Department of Chemistry
Memorial University of Newfoundland
Chemistry 1050

FINAL EXAMINATION Fall 2019 TIME: 2 hours

READ THE FOLLOWING CAREFULLY

1. This examination consists of 13 pages including a Data Sheet at the end. Ensure that this examination paper is complete, i.e. that all 13 pages are present.

2. A Data Sheet with a periodic table, equations and physical constants is provided. These are on the last sheet of the exam and may be detached for use during the examination.

3. DO NOT REMOVE ANY PART OF THIS EXAM FROM THE EXAM ROOM.

4. Answer each question in the space provided. Should you require more space, use the back of the previous page and indicate clearly where this has been done.

5. Show all relevant calculations and justify all simplifying assumptions.

6. Numerical answers must be reported to the appropriate number of significant digits with the correct units (if any).

Do not write in the table below.

Good Luck!

Page	Value	Mark
2	8	
3	8	
4	9	
5	9	
6	10	
7	9	
8	10	
9	10	
10	9	
11	9	
12	3	
	Total Marks	**/94**

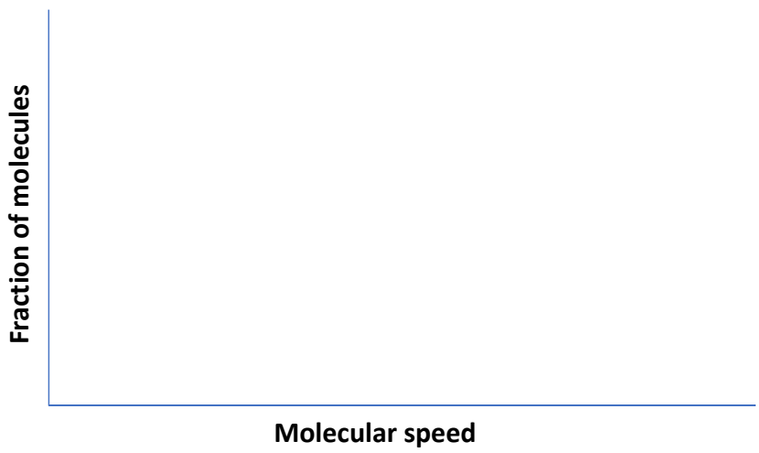
1) Balloons for a New Year's Eve party in St. John's, Newfoundland, are filled with N_2 gas to a volume of 5.0 L at a temperature of 25 ^oC (298 K), sealed and then hung outside where the temperature is -10 ^oC (263 K). Assume that the atmospheric pressure inside and outside the house is the same at 101.85 kPa.

a) What is the volume (in L) of the balloons after they have cooled to the outside temperature of -10 ^oC (263 K)? **[2 marks]**

b) Use kinetic molecular theory to explain the simple gas law observed in part a of this question. **[2 marks]**

c) Assuming the conditions described above are the same but the balloons were filled with carbon dioxide gas (CO_2), would you expect the volume of the balloons at -10 ^oC (263 K) to be the same or different than those filled with nitrogen gas (N_2). Explain. **[2 marks]**

d) On the set of axis below, sketch the distribution of molecular speeds for both N_2 and CO_2 at -10 ^oC (263 K). Clearly label your sketches with respect to the identity of the molecule of interest. **[2 marks]**



2) A sample $KClO_3$ (122.55 g·mol^{-1}) was heated generating O_2 gas which occupied 1.40×10^2 mL at STP. What was the mass (in g) of the sample of $KClO_3$? **[3 marks]**

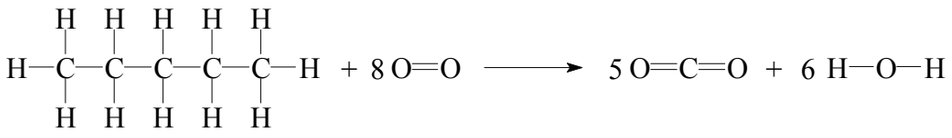
$KClO_3$ decomposes as follows:

$$2\ KClO_3(s) \rightarrow 2\ KCl(s) + 3\ O_2(g)$$

3) An unknown gas effuses at 0.828 times the effusion rate of sulfur dioxide, SO_2 (64.0588 g mol^{-1}). What is the molar mass of the unknown gas? **[2 marks]**

