STOICHIOMETRIC PROBLEMS

SHEET #1: MOLE RATIO PROBLEMS

1. The combustion of a sample of butane, C_4H_{10} (lighter fluid), produced 2.46 g of water according to the following equation:

$$2C_4H_{10} + 13O_2 \Longrightarrow 8CO_2 + 10H_2O$$

Calculate:
a) the amount of water formed.
b) the amount of butane burned.
c) the mass of butane burned.
d) the mass of oxygen used.

2. The ethanol in ethanol gasoline burns according to the following equation:

$$C_2H_6O + 3O_2 \Longrightarrow 2CO_2 + 3H_2O$$

a) If 25 mol of ethanol burns this way, what amount of oxygen is needed?
b) If 30 mol of oxygen is consumed by this reaction, what amount of ethanol is used up? How many moles of carbon dioxide are formed?
c) In one test, 23 mol of carbon dioxide was produced by this reaction. How many moles of oxygen were consumed?
d) In another test, 41 mol of water is collected from this reaction. What amount of oxygen was used up? What amount of carbon dioxide was formed?

3. One way to change iron ore, Fe_2O_3, into metallic iron is to heat it with hydrogen gas.

$$Fe_2O_3(s) + 3H_2(g) \Longrightarrow 2Fe(s) + 3H_2O(l)$$

a) How many moles of iron are made from 25 mol of Fe_2O_3?
b) What amount of hydrogen is needed to make 30 mol of Fe?
c) If 120 mol of H_2O forms, what mass of Fe_2O_3 was used up?

4. The reaction between hydrazine, N_2H_4, and hydrogen peroxide is used to power some rocket engines. The balanced equation for the reaction is:

$$N_2H_4 + 7H_2O_2 \Longrightarrow 2HNO_3 + 8H_2O$$

2.68 mol of hydrazine is completely consumed in a rocket engine. Calculate:
a) the amount of H_2O_2 required.
b) the amount of HNO_3 formed.
c) the amount of water formed.

5. The metal tungsten, which is used to make filaments for incandescent light bulbs, can be obtained from its oxide by heating it with hydrogen.

$$WO_3(s) + 3H_2(g) \Longrightarrow W(s) + 3H_2O(l)$$

a) What mass of tungsten can be obtained from 250 g of tungsten (VI) oxide?
b) What mass of hydrogen is required in part a)?

Answers:
1. a) 0.137 mol H_2O, b) 0.0273 mol C_4H_{10}, c) 1.59 g C_4H_{10}, d) 5.68 g O_2
2. a) 75 mol O_2, b) 10 mol C_2H_6O, 20 mol CO_2 c) 34.5 mol O_2, d) 41 mol O_2, 27.3 mol CO_2
3. a) 50 mol Fe, b) 45 mol H_2, c) 6388 g Fe_2O_3
4. a) 18.76 mol H_2O_2, b) 5.36 mol HNO_3, c) 21.44 mol H_2O
5. a) 198 g W, b) 6.54 g H_2

STOICHIOMETRIC PROBLEMS

SHEET #2: MASS ==> AMOUNT ==> AMOUNT ==> MASS

1. How many moles of sulphur will react with 9 mol of oxygen gas for the reaction shown?

   $2S(s) + 3O_2(g) \Rightarrow 2SO_3(g)$

2. For the following reaction, what mass of FeS is needed to react with 7.81 g of oxygen? What amount of oxygen is needed to react with 6.79 mol of FeS?

   $4FeS(s) + 7O_2 \Rightarrow 2Fe_2O_3(s) + 4SO_2(g)$

3. What mass of O_2 is needed to react with 6.4 g of methane according to the following equation? What mass of carbon dioxide forms?

   $CH_4(g) + 2O_2(g) \Rightarrow CO_2(g) + 2H_2O(l)$

4. Sodium carbonate and hydrochloric acid react to give sodium chloride, carbon dioxide and water. How many grams of sodium carbonate and hydrochloric acid would be required to produce 286 g of carbon dioxide.

5. What amount of NaOH is required to produce 8.61 mol of sodium sulphate?

   $2NaOH(aq) + H_2SO_4(aq) \Rightarrow Na_2SO_4(aq) + 2H_2O(l)$

   What mass of sulphuric acid is required to produce 4.77 mol of sodium sulphate?

6. If 20.0 g of zinc reacts with excess (more than you need) hydrochloric acid, what mass of zinc chloride and hydrogen gas is produced? What mass of hydrochloric acid is actually required for the reaction?

