First Midterm – CHM 1311 – F **Prof. Sandro Gambarotta**

Date: Oct 18th 2018 **Length: 80 min**

Last Name: ____________________ **First Name:_____________________**

Student #_____________

- **Instructions:**

- **Calculator permitted (Faculty approved or non-programmable)**
- **Open book**
- **This exam contains 14 pages**

Cellular phones, unauthorized electronic devices or course notes (unless an open-book exam)
are not allowed during this exam. Phones and devices must be turned off and put away in your
bag. Do not keep them in your possession, such as in your pockets. If caught with such
a device or document, the following may occur: you will be asked to leave immediately
the exam, academic fraud allegations will be filed which may result in you obtaining a 0 (zero) for the exam.

Read carefully:

By signing below, you acknowledge that you have read and ensured that you are complying with the above statement.

Signature:____________________________

1	**/4**	**6**	**/1**
2	**/1**	**7**	**/1**
3	**/3**	**8**	**/4**
4	**/2**	**9**	**/5**
5	**/3**	**total**	**/24**

Total/10 =

1. (**4 points**)

A sample of 0.1595 g of menthol (Molar mass = 156.3) was analyzed in a combustion analyzer and yielded 0.449 g CO_2 and 0.184 g of H_2O. What is menthol's molecular formula?

Plan: In combustion analysis, finding the amount (mol) of carbon and hydrogen is relatively simple because all of the carbon present in the sample is found in the carbon of CO_2, and all of the hydrogen present in the sample is found in the hydrogen of H_2O. Convert the mass of CO_2 to moles and use the ratio between CO_2 and C to find the amount (mol) and mass of C present. Do the same to find the amount (mol) and mass of H from H_2O. The amount (mol) of oxygen are more difficult to find, because additional O_2 was added to cause the combustion reaction. Subtracting the masses of C and H from the mass of the sample gives the mass of O. Convert the mass of O to moles of O. Take the moles of C, H, and O and divide by the smallest value to convert to whole numbers to get the empirical formula. Determine the empirical formula mass and compare it to the molar mass given in the problem to see how the empirical and molecular formulas are related. Finally, determine the molecular formula.

Solution:

$$\text{Amount (mol) of C} = (0.449\ \text{g CO}_2)\left(\frac{1\ \text{mol CO}_2}{44.01\ \text{g CO}_2}\right)\left(\frac{1\ \text{mol C}}{1\ \text{mol CO}_2}\right) = 0.010202\ \text{mol C}$$

$$\text{Mass (g) of C} = (0.010202\ \text{mol C})\left(\frac{12.01\ \text{g C}}{1\ \text{mol C}}\right) = 0.122526\ \text{g C}$$

$$\text{Amount (mol) of H} = (0.184\ \text{g H}_2\text{O})\left(\frac{1\ \text{mol H}_2\text{O}}{18.02\ \text{g H}_2\text{O}}\right)\left(\frac{2\ \text{mol H}}{1\ \text{mol H}_2\text{O}}\right) = 0.020422\ \text{mol H}$$

$$\text{Mass (g) of H} = (0.020422\ \text{mol H})\left(\frac{1.008\ \text{g H}}{1\ \text{mol H}}\right) = 0.020585\ \text{g H}$$

Mass (g) of O = Sample mass – (mass of C + mass of H)
= 0.1595 g – (0.122526 g C + 0.020585 g H) = 0.016389 g O

$$\text{Amount (mol) of O} = (0.016389\ \text{g O})\left(\frac{1\ \text{mol O}}{16.00\ \text{g O}}\right) = 0.0010243\ \text{mol O}$$

Preliminary formula = $C_{0.010202}H_{0.020422}O_{0.0010243}$

Converting to integer subscripts (dividing all by the smallest subscript):

$$C_{\frac{0.010202}{0.0010243}}H_{\frac{0.020422}{0.0010243}}O_{\frac{0.0010243}{0.0010243}} \rightarrow C_{10}H_{20}O_1$$

Empirical formula = $C_{10}H_{20}O$

Empirical formula mass = 10(12.01 g/mol C) + 20(1.008 g/mol H) + 1(16.00 g/mol O) = 156.26 g/mol

The empirical formula mass is the same as the given molar mass so the empirical and molecular formulas are the same. The molecular formula is $\mathbf{C_{10}H_{20}O}$.

