CHEM 101A – TOPIC A
EQUATIONS, FORMULAS, AND STOICHIOMETRY

WHAT YOU SHOULD BE ABLE TO DO WHEN YOU HAVE FINISHED THIS TOPIC:
1) Write and balance chemical equations involving pure elements and compounds.
2) Find empirical and molecular formulas and molar masses of compounds from analytical data, and use molecular formulas to determine percent composition.
3) Use combustion analysis to determine the empirical formula of an organic compound.
4) Use stoichiometric relationships to determine limiting reactants, masses of reactants and products, and percent yield, given appropriate data.
5) Determine the composition of a mixture of substances, given appropriate analytical data.
6) Know the names and formulas of common inorganic compounds.

READING ASSIGNMENT:
Chapter 2: entire chapter (most of this is background information)
Chapter 3: entire chapter

RELEVANT PROBLEMS: (these will not be collected, but you are expected to be able to do them)
(6th edition): Chapter 3, problems 17, 18, 25, 31, 33, 39, 41, 45, 47, 55, 57, 63, 71, 81, 83, 91 and 93. If you would like to try some harder problems, we suggest numbers 101, 107 and 109.
(5th edition): Chapter 3, problems 17, 18, 25, 31, 33, 39, 41, 45, 47, 55, 57, 61, 67, 77, 79, 87 and 91. If you would like to try some harder problems, we suggest numbers 99, 105 and 107.

ADDITIONAL RELEVANT PROBLEMS: (answers available on the Chem 101A web site)
1) A 3.61 gram sample of a metal combines with 2.00 grams of oxygen to form a single compound. The atomic mass of the metal is known to be around 43 g/mol. What is the empirical formula of the metal oxide? What is the exact atomic mass of the metal, based on this information?
2) A sample of an unknown metal weighing 1.90 grams combines with 0.0252 grams of gaseous H$_2$ to form a single compound. The atomic mass of the metal is known to be around 220 g/mol. What is the exact atomic mass of the metal, based on this information?

THE REQUIRED HOMEWORK ASSIGNMENT STARTS ON THE NEXT PAGE OF THIS HANDOUT.
CHEM 101A  TOPIC A HOMEWORK PROBLEMS

These problems are required homework and will be counted toward your course grade. See the course information sheet for additional information about homework grading. Your instructor will give you the due dates for the problems.

1) The chemical formula of ammonium dichromate is \((\text{NH}_4)_2\text{Cr}_2\text{O}_7\). If you have a 12.50 g sample of this compound…
   a) How many moles of ammonium dichromate do you have?
   b) How many moles of oxygen atoms do you have?
   c) How many hydrogen atoms do you have?
   d) How many grams of chromium do you have?
   e) How many ammonium ions do you have?

2) What is the mass percentage of hydrogen in ammonium phosphate, \((\text{NH}_4)_3\text{PO}_4\)?

3) Sulfur pentachloride reacts with aluminum to form aluminum chloride and sulfur. The chemical equation for this reaction is \(3 \text{SCl}_5 + 5 \text{Al} \rightarrow 5 \text{AlCl}_3 + 3 \text{S}\)
   a) How many grams of aluminum will react with 3.516 g of sulfur pentachloride?
   b) If you need to make 65.0 g of aluminum chloride, how many grams of aluminum will you need?
   c) If you mix 12.5 g of aluminum with 25.0 g of sulfur pentachloride, which reactant is present in excess, and what mass of that reactant will remain after the reaction has gone to completion?
   d) What is the theoretical yield of \(\text{AlCl}_3\) under the conditions in part c?

4) Potassium phosphate reacts with magnesium chloride to form magnesium phosphate and potassium chloride. If 715 kg of potassium phosphate reacts with excess magnesium chloride, how many kilograms of magnesium phosphate will be produced, assuming 100% yield?

5) A chemist mixes 4.175 g of \(\text{KMnO}_4\) (potassium permanganate), 2.318 g of \(\text{C}_2\text{H}_5\text{OH}\) (ethanol), and excess sulfuric acid. These chemicals react as follows:
   \(4 \text{KMnO}_4 + 5 \text{C}_2\text{H}_5\text{OH} + 6 \text{H}_2\text{SO}_4 \rightarrow 4 \text{MnSO}_4 + 5 \text{HC}_2\text{H}_3\text{O}_2 + 2 \text{K}_2\text{SO}_4 + 11 \text{H}_2\text{O}\)
   a) What mass of sulfuric acid (\(\text{H}_2\text{SO}_4\)) is consumed in this reaction, assuming that the reaction goes to completion?
   b) The chemist isolates 1.720 g of acetic acid. Calculate the percent yield of acetic acid in this experiment.

