Chemistry 1154 R25 Fall 2023 Test 1

Friday, September 29, 2023 Time: 1 hour 50 minutes

Name: ANSWERS Student #: ______________________

*This test consists of **nine** pages of questions, a page of useful constants and conversions, and a periodic table. Please ensure that you have a complete test and, if you do not, obtain one from me **immediately**. There are **39** marks available. Good luck!*

1) **[2 marks]** How many mL of 0.01056 M H_3PO_4 are required to titrate 20.00 mL of 0.01188 M $Ca(OH)_2$?

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

$$20\text{ mL} \times \frac{0.01188\text{ moles } Ca(OH)_2}{L} \times \frac{2H_3PO_4}{3\,Ca(OH)_2} \times \frac{1L}{0.01056\text{ moles}}$$

$$= \boxed{15.00\text{ mL}}$$

2) **[3 marks]** When 264.6 mg of MCl_2 is mixed with excess $AgNO_3$, 400.0 mg of AgCl (143.32 g/mol) is collected:

$$MCl_2(aq) + 2AgNO_3(aq) \longrightarrow M(NO_3)_2(aq) + 2AgCl(s)$$

What is the metal, M?

$$400 \text{ mg AgCl} \times \frac{1 \text{ mol}}{143.32} \times \frac{1\, MCl_2}{2\, AgCl} = 1.395 \text{ mmol } MCl_2$$

$$\frac{264.6 \text{ mg}}{1.395 \text{ mmol}} = 189.61236 \frac{g}{mol}$$

$$= M + 35.453 \times 2$$

$$\Rightarrow M = 118.70636$$

$$= Sn$$

3) **[4 marks]** A 789.6-mg sample of $Na_2X_2O_3$ was reacted with 20 mL of 0.500 M $KMnO_4$:

$5Na_2X_2O_3(aq) + 14HCl(aq) + 8KMnO_4(aq) \longrightarrow$ <products>

The resulting solution was made up to a total volume of 200.0 mL and a 25.00-mL aliquot taken. The excess $KMnO_4$ in the aliquot required 15.70 mL of 0.0400 M $Na_2C_2O_4$ for complete titration:

$2KMnO_4(aq) + 5Na_2C_2O_4(aq) + 16HCl(aq) \longrightarrow$ <products>

What is the element, X?

$15.70 \text{ mL} \times 0.04 \frac{\text{moles } Na_2C_2O_4}{L} \times \frac{2KMnO_4}{5Na_2C_2O_4}$

$= 0.2512 \text{ mmol}$ excess $KMnO_4$ in 25 mL

$0.2512 \times \frac{200}{25} = 2.0096$ mmol excess $KMnO_4$ in 200 mL

total $KMnO_4 = 20 \text{ mL} \times 0.5 \frac{\text{mol}}{L} = 10$ mmol

∴ reacted $KMnO_4 = 10 - 2.0096 = 7.9904$ mmol

∴ mmol $Na_2X_2O_3 = 7.9904$ mmol $KMnO_4 \times \frac{5Na_2X_2O_3}{8KMnO_4}$

$= 4.994$ mmol

$\frac{789.6 \text{ mg}}{4.994 \text{ mmol}} = 158.109... \frac{g}{mol}$

$\Rightarrow$ X = 32.066...

≡ S

4) **[6 marks]** "Compound X" consists of 38.703 percent carbon, 51.554 percent oxygen, and the rest hydrogen, all by mass.

a) What is the empirical formula of "Compound X"?

%H = 100 − 38.703 − 51.554 = 9.743

assume 100 g sample...

$$38.703\,g\,C \times \frac{1\,mol}{12.011\,g} = 3.22..\,mol\,C$$

$$9.743\,g\,H \times \frac{1\,mol}{1.0079\,g} = 9.66..\,mol\,H$$

$$51.554\,g\,O \times \frac{1\,mol}{15.999\,g} = 3.22..\,mol\,O$$

$$C_{3.22}H_{9.66}O_{3.22} \Rightarrow \boxed{CH_3O}$$

b) As a gas, "Compound X" has a density of 0.167 g/L when its pressure is 50 torr and its temperature is 24.83°C. What is the molecular formula of "Compound X"?

$$MM = \frac{0.167 \times 62.3635... \times 297.98}{50} = 62.06...\,\frac{g}{mol}$$

12.011
+ 1×15.999
+ 3×1.0079

31.0337

$$\frac{62.06}{31.03} \simeq 2, \text{ so } \boxed{C_2H_6O_2}$$

5) **[6 marks]** A 690.7-mg sample of "Compound Y", known to contain C, H, and O, was burned, and 990.2 mg of CO_2 (44.009 g/mol) and 540.5 mg of H_2O (18.015 g/mol) collected.

a) What is the empirical formula of "Compound Y"?

$$990.2\ mg\ CO_2 \times \frac{1\ mol}{44.009\ g} \times \frac{1\ C}{1\ CO_2} = 22.49\ldots\ mmol\ C$$

$$540.5\ mg\ H_2O \times \frac{1\ mol}{18.015\ g} \times \frac{2\ H}{1\ H_2O} = 60\ldots\ mmol\ H$$

$$690.7 - 22.49\ldots\ mmol \times 12.011\ \frac{g}{mol} - 60.\ldots\ mmol \times 1.0079\ \frac{g}{mol}$$

