

Wednesday, November 22, 2000

Time: 2 hours

Name: Answers

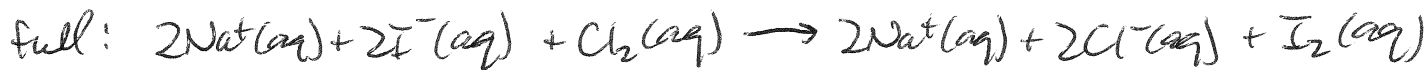
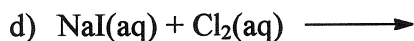
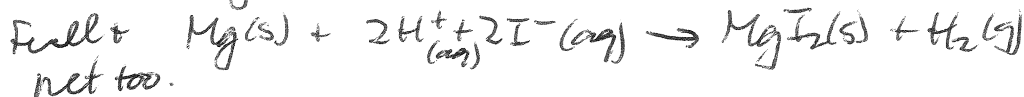
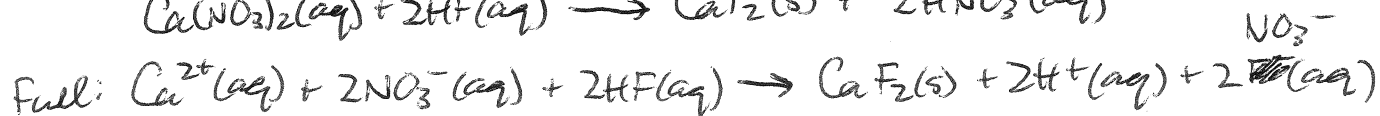
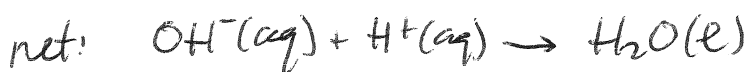
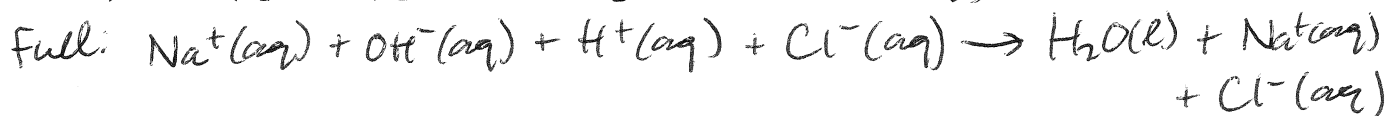
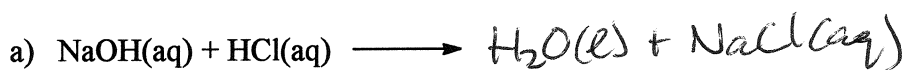
Student Number: _____

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 $6.0221367 \times 10^{23} \text{ mol}^{-1}$.

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.



2) [2 marks] Calculate the mass of a single atom of $^{12}_6\text{C}$ in grams.

$$\frac{12 \text{ g}}{\text{mol}} \times \frac{1 \text{ mole}}{6.0221367 \times 10^{23} \text{ atoms}} = \boxed{1.9926 \times 10^{-23} \text{ g/atom}}$$

~~1.9926~~ (4 s.f.)

3) [2 marks] How many phosphorus atoms are there in 0.3 moles of $\text{Ca}_3(\text{PO}_4)_2$?

$$0.3 \text{ moles } \text{Ca}_3(\text{PO}_4)_2 \times \frac{2 \text{ P}}{1 \text{ Ca}_3(\text{PO}_4)_2} \times \frac{6.0221367 \times 10^{23} \text{ atoms}}{\text{mole}} = \boxed{3.61 \times 10^{23}}$$

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?

$$\% \text{ O} = 100 - 8.202 - 79.963 = 11.835$$

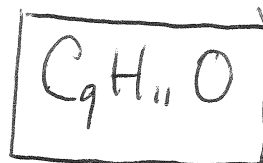
Assume 100 g:

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

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

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

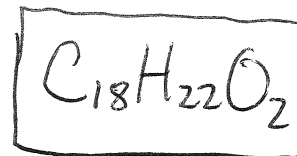
$$\therefore \text{C}:\text{H}:\text{O} = 9:11:1$$



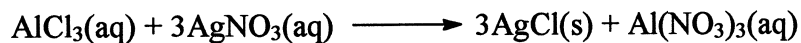
b) [3 marks] Estrone has a molar mass of 270.371 grams. What is the molecular formula of Estrone?

$$\begin{aligned} \text{Empirical formula mass} &= 9 \times 12.011 \\ &+ 11 \times 1.00794 \\ &+ 1 \times 15.9994 \\ &= 135.186 \end{aligned}$$

$$n = \frac{270.371}{135.186} = 2, \text{ so formula is } 2 \times \text{C}_9\text{H}_{11}\text{O}$$



- 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 :



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.

$$4.0000\text{g} \times \frac{1\text{mole}}{143.3209\text{g}} \times \frac{1\text{AlCl}_3}{3\text{AgCl}} \times 133.3396\frac{\text{g}}{\text{mole}} = 1.2405\text{g}$$

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

- 6) [4 marks] A 50.00 mL sample of solution A, which had $[\text{NaCl}] = 2.000\text{ M}$, 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 $[\text{NaCl}] = 0.05000\text{ M}$. How many mL of solution B were made?

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

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

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

$$\begin{aligned} \text{Therefore total volume of B} &= 0.1000\text{ moles} \times \frac{1\text{L}}{0.5000\text{ moles}} \times \frac{1000\text{mL}}{1\text{L}} \\ &= \boxed{200.\text{mL}} \end{aligned}$$

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.

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

$$\text{grams C} = 0.058389 \text{ moles} \times \frac{12.011 \text{ g}}{1 \text{ mole}} = 0.70131$$

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

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

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

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

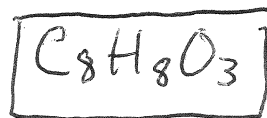
b) [4 marks] In another experiment, 1.7683 grams of methyl salicylate were reacted with 20.96 mL of 1.109 M KOH:



What is the molecular formula of methyl salicylate?

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

$$\begin{aligned} \therefore \text{C} : \text{H} : \text{O} \\ &= 2.666 : 2.667 : 1 \\ &= 8 : 8 : 3 \end{aligned}$$



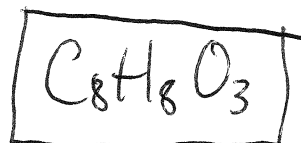
$$\therefore \text{moles methyl salicylate} = 0.02324 \text{ moles} \times \frac{1 \text{ meth. sal.}}{2 \text{ KOH}} = 0.01162232$$

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

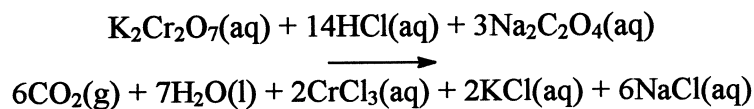
$$\text{molar mass} : 1 \text{ mole} \times \frac{1.7683 \text{ g}}{0.0116 \text{ mole}} = 152.15 \text{ g}$$

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

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



- 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 $Na_2C_2O_4$:



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

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

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

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

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

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

- 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?

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

$$= \boxed{0.5215 M}$$