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Chemistry 1110 R10 Fall 2023 Test 1

Thursday, September 28, 2023 Time: 1 hour 50 minutes

Name: ANSWERS Student #: _____

*This test consists of **eight** 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 **40** marks available. Good luck!*

1) **[3 marks]** How many mL of 0.1116 M H_3PO_4 are required to completely titrate a 635.9 mg sample of Na_2CO_3 (105.99 g/mol)?

$2H_3PO_4(aq) + 3Na_2CO_3(aq) \longrightarrow 2Na_3PO4(aq) + 3CO_2(g) + 3H_2O(l)$

$$635.9\ mg\ Na_2CO_3 \times \frac{1\ mol}{105.99\ g} \times \frac{2H_3PO_4}{3Na_2CO_3} \times \frac{1\ L}{0.1116\ mol}$$

$$= \boxed{35.84\ mL}$$

2) **[3 marks]** A 612.7-mg sample of CuX_2 was reacted with excess Na_3PO_4 and 578.1 mg of $Cu_3(PO_4)_2$ (380.58 g/mol) collected:

$3CuX_2(aq) + 2Na_3PO_4(aq) \longrightarrow Cu_3(PO_4)_2(s) + 6NaX(aq)$

What is the element, X?

$$578.1\ mg\ Cu_3(PO_4)_2 \times \frac{1\ mol}{380.58\ g} \times \frac{3\ CuX_2}{1\ Cu_3(PO_4)_2} = 4.55...\ mmol\ CuX_2$$

$$\frac{612.7\ mg}{4.55...\ mmol} = 134.452...\ \frac{g}{mol}$$

$$= 63.546 + 2x$$

$$\Rightarrow \boxed{x = 35.453 \text{ or } Cl}$$

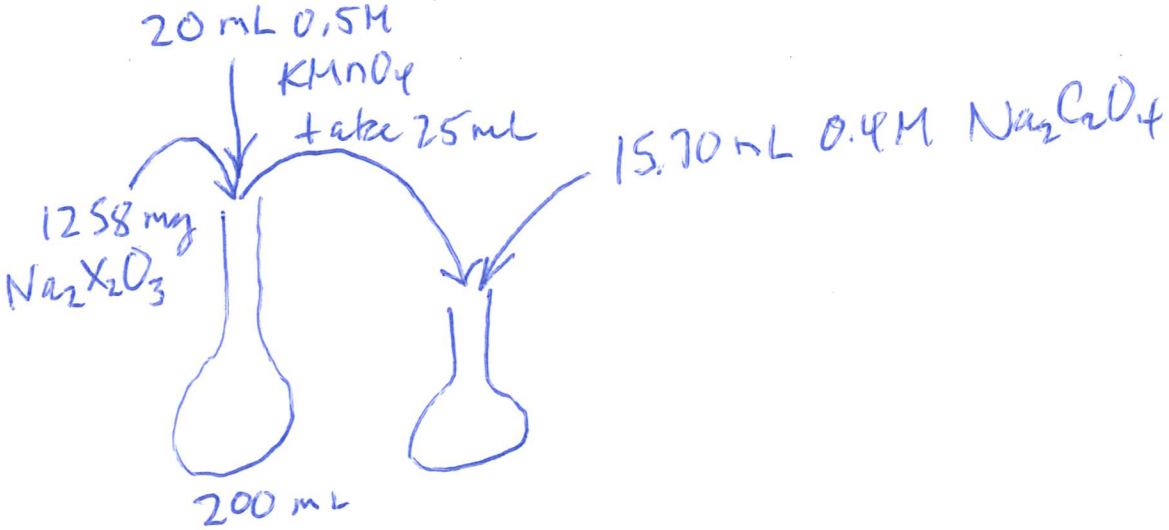
3) **[4 marks]** A 1258.0-mg sample of $Na_2X_2O_3$ was reacted with 20 mL of 0.500 M $KMnO_4$:

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



$Na_2C_2O_4$: $15.70\ mL \times \frac{0.04\ moles\ Na_2C_2O_4}{L} = 0.628\ mmoles\ in\ 25\ mL$