7. What mass of oxygen is produced in the thermal decomposition of 5.0 g of potassium chlorate?

8. What mass of copper metal is required to replace the silver in 4.0 g of silver nitrate which is dissolved in water. Hint: copper metal has an oxidation state of zero and after reacting with silver nitrate is acquires an oxidation state of 2^+.

9. Ammonium sulphate reacts with calcium hydroxide to produce calcium sulphate, ammonia gas and water. If 20.0 g of calcium hydroxide is reacted with excess ammonium sulphate, what mass of ammonia gas is produced?

10. Sulphuric acid reacts with sodium chloride to form hydrochloric acid and sodium sulphate. If 30.0 g of sodium chloride is allowed to react with sufficient sulphuric acid, what mass of hydrochloric acid will form?

Answers:
1. 6 mol S
2. 12.3 g FeS, 11.9 mol O_2
3. 25.5 g O_2, 17.5 CO_2 g
4. 689 g Na_2CO_3, 474 g HCl
5. 17.22 mol NaOH, 468 g H_2SO_4
6. 41.7 g $ZnCl_2$, 0.618 g H_2, 22.3 g HCl
7. 1.96 g O_2
8. 0.748 g Cu
9. 9.20 g NH_3
10. 18.7 g HCl

STOICHIOMETRIC PROBLEMS 2B

PLEASE NOTE THAT ALL EQUATIONS NEED TO BE BALANCED FIRST!

1. For the reaction:

Determine the mass of butane that would be required to produce 100.0 g of water.

2. Give the reaction

What amount of oxygen gas would you expect to get from the decomposition of 2.50 mol of potassium chlorate

3. For the reaction:

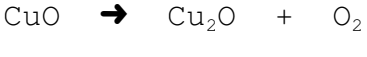
What mass of calcium phosphate would you expect to from if 80.00 g of calcium nitrate was used in the reaction? What mass of potassium phosphate would be required to make this work? What mass of potassium nitrate would form as well? Yes this is three separate question and three separate lines! Use four significant figures for this calculation.

4. For the above question what is the sum of the reactant masses? What is the sum of the product masses? Why are these two sums the same (or close to the same). Please use three lines when added the reactants and adding the products (one line for what you are going to add, one line for the numbers and a third line for the answer).

5. Given the following equation:

What mass of aluminum hydroxide would you expect to get if 25.0 g of aluminum oxide were reacted.

6. For the reaction:



35.0 g of copper(II) oxide is reacted. What mass of Copper(I) oxide would you expect to form?

7. Given the decomposition reaction:

$$Ca(ClO_3)_2 \rightarrow CaCl_2 + O_2$$

If 11.0 mole of calcium chlorate is decomposed what amount of oxygen would you expect to get and what mass of calcium chloride would you expect to get

8. Given this single replacement reaction:

$$Cu + AgNO_3 \rightarrow Cu(NO_3)_2 + Ag$$

How many moles of Cu are needed to fully react with 1.25 moles of $AgNO_3$? If 132 g of Ag are produced, what mass of silver nitrate was reacted

9. Molten iron and carbon monoxide are produced in a blast furnace by the reaction of iron(III) oxide and coke (pure carbon). If 25.0 kilograms of pure Fe_2O_3 is used, how many kilograms of iron can be produced? The reaction is:

$$Fe_2O_3 + C \rightarrow Fe + CO$$

10. The average human brain consumes 120.0 grams of glucose ($C_6H_{12}O_6$) per day. How many grams of CO_2 are exhaled per day, just to keep your brain functioning. Use the cellular respiration reaction to figure this out:

$$C_6H_{12}O_6 + O_2 \rightarrow CO_2 + H_2O$$

Why is the mass of CO_2 formed more than the mass of glucose used?

11. Given the reaction:

$$NH_3 + O_2 \rightarrow NO + H_2O$$

What mass of water is produces when 14.0 g of ammonia (NH_3) is reacted. What amount of oxygen is required for this.

Answers:

1. 64.53 g C_4H_{10}
2. 3.75 mol O_2
3. 50.41 g $Ca_3(PO_4)_2$
   68.99 g K_3PO_4
   98.58 g KNO_3
4. 148.99 g reactants
   148.99 g products
5. 38.3 g $Al(OH)_3$
6. 31.5 g Cu_2O
7. 33.0 mol O_2
   1220 g $CaCl_2$
8. 0.625 mol Ca
   208 g $AgNO_3$
9. 17.5 kg Fe
10. 176 g CO_2
11. 22.2 g H_2O
    1.03 mol O_2

STOICHIOMETRIC PROBLEMS

SHEET #3: VOLUME ==> AMOUNT ==> AMOUNT ==> VOLUME

1. Quicklime, CaO is prepared by heating limestone, $CaCO_3$. The equation for the reaction is :

$$CaCO_3 \Longrightarrow CaO + CO_2$$

   a) Calculate the mass of quicklime that can be obtained by heating 1 kg of limestone.
   b) Calculate the volume of carbon dioxide gas that forms at S.T.P. when 1 kg of limestone is reacted?

