# Worksheet 1

1. Given the reaction: 3 Cu + 8 HNO3 🡪 3 Cu(NO3)2 + 2 NO + 4 H2O

a. if 60.0 g of copper reacts completely, how many grams of NO are produced?

 b. if 108 g of water are produced, how many grams of Copper reacted?

 c. if 40.0 g of NO are produced, how many grams of Cu(NO3)2 are produced?

 d. if 6.00 moles of HNO3 reacts, how many moles of water are produced?

 e. if 12.0 moles of copper react, how many grams of HNO3 are needed?

f. If one wants to produce 500.0 grams of water, how many grams of HNO3 must react?

**Worksheet 2**

1. How many liters of oxygen are produced by the complete decomposition of 10.0 grams of mercuryII oxide?

2 An excess of sulfuric acid reacts with 8.10 grams of Magnesium.

 a. How many moles of hydrogen gas are produced?

 b. How many grams of hydrogen gas (H2) are produced?

 c. How many grams of magnesium sulfate are produced?

3. In a reaction between carbon and oxygen, 10.0 liters of carbon dioxide are formed. How many grams of carbon were burned?

4. What mass in grams of copper is precipitated when 13.5 grams of aluminum reacts with cupric sulfate in solution?

5. How many grams of calcium nitrate are produced in the reaction between 12.6 grams of nitric acid and an excess of calcium hydroxide?

6. How many liters of chlorine gas are needed to react completely with 10.0 g of sodium when forming salt?

**Worksheet 3**

1 How many grams of hydrochloric acid are required to react completely with 100. grams of calcium hydroxide to form salt water?

2. 23.4 g of nitrogen reacts with 2.00 g of hydrogen to produce ammonia. How many moles of ammonia does this reaction yield?

3. How many liters of hydrogen gas are produced when 5.00 gram of aluminum reacts with 12.1 g of hydrochloric acid?

4. What is the molecular mass of a gas if 500. ml of that gas weighs 10.0 grams?

5. 200. g of Sodium reacts with 150. L of chlorine gas to form sodium chloride. How many grams of NaCl are theoretically produced? If 468 g of NaCl is actually produced, what is the percent yield?

6. 31.3 grams of Bromine will react with hydrogen gas to yield hydrogen bromide. If 5.60 liters of hydrogen react, how many grams of hydrogen bromide are theoretically produced at STP? If 27.0 g of HBr are actually produced, what is the percent yield?

7. How many liters of ammonia gas are produced when 56.0 L of nitrogen gas react with excess hydrogen gas to produce ammonia at standard temperature and pressure? If 104 L of ammonia gas are actually produced, what is the percent yield?

8. How many liters of ammonia are theoretically produced if 10.0 g of hydrogen gas will react with 42.0 grams of nitrogen gas @ STP? What is the % yield if 59.8 L of ammonia are produced?

9. How many liters of oxygen gas are required for the combustion of 100. liters of methane at STP?

10. What is the density of propane gas @ STP (molecular formula = C3H8)

11. A sample of gas occupies 0.250 L @ STP. Its mass is 0.625 grams.

a. What is the molecular mass of the gas?

 b. What is the number of molecules in this sample?

**Worksheet 4** Limiting Reagents

1. The equation for the complete combustion of ethene (C2H4) is

C2H4(*g*) + 3O2(*g*) → 2CO2(*g*) + 2H2O(*g*)

If 2.70 moles of ethene reacted with 6.30 moles of oxygen, identify the limiting reagent. What is the theoretical yield of water?

2. 84.8 g of iron(III) oxide reacts with 11.5 g of carbon monoxide, iron is produced.

Fe2O3(*s*) + 3CO(*g*) → 2Fe(*s*) + 3CO2(*g*)

What is the limiting reagent? What is the theoretical yield of iron?

# ANSWERS Worksheet 1

1. Given the reaction: 3 Cu + 8 HNO3 🡪 3 Cu(NO3)2 + 2 NO + 4 H2O

a. if 60.0 g of copper reacts completely, how many grams of NO are produced?

60.0 g / 63.5 g/mol Cu = 0.945 mol N 1 x 14 g/mol = 14 g/mol

3 : 2 mole ratios of Cu to NO O 1 x 16 g/mol = 16 g/mol

 30.0 g/mol

0.945 mol / 3 = X mol of NO / 2 = 0.630 mol

0.630 mol x 30.0 g/mole = 18.9 **g** of NO

 b. if 108 g of water are produced, how many grams of copper reacted?

