Unit 5:

Stoichiometry & Rxn Math
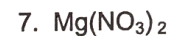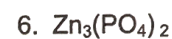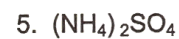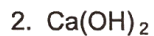
HW Packet

Name: _____

Chemistry: *Molar Mass and Percentage Composition*

Calculate the molar masses and percentage composition of each of the following compounds. Show your work and always include units.

1. Ca_3P_2

2. $Ca(OH)_2$

3. Na_2SO_4

4. $CaSO_4$

5. $(NH_4)_2SO_4$

6. $Zn_3(PO_4)_2$

7. $Mg(NO_3)_2$

8. KCl

Answers:
1. 182.3 g, 66.0% Ca, 34.0% P
2. 74.1 g, 54.1% Ca, 43.2% O, 2.7% H
3. 142.1 g, 32.4% Na, 22.6% S, 45.0% O
4. 136.2 g, 29.4% Ca, 23.6% S, 47.0% O

5. 132.1 g, 21.2% N, 6.1% H, 24.3% S, 48.4% O
6. 386.2 g, 50.8% Zn, 16.1% P, 33.1 % O
7. 116.3 g, 20.9% Mg, 24.1% N, 55.0% O
8. 74.6g, 52.4% K, 47.6% Cl

Chemistry: *Percentage Composition and Empirical & Molecular Formula*

Solve the following problems. Show your work, and always include units where needed.

1. A compound is found to contain 36.5% Na, 25.4% S, and 38.1% O. Find its empirical formula.

2. Find the empirical formula of a compound that is 53.7% iron and 46.3% sulfur.

3. Analysis of a sample of a compound indicates that is has 1.04 g K, 0.70 g Cr, and 0.86 g O. What is its empirical formula?

4. If 4.04 g of nitrogen combine with 11.46 g of oxygen to produce a compound with a molar mass of 108.0g, what is the molecular formula of this compound?

5. The molar mass of a compound is 92 g. Analysis of the sample indicates that it contains 0.606 g N and 1.390 g O. Find the compound's molecular formula.

6. An acid commonly used in the automotive industry is shown to be 31.6% phosphorous, 3.1% hydrogen, and 63.5% oxygen. Determine the empirical formula of this acid.

7. A solvent is found to be 50.0% oxygen, 37.5% carbon, and 12.5% hydrogen. What is the empirical formula of this solvent.

8. A particular sugar is determined to have the following composition: 40.0% carbon, 6.7% hydrogen, and 53.5% oxygen. Determine the empirical formula of this sugar molecule.

9. If the molar mass of the sugar in question #8 is 180.0 g, find the molecular formula of the sugar.

10. Ethene, a gas used extensively in preparing plastics and other polymers, has a composition of 85.7% carbon and 14.3% hydrogen. Its molar mass is 28 g. Find the molecular formula for ethane.

Chemistry: *Stoichiometry*

Name _____ Hr ___

1. How many moles of O_2 should be supplied to burn 1 mol of C_3H_8 (propane) molecules in a camping stove?

2. How many moles of O_2 molecules should be supplied to burn 1 mol of CH_4 molecules in a domestic furnace?

3. Sodium thiosulfate ($Na_2S_2O_3$), photographer's "hypo" reacts with unexposed silver bromide in the film emulsion to form sodium bromide and a compound of formula $Na_5[Ag(S_2O_3)_3]$. How many moles of $Na_2S_2O_3$ formula units are needed to make 0.10 mol of AgBr soluble?

4. Calculate the mass of alumina (Al_2O_3) produced when 100 g of aluminum burns in oxygen.

5. "Slaked lime," $Ca(OH)_2$, is formed from "quick-lime" (CaO) by adding water. What mass of water is needed to convert 10 kg of quicklime to slaked lime? What mass of slaked lime is produced?

6. Camels store the fat tristearin ($C_{57}H_{110}O_6$) in the hump. As well as being a source of energy, the fat is a source of water, because when it is used the reaction
$$2\ C_{57}H_{110}O_6(s)\ +\ 163\ O_2(g)\ \rightarrow$$
$$114\ CO_2(g)\ +\ 110\ H_2O(l)$$
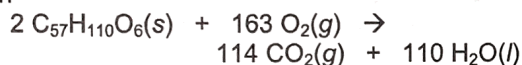
takes place. What mass of water is available from 1.0 kg of fat?

