

Chemistry 1154 Spring 2011 Test 1

Wednesday, January 26, 2011

Time: 1 hour 50 minutes

Name: ANSWERS

Student Number: _____

This exam consists of nine pages of questions, a periodic table, and a page of useful constants. Please ensure that you have a complete paper and, if you do not, obtain one from me immediately. There are 38 marks available. Good luck!

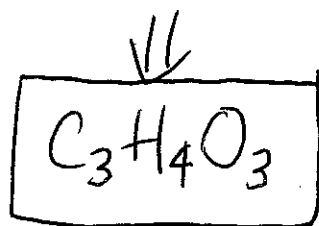
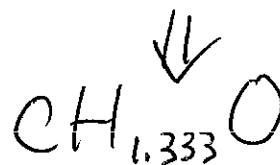
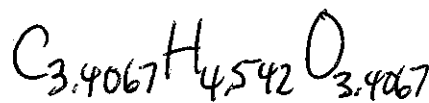
- 1) [4 marks] "Compound X" is 40.918 percent carbon by mass, 4.578 percent hydrogen by mass, and the rest oxygen.

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

$$40.918 \text{ g C} \times \frac{1 \text{ mol}}{12.011 \text{ g}} = 3.4067 \text{ mol C}$$

$$4.578 \text{ g H} \times \frac{1 \text{ mol}}{1.0079 \text{ g}} = 4.542 \text{ mol H}$$

$$54.504 \text{ g O} \times \frac{1 \text{ mol}}{15.999 \text{ g}} = 3.4067 \text{ mol O}$$



- b) As a gas, "Compound X" has a density of 2.267 g/L at 200°C and 0.500 atm of pressure. What is the molecular formula of "Compound X"?

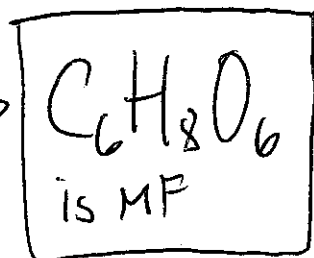
Assume 1L, so that:

$$m = 2.267 \text{ g}$$

$$\begin{array}{r} 3 \times 12.011 \\ + 4 \times 1.0079 \\ + 3 \times 15.999 \\ \hline 88.062 \end{array}$$

$$n = \frac{PV}{RT} = \frac{(0.500 \text{ atm})(1 \text{ L})}{(0.0820575 \text{ L}\cdot\text{atm}\cdot\text{mol}^{-1}\cdot\text{K})(473.15 \text{ K})} = 0.0129 \text{ moles}$$

$$\text{MM: } \frac{2.267 \text{ g}}{0.0129 \text{ moles}} = 176 \frac{\text{g}}{\text{mol}} \quad \frac{176}{88.062} \approx 2, \text{ so}$$



- 2) [6 marks] A 996.8-mg sample of "Compound Y," known to contain carbon, hydrogen, and oxygen, was burned and 2112 mg of CO_2 (44.0 g/mol) and 324 mg of H_2O (18.0 g/mol) collected.

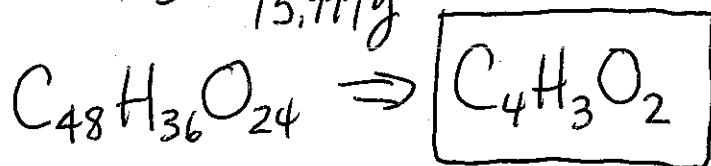
a) What is the empirical formula of "Compound Y"?

$$n_{\text{C}} : 2112 \text{ mg } \text{CO}_2 \times \frac{1 \text{ mol}}{44.0 \text{ g}} \times \frac{1 \text{ C}}{1 \text{ CO}_2} = 48.0 \text{ mmol C}$$