6) Many fertilizers contain urea (\(\text{N}_2\text{H}_4\text{CO}\)) as a source of nitrogen. A 7.225 g sample of a fertilizer that contains urea (and other ingredients) is dissolved in water containing an enzyme that breaks down urea into ammonia and carbon dioxide:
   \(\text{N}_2\text{H}_4\text{CO(aq)} + \text{H}_2\text{O(aq)} \rightarrow 2 \text{NH}_3(\text{aq}) + \text{CO}_2(\text{g})\)
   The reaction forms 0.978 g of ammonia. Using this information, calculate the percentage (by mass) of urea in the fertilizer.

7) A compound contains 87.73% carbon and 12.27% hydrogen. What is the empirical formula of this compound?
8) The amino acid arginine is an essential component of all proteins. This compound contains 41.36% carbon, 8.10% hydrogen, and 32.17% nitrogen, with the remainder being oxygen.
   a) Determine the empirical formula of arginine.
   b) The molar mass of arginine is known to be between 100 and 200 g/mol. Determine the molecular formula of arginine.

9) The name “penicillin” is used for several closely-related antibiotics. A 1.2177 g sample of one of these compounds is burned, producing 0.4503 g of SO₂, 2.1654 g of CO₂, 0.6965 g of H₂O, and 0.2109 g of NO. Determine the empirical formula of this compound.

10) You have a 275 mg sample of a compound that contains aluminum and a group 7A element (F, Cl, Br, I or At). This compound reacts with excess silver nitrate as follows (“X” represents the unknown element):
    \( \text{AlX}_3 + 3 \text{AgNO}_3 \rightarrow 3 \text{AgX} + \text{Al(NO}_3)_3 \)
    This reaction forms 581 mg of AgX. Identify element X.

11) 1.000 g of vanadium (V) is mixed with 8.000 g of bromine (Br₂). After the elements react, some bromine is left over, along with a single compound that contains the two elements. The excess bromine is removed and allowed to react with excess sodium sulfite and excess sodium hydroxide, producing a mixture that contains 1.534 g of sodium sulfate. The balanced equation for this second reaction is:
    \( 2 \text{NaOH} + \text{Na}_2\text{SO}_3 + \text{Br}_2 \rightarrow 2 \text{NaBr} + \text{Na}_2\text{SO}_4 + \text{H}_2\text{O} \)
    Based on this information, determine the empirical formula of the compound that was formed when vanadium reacted with bromine.

12) All of the lanthanide metals (La through Lu, elements 57 through 71) react with HCl to form compounds having either the formula MCl₂, MCl₃ or MCl₄ (where M represents the metallic element). Each metal forms a single compound. A chemist has a 0.250 g sample of a lanthanide metal, and she wishes to identify the metal. She reacts the metal with excess HCl and obtains 0.427 g of product. Based on this information, identify the metal and write the chemical formula of the product.

13) A piece of metal is made from a mixture of magnesium and aluminum. A 0.317 g sample of this metal is placed into a container of aqueous HCl, and the following reactions occur:
    \( \text{Mg(s)} + 2 \text{HCl(aq)} \rightarrow \text{MgCl}_2(\text{aq}) + \text{H}_2(\text{g}) \)
    \( 2 \text{Al(s)} + 6 \text{HCl(aq)} \rightarrow 2 \text{AlCl}_3(\text{aq}) + 3 \text{H}_2(\text{g}) \)
    A total of 337 mL of gaseous hydrogen is formed. The density of gaseous hydrogen under these conditions is 0.08158 g/L. Use this information to determine the percentage of each metal in the original sample.

14) Write chemical formulas for each of the following compounds:
    a) sodium sulfate      b) iron(III) oxide      c) zinc nitrate      d) aluminum iodide

15) Name each of the following compounds:
    a) CaF₂      b) K₃PO₄      c) CuCO₃      d) H₂SO₄      e) Ag₂S