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 $Ca(OH)_2$ (74.092 g/mol)?

$2H_3PO_4(aq) + 3Ca(OH)_2(s) \longrightarrow Ca_3(PO_4)_2(s) + 6H_2O(l)$

$$0.5078\ g\ Ca(OH)_2 \times \frac{1\ mol}{74.092\ g} \times \frac{2H_3PO_4}{3Ca(OH)_2} \times \frac{1000\ mL}{0.1048\ moles}$$

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

2) **[3 marks]** A 0.2999-gram sample of $Al_2(CO_3)_3 \cdot nH_2O$ required 25.90 mL of 0.2031 M HCl for complete titration:

$$Al_2(CO_3)_3 \cdot nH_2O(s) + 6HCl(aq) \longrightarrow 2AlCl_3(aq) + 3CO_2(g) + (3+n)H_2O(l)$$

What is the value of n in the formula $Al_2(CO_3)_3 \cdot nH_2O$?

$$25.90\,mL \times \frac{0.2031\ moles\ HCl}{1000\,mL} \times \frac{1\ Al\ldots}{6\,HCl} = 8.76715 \times 10^{-4}\ moles\ Al\ldots$$

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

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

$$\Rightarrow \boxed{n = 5.99968\ldots = 6}$$

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 $Mg(OH)_2$ for complete reaction:

$Mg(OH)_2(aq) + 2HCl(aq) \longrightarrow MgCl_2(aq) + 2H_2O(l)$

What was the concentration of solution **A**?

$18.51\ mL \times \frac{0.002\ moles\ Mg(OH)_2}{1000\ mL} \times \frac{2HCl}{1\ Mg(OH)_2} = 7.404\times10^{-5}$ moles HCl

$[HCl]\ in\ B = \frac{7.404\times10^{-5}\ mol}{20\times10^{-3}\ L} = 3.702\times10^{-3}$ M in 20. mL

moles HCl taken from A:

$3.702\times10^{-3}\ \frac{moles\ HCl}{L} \times 250.0\times10^{-3}\ L = 9.255\times10^{-4}$ moles

So [HCl] in A is $\frac{9.255\times10^{-4}\ moles}{10\times10^{-3}\ L} = \boxed{0.09255\ M}$

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):

$MCl_3(aq) + 3AgNO_3(aq) \longrightarrow 3AgCl(s) + M(NO_3)_3(aq)$

What is the element, M?

$1592.4\times10^{-3}\ g\ AgCl \times \frac{1\ mol}{143.321\ g} \times \frac{1\ MCl_3}{3\ AgCl} = 0.0037\ldots$ mol MCl_3

$\frac{652.1\times10^{-3}\ g}{0.0037\ldots\ mol} = 176.073\ldots\ \frac{g}{mol}$

$= M + 3\times35.453$

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

5) **[4 marks]** A 0.5000-gram sample of $Na_2X_2O_3$ 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:

$Na_2X_2O_3(aq) + 2HCl(aq) \longrightarrow 2NaCl(aq) + XO_2(g) + X(s) + H_2O(l)$

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

$HCl(aq) + NaOH(aq) \longrightarrow NaCl(aq) + H_2O(l)$

What is the element, X?

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

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

$= 0.00295949 \text{ moles}$

$\therefore$ reacted HCl $= 0.00079055$

$\therefore$ reacted $Na_2\cdots = 0.00079\ldots \text{ moles HCl} \times \frac{1 Na_2\cdots}{2 \text{HCl}}$

$= 3.952756 \times 10^{-4} \text{ moles } Na_2\cdots$

mass $Na_2\cdots = 0.5000 \text{ g} \times \frac{25 \text{ mL}}{200 \text{ mL}} = 6.25 \times 10^{-2} \text{ g}$

$\frac{6.25 \times 10^{-2} \text{ g}}{3.95\ldots \times 10^{-4} \text{ moles}} = 158.117\ldots \frac{\text{g}}{\text{mol}}$

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

$\Rightarrow \boxed{x = 32.070\ldots, \text{S}}$

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?

