Chemistry 0094 R10
Fall 2000
Test #3

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Wednesday, November 22, 2000 Time: 2 hours

Name: Answers Student Number: _____

*This exam consists of **five** pages of questions and a periodic table. Please ensure that you have a complete paper and, if you do not, obtain one from me **immediately**. Good luck!*

Avogadro's number, should you need it, is $6.0221367 \times 10^{+23}$ mol^{-1}.

*Note: **all** work must be shown for a question in order to receive **any** credit for that question.*

1) **[8 marks]** Complete and balance the following reactions. Provide the molecular, full ionic, and net ionic equations in each case. Indicate the phases of all products and reactants, and assume that a reaction occurs in each case.

a) $NaOH(aq) + HCl(aq) \longrightarrow H_2O(l) + NaCl(aq)$

Full: $Na^+(aq) + OH^-(aq) + H^+(aq) + Cl^-(aq) \rightarrow H_2O(l) + Na^+(aq) + Cl^-(aq)$

net: $OH^-(aq) + H^+(aq) \rightarrow H_2O(l)$

b) $Ca(NO_3)_2(aq) + HF(aq) \longrightarrow$

$Ca(NO_3)_2(aq) + 2HF(aq) \longrightarrow CaF_2(s) + 2HNO_3(aq)$

Full: $Ca^{2+}(aq) + 2NO_3^-(aq) + 2HF(aq) \rightarrow CaF_2(s) + 2H^+(aq) + 2NO_3^-(aq)$

net: $Ca^{2+}(aq) + 2HF(aq) \rightarrow CaF_2(s) + 2H^+(aq)$

c) $Mg(s) + HI(aq) \longrightarrow$

$Mg(s) + 2HI(aq) \rightarrow MgI_2(s) + H_2(g)$

Full + net too: $Mg(s) + 2H^+_{(aq)} + 2I^-(aq) \rightarrow MgI_2(s) + H_2(g)$

d) $NaI(aq) + Cl_2(aq) \longrightarrow$

$2NaI(aq) + Cl_2(aq) \longrightarrow 2NaCl(aq) + I_2(aq)$

full: $2Na^+(aq) + 2I^-(aq) + Cl_2(aq) \rightarrow 2Na^+(aq) + 2Cl^-(aq) + I_2(aq)$

net: $2I^-(aq) + Cl_2(aq) \rightarrow I_2(aq) + 2Cl^-(aq)$

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2) **[2 marks]** Calculate the mass of a single atom of $^{12}_{6}C$ in grams.

$$12\ \frac{g}{mol} \times \frac{1\ mole}{6.0221367\times10^{23}\ atoms} = \boxed{1.9926\times10^{-23}\ g/atom \quad (5\ s.f.)}$$

3) **[2 marks]** How many phosphorus atoms are there in 0.3 moles of $Ca_3(PO_4)_2$?

$$0.3\ moles\ Ca_3(PO_4)_2 \times \frac{2P}{1\ Ca_3(PO_4)_2} \times 6.0221367\times10^{23}\ \frac{atoms}{mole}$$

$$= \boxed{3.61\times10^{23}}$$

4) **[6 marks total]** Estrone is a component of estrogen (a female hormone). Estrone is 79.963% carbon, 8.202% hydrogen, and the rest oxygen:

a) **[3 marks]** What is the empirical formula of Estrone?

$\%O = 100 - 8.202 - 79.963 = 11.835$

Assume 100 g:

$$moles\ C = 79.963\ g \times \frac{1\ mole}{12.011\ g} = 6.6575$$

$$moles\ H = 8.202\ g \times \frac{1\ mole}{1.00794\ g} = 8.1374$$

$$moles\ O = 11.835\ g \times \frac{1\ mole}{15.9994\ g} = 0.73972$$

$\therefore C:H:O = 9:11:1$

$\boxed{C_9H_{11}O}$

b) **[3 marks]** Estrone has a molar mass of 270.371 grams. What is the molecular formula of Estrone?

Empirical formula mass $= 9\times12.011 + 11\times1.00794 + 1\times15.9994 = 135.186$

$n = \frac{270.371}{135.186} = 2$, so formula is $2\times C_9H_{11}O$

$\boxed{C_{18}H_{22}O_2}$

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5) **[4 marks]** In one experiment, 5.0000 grams of an impure sample of $AlCl_3$ was dissolved in water and reacted with excess $AgNO_3$:

$AlCl_3(aq) + 3AgNO_3(aq) \longrightarrow 3AgCl(s) + Al(NO_3)_3(aq)$

The solid collected had a mass of 4.0000 grams. What was the percent by mass of $AlCl_3$ in the original sample? AgCl has a molar mass of 143.3209 grams, and $AlCl_3$ has a molar mass of 133.3396 grams.

$$4.000\text{g} \times \frac{1\text{ mole}}{143.3209\text{g}} \times \frac{1\,AlCl_3}{3\,AgCl} \times 133.3396\frac{\text{g}}{\text{mole}} = 1.2405\text{g}$$

$$\frac{1.2405\text{g}}{5.0000\text{g}} \times 100\% = \boxed{24.810\%}$$

6) **[4 marks]** A 50.00 mL sample of solution **A**, which had [NaCl] = 2.000 M, was taken and diluted to a certain volume to form solution **B**. 25.00 mL of solution **B** was taken and diluted to form 250.0 mL of solution **C**, which had [NaCl] = 0.05000 M. How many mL of solution **B** were made?