108 g / 18.0 g/mol H2O = 6.00 mol H2O 18.0 g/mol

3 : 4 mole ratios of Cu to water Cu 1 x 63.5 g/mol = 63.5 g/mol

6 mol of water / 4 = X mol of Cu / 3 = 4.50 mol

4.50 mol x 63.5 g/mol = 286 **g** of copper

 c. if 40.0 g of NO are produced, how many grams of Cu(NO3)2 are produced?

Cu 1 x 63.5 g/mol = 63.5 g/mol N 1 x 14.0 g/mole = 14.0 g/mol

N 2 x 14.0 g/mol = 28.0 g/mol O 1 x 16.0 g/mole = 16.0 g/mol

O 6 x 16.0 g/mol = 96.0 g/mol 30.0 g/mol

 187.5 g/mol

40.0 g / 30.0 g/mole of NO = 1.33 moles 2 : 3 mole ratio of No to Cu(NO3)2

1.33 mol / 2 = X mol / 3 = 2.00 mol of copper II nitrate

2.00 mol x 187.5 g/mol = 375 **g** of copper II nitrate

 d. if 6.00 moles of HNO3 reacts, how many moles of water are produced?

* According to the equation, the mole ratio of HNO3 to water is 8 : 4
* 6 moles / 8 = X moles / 4 … 6.00 moles of HNO3 would yield **3.00 moles** of water

 e. if 12.0 moles of copper react, how many grams of HNO3 are needed?

* According to the equation, the mole ratio of copper to HNO3 is 3 : 8
* Therefore, 12 moles of copper would yield 32 moles of HNO3 🡪 12 / 3 = X / 8

 H 1 x 1.00 g/mol = 1.00 g/mol

 N 1 x 14.0 g/mol = 14.0 g/mol

 O 3 x 16.0 g/mol = 48.0 g/mol 🡪 63.0 g/mol

32.0 mol x 63.0 g/mol = 2020 **g HNO**3

 3 Cu + 8 HNO3 🡪 3 Cu(NO3)2 + 2 NO + 4 H2O

f. If one wants to produce 500.0 grams of water, how many grams of HNO3 must react?

 500.0 g x 1 mol / 18.02 g = 27.75 mol Water 🡪 18.02 g / mol

 HNO3 🡪 63.01 g / mol

* According to the equation, the mole ratio of water to HNO3 is 4 : 8
* Therefore, 27.75 moles of water were produced from 55.49 mol of HNO3 🡪

27.75 mol / 4 = X mol / 8

55.49 mol x 63.01 g / mol = 3497 **g**

**Worksheet 2**

1. How many liters of oxygen are produced by the complete decomposition of 10.0 grams of mercuryII oxide?

2 Hg+2O-2 🡪 2 Hg0 + O20(g)

Hg 1 x 201 g/mol = 201 g/mol

O 1 x 16.0 g/mol = 16.0 g/mol

 217 g / mol

10.0 g x 1 mol / 217 g = 0.0460 moles of HgO

mole ratio of HgO to O2 = 2: 1 🡪 0.046 mol / 2 = X mol / 1

0.0230 mol of O2 0.0230 mol x 22.4 L / mol = 0.515 **L**

2 An excess of sulfuric acid reacts with 8.10 grams of Magnesium.

 a. How many moles of hydrogen gas are produced?

H2SO4 (aq) + Mg (s) 🡪 MgSO4 + H2 (g)

8.10 g x 1 mol / 24.0 g = 0.340 mol Mg

Mole ratio of Mg to H2 (g) = 1 : 1 🡪 therefore, 0.340 moles of H2 are produced

 b. How many grams of hydrogen gas (H2) are produced?

H 2 x 1.0 g / mol = 2.0 g/mol 0.34 mol x 2.0 g / mol = 0.68 **g**

 c. How many grams of magnesium sulfate are produced?

Mg 1 x 24.0 g/mol = 24.0 g/mol

S 1 x 32.0 g/mol = 32.0 g/mol

O 4 x 16.0 g / mol = 64.0 g/mol 120.0 g / mol

Mole ratio of Mg to MgSO4 = 1 : 1 🡪 therefore, 0.340 mol of MgSO4 are produced

0.340 mol x 120.0 g/mol = 40.8 **g** of Magnesium Sulfate

3. In a reaction between carbon and oxygen, 10.0 liters of carbon dioxide are formed. How many grams of carbon were burned?