2. (**1 point**)

Chromium oxide reacts with H_2S according to the following equation:

$Cr_2O_3(s)$ + $H_2S(g)$ → $Cr_2S_3(s)$ + H_2O (l) (**please balance it**)

To produce 421 g of $Cr_2S_3(s)$ how many (a) moles and (b) grams of $Cr_2O_3(s)$ are required?

Plan: Convert mass of Cr_2S_3 to amount (mol) by dividing by its molar mass. Use the mole ratio between Cr_2S_3 and Cr_2O_3 from the balanced chemical equation to determine the amount (mol) of Cr_2O_3 required. Multiply the amount (mol) of Cr_2O_3 by its molar mass to obtain the mass in grams.

Solution:

a) Amount (mol) of $Cr_2S_3 = (421 \text{ g } Cr_2S_3)\left(\frac{1 \text{ mol } Cr_2S_3}{200.21 \text{ g } Cr_2S_3}\right) = 2.102792 \text{ mol } Cr_2S_3$

Amount (mol) of $Cr_2O_3 = (2.102792 \text{ mol } Cr_2S_3)\left(\frac{1 \text{ mol } Cr_2O_3}{1 \text{ mol } Cr_2S_3}\right) = 2.102792$ mol= **2.10 mol Cr_2O_3**

b) Mass (g) of $Cr_2O_3 = (2.102792 \text{ mol } Cr_2O_3)\left(\frac{152.00 \text{ g } Cr_2O_3}{1 \text{ mol } Cr_2O_3}\right) = 319.624$ g= **$3.20\text{x}10^2$ g Cr_2O_3**

Combining all steps gives:

$$\text{Mass (g) of } Cr_2O_3 = (421 \text{ g } Cr_2S_3)\left(\frac{1 \text{ mol } Cr_2S_3}{200.21 \text{ g } Cr_2S_3}\right)\left(\frac{1 \text{ mol } Cr_2O_3}{1 \text{ mol } Cr_2S_3}\right)\left(\frac{152.00 \text{ g } Cr_2O_3}{1 \text{ mol } Cr_2O_3}\right)$$

$= 319.624$ g= **$3.20\text{x}10^2$ g Cr_2O_3**

3. (**3 points**)

Calculate the mass (g) of calcium nitrate in a milliliter of a solution prepared by diluting 64.0 mL of 0.745 mml/L calcium nitrate to a final volume of 0.100L

d) $c_1 = 0.745$ mol/L $\quad V_1 = (64.0 \text{ mL})\left(\frac{10^{-3} \text{ L}}{1 \text{ mL}}\right) = 0.0640 \text{ L}$ $\quad c_2 = ?$ $\quad V_2 = 0.100$ L

$c_1V_1 = c_2V_2$

$$c_2 = \frac{c_1 \text{ x } V_1}{V_2} = \frac{(0.745 \text{ mol / L})(0.0640 \text{ L})}{(0.100 \text{ L})} = 0.4768 \text{ mol/L}$$

The concentration in concentration (mol/L) must now be converted to grams per millilitre.

$$\left(\frac{0.4768 \text{ mol Ca(NO}_3)_2}{\text{L}}\right)\left(\frac{10^{-3} \text{ L}}{1 \text{ mL}}\right)\left(\frac{164.10 \text{ g Ca(NO}_3)_2}{1 \text{ mol Ca(NO}_3)_2}\right) = 0.07824 \text{ g/mL}$$

= **0.0782 g $Ca(NO_3)_2$/mL**

4. (**2 points**)