7. The compound diborane (B_2H_6) was at one time considered for use as a rocket fuel. How many grams of liquid oxygen would a rocket have to carry to burn 10 kg of diborane completely? (The products of the combustion are B_2O_3 and H_2O.)

8. Given the balanced chemical equation

$$Br_2\ +\ 2\ NaI\ \rightarrow\ 2\ NaBr\ +\ I_2$$

How many moles of sodium bromide (NaBr) could be produced from 0.172 mol of bromine (Br_2)?

9. How many formula units of calcium oxide (CaO) can be produced from 4.9×10^5 molecules of oxygen gas (O_2) that react with calcium (Ca) according to this balanced chemical equation?

$$2\ Ca(s)\ +\ O_2\ (g)\ \rightarrow\ 2\ CaO(s)$$
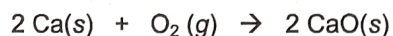
10. Aluminum metal (Al) reacts with sulfur (S) to produce aluminum sulfide (Al_2S_3) according to this balanced chemical equation:
$$2\ Al(s)\ +\ 3\ S(s)\ \rightarrow\ Al_2S_3(s)$$
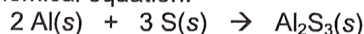
How many atoms of aluminum will react completely with 1.33×10^{24} atoms of sulfur?

LIMITING REAGENTS

11. What is the maximum mass of methane (CH_4) that can be burned if only 1.0 g of oxygen is available?

12. What is the maximum mass of glucose ($C_6H_{12}O_6$) that can be burned in 10 g of oxygen?

13. The solid fuel in the booster stage of the space shuttle is a mixture of ammonium perchlorate and aluminum powder, which react as follows:

$$6\ NH_4ClO_4(s)\ +\ 10\ Al(s)\ \rightarrow\ 5\ Al_2O_3(s)\ +$$
$$3\ N_2(g)\ +\ 6\ HCl(g)\ +\ 9\ H_2O(g)$$
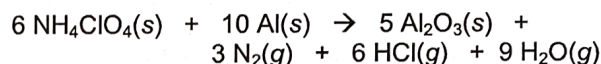
What mass of aluminum should be mixed with 5.0 $\times 10^3$ kg of ammonium perchlorate, if the reaction proceeds as stated?

14. A solution containing 5.0 g of silver nitrate was mixed with another containing 5.0 g of potassium chloride. Which was the limiting reagent for the precipitation of silver chloride?

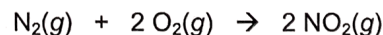15. Given the balanced chemical equation

$$2\ Ag\ +\ I_2\ \rightarrow\ 2\ AgI$$
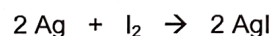
How many atoms of silver metal (Ag) are required to react completely with 531.8 g of iodine (I_2) to produce silver iodide (AgI)?

16. The theoretical yield of ammonia in an industrial synthesis was 550 tons, but only 480 tons was obtained. What was the percentage yield of the reaction?
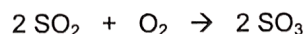
17. Calculate the volume occupied by 16.3 moles of nitrogen gas (N_2) at STP.

18. How many moles of fluorine gas (F_2) are contained in 0.269 dm^3 container at STP?

19. Assuming that the gases are all at STP, find the volume of nitrogen dioxide gas (NO_2) that could be produced from 71.11 dm^3 of nitrogen gas (N_2) according to this balanced chemical equation.

$$N_2(g)\ +\ 2\ O_2(g)\ \rightarrow\ 2\ NO_2(g)$$

20. How many moles of oxygen (O_2) would be needed to produce 79.60 moles of sulfur trioxide (SO_3) according to the following balanced chemical equation?

