

Last name : _____ Given name : _____

Student number: _____

Lab Section: _____ Lab TA: _____

Chemistry 1311D

Test 1 V1

October 9, 2014

1. a) (4 points) CFCs which contain only carbon, chlorine and fluorine wreak havoc with the ozone layer. A 2.55 g sample of a particular CFC is contained in a 1.50 L flask at 25°C and has a pressure of 262 torr. What is the molar mass of this compound?

$$m = 2.55 \text{ g}$$

$$V_T = 1.50 \text{ L} \quad (3.00 \text{ L}) \quad (0.75 \text{ L})$$

$$T = 25^\circ\text{C} = 298.2 \text{ K}$$

$$P_T = 262 \text{ torr} \quad (131 \text{ torr}) \quad (524 \text{ torr}) = 262 \text{ torr} \times \frac{1 \text{ bar}}{750.06 \text{ torr}} = 0.3493 \text{ bar} \quad (1)$$

$$PV = nRT \quad (1)$$

$$\frac{n}{V} = \frac{P}{RT}$$

$$\frac{m}{V} = \frac{MP}{RT}$$

$$\frac{2.55 \text{ g}}{1.5 \text{ L}} = \frac{M (0.3493 \text{ bar})}{0.08314 \frac{\text{L bar}}{\text{mol K}} (298.2 \text{ K})} \quad (1)$$

$$1.7 = M (0.01409) \quad (1)$$

$$M = 120.7 \text{ g/mol}$$

$$120.7 \text{ g/mol} \quad (1)$$

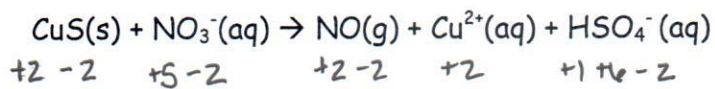
$$120.7 \text{ g/mol}$$

- b) (1 points) Assuming the compound contains only one carbon atom, what is the molecular formula?

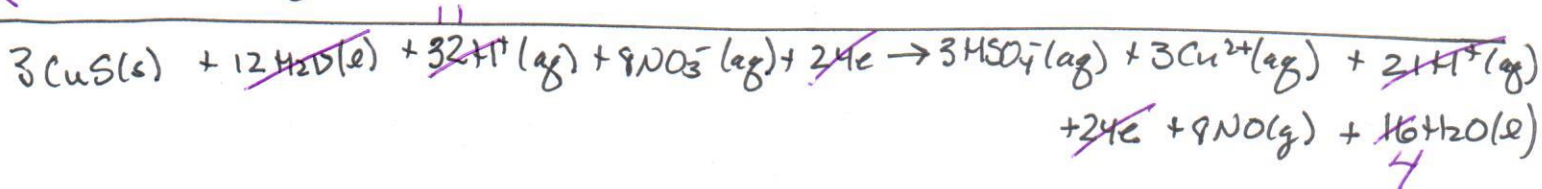
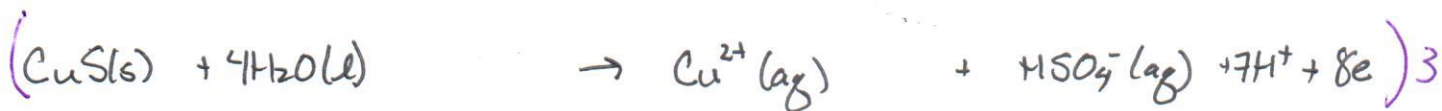


← all versions

2.a) (4 points) An aqueous nitric acid, HNO_3 , solution can convert CuS into soluble copper (II) hydrogen sulphate. Balance the following reaction:



oxidation states



b) (4 points) Calculate the mass of NO(g) if 500 ml of 2 M nitric acid (an aqueous solution of 2M nitric acid contains 2 M of $\text{H}^+(\text{aq})$ and 2M of $\text{NO}_3^-(\text{aq})$) react with 46.2 g of CuS

Limiting reagent!

$$n_{\text{H}^+} = 0.500\text{L}(2\text{M}) = 1\text{mole} \quad (0.250\text{L}, 0.5\text{mole}) \quad (0.750\text{L}, 1.5\text{mole}) \quad \textcircled{1}$$

$$n_{\text{NO}_3^-} = 1\text{mole}$$

$$n_{\text{CuS}} = m/M = 46.2\text{g}/95.61\text{g/mol} = 0.483\text{moles} \quad (23.1\text{g}, 0.242) \quad (69.3\text{g}, 0.725) \quad \textcircled{1}$$

