

Chemistry 1154 Fall 2011 test 1

Thursday, September 29, 2011

Time: 1 hour 50 minutes

Name: ANSWERS

Student number: _____

This test consists of **seven** pages of questions, a page of useful constants, and a periodic table. Please ensure that you have a complete paper and, if you do not, obtain one from me **immediately**. There are **30** marks available. Good luck!

1) [4 marks] "Compound X" is known to be 7.74 percent hydrogen by mass, and the rest carbon.

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

$$7.74 \text{ g H} \times \frac{1 \text{ mol}}{1.008 \text{ g}} = 7.68 \text{ mol H}$$

$$(100 - 7.74) \text{ g C} \times \frac{1 \text{ mol}}{12.01 \text{ g}} = 7.68 \text{ mol C}$$

∴ EF is $\boxed{\text{CH}}$ (Empirical formula mass $13.02 \frac{\text{g}}{\text{mol}}$)

b) As a gas, "Compound X" has a density of 1.276 g/L at 0.500 atm pressure and 100.0°C. What is the molecular formula of "Compound X"?

$$\text{MM} = \frac{DRT}{P} = \frac{1.276 \frac{\text{g}}{\text{L}} \times 0.0820575 \frac{\text{L} \cdot \text{atm}}{\text{mol} \cdot \text{K}} \times 373.15}{0.500 \text{ atm}}$$

$$= 78.1 \frac{\text{g}}{\text{mol}}$$

$$\frac{78.1}{13.02} \approx 6, \text{ so MF is } \boxed{\text{C}_6\text{H}_6}$$

- 2) [5 marks total] A 310.3-mg sample of "Compound Y" was burned and 440.1 mg of CO_2 (44.01 g/mol) and 270.3 mg of H_2O (18.02 g/mol) were collected.

a) [3 marks] What is the empirical formula of "Compound Y"?

$$\text{Moles C: } 440.1 \text{ mg} \times \frac{1 \text{ mol}}{44.01 \text{ g}} \times \frac{1 \text{ C}}{1 \text{ CO}_2} = 10 \text{ mmol C}$$

$$\text{Moles H: } 270.3 \text{ mg} \times \frac{1 \text{ mol}}{18.02 \text{ g}} \times \frac{2 \text{ H}}{1 \text{ H}_2\text{O}} = 30 \text{ mmol H}$$

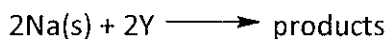
mass O:

$$310.3 \text{ mg} - 10 \text{ mmol C} \times \frac{12.01 \text{ g}}{\text{mol}} - 30 \text{ mmol H} \times \frac{1.008 \text{ g}}{\text{mol}} = 159.96 \text{ mg}$$

$$\text{moles O: } 159.96 \text{ mg} \times \frac{1 \text{ mol}}{16.00 \text{ g}} = 10 \text{ mmol O}$$

∴ EF is $\boxed{\text{CH}_3\text{O}}$ (EF mass $31.03 \frac{\text{g}}{\text{mol}}$)

b) [2 marks] "Compound Y" reacts with elemental sodium:



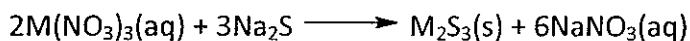
In one experiment, 124.1 mg of "Compound Y" required 46.0 mg of Na for complete reaction. What is the molecular formula of "Compound Y"?

$$46.0 \text{ mg Na} \times \frac{1 \text{ mol}}{23.0 \text{ g}} \times \frac{2\text{Y}}{2\text{Na}} = 2 \text{ mmol Na}$$

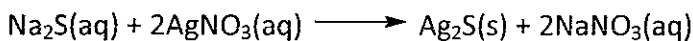
$$\text{MH} = \frac{124.1 \text{ mg}}{2 \text{ mmol}} = 62.05 \frac{\text{g}}{\text{mol}}$$

$$\frac{62}{31} = 2, \text{ so MF is } \boxed{\text{C}_2\text{H}_6\text{O}_2}$$

- 3) [4 marks] A 902.5-mg sample of a compound of formula $M(\text{NO}_3)_3$, (where M is an unknown element) was dissolved in enough water to make 200.0 mL of solution. A 20.0-mL aliquot was taken and reacted with 20.0 mL of 0.0300 M Na_2S :



The excess Na_2S was titrated with 15.0 mL of 0.0200 M AgNO_3 :



What is the metal, M?

$$20 \text{ mL} \times \frac{0.03 \text{ moles}}{\text{L}} - 15 \text{ mL} \times \frac{0.02 \text{ moles}}{\text{L}} \text{ AgNO}_3 \times \frac{1 \text{ Na}_2\text{S}}{2 \text{ AgNO}_3}$$

$$\approx 0.45 \text{ mmol Na}_2\text{S} \text{ reacted}$$

$$0.45 \text{ mmol Na}_2\text{S} \times \frac{2M(\text{NO}_3)_3}{3\text{Na}_2\text{S}} = 0.3 \text{ mmol } M(\text{NO}_3)_3 \text{ in 20 mL}$$

