Chemistry 1105 R11 Fall 2011 Test 2

Friday, October 28, 2011

Time: 1 hour 50 minutes

Name: ANSWERS

Student Number: ____________________

*This test consists of **seven** pages of questions, a periodic table, and a page of useful constants. Please ensure you have a complete paper and, if you do not, obtain one from me **immediately**. There are **36** marks (and one bonus mark) available. Good luck!*

1) **[6 marks total]** Given the following (unbalanced) redox reaction, that occurs in acidic solution:

$$C_7H_8 + MnO_4^{-1} \longrightarrow CO_2 + Mn^{+2}$$

a) **[3 marks]** Balance the reaction.

$$(14H_2O + C_7H_8 \rightarrow 7CO_2 + 36H^+ + 36e^-) \times 5$$

$$(8H^+ + 5e^- + MnO_4^- \rightarrow Mn^{2+} + 4H_2O) \times 36$$

~~$70H_2O +$~~ $5C_7H_8 +$ ~~288~~ $108\,H^+ + 36MnO_4^- \longrightarrow 35CO_2 +$ ~~$180H^+$~~ $+ 36Mn^{2+} +$ ~~$144H_2O$~~ 70

$$5C_7H_8 + 108H^+ + 36MnO_4^- \longrightarrow 35CO_2 + 36Mn^{2+} + 74H_2O$$

b) **[1 mark]** Which species is the oxidizing agent? MnO_4^-

c) **[1 mark]** Which species is reduced? MnO_4^-

d) **[1 mark]** How many electrons are in the reduction half-reaction? 5

2) **[4 marks]** "Compound X" is known to be 2.144 percent hydrogen by mass, 68.062 percent oxygen by mass, and the rest nitrogen.

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

$m_N = (100 - 2.144 - 68.062)\,g = 29.794\,g$

$n_H = 2.144\,g\,H \times \frac{1\,mol}{1.0079\,g} = 2.127\,mol$

$n_O = 68.062\,g\,O \times \frac{1\,mol}{15.999\,g} = 4.2541\,mol$

$n_N = 29.794\,g \times \frac{1\,mol}{14.007\,g} = 2.1271\,mol$

$H_{2.127}N_{2.1271}O_{4.2541} \rightarrow \boxed{HNO_2}$

b) **[2 marks]** "Compound X" reacts with calcium hydroxide according to the (balanced) equation

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

It took 20.00 mL of 0.05000 M $Ca(OH)_2$ to titrate 94.0 mg of "Compound X." What is the molecular formula of "Compound X"?

$n_X = 20.00\,mL \times 0.05000\,\frac{moles}{L} \times \frac{2X}{1\,Ca(OH)_2} = 2.000\,mmol\,X$

$\frac{94.0\,mg}{2\,mmol} = 47.0\,\frac{g}{mol}$

MM = EFM, so MF is $\boxed{HNO_2}$

H 1
N 14
2× Oxy 32
} 47 g/mol

c) **[bonus - 1 mark]** What is the name of "Compound X"?

$\boxed{\text{nitrous acid}}$

3) **[5 marks total]** "Compound Y" is known to contain carbon, hydrogen, and oxygen. A 1761-mg sample of "Compound Y" was burned and 720.6 mg of H_2O (18.015 g/mol) and 2640.54 mg of CO_2 (44.009 g/mol) collected.

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

n_C : $2640.54 \text{ mg } CO_2 \times \frac{1 \text{ mol}}{44.009 \text{ g}} \times \frac{1 C}{1 CO_2} = 60 \text{ mmol C}$

n_H : $720.6 \text{ mg } H_2O \times \frac{1 \text{ mol}}{18.015 \text{ g}} \times \frac{2H}{1 H_2O} = 80 \text{ mmol H}$

m_{ox} : $1761 \text{ mg} - 60 \text{ mmol C} \times 12.011 \frac{g}{mol} - 80 \text{ mmol H} \times 1.0079 \frac{g}{mol}$

$= 959.708 \text{ mg O}$

$n_{ox} = 959.708 \text{ mg O} \times \frac{1 \text{ mol}}{15.999 \text{ g}} = 60. \text{ mmol O}$

$C_{60}H_{80}O_{60} \rightarrow \boxed{C_3H_4O_3}$

b) **[2 marks]** As a gas, "Compound Y" has a density of 1.761 g/L at 336.18°C and 0.500 atm pressure. What is the molecular formula of "Compound Y"?

