P J2 Stoichiometry and Percent Yield

Name______________________Per___

Write out your dimensional analysis work. If you need more room, work on another piece of paper. Circle your final answer. Put units, identifiers and descriptors on your answers. Concern yourself at least a little bit with significant figures.

1. In the problem on Notesheet J1 Eva and Juan reacted aluminum with copper(II) chloride dihydrate. The balanced equation for the reaction is shown below. Eva measured out 6.36 g of aluminum and Juan made a solution with 47.6 g copper(II) chloride. After washing and drying, the copper metal product weighed 17.2 g. Juan and Eva calculated their percent yield as 76.4 %. It turns out that Juan had made a mistake because he did not realize that the copper(II) chloride was a dihydrate, and as a result the amount that he had calculated to use was too small causing the low percent yield.

$$2\ Al + 3\ CuCl_2 \rightarrow 3\ Cu + 2\ AlCl_3$$

   a. Using the 47.6 g of copper(II) chloride dihydrate that Juan measured out, calculate the mass of aluminum that would be used up and calculate the mass of aluminum that would have been left over.

   b. What mass of copper can be formed when using the 47.6 g of copper(II) chloride dihydrate, and how does Juan and Eva's percent yield calculate now?

2. Iron (steel) is a very important metal. Iron is dug out of the ground as the mineral hematite which is iron(III) oxide. That mineral ore needs to be processed so that the metal iron can be extracted. This is done by reacting (aka smelting) the ore at very high temperatures with solid carbon called coke to produce metallic iron and carbon dioxide. Write the balanced equation in the space below.

   a. A small foundry was able to recover 975 kg of iron from 1650 kg of hematite. Calculate the foundry's percent yield.

   b. Chemists have determined that the process works best if and excess of coke is used for the reaction. Calculate the minimum mass of coke that would be necessary to react with 1650 kg of iron(III) oxide.

 Stoichiometry and Percent Yield

3. Shrek and Fiona dissolved 3.5 g of sodium hydroxide in water and reacted with an excess of cobalt(II) nitrate solution. A beautiful deep green precipitate forms which they filtered, dried and measured a mass of 6.2 g. Write a chemical equation for this precipitation reaction in the space below.

   a. Calculate their percent yield.

   b. Does the percent yield imply (or suggest) that the precipitate was not dried completely, or that some of the precipitate slipped through the filter paper? Justify your response.

   c. After completing the lab, Shrek was wondering if Fiona used a different solution, since Shrek was sure that the precipitate was fully dry. The other solutions that were available in the lab was copper(I) nitrate and iron(III) nitrate. Considering the high percent yield, which solution would be the most likely substitute? Support your answer with calculations.

P J2 (pg 3 of 4) Stoichiometry *ANSWERS*

Write out your dimensional analysis work. If you need more room, work on another piece of paper. Circle your final answer. Put units, identifiers and descriptors on your answers. Concern yourself at least a little bit with significant figures.

1. In the problem on Notesheet J1 Eva and Juan reacted aluminum with copper(II) chloride dihydrate. The balanced equation for the reaction is shown below. Eva measured out 6.36 g of aluminum and Juan made a solution with 47.6 g copper(II) chloride. After washing and drying, the copper metal product weighed 17.2 g. Juan and Eva calculated their percent yield as 76.4 %. It turns out that Juan had made a mistake because he did not realize that the copper(II) chloride was a dihydrate, and as a result the amount that he had calculated to use was too small causing the low percent yield.

$$2\,Al \quad + \quad 3\,CuCl_2 \quad \rightarrow \quad 3\,Cu \quad + \quad 2\,AlCl_3$$

   a. Using the 47.6 g of copper(II) chloride dihydrate that Juan measured out, calculate the mass of aluminum that would be used up and calculate the mass of aluminum that would have been left over.

$$47.6\,\cancel{g\,CuCl_2 \cdot 2H_2O} \times \frac{1\,\cancel{mol\,CuCl_2 \cdot 2H_2O}}{170.49\,\cancel{g\,CuCl_2 \cdot 2H_2O}} \times \frac{2\,\cancel{mol\,Al}}{3\,\cancel{mol\,CuCl_2}} \times \frac{26.98\,g\,Al}{1\,\cancel{mol\,Al}} = 5.02\,g\text{ Al needed to go with } CuCl_2$$

$$\begin{array}{rl} & 6.36\,g\text{ Al used} \\ - & 5.02\,g\text{ Al needed} \\ \hline & 1.34\,g\text{ Al should have been left over} \end{array}$$

   b. What mass of copper can be formed when using the 47.6 g of copper(II) chloride dihydrate, and how does Juan and Eva's percent yield calculate now?

$$47.6\,\cancel{g\,CuCl_2 \cdot 2H_2O} \times \frac{1\,\cancel{mol\,CuCl_2 \cdot 2H_2O}}{170.49\,\cancel{g\,CuCl_2 \cdot 2H_2O}} \times \frac{3\,\cancel{mol\,Cu}}{3\,\cancel{mol\,CuCl_2}} \times \frac{63.55\,g\,Cu}{1\,\cancel{mol\,Cu}} = 17.7\,g\text{ Cu could be produced (theor)}$$

$$\frac{17.2\,g\text{ Cu was produced in Lab}}{17.7\,g\text{ Cu theoretical}} \times 100\% = 97.2\%\text{ yield}$$

2. Iron (steel) is a very important metal. Iron is dug out of the ground as the mineral hematite which is iron(III) oxide. That mineral ore needs to be processed so that the metal iron can be extracted. This is done by reacting (aka smelting) the ore at very high temperatures with solid carbon called coke to produce metallic iron and carbon dioxide. Write the balanced equation in the space below.

$$2\,Fe_2O_3 \quad + \quad 3\,C \quad \rightarrow \quad 4\,Fe \quad + \quad 3\,CO_2$$

   a. A small foundry was able to recover 975 kg of iron (exp) from 1650 kg of hematite. Calculate the foundry's percent yield.

$$1650\,\cancel{kg\,Fe_2O_3} \times \frac{1\,\cancel{mol\,Fe_2O_3}}{159.7\,\cancel{g\,Fe_2O_3}} \times \frac{4\,\cancel{mol\,Fe}}{2\,\cancel{mol\,Fe_2O_3}} \times \frac{55.85\,g\,Fe}{1\,\cancel{mol\,Fe}} = 1150\,kg\text{ Fe should be produced}$$

$$\frac{975\,kg\,Fe}{1150} \times 100 = 84.5\%\text{ yield}$$

why can I use kg ?

   b. Chemists have determined that the process works best if and excess of coke is used for the reaction. Calculate the minimum mass of coke that would be necessary to react with 1650 kg of iron(III) oxide.

$$1650\,\cancel{kg\,Fe_2O_3} \times \frac{1\,\cancel{mol\,Fe_2O_3}}{159.7\,\cancel{g\,Fe_2O_3}} \times \frac{3\,\cancel{mol\,C}}{2\,\cancel{mol\,Fe_2O_3}} \times \frac{12.01\,g\,C}{1\,\cancel{mol\,C}} = 186\,kg\text{ of C are necessary}$$

You might be wondering why you can leave 1650 in kg? You can, but the answer will come out in kg.
Here's why:

$$1650\,\cancel{kg} \times \frac{1000\,g}{1\,\cancel{kg}}$$ ...do problem

then answer would be $1{,}150{,}000\,\cancel{g} \times \frac{1\,kg}{1000\,\cancel{g}} = 1150\,kg$ voila!

3. Shrek and Fiona dissolved 3.5 g of sodium hydroxide in water and reacted with an excess of cobalt(II) nitrate solution. A beautiful deep green precipitate forms which they filtered, dried and measured a mass of 6.2 g. Write a chemical equation for this precipitation reaction in the space below.

$$Co(NO_3)_2 + 2\,NaOH \rightarrow \underbrace{Co(OH)_2}_{\text{precipitate}} + 2\,NaNO_3$$

a. Calculate their percent yield.

$$3.5\,g\ \cancel{NaOH} \times \frac{1\ \cancel{mol\ NaOH}}{40\,g\ \cancel{NaOH}} \times \frac{1\ \cancel{mol\ Co(OH)_2}}{2\ \cancel{mol\ NaOH}} \times \frac{92.95\,g\ Co(OH)_2}{1\ \cancel{mol\ Co(OH)_2}} = 4.07\,g\ Co(OH)_2$$

should be produced (theor)

$$\frac{6.02\,g\ Co(OH)_2\ \text{experimental}}{4.07\,g\ Co(OH)_2\ \text{theoretical}} \times 100 = 148\%\ \text{yield}$$

Yikes! too large

b. Does the percent yield imply (suggest) that the precipitate was not dried completely, or that some of the precipitate slipped through the filter paper? Justify your response.

Since the experimental value of the precipitate (6.2g) is larger than the theoretical (expected) value the precipitate could be wet. The extra water could be adding to the mass, making the % yield too large.

(If some of the precipitate slipped through the filter paper, the loss of precipitate would make the experimental value smaller — but the experimental value is larger.)

c. After completing the lab, Shrek was wondering if Fiona used a different solution, since Shrek was sure that the precipitate was fully dry. The other solutions that were available in the lab was copper(I) nitrate and iron(III) nitrate. Considering the high percent yield, which solution would be the most likely substitute? Support your answer with calculations.

copper(I) nitrate ?? $CuNO_3 + NaOH \rightarrow CuOH + NaNO_3$

— OR —

iron(III) nitrate ?? $Fe(NO_3)_3 + 3\,NaOH \rightarrow Fe(OH)_3 + 3\,NaNO_3$

It might tempting to think $Fe(OH)_3$ with a higher molar mass (106.88g/mol) than CuOH (80.56g/mol) might be causing the experimental precipitate to be too large. However, we really should do two separate calculations, one for each substance to determine the theoretical yield for each.

$$3.5\,g\ NaOH \times \frac{1\ mol\ NaOH}{40\,g\ NaOH} \times \frac{1\ mol\ Fe(OH)_3}{3\ mol\ NaOH} \times \frac{106.88\,g\ Fe(OH)_3}{1\ mol\ Fe(OH)_3} = 3.12\,g\ Fe(OH)_3\ \text{theoretical}$$

$$3.5\,g\ NaOH \times \frac{1\ mol\ NaOH}{40\,g\ NaOH} \times \frac{1\ \cancel{mol\ CuOH}}{1\ mol\ NaOH} \times \frac{80.56\,g\ CuOH}{1\ \cancel{mol\ CuOH}} = 7.05\,g\ CuOH\ \text{theoretical}$$

$$\frac{6.2\,g\ \text{precipitate exp}}{3.12\,g\ Fe(OH)_3\ \text{theor}} \times 100 = 199\%\ \text{yield}$$

This is even higher!

$$\frac{6.2\,g\ \text{precipitate exp}}{7.05\,g\ CuOH\ \text{theor}} \times 100 = 87.9\%$$

This is much more realistic percent yields are usually less than 100%