Balance the following redox equation in acidic conditions (use either the semi-equation or the direct method. Whatever you feel more comfortable with):

$$MnO_4^- + Cl^- \rightarrow Mn^{2+} + Cl_2$$

$$2 \times [5e + 8H^+ + MnO_4^- \rightarrow Mn^{2+} + 4H_2O]$$

$$5 \times [2Cl^- \rightarrow Cl_2 + 2e]$$

$$16H^+ + 2MnO_4^- + 10Cl^- \rightarrow 2Mn^{2+} + 5Cl_2 + 8H_2O$$

$$\mathbf{16H_3O^+ + 2MnO_4^- + 10Cl^- \text{-->} 2Mn_2^+ + 5Cl_2 + 24H_2O}$$

5. (**3 points**) The series of emission lines that result from excited hydrogen atoms undergoing transitions from higher levels to the n = 3 level is called the "Paschen series". Calculate the energy (in J) of the first two lines of this series. $E = -2.18\times10^{-18}/n^2$ J

first = $2.18\times10^{-18}(1/4^2 - 1/3^2)$ = 1.06E-19
second = $2.18\times10^{-18}(1/5^2 - 1/3^2)$ = 1.55E-19

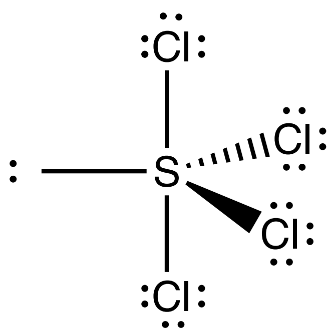
6. (**1 point**) Which element has the electron configuration $[Ar]4s^1 3d^5$ in its ground state ?

Cr

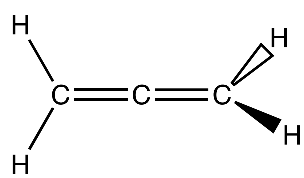
7. (**1 point**) Give the quantum numbers describing the two outermost electrons of the ground state of carbon (n, l, m_l, m_s)

(2,1,1,+1/2) and (2,1,0,+1/2)

8. (4 points) Write the Lewis structure of SCl_4 and draw its structure and geometry.

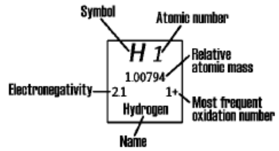


9. (5 points) Draw the 3D structure (bold, solid and broken lines) of CH_2=C=CH_2 and specify the hybridization of each of the three C atoms.