$MM = \frac{DRT}{P} = \frac{1.761 \frac{g}{L} \times 0.0820575 \frac{L \cdot atm}{mol \cdot K} \times 609.33 K}{0.500 \text{ atm}}$

$= 176.1 \frac{g}{mol}$

3×12
4×1
3×16
88

$\frac{176}{88} = 2$, so MF is $\boxed{C_6H_8O_6}$

4) **[3 marks]** A 530.0-mg sample of a compound of formula M_2CO_3 (where M is an unknown element) was reacted with excess aluminum chloride:

$$3M_2CO_3(aq) + 2AlCl_3(aq) \longrightarrow Al_2(CO_3)_3(s) + 6MCl(aq)$$

A total of 390.0 mg of $Al_2(CO_3)_3$ (234.0 g/mol) were collected. What is the metal, M?

$$390.0\ mg\ Al_2(CO_3)_3 \times \frac{1\ mol}{234.0\ g} \times \frac{3M_2CO_3}{1Al_2(CO_3)_3} = 5\ mmol\ M_2CO_3$$

$$\frac{530.0\ mg}{5.000\ mmol} = 106.0\ \frac{g}{mol}$$

$$2M + 12.011 + 3\times15.999 = 106.0$$

$\Rightarrow M = 23.0\ \frac{g}{mol}$

Na

5) **[3 marks]** A 20.00 mL aliquot of solution **A** was taken and diluted to 500.0 mL to form solution **B**. A 15.00 mL aliquot of solution **B** was taken and diluted to 100.0 mL to form solution **C**. The concentration of KI in solution **B** was 0.02000 M. What were the concentrations of KI in solutions **A** and **C**?

$$[KI]\ in\ A = 0.02000M \times \frac{500.0\ mL}{20.00\ mL} = 0.5000M$$

$$[KI]\ in\ B = 0.02000M \times \frac{15.00\ mL}{100.0\ mL} = 3.000\times10^{-3}M$$

6) **[3 marks]** It took 15.00 mL of $Ca(OH)_2$ to titrate a 20.00 mL aliquot of H_3PO_4:

$$3Ca(OH)_2(aq) + 2H_3PO_4(aq) \longrightarrow Ca_3(PO_4)_2(s) + 6H_2O(l)$$

The mass of $Ca_3(PO_4)_2$ (310.2 g/mol) isolated was 77.55 mg. What was the concentration of the $Ca(OH)_2$ before titration?

$$\frac{77.55\,mg\ Ca_3(PO_4)_2 \times \frac{1\,mol}{310.2\,g} \times \frac{3\,Ca(OH)_2}{1\,Ca_3(PO_4)_2}}{15.00\,mL}$$

$= \boxed{0.05000\,M}$

7) **[3 marks]** How many grams of 80.00-percent pure $AgNO_3$ (169.9 g/mol) are required to produce exactly 0.4186 grams of Ag_3PO_4 (418.6 g/mol) if the reaction:

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

Proceeds with a 60.00-percent yield?

$$0.4186\,g\ Ag_3PO_4 \times \frac{100}{60} \times \frac{1\,mol}{418.6\,g} \times \frac{3AgNO_3}{1Ag_3PO_4} \times \frac{169.9\,g}{1\,mol} \times \frac{100}{80}$$

$= \boxed{1.0619\,g}$

8) **[5 marks total]** If 20.00 mL of 1.000 M H_2SO_4 are mixed with 30.00 mL of 1.000 M NaOH:

$2NaOH(aq) + H_2SO_4(aq) \longrightarrow Na_2SO_4(aq) + 2H_2O(l)$

a) **[3 marks]** What will be the concentration of Na_2SO_4 after the reaction has taken place?

$20.00\,mL \times \frac{1.000\,mole\ H_2SO_4}{L} \times \frac{1\,Na_2SO_4}{1\,H_2SO_4} = 20.00\,mmol\ Na_2SO_4$

LR → $30.00\,mL \times \frac{1\,mole\ NaOH}{L} \times \frac{1\,Na_2SO_4}{2\,NaOH} = 15.00\,mmol\ Na_2SO_4$

$\frac{15.00\,mmol}{50.00\,mL} = \boxed{0.3000\,M}$

b) **[2 marks]** What will be the concentration of the excess reagent after the reaction has taken place?

$20\,mmol\ H_2SO_4 - 30\,mmol\ NaOH \times \frac{1\,H_2SO_4}{2\,NaOH} = 5.00\,mmol\ H_2SO_4$

$\frac{5.00\,mmol}{50.00\,mL} = \boxed{0.100\,M}$

9) **[4 marks]** The molar mass of aluminum was determined in exactly the same way as the molar mass of magnesium. The following data were collected:

Data (units)	Value
Mass Al (mg)	40.0
V_{gas} (mL)	56.6
$T_{sol'n}$ (°C)	20.8
VP H_2O (mmHg)	18.8
P_{atm} (mmHg)	754.1
h (mmH_2O)	204
D_{H2O} (kg/m^3)	1000

Given that the reaction between Al and HCl is:

$$2Al(s) + 6HCl(aq) \longrightarrow 2AlCl_3(aq) + 3H_2(g)$$

and assuming that the experiment worked perfectly, how many milligrams of aluminum were used in the experiment?

$$P_{H_2} = 754.1\ mmHg - 18.8\ mmHg - 1000 \times 9.80665 \times 0.204 \times \frac{760\ mmHg}{101325\ Pa}$$

$$= 720.29\ mmHg$$

$$n_{H_2} = \frac{(720.29\ mmHg)(56.6\ mL)}{(62.3637\ \frac{L \cdot torr}{mol \cdot K})(293.95K)} = 2.224\ mmol\ H_2$$

$$2.224\ mmol\ H_2 \times \frac{2Al}{3H_2} \times 26.982\ \frac{g}{mol} = \boxed{40.0\ mg\ Al}$$