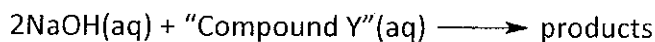
$$n_{\text{H}} : 324 \text{ mg } \text{H}_2\text{O} \times \frac{1 \text{ mol}}{18.0 \text{ g}} \times \frac{2 \text{ H}}{1 \text{ H}_2\text{O}} = 36.0 \text{ mmol H}$$

$$m_{\text{O}} : 996.8 \text{ mg} - 48.0 \text{ mmol C} \times \frac{12.011 \text{ g}}{\text{mol}} - 36.0 \text{ mmol H} \times \frac{1.0079 \text{ g}}{\text{mol}} = 384 \text{ mg}$$

$$n_{\text{O}} : 384 \text{ mg } \text{O} \times \frac{1 \text{ mol}}{15.999 \text{ g}} = 24.0 \text{ mmol O}$$



- b) A fresh 1.6613-gram sample of "Compound Y" reacted completely with 25.0 mL of 0.80 M NaOH according to the (balanced) equation:



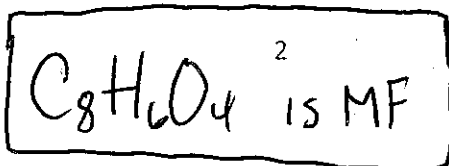
What is the molecular formula of "Compound Y"?

$$n_{\text{Y}} : 25.0 \text{ mL} \times \frac{1 \text{ L}}{1000 \text{ mL}} \times \frac{0.80 \text{ moles}}{1 \text{ L}} \times \frac{1 \text{ Y}}{2 \text{ NaOH}} = 0.010 \text{ mol}$$

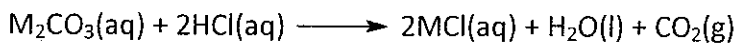
$$\frac{1.6613 \text{ g}}{0.010 \text{ mol}} = 166.13 \frac{\text{g}}{\text{mol}} \quad \begin{array}{r} 4 \times 12.011 \\ + 3 \times 1.0079 \\ + 2 \times 15.999 \end{array}$$

$$\frac{166.13}{83.066} \approx 2, \text{ so}$$

$$83.066$$



- 3) [3 marks] A 954-mg sample of M_2CO_3 was reacted with excess HCl and the resulting CO_2 collected and purified:



If the CO_2 collected occupied 201.73 mL at STP, what is the metal, M?

$$n_{CO_2} = \frac{(1 \text{ atm})(201.73 \text{ mL})}{(0.0820575 \frac{\text{L}\cdot\text{atm}}{\text{mol}\cdot\text{K}})(273.15 \text{ K})} = 9.0002 \text{ mmol } CO_2$$

~~9.0002~~
= mmol M_2CO_3 (by stoich)

$$\frac{954 \text{ mg}}{9.0002 \text{ mmol}} = 106 \frac{\text{g}}{\text{mol}}$$

$$2M + 12.011 + 3 \times 15.999 = 106$$

$$\therefore M = 23 \frac{\text{g}}{\text{mol}}, \text{ which is } \boxed{\text{Na}}$$

- 4) [2 marks] A bag of 0.900% (by mass) NaX solution ("X" is some unknown element) has a density of 1.007179 g/mL and a concentration of NaX of 0.1551 M. What is the element, "X"?

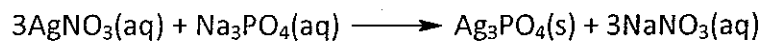
$$1.007179 \frac{\text{g sol'n}}{\text{mL sol'n}} \times \frac{1000 \text{ mL}}{1 \text{ L}} \times \frac{0.900 \text{ g NaX}}{100 \text{ g sol'n}} \times \frac{1 \text{ L sol'n}}{0.1551 \text{ moles}}$$

$$= 58.4 \frac{\text{g NaX}}{\text{mol}}$$

$$\text{So } 22.99 + X = 58.4$$

$$\Rightarrow X = 35.45, \text{ which is } \boxed{\text{Cl}}$$

- 5) [3 marks] How many grams of 80.0-percent pure AgNO_3 (169.9 g/mol) are required to prepare 3.1393 grams of Ag_3PO_4 (418.6 g/mol) if the reaction



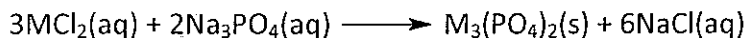
is known to proceed with 75.0 percent yield?

