Prelaboratory Exercise: Limiting Reagent

Lab Grade

Prelab Questions		26
General Format (Signature, ink, no obliterations, etc.)		8
Data and Analysis (observations, questions, units, significant figures, sample calculations, etc.)		20
Accuracy (% error)		20
Post Lab Questions		26
Total		100

Name: ____________________

Section: ____________________

1. A student weighs out 1.100 grams of copper(II) chloride dihydrate and 3.500 grams of silver nitrate:
   a. Calculate the molar masses for the reactants:

	$CuCl_2 \cdot 2\,H_2O$	$AgNO_3$
Molar Mass (g/mol)	170.5	169.9

   b. Calculate the moles of copper(II) chloride dihydrate.

$$1.100\text{ g } CuCl_2\cdot 2H_2O \left| \frac{1\text{ mol } CuCl_2\cdot 2H_2O}{170.5\text{ g } CuCl_2\cdot 2H_2O} \right. = 6.4516\times10^{-3}\text{ mol } CuCl_2\cdot 2H_2O$$

   c. Calculate the moles of copper(II) chloride from the moles of copper(II) chloride dihydrate.

$$6.4516\times10^{-3}\text{ mol } CuCl_2\cdot 2H_2O \left| \frac{1\text{ mol } CuCl_2}{1\text{ mol } CuCl_2\cdot 2H_2O} \right. = 6.4516\times10^{-3}\text{ mol } CuCl_2$$

   d. What happens to the water of hydration when the solid dissolves?

The water becomes part of the solution

   e. Calculate the moles of silver nitrate.

$$3.500\text{ g } AgNO_3 \left| \frac{1\text{ mol } AgNO_3}{169.9\text{ g } AgNO_3} \right. = 0.02060\text{ mol } AgNO_3$$

   f. Write the balanced chemical equation for the reaction of copper(II) chloride and silver nitrate.

$$CuCl_{2\,(aq)} + 2AgNO_{3\,(aq)} \longrightarrow 2AgCl_{(s)} + Cu(NO_3)_{2\,(aq)}$$

   g. Determine the limiting reagent by comparing the theoretical mole ratio to the actual mole ratio:

Theoretical mole ratio	Actual mole ratio	Limiting Reagent is
$\frac{1\text{ mol } CuCl_2}{2\text{ mol } AgNO_3} = 0.5$	$\frac{6.4516\times10^{-3}\ CuCl_2}{0.02060\text{ m } AgNO_3} = 0.31$	$CuCl_2$

h. Write the balanced chemical equation for the reaction and complete the table below. Be sure to use the correct number of significant figures. Remember that leading zeros are not considered significant

Reaction	$CuCl_2$ (aq)	+ $2AgNO_3$ (aq)	→ $2AgCl$ (s)	+ $Cu(NO_3)_2$ (aq)
Initial moles	6.4516×10^{-3} mol	0.02060 mol	0 mol	0 mol
Change moles	− X	−2X	+ 2X	+X
End moles	6.4516×10^{-3} moles − X	0.02060 moles −2x	2x	x
End moles numerical	0 mol left	0.02060 moles − $2(6.4516 \times 10^{-3}$ moles) = 7.6968×10^{-3} mol	$2(6.4516 \times 10^{-3})$ = 0.01290 mol	6.4516×10^{-3} mol

i. What does x equal?

$6.4516 \times 10^{-3} - x = 0 \quad \therefore \quad x = 6.4516 \times 10^{-3}$ moles

j. Calculate the molar masses for the products:

	$Cu(NO_3)_2$	AgCl
Molar Mass (g/mol)	187.5	143.4

k. How many grams of precipitate can be collected?

$$0.01290 \text{ mol } AgCl_{(s)} \left| \frac{143.4 \text{ g } AgCl_{(s)}}{1 \text{ mol } AgCl_{(s)}} \right. = 1.8499 \text{ g } AgCl_{(s)}$$

l. If 0.8525 g of silver chloride is collected what is the percent yield?

$$\% \text{ yield} = \frac{0.8525}{1.8499} \times 100\% = 46.08\%$$

m. How many grams of the excess reagent are left at the end of the reaction?

$$1.2452 \times 10^{-3} \text{ mol } AgNO_{3\,(exc)} \left| \frac{169.9 \text{ g } AgNO_3}{1 \text{ mol } AgNO_3} \right. = 0.2116 \text{ g } AgNO_{3\,(exc)}$$

2. Complete the table below:

	Na_2CO_3	$CaCl_2 \cdot 2H_2O$	$CaCO_3$	NaCl
Molar Mass (g/mol)	106	147	100	58.5

Data Sheet: Limiting Reagent

TABLE 10.2

Data		Sample Calculations
Assigned Letter		
Spreadsheet ID		
Actual weight of Na_2CO_3 used mass Na_2CO_3 + beaker =	45.9798 g	
mass beaker =	44.9709 g	
mass Na_2CO_3 =	1.0089 g	
Describe the Na_2CO_3	White granulated solid	
Actual moles Na_2CO_3 used	9.5179×10^{-3} mol	
Actual weight of $CaCl_2 \cdot 2\,H_2O$ used mass $CaCl_2 \cdot 2\,H_2O$ + beaker =	48.2015 g	
mass beaker=	46.5511 g	
mass $CaCl_2 \cdot 2\,H_2O$ =	1.6504 g	
Describe the $CaCl_2 \cdot 2\,H_2O$	White solid pellets	
Actual moles $CaCl_2 \cdot 2\,H_2O$ used	0.011226	
Actual moles $CaCl_2$ used	0.011226	
Weight of filter paper	0.3922 g	
Weight of watch glass	1.5107 g	
Describe the wet $CaCO_3$	White and thick	
Weight of filter paper, watch glass and precipitate 1st drying	3.4723 g	
Weight of filter paper, watch glass and precipitate 2nd drying	3.4003 g	

TABLE 10.3

	$Na_2CO_{3(aq)}$	+ $CaCl_{2(aq)}$	→ $CaCO_{3(s)}$	+ 2 $NaCl_{(aq)}$
Initial moles	9.5179×10^{-3} mol	0.011263 mol	0	0
Change moles	− x	− x	+ x	+ 2x
End moles	9.5179×10^{-3} mol − x	0.011263 mol − x	x	2x
End moles numerical	0	1.7451×10^{-3} mol	9.5179×10^{-3} mol	0.01904 mol

TABLE 10.4

Theoretical mole ratio	Actual mole ratio	Limiting Reagent is
$\frac{1\ mol\ CaCl_2}{1\ mol\ Na_2CO_3} = 1$	$\frac{0.011226\ mol\ CaCl_2}{9.5179 \times 10^{-3}\ mol\ Na_2CO_3} = 1.18$	Na_2CO_3

Sample Calculations

Na_2CO_3

$9.5179 \times 10^{-3} - 9.5179 \times 10^{-3} = 0$

$CaCl_2$

$0.11263 - 9.5179 \times 10^{-3} = 1.7451 \times 10^{-3}$ mol

$CaCO_3$

9.5179×10^{-3} mol

$NaCl$

$2(9.5179 \times 10^{-3}) = 0.01904$ mol

TABLE 10.5

Results	
Theoretical weight of $CaCO_3$	0.9527 g
Actual weight of $CaCO_3$ collected	1.4974 g
Describe the dried $CaCO_3$	White powder
Percent Yield	157%

Sample Calculations

$$9.5179 \times 10^{-3}\ mol\ CaCO_3 \times \frac{100.1\ g\ CaCO_3}{1\ mol\ CaCO_3} = 0.9527\ g\ CaCO_3$$

$$3.4003\ g - 0.3922\ g - 1.5107\ g = 1.4974\ g$$

$$\%\ yield = \frac{1.4974\ g}{0.9527\ g} \times 100\% = 157\%$$

Post Lab Questions

1. Describe the effect on the actual yield and percent yield (increase, decrease, or no change), if the following errors occurred. Be sure to explain your reasoning.
   a. The filter paper was still wet when the final product was weighed.

   The mass would have been higher, so the % yield would be higher too.

   b. Some product fell through the filter paper and was seen in the filter flask during the vacuum filtration.

   The mass would have diminished, so the % yield would be lower.

   c. Some product fell on the floor and was scraped up with some dust particles, and then weighed for the final mass.

   Same as part a.

2. What are you to do with unused chemical in the lab?

   Put the unused chemicals in a waste container.

3. In the reaction below 25.00 g of $MnCl_2$ is reacted with 100.0 g of PbO_2, excess KCl and excess HCl.

$$2\,KCl_{(aq)} + 2\,MnCl_{2\,(aq)} + 5\,PbO_{2\,(s)} + 4\,HCl_{(aq)} \rightarrow 2\,KMnO_{4\,(aq)} + 5\,PbCl_{2\,(s)} + 2\,H_2O_{(l)} \quad \text{(EQ 10.3)}$$

a. How many grams of $KMnO_4$ can be produced by this reaction? Use an ICE table.

$25.0\text{ g } MnCl_2 \times \frac{1\text{ mol } MnCl_2}{125.8\text{ g } MnCl_2} = 0.1987$

$100\text{ g } PbO_2 \times \frac{1\text{ mol } PbO_2}{239.2\text{ g } PbO_2} = 0.4181\text{ mol}$

Reaction	$2MnCl_2$	$5PbO_2$	$2KMnO_4$
Initial moles	0.1987 mol	0.4181 mol	0
change moles	− 2x	− 5x	+ 2x
End moles	0.1987 − 2x = 0 x = 0.09935 mol	0.4181 − 5x = 0 x = 0.08362 mol	—
End moles numerical	0.1987 − 2(0.08362) = 0.03146 mol	0	2(0.08362) = 0.1672 mol

$0.1672\text{ mol } KMnO_4 \times \frac{158\text{ g } KMnO_4}{1\text{ mol } KMnO_4} = \boxed{26.42\text{ g } KMnO_4}$

b. If 21.42 g of $KMnO_4$ is actually produced, what is the percent yield?

$\%\text{ yield} = \frac{21.42\text{ g}}{26.42\text{ g}} \times 100\% = \boxed{81.07\%}$

c. How many grams of what starting substances will be left over after the reaction?

$0.0314\text{ mol } MnCl_2 \times \frac{125.8\text{ g } MnCl_2}{1\text{ mol } MnCl_2} = \boxed{3.95\text{ g } MnCl_2}$

d. How many grams of what starting substance (i.e., $MnCl_2$ or PbO_2) must be added to the original quantities of reactants so that there will be neither PbO_2 nor $MnCl_2$ left over after the reaction?

$0.0314\text{ mol } MnCl_2 \times \frac{5\text{ mol } PbO_2}{2\text{ mol } MnCl_2} \times \frac{239.2\text{ g } PbO_2}{1\text{ mol } PbO_2} = \boxed{18.78\text{ g } PbO_2}$ more to react with the leftover $MnCl_2$.