$KMnO_4$: $0.628\ mmol\ Na_2C_2O_4 \times \frac{2\ KMnO_4}{5\ Na_2C_2O_4} = 0.2512\ mmol$

∴ excess $KMnO_4$ in 200 mL:

$0.2512\ mmol \times \frac{200}{25} = 2.0096\ mmol$

∴ reacted $KMnO_4$ in 200 mL:

$20\ mL \times 0.5\ \frac{moles}{L}\ KMnO_4 - 2.0096 = 7.9904\ mmol$

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

$= 4.994\ mmol$

∴ $MM = \frac{1258.0}{4.994} = 251.9 \Rightarrow$ **$X = 78.96 \equiv Se$**

4) **[6 marks]** Caffeine is known to be 49.481 percent carbon, 28.852 percent nitrogen, and 16.477 percent oxygen (all by mass); the rest is hydrogen.

a) What is the empirical formula of caffeine?

$\%H = 100 - 49.481 - 28.852 - 16.477 = 5.19$

assume 100 g sample:

$49.481\ g\ C \times \frac{1\ mol}{12.011\ g} = 4.11\ldots\ mol\ C$

$5.19\ g\ H \times \frac{1\ mol}{1.0079\ g} = 5.149\ldots\ mol\ H$

$28.852\ g\ N \times \frac{1\ mol}{14.007\ g} = 2.0598\ldots\ mol\ N$

$16.477\ g\ O \times \frac{1\ mol}{15.999\ g} = 1.0298\ldots\ mol\ O$

$C_{4.11}H_{5.15}N_{2.06}O_{1.03}$

$\Downarrow$

$\boxed{C_4H_5N_2O}$

b) Caffeine is a base; there are four potential parts of it where an acid (like HCl) could attach. If all of them attached an HCl, the balanced reaction would be:

Caffeine + 4HCl(aq) ⟶ <products>

A fresh 592.5-mg sample of caffeine reacting in this way required 39.00 mL of 0.3129 M HCl for complete reaction. What is the molecular formula of caffeine?

$39\ mL \times 0.3129\ \frac{moles\ HCl}{L} \times \frac{1\ caf}{4\ HCl} = 3.05\ldots\ \frac{mmol}{caf}$

$\frac{592.5\ mg}{3.05\ldots\ mmol} = 194.2\ldots\ \frac{g}{mol}$

4×12.011
$+ 5 \times 1.0079$
$+ 2 \times 14.007$
$+ 1 \times 15.999$
$= 97.0965$

$\frac{194.2\ldots}{97.09\ldots} \simeq 2$, so MF is

$\boxed{C_8H_{10}N_4O_2}$

5) **[6 marks]** Propylene glycol is known to contain C, H, and O.

a) Combustion of a 501.6-mg sample of propylene glycol resulted in the production of 870.3 mg of CO_2 (44.009 g/mol) and 475.0 mg of H_2O (18.015 g/mol). What is the empirical formula of propylene glycol?

$870.3\ mg\ CO_2 \times \frac{1\ mol}{44.009\ g} = 19.77...\ mmol\ CO_2$

$= 19.77\ mmol\ C$ in sample

$475.0\ mg\ H_2O \times \frac{1\ mol}{18.015\ g} = 26.366...\ mmol\ H_2O$

$= 52.73...\ mmol\ H$ in sample

Mass O:

$501.6\ mg - 19.77\ mmol \times 12.011\ \frac{g}{mol} - 52.73\ mmol \times 1.0079\ \frac{g}{mol}$

$= 210.9\ mg$; $210.9\ mg\ O \times \frac{1\ mol}{15.999\ g} = 13.183\ mmol\ O$

$C_{19.77}H_{52.73}O_{13.183} \Rightarrow C_{1.5}H_4O \Rightarrow \boxed{C_3H_8O_2}$

$(3 \times 12.011 + 8 \times 1.0079 + 15.999 \times 2 = 76.0942\ \frac{g}{mol})$

b) As a gas, propylene glycol has a density of 0.211 g/L at a pressure of 50 torr and a temperature of 15.99°C. What is the molecular formula of propylene glycol?