IF all CuS used

$$\left. \begin{aligned} n_{\text{H}^+} &= 0.483\text{moles CuS} \times \frac{11}{3} = 1.77\text{moles} \\ n_{\text{NO}_3^-} &= 0.483\text{moles CuS} \times \frac{8}{3} = 1.29\text{moles} \end{aligned} \right\} \text{needed} \quad \text{CuS is in excess} \\ \text{H}^+ \text{ runs out first} \quad \textcircled{1.5}$$

$$n_{\text{NO}} = n_{\text{H}^+} \times \frac{8\text{NO}}{11\text{H}^+} = 1 \times 8/11 = 0.7273\text{moles} \quad (0.3636\text{moles}) \quad (1.0909\text{moles}) \quad \textcircled{1}$$

$$\text{mass NO} = n_{\text{NO}}(16+14.01\text{g/mol}) = 21.8\text{g} \quad (10.9\text{g}) \quad (32.7\text{g}) \quad \textcircled{0.5}$$

3. A 6.47 g sample of compound containing only C, H and O combusts in air. $\text{CO}_2(\text{g})$ is collected at 22.5°C and 1.088 bar over water to a volume of 8.06 L. This combustion experiment also produced 6.30 ml of $\text{H}_2\text{O}(\text{l})$. Using the appropriate data for vapour pressure and density of water from Table 3.1 below:

Temperature	Vapour Pressure (mm Hg)	Density (g/ml)
20	17.55	0.9982
21	18.66	0.9980
22	19.84 *	0.9978 *
23	21.09 *	0.9975 *
24	22.40	0.9970

a) (2 points) determine the amount (in moles) of hydrogen, H, in the 6.47 g sample

$$V_{\text{H}_2\text{O}} = 6.30 \text{ ml}$$

$$\Delta \rho_{\text{H}_2\text{O}} = 0.9977 \text{ g/ml}$$

$$\rho_{\text{H}_2\text{O}} = 18.02 \text{ g/ml}$$

$$m = d \times V = 6.30 \text{ ml} \times 0.9977 \text{ g/ml} = 6.2855 \text{ g}$$

$$n_{\text{H}_2\text{O}} = 6.2855 \text{ g} / 18.02 \text{ g/mol} = 0.3488 \text{ moles}$$

$$n_{\text{H}} = n_{\text{H}_2\text{O}} \times \frac{2\text{H}}{\text{H}_2\text{O}} = 0.3488 \times 2 = 0.6976 \text{ moles} \quad (0.703 \text{ g})$$

b) (3 points) determine the amount (in moles) of carbon, C, in the 6.47 g sample

$$P_{\text{T}} = 1.088 \text{ bar}, \quad V_{\text{T}} = 8.06 \text{ L}, \quad T = 22.5^\circ\text{C} = 295.7 \text{ K}$$

$$P_{\text{H}_2\text{O}} = 20.465 \text{ mm Hg} \times \frac{1 \text{ bar}}{750.01 \text{ mm Hg}} = 0.027 \text{ bar}$$

$$P_{\text{CO}_2} = P_{\text{T}} - P_{\text{H}_2\text{O}} = 1.088 - 0.027 = 1.061 \text{ bar}$$

$$n_{\text{C}} = n_{\text{CO}_2} = \frac{PV}{RT} = \frac{1.061 \text{ bar} (8.06 \text{ L})}{0.08314 \frac{\text{L bar}}{\text{mol K}} (295.7 \text{ K})} = 0.3478 \text{ moles} \quad (4.178 \text{ g})$$

c) (1 point) determine the amount (in moles) of oxygen, O, in the 6.47 g sample

$$\text{mass O} = m_{\text{T}} - m_{\text{C}} - m_{\text{H}} = 6.47 - 0.703 - 4.178 \text{ g} = 1.589 \text{ g}$$

$$n_{\text{O}} = 1.589 \text{ g} / 15.999 \text{ g/mol} = 0.0993 \text{ moles}$$

d) (2 points) determine the empirical formula

$$\frac{0.3478 \text{ mol C}}{0.0993} \frac{0.6976 \text{ mol H}}{0.0993} \frac{0.0993 \text{ mol O}}{0.0993} = \text{C}_{3.5} \text{H}_{7.03} \text{O} \rightarrow \text{C}_7 \text{H}_{14} \text{O}_2$$

e) (2 points) if the experimentally determine molar mass was found to be 265 g/mol, what is the molecular formula of the compound.

