknown.

$$29.3\,g\,CO_2 \times \frac{1\ mol\ CO_2}{44.01\ g\,CO_2} \times \frac{1\ mol\ C}{1\ mol\ CO_2} \times \frac{12.01\ g\ C}{1\ mol\ C} = 7.996\ g\ C$$

$$20.8\,g\,H_2O \times \frac{1\ mol\ H_2O}{18.016\ g\,H_2O} \times \frac{2\ mol\ H}{1\ mol\ H_2O} \times \frac{1.008\ g\ H}{1\ mol\ H} = 2.328\ g\ H$$

$= 10.324\ g$

15.00
− 10.324
4.676 g N

$$7.996\ g\ C \times \frac{1\ mol\ C}{12.01\ g\ C} = 0.6658 / 0.3338 = 2$$

$$2.328\ g\ H \times \frac{1\ mol\ H}{1.008\ g\ H} = 2.300 / 0.3338 = 7$$

C_2H_7N

$$4.676\ g\ N \times \frac{1\ mol\ N}{14.01\ g\ N} = 0.3338 / 0.3338 = 1$$

18

Extension Questions

16. It is critical in combustion analysis procedures that the sample be dry. Discuss what errors in data would occur if the sample contained moisture. How might this affect the final empirical formula?

If the sample had moisture in it the sample would seem to have a higher mass, making it seem like there were more carbons and hydrogens in the sample then there really were

17. Discuss what errors in data would occur if the sample contained a carbon-based impurity. How might this affect the final empirical formula?

The final empirical formula would have more C in it because more CO_2 would have been formed

18. Balance the general combustion equation below using variables for the missing coefficients.

$$C_xH_y + \underset{\uparrow \atop \frac{2X+Y}{2}}{} O_2 \rightarrow X\, CO_2 + \tfrac{1}{2}Y H_2O$$

Midterm Review Packet page 20

1) $34.71\,g\ CO_2 \mid \frac{1\ mol\ CO_2}{44.01\,g\ CO_2} = 0.7887\ mol\ CO_2 \mid \frac{1}{0.26297} = 3$

$14.20\,g\ H_2O \mid \frac{1\ mol\ H_2O}{18.016\,g\ H_2O} \mid \frac{2\ mol\ H}{1\ mol\ H_2O} = 1.576\ mol\ H \mid \frac{1}{0.26297} = 6$

$27.59/100 = .2759 \times 15.25 = 4.207\,g\ O \mid \frac{1}{16.00} = 0.26297\ mol\ O / 0.262\ldots = 1$

C_3H_6O

2) $21.41\,g\ CO_2 \mid \frac{1\ mol}{44.01\,g} = 0.4865/0.3242 = 1.5 \times 2$

$14.59\,g\ H_2O \mid \frac{1\ mol\ H_2O}{18.016\,g\ H_2O} \mid \frac{2\ mol\ H}{1\ mol\ H_2O} = 1.6197/0.3242 = 5 \times 2$

$17.51\,g\ N_2O_5 \mid \frac{1\ mol\ N_2O_5}{108.02\,g\ N_2O_5} \mid \frac{2\ mol\ N}{1\ mol\ N_2O_5} = 0.3242/0.3242 = 1 \times 2$

$C_2H_{10}N_2$

$C_4H_3O_2$

3) $21.2\,g\ CO_2 \mid \frac{1\ mol\ CO_2}{44.01\,g\ CO_2} \mid \frac{1\ mol\ C}{1\ mol\ CO_2} \mid \frac{12.01\,g\ C}{1\ mol\ C} = 5.785\,g\ C$

$3.25\,g\ H_2O \mid \frac{1\ mol\ H_2O}{18.016\,g\ H_2O} \mid \frac{2\ mol\ H}{1\ mol\ H_2O} \mid \frac{1.008\,g\ H}{1\ mol\ H} = .3637\,g\ H$

$5.785\,g\ C \mid \frac{1\ mol}{12.01\,g\ C} = 0.4817/0.2407 = 2 \times 2$

10 − 6.1487 g = 3.8513 g O

$3.8513\,g\ O \mid \frac{1\ mol}{16.00\,g\ O} = 0.2407/0.2407$

$0.3637\,g\ H \mid \frac{1\ mol\ H}{\ldots} = 0.3608/0.2407 = 1.5 \times 2$

Midterm Review Packet page 20

1) 34.71 g CO_2 | 1 mol CO_2 / 44.01 g CO_2 = 0.7887 mol C | 1 / 0.26297 = 3

14.20 g H_2O | 1 mol H_2O / 18.016 g H_2O | 2 mol H / 1 mol H_2O = 1.576 mol H | 1 / 0.26297 = 6

