

Chemistry 1110 Spring 2024 Test 1

Wednesday, January 31, 2024

Time: 1 hour 50 minutes

Name: ANSWERS

Student #: _____

This test consists of **eight** pages of questions and a periodic table. Please ensure that you have a complete test and, if you do not, obtain one from me **immediately**. There are **38** marks available. Good luck!

- 1) [2 marks] How many mL of 0.1048 M H_3PO_4 are required to titrate 0.5078 grams of $\text{Ca}(\text{OH})_2$ (74.092 g/mol)?



$$0.5078 \text{ g } \text{Ca}(\text{OH})_2 \times \frac{1 \text{ mol}}{74.092 \text{ g}} \times \frac{2 \text{ H}_3\text{PO}_4}{3 \text{ Ca}(\text{OH})_2} \times \frac{1000 \text{ mL}}{0.1048 \text{ moles}}$$

$$= \boxed{43.60 \text{ mL}}$$

- 2) [3 marks] A 0.2999-gram sample of $\text{Al}_2(\text{CO}_3)_3 \cdot n\text{H}_2\text{O}$ required 25.90 mL of 0.2031 M HCl for complete titration:



What is the value of n in the formula $\text{Al}_2(\text{CO}_3)_3 \cdot n\text{H}_2\text{O}$?

$$25.90 \text{ mL} \times \frac{0.2031 \text{ moles HCl}}{1000 \text{ mL}} \times \frac{1 \text{ Al}_2\text{CO}_3 \cdot n}{6 \text{ HCl}} = 8.76715 \times 10^{-4} \text{ moles Al}_2\text{CO}_3 \cdot n$$

$$\frac{0.2999 \text{ g}}{8.76715 \times 10^{-4} \text{ mol}} = 342.07 \frac{\text{g}}{\text{mol}}$$

$$= 2 \times 26.982 + 3 \times 12.011 + 9 \times 15.999 + n \cdot 18.015$$

$$\Rightarrow \boxed{\begin{array}{l} n = 5.99968 \dots \\ = 6 \end{array}}$$

- 3) [4 marks] HCl solution A had an unknown concentration. A 10.00 mL aliquot of solution A was taken and diluted to 250.0 mL to form solution B. A 20.00 mL aliquot of solution B required 18.51 mL of 0.002000 M $\text{Mg}(\text{OH})_2$ for complete reaction:



What was the concentration of solution A?

$$18.51 \text{ mL} \times \frac{0.002 \text{ moles Mg}(\text{OH})_2}{1000 \text{ mL}} \times \frac{2\text{HCl}}{1\text{Mg}(\text{OH})_2} = 7.404 \times 10^{-5} \text{ moles HCl}$$

$$[\text{HCl}] \text{ in B} = \frac{7.404 \times 10^{-5} \text{ mol}}{20 \times 10^{-3} \text{ L}} = 3.702 \times 10^{-3} \text{ M in } 20 \text{ mL}$$

moles HCl taken from A:

$$3.702 \times 10^{-3} \frac{\text{moles HCl}}{\text{L}} \times 250.0 \times 10^{-3} \text{ L} = 9.255 \times 10^{-4} \text{ moles}$$

$$\text{So } [\text{HCl}] \text{ in A is } \frac{9.255 \times 10^{-4} \text{ moles}}{10 \times 10^{-3} \text{ L}} = \boxed{0.09255 \text{ M}}$$

- 4) [3 marks] Reaction of 652.1 mg of MCl_3 with excess AgNO_3 resulted in the collection of 1592.4 mg of AgCl (143.321 g/mol):



What is the element, M?

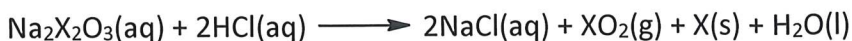
$$1592.4 \times 10^{-3} \text{ g AgCl} \times \frac{1 \text{ mol}}{143.321 \text{ g}} \times \frac{1 \text{ MCl}_3}{3 \text{ AgCl}} = 0.0037 \dots \text{ mol MCl}_3$$

$$\frac{652.1 \times 10^{-3} \text{ g}}{0.0037 \dots \text{ mol}} = 176.073 \dots \frac{\text{g}}{\text{mol}}$$

$$= \text{M} + 3 \times 35.453$$

$$\Rightarrow \boxed{\text{M} = 69.71, \text{Ga}}$$

- 5) [4 marks] A 0.5000-gram sample of $\text{Na}_2\text{X}_2\text{O}_3$ was dissolved in enough water to make 200.0 mL of solution. A 25.00-mL aliquot was taken and 15.00 mL of 0.2500 M HCl added:



The excess HCl required 29.96 mL of 0.09878 M NaOH to titrate:



What is the element, X?

$$\text{Total HCl: } 0.2500 \frac{\text{moles}}{\text{L}} \times 15.00 \times 10^{-3} \text{ L} = 0.00375 \text{ moles}$$

$$\text{Excess HCl: } 29.96 \text{ mL} \times 0.09878 \frac{\text{moles NaOH}}{1000 \text{ mL}} \times \frac{1 \text{ HCl}}{1 \text{ NaOH}}$$

$$= 0.002959449 \text{ moles}$$

$$\therefore \text{reacted HCl} = 0.000790551$$

$$\therefore \text{reacted Na}_2\text{...} = 0.000790551 \text{ moles HCl} \times \frac{1 \text{ Na}_2\text{...}}{2 \text{ HCl}}$$

$$= 3.952756 \times 10^{-4} \text{ moles Na}_2\text{...}$$

$$\text{mass Na}_2\text{...} = 0.5000 \text{ g} \times \frac{25 \text{ mL}}{200 \text{ mL}} = 6.25 \times 10^{-2} \text{ g}$$

$$\frac{6.25 \times 10^{-2} \text{ g}}{3.952756 \times 10^{-4} \text{ moles}}$$

$$= 158.117... \frac{\text{g}}{\text{mol}}$$

$$= 2 \times 22.99 + 2X + 3 \times 15.999$$

$$\Rightarrow \boxed{X = 32.070... \text{ S}}$$

6) [6 marks] 1,2,4-trithiolane (found commonly in shitake mushrooms and truffles) contains 19.334 percent carbon, 3.245 percent hydrogen, and the rest sulphur, all by mass.

a) What is the empirical formula of 1,2,4-trithiolane?

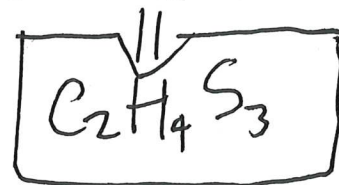
$$\% S = 100 - 3.245 - 19.334 = 77.421$$

$$19.334 \text{ g C} \times \frac{1 \text{ mol}}{12.011 \text{ g}} = 1.60969 \dots \text{ mol C}$$

$$3.245 \text{ g H} \times \frac{1 \text{ mol}}{1.0079 \text{ g}} = 3.2195 \dots \text{ mol H}$$

$$77.421 \text{ g S} \times \frac{1 \text{ mol}}{32.065 \text{ g}} = 2.4145 \dots \text{ mol S}$$

$$C_{1.609} \dots \text{ mol H}_{3.2195} \dots \text{ mol S}_{2.4145} \dots \text{ mol} \Rightarrow CH_2S_{1.5}$$



b) 1,2,4-trithiolane is flammable, according to the equation:



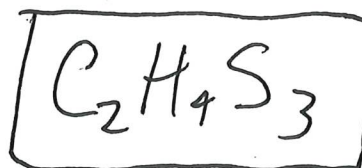
A 254-mg sample of 1,2,4-trithiolane required 490.6 mg of O_2 for complete reaction. What is the molecular formula of 1,2,4-trithiolane?

$$490.6 \times 10^{-3} \text{ g } O_2 \times \frac{1 \text{ mol}}{31.998 \text{ g}} \times \frac{2 \langle \rangle}{15 O_2} = 0.002044 \dots \text{ mol } \langle \rangle$$

$$\frac{254 \times 10^{-3} \text{ g}}{0.002044 \dots \text{ mol}} = 124.248247 \text{ g/mol}$$

$$\begin{array}{r} 2 \times 12.011 \\ 4 \times 1.0079 \\ 3 \times 32.065 \\ \hline 124.2486 \end{array}$$

$$\frac{124.2482}{124.2486} \approx 1, \text{ so}$$



7) [5 marks total] Sulfamethoxazole (SMZ) is an antibiotic used to treat bacterial infections and bronchitis (among others). SMZ contains carbon, hydrogen, nitrogen, oxygen, and sulphur.

a) [4 marks] Combustion of a 511-mg sample of SMZ produced 887.9 mg of CO_2 (44.009 g/mol), 199.9 mg of H_2O (18.015 g/mol), 133.2 mg of N_2O (44.013 g/mol), and 161.5 mg of SO_3 (80.062 g/mol). What is the empirical formula for SMZ?