4) Calculate the standard enthalpy of reaction (in kJ mol^{-1}) for the combustion of pentane using the given average bond energies in the table. **[3 marks]**

Bond	Average Bond Energies (kJ·mol^{-1})
C-C	347
C-H	414
O=O	498
C=O	799
O-H	464



5) Liquid dimethylhydrazine, $C_2H_8N_2$ (60.0983 g mol^{-1}) burns in oxygen according to the following reaction:

$$C_2H_8N_2(l) + 4\,O_2(g) \rightarrow 2\,CO_2(g) + N_2(g) + 4\,H_2O(l)$$

A 0.48233 g sample of dimethylhydrazine was burned in a bomb calorimater with a heat capacity of 9.9095 kJ $^{o}C^{-1}$ and the temperature increased from 22.709 ^{o}C to 24.100 ^{o}C. Find both $\Delta_r U^o$ and $\Delta_r H^o$ (in kJ mol^{-1}) for the combustion reaction at 298 K. **[5 marks]**

6) A 32.5 g cube of aluminum (0.903 J g^{-1} $^{o}C^{-1}$) initially at 45.8 ^{o}C is submerged into 105.3 g of water at 15.4 ^{o}C. What is the final temperature of both substances at thermal equilibrium. The specific heat of water is 4.184 J g^{-1} $^{o}C^{-1}$. (Assume no heat was lost to the surroundings.) **[4 marks]**

7) a) Compute the change in energy, in kJ mol^{-1}, for an $n = 4$ to $n = 3$ transition in He^{+}. **[3 marks]**

b) What is the wavelength (in m) associated with the transition in **part a** of this question? **[1 mark]**

8) a) List the following elements in order of increasing first ionization energy. **[1 mark]**

Ca, Rb, Cl, He

_____ < _____ < _____ < _____
Lowest Highest

b) i) Circle the ionic compound expected to have the highest (most negative) lattice energy? **[1 mark]**

NaCl Al_2O_3 MgO

ii) Explain your choice for the ionic compound expected to have the highest (most negative) lattice energy in **the previous part i)** of this question. **[1 mark]**

c) i) Of the ionization processes show below, circle the process which requires the most energy? **[1 mark]**

$S(g) \rightarrow S^{+}(g) + e^{-}$ $S^{+}(g) \rightarrow S^{2+}(g) + e^{-}$

ii) Explain your choice for the process in **in the previous part i)** of this question expected to require the most energy. **[1 mark]**

9) Use words from the box below to fill in the blanks in the statements below. **[10 marks]**

penetrates	shielded	attracts
repelled	beryllium	boron
oxygen	nitrogen	radial
angular	farther from	closer to
zero	small	negative
particle	amplitude	restricted
oriented	matter	interferes

a) The reason that the 2*p* orbitals are higher in energy than the 2*s* orbital for multielectron atoms is due to the fact that an electron in a 2*s* orbital _____ close to the nucleus and into the 1*s* orbital. Therefore, electrons in a 2*s* orbital are not _____ as much as electrons in the 2*p* orbitals by the 1*s* electrons. This has the effect that _____ has a larger ionization energy than _____ despite the general trend that ionization energies increase as you move to the right in the periodic table.

b) A node is a point or surface where the probability of finding an electron is _____.

c) Both a 1*s* orbital and a 2*p* orbital have no _____ nodes, however, the 2*p* orbital has an _____ node. The overall shape of the radial probability diagrams is similar for the 1*s* and 2*p* orbitals, but that for the 2*p* orbital has its maximum _____ the nucleus along the r axiz.

d) The sign of the _____ of a wave is known as its phase. The phase of the wave determines how it _____ with another wave, either constructively or destructively.