$MM \times P = D \times R \times T$

$\Rightarrow MM = \frac{(0.211)(62.3635...)(289.14)}{50} = 76.09...$

$n = \frac{76.09...}{76.0942} = 1$, so $\boxed{C_3H_8O_2}$

6) **[4 marks]** How many grams of 62.5 percent pure $CaCl_2$ (110.98 g/mol) are required to collect 14.58 grams of AgCl (143.32 g/mol) if the reaction

$CaCl_2(aq) + 2AgNO_3(aq) \longrightarrow Ca(NO_3)_2(aq) + 2AgCl(s)$

proceeds with an 80.0 percent yield?

$$14.58\,g \times \frac{100}{80} \times \frac{1\,mol}{143.32\,g} \times \frac{1\,CaCl_2}{2\,AgCl} \times \frac{110.98\,g}{1\,mol} \times \frac{100}{62.5}$$

$$= \boxed{11.29\,g}$$

7) **[3 marks]** A 0.500 M solution of NaBr (102.9 g/mol) is 5.059 percent NaBr by mass. What is the density of the solution? Give your answer in g/mL.

Assume 1L of solution.
(so V = 1000 mL)

$$0.5\ moles\ NaBr \times \frac{102.9\,g}{mol} \times \frac{100\,g\ soln}{5.059\,g\ NaBr} = 1017\,g\ soln.$$

$$D = \frac{1017\,g}{1000\,mL} = \boxed{1.017\,\frac{g}{mL}}$$

8) **[4 marks]** If you mix 49.23 grams of $Ca(NO_3)_2$ (164.1 g/mol) with 49.18 grams of Na_3PO_4 (163.9 g/mol), how many grams of $Ca_3(PO_4)_2$ (310.2 g/mol) should you collect?

$3Ca(NO_3)_2(aq) + 2Na_3PO_4(aq) \longrightarrow Ca_3(PO_4)_2(s) + 6NaNO_3(aq)$

$$49.23\,g\ Ca(NO_3)_2 \times \frac{1\ mol}{164.1\,g} \times \frac{1\ Ca_3(PO_4)_2}{3\ Ca(NO_3)_2} \times 310.2\ \frac{g}{mol}$$

$$\approx 31.02\,g$$

$$49.18\,g\ Na_3PO_4 \times \frac{1\ mol}{163.9\,g} \times \frac{1\ Ca_3(PO_4)_2}{2\ Na_3PO_4} \times 310.2\ \frac{g}{mol}$$

$$\approx 46.53\ldots g$$

$$\therefore \boxed{31.02\,g}$$

9) **[3 marks]** If you wanted to build a barometer that used maple syrup to indicate its pressures (decidedly more delicious and less lethal than mercury), how many metres tall would it need to be to indicate a pressure of 765.9 torr? The density of maple syrup is 1.37 g/cm^3.

$$1.37\ \frac{g}{cm^3} \times \left(\frac{100\,cm}{1\,m}\right)^3 \times \frac{1\,kg}{1000\,g} = 1370\ \frac{kg}{m^3}$$

$$765.9\,torr \times \frac{101325\,Pa}{760\,torr} = 1370 \times 9.80665 \times h$$

$$\Rightarrow \boxed{h = 7.60\,m}$$

10) **[4 marks]** The Sinn UX EZM 2 B GSG9 diving watch is waterproof to 5000 metres (yes, five *thousand* metres) of seawater. If you were to dive into maple syrup (density 1.37 g/cm^3) instead of seawater (1.025 g/cm^3), to how many feet would you be able to dive with the Sinn UX EZM 2 B GSG9 diving watch? One foot is 12 inches, and one inch is 2.54 cm.

$$1.025 \times 9.80665 \times 5000 = 1.37 \times 9.80665 \times h$$

$$\Rightarrow h = 3740.8 \text{ m}$$

$$3740.8 \text{ m} \times \frac{100 \text{ cm}}{1 \text{ m}} \times \frac{1 \text{ in}}{2.54 \text{ cm}} \times \frac{1 \text{ ft}}{12 \text{ in}}$$

$$= \boxed{12,273.2 \text{ ft}}$$