AP Chemistry – Quantitative Chemistry Problem Set

1. Allicin is the compound responsible for the characteristic smell of garlic. An analysis of the compound gives the following percent composition by mass: C: 44.4percent; H: 6.21 percent; S: 39.5 percent; O: 9.86 percent. Calculate its empirical formula. Determine the molecular formula of allicin if the molar mass is about 162 g.

2. The formula for rust can be represented by Fe_2O_3. How many moles of Fe are present in 24.6 g of the compound?

3. Calculate the mass of iodine (I_2) that will completely react with 20.4 g of aluminum (Al) to form aluminum iodide (AlI_3)

4. Nitrous oxide (N_2O) is also called "laughing gas." It can be prepared by the thermal decomposition of ammonium nitrate. The other product is H_2O. (a) Write the balanced equation for this reaction. (b) How many grams of N_2O are formed if 0.46 moles of NH_4NO_3 is used in the reaction?

5. When baking soda (sodium bicarbonate or sodium hydrogen carbonate) is heated, it releases carbon dioxide gas, which is responsible for the rising of cookies, donuts and cakes. (a) Write a balanced equation for the decomposition of sodium hydrogen carbonate (one of the products is sodium carbonate). (b) Calculate the mass of baking soda required to produce 20.5 g of CO_2.

6. The depletion of ozone (O_3) in the stratosphere has been a matter of great concern among scientists in recent years. It is believed that ozone can react with nitric oxide (NO) that is discharged from the high altitude jet plane, the SST. The reaction is:

   $$O_3 + NO \rightarrow O_2 + NO_2$$

   If 0.740 g of O_3 reacts with 0.670 g of NO, how many grams of NO_2 will be produced? Which compound is the limiting reactant? Calculate the number of moles of excess reactants remaining at the end of the reaction.

7. Consider the reaction:

   $$MnO_2 + 4HCl \rightarrow MnCl_2 + Cl_2 + 2H_2O$$

   If 0.86 mol of MnO_2 and 48.2 g of HCl react, which reagent will be used up first? How many grams of Cl_2 will be produced?

8. Nitroglycerin ($C_3H_5N_3O_9$) is a powerful explosive. Its decomposition may be represented by:

   $$4\ C_3H_5N_3O_9 \rightarrow 6N_2 + 12CO_2 + 10H_2O + O_2$$

This reaction generates a large amount of heat and many gaseous products. It is the sudden formation of these gases, together with their rapid expansion, that produces the explosion. (a) What is the maximum amount of O_2 in grams that can be obtained from 2.00 x 10^2 g of nitroglycerin? (b) Calculate the percent yield in this reaction if the amount of O_2 generated is found to be 6.55 g.

9. Industrially, nitric acid is produced by the Ostwald process represented by the following equations:

$$4NH_{3(g)} + 5O_{2(g)} \longrightarrow 4NO_{(g)} + 6H_2O_{(l)}$$

$$2NO_{(g)} + O_{2(g)} \longrightarrow 2NO_{2(g)}$$

$$2NO_{2(g)} + H_2O_{(l)} \longrightarrow HNO_{3(aq)} + HNO_{2(aq)}$$

What mass of NH_3 must be used to produce 1.00 ton of HNO_3 by the above procedure assuming an 80% yield in each step? (1 ton = 2000 lbs; 1 lb = 453.6 g)

10. A sample of a compound of Cl and O reacts with an excess of H_2 to give 0.233 g of HCl and 0.403 g of H_2O. Determine the empirical formula of the compound.

11. The carat is a unit of mass used by jewelers. One carat is exactly 200 mg. How many carbon atoms are present in a 24-carat diamond?

12. An iron bar weighed 664 g. After the bar had been standing in moist air for a month, exactly one-eight of the iron turned to rust. (Fe_2O_3). Calculate the final mass of the iron bar and rust.

13. One of the reactions that occurs in a blast furnace, where iron ore is converted to cast iron, is:

$$Fe_2O_3 + 3CO \rightarrow 2Fe + 3CO_2$$

Suppose that 1.64 x 10^3 kg of Fe are obtained from a 2.62 x 10^3 kg sample of Fe_2O_3. Assuming that the reaction goes to completion, what is the percent purity of Fe_2O_3 in the original sample?

14. Myoglobin stores oxygen for metabolic processes in the muscles. Chemical analysis shows that it contains 0.34 percent Fe by mass. What is the molar mass of myoglobin? (there is one Fe atom per molecule)

15. Which of the following substances has the greatest mass of chlorine? (a) 5.0 g Cl_2, (b) 60.0 g $NaClO_3$, (c) 0.10 mol KCl, (d) 30.0 g $MgCl_2$, (e) 0.50 mol Cl_2

16. The formula of a hydrate of barium chloride is $BaCl_2 \cdot xH_2O$. If 1.936 g of the compound gives 1.864 g of anhydrous $BaSO_4$ upon treatment with sulfuric acid, calculate the value of *x*.

17. Leaded gasoline contains an additive to prevent engine "knocking." On analysis, the additive compound is found to contain carbon, hydrogen, and lead (hence, leaded gasoline). When 51.36 g of this compound are burned in a combustion analysis apparatus, 55.90 g of CO_2 and 28.61 g of H_2O are produced. Determine the empirical formula of the gasoline additive.

18. A certain sample of coal is contains 1.6 percent sulfur by mass. When the coal is burned, the sulfur is converted to sulfur dioxide. To prevent air pollution, this sulfur dioxide is treated with calcium oxide to form calcium sulfite. Calculate the daily mass (in kg) of calcium oxide needed by a power plant that uses 6.60×10^6 kg of coal per day.

19. In the production of printed circuit boards for the electronics industry, a 0.60-mm layer of copper is laminated onto an insulating plastic board. Next, a circuit pattern made of a chemically resistant polymer is printed on the board. The unwanted copper is removed by chemical etching, and the protective polymer is finally removed by solvents. One etching reaction is:

$$Cu(NH_3)_4Cl_{2(aq)} + 4NH_{3(aq)} + Cu_{(s)} \longrightarrow 2Cu(NH_3)_4Cl_{(aq)}$$

A plant needs to manufacture 10,000 printed circuit boards, each 8.0 x 16.0 cm in area. An average of 80% of the copper is removed from each board (density of copper = 8.96 g/cm^3). What masses of $Cu(NH_3)_4Cl_2$ and NH_3 are needed to do this? Assume 100% yield

20. A student prepared aspirin in the laboratory using the reaction used in class. The student reacted 1.50 g of salicylic acid with 2.00 g of acetic anhydride. The yield was 1.50 g of aspirin. Calculate the theoretical yield and the percent yield for this experiment.

21. Tetrodoxin is a toxic chemical found in fugu pufferfish, a popular but rare delicacy in Japan. This compound has a LD_{50} (the amount of substance that is lethal to 50% of a population sample) of 10 μg per kg of body mass. Tetrodoxin is 41.38% carbon, 13.16% nitrogen, and 5.37% hydrogen by mass, with the remaining amount consisting of oxygen. What is the empirical formula of tetrodoxin? If three molecules of tetrodoxin have a mass of 1.59×10^{-21} g, what is the molecular formula of tetrodoxin? What number of molecules of tetrodoxin would be the LD_{50} dosage for a person weighing 165 lbs?