sp^2 sp sp^2

Mokeur's Periodic table of the elements



	1 IA	2 IIA	3 IIIB	4 IVB	5 VB	6 VIB	7 VIIB	8	9 VIII	10	11 IB	12 IIB	13 IIIA	14 IVA	15 VA	16 VIA	17 VIIA	18 VIIIA
1	*H 1* 1.00794 2.1 1+ Hydrogen																	*He 2* 4.002602 - - Helium
2	**Li 3** 6.941 1.0 1+ Lithium	**Be 4** 9.012182 1.5 2+ Beryllium											**B 5** 10.811 2.0 3+ Boron	**C 6** 12.011 2.5 4+,4- Carbon	*N 7* 14.00674 3.0 3+,3- Nitrogen	*O 8* 15.9994 3.5 2- Oxygen	*F 9* 18.9984032 4.0 1- Fluorine	*Ne 10* 20.1797 - - Neon
3	**Na 11** 22.989768 0.9 1+ Sodium	**Mg 12** 24.3050 1.2 2+ Magnesium											**Al 13** 26.981539 1.5 3+ Aluminum	**Si 14** 28.0855 1.8 4+ Silicon	**P 15** 30.973762 2.1 5+ Phosphorus	**S 16** 32.066 1.8 4+ Sulfur	*Cl 17* 35.4527 3.0 1- Chlorine	*Ar 18* 39.948 - - Argon
4	**K 19** 39.0983 0.8 1+ Potassium	**Ca 20** 40.078 1.0 2+ Calcium	**Sc 21** 44.955910 1.3 3+ Scandium	**Ti 22** 47.88 1.5 4+ Titanium	**V 23** 50.9415 1.6 5+ Vanadium	**Cr 24** 51.9961 1.6 3+ Chromium	**Mn 25** 54.93805 1.5 2+ Manganese	**Fe 26** 55.847 1.8 3+ Iron	**Co 27** 58.9332 1.8 2+ Cobalt	**Ni 28** 58.6934 1.8 2+ Nickel	**Cu 29** 63.546 1.9 2+ Copper	**Zn 30** 65.39 1.6 2+ Zinc	***Ga 31*** 69.723 1.6 3+ Gallium	**Ge 32** 72.61 1.6 4+ Germanium	**As 33** 74.92159 2.0 3+,3- Arsenic	**Se 34** 78.96 2.4 4+ Selenium	***Br 35*** 79.904 2.8 1- Bromine	*Kr 36* 83.80 - - Krypton
5	**Rb 37** 85.4678 0.8 1+ Rubidium	**Sr 38** 87.62 1.0 2+ Strontium	**Y 39** 88.90585 1.3 3+ Yttrium	**Zr 40** 91.224 1.4 4+ Zirconium	**Nb 41** 92.90638 1.6 5+ Niobium	**Mo 42** 95.94 1.8 6+ Molybdenum	Tc 43 98.9063 1.9 7+ Technetium	**Ru 44** 101.57 2.2 3+,4+ Ruthenium	**Rh 45** 102.9055 2.2 3+ Rhodium	**Pd 46** 106.42 2.2 2+ Palladium	**Ag 47** 107.8682 1.9 1+ Silver	**Cd 48** 112.411 1.7 2+ Cadmium	**In 49** 114.82 1.7 3+ Indium	**Sn 50** 118.71 1.8 4+ Tin	**Sb 51** 121.757 1.9 3+,3- Antimony	**Te 52** 127.60 2.1 4+ Tellurium	**I 53** 126.90447 2.5 1- Iodine	*Xe 54* 131.29 - - Xenon
6	***Cs 55*** 132.90543 0.7 1+ Cesium	**Ba 56** 137.327 0.9 2+ Barium	**La 57** 138.9055 1.1 3+ Lanthanum	**Hf 72** 178.49 1.3 4+ Hafnium	**Ta 73** 180.9479 1.5 5+ Tantalum	**W 74** 183.85 1.7 6+ Tungsten	**Re 75** 186.207 1.9 7+ Rhenium	**Os 76** 190.2 2.2 4+ Osmium	**Ir 77** 192.22 2.2 4+ Iridium	**Pt 78** 195.08 2.2 4+ Platinum	**Au 79** 196.96654 2.4 3+ Gold	***Hg 80*** 200.59 1.9 2+ Mercury	**Tl 81** 204.3833 1.8 1+ Thallium	**Pb 82** 207.2 1.8 2+ Lead	**Bi 83** 208.98037 1.9 3+ Bismuth	**Po 84** 208.9824 2.0 2+ Polonium	**At 85** 209.9871 2.2 1- Astatine	*Rn 86* 222.0176 - - Radon
7	***Fr 87*** 223.0197 0.7 1+ Francium	**Ra 88** 226.0254 0.9 2+ Radium	**Ac 89** 227.0278 1.1 3+ Actinium	Rf 104 261.11 - - Rutherfordium	Db 105 262.11 - - Dubnium	Sg 106 263.12 - - Seaborgium	Bh 107 262.12 - - Bohrium	Hs 108 264 - - Hassium	Mt 109 266.1378 - - Meitnerium	Uun 110 269 - - Ununnilium	Uuu 111 272 - - Unununium	Uu 112 277 - - Ununbium		Uuq 114 289 - - Ununquadium		Uuh 116 289 - - Ununhexium		Uuo 118 293 - - Ununoctium

6	**Ce 58** 140.115 1.1 3+ Cerium	**Pr 59** 140.90765 1.1 3+ Praseodymium	**Nd 60** 144.24 1.1 3+ Neodymium	Pm 61 144.9127 1.1 3+ Promethium	**Sm 62** 150.36 1.2 3+ Samarium	**Eu 63** 151.965 1.2 3+ Europium	**Gd 64** 157.25 1.2 3+ Gadolinium	**Tb 65** 168.92534 1.2 3+ Terbium	**Dy 66** 162.50 1.2 3+ Dysposium	**Ho 67** 164.93032 1.2 3+ Holmium	**Er 68** 167.26 1.2 3+ Erbium	**Tm 69** 168.93421 1.2 3+ Thulium	**Yb 70** 173.04 1.1 3+ Ytterbium	**Lu 71** 174.967 1.2 3+ Lutetium
7	**Th 90** 232.0381 1.3 4+ Thorium	**Pa 91** 231.03588 1.5 5+ Protactinium	**U 92** 238.0289 1.4 6+ Uranium	Np 93 237.082 1.3 5+ Neptunium	Pu 94 244.0642 1.3 4+ Plutonium	Am 95 243.0614 1.3 3+ Americium	Cm 96 247 1.3 3+ Curium	Bk 97 247.0703 1.3 3+ Berkelium	Cf 98 251.0796 1.3 3+ Californium	Es 99 252.03 1.3 - Einsteinium	Fm 100 257.0951 1.3 - Fermium	Md 101 258.01 1.3 - Mendelevium	No 102 259.1009 1.3 - Nobelium	Lr 103 260.1053 - - Lawrencium