$$3.1393 \text{ g actual} \times \frac{100\% \text{ theo}}{75\% \text{ actual}} \times \frac{1 \text{ mol Ag}_3\text{PO}_4}{418.6 \text{ g}}$$

$$\times \frac{3 \text{ AgNO}_3}{1 \text{ Ag}_3\text{PO}_4} \times \frac{169.9 \text{ g}}{1 \text{ mol}} \times \frac{100\% \text{ impure}}{80\% \text{ pure}}$$

$$= \boxed{6.37 \text{ g}}$$

- 6) [4 marks] In one experiment, 760.5 mg of MCl_2 ("M" is an unknown element) was reacted with excess Na_3PO_4 and 715.0 mg of $M_3(PO_4)_2(s)$ were collected:



What is the metal, M?

$$760.5 \text{ mg } MCl_2 \times \frac{1 \text{ mol}}{(M + 70.906) \text{ g}} \times \frac{1 M_3(PO_4)_2}{3 MCl_2}$$

$$= 715.0 \text{ mg} \times \frac{1 \text{ mol}}{(3M + 189.94) \text{ g}}$$

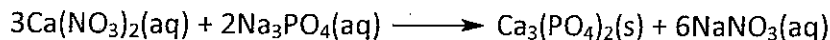
$$\frac{253.5}{M + 70.906} = \frac{715.0}{3M + 189.94}$$

$$760.5M + 48149.79 = 715.0M + 50697.79$$

$$45.5M = 2548$$

$$M = 56, \text{ which is close to } \boxed{\text{Fe}}$$

- 7) [5 marks total] In one experiment, 20.00 mL of $\text{Ca}(\text{NO}_3)_2$ was mixed with 30.00 mL of 0.200 M Na_3PO_4



The resulting $\text{Ca}_3(\text{PO}_4)_2(\text{s})$ (310.2 g/mol) had a mass of 930.6 mg.

- a) [3 marks] If the concentration of the $\text{Ca}(\text{NO}_3)_2$ *after reaction* was 0.0200 M, what was it before reaction?

$$\begin{aligned} \text{moles } \text{Ca}(\text{NO}_3)_2 \text{ L.O.} &= 0.0200 \text{ moles} \times 50.00 \text{ mL} = 1.00 \text{ mmol} \\ \text{moles } \text{Ca}(\text{NO}_3)_2 \text{ reacted} &: 930.6 \text{ mg} \times \frac{1 \text{ mol}}{310.2 \text{ g}} \times \frac{3 \text{ Ca}(\text{NO}_3)_2}{1 \text{ Ca}_3(\text{PO}_4)_2} \\ &= 9.000 \text{ mmol} \end{aligned}$$

So $[\text{Ca}(\text{NO}_3)_2]$ must have been:

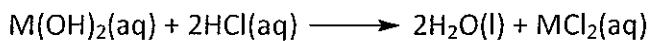
$$\frac{10.00 \text{ mmol}}{20.00 \text{ mL}} = \boxed{0.5000 \text{ M}}$$

- b) [2 marks] What was the concentration of NaNO_3 after reaction?

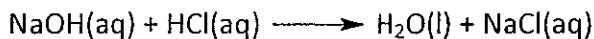
$$930.6 \text{ mg } \text{Ca}_3(\text{PO}_4)_2 \times \frac{1 \text{ mol}}{310.2 \text{ g}} \times \frac{6 \text{ NaNO}_3}{1 \text{ Ca}_3(\text{PO}_4)_2} = 18.00 \text{ mmol NaNO}_3$$

$$[\text{NaNO}_3] = \frac{18.00 \text{ mmol}}{50.00 \text{ mL}} = \boxed{0.3600 \text{ M}}$$

- 8) [4 marks] A 1.1664 gram sample of $M(OH)_2$ was mixed with 25.00 mL of 3.000 M HCl and enough water added to make 100.0 mL of solution A.



A 10.00 mL aliquot of solution A was taken and titrated with 20.00 mL of 0.1750 M NaOH.



What is the metal, M?