2. When grape sugar ($C_6H_{12}O_6$) ferments the products are ethyl alcohol (C_2H_5OH) and carbon dioxide. If 1.00 lbs. (454 g) of grape sugar ferments, calculate:
   a) the mass of ethyl alcohol produced.
   b) the volume of carbon dioxide produced at 27 °C and 1 atm. pressure

3. The oxidation of NH_3 is an important reaction in the preparation of nitric acid. The equation is:

$$4NH_3 + 5O_2 \Longrightarrow 6H_2O + 4NO$$

   a) How many liters of oxygen gas at S.T.P. are needed to react with 2500 g of NH_3?
   b) What mass of NO is formed when 2500 g of NH_3 reacts?

4. When MoO_3 ==> and Zn are heated together, they react as follows:

$$3Zn + 2MoO_3 \Longrightarrow Mo_2O_3 + 3ZnO$$

   What mass of Mo_2O_3 and what mass of ZnO is formed when 20.0 g of MoO_3 reacts?

5. Carbon dioxide is produced in the reaction between calcium carbonate and hydrochloric acid. How many grams of calcium carbonate would be needed to react completely with 15.0 g of hydrochloric acid? How many grams of carbon dioxide would be produced in this experiment?

6. When black gunpowder explodes, potassium nitrate, carbon and sulphur react with each other to form nitrogen, carbon dioxide and potassium sulphide. If the original mixture contains 50.0 g of potassium nitrate, what is the total volume of gases produced in this reaction? Assume S.T.P. conditions.

7. When ammonia (NH_3) is passed over hot calcium, calcium hydride (CaH_2) and nitrogen gas are produced. If 30 L of nitrogen are recovered at S.T.P., what mass of calcium was originally used?

8. The combustion of propane (C_3H_8) is a very common method of home heating. Write a reaction for the combustion of propane. Using the stoichiometry of this equation, determine the ratio of the volume of propane to the volume of air required for optimum performance. Hint: air contains 21.0 % oxygen by volume.

Answers:
1. a) 560 g CaO, b) 224 L CO_2
2. a) 232 g C_2H_5OH, b) 124 L CO_2
3. a) 4111 L O_2, b) 4403 g NO
4. 16.7 g Mo_2O_3, 17.0 g ZnO
5. 20.6 g $CaCO_3$, 9.05 g CO_2
6. 22.2 L gas
7. 161 g Ca
8. propane : air = 1 : 23.8

STOICHIOMETRIC PROBLEMS

SHEET #4

1. Balance the following skeleton equation:

   a) $Cu_2S + O_2 \Longrightarrow Cu_2O + SO_2$

   b) $C_2H_6 + F_2 \Longrightarrow C_2HF_5 + H_2$

   c) $Bi_2O_3 + H_2 \Longrightarrow Bi + H_2O$

   d) $Al_4C_3 + H_2O \Longrightarrow CH_4 + Al(OH)_3$

2. Steam when passed over hot iron filings reacts as shown in the following equation:

   $Fe + H_2O \Longrightarrow Fe_3O_4 + H_2$

   How many liters of hydrogen gas at S.T.P. would be obtained if 16.8 g of iron were completely converted to iron oxide?

3. Butane gas (C_4H_{10}), when burnt in air, yields carbon dioxide and water.
   a) What mass of oxygen is required for the complete combustion of 11 g of butane?
   b) What volume of carbon dioxide (at S.T.P.) is produced by the combustion of 11 g of butane?

4. In one method for the production of zinc metal, the compound zinc sulphide (wurtzite) is heated with oxygen to form zinc oxide and sulphur dioxide. In the second step, the zinc oxide is heated with carbon to form zinc metal and carbon monoxide. If a sample of zinc sulphide weights 150.0 g, how much zinc metal can be produced?

5. What volume of oxygen gas at S.T.P. is required to react with one mole of ammonia according to the following equation?

   $NH_3(g) + O_2(g) \Longrightarrow NO(g) + H_2O(l)$

   How many liters of NO are formed at S.T.P.?

6. How many grams of benzene (C_6H_6) are required to react with 25.0 L of oxygen at S.T.P. in a combustion reaction.

7. What mass of hydrogen is required to produce 5.00 L of ammonia at S.T.P. when hydrogen gas is reacted with nitrogen gas.

8. What volume of oxygen is formed at 100 °C and 1 atm. pressure when 125 g of potassium chlorate is thermally decomposed to yield potassium chloride and oxygen gas?

9. Given: $Fe_2O_3 + CO \Longrightarrow Fe_3O_4 + CO_2$

   How many grams of Fe_2O_3 can be converted to Fe_3O_4 by 14.0 g of CO

Answers:
2. 8.98 L H_2
3. 39.4 g O_2, 17.0 L CO_2
4. 101 g
5. 28.0 L O_2, 22.4 L NO
6. 11.6 g C_6H_6
7. 0.670 g H_2
8. 46.8 L O_2
9. 239 g Fe_2O_3

STOICHIOMETRIC PROBLEMS

SHEET #5

1. Coal from a certain mine contains 2.8 % S. When the coal is burned at a power generating station, the sulphur is converted to $SO_2(g)$. The $SO_2(g)$ is then reacted at the plant with $CaO(s)$ to form $CaSO_3(s)$. If 1200 tonne of coal is burned at the power plant each day, what is the daily output of $CaSO_3(s)$?

2. Copper metal reacts with silver nitrate solution to form silver and copper (ii) nitrate. Calculate the mass of silver formed when 158 g of copper reacts.

3. A 12.0 g sample of ammonium nitrate is exploded. What is the total volume of gas produced at 745 torr and 527 °C? The reaction is:

$$2NH_4NO_3(s) \Longrightarrow 4H_2O(g) + 2N_2(g) + O_2(g)$$

4. Calcium carbonate under goes thermal decomposition according to the equation:

$$CaCO_3(s) \Longrightarrow CaO(s) + CO_2(g)$$

When an impure sample of $CaCO_3(s)$, with a mass of 500 g, was completely decomposed, the residue had a mass of 300 g. What was the percentage of $CaCO_3(s)$ in the original sample? Hint: use the mass of $CO_2(g)$ to figure out the mass of $CaCO_3(s)$ in the original sample.

5. What mass of $CO_2(g)$ is released when a 50.0 g sample of $Na_2CO_3(s)$ with a 60.0 % purity react completely with HCl according to the following equation.

$$Na_2CO_3(s) + HCl(aq) \Longrightarrow CO_2(g) + H_2O(l) + NaCl(aq)$$

6. Iron (III) oxide reacts with carbon monoxide to produce iron and carbon dioxide. How many kilograms of iron can be produced by 1.00 t of iron (III) oxide)?

7. The most common ore of arsenic (mispickel) can be heated to produce arsenic:

$$FeSAs(s) \Longrightarrow FeS(s) + As(s)$$

How many kilograms of mispickel are required to produce one kilogram of arsenic?

8. The following reaction between nitrogen tetroxide and hydrazine is used in rocket engines:

$$N_2O_4(l) + 2N_2H_4(l) \Longrightarrow 3N_2(g) + 4H_2O(g)$$

If 25.0 t of nitrogen tetroxide is carried in one tank, what mass of hydrazine should be carried in the other tank?

Answers:

1. 126 t $CaCO_3(s)$
2. 537 g Ag(s)
3. 35.1 L gas
4. 91.0 %
5. 12.5 g $CO_2(g)$
6. 698 kg Fe(s)
7. 2.17 kg FeSAs(s)
8. 17.39 t $N_2H_4(l)$

STOICHIOMETRIC PROBLEMS

SHEET #6 – LIMITING EXCESS REAGENT PROBLEMS

1. 16.0 g of CaC_2 reacts with 42.0 g of H_2O according to the following reaction:

$$CaC_2(s) + 2H_2O(l) \Longrightarrow C_2H_2(g) + Ca(OH)_2(s)$$

   a) Determine which reactant in the limiting reagent.
   b) What mass of $C_2H_2(g)$ and $Ca(OH)_2(s)$ is produced.
   c) Calculate the excess mass of the excess reagent.

2. Consider the following reaction at S.T.P.

$$WO_3(s) + 3H_2(g) \Longrightarrow W(s) + 3H_2O(s)$$

   If 35 g of tungsten trioxide reacts with 15 L of H_2 at S.T.P., what mass of tungsten is produced?

3. What mass of H_2SO_4 can be produced from 50.0 g of SO_2, 15.0 g O_2 and an unlimited amount of H_2O? The equation is:

$$2SO_2(g) + O_2(g) + 2H_2O(l) \Longrightarrow 2H_2SO_4(aq)$$

4. 40.0 L of O_2 react with 19.6 L of methane (CH_4) at S.T.P. according to the reaction shown below. What volume of water and carbon dioxide are produced at S.T.P.

$$CH_4(g) + 2O_2(g) \Longrightarrow CO_2(g) + 2H_2O(g)$$

5. What is the maximum mass of carbon dioxide that can be produced by the reaction between 15.0 g of propane (C_3H_8) with 60.0 g of oxygen gas?

6. What mass of iron (III) oxide is produced when 20.9 g of iron (II) sulphide reacts with 10.0 L of oxygen gas at 105.5 kPa and a temperature of 42 °C? What volume of sulphur dioxide is produced at S.T.P.?

7. Nickel metal can be highly purified using the Mond Process:

$$Ni(s) + 4CO(g) \Longrightarrow Ni(CO)_4(g)$$

   In the first step of this process nickel metal is reacted with carbon monoxide under high pressure and heat to produce a gas product known as nickel carbonyl ($Ni(CO)_4$). If 40.0 g of nickel metal is reacted with 5.00 L of carbon monoxide at 60.75 atm. pressure and a temperature of 875 K, calculate the resulting total pressure of all gases at 25 °C and total volume 5.00 L. Hints: nickel is the limiting reagent, Dalton's Law of Partial Pressures could be used to solve this problem

Answers:
1. a) CaC_2, b) 6.5 g C_2H_2, 18.5 g $Ca(OH)_2$, c) 33 g H_2O
2. 27.8 g W
3. 76.6 g H_2SO_4
4. 39.2 L H_2O, 19.6 L CO_2
5. 44.9 g CO_2
6. 18.4 g Fe_2O_3, 5.16 L SO_2
7. 10.7 atm.

STOICHIOMETRIC PROBLEMS

SHEET #7 – PERCENT YIELD PROBLEMS

1. 225 g of calcium carbonate is decomposed to yield calcium oxide and carbon dioxide. Only 28.2 L of carbon dioxide is recovered at S.T.P.
   a) Write a balanced chemical equation for the reaction.
   b) Calculate the theoretical yield of CO_2 as a volume of gas at S.T.P.
   c) Using the actual yield stated in the problem, determine the percent yield of the reaction.

2. 50 g of iron metal is reacted with 150 g of copper (II)sulphate (anhydrous). The reaction produces iron (II) sulphate and copper metal. 43 g of copper metal is recovered.
   a) Determine the limiting reagent in this reaction.
   b) Calculate the theoretical yield of copper metal as a mass.
   c) Using the actual yield stated in the problem, determine the percent yield for the reaction.

3. 40 g of ethane gas (C_2H_6) is burned in air. 60 g of water is recovered. If the only products of the burning are carbon dioxide and water, what is the percent yield of the reaction?

4. 50.0 g of magnesium nitride is mixed with 30.0 g of water. The reaction produces a certain volume of ammonia gas and 40 g of magnesium hydroxide? What is the percent yield of magnesium hydroxide? What is the maximum possible volume (theoretical yield) of ammonia gas collected at 25 °C and 98 kPa? What would the volume of ammonia gas be if its percent yield is the same as the percent yield of magnesium hydroxide?

5. 10 L of nitrogen gas at S.T.P. is reacted with 25 L of hydrogen gas at S.T.P. The gases are found to react to produce 15 L of ammonia gas at S.T.P. What is the percent yield of the reaction?

6. 5 L of oxygen gas at S.T.P. is reacted with 2 g of aluminum metal. What is the percent yield if 2.95 g of aluminum oxide is recovered?

7. In the thermal decomposition of 500 g of mercurous oxide 6.95 L of a gas is recovered at 185 °C and 1 atm. pressure.
   a) What is the percent yield of the reaction?
   b) What is the theoretical yield of mercury metal?
   c) What would the yield of mercury metal be if it had the same percent yield as the gas collected?
   d) Which mass of mercury you have just calculated is likely to be closest to experimental observations? Explain.

8. An industrial decomposition process for Fe_2O_3 has a 85.5 % efficiency. Calculate the mass of iron metal that can be produced by this process using 12200 t of iron ore that is 56.1 % pure.

Answers:
1. b) 50.4 L CO_2, c) 56.0 %
2. b) 56.9 g Cu, c) 75.6 %
3. 83.5 %
4. 82.4 %, 14.0 L NH_3, 11.6 L NH_3
5. 89.6 %
6. 78.1 %
7. a) 30.8 %, b) 481 g Hg, c)148 g Hg
8. 4090 t Fe