$$M_{\text{C}_7\text{H}_{14}\text{O}} = 7(12) + 14 + 2(16) = 130 \text{ g/mol}$$

$$\text{Factor} = \frac{265 \text{ g/mol}}{130 \text{ g/mol}} \cdot 2.03 = 2 \quad \underline{\text{C}_{14}\text{H}_{28}\text{O}_4}$$

(128, $\text{C}_7\text{H}_{14}\text{O}_2$)
(387, $\text{C}_{21}\text{H}_{42}\text{O}_6$)

/10

4. Ammonia(g) reacts with O₂(g) to form nitric acid via the following overall process:



a) (2 points) Given the heats of formation:

$$\Delta_f H^\circ(\text{NH}_3(\text{g})) = -45.9 \text{ kJ mol}^{-1}$$

$$\Delta_f H^\circ(\text{HNO}_3(\text{g})) = -133.9 \text{ kJ mol}^{-1}$$

$$\Delta_f H^\circ(\text{H}_2\text{O}(\text{g})) = -241.8 \text{ kJ mol}^{-1}$$

$$\Delta_f H^\circ(\text{NO}(\text{g})) = 91.3 \text{ kJ mol}^{-1}$$

Determine the enthalpy of the reaction per mole of NH₃(g)

$$\begin{aligned} \Delta_{\text{rxn}} H^\circ &= 14 \Delta_f H^\circ(\text{H}_2\text{O}) + 4 \Delta_f H^\circ(\text{NO}) + 8 \Delta_f H^\circ(\text{HNO}_3) - 12 \Delta_f H^\circ(\text{NH}_3) - 21 \Delta_f H^\circ(\text{O}_2) \\ &= 14(-241.8) + 4(91.3) + 8(-133.9) - 12(-45.9) - 21(0) \\ &= -3540.4 \text{ kJ} \text{ For } 12 \text{ moles } \text{NH}_3 \end{aligned}$$

$$\Delta_{\text{rxn}} H^\circ (\text{per mole}) = -3540.4 \text{ kJ} / 12 = -295.0 \text{ kJ} / \text{mol } \text{NH}_3.$$

b) (6 points) Heat given off is measured via calorimetry. If the temperature of a calorimeter containing 1000g of water with a calorimeter constant C of 1235 J °C⁻¹ increases from 25°C to 46°C, determine the mass of NH₃(g) used. The specific heat capacity of water is 4.18 J mol⁻¹ °C⁻¹.

1000g H₂O
C_{H₂O} 4.18 J mol⁻¹ °C⁻¹

C_{cal} 1235 J °C⁻¹

T_f = 46°C (67°C) (88°C)

T_i = 25°C

$$q_{\text{sys}} = q_{\text{rxn}} + q_{\text{H}_2\text{O}} + q_{\text{cal}} = 0 \quad (1)$$

$$-q_{\text{rxn}} = q_{\text{H}_2\text{O}} + q_{\text{cal}}$$

$$= m C_{\text{H}_2\text{O}} \Delta T + C_{\text{cal}} \Delta T$$

$$= 1000 \text{ g} \left(\frac{4.18 \text{ J}}{\text{g} \cdot \text{°C}} \right) (46 - 25) + 1235 \text{ J} (46 - 25)$$

$$= 113715 \text{ J}$$

$$= 113.7 \text{ kJ} \quad (227.4 \text{ kJ}) \quad (341.1 \text{ kJ})$$

$$n_{\text{NH}_3} = \frac{q_{\text{rxn}}}{\Delta_{\text{rxn}} H^\circ (\text{per mole})} \quad (1)$$

$$= \frac{-113.7 \text{ kJ}}{-295.0}$$

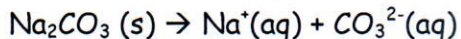
$$= 0.385 \text{ moles} \quad (0.771 \text{ moles}) \quad (1.156 \text{ moles})$$

$$\text{mass NH}_3 = n M = 0.385 \text{ moles} (17.03 \text{ g/mol})$$

$$= 6.6 \text{ g} \quad (13.1 \text{ g}) \quad (19.7 \text{ g})$$

5. A solution is prepared by dissolving 27.575 g sodium carbonate, Na_2CO_3 , in water to make 250 ml of a solution of density 1.103 g/ml. At these concentrations sodium carbonate dissolves completely.