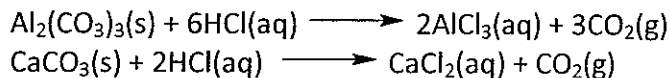
$$902.5 \text{ mg} \times \frac{20 \text{ mL}}{200 \text{ mL}} = 90.25 \text{ mg in 20 mL}$$

$$\therefore \text{MM is } \frac{90.25 \text{ mg}}{0.3 \text{ mmol}} = 300.8 \frac{\text{g}}{\text{mol}}$$

$$300.8 - 3(14.01 + 3 \times 16.00) = 114.8 \frac{\text{g}}{\text{mol}}$$

In

- 4) [4 marks] A 1570-mg mixture of $\text{Al}_2(\text{CO}_3)_3$ (234 g/mol) and CaCO_3 (100 g/mol) was reacted with excess aqueous HCl:



The partial pressure of the CO_2 was found to be 0.914 atm when collected in a 0.500-L flask at 20.0°C . What was the percent by mass of the CaCO_3 in the original mixture?

$$x = \text{mmol Al}_2(\text{CO}_3)_3$$

$$y = \text{mmol CaCO}_3$$

then:

$$234x + 100y = 1570 \quad (1)$$

and:

$$n_{\text{CO}_2} = \frac{PV}{RT} = \frac{(0.914)(0.5)}{(0.0820575)(293.15)} = \cancel{19} \cdot 0.019 \text{ moles} = 19 \text{ mmol}$$

So that

$$3x + y = 19 \quad (2)$$

Solving (1) + (2) gives $x = 5$ and $y = 4$

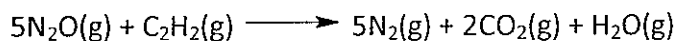
$$\therefore \% (\text{m/m}) \text{ CaCO}_3 = \frac{400 \text{ mg}}{1570 \text{ mg}} \times 100 = \boxed{25.5\%}$$

- 5) [2 marks] Vinegar is actually a dilute solution of acetic acid. A certain vinegar solution has a density of 1.00 g/mL and a concentration of 0.8493 M. If the solution is known to be 5.10 percent acetic acid by mass, what is the molar mass of acetic acid?

$$1.00 \frac{\text{g}}{\text{mL}} \times \frac{1000 \text{ mL}}{\text{L}} \times \frac{5.10 \text{ g acetic}}{100 \text{ g sol'n}} \times \frac{1 \text{ L}}{0.8493 \text{ moles}}$$

$$= \boxed{60.05 \frac{\text{g}}{\text{mol}}}$$

- 6) [3 marks] Suppose the reaction:

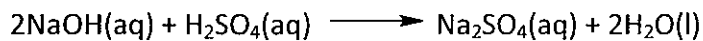


proceeded with a 75.00-percent yield. How many grams of 90.00-percent pure N_2O (44.01 g/mol) would be necessary to guarantee collection of exactly 88.02 grams of CO_2 (44.01 g/mol)?

$$88.02 \text{ g CO}_2 \times \frac{100}{75.00} \times \frac{1 \text{ mol}}{44.01 \text{ g}} \times \frac{5 \text{ N}_2\text{O}}{2 \text{ CO}_2} \times \frac{44.01 \text{ g}}{\text{mol}} \times \frac{100}{90.00}$$

$$= \boxed{326 \text{ g}}$$

- 7) [5 marks total] In one experiment, 20.00 mL of 0.0500 M NaOH was mixed with 30.00 mL of 0.0200 M H₂SO₄:



- a) [3 marks] What would be the concentration of the Na₂SO₄ in moles/L after the reaction?

$$1 \text{ mmol NaOH} \times \frac{1 \text{ rxn}}{2 \text{ NaOH}} = 0.5 \text{ mmol rxn} \leftarrow \text{NaOH limits}$$

$$0.6 \text{ mmol H}_2\text{SO}_4 \times \frac{1 \text{ rxn}}{1 \text{ H}_2\text{SO}_4} = 0.6 \text{ mmol rxn}$$

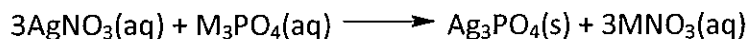
$$\frac{0.5 \text{ mmol rxn} \times \frac{1 \text{ Na}_2\text{SO}_4}{1 \text{ rxn}}}{50.0 \text{ mL}} = \boxed{0.01 \text{ M}}$$

- b) [2 marks] What would be the concentration of the excess reagent in moles/L after the reaction?

enough H₂SO₄ for 0.1 mmol more rxn:

$$\frac{0.1 \text{ mmol rxn} \times \frac{1 \text{ H}_2\text{SO}_4}{1 \text{ rxn}}}{50 \text{ mL}} = \boxed{0.002 \text{ M}}$$

- 8) [3 marks] In another experiment, 1639 mg of M_3PO_4 (M is an unknown metal) were mixed with excess $AgNO_3$ and 2549.7 mg of MNO_3 were isolated:



What is the metal, M?

$$1639 \text{ mg} \times \frac{1 \text{ mol}}{3x + 94.97} \times \frac{3MNO_3}{1M_3PO_4} \times \frac{(x + 62.00) \text{ g}}{\text{mol}} = \frac{2549.7 \text{ mg}}{\text{mol}}$$

$$\frac{4917}{3x + 94.97} = \frac{2549.7}{x + 62}$$

$$4917x + 304854 = 7649.1x + 242145.009$$

$$2732.1x = 62708.991$$

$$x = \boxed{23.0}$$

which is \boxed{Na}