STOICHIOMETRY WORKSHEET
ANSWER KEY

1. One mole of nitrogen combines with one mole of oxygen according to the equation: $N_2(g) + O_2(g) \rightarrow 2NO(g)$
How many (a) atoms are there in each molecule of N_2? **2** ***synthesis***
(b) moles of oxygen combine with 0.5 mole of N_2? **0.5** (c) moles of NO are formed if 5 moles of N_2 combine with excess O_2? **10** (d) moles of oxygen atoms could be derived from 2 moles of NO? **2**

2. These questions refer to the following equation: $3Ag(s) + 4HNO_3(aq) \rightarrow 3AgNO_3(aq) + NO(g) + 2H_2O(l)$
(a) How many moles of NO are produced when 1.5 moles of Ag reacts with excess HNO_3?

1.5 moles Ag x $\frac{\text{1 mole NO}}{\text{3 moles Ag}}$ = 0.5 mole NO ***single replacement/decomposition***

(b) How many grams of NO are produced when 1.5 moles of Ag reacts with excess HNO_3?

1.5 moles Ag x $\frac{\text{1 mole NO}}{\text{3 moles Ag}}$ x $\frac{\text{30 g NO}}{\text{1 mole NO}}$ = 15 grams NO

(c) How many liters of NO are produced at STP when 162 g of Ag reacts with excess HNO_3?

162 g Ag x $\frac{\text{1 mole Ag}}{\text{107.87 g Ag}}$ x $\frac{\text{1 mole NO}}{\text{3 mole Ag}}$ x $\frac{\text{22.4 liters NO}}{\text{1 mole NO}}$ = 11.2 liters NO

3. The following questions refer to the following equation:

$$3Cu(s) + 8HNO_3(aq) \rightarrow 3Cu(NO_3)_2(aq) + 2NO(g) + 4H_2O(l)$$

(a) How many moles of NO are produced by the reaction of 4.0 moles of copper with excess HNO_3?

4.0 moles Cu x $\frac{\text{2 mole NO}}{\text{3 mole Cu}}$ = 2.67 mole NO ***single replacement/decomposition***

(b) How many moles of HNO_3 are required to react completely with 5.0 moles of copper?

5.0 moles Cu x $\frac{\text{8 moles } HNO_3}{\text{3 moles Cu}}$ = 13.3 moles HNO_3

(c) How many moles of NO are produced by the reaction of 6.35 grams of Cu with excess HNO_3?

6.35 g Cu x $\frac{\text{1 mole Cu}}{\text{63.5 g Cu}}$ x $\frac{\text{2 mole NO}}{\text{3 mole Cu}}$ = 0.067 mole NO

(d) What mass of NO is produced by the reaction of 6.35 grams of Cu with excess HNO_3?

6.35 g Cu x $\frac{\text{1 mole Cu}}{\text{63.5 g Cu}}$ x $\frac{\text{2 mole NO}}{\text{3 mole Cu}}$ x $\frac{\text{30 g NO}}{\text{1 mole NO}}$ = 1.998 grams NO

4. Given: $3Fe_2O_3 + CO$ -----> $2Fe_3O_4 + CO_2$ How many grams of Fe_2O_3 can be converted to Fe_3O_4 by 14.0 g of CO?

14.0 g CO x $\frac{\text{1 mole CO}}{\text{i. CO}}$ x $\frac{\text{3 mole } Fe_2O_3}{\text{1 mole CO}}$ x $\frac{\text{159.7 g } Fe_2O_3}{\text{1 mole } Fe_2O_3}$ = 239.55 g Fe_2O_3

5. How many moles of ammonium sulfate can be made from the reaction of 30.0 mol of NH_3 with H_2SO_4 according to the following equation: $2NH_3 + H_2SO_4 \rightarrow (NH_4)_2SO_4$

31 mol NH_3 x $\frac{\text{1 mol } (NH_4)_2SO_4}{\text{2 mol } NH_3}$ = **15 mol $(NH_4)_2SO_4$** ***synthesis/combination***

6. In a very violent reaction called a thermite reaction, aluminum metal reacts with iron(III) oxide to form iron metal and aluminum oxide according to the following equation: $Fe_2O_3 + 2Al \rightarrow 2Fe + Al_2O_3$

a. What mass of Al will react with 150 g of Fe2O3?

