

CHM1311 B: Principles of Chemistry

Prof. N. Goto  
Assignment #1

Due Sept 26<sup>th</sup>, at the beginning of class

Solutions must be written legibly, in the space provided. Adequate detail to the calculation (including units, appropriate sig figs) must be provided to make it possible for other students to understand how you arrived at the final solution. If more space is needed, use the back of the page. Do not add extra pages, as they will not be marked. Assignment pages must be stapled together.

Assignments can be submitted individually, or by groups of up to 4 students.

1) Name: \_\_\_\_\_ Student ID: \_\_\_\_\_

2) Name: \_\_\_\_\_ Student ID: \_\_\_\_\_

3) Name: \_\_\_\_\_ Student ID: \_\_\_\_\_

4) Name: \_\_\_\_\_ Student ID: \_\_\_\_\_

**NOTE:** For each question an on-line resource in WileyPLUS is given in brackets that can walk you through a similar type of problem. (ILW = Interactive Learning Ware.)

**Question 1. (ILW 1.21)**

**5 marks**

Use the data in the following table to calculate the molar mass of naturally occurring element:

Isotope	Isotopic Molar Mass (g/mol)	Abundance (%)
<sup>136</sup> Ce	135.9071	0.185
<sup>138</sup> Ce	137.9060	0.251
<sup>140</sup> Ce	139.9054	88.450
<sup>142</sup> Ce	141.9092	11.114

$$\begin{aligned}
 \text{MASS FROM: } & {}^{136}\text{Ce} = 135.9071 \frac{\text{g}}{\text{mol}} \times \frac{0.185\%}{100\%} = 0.2514 \frac{\text{g}}{\text{mol}} \\
 & {}^{138}\text{Ce} = 137.9060 \frac{\text{g}}{\text{mol}} \times \frac{0.251\%}{100\%} = 0.3461 \frac{\text{g}}{\text{mol}} \\
 & {}^{140}\text{Ce} = 139.9054 \frac{\text{g}}{\text{mol}} \times \frac{88.450\%}{100\%} = 123.746 \frac{\text{g}}{\text{mol}} \\
 & {}^{142}\text{Ce} = 141.9092 \frac{\text{g}}{\text{mol}} \times \frac{11.114\%}{100\%} = 15.7718 \frac{\text{g}}{\text{mol}} \\
 & \underline{\hspace{10em}} \\
 & \hspace{10em} 140.12 \frac{\text{g}}{\text{mol}}
 \end{aligned}$$

**Question 2. (ILW 39 and FAQ: How do I write an equation to describe the dissociation of an ionic compound?)**

Solution A is prepared by dissolving 83.9 g of  $K_3PO_4$  in enough water to make 1.50 L of solution. Solution B is 2.5 L of 0.684 M KCl.

a) What is the molar concentration of  $K_3PO_4$  in Solution A? (3 marks)

$$M_{K_3PO_4} = (3 \times 39.10 + 30.97 + 4 \times 16.00) \frac{g}{mol} = 212.27 \frac{g}{mol}$$

$$c = \frac{n}{V} = \frac{m}{MV} = \frac{83.9 g}{(212.27 g/mol)(1.50 L)}$$

$$= 0.264 M$$

b) What volume of Solution A will give 2.50 g of  $K_3PO_4$ ? (2 marks)

$$V = \frac{m}{Mc} = \frac{2.50 g}{(212.27 g/mol)(0.264 M)}$$

$$= 44.7 mL$$

c) If 25.0 mL of Solution B is mixed with 35.00 mL of Solution A, what is the concentration of  $K^+$  ions in the final solution? (4 marks)

$$C_K = \frac{n_{K,A} + n_{K,B}}{V_A + V_B}$$

$$= \frac{C_A V_A \times \frac{3 \text{ mol } K^+}{1 \text{ mol } K_3PO_4} + C_B V_B \times \frac{1 \text{ mol } K^+}{1 \text{ mol } KCl}}{V_A + V_B}$$

$$= \frac{(0.2635 M)(35.00 mL) \times 3 + (0.684 M)(25.0 mL)}{35.00 mL + 25.0 mL} = 0.746 M$$

**Question 3. (ILW 1.35)**

One dose of an antibiotic was found to contain 53.6 mg penicillin G ( $C_{16}H_{18}N_2O_4S$ ) in one pill.

a) How many carbon atoms are in a 53.6 mg sample of penicillin G? (3 marks)

$$N_C = n_C N_A = n_{PenG} \times \frac{16 \text{ mol C}}{1 \text{ mol PenG}} N_A = \frac{M_{PenG}}{M_{PenG}} \times \frac{16 \text{ mol C}}{1 \text{ mol PenG}} \times N_A$$

$$= \frac{(53.6 \text{ mg})(10^{-3} \text{ g/mg})}{334.384 \text{ g/mol}} \times \frac{16 \text{ mol C}}{1 \text{ mol PenG}} \times 6.022 \times 10^{23} \frac{\text{ATOMS}}{\text{mol}}$$

$$= 1.54 \times 10^{21} \text{ ATOMS}$$

$$M_{PenG} = (16 \times 12.01 + 18 \times 1.008 + 14.01 \times 2 + 16.00 \times 4 + 32.06) \text{ g/mol} = 334.384 \text{ g/mol}$$

b) What mass of carbon is this? (2 marks)

$$m_C = n_C M_C = \frac{N_C}{N_A} M_C = \frac{1.54 \times 10^{21} \text{ ATOMS}}{6.022 \times 10^{23} \frac{\text{ATOMS}}{\text{mol}}} \times 12.01 \text{ g/mol}$$

$$= 30.8 \text{ mg}$$

**Question 4. (ILW 1.61)**

Ammonia gas undergoes oxidation to produce liquid water and molecular nitrogen.

a) Write the balanced chemical equation for this reaction. Be sure to include the phases. (2 marks)



b) What is the mass of ammonia gas that is required to completely react with 780 kg of molecular oxygen? (3 marks)

$$\begin{aligned} m_{\text{NH}_3} &= n_{\text{NH}_3} M_{\text{NH}_3} = n_{\text{O}_2} \times \frac{2 \text{ mol NH}_3}{\frac{3}{2} \text{ mol O}_2} M_{\text{NH}_3} \\ &= \frac{m_{\text{O}_2}}{M_{\text{O}_2}} \times \frac{2 \text{ mol NH}_3}{\frac{3}{2} \text{ mol O}_2} M_{\text{NH}_3} \\ &= \frac{(780 \text{ kg})}{2 \times 16.00 \text{ g/mol}} \times \frac{4}{3} \underbrace{(14.01 + 3 \times 1.008)}_{17.034} \frac{\text{g}}{\text{mol}} = 550 \text{ kg} \end{aligned}$$

**Question 5. (Office hours video, 1.93)**

Hydrogen fluoride is produced industrially by the action of sulphuric acid on  $\text{CaF}_2$ . Suppose 312 kg of  $\text{CaF}_2$  is treated with an excess of sulphuric acid and 106 kg of HF is produced. What is the percent yield of HF? (6 marks)



$$\text{THEORETICAL YIELD: } m_{\text{HF}} = n_{\text{HF}} M_{\text{HF}} = n_{\text{CaF}_2} \times \frac{2 \text{ mol HF}}{1 \text{ mol CaF}_2} M_{\text{HF}}$$

$$= \frac{m_{\text{CaF}_2}}{M_{\text{CaF}_2}} \times \frac{2 \text{ mol HF}}{1 \text{ mol CaF}_2} \times M_{\text{HF}}$$

$$= \frac{312 \text{ kg}}{\underbrace{(40.08 + 2 \times 19.00)}_{78.08} \frac{\text{g}}{\text{mol}}} \times 2 \times \underbrace{(1.008 + 19.00)}_{20.008} \frac{\text{g}}{\text{mol}}$$

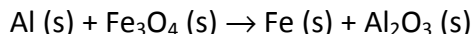
$$= 159.9 \text{ kg}$$

$$\% \text{ YIELD} = \frac{\text{ACTUAL YIELD}}{\text{THEORETICAL YIELD}} \times 100\%$$

$$= \frac{106 \text{ kg}}{159.9 \text{ kg}} \times 100\% = 66.3\%$$

**Question 6. (Video for 1.75)**

The following unbalanced reaction is called the thermite reaction. It releases tremendous amounts of energy and is sometimes used to generate heat for welding.



a) Write the balanced chemical equation for this reaction. (1 mark)



b) Determine the masses of all the substances present after the reaction if 120 g of Al and 711 g of  $\text{Fe}_3\text{O}_4$  react to completion. Enter your final answers in the table below. (10 marks)

THEORETICAL YIELD OF  $\text{Fe (s)}$  FROM  $\text{Al (s)}$ :  $n_{\text{Fe}} = n_{\text{Al}} \times \frac{9 \text{ mol Fe}}{8 \text{ mol Al}} = \frac{m_{\text{Al}}}{M_{\text{Al}}} \times \frac{9}{8}$

$$= \frac{120 \text{ g}}{26.98 \text{ g/mol Al}} \times \frac{9 \text{ mol Fe}}{8 \text{ mol Al}} = 5.00 \text{ mol}$$

THEORETICAL YIELD OF  $\text{Fe (s)}$  FROM  $\text{Fe}_3\text{O}_4$ :  $n_{\text{Fe}} = n_{\text{Fe}_3\text{O}_4} \times \frac{9 \text{ mol Fe}}{3 \text{ mol Fe}_3\text{O}_4}$

$$= \frac{m_{\text{Fe}_3\text{O}_4}}{M_{\text{Fe}_3\text{O}_4}} \times \frac{9 \text{ mol Fe}}{3 \text{ mol Fe}_3\text{O}_4}$$

$$= \frac{711 \text{ g}}{231.55 \text{ g/mol}} \times \frac{9 \text{ mol Fe}}{3 \text{ mol Fe}_3\text{O}_4} = 9.21 \text{ mol}$$

$$M_{\text{Fe}_3\text{O}_4} = (3 \times 55.85 + 4 \times 16.00) \text{ g/mol} = 231.55 \text{ g/mol}$$

$$M_{\text{Al}_2\text{O}_3} = (2 \times 26.98 + 3 \times 16.00) \text{ g/mol} = 101.96 \text{ g/mol}$$

$\therefore \text{Al}$  is LIMITING,  $m_{\text{Al}} = 0 \text{ kg}$

$$m_{\text{Fe}} = n_{\text{Fe}} M_{\text{Fe}} = (5.00 \text{ mol})(55.85 \text{ g/mol}) = 279 \text{ g}$$

$$m_{\text{Fe}_3\text{O}_4} = n_{\text{Fe}} \times \frac{3 \text{ mol Fe}_3\text{O}_4}{9 \text{ mol Fe}} \times M_{\text{Fe}_3\text{O}_4} = (5.00 \text{ mol Fe}) \frac{3 \text{ mol Fe}_3\text{O}_4}{9 \text{ mol Fe}} (231.55 \frac{\text{g}}{\text{mol}}) = 386 \text{ g} \therefore \text{REMAINING Fe}_3\text{O}_4 = 711 \text{ g} - 386 \text{ g} = 325 \text{ g}$$

$$m_{\text{Al}} + m_{\text{Fe}_3\text{O}_4} = m_{\text{Fe}} + m_{\text{Al}_2\text{O}_3} \therefore m_{\text{Al}_2\text{O}_3} = m_{\text{Al}} + m_{\text{Fe}_3\text{O}_4} - m_{\text{Fe}} = 120 + 386 - 279 = 227 \text{ g}$$

	Al (s)	$\text{Fe}_3\text{O}_4$ (s)	Fe (s)	$\text{Al}_2\text{O}_3$ (s)
Mass (in g)	0	325	280	227

**Question 7. (Office hours video, 21.3)**

a) What is Z, A and N for the nuclide of the actinide thorium with a neutron:proton ratio of 1.5? (2 marks)

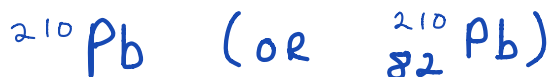
$$Z = \text{NUMBER OF PROTONS} = 90$$

$$N = \text{NUMBER OF NEUTRONS} = Z \times 1.5 = 135$$

$$A = \text{MASS NUMBER} = Z + N = 90 + 135 = 225$$

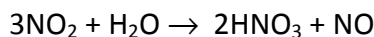
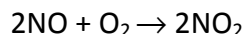
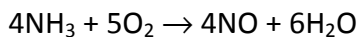
b) What is the nuclear symbol for the lead isotope that contains 128 neutrons? (2 marks)

$$Z = 82 \quad N = 128$$



**Question 8. (Student's solution manual for problem 1.65)**

Nitric acid is produced by a three-step synthesis called the Ostwald process:



The NO is recycled so that every mole of ammonia theoretically yields one mole of nitric acid. Starting with 626 kg of ammonia, what mass of nitric acid can be produced if each step is 94.5 % efficient? (5 marks)

$$\begin{aligned} \text{THEORETICAL YIELD} &= m_{\text{HNO}_3} = \frac{m_{\text{NH}_3}}{M_{\text{NH}_3}} \times \frac{1 \text{ mol HNO}_3}{1 \text{ mol NH}_3} \times M_{\text{HNO}_3} \\ &= \frac{626 \text{ kg}}{17.034 \text{ g/mol}} \times \frac{1 \text{ mol HNO}_3}{1 \text{ mol NH}_3} \times \frac{(1.008 + 14.01 + 3 \times 16.00)}{1 \text{ mol}} \\ &= 2316 \text{ kg} \end{aligned}$$

$$\% \text{ YIELD OVERALL} = 0.945 \times 0.945 \times 0.945 \times 100\% = 84.3\%$$

$$= \frac{\text{ACTUAL YIELD}}{\text{THEORETICAL YIELD}} \times 100\%$$

$$\begin{aligned} \therefore \text{ACTUAL YIELD} &= \frac{\% \text{ YIELD}}{100\%} \times \text{THEORETICAL YIELD} \\ &= 0.843 \times 2316 \text{ kg} = 1954 \text{ kg} \end{aligned}$$

**Question 9. (Additional Interactive LearningWare Problem 10)**

A 31.15 g sample of an unknown organic compound is subjected to combustion analysis. The sample gives 51.07 g of  $\text{CO}_2$  and 20.91 g of  $\text{H}_2\text{O}$ . When this sample is analyzed for sulfur content, it is found to be 23.9% by mass. What is the empirical formula of the compound? (8 marks)

$$n_{\text{C}} = \frac{m_{\text{CO}_2}}{M_{\text{CO}_2}} = \frac{51.07 \text{ g}}{44.01 \text{ g/mol}} = 1.1604 \text{ mol}$$

$$n_{\text{H}} = \frac{m_{\text{H}_2\text{O}}}{M_{\text{H}_2\text{O}}} \times \frac{2 \text{ mol H}}{1 \text{ mol H}_2\text{O}} = \frac{20.91 \text{ g}}{18.016 \text{ g/mol}} \times \frac{2 \text{ mol H}}{1 \text{ mol H}_2\text{O}} = 2.3213 \text{ mol}$$

$$m_{\text{S}} = m_{\text{TOTAL}} \times \frac{\% \text{ S}}{100\%} = 31.15 \times 0.239 = 7.44 \text{ g}$$

$$n_{\text{S}} = \frac{m_{\text{S}}}{M_{\text{S}}} = \frac{7.44 \text{ g}}{32.06 \text{ g/mol}} = 0.2322 \text{ mol}$$

$$\begin{aligned} m_{\text{O}} &= m_{\text{TOTAL}} - m_{\text{C}} - m_{\text{H}} - m_{\text{S}} = m_{\text{TOTAL}} - n_{\text{C}} M_{\text{C}} - n_{\text{H}} M_{\text{H}} - m_{\text{S}} \\ &= 31.15 \text{ g} - (1.1604 \text{ mol}) \left( \frac{12.01 \text{ g}}{\text{mol}} \right) - (2.3213 \text{ mol}) (1.008 \text{ g/mol}) - 7.44 \text{ g} \\ &= 7.429 \text{ g} \end{aligned}$$

$$n_{\text{O}} = \frac{m_{\text{O}}}{M_{\text{O}}} = \frac{7.429 \text{ g}}{16.00 \text{ g/mol}} = 0.4643 \text{ mol}$$

$$\begin{aligned} \therefore \text{EMPIRICAL FORMULA IS } & \text{C}_{\frac{1.1604}{0.2322}} \text{H}_{\frac{2.3213}{0.2322}} \text{S}_{\frac{0.2322}{0.2322}} \text{O}_{\frac{0.4643}{0.2322}} \\ &= \text{C}_5\text{H}_{10}\text{SO}_2 \end{aligned}$$