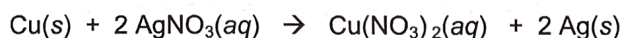$$2\ SO_2\ +\ O_2\ \rightarrow\ 2\ SO_3$$

21. How many grams of water will be produced from 50 g hydrogen reacting with 50 g oxygen?

Think Critically

22. The reaction of 1 mol of C to form carbon monoxide in the reaction 2 C(s) + O_2(g) → 2 CO(g) releases 113 kJ of heat. How much heat will be released by the combustion of 100 g of C according the the above information?

23. According to the balanced chemical equation; how many atoms of silver will be produced from combining 100 g of copper with 200 g of silver nitrate?

Cu(s) + 2 $AgNO_3$(aq) → Cu$(NO_3)_2$(aq) + 2 Ag(s)

24. According to the balanced chemical equation; how many moles of SO_2(g) will be produced when 1.5 x 10^8 molecules of zinc sulfide react with 1000 dm^3 of oxygen gas? Assume a 75% yield.

2 ZnS(s) + 3 O_2 (g) → 2 ZnO(s) + 2 SO_2(g)

25. I need to produce 500 g of lithium oxide(Li_2O)
    a) how many grams of Lithium AND
    b) how many liters of oxygen do I need

The balanced equation is: Li + O_2 → LiO_2

26. How many grams of water will be produce from 50 g hydrogen reacting with 50 g oxygen?

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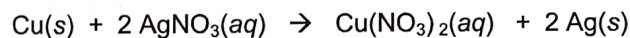The balanced equation is: Li + O_2 → LiO_2

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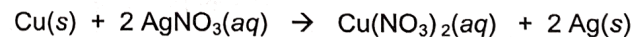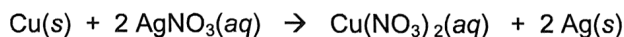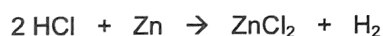   b) how many liters of oxygen do I need

The balanced equation is: Li + O$_2$ → LiO$_2$

26. A tin ore contains 3.5% SnO$_2$. How much tin is produced by reducing 2.0 kg of the ore with carbon?
SnO$_2$ + C → Sn + CO$_2$

27. If 36.5 g of HCl and 73 g of Zn are put together:

2 HCl + Zn → ZnCl$_2$ + H$_2$

   a. Determine which reactant is the limiting reactant,
   b. Find the mass of ZnCl$_2$ formed,
   c. Find the volume of H$_2$ (@ STP) formed,
   d. Determine which reactant is in excess and by how much.

28. Many plants synthesize glucose by photosynthesis as follows:
CO$_2$(g) + H$_2$O(l) + energy → C$_6$H$_{12}$O$_6$(s) + O$_2$(g)

   a. Write a balanced equation for this process,
   b. How many molecules of water are needed to make one molecule of glucose?
   c. How many liters of oxygen (@STP) are given off when 2.50 mol of glucose is synthesized?
   d. How many moles of CO$_2$ are needed for a plant to make 2.50 mole of glucose?
   e. How many carbon atoms are used to produce 2.50 mole of glucose?
   f. How many dm^3 of oxygen gas are produced from 9.32 dm^3 of CO$_2$ (all @ STP)?

29. Assume that the human body requires daily energy that comes from metabolizing 816 g of sucrose, C$_{12}$H$_{22}$O$_{11}$, using the following reaction:
C$_{12}$H$_{22}$O$_{11}$(s) + 12 O$_2$(g) → 12 CO$_2$(g) + 11 H$_2$O(l) + energy

How many dm^3 of pure oxygen (@ STP) is consumed by a human being in 24 hours?

30. A student has a mixture of KClO$_3$, K$_2$CO$_3$, and KCl. She heats 50 g of the mixture and determines that 5 g O$_2$ and 7 g CO$_2$ are produced by these reactions:

2 KClO$_3$(s) → 2 KCl(s) + 3 O$_2$(g)
K$_2$CO$_3$(s) → K$_2$O(s) + CO$_2$(g)
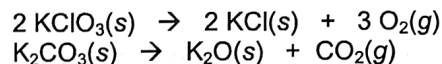
KCl is not affected by the heat. What is the percent composition of the original mixture?