150 g Fe_2O_3 x $\frac{\text{1 mol } Fe_2O_3}{\text{160 g } Fe_2O_3}$ x $\frac{\text{2 mol Al}}{\text{1 mol } Fe_2O_3}$ x $\frac{\text{27 g Al}}{\text{1 mol Al}}$ = **50.6 g Al** ***single replacement***

b. If 0.905 mol Al_2O_3 is produced in the reaction, what mass of Fe is produced?

0.905 mol Al_2O_3 x $\frac{\text{2 mol Fe}}{\text{1 mol } Al_2O_3}$ x $\frac{\text{56 g Fe}}{\text{1 mol Fe}}$ = **101.36 g Fe**

c. How many moles of Fe_2O_3 will react with 99.0 g of Al?

99.0 g Al x $\frac{\text{1 mol Al}}{\text{27 Al}}$ x $\frac{\text{1 mol } Fe_2O_3}{\text{2 mol Al}}$ = **1.83 mol Fe_2O_3**

7. What mass of sulfuric acid, H_2SO_4, is required to react with 1.27 g of potassium hydroxide, KOH? The products of this reaction are potassium sulfate and water. (Write out the balanced equation first!)

$H_2SO_4 + 2KOH \rightarrow K_2SO_4 + 2H_2O$ **double replacement/neutralization**

1.27 KOH x 1 mol KOH x 1 mol H_2SO_4 x 98 g H_2SO_4 = **1.11 g H_2SO_4**

56g KOH 2 mol KOH 1 mol H_2SO_4

8. Ammonium nitrate decomposes to yield nitrogen gas, water, and oxygen gas in the following reaction:

$2NH_4NO_3 \rightarrow 2N_2 + O_2 + 4H_2O$ **decomposition**

a. How many liters of nitrogen gas (at STP) are produced when 36.0 g of NH_4NO_3 reacts?

36 g NH_4NO_3 x 1 mol NH_4NO_3 x 2 mol N_2 x 22.4 liter N_2 = **10.08 liters N_2**

80 g NH_4NO_3 2 mol NH_4NO_3 1 mol N_2

b. If 7.35 mol of H_2O are produced in this reaction, what mass of NH_4NO_3 reacted?

7.35 mol H_2O x 2 mol NH_4NO_3 x 80 g NH_4NO_3 = **294 g NH_4NO_3**

2 mol H_2O 1 mol NH_4NO_3

9. Lead (II) nitrate reacts with potassium iodide to produce lead (II) iodide and potassium nitrate. If 1.23 mg of lead nitrate is consumed, what is the mass (in mg) of the lead (II) iodide produced? (Write out the balanced equation first!) $Pb(NO_3)_2 + 2KI \rightarrow PbI_2 + 2KNO_3$ **Double r eplacement/precipitation**

1.23 mg $Pb(NO_3)_2$ x 1 g x 1 mol $Pb(NO_3)_2$ x 1 mol PbI_2 x 461 g PbI_2 x 1000 mg = **1.71 mg PbI_2**

1000 331 g $Pb(NO_3)_2$ 1 mol $Pb(NO_3)_2$ 1 mol PbI_2 1 g

10. In a 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 448.0 liters of CO_2 daily. What mass of water will be produced when this amount reacts with LiOH? The other product of the reaction is Li_2CO_3. (Write out the balanced chemical equation first!)

$2LiOH + CO_2 \rightarrow Li_2CO_3 + H_2O$ **double replacement**

448.0 liters CO_2 x 1 mol CO_2 x 1 mol H_2O x 18 g H_2O = **360 g H_2O**

22.4 liters CO_2 1 mol CO_2 1 mol H_2O

11. Ethanol, C_2H_5OH, is considered a clean fuel because it burns in oxygen to produce carbon dioxide and water with few trace pollutants. If 95.0 g of H_2O are produced during the combustion of ethanol, how many grams of ethanol were present at the beginning of the reaction? (Write out the balanced chemical equation first!)

$C_2H_5OH + 3O_2 \rightarrow 2CO_2 + 3H_2O$ **combustion**

95.0 g H_2O x 1 mol H_2O x 1 mol C_2H_5OH x 46 g C_2H_5OH = **80.9 g C_2H_5OH**

18 H_2O 3 mol O_2 1 mol C_2H_5OH

12. Sulfur dioxide is one of the major contributors to acid rain. Sulfur dioxide can react with oxygen and water in the atmosphere to form sulfuric acid, as shown in the following equation:

$2H_2O(l) + O_2(g) + 2SO_2(g) \rightarrow 2H_2SO_4(aq)$ **combination/synthesis**

If 50.0 g of sulfur dioxide from pollutants reacts with water and oxygen found in the air, how many grams of sulfuric acid can be produced? How many molecules of oxygen are used in the process?

50 g SO_2 x 1 mol SO_2 x 2 mol H_2SO_4 x 98 g H_2SO_4 = **76.6 g H_2SO_4**

64 g SO_2 2 mol SO_2 1 mol H_2SO_4

50 g SO_2 x 1 mol SO_2 x 1 mol O_2 x 6.02×10^{23} molecules O_2 = **2.35×10^{23} molecules O_2**

64 SO_2 2 mol SO_2 1 mol O_2

13. When heated, sodium bicarbonate, $NaHCO_3$, decomposes into sodium carbonate, Na_2CO_3, water, and carbon dioxide. If 5.00 g of NaHCO3 decomposes, how many liters (at STP) of carbon dioxide gas are produced? (Write out the balanced chemical equation first!)

$2NaHCO_3 \rightarrow Na_2CO_3 + CO_2 + H_2O$ **decomposition**

5.00 g $NaHCO_3$ x 1mol $NaHCO_3$ x 1 mol CO_2 x 22.4 liters CO_2 = **0.67 liters CO_2**

84 g $NaHCO_3$ 2 mol $NaHCO_3$ 1 mol CO_2

14. A reaction between hydrazine, N_2H_4 , and dinitrogen tetroxide, N_2O_4 , has been used to launch rockets into space. The reaction produces nitrogen gas and water vapor.

a. Write a balanced chemical equation for this reaction. $2N_2H_4 + N_2O_4 \rightarrow 3N_2 + 4H_2O$ **decomposition**

b. What is the mole ratio of N_2O_4 to N_2? 2:3

c. How many molecules of N_2 will be produced if 20.0 mol of N_2H_4 are used by a rocket?

$$20.0 \text{ mol } N_2H_4 \times \frac{3 \text{ mol } N_2}{2 \text{ mol } N_2H_4} \times \frac{6.02 \times 10^{23} \text{ molecules } N_2}{1 \text{ mol } N_2} = \mathbf{1.806 \times 10^{25} \text{ molecules } N_2}$$

d. How many grams of H_2O are made when 450. kg of N_2H_4 are consumed?

$$450. \text{ kg } N_2O_4 \times \frac{1000 \text{ g}}{1 \text{ kg}} \times \frac{1 \text{mol } N_2O_4}{92 \text{ g} N_2O_4} \times \frac{4 \text{ mol } H_2O}{1 \text{ mol } N_2O_4} \times \frac{18 \text{ g } H_2O}{1 \text{ mol } H_2O} = \mathbf{3.52 \times 10^5 \text{ g } H_2O}$$

15. (a) Which element is in excess when 3.00 g of Mg is ignited in 2.20 g of pure oxygen?

$2Mg (s) + O_2 (g) \rightarrow 2MgO (s)$ synthesis/combination

$$\mathbf{2.00 \text{ g Mg} \times \frac{1 \text{ mole Mg}}{24 \text{ g Mg}} \times \frac{1 \text{ mole } O_2}{2 \text{ mole Mg}} \times \frac{32 \text{ g } O_2}{1 \text{ mole } O_2} = 2.0 \text{ g } O_2 \text{ required}}$$ **(so it is excess, Mg LR)**

(b) What mass is in excess? **$2.2 \text{ g } O_2$ given – $2.0 \text{ g } O_2$ = $0.2 \text{ g } O_2$ excess**

(c) What mass of magnesium oxide is formed?

$$\mathbf{3.0 \text{ Mg} \times \frac{1 \text{ mole Mg}}{24.0 \text{g Mg}} \times \frac{2 \text{ mole MgO}}{2 \text{ mole Mg}} \times \frac{40 \text{ g MgO}}{1 \text{ mole MgO}} = 5.0 \text{ g MgO}}$$

16. How many grams of Al_2S_3 are formed when 5.00 g of Al is heated with 10.0 g of sulfur?

$16Al (s) + 3S_8 (s) \rightarrow 8Al_2S_3 (s)$

$$\mathbf{5.00 \text{g Al} \times \frac{1 \text{ mole Al}}{27 \text{ g Al}} \times \frac{3 \text{ mole } S_8}{16 \text{ mole Al}} \times \frac{256 \text{ g } S_8}{1 \text{ mole } S_8} = 8.8 \text{ g S}}$$ **required, so Al is the limiting reagent**

$$\mathbf{5.00 \text{ g Al} \times \frac{1 \text{ mole Al}}{27 \text{ g Al}} \times \frac{8 \text{ mole } Al_2S_3}{16 \text{ mole Al}} \times \frac{150 \text{ g } Al_2S_3}{1 \text{ mole } Al_2S_3} = 13.89 \text{ g } Al_2S_3}$$

15. When MoO_3 and Zn are heated together they react as follows: $3Zn(s) + 2MoO_3(s) \rightarrow Mo_2O_3(s) + 3ZnO(s)$

What mass of ZnO is formed when 20.0 g of MoO_3 is reacted with 10.0 g of Zn?

$$\mathbf{10.0 \text{ g Zn} \times \frac{1 \text{ mole Zn}}{65 \text{ g Zn}} \times \frac{2 \text{ mole } MoO_3}{3 \text{ mole Zn}} \times \frac{144 \text{ g } MoO_3}{1 \text{ mole } MoO_3} = 14.76 \text{ g } MoO_3}$$ **required, so Zn is LR**

$$\mathbf{10.0 \text{ g Zn} \times \frac{1 \text{ mole Zn}}{65 \text{ Zn}} \times \frac{3 \text{ mole ZnO}}{3 \text{ mole Zn}} \times \frac{81 \text{ g ZnO}}{1 \text{ mole ZnO}} = 12.5 \text{ g ZnO}}$$

16. Upon heating, calcium carbonate decomposes to produce calcium oxide and carbon dioxide.

a. Write out and balance the above equation. **$CaCO_3 (s) \rightarrow CaO (s) + CO_2 (g)$**

b. Determine the theoretical yield of CO_2 if 235.0 g of $CaCO_3$ is heated.

$$\mathbf{235.0 \text{ g } CaCO_3 \times \frac{1 \text{ mole } CaCO_3}{100 \text{ g } CaCO_3} \times \frac{1 \text{ mole } CO_2}{1 \text{ mole } CaCO_3} \times \frac{44 \text{ g } CO_2}{1 \text{ mole } CO_2} = 103.4 \text{ g } CO_2}$$

c. What is the percent yield of CO_2 if 97.5 g of CO_2 is collected? $\mathbf{\frac{97.5 \text{ g}}{103.4 \text{ g}} \times 100 = 94.3 \%}$

19. Phosphorus is commercially prepared by heating a mixture of calcium phosphate, sand, and coke in an electric furnace. The process involves two reactions.

$$2Ca_3(PO_4)_2 \text{ (s)} + 6SiO_2 \text{ (s)} \rightarrow 6CaSiO_3 \text{ (l)} + P_4O_{10} \text{ (g)}$$

$$P_4O_{10} \text{ (g)} + 10C \text{ (s)} \rightarrow P_4 \text{ (g)} + 10CO \text{ (g)}$$

The P_4O_{10} produced in the first reaction reacts with an excess of coke (C) in the second reaction. Determine the theoretical yield of P_4 if 250.0 g $Ca_3(PO_4)_2$ and 400.0 g SiO_2 are heated. If the actual yield of P_4 is 45.0 g, determine the percent yield of P_4.

$$\mathbf{250.0 \text{ g } Ca_3(PO_4)_2 \times \frac{1 \text{ mole } Ca_3(PO_4)_2}{310 \text{ g } Ca_3(PO_4)_2} \times \frac{6 \text{ moles } SiO_2}{2 \text{ moles } Ca_3(PO_4)_2} \times \frac{60 \text{ g } SiO_2}{1 \text{ mole g } SiO_2} = 145 \text{ g } SiO_2 \text{ required (excess)}}$$

$$\mathbf{250.0 \text{ g } Ca_3(PO_4)_2 \times \frac{1 \text{ mole } Ca_3(PO_4)_2}{310 \text{ g } Ca_3(PO_4)_2} \times \frac{1 \text{ mole } P_4O_{10}}{2 \text{ mole } Ca_3(PO_4)_2} \times \frac{1 \text{ mole } P_4}{1 \text{ mole } P_4O_{10}} \times \frac{124 \text{ g } P_4}{1 \text{ mole } P_4} = 49.99 \text{ g } P_4}$$

$$\mathbf{\frac{45.0 \text{ g } P_4}{49.99 \text{ g } P_4} \times 100\% = 90.0 \% \text{ yield } P_4}$$