Subject Code	Chem 1	**Chemistry 1**
Module Code	2.0	**Nomenclature of Inorganic Compounds**
Lesson Code	2.4	**Stoichiometry Part I**
Time Frame		**30 minutes**

Components	**Tasks**	**TA[1] (min)**	**ATA[2] (min)**
Target 	After completing this module, you are expected to: **1.** determine the mole ratio/s from the balance chemical equation. **2.** compute and solve stoichiometric problems using the factor-label method.	0.5	
Hook 	Chemists often times consider the relative amounts of raw materials (reactants) and products in synthesizing new compounds. Metallurgists need to consider the amounts of materials involved in obtaining metals from their ores. Chemical engineers make chemical calculations in order to have a smooth flow of operations in manufacturing industries. A basic question raised in the chemical laboratory is "**How much product will be formed from specific amounts of starting materials**?" Or, "**How much starting material must be used to obtain a specific amount of product**?" In this module, you will learn how to compute and predict the amount of product from a given amount of reactant or compute the amount of reactant in order to produce a certain amount of product.	2.5	
Ignite 	**Stoichiometry**: Quantitative Relations in Chemical Reactions Stoichiometry(pronounced "stoy-key-om'-e-tree") is the calculation of the quantities of reactants and products involved in a chemical reaction. It is based on the chemical equation and on the relationship between mass and moles. Such calculations are fundamental to most quantitative work in chemistry. Molar Interpretation of a Chemical Equation Consider the equation $2H_{2(g)} + O_{2(g)} \rightarrow 2H_2O_{(l)}$ we know that if 1 mol O_2 is consumed in this reaction, then 2 mol H_2O is formed. This interpretation of the coefficients as numbers of moles is the basis of all calculations in stoichiometry. **Mole-to-Mole Calculations** Example 1.1 Find the number of moles of N_2 needed to produce 7.0 moles NH_3 by reaction with H_2. The balanced chemical equation is	10	

[1]Time allocation suggested by the teacher.

[2]Actual time allocation spent by the student (for information purposes only).

$$N_{2(g)} + 3H_{2(g)} \rightarrow 2NH_{3(g)}$$

Solution: moles N_2 = $(7.0\ \cancel{mol\ NH_3}) \times \dfrac{1\ mol\ N_2}{2\ \cancel{mol\ NH_3}}$ = **3.5 mol N_2**

mole ratio (from the balanced chemical equation)

Mass-to-Mass Calculations

Example 1.2 The final step in the production of nitric acid involves the reaction of nitrogen dioxide with water; nitrogen monoxide is also produced. How many grams of nitric acid are produced for every 120.0 g of nitrogen dioxide that reacts?

Solution:
Set-up the equation first:

$$NO_2 + H_2O \rightarrow 1\ HNO_3 + NO$$

Balance the equation:

$$3\ NO_2 + H_2O \rightarrow 2\ HNO_3 + NO$$

Calculate: $gHNO_3 = 120.0\ \cancel{g}\ NO_2 \times \dfrac{1\ \cancel{mol\ NO_2}}{46.006\ g\ \cancel{NO_2}} \times \dfrac{2\ \cancel{mol\ HNO_3}}{3\ \cancel{mol\ NO_2}} \times \dfrac{63.013\ g\ HNO_3}{1\ \cancel{mol\ HNO_3}}$

1 /molar mass of NO_2

mole ratio

molar mass of HNO_3

=**109.6 g HNO_3**

More Examples:

Example 1.3 Nitrous oxide (N_2O) is also calle "laughing gas." It can be prepared by the thermal decomposition of ammonium nitrate (NH_4NO_3). The other product is H_2O. (a) Write a balanced equation for this reaction. (b) How many grams of N_2O are formed if 0.55 mole of NH_4NO_3 is used in the reaction?

Solution:

(a) $NH_4NO_3 \rightarrow N_2O + H_2O$ (unbalanced)
$NH_4NO_3 \rightarrow N_2O + 2H_2O$ (balanced)

(b) $0.55\ \cancel{mol\ NH_4NO_3} \times \dfrac{1\ \cancel{mol\ N_2O}}{1\ \cancel{mol\ NH_4NO_3}} \times \dfrac{44\ g\ N_2O}{1\ \cancel{mol\ N_2O}}$ =

24 g N_2O

Example 1.4 Potassium nitrate decomposes on heating, producing potassium oxide and gaseous nitrogen and oxygen:

$$4KNO_{3(s)} \rightarrow 2K_2O_{(s)} + 2N_{2(g)} + 5O_{2(g)}$$

To produce 58.7 kg of oxygen, how many (a) moles of KNO_3 must be heated?

$$58.7\ \cancel{kg\ O_2} \times \frac{1000\ \cancel{g\ O_2}}{1\ \cancel{kg}\ O_2} \times \frac{1\ \cancel{mol}\ O_2}{32.0\ g\ \cancel{O_2}} \times \frac{4\ mol\ KNO_3}{5\ \cancel{mol}O_2} =$$

1.47×10^3 mol KNO_3

Example 1.5 How many oxygen molecules reacted during the combustion of 275 g of hydrogen gases?