ANSWERS:

1. 5 mol O$_2$
2. 2 mol O$_2$
3. 0.3 mol Na$_2$S$_2$O$_3$
4. 189 g Al$_2$O$_3$
5. 3214 g H$_2$O and 13.2 kg slaked lime [Ca(OH)$_2$]
6. 998 g water
7. 34,783 g O$_2$
8. 0.344 mol NaBr
9. 9.8 x 10^5 molecules CaO
10. 8.9 x 10^{23} atoms Al
11. 0.25 g CH$_4$
12. 9.375 g C$_6$H$_{12}$O$_6$
13. 1915 kg Al
14. silver nitrate
15. 2.5 x 10^{24} atoms Ag
16. 87.3 % yield
17. 365 L N$_2$
18. 0.012 mol F$_2$
19. 142 L NO$_2$
20. 39.8 mol O$_2$
21. 56.25 g H$_2$O
22. 942,000 J
23. 7.1 x 10^{23} atoms Ag
24. 1.9 x 10^{-16}mol (NOT 2.5 x 10^{-16}mol: 75% Yield)
25a.   g Li   b.   L O$_2$
26.
27a.   b.   c.   d.
28a.   b. 6   c. 336   d. 15   e. 9 x 10^{24} f. 9.32
29. 641 L O$_2$
30. 15.2 g KCl

1. *The human body needs at least 1.03 x 10⁻² mol O_2 every minute. If all of this oxygen is used for the cellular respiration reaction that breaks down glucose, how many grams of glucose does the human body consume each minute?*

$$C_6H_{12}O_6(s) \ + \ 6 \ O_2(g) \ \text{-----} > \ 6 \ CO_2(g) \ + \ 6 \ H_2O(l)$$

2. *In the space shuttle, the CO_2 that the crew exhales is removed from the air by a reaction within canisters of lithium hydroxide. On average, each astronaut exhales about 20.0 mol of CO_2 daily. What volume of water will be produced when this amount of CO_2 reacts with an excess of LiOH?   (Hint: the density of water is about 1.oo g/mL.)*

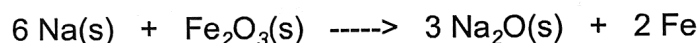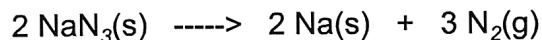$$CO_2(g) \ + \ 2 \ LiOH(s) \ \text{------} > \ Li_2CO_3(aq) \ + \ H_2O$$
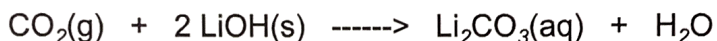
3. *Carbon monoxide can be combined with hydrogen to produce methanol, CH_3OH. Methanol is used as an industrial solvent, as a reactant in synthesis, and as a clean-burning fuel for some racing cars. If you had 152.5 kg CO and 24.50 kg H_2, how many kilograms of CH_3OH could be produced?*

4. *One step in making para-aminobenzoic acid, PABA, an ingredient in some suntan lotions, involves replacing one of the hydrogen atoms in a toluene molecule with an -NO_2 group, directly opposite the -CH_3 group. Calculate the percent yield if 550 g of toluene added to an excess of nitric acid provides 305 g of the nitrotoluene product.*

5. *A more efficient way to prepare the molecule that was used to produce PABA for suntan lotions involves a slightly different starting material, known as isopropyl-benzene. This reaction usually has a 91.2% yield. How many grams of the product, para-nitro-isopropylbenzene, can you expect if 775 g of isopropylbenzene react with an excess of nitric acid?*
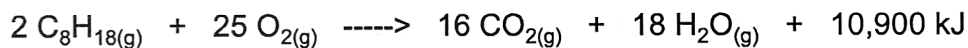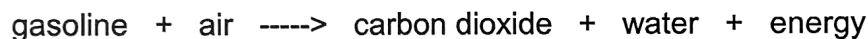
6. *Air-bag design depends on stoichiometric precision.*

$$2 \text{ NaN}_3(s) \quad \text{-----> } \quad 2 \text{ Na}(s) \ + \ 3 \text{ N}_2(g)$$

$$6 \text{ Na}(s) \ + \ \text{Fe}_2\text{O}_3(s) \quad \text{-----> } \quad 3 \text{ Na}_2\text{O}(s) \ + \ 2 \text{ Fe}$$