10) The following questions are related to electron configurations in multielectron atoms and ions.

a) Give the orbital designation (type of orbital) of electrons with the quantum numbers: $n = 5$, $\ell = 2$. **[1 mark]**

b) Give the condensed ground state electron configuration and the condensed orbital box diagram for each of the following. Show each electron as an up or down arrow. **[6 marks]**

i) Ti (Titanium):

ii) Bi (Bismuth):

iii) P^{3-} (Phosphorus 3^- anion):

c) i) Is copper (Cu) diamagnetic or paramagnetic? Justify your choice. **[1 mark]**

ii) Copper forms a +1 cation (Cu^+). Write the electron configuration for Cu^+. **[1 mark]**

11) a) Draw three (3) different resonance structures that obey the octet rule for N_2O. In N_2O the skeletal structure is N-N-O. **[3 marks]**

b) Assign formal charges to each of the atoms with nonzero formal charges in each of the resonance structures above. **[3 marks]**

c) Identify the probable major contributor (lowest energy structure) from **part a** of this question to the resonance hybrid and explain your reasoning. **[1 mark]**

12) Write the balanced equations for the following. **[3 marks]**

(a) Write a balanced chemical equation to demonstrate the reaction between solid chromium and chlorine gas to form the corresponding chromium (II) compound.

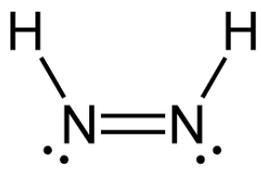
(b) Write a balanced chemical equation to demonstrate the reaction between solid potassium and liquid water.

(c) Write a balanced chemical equation to demonstrate the reaction between solid iodine and hydrogen gas.

13) Complete the following table to provide the missing data. For the Lewis structures, the final structures should consider minimizing formal charge. Be sure to include all bonding and nonbonding electrons in your drawings.

	ClF_3 (Chlorine Triflouride)	IBr_5 (Iodine Pentabromide)
Determine the total number of **valence electrons** in this molecule/ion. **[1 mark each]**		
Draw a Lewis Structure for the molecule. **[1 mark each]**		
Sketch of VSEPR shape of the molecule and include **all** bond angles. **[1 mark each]**		
Give the name representative of the molecular geometry for the molecule. **[1 mark each]**		
Is the molecule polar or nonpolar? **[1 mark each]**		

14) A Lewis structure for HNNH is provided below. Use valence bond and orbital hybridization theories to describe the bonding in this molecule. You are required to add a sketch of the molecule below, illustrating and labelling the types of all the bonds in the molecule, sigma (σ) or pi (π) bonds, and the atomic and/or hybrid orbitals that overlap to form these bonds. Also show the type of orbital responsible for the lone pairs of electrons. **[5 marks]**



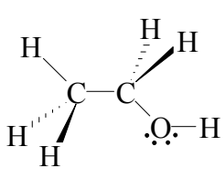
15) Answer the following questions with respect to intermolecular forces.

a) i) Circle the substance below which is expected to have the largest dispersion forces. **[1 mark]**

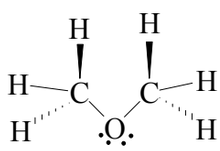
C_2H_6 C_8H_{18} N_2 CO_2

ii) Explain your answer to **the previous part i)**. **[1 mark]**

b) i) Of the following two isomeric compounds below, circle the compound which is likely to have the highest boiling point. **[1 mark]**



CH_3CH_2OH (Ethanol)



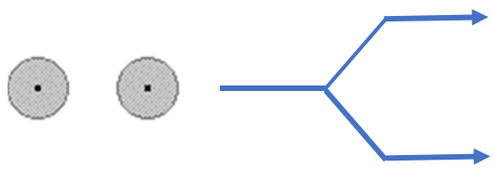
CH_3OCH_3 (Dimethyl ether)

ii) Explain your choice in **the previous part i)** of this question. **[1 mark]**