Combustion of hydrogen: $H_{2(g)} + O_{2(g)} \rightarrow H_2O_{(l)}$

Balance the equation: $\mathbf{2}H_{2(g)} + O_{2(g)} \rightarrow \mathbf{2}H_2O_{(l)}$

$$275\ g\ H_2 \times \frac{1\ mol\ H_2}{2.016\ g\ H_2} \times \frac{1\ mol\ O_2}{2\ mol\ H_2} \times \frac{6.02 \times 10^{23}\ O_2\ molecules}{1\ mol\ O_2}$$

= **4.11×10^{25} O_2 molecules**

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PART I. NONGRADED ASSESSMENT

For practice, solve the following:

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1. Silicon tetrachloride ($SiCl_4$) can be prepared by heating Si in chlorine gas:

   $$Si_{(s)} + 2Cl_{2(g)} \rightarrow SiCl_{4(l)}$$

   In one reaction, 0.625 mole of $SiCl_4$ is produced. How many moles of molecular chlorine were used in the reaction?

   Answer: 1.25 mol

2. Iron metal reacts with chlorine gas. How many grams of $FeCl_3$ are obtained whn 524 g Cl_2 reacts with excess Fe?

   $2Fe_{(s)} + 3Cl_{2(g)} \rightarrow 2FeCl_{3(s)}$ **Answer: 799 g**

3. Calculate the mass (g) of each product formed when 44.53 g of diborane (B_2H_6) reacts with excess water:

   $B_2H_{6(g)} + H_2O_{(l)} \rightarrow H_3BO_{3(s)} + H_{2(g)}$ (unbalanced)

   Answer: 199. 0 g H_3BO_3 ; 19.47 g H_2

4. How many moles of Ag_2CO_3 are decomposed to yield 75.1 g Ag in this reaction?

   $Ag_2CO_{3(s)} \xrightarrow{\Delta} Ag_{(s)} + CO_{2(g)} + O_{2(g)}$(not balanced)

   Answer: 0.348 molAg_2CO_3

5. Elemental phosphorus occurs as tetratomic molecules, P_4. How many molecules of chlorine gas are needed to react

completely with 455 g of phosphorus to form phosphorus pentachloride?

Answer: 2.21 x 10^{23} molecules of Cl_2

PART II GRADED ASSESSMENT (Must be done outside the 30 minute time limit of the module)

1. Consider the combustion of butane (C_4H_{10}):

   $2C_4H_{10(g)} + 13O_2 \rightarrow 8CO_{2(g)} + 10H_2O_{(l)}$

   In a particular reaction, 6.5 moles of C_4H_{10} are reacted with an excess of O_2. Calculate the number of moles of CO_2 formed.

2. A laboratory method of preparing $O_{2(g)}$ involves the decomposition of $KClO_{3(s)}$.

   $2KClO_{3(s)} \xrightarrow{\Delta} 2KCl_{(s)} + 3O_{2(g)}$

   (a) How many moles of $O_{2(g)}$ can be produced by the decomposition of 34.6 g $KClO_3$?
   (b) How many grams of $KClO_3$ must decompose to produce 45.5 g O_2?
   (c) How many grams of KCl are formed, together with 27.5 g O_2, in the decomposition of $KClO_3$?

3. The reaction of calcium hydride with water can be used to prepare small quantities of hydrogen gas, as is done to fill weather-observation balloons.

   $CaH_{2(s)} + H_2O_{(l)} \rightarrow Ca(OH)_{2(s)} + H_{2(g)}$ (not balanced)

   (a) How many grams of $H_{2(g)}$ result from the reaction of 134 g CaH_2 with an excess of water?
   (b) How many grams of water are consumed in the reaction of 58.3 g CaH_2?
   (c) What mass of $CaH_{2(s)}$, in g, must react with an excess of water to produce 4.15 x 10^{24} molecules of H_2?

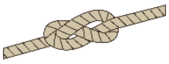
4. Fermentation is a complex chemical process of wine making in which glucose is converted into ethanol and carbon dioxide:

   $C_6H_{12}O_6 \rightarrow 2C_2H_5OH + 2CO_2$

   glucose ethanol

   Starting with 512.5 g of glucose, what is the maximum amount of ethanol in grams and in liters that can be obtained by this process? (Density of ethanol = 0.789 g/mL)

5. When baking soda (sodium bicarbonate or sodium hydrogen carbonate, $NaHCO_3$) is heated, it releases carbon dioxide gas, which is responsible for the rising of cookies, donuts, and bread. (a) Write a balanced equation for the decomposition of the compound (one of the products is Na_2CO_3). (b) Calculate the mass of $NaHCO_3$ required to produce 22.2 g of CO_2.

Knot 	Stoichiometry is the quantitative study of products and reactants in chemical reactions. Stoichiometric factors – also called mole ratios – are based on the coefficients in the balanced equation and are used to relate moles of one reactant or product to another. Molar masses and stoichiometric factors, together with other factors, are used to determine information about one reactant or product in a chemical reaction from known information about another. The strategy for reaction stoichiometry calculations can be outlined diagrammatically, as suggested below. Various calculation (if necessary) $\rightarrow$ **Moles A** $\xrightarrow{\times \frac{no.mol\ B}{no.mol\ A}}$ **Moles B** $\rightarrow$ Various calculation (if necessary)	2	

References

Petrucci, R.H. et. al. (2017).*GENERAL CHEMISTRY: Principles and Modern Applications*, 11th Ed. U.S.A.: Pearson Canada

Silberberg, M.S. (2013). *Principles of General Chemistry*, 3rd Ed. New York: The McGraw-Hill Companies, Inc

Chang, R. and Overby, J. (2011).*General Chemistry: The Essential Concepts*, 6th Ed. New York: McGraw-Hill

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