

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 $\text{Ca}(\text{OH})_2$?



$$20 \text{ mL} \times 0.01188 \frac{\text{moles Ca}(\text{OH})_2}{\text{L}} \times \frac{2\text{H}_3\text{PO}_4}{3\text{Ca}(\text{OH})_2} \times \frac{1\text{L}}{0.01056 \text{ moles}}$$

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

- 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:



What is the metal, M?

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

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

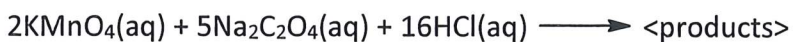
$$= M + 35.453 \times 2$$

$$\Rightarrow M = 118.70636$$
$$\equiv Sn$$

3) [4 marks] A 789.6-mg sample of $\text{Na}_2\text{X}_2\text{O}_3$ was reacted with 20 mL of 0.500 M KMnO_4 :



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 $\text{Na}_2\text{C}_2\text{O}_4$ for complete titration:



What is the element, X?

$$15.70 \text{ mL} \times 0.04 \frac{\text{mmoles Na}_2\text{C}_2\text{O}_4}{\text{mL}} \times \frac{2 \text{ KMnO}_4}{5 \text{ Na}_2\text{C}_2\text{O}_4}$$

$$= 0.2512 \text{ mmol excess KMnO}_4 \text{ in } 25 \text{ mL}$$

$$0.2512 \times \frac{200}{25} = 2.0096 \text{ mmol excess KMnO}_4 \text{ in } 200 \text{ mL}$$

$$\text{total KMnO}_4 = 20 \text{ mL} \times 0.5 \frac{\text{mol}}{\text{L}} = 10 \text{ mmol}$$

$$\therefore \text{reacted KMnO}_4 = 10 - 2.0096 = 7.9904 \text{ mmol}$$

$$\therefore \text{mmol Na}_2\text{X}_2\text{O}_3 = 7.9904 \text{ mmol KMnO}_4 \times \frac{5 \text{ Na}_2\text{X}_2\text{O}_3}{8 \text{ KMnO}_4}$$

$$= 4.994 \text{ mmol}$$

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

$$\Rightarrow \boxed{X = 32.066 \dots}$$

$$\equiv \text{S}$$

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"?

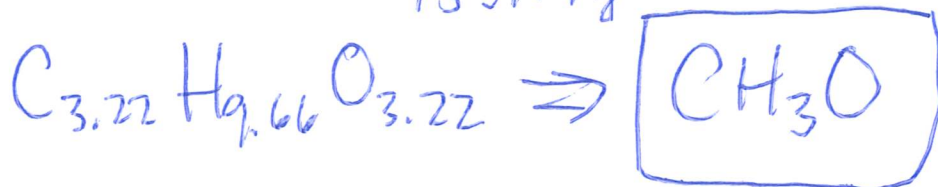
$$\%H = 100 - 38.703 - 51.554 = 9.743$$

assume 100 g sample...

$$38.703 \text{ g C} \times \frac{1 \text{ mol}}{12.011 \text{ g}} = 3.22 \dots \text{ mol C}$$

$$9.743 \text{ g H} \times \frac{1 \text{ mol}}{1.0079 \text{ g}} = 9.66 \dots \text{ mol H}$$

$$51.554 \text{ g O} \times \frac{1 \text{ mol}}{15.999 \text{ g}} = 3.22 \dots \text{ mol O}$$



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"?

$$\text{MM} = \frac{0.167 \times 62.3635 \dots \times 297.98}{50} = 62.06 \dots \frac{\text{g}}{\text{mol}}$$

$$\begin{array}{r} 12.011 \\ + 3 \times 15.999 \\ + 3 \times 1.0079 \\ \hline 31.0337 \end{array}$$

$$\frac{62.06}{31.03} \approx 2, \text{ so } \boxed{\text{C}_2\text{H}_6\text{O}_2}$$

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 CO₂ (44.009 g/mol) and 540.5 mg of H₂O (18.015 g/mol) collected.