$= 359.9\ldots$ mg O

$= 22.499\ldots$ mmol O

$$C_{22.49}H_{60}O_{22.49} \Rightarrow CH_{2.66\ldots}O$$

$\Downarrow \times 3$

$$\boxed{C_3H_8O_3}$$

b) "Compound Y" reacts with alkali metals (like sodium) according to the balanced equation:

$6Na(s) + 2Y \longrightarrow$ <products>

A fresh 920.9-mg sample of "Compound Y" required 689.7 mg of sodium for complete reaction. What is the molecular formula of "Compound Y"?

$$689.7 \text{ mg Na} \times \frac{1 \text{ mol}}{22.990 \text{ g}} \times \frac{2Y}{6Na} = 10 \text{ mmol } Y$$

$$\frac{920.9 \text{ mg}}{10 \text{ mmol}} = 92.09 \frac{\text{g}}{\text{mol}}$$

3×12.011
8×1.0079
3×15.999
92.0932

$$n = \frac{92.09...}{92.0932} \simeq 1.50$$

$C_3H_8O_3$

6) **[4 marks]** How many grams of 70.711-percent pure $Ti(NO_3)_4$ (295.88 g/mol) are required to collect 52.348 grams of $Ti_3(PO_4)_4$ (523.48 g/mol) if the reaction

$$3Ti(NO_3)_4(aq) + 4Na_3PO_4(aq) \longrightarrow Ti_3(PO_4)_4(s) + 12NaNO_3(aq)$$

proceeds with an 80.00 percent yield?

$$52.348\,g \times \frac{100}{80} \times \frac{1\,mol}{523.48\,g} \times \frac{3\,Ti(NO_3)_4}{1\,Ti_3(PO_4)_4} \times \frac{295.88\,g}{mol} \times \frac{100}{70.711}$$

$$= \boxed{156.91...\,g}$$

7) **[3 marks]** A 0.46 M solution of NaX (where X is an unknown element) has a density of 1.02 g/mL and is found to be 6.76 percent NaX by mass. What is the element, X?

assume 1000 mL:

$$1020\,g \times \frac{6.76\,g\,NaX}{100\,g} = 68.952\,g$$

$$\frac{68.952\,g}{0.46\,moles} = 149.89\,\frac{g}{mol}$$

$$\Rightarrow \boxed{X = 126.91 \equiv I}$$

8) **[4 marks]** If you mix 200 mL of 0.0100 M $Mg(OH)_2$ with 300 mL of 0.0100 M HCl:

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

what will be the $[MgCl_2]$ (in moles/L) after reaction?

$$200\ mL \times \frac{0.01\ moles\ Mg(OH)_2}{L} \times \frac{1\ MgCl_2}{1\ Mg(OH)_2} = 2\ mmol\ MgCl_2$$

$$300\ mL \times \frac{0.01\ moles\ HCl}{L} \times \frac{1\ MgCl_2}{2HCl} = 1.5\ mmol\ MgCl_2$$

$$\frac{1.5\ mmol}{500\ mL} = \boxed{3 \times 10^{-3}\ M}$$

9) **[3 marks]** The Sinn UX EZM 2 B GSG9 diving watch is rated water-resistant to a depth of 5000 metres (yes, five *thousand* metres). Assuming the density of seawater is 1.025 g/cm^3, how many atmospheres of pressure will the Sinn UX EZM 2 B GSG9 withstand?

$$\frac{1.025\ g}{cm^3} \times \frac{1\ kg}{1000\ g} \times \left(\frac{100\ cm}{1\ m}\right)^3 = 1025\ \frac{kg}{m^3}$$

$$1025 \times 9.80665 \times 5000 \times \frac{1\ atm}{101325\ Pa} = \boxed{496\ atm}$$

10) **[4 marks]** If you want to take your fancy new Sinn watch scuba diving, you'll need an appropriate mixture of gases in your scuba tank. One such might be "Tx 20/40," which is 20% oxygen, 40% helium and the remaining 40% nitrogen (all percents by mole). According to Wikipedia this mixture would be suitable for dives up to 60 metres (rather less than 5000 metres, I know, but hey – you have to start somewhere...). If the pressure of oxygen must not exceed 1.40 bar, what mass of each of the three gases must be in the tank? Assume that the tank has a volume of 15 litres, and the temperature of the gases in the tank is 15°C.

$$P_{TOT} = \frac{1.4}{0.2} = 7 \text{ bar}$$

$$n_{O_2} = \frac{(1.4)(15)}{(0.083\ldots)(288.15)} = 0.876$$

$$m_{O_2} = 0.876 \text{ mol} \times 31.998 \frac{g}{mol} = \boxed{28.05 g}$$

$P_{He} = 2P_{O_2}$, so...

$$n_{He} = n_{N_2} = 2n_{O_2} = 1.753\ldots$$

$$m_{He} = 1.753 \text{ mol} \times 4.0026 \frac{g}{mol} = \boxed{7.017 g}$$

$$m_{N_2} = 1.753 \text{ mol} \times 28.014 \frac{g}{mol} = \boxed{49.11 g}$$