C + O2 (g) 🡪 CO2 (g)

C 1 x 12.0 g/mol = 12.0 g/mol

10.0 L x 1 mol / 22.4 L = 0.446 mol mole ratio 1 : 1

0.446 mol x 12.0 g / mol = **5.35 g** of carbon

4. What mass in grams of copper is precipitated when 13.5 grams of aluminum reacts with cupric sulfate in solution?

2 Al (s) + 3 CuSO4 (aq) 🡪 Al2(SO4)3 + 3 Cu (s)

GAM of aluminum = 27.0 g/mol 13.5 g x 1 mol / 27.0 g Al = 0.500 mol Al

mole ratio of Al to Cu 🡪 2 : 3 0.500 mol / 2 = X / 3 X = 0.750 mol Cu

0.750 mol Cu x 63.5 g / mol = **47.6 g** Cu

5. How many grams of calcium nitrate are produced in the reaction between 12.6 grams of nitric acid and an excess of calcium hydroxide?

Ca (OH)2 (aq) + 2 H(NO3) (aq) 🡪 Ca(NO3)2 (aq) + 2 H2O

H 1 x 1 g/mol = 1.00 g/mol Ca 1 x 40.0 g/mol = 40.0 g/mol

N 1 x 14 g/mol = 14.0 g/mol N 2 x 14.0 g/mol = 28.0 g/mol

O 3 x 16 g/mol = 48.0 g/mol O 6 x 16.0 g/mol = 96.0 g/mol

 63.0 g/mol 164.0 g/mol

12.6 g x 1 mol / 63.0 g = 0.200 mol of H(NO3) (aq)

mole ratio of H(NO3) (aq) to Ca(NO3)2 (aq) 🡪 2 : 1

0.200 mol / 2 = X / 1 X = 0.100 mol Ca(NO3)2 (aq)

0.100 mol x 164.0 g / mol = **16.4 g** Ca (NO3)2 (aq)

6. How many liters of chlorine gas are needed to react completely with 10.0 g of sodium when forming salt?

2 Na + Cl2 (g) 🡪 2 NaCl

GAM of sodium = 23.0 g/mol 10.0 g x 1 mol / 23.0 g = 0.430 mol of Na

mole ratio of Na to Cl2 (g) 🡪 2 : 1

0.430 mol / 2 = X / 1 X = 0.215 mol Cl2 (g)

0.215 moles x 22.4 L / mol = **4.82 L** Cl2 (g)

**Worksheet 3**

1 How many grams of hydrochloric acid are required to react completely with 100. grams of calcium hydroxide to form salt water?

2 HCl + Ca(OH)2 (aq) 🡪 CaCl2 (aq) + 2 H2O

Ca 1 x 40.1 g/mol = 40.1 g/mol GFM = 74.1 g/mol

O 2 x 16.0 g/mol = 32.0 g/mol

H 2 x 1.00 g/mol = 2.00 g/mol 100. g / 74.1 g/mol = 1.35 mol Ca(OH)2

mole ratio of Ca(OH)2 to HCl = 1 : 2 🡪 1.35 mol / 1 = X / 2 🡪 X = 2.70 mol HCl

GFM of HCl = 36.5 g/mol 2.70 mol x 36.5 g/mol = 98.6 **g** HCl

2. 23.4 g of nitrogen reacts with 2.00 g of hydrogen to produce ammonia. How many moles of ammonia does this reaction yield?

N2 (g) + 3 H2 (g) 🡪 2 NH3 (g)

GAM of hydrogen gas (H2) = 2.00 g/mol 2.00 g x 1 mol / 2 g = 1.00 mol of H2 (g)

GAM of nitrogen gas (N2) = 28.0 g/mol 23.4 g x 1 mol / 28.0 g = 0.836 mol H2

1 mol H2 / 3 mol H2 =? mol N2 / 1 mol N2 = 0.333 mol N2

and we have 0.836 mol available. Therefore, H2 is the **limiting reagent**.

mole ratio of H2 (g) to NH3 (g) = 3 : 2 🡪 1.00 mol / 3 = X / 2 🡪 X = 0.670 **moles NH3**

3. How many liters of hydrogen gas are produced when 5.00 g of aluminum react with 12.1 g of hydrochloric acid?

2 Al (s) + 6 HCl (aq) 🡪 2 AlCl3 (aq) + 3 H2 (g)

GAM of aluminum = 27.0 g/mol 5.00 g x 1 mol / 27.0 g = 0.185 mol Al

GFM of HCl (aq)= 36.5 g/mol 12.1 g x 1 mol / 36.5 g = 0.332 mol HCl

0.185 mol Al / 2 mol Al = ? mol HCl / 6 mol HCl = 0.555 mol HCl

and we only have 0.332 mol HCl. Therefore, HCl is the **limiting reagent**.

mole ratio of HClto H2 (g) = 6 : 3 🡪 0.332 mol / 6 = X / 3 🡪 X = 0.166 mol H2 (g)

0.166 mol x 22.4 L / mol = 3.72 **L** of hydrogen gas

4. What is the molecular mass of a gas if 500. ml of that gas weighs 10.0 grams?

D = m / V 10.0 g / 500. ml = 10.0 g / 0.500 L x 22.4 L/mol = 448 **g/mole**

5. 200. g of Sodium reacts with 150. L of chlorine gas to form sodium chloride. How many grams of NaCl are theoretically produced? If 468 g of NaCl is actually produced, what is the percent yield?

2 Na + Cl2 (g) 🡪 2 NaCl

GAM of sodium = 23.0 g/mol 200. g x 1 mol / 23.0 g = 8.70 mol of Na

Chlorine gas 🡪 150. L x 1 mol / 22.4 L = 6.70 mol Cl2

mole ratio of Nato Cl2 (g) = 2 : 1 🡪 8.70 mol / 2 = X / 1 🡪 X = 4.35 mol Cl2 (g)

and we have 6.70 mol available. Therefore, Na is the **limiting reagent**.

mole ratio of Nato NaCl = 2 : 2 🡪 1:1 🡪 8.70 mol NaCl

8.70 mol x 58.5 g / mol = 508.9 **g** of sodium chloride

 Percent Yield = Actual/Theoretical x 100 % 🡪 468 g / 509 g x 100% = **91.9 %**

6. 31.3 grams of Bromine will react with hydrogen gas to yield hydrogen bromide. If 5.60 liters of hydrogen react, how many grams of hydrogen bromide are theoretically produced at STP? If 27.0 g of HBr are actually produced, what is the percent yield?

H2 (g) + Br2 (g) 🡪 2HBr

 5.60 L x 1 mol / 22.4 L = 0.250 mol H2 (g)

GMM of Br2 = 2 x 79.9 g/mol 31.3 g x 1 mol / 159.8 g = 0.196 mol Br2

0.250 mol H2 / 1 mol H2 = ? mol Br2 / 1 mol Br2 = 0.250 mol Br2

but we only have 0.196 mol available. Therefore, Br2 is the **limiting reagent**.

mole ratio of Br2 (g) to HBr = 1 : 2 🡪 0.196 mol / 1 = X / 2 🡪 X = 0.392 mol HBr

H 1 x 1.00 g/mol = 1.00 g/mole GFM = 80.9 g/mol

Br 1 x 79.9 g/mol = 79.9 g/mole

 0.392 mol x 80.9 g / mol = 31.7 **g** of HBr … theoretical yield

 Percent Yield = Actual/Theoretical x 100 % 🡪 27.0 g/31.7 g x 100% = **85%**

7. How many liters of ammonia gas are produced when 56.0 L of nitrogen gas react with excess hydrogen gas to produce ammonia at standard temperature and pressure? If 104 L of ammonia gas are actually produced, what is the percent yield?

N2 (g) + 3 H2 (g) 🡪 2 NH3 (g)

GMM of N2 (g) = 28.0 g/mol 56.0 L x 1 mole / 22.4 L = 2.50 mol of N2 (g)

mole ratio of N2 (g) to NH3 (g) = 1 : 2 🡪 2.5 mol / 1 = X / 2 🡪 X = 5.00 mol NH3 (g)

5.00 mol x 22.4 L / mol = 112 **L** of hydrogen gas

 Percent Yield = Actual/Theoretical x 100 % 🡪 104 L / 112 L x 100% = **92.9 %**

8. How many liters of ammonia are theoretically produced if 10.0 g of hydrogen gas will react with 42.0 grams of nitrogen gas @ STP? What is the % yield if 59.8 L of ammonia are produced?

N2 (g) + 3 H2 (g) 🡪 2 NH3 (g)

GAM of hydrogen gas = 2.00 g/mol 10.0 g x 1 mol / 2.00 g = 5.00 mol of H2 (g)

GAM of nitrogen gas = 28.0 g/mol 42.0 g x 1 mol / 28.0 g = 1.50 mol of N2 (g)

5.00 mol H2 / 3 mol H2 = ? mol N2 / 1 mol N2 = 1.67 mol N2

and we only have 1.50 mol available. Therefore, N2 is the **limiting reagent**.

mole ratio of N2 (g) to NH3 (g) = 1 : 2 🡪 1.50 mol / 1 = X / 2 🡪 X = 3.00 mol NH3 (g)

3.00 mol x 22.4 L / mol = 67.2 **L** of ammonia gas

 Percent Yield = Actual/Theoretical x 100 % 🡪 59.8 L / 67.2 L x 100% = **89.0 %**

9. How many liters of oxygen gas are required for the combustion of 100. liters of methane at STP?

CH4 (g) + 2 O2 (g) 🡪 CO2 (g) + 2 H2O

GMM of CH4 (g) = 16.0 g/mol 100. L x 1 mol / 22.4 L = 4.46 mol of CH4 (g)

mole ratio of CH4 (g) to O2 (g) = 1 : 2 🡪 4.46 mol / 1 = X / 2 🡪 X = 8.92 mol O2 (g)

8.92 mol x 22.4 L / mol = 200**. L** of oxygen gas

10. What is the density of propane gas @ STP (molecular formula = C3H8)

C 3 x 12.0 g/mol = 36.0 g/mole GFM = 44.0 g/mol

H 8 x 1.00 g/mol = 8.00 g/mole

44.0 g/mol x 1 mol / 22.4 L = **1.96 g/L** [*check reference table* C]

11. A sample of gas occupies 0.250 L @ STP. Its mass is 0.625 grams.

a. What is the molecular mass of the gas?

0.625 g / 0.250 L x 22.4 L / mol = **56.0 g/mole**

 b. What is the number of molecules in this sample?

0.250 L x 1 mol / 22.4 L = 0.0110 mol

0.0110 mol x 6.02 x 1023 molecules/mol = **6.72 x 1021 molecules**

**Worksheet 4** Limiting Reagents

1. The equation for the complete combustion of ethene (C2H4) is

C2H4(*g*) + 3O2(*g*) → 2CO2(*g*) + 2H2O(*g*)

If 2.70 moles of ethene reacted with 6.30 moles of oxygen, identify the limiting reagent. What is the theoretical yield of water in grams?

**Step 1** Calculate the number of moles of oxygen needed to react with 2.70 moles of ethene.

Multiply by the mole ratio.

 Mole ratio C2H4:O2 *= 1:3 2.70 mol / 1mol = X mol / 3 mol = 8.10 mol oxygen*

**Step 2** Compare the number of moles of oxygen needed to the number given.

Based on the mole ratio, theoretically, 8.10 mol oxygen are needed to react with 2.70 mol

ethane. But there is only 6.30 mol of oxygen available for the reaction as given in the

problem.

**Step 3** Identify the limiting reagent.

Based on the theoretical values in the equation, the reaction calls for 8.10 mol oxygen,

but only 6.30 mol oxygen is available. Therefore, oxygen is the limiting reagent

**Step 4** Find the theoretical yield of water.

Mole ratio O2 : H2O *= 3:2 6.30 mol / 3mol = X mol / 2 mol = 4.20 mol water*

4.20 mol water x 18.0 g/mol = 75.6 g water

2. 84.8 g of iron(III) oxide reacts with 11.5 g of carbon monoxide, iron is produced.

Fe2O3(*s*) + 3CO(*g*) → 2Fe(*s*) + 3CO2(*g*)

What is the limiting reagent? What is the theoretical yield of iron?

**Step 1** Finding the molar mass of Fe2O3(*s*).

Fe 2 × 55.8 g/mol = 111.6 g/mol C 1 x 12 g/mol = 12.0 g/mol

O 3 x 16.0 g/mol = 48.0 g/mol O 1 x 16 g/mol = 16.0 g/mol

 **159.6 g/mol 28.0 g/mol**

**Step 2** Calculate the ACTUAL number of moles produced.

 84.8 g x 1 mol/159.6 g = **0.531 mol** **Fe2O3(*s*)**

 11.5 g x 1 mol/28.0 g = **0.411 mol CO*(s)***

**Step 3** Use the mole ratio to find the number of moles of Fe expected.

Fe2O3: Fe = 1 : 21/0.531 = 2/X X = **1.062 mol Fe** based on Fe2O3

Coffee = 3 : 2 3/0.411 = 2/X X = **0.274 mol Fe** based on CO … **limiting reagent**

**Step 4** Convert moles to grams of iron.

 1.062 mol Fe x 55.8 g/mol = 59.3 **g Fe**

0.274 mol Fe x 55.8 g/mol = **15.3 g Fe … Theoretical Yield**