Under normal conditions, bold symbols correspond to solid state, bold italic correspond to liquid state, italic correspond to gaseous state and normal correspond to synthetic elements.

Data For Water

Density = 1.00 g/mL (at 25°C)
s = 2.13 J g^{-1} K^{-1} (solid)
s = 4.184 J g^{-1} K^{-1} (liquid) $\Delta H°_{fus}$ = 6.02 kJ mol^{-1}
s = 2.01 J g^{-1} K^{-1} (gas) $\Delta H°_{vap}$ = 40.7 kJ mol^{-1}

Constants and Conversion Factors

1 mmHg = 1 torr 760 mmHg = 1 atm 1 atm = 101.325 kPa 1 atm = 1.013125 bar
1 cm^3 = 1 mL 1000 mL = 1 L 1000 L = 1 m^3

Avogadro's Number	*N*	$6.022 x 10^{23}$ mol^{-1}	
Boltzmann's constant	*k*	$1.30866 x 10^{-23}$ $J \cdot K^{-1}$	
Faraday's constant	*F*	96,485 $C \cdot mol^{-1}$	
Gas constant	*R*	8.31451 $J \cdot K^{-1} \cdot mol^{-1}$	
	R	0.08206 $atm \cdot L \cdot K^{-1} \cdot mol^{-1}$	
	R	8.31451 $m^3 Pa \cdot K^{-1} \cdot mol^{-1}$	
	R	0.0831451 bar $L \cdot K^{-1} \cdot mol^{-1}$	
Planck's constant	*h*	$6.62608 x 10^{-34}$	$J \cdot s$
Speed of Light	*c*	$2.99792458 x 10^{8}$	$m \cdot s^{-1}$

Gas Laws

$PV = nRT$

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$$

$P_T = P_1 + P_2 + P_3 + \ldots$

$$d = \frac{m}{V} = \frac{P \cdot MM}{RT}$$

$$E_K = \frac{1}{2}mv^2$$

$$u_{rms} = \sqrt{\frac{3RT}{MM}}$$

$$\frac{Rate\ A}{Rate\ B} = \sqrt{\frac{MM_B}{MM_A}}$$

$$\left(P + \frac{n^2a}{V^2}\right)(V - nb) = nRT$$

Equilibrium

$K_P = K_C(RT)^{\Delta n}$

Acid/Base

$pOH = -\log[OH^{-1}]$

$pH = -\log[H^+]$

$pH + pOH = 14$

$K_a \times K_b = K_W$

$pH = pK_a + \log [A^-]/[HA]$

$$pH = \frac{pK_{a1} + pK_{a2}}{2}$$

Thermochemistry

$\Delta U = q + W$

$W_{system} = -P\Delta V = -\Delta nRT$

$\Delta H = \Delta U + P\Delta V$

$q_P = \Delta U + P\Delta V$

$q = ms\Delta T$

$\Delta H_{rxn}° = \sum n\Delta H_f°(pdts) - \sum n\Delta H_f°(rxts)$

The atom

$E = h\nu$

$c = \nu\lambda$

$E = -B/n^2$

Kinetics

$[A]_t = [A]_o - kt$

$\ln[A]_t = \ln[A]_o - kt$

$1/[A]_t = 1/[A]_o + kt$

$k = Ae^{(-Ea/RT)}$

$\ln(k_2/k_1) = (-Ea/R)(1/T_2 - 1/T_1)$