a) (1 point) Balance the reaction for dissociation of sodium carbonate:



b) (1 point) Determine the molarity of $\text{Na}^+(aq)$ in the solution.

$$m = 27.575 \text{ g}$$

$$M_{\text{Na}_2\text{CO}_3} = 2(M_{\text{Na}}) + M_{\text{C}} + 3M_{\text{O}} = 105.99 \text{ g/mol}$$

$$n_{\text{Na}_2\text{CO}_3} = 27.575 \text{ g} / 105.99 = 0.260 \text{ moles}$$

c) (1 point) Determine the molality of $\text{Na}^+(aq)$ in the solution.

$$\text{molality} = \frac{\text{moles Na}^+}{\text{kg H}_2\text{O}}$$

$$\text{mass solution} = V \times d = 1.103 \text{ g/ml} \times 250 \text{ ml} = 275.75 \text{ g}$$

$$\text{mass H}_2\text{O} = \text{mass sol}^n - \text{mass Na}_2\text{CO}_3 = 275.75 - 27.575 \text{ g} = 248.175 \text{ g}$$

d) (2 point) Determine the mole fraction of $\text{Na}^+(aq)$ in the solution.

$$X = \frac{n_{\text{Na}^+}}{n_{\text{Na}^+} + n_{\text{CO}_3^{2-}} + n_{\text{H}_2\text{O}}}$$

$$n_{\text{Na}^+} = 0.520 \text{ moles}$$

$$n_{\text{CO}_3^{2-}} = n_{\text{Na}^+} \times \frac{1 \text{ CO}_3^{2-}}{2 \text{ Na}^+} = 0.260 \text{ moles}$$

$$n_{\text{H}_2\text{O}} = \frac{\text{mass H}_2\text{O}}{M_{\text{H}_2\text{O}}} = \frac{248.175 \text{ g}}{18.02 \text{ g/mol}} = 13.772 \text{ moles}$$

Bonus: What is the molarity of CO_3^{2-} ?

$$[\text{CO}_3^{2-}] = \frac{1}{2} [\text{Na}^+] = 1.04 \text{ M}$$

$$0.97 \text{ M}$$

$$0.97 \text{ M}$$

$$n_{\text{Na}^+} = 2 \times n_{\text{Na}_2\text{CO}_3} = 0.520 \text{ moles}$$

$$[\text{Na}^+] = \frac{0.520 \text{ moles}}{0.250 \text{ L}} = 2.08 \text{ M}$$

$$\text{molality} = \frac{0.520}{2.482 \text{ kg}} = 2.10 \text{ molal}$$

$$\frac{50.035}{100.075}$$

$$X_{\text{Na}^+} = \frac{0.520}{0.520 + 0.260 + 13.772}$$

$$= 3.57 \times 10^{-2}$$

$$3.32 \times 10^{-2}$$

$$3.30 \times 10^{-2}$$

↓ if no $n_{\text{CO}_3^{2-}}$

6. An element has three naturally occurring isotopes with the following molar masses: 27.97693 amu (natural abundance 92.23 %), 28.97649 amu (natural abundance 3.10 %), and 29.97376 amu.

a) (2 points) Determine the average atomic mass for this element.

% abundance 3rd isotope = $100 - 92.23 - 3.10 = 4.67\%$

$$\begin{aligned}
 M &= \sum (\text{natural abundance} \times \text{molar mass}) \\
 &= 0.9223(27.97693 \text{ amu}) + 0.0310(28.97649) \\
 &\quad + (0.0467)(29.97376) \text{ amu} \\
 &= 28.10117 \text{ amu}
 \end{aligned}$$

Average atomic mass: 28.10117

b) (1 point) What is this element? Si

c) (1 point) How many neutrons does the most abundant isotope of have? 14

(15)

(16)

14

Page	Maximum	Score
1	5	
2	8	
3	10	
4	8	
5	5	
6	4	
Total	40	