$$887.9 \times 10^{-3} \text{ g } \text{CO}_2 \times \frac{1 \text{ mol}}{44.009 \text{ g}} \times \frac{1 \text{ C}}{1 \text{ CO}_2} = 0.020175419 \text{ moles C}$$

$$= 0.2423... \text{ g C}$$

$$199.9 \times 10^{-3} \text{ g } \text{H}_2\text{O} \times \frac{1 \text{ mol}}{18.015 \text{ g}} \times \frac{2 \text{ H}}{1 \text{ H}_2\text{O}} = 0.022192617 \text{ mol H}$$

$$= 0.022367939 \text{ g H}$$

$$133.2 \times 10^{-3} \text{ g } \text{N}_2\text{O} \times \frac{1 \text{ mol}}{44.013 \text{ g}} \times \frac{2 \text{ N}}{1 \text{ N}_2\text{O}} = 0.006052757 \text{ mol N}$$

$$= 0.0847... \text{ g N}$$

$$161.5 \times 10^{-3} \text{ g } \text{SO}_3 \times \frac{1 \text{ mol}}{80.062} \times \frac{1 \text{ S}}{1 \text{ SO}_3} = 0.002017187 \text{ mol S}$$

$$= 0.064681091 \text{ g S}$$

$$\therefore \text{mass O} = 511. \times 10^{-3} \text{ g} - 0.2423 \text{ g} - 0.02236... \text{ g} - 0.0847... \text{ g} - 0.06468... \text{ g S}$$

$$= 0.09684... \text{ g} \Rightarrow \text{moles O} = 0.006053069$$

$$\text{C}_{0.02017} \text{H}_{0.02219} \text{N}_{0.006053} \text{O}_{0.006053} \text{S}_{0.002017} \Rightarrow \boxed{\text{C}_{10} \text{H}_{11} \text{N}_3 \text{O}_3 \text{S}}$$

b) [1 mark] The molar mass of SMZ is 253.28 grams. What is the molecular formula of SMZ?

$$\left. \begin{array}{l} 12.011 \times 10 \\ 1.0079 \times 11 \\ 14.007 \times 3 \\ 15.999 \times 3 \\ 32.065 \times 1 \end{array} \right\} \Rightarrow 253.28 \therefore \text{MF is } \boxed{\text{C}_{10} \text{H}_{11} \text{N}_3 \text{O}_3 \text{S}}$$

- 8) [3 marks] A 0.3217 M solution of CaX_2 (where X is an unknown element) is 3.500 percent CaX_2 by mass, and has a density of 1.02 g/mL. What is the element, X?

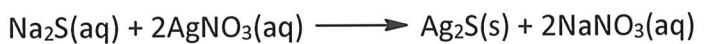
$$1000 \text{ mL} \times \frac{1.02 \text{ g}}{\text{mL}} \times \frac{3.5 \text{ g CaX}_2}{100 \text{ g sol'n}} = 35.7 \text{ g CaX}_2$$

$$\frac{35.7 \text{ g}}{0.3217 \text{ moles}} = 110.97 \dots$$

$$= 40.078 + 2X$$

$$\Rightarrow X = 35.447 \text{ Cl}$$

- 9) [4 marks] The reaction of 25.13 grams of (impure) AgNO_3 (169.872 g/mol) with excess Na_2S resulted in the collection of 11.00 grams of Ag_2S (247.801 g/mol):



If the reaction proceeded with 75.00 percent yield, what was the percent purity of the AgNO_3 ?

$$11.00 \text{ g} \times \frac{100}{75} \times \frac{1 \text{ mol}}{247.801 \text{ g}} \times \frac{2 \text{ AgNO}_3}{1 \text{ Ag}_2\text{S}} \times 169.872 \frac{\text{g}}{\text{mol}}$$

$$= 20.1085 \dots \text{ g}$$

$$\frac{20.1085 \text{ g}}{25.13 \text{ g}} \times 100 = 80.0\%$$

10) [4 marks] If you react 390 mg of $\text{Al}(\text{OH})_3$ (78.00 g/mol) with 60.0 mL of 0.100 M H_2SO_4 :



what will be the concentration of the $\text{Al}_2(\text{SO}_4)_3$ (in moles/L) after reaction?

$$390 \times 10^{-3} \text{ g Al}(\text{OH})_3 \times \frac{1 \text{ mol}}{78 \text{ g}} \times \frac{1 \text{ rxn}}{2 \text{ Al}(\text{OH})_3} = 0.0025 \text{ mol rxn}$$

$$60.0 \text{ mL} \times \frac{0.100 \text{ moles H}_2\text{SO}_4}{1000 \text{ mL}} \times \frac{1 \text{ rxn}}{3 \text{ H}_2\text{SO}_4} = 0.002 \text{ mol rxn}$$

H_2SO_4 is LR

$$0.002 \text{ mol rxn} \times \frac{1 \text{ Al}_2(\text{SO}_4)_3}{1 \text{ rxn}}$$

$$\frac{\quad}{60 \times 10^{-3} \text{ L}} = \boxed{0.033 \dots \text{ M}}$$