moles of NaCl in C: $0.2500\text{L} \times 0.05000\frac{\text{moles}}{\text{L}} = 0.01250$

$\therefore$ [NaCl] in B $= \frac{0.01250\text{ moles}}{0.02500\text{L}} = 0.5000\frac{\text{moles}}{\text{L}}$

total moles in B $= 0.05000\text{L} \times 2.000\frac{\text{moles}}{\text{L}} = 0.1000\text{ moles}$

Therefore total volume of B $= 0.1000\text{ moles} \times \frac{1\text{L}}{0.5000\text{ moles}} \times \frac{1000\text{mL}}{1\text{L}}$

$= \boxed{200.0\text{mL}}$

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7) **[9 marks total]** Methyl salicylate is a compound used in "oil of wintergreen" flavouring. It is known to contain carbon, hydrogen, and oxygen:

a) **[5 marks]** In one experiment, a 1.1105-gram sample of methyl salicylate was burned and 2.5697 grams of CO_2 and 0.5260 grams H_2O collected. What is the empirical formula of methyl salicylate? The molar masses of CO_2 and H_2O are 44.010 grams and 18.0153 grams respectively.

$$\text{moles C: } 2.5697\text{g} \times \frac{1\text{ mole}}{44.010\text{g}} \times \frac{1\text{ C}}{1\text{CO}_2} = 0.058389$$

$$\text{grams C} = 0.058389\text{ moles} \times \frac{12.011\text{g}}{\text{mole}} = 0.70131$$

$$\text{moles H: } 0.5260\text{g} \times \frac{1\text{ mole}}{18.0153\text{g}} \times \frac{2\text{H}}{1\text{H}_2\text{O}} = 0.058395$$

$$\text{mass H: } 0.058395\text{ moles} \times \frac{1.00794\text{g}}{1\text{ mole}} = 0.05886$$

$$\therefore \text{mass O} = 1.1105\text{g} - 0.70131\text{g} - 0.05886\text{g}$$
$$= 0.3503\text{g}$$

$$\therefore \text{moles O} = 0.3503\text{g} \times \frac{1\text{ mole}}{15.9994\text{g}} = 0.021897$$

b) **[4 marks]** In another experiment, 1.7683 grams of methyl salicylate were reacted with 20.96 mL of 1.109 M KOH:

methyl salicylate + 2KOH ⟶ products

What is the molecular formula of methyl salicylate?

$$\text{moles KOH} = 0.02096\text{L} \times 1.109\frac{\text{moles}}{\text{L}}$$
$$= 0.02324464$$

$$\therefore \text{moles methyl salicylate} = 0.02324\text{ moles} \times \frac{1\text{ meth. sal.}}{2\text{ KOH}}$$
$$= 0.01162232$$

$$\therefore 1.7683\text{g} = 0.01162232\text{ moles}$$

$$\text{molar mass: } 1\text{ mole} \times \frac{1.7683\text{g}}{0.01162\text{ mole}} = 152.15\text{g}$$

$$\text{E.F. mass} = 8 \times 12.011\text{g} + 8 \times 1.00794\text{g} + 3 \times 15.9994\text{g} = 152.150\text{g}$$

$$n = \frac{152.15\text{g}}{152.150\text{g}} = 1$$

$\therefore$ C : H : O
$= 2.666 : 2.667 : 1$
$= 8 : 8 : 3$

$C_8H_8O_3$

$C_8H_8O_3$

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8) **[6 marks total]** It took 23.12 mL of 0.1184 M $K_2Cr_2O_7$ to standardize a 15.00 mL sample of $Na_2C_2O_4$:

$$K_2Cr_2O_7(aq) + 14HCl(aq) + 3Na_2C_2O_4(aq) \longrightarrow 6CO_2(g) + 7H_2O(l) + 2CrCl_3(aq) + 2KCl(aq) + 6NaCl(aq)$$

a) **[3 marks]** What was the concentration of the $Na_2C_2O_4$ in the 15.00 mL sample?

$0.02312\,L \times 0.1184 \frac{moles}{L} \times \frac{3\,Na_2C_2O_4}{1\,K_2Cr_2O_7} = 0.008212224$ moles $Na_2C_2O_4$

$\frac{0.008212224\,moles}{0.01500\,L} = \boxed{0.5475\,M}$

b) **[3 marks]** What was the concentration of KCl after the reaction?

$0.02312\,L \times 0.1184 \frac{moles}{L} \times \frac{2\,KCl}{1\,K_2Cr_2O_7} = 0.005474816$ moles KCl

$\frac{0.005474816\,moles}{0.03812\,L} = \boxed{0.1436\,M}$

9) **[4 marks]** Pure NaCl has a molar mass of 58.4425 grams. A certain NaCl solution had a density of 1.016 g/mL and was 3.00 percent NaCl by mass. What (in moles/L) is the concentration of NaCl in this solution?

$1.016 \frac{g\,sol'n}{mL} \times 0.03 \frac{g\,NaCl}{g\,sol'n} \times \frac{1\,mole}{58.4425\,g} \times \frac{1000\,mL}{1\,L}$

$= \boxed{0.5215\,M}$

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