Department of Chemistry
Memorial University
Chemistry 1050

Fall 2015 Final Examination

Time 3 hours

Read the Following Carefully

1. This exam has 14 pages. Question are on pages 2 through 13 and a periodic table is on page 14. Ensure that all pages for the examination paper are present.

2. A sheet containing the periodic table, physical constants and some equations which may be useful to you are provided. The periodic table sheet is the last page of the exam paper **and should be detached for easier use.**

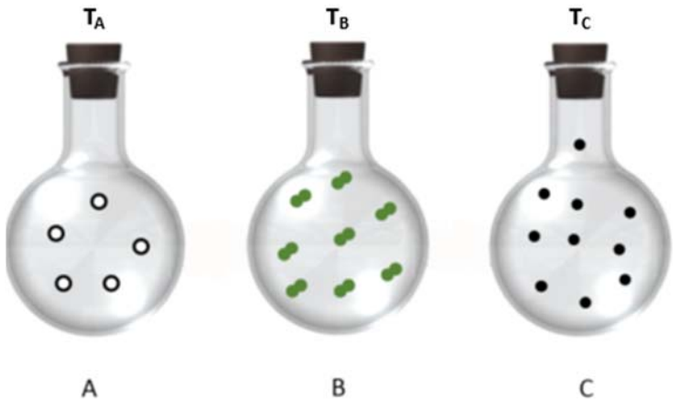
3. **Read each question carefully** and answer each question in the space provided.

4. Show all relevant calculations.

5. Numerical answers should be reported to the appropriate number of significant digits and MUST include the correct units.

Questions	Points	Grade
1-3	10	
4-7	10	
8-9	8	
10-11	8	
12-14	10	
15-16	10	
17-20	11	
21-22	11	
23-24	9	
25-26	9	
27-29	9	
30	4	
total	109	

1. The figure below shows three containers all of ***equal volumes*** and all are at the ***same pressure***. Each vessel contains an ideal gas with molar amounts proportional to the number of atoms or molecules.



a) Which vessel is at the highest temperature? Explain your answer in terms of the kinetic molecular theory! **(1 mark)**

b) If the temperature of container B is 299.5 K, what is the temperature in container C? **(2 marks)**

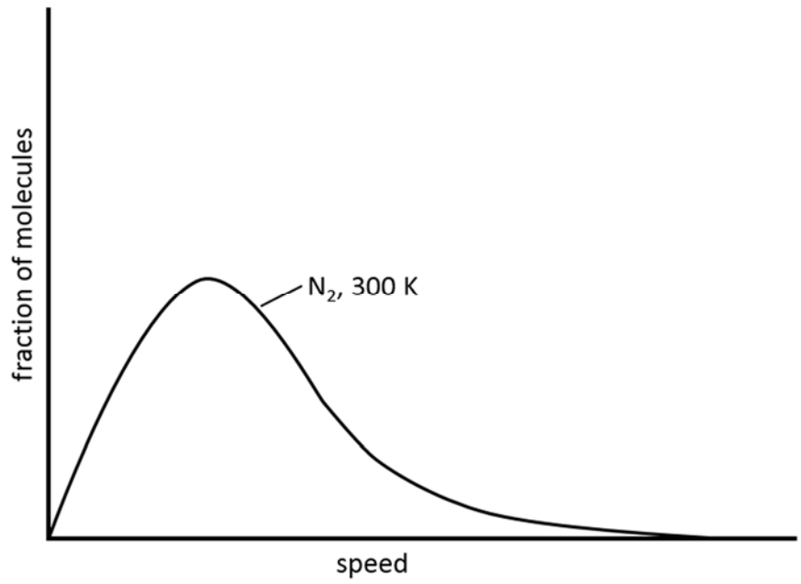
2. A 2.5 L balloon with a fixed amount of gas in it is currently 6.5 m under the surface of the ocean where the pressure is 165 kPa and the temperature is 1.0 ^{o}C. If the balloon is brought out of the ocean where the pressure and temperature are 99 kPa and 10 ^{o}C, respectively, what will be the volume of the balloon? **(3 marks)**

3. One tank of gasoline (C_8H_{18}) in a Ford F150 is about 120 L or a mass of about 86 kg. Gasoline burns according to the following balanced chemical reaction:

$$C_8H_{18}(l) + \tfrac{25}{2}\, O_2(g) \rightarrow 8\, CO_2(g) + 9\, H_2O(l)$$

What volume of CO_2 is produced at 298 K and 1.02 bar when 86 kg of C_8H_{18} is burned? **(4 marks)**

4. Below is a plot showing the distribution of molecular speeds for N_2 at 300 K.



a) On this plot, sketch the distribution for H_2 at 300 K and the one for N_2 at 100 K. **(2 marks)**

b) If samples of H_2 and N_2 are at the same temperature, which of the molecules if either has the higher average kinetic energy. Explain your answer. **(2 marks)**

5. A sample of gas contains 0.025 mol of H_2 and 0.050 mol of N_2 at STP. What is the partial pressure of H_2? **(2 marks)**

6. Oxygen and hydrogