Chemistry 1105 Spring 2011 test 2

Friday, February 25, 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 you have a complete paper and, if you do not, obtain one from me immediately. There are **30** marks (and four bonus marks) available. Good luck!*

1) **[5 marks total]** "Compound X" is known to be 40.0010 percent carbon by mass, 53.2852 percent oxygen by mass, and the rest hydrogen.

   a) **[2 marks]** What is the empirical formula of "Compound X"?

$$40.0010\,g\,C \times \frac{1\ mol}{12.0107\,g} = 3.33045\ moles\ C$$

$$53.2852\,g\,O \times \frac{1\ mol}{15.9994\,g} = 3.33045\ moles\ O$$

$$(100 - 40.0010 - 53.2852)\,g\,H \times \frac{1\ mol}{1.00794\,g} = 6.6609\ moles\ H$$

$$C_{3.33}H_{6.66}O_{3.33} \longrightarrow \boxed{CH_2O}$$

   b) **[3 marks]** "Compound X" reacts with calcium hydroxide according to the balanced reaction:

   $Ca(OH)_2(aq) + 2X \longrightarrow$ products

   A 0.1201-gram sample of "Compound X" required 20.0 mL of 0.0500 M $Ca(OH)_2$ for complete reaction. What is the molecular formula of "Compound X"?

$$20.0\ mL \times \frac{0.0500\ moles\ Ca(OH)_2}{1000\ mL} \times \frac{2X}{1\ Ca(OH)_2} = 2\times10^{-3}\ moles\ X$$

$$\frac{0.1201\ g}{2\times10^{-3}\ moles} = 60.05\ \frac{g}{mol}$$

EF mass = 12.0107 + 2×1.00794 + 15.9994 = 30.0260

$$\frac{60.05}{30.026} \simeq 2, \text{ so MF is } \boxed{C_2H_4O_2}$$

2) **[6 marks]** A 0.2763-gram sample of "Compound Y" was burned in excess oxygen and 0.3961 g of CO_2 (44.01 g/mol) and 0.2162 g of H_2O (18.02 g/mol) collected.

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

moles C: $0.3961 g\ CO_2 \times \frac{1 mol}{44.01 g} \times \frac{1 C}{1 CO_2} = 9.000 \times 10^{-3}$

moles H: $0.2162 g\ H_2O \times \frac{1 mol}{18.02 g} \times \frac{2H}{1 H_2O} = 24.00 \times 10^{-3}$

mass O: $0.2763 g - 9.000 \times 10^{-3}$ moles C $\times 12.0107 \frac{g}{mol} - 24.00 \times 10^{-3}$ moles H $\times 1.00794 \frac{g}{mol}$

$= 0.1440 g$

moles O: $0.1440 g\ O \times \frac{1 mol}{15.9994 g} = 9.001 \times 10^{-3}$

$C_{9\times10^{-3}} H_{24\times10^{-3}} O_{9.001\times10^{-3}} \Rightarrow \boxed{C_3H_8O_3}$

b) As a gas, "Compound Y" has a density of 1.882 g/L at 25°C and 0.500 atm pressure. What is the molecular formula of "Compound Y"?

$MM = \frac{DRT}{P} = \frac{1.882 \frac{g}{L} \times 0.0820575 \frac{L \cdot atm}{mol \cdot K} \times 298.15 K}{0.500 atm}$

$= 92.09 \frac{g}{mol}$

3×12.0107
$+ 8 \times 1.00794$
$+ 3 \times 15.9994$
92.0938

$\frac{92.09}{92.0938} \simeq 1$, so MF is $\boxed{C_3H_8O_3}$

3) **[3 marks]** A 0.6359-gram sample of M_2CO_3 (where "M" is an unknown metal) gave 0.4680 grams of $Al_2(CO_3)_3$ (234.0 g/mol) when reacted with excess $Al(NO_3)_3$:

$$2Al(NO_3)_3(aq) + 3M_2CO_3(aq) \longrightarrow Al_2(CO_3)_3(s) + 6MNO_3(aq)$$

What is the metal, M?

$$0.4680\,g\ Al_2(CO_3)_3 \times \frac{1\,mol}{234.0\,g} \times \frac{3M_2CO_3}{1Al_2(CO_3)_3} = 6.000\times10^{-3}\ moles\ M_2CO_3$$

$$\frac{0.6359\,g}{6.000\times10^{-3}\ moles} = 106.0\,\frac{g}{mol}$$

So: $2M + 12.0107 + 3\times15.9994 = 106.0$

$\Rightarrow M = 23.0\,\frac{g}{mol}$, which is **Na**

4) **[3 marks]** How many grams of 80.0-percent pure $AgNO_3$ (pure $AgNO_3$ molar mass 169.9 g/mol) are necessary to prepare 41.86 grams of Ag_3PO_4 (418.6 g/mol) if the reaction

$$3AgNO_3(aq) + Na_3PO_4(aq) \longrightarrow 3NaNO_3(aq) + Ag_3PO_4(s)$$

is known to proceed with a 62.5 percent yield?

$$41.86\,g \times \frac{100}{62.5} \times \frac{1\,mol}{418.6\,g} \times \frac{3\,AgNO_3}{1\,Ag_3PO_4} \times \frac{169.9\,g}{mol} \times \frac{100}{80.0}$$

$= $ **102 g**

5) **[2 marks]** A 10.00-mL aliquot of solution **A** was diluted to 100.0 mL to form solution **B**. If solution **B** had an [NaCl] = 1.0 x 10^{-3} M, what was the [NaCl] in solution **A**?

$$\frac{1.0\times10^{-3}\,\frac{\text{moles}}{\text{L}}\times100.0\,\text{mL}}{10.00\,\text{mL}} = \boxed{1.0\times10^{-2}\,\text{M}}$$

6) **[3 marks]** A solution of HX (where "X" is some unknown element) has a concentration of 12.39 M, a density of 1.189 g/cm^3, and is 38 percent HX by mass. What is the element, X?

$$1.189\,\frac{\text{g}}{\text{cm}^3}\times\frac{1000\,\text{cm}^3}{1\,\text{L}}\times\frac{38\,\text{g HX}}{100\,\text{g sol'n}}\times\frac{1\,\text{L}}{12.39\,\text{moles}} \approx 36\,\frac{\text{g}}{\text{mol}}$$

Therefore the molar mass of X must be 35 g, which is $\boxed{\text{Cl}}$

7) **[2 marks]** How many millilitres of 0.0500 M $Ba(OH)_2$ are needed to react with 40.00 mL of 0.0750 M HCl?

$$2HCl(aq) + Ba(OH)_2(aq) \longrightarrow BaCl_2(aq) + 2H_2O(l)$$

$$40.00\,mL \times \frac{0.0750\,moles\,HCl}{1000\,mL} \times \frac{1\,Ba(OH)_2}{2\,HCl} \times \frac{1000\,mL}{0.0500\,moles}$$

$$= \boxed{30.0\,mL}$$

8) **[6 marks]** A 20.0-mL aliquot of 0.200 M Na_3PO_4 was mixed with 27.0 mL of 0.200 M $Ca(NO_3)_2$:

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

a) How many grams of $Ca_3(PO_4)_2$ (310.2 g/mol) should be collected, assuming 100 percent yield?

$$20.0\,mL \times \frac{0.200\text{ moles } Na_3PO_4}{1000\,mL} \times \frac{1\,Ca_3(PO_4)_2}{2\,Na_3PO_4} = 2.00\times10^{-3}\text{ moles } Ca_3(PO_4)_2$$

$$27.0\,mL \times \frac{0.200\text{ moles } Ca(NO_3)_2}{1000\,mL} \times \frac{1\,Ca_3(PO_4)_2}{3Ca(NO_3)_2} = 1.80\times10^{-3}\text{ moles } Ca_3(PO_4)_2$$

$$\therefore \text{ get } 1.80\times10^{-3}\text{ moles } Ca_3(PO_4)_2 \times \frac{310.2\,g}{mol} = \boxed{0.558\,g}$$

b) What is the excess reagent, and what should its concentration be after reaction?

ER is Na_3PO_4:

$$\frac{\left(2.00\times10^{-3}\text{ moles } Ca_3(PO_4)_2 - 1.80\times10^{-3}\text{ moles } Ca_3(PO_4)_2\right) \times \frac{2Na_3PO_4}{1\,Ca_3(PO_4)_2}}{0.0470\,L}$$

$$= \boxed{8.5\times10^{-3}\ \frac{moles}{L}}$$

Bonus question

[4 marks] When a certain mass of MCl ("M" is an unknown metal) is reacted with excess $AgNO_3$, 1.4332 grams of AgCl (143.32 g/mol) are collected. When the exact same mass of MBr ("M" is the same unknown metal) is used, 0.9165 grams of AgBr (187.77 g/mol) are collected. What is the unknown metal, M?

$AgNO_3(aq) + MCl(aq) \longrightarrow AgCl(s) + MNO_3(aq)$
$AgNO_3(aq) + MBr(aq) \longrightarrow AgBr(s) + MNO_3(aq)$

Let mass metal halide used be "m" grams, and let ~~the molar mass be~~ the molar mass of "M" be "M" g.

Then:

$$m\,g\ MCl \times \frac{1\ mol}{(M + 35.4527)\,g} \times \frac{1\ AgCl}{1\ MCl} \times \frac{143.32\,g}{1\ mol} = 1.4332\,g\ AgCl$$

or: $$\frac{m \times 143.32}{M + 35.4527} = 1.4332$$

which rearranges to:

$$\frac{1.4332}{143.32}(M + 35.4527) = m$$

For MBr, we get:

$$\frac{0.9165}{187.77}(M + 79.904) = m$$

So that $$\frac{1.4332}{143.32}(M + 35.4527) = \frac{0.9165}{187.77}(M + 79.904)$$

Which gives M = 6.93, which is **Li** (or very close to it)