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

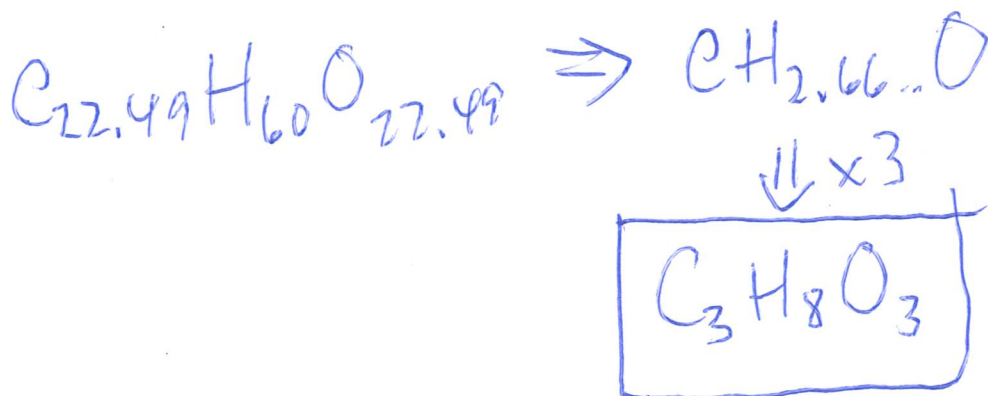
$$990.2 \text{ mg CO}_2 \times \frac{1 \text{ mol}}{44.009 \text{ g}} \times \frac{1 \text{ C}}{1 \text{ CO}_2} = 22.49 \dots \text{ mmol C}$$

$$540.5 \text{ mg H}_2\text{O} \times \frac{1 \text{ mol}}{18.015 \text{ g}} \times \frac{2 \text{ H}}{1 \text{ H}_2\text{O}} = 60 \dots \text{ mmol H}$$

$$690.7 - 22.49 \dots \text{ mmol} \times 12.011 \frac{\text{g}}{\text{mol}} - 60 \dots \text{ mmol} \times 1.0079 \frac{\text{g}}{\text{mol}}$$

$$= 359.9 \dots \text{ mg O}$$

$$= 22.499 \dots \text{ mmol O}$$



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



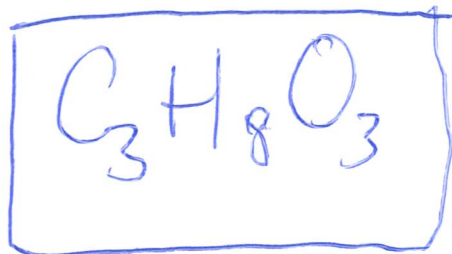
A fresh 920.9-mg sample of "Compound Y" required 689.7 mg of sodium for complete reaction. What is the molecular formula of "Compound Y"?

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

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

$$\begin{array}{r} 3 \times 12.011 \\ 8 \times 1.0079 \\ 3 \times 15.999 \\ \hline 92.0932 \end{array}$$

$$n = \frac{92.09 \dots}{92.0932} \approx 1.50$$



- 6) [4 marks] How many grams of 70.711-percent pure $\text{Ti}(\text{NO}_3)_4$ (295.88 g/mol) are required to collect 52.348 grams of $\text{Ti}_3(\text{PO}_4)_4$ (523.48 g/mol) if the reaction



proceeds with an 80.00 percent yield?

$$52.348 \text{ g} \times \frac{100}{80} \times \frac{1 \text{ mol}}{523.48 \text{ g}} \times \frac{3 \text{ Ti}(\text{NO}_3)_4}{1 \text{ Ti}_3(\text{PO}_4)_4} \times \frac{295.88 \text{ g}}{\text{mol}}$$

$$\times \frac{100}{70.711}$$

$$= 156.91 \text{ g}$$

- 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:

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

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

$$\Rightarrow X = 126.91 \approx \text{I}$$

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



what will be the $[\text{MgCl}_2]$ (in moles/L) after reaction?

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

$$300 \text{ mL} \times \frac{0.01 \text{ moles HCl}}{\text{L}} \times \frac{1 \text{ MgCl}_2}{2 \text{ HCl}} = 1.5 \text{ mmol MgCl}_2$$

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

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?

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

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

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.

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

$$n_{\text{O}_2} = \frac{(1.4)(15)}{(0.08314)(288.15)} = 0.876$$

$$m_{\text{O}_2} = 0.876 \text{ mol} \times \frac{31.998 \text{ g}}{\text{mol}} = 28.05 \text{ g}$$

$$P_{\text{He}} = 2P_{\text{O}_2}, \text{ so ...}$$

$$n_{\text{He}} = n_{\text{N}_2} = 2n_{\text{O}_2} = 1.753 \text{ ...}$$

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

$$m_{\text{N}_2} = 1.753 \text{ mol} \times \frac{28.014 \text{ g}}{\text{mol}} = 49.11 \text{ g}$$