27.59/100 = .2759 × 15.25 = 4.207 g O | 1 / 16.00 = 0.26297 mol O / 0.26297 = 1

(C_3H_6O)

2) 21.41 g CO_2 | 1 mol / 44.01 g = 0.4865 / 0.3242 = 1.5 × 2

14.59 g H_2O | 1 mol H_2O / 18.016 g H_2O | 2 mol H / 1 mol H_2O = 1.6197 / 0.3242 = 5 × 2

17.51 g N_2O_5 | 1 mol N_2O_5 / 108.02 g N_2O_5 | 2 mol N / 1 mol N_2O_5 = 0.3242 / 0.3242 = 1 × 2

($C_2H_{10}N_2$)

($C_4H_3O_2$)

3) 21.2 g CO_2 | 1 mol CO_2 / 44.01 g CO_2 | 1 mol C / 1 mol CO_2 | 12.01 g C / 1 mol C = 5.785 g C

3.25 g H_2O | 1 mol H_2O / 18.016 g H_2O | 2 mol H / 1 mol H_2O | 1.008 g H / 1 mol H = .3637 g H

10 − 6.1487 g = 3.8513 g O

5.785 g C | 1 mol / 12.01 g C = 0.4817 / 0.2407 = 2 × 2

3.8513 g O | 1 mol / 16.00 g O = 0.2407 / 0.2407 = 1 × 2

0.3637 g H | 1 mol H / 1.008 g H = 0.3608 / 0.2407 = 1.5 × 2

5 4a) $\frac{48.65\,g\,C \mid 1\ mol\ C}{12.01\ g\,C}$ = 4.0508 / 2.7025 = 1.5 × 2 = 3

$\frac{8.11\,g\,H \mid 1\ mol\ H}{1.008\ g\,H}$ = 8.0456 / 2.7025 = 3 × 2 = 6

$\frac{43.24\,g\,O \mid 1\ mol\ O}{16.00\ g\,O}$ = 2.7025 / 2.7025 = 1 × 2 = 2

$C_3H_6O_2$

4 b) $\frac{17.84\,g\,CO_2 \mid 1\ mol\ CO_2 \mid 1\ mol\ C \mid 12.01\ g\ C}{44.01\ g\ CO_2 \mid 1\ mol\ CO_2 \mid 1\ mol\ C}$ = 4.868 g C

$\frac{7.30\,g\ H_2O \mid 1\ mol\ H_2O \mid 2\ mol \mid 1.008\ g\ H}{18.016\ g\ H_2O \mid 1\ mol\ H_2O \mid 1\ mol\ H}$ = 0.8169 g H

10 − (4.868 + 0.8169) = 4.315 g O

$\frac{4.868\,g\,C \mid 1\ mol}{12.01\ g}$ = 0.4053 / 0.2697 = 1.5 × 2 = 3

$\frac{0.8169\,g\,H \mid 1\ mol\ H}{1.008\ g\ H}$ = 0.8104 / 0.2697 = 3 × 2 6

$\frac{4.315\,g\,O \mid 1\ mol\ O}{16.00\ g\ O}$ = 0.2697 / 0.2697 = 1 × 2 2

$C_3H_6O_2$

6) $$\frac{47.57\,g\,CO_2}{} \cdot \frac{1\ mol\ CO_2}{44.01\,g\,CO_2} \cdot \frac{1\ mol\ C}{1\ mol\ CO_2} \cdot \frac{12.01\,g\,C}{1\ mol\ C} = 12.98$$

$$\frac{4.86\,g\,H_2O}{} \cdot \frac{1\ mol\ H_2O}{18.016\,g\,H_2O} \cdot \frac{2\ mol\ H}{1\ mol\ H_2O} \cdot \frac{1.008\ mol\ H}{1\ mol\ H} = .5395$$

$20 - (12.98 + .5395) = 6.4805\,g\,O$

$\frac{12.98\,g\,C}{} \cdot \frac{1\ mol\ C}{12.01\,g\,C} = 1.0807 / 0.4050 = 2.67 \times 3 = 8$

$\frac{0.5395\,g\,H}{} \cdot \frac{1\ mol\ H}{1.008\,g\,H} = 0.5352 / 0.4050 = 1.321 \times 3 = 4$

$\frac{6.4805\,g\,O}{} \cdot \frac{1\ mol\ O}{16.00\,g\,O} = 0.4050\ mol / .4050 = 1 \times 3 = 3$

$C_8H_4O_3$