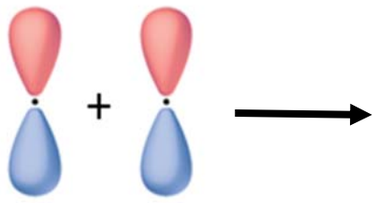
16) Answer the following questions:

a) In the space below, sketch and correctly label a *d* orbital and a *p* orbital. In your drawings include orbital phases (+ or –) and a set of cartesian axes. **[2 marks]**

b) Below are two 1*s* orbitals. Sketch the bonding and antibonding molecular orbitals **and** give their appropriate orbital labels that result from the combination of two 1*s* orbitals. **[2 marks]**



c) Below are two $2p_x$ orbitals. Sketch and label the phases (+ and -) of the ***bonding*** π_{2p} molecular orbital they would generate. **[1 mark]**



17) Using molecular orbital theory, provide the following:

a) Draw a molecular orbital energy level diagram for a hypothetical molecule formed between an atom of Li and an atom of Be. In your diagram, label all atomic and molecular orbitals and place the correct number of electrons in the MOs. Consider only the 2*s* orbitals of each atom. **[2 marks]**

b) Determine the bond order for LiBe and comment on its possible stability with respect to the atoms, Li + Be. [**2 marks]**

18) Methanol has a normal boiling point of 64.60 ºC (337.75 K). What is the vapor pressure (in bar) of methanol at 25.00 ºC (298.15 K)? The molar heat of vaporization of methanol is 35.2 kJ mol^{-1}. **[3 marks]**

Periodic Table of the Elements

1																	18
1 H 1.01	2											13	14	15	16	17	2 He 4.00
3 Li 6.94	4 Be 9.01											5 B 10.81	6 C 12.01	7 N 14.01	8 O 16.00	9 F 19.00	10 Ne 20.18
11 Na 22.99	12 Mg 24.31	3	4	5	6	7	8	9	10	11	12	13 Al 26.98	14 Si 28.09	15 P 30.97	16 S 32.07	17 Cl 35.45	18 Ar 39.95
19 K 39.10	20 Ca 40.08	21 Sc 44.96	22 Ti 47.87	23 V 50.94	24 Cr 51.99	25 Mn 54.94	26 Fe 55.85	27 Co 58.93	28 Ni 58.69	29 Cu 63.55	30 Zn 65.38	31 Ga 69.72	32 Ge 72.63	33 As 74.92	34 Se 78.97	35 Br 79.90	36 Kr 83.80
37 Rb 85.47	38 Sr 87.62	39 Y 88.91	40 Zr 91.22	41 Nb 92.91	42 Mo 95.95	43 Tc 98.91	44 Ru 101.07	45 Rh 102.91	46 Pd 106.42	47 Ag 107.87	48 Cd 112.41	49 In 114.82	50 Sn 118.71	51 Sb 121.76	52 Te 127.6	53 I 126.90	54 Xe 131.29
55 Cs 132.91	56 Ba 137.33	57-71	72 Hf 178.49	73 Ta 180.95	74 W 183.84	75 Re 186.21	76 Os 190.23	77 Ir 192.22	78 Pt 195.09	79 Au 196.97	80 Hg 200.59	81 Tl 204.38	82 Pb 207.2	83 Bi 208.98	84 Po [208.98]	85 At 209.99	86 Rn 222.02
87 Fr 223.02	88 Ra 226.03	89-103	104 Rf [261]	105 Db [262]	106 Sg [266]	107 Bh [264]	108 Hs [269]	109 Mt [278]	110 Ds [281]	111 Rg [280]	112 Cn [285]	113 Nh [286]	114 Fl [289]	115 Mc [289]	116 Lv [293]	117 Ts [294]	118 Og [294]