Assume that 65.1 L of N_2 gas are needed to inflate an air bag to the proper size. How many grams of NaN_3 must be included in the gas generant to generate this amount of N_2? (Hint: the density of N_2 gas at this temperature is about 0.916 g/L).
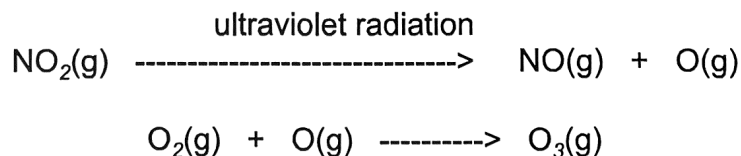
How much Fe_2O_3 must be added to the gas generant for this amount of NaN_3?

7. *Engine efficiency depends on the reactant proportions*

$$\text{gasoline} \ + \ \text{air} \quad \text{-----> } \quad \text{carbon dioxide} \ + \ \text{water} \ + \ \text{energy}$$

$$2 \text{ C}_8\text{H}_{18(g)} \ + \ 25 \text{ O}_{2(g)} \quad \text{-----> } \quad 16 \text{ CO}_{2(g)} \ + \ 18 \text{ H}_2\text{O}_{(g)} \ + \ 10{,}900 \text{ kJ}$$

How many liters of air must react with 1.000 L of isooctane in order for combustion to occur completely? At 20 degrees Celcius, the density of isooctane is 0.6916 g/mL, and the density of oxygen is 1.331 g/L. (Hint: remember to use the percentage of oxygen in air.)

8. *Car designers use stoichiometry to control pollution*

$$\text{NO}_2(g) \quad \xrightarrow{\text{ultraviolet radiation}} \quad \text{NO}(g) \ + \ \text{O}(g)$$

$$\text{O}_2(g) \ + \ \text{O}(g) \quad \text{---------> } \quad \text{O}_3(g)$$

Chemistry: *Supplemental Stoichiometry Problems*

Directions: Solve each of the following problems. Assume excess of any reactant that isn't mentioned, unless otherwise specified. Show your work, including proper units, to earn full credit.

1. Given the balanced equation, show what the following molar ratios
   (i.e., the conversion factors) should be. Include units in all terms. $2 C_4H_{10} + 13 O_2 \rightarrow 8 CO_2 + 10 H_2O$

a. C_4H_{10} / O_2 b. O_2 / CO_2 c. O_2 / H_2O d. C_4H_{10} / CO_2 e. C_4H_{10} / H_2O

2. How many moles of oxygen are made if 12.0 moles of potassium chlorate react? $2 KClO_3 \rightarrow 2 KCl + 3 O_2$

Q3 involves the reaction: Copper(II) chloride reacts w/sodium nitrate to produce copper(II) nitrate and sodium chloride.

3A. Write the balanced equation
    for the reaction.

3B. If 20.0 g of copper(II) chloride react with 20.0 g of sodium nitrate, what mass of sodium chloride is formed?
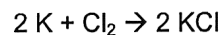
3C.   What is the limiting reactant? _____

3D.   How many moles of copper(II) nitrate are formed?

3E.   What mass of excess reactant is left over?

ANSWERS: 2. 18.0 mol O_2 3B. 13.8 g NaCl   3C. NaNO$_3$ 3D. 0.118 mol Cu(NO$_3$)$_2$ 3E. 4.2 g CuCl$_2$

4A. How many grams of potassium chloride are produced from… $2 K + Cl_2 \rightarrow 2 KCl$

...2.50 g of potassium and excess chlorine?

4B.   …1.00 g of chlorine and excess potassium?

5A. If 25.0 g of iron(III) phosphate react with excess sodium $2 FePO_4 + 3 Na_2SO_4 \rightarrow Fe_2(SO_4)_3 + 2 Na_3PO_4$
sulfate, how many grams of iron(III) sulfate can be made?

5B. If 18.5 grams of iron(III) sulfate are actually
produced in Q5A, what is the percent yield?