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

$19.334\,g\,C \times \frac{1\,mol}{12.011\,g} = 1.60969\ldots\,mol\,C$

$3.245\,g\,H \times \frac{1\,mol}{1.0079\,g} = 3.2195\ldots\,mol\,H$

$77.421\,g\,S \times \frac{1\,mol}{32.065\,g} = 2.4145\ldots\,mol\,S$

$C_{1.609\ldots\,mol}\,H_{3.2195\ldots\,mol}\,S_{2.4145\ldots\,mol} \Rightarrow CH_2S_{1.5}$

$\Rightarrow C_2H_4S_3$

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

$2(\text{1,2,4-trithiolane}) + 15O_2(g) \longrightarrow \text{products}$

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?

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

$\frac{254 \times 10^{-3}\,g}{0.00204\ldots\,mol} = 124.248247\,\frac{g}{mol}$

2×12.011
4×1.0079
3×32.065
124.2486

$\frac{124.2482}{124.2486} \simeq 1$, so $C_2H_4S_3$

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?

$887.9\times10^{-3}\,g\,CO_2 \times \frac{1\,mol}{44.009\,g} \times \frac{1C}{1CO_2} = 0.020175419\ moles\ C$

$= 0.2423\ldots g\ C$

$199.9\times10^{-3}\,g\,H_2O \times \frac{1\,mol}{18.015\,g} \times \frac{2H}{1H_2O} = 0.022192617\ mol\ H$

$= 0.022367939\ g\ H$

$133.2\times10^{-3}\,g\,N_2O \times \frac{1\,mol}{44.013\,g} \times \frac{2N}{1N_2O} = 0.006052757\ mol\ N$

$= 0.0847\ldots g\ N$

$161.5\times10^{-3}\,g\,SO_3 \times \frac{1\,mol}{80.062} \times \frac{1S}{1SO_3} = 0.002017187\ mol\ S$

$= 0.06468109\ g\ S$

$\therefore$ mass $O = 511.\times10^{-3}\,g - 0.2423\,g - 0.02236\ldots g - 0.0847\ldots g - 0.06468\ldots g\ S$

$= 0.09684\ldots g \Rightarrow$ moles $O = 0.006053069$

$C_{0.02017}H_{0.02219}N_{0.006053}O_{0.006053}S_{0.002017} \Rightarrow \boxed{C_{10}H_{11}N_3O_3S}$

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

12.011×10
1.0079×11
14.007×3
15.999×3
32.065×1

$\Rightarrow 253.28 \therefore$ MF is $\boxed{C_{10}H_{11}N_3O_3S}$

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?

$$1000\,mL \times \frac{1.02\,g}{mL} \times \frac{3.5\,g\,CaX_2}{100\,g\,sol'n} = 35.7\,g\,CaX_2$$

$$\frac{35.7\,g}{0.3217\,moles} = 110.97\ldots$$

$$= 40.078 + 2X$$

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

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):

$$Na_2S(aq) + 2AgNO_3(aq) \longrightarrow Ag_2S(s) + 2NaNO_3(aq)$$

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

$$11.00\,g \times \frac{100}{75} \times \frac{1\,mol}{247.801\,g} \times \frac{2\,AgNO_3}{1\,Ag_2S} \times \frac{169.872\,g}{mol}$$

$$= 20.1085\ldots g$$

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

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

$2Al(OH)_3(s) + 3H_2SO_4(aq) \longrightarrow Al_2(SO_4)_3(aq) + 6H_2O(l)$

what will be the concentration of the $Al_2(SO_4)_3$ (in moles/L) after reaction?

$390\times10^{-3}\,g\ Al(OH)_3 \times \frac{1\ mol}{78\,g} \times \frac{1\ rxn}{2\,Al(OH)_3} = 0.0025\ mol\ rxn$

$60.0\ mL \times \frac{0.100\ moles\ H_2SO_4}{1000\ mL} \times \frac{1\ rxn}{3\ H_2SO_4} = 0.002\ mol\ rxn$

H_2SO_4 is LR

$$\frac{0.002\ mol\ rxn \times \frac{1\ Al_2(SO_4)_3}{1\ rxn}}{60\times10^{-3}\ L} = \boxed{0.033\ldots\ M}$$