In the erlenmeyer:

$$m_{M(OH)_2} : 1.1664 \text{ g} \times \frac{10.00 \text{ mL}}{100.0 \text{ mL}} = 0.11664 \text{ g } M(OH)_2$$

$$n_{HCl} : 25.00 \text{ mL} \times \frac{3.000 \text{ moles}}{\text{L}} \times \frac{10.00 \text{ mL}}{100.0 \text{ mL}} = 7.500 \text{ mmol}$$

$$n_{NaOH} : 20.00 \text{ mL} \times \frac{0.1750 \text{ moles}}{\text{L}} = 3.500 \text{ mmol}$$

∴ reacted HCl:

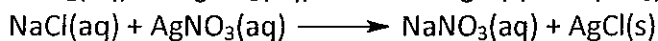
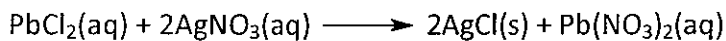
$$7.500 \text{ mmol} - 3.500 \text{ mmol NaOH} \times \frac{1 \text{ HCl}}{1 \text{ NaOH}} = 4.000 \text{ mmol}$$

$$\therefore \text{ moles } M(OH)_2 = 4.000 \text{ mmol HCl} \times \frac{1 \text{ } M(OH)_2}{2 \text{ HCl}} = 2.000 \text{ mmol}$$

$$\frac{0.11664 \text{ g}}{2.000 \times 10^{-3} \text{ mol}} = 58.32 \frac{\text{g}}{\text{mol}}$$

$$M + 2(1.0079 + 15.999) = 58.32 \Rightarrow M = 24.31 \frac{\text{g}}{\text{mol}}, \quad \boxed{\text{Mg}}$$

- 9) [4 marks] A mixture of PbCl_2 (278.1 g/mol) and NaCl (58.44 g/mol) of mass 570.3 mg was reacted with excess AgNO_3 and 1003.1 mg of AgCl (143.3 g/mol) collected:



What was the mole fraction of NaCl in the original mixture?

$$\text{Let } x = \text{mmol PbCl}_2$$

$$y = \text{mmol NaCl}$$

then:

$$278.1x + 58.44y = 570.3$$

$$\text{and } 2x + y = 1003.1 \text{ mg AgCl} \times \frac{1 \text{ mol}}{143.3 \text{ g}} = 7 \text{ mmol}$$

$$\uparrow$$

$$2 \text{ AgCl from } 1 \text{ PbCl}_2$$

$$278.1x + 58.44y = 570.3$$

$$58.44(2x + y = 7)$$

$$- \quad 116.88x + 58.44y = 409.08$$

$$161.22x = 161.22$$

$$\Rightarrow x = 1 \text{ mmol PbCl}_2$$

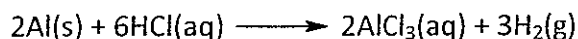
$$+ y = 5 \text{ mmol NaCl}$$

$$X_{\text{NaCl}} = \boxed{\frac{5}{6}}$$

10) [3 marks] The following data were collected for the molar mass of aluminum, carried out in exactly the same way as the molar mass of magnesium lab:

Measurement	Value
Mass of Al (mg)	53.964
V_{gas} (mL)	76.4345
$T_{\text{sol'n}}$ ($^{\circ}\text{C}$)	21.0
$VP_{\text{sol'n}}$ (mmHg)	18.75
P_{atm} (mmHg)	758.75
$D_{\text{H}_2\text{O}}$ (g/mL)	1.00
D_{Hg} (g/mL)	13.6

What is the height of the column of water present after the experiment? The reaction between aluminum and hydrochloric acid is:



$$n_{\text{H}_2} : 53.964 \text{ mg Al} \times \frac{1 \text{ mol}}{26.982 \text{ g}} \times \frac{3 \text{ H}_2}{2 \text{ Al}} = 2.0000 \text{ mmol H}_2$$

$$P_{\text{H}_2} = \frac{(2.0000 \text{ mmol}) \left(\frac{62.363 \text{ L} \cdot \text{atm}}{\text{mol} \cdot \text{K}} \right) (294.15 \text{ K})}{76.4345 \text{ mL}}$$

$$= 720.00 \text{ torr}$$

$$P_{\text{atm}} = P_{\text{H}_2} + VP_{\text{sol'n}} + P_h$$

$$\Rightarrow P_h = 20.00 \text{ mmHg}$$

$$\therefore \text{in water mm: } 20.00 \text{ mmHg} \times \frac{13.6}{1.00} = \boxed{272 \text{ mm}}$$