57 La 138.91	58 Ce 140.12	59 Pr 140.91	60 Nd 144.24	61 Pm 144.91	62 Sm 150.36	63 Eu 151.96	64 Gd 157.25	65 Tb 158.93	66 Dy 162.50	67 Ho 164.93	68 Er 167.26	69 Tm 168.93	70 Yb 173.06	71 Lu 174.97
89 Ac 227.03	90 Th 232.04	91 Pa 231.04	92 U 238.03	93 Np 237.05	94 Pu 244.06	95 Am 243.06	96 Cm 247.07	97 Bk 247.07	98 Cf 251.08	99 Es [254]	100 Fm 257.10	101 Md 258.1	102 No 259.10	103 Lr [262]

Constants

$\Delta_{\text{fus}}H^{\text{o}}_{\text{H}_2\text{O(s)}} = 6.01 \text{ kJ mol}^{-1}$ at 273 K

$\Delta_{\text{vap}}H^{\text{o}}_{\text{H}_2\text{O}(l)} = 40.7 \text{ kJ mol}^{-1}$ at 373 K

$\Delta_{\text{vap}}H^{\text{o}}_{\text{H}_2\text{O}(l)} = 44.0 \text{ kJ mol}^{-1}$ at 298 K

specific heat of $\text{H}_2\text{O}(l) = 4.184 \text{ J g}^{-1} \text{ K}^{-1}$

specific heat of $\text{H}_2\text{O}(s) = 1.960 \text{ J g}^{-1} \text{ K}^{-1}$ at 0 °C

density of $\text{H}_2\text{O}(l)$ near $0\ ^{\text{o}}\text{C} = 1.000 \text{ g mL}^{-1}$

$c = 2.998 \times 10^{8} \text{ m s}^{-1}$

$R_H = 1.0973 \times 10^{7} \text{ m}^{-1}$

$h = 6.626 \times 10^{-34} \text{ J s}$

$N_A = 6.022 \times 10^{23} \text{ mol}^{-1}$

$R = 8.314 \text{ J mol}^{-1} \text{ K}^{-1}$
$= 0.08314 \text{ L bar mol}^{-1} \text{ K}^{-1}$

$F = 9.6485 \times 10^{4} \text{ C mol}^{-1}$

Some Useful Equations

$PV = nRT$

$E_n(\text{J}) = -2.179 \times 10^{-18} \times \frac{Z^2}{n^2}$

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

$\Delta U = q + w$

$\Delta E(\text{J}) = -Z^2 \times 2.179 \times 10^{-18} \left(\frac{1}{n_{\text{f}}^2} - \frac{1}{n_{\text{i}}^2}\right)$

$\Delta_{\text{r}}H^{\text{o}} = \Sigma \nu_{\text{p}} \Delta_{\text{f}} H^{\text{o}}_{\text{products}} - \Sigma \nu_{\text{r}} \Delta_{\text{f}} H^{\text{o}}_{\text{reactants}}$

$\ln\left(\frac{P_2}{P_1}\right) = \frac{-\Delta_{\text{vap}}H}{R}\left(\frac{1}{T_2} - \frac{1}{T_1}\right)$

$E_k = \frac{1}{2} m \text{v}^2$

$\Delta_{\text{r}}H = \Delta_{\text{r}}U + \Delta nRT$

$E_n = h\nu$

$\lambda \nu = c$

$\lambda = \frac{h}{m\text{v}}$

$r_n = \frac{n^2 a_{\text{o}}}{Z^2}$

$u_{\text{rms}} = \sqrt{\frac{3RT}{M}}$

$\frac{\text{rate}_{\text{A}}}{\text{rate}_{\text{B}}} = \sqrt{\frac{M_{\text{B}}}{M_{\text{A}}}}$

Conversion Factors

1 bar L = 100 J

1 atm L = 101.325 J

1 cal = 4.184 J (exactly)

$1 \text{ L} = 1 \text{ dm}^3$

$1 \text{ mL} = 1 \text{ cm}^3$

$1 \text{ J} = 1 \text{ kg m}^2 \text{ s}^{-2}$

$1 \text{ bar} = 10^5 \text{ Pa} = 100 \text{ kPa} = 750.1 \text{ torr} = 0.9869 \text{ atm}$