5C. Now, a different trial of the reaction is done, starting with 15.0 grams of sodium sulfate and excess iron(III)
phosphate. If that trial achieves a 65.0% yield, how many grams of sodium phosphate were made?

6A. What mass of sodium hydroxide is made from 1.20×10^2 g of sodium oxide? $Na_2O + H_2O \rightarrow 2 NaOH$
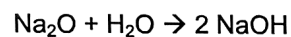
6B. How many grams of sodium oxide are required to produce 1.60×10^2 grams of sodium hydroxide?

7. A human needs about 120. grams of glucose per day. How many
grams of carbon dioxide are used by plants to produce this $6 CO_2 + 6 H_2O \rightarrow C_6H_{12}O_6 + 6 O_2$
amount of glucose?
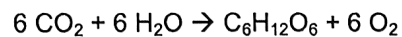
ANSWERS: 4A. 4.77 g KCl   5A. 33.1 g $Fe_2(SO_4)_3$ 5C. 7.50 g Na_3PO_4 6B. 124 g Na_2O
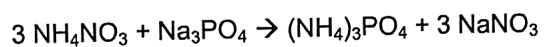   4B. 2.10 g KCl   5B. 55.9%   6A. 155 g NaOH   7. 176 g CO_2
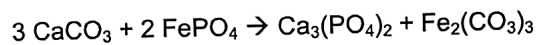
For Q8 and Q9:   A.   Which reactant is the limiting reactant?
                  B.   What number of moles of each product is formed?
                  C.   What mass of excess reactant is left over after the reaction is complete?

8. Start with 30.0 grams of ammonium nitrate and
   50.0 grams of sodium phosphate.

$3 NH_4NO_3 + Na_3PO_4 \rightarrow (NH_4)_3PO_4 + 3 NaNO_3$

9. Start with 100.0 grams of calcium carbonate and
   45.0 grams of iron(III) phosphate.

$3 CaCO_3 + 2 FePO_4 \rightarrow Ca_3(PO_4)_2 + Fe_2(CO_3)_3$

10. What quantity of energy is released when $2 C_5H_{10} + 15 O_2 \rightarrow 10 CO_2 + 10 H_2O + 6{,}199$ kJ
     540 g of cyclopentane are burned?

11A. What mass of iron is needed to react with 16.0 grams of sulfur? $8 Fe + S_8 \rightarrow 8 FeS$
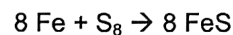
11B. How many grams of iron(II) sulfide are produced?

12. A chemical company must produce 650 L of hydrogen at STP.
     The company has done this reaction many times before, $Mg + 2 HNO_3 \rightarrow Mg(NO_3)_2 + H_2$
     and the percent yield is always about 84%. What mass of each
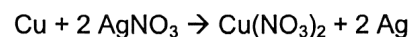   reactant must they use in order to ensure that they produce 650 L of hydrogen?
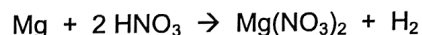
13A. What volume of oxygen at STP is produced from 19.4 moles of sodium chlorate? $2 NaClO_3 \rightarrow 2 NaCl + 3 O_2$
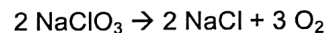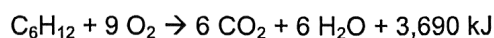
13B. How many molecules of oxygen are produced when 80.0 grams of sodium chloride are produced?

14A. How many moles of copper react with 3.50 moles of silver nitrate? $Cu + 2 AgNO_3 \rightarrow Cu(NO_3)_2 + 2 Ag$

14B. If 89.5 grams of silver were produced, how many grams of copper reacted?

15. What quantity of heat is produced if 32 g of cyclohexane $C_6H_{12} + 9 O_2 \rightarrow 6 CO_2 + 6 H_2O + 3{,}690$ kJ
     react with 95 L of oxygen at STP?

ANSWERS: 10. 2.4×10^4 kJ   12. 840 g Mg, 4400 g HNO_3 14A. 1.75 mol Cu
                11A. 27.8 g Fe   13A. 652 L O_2 14B. 26.3 g Cu
                11B. 43.8 g FeS   13B. 1.23×10^{24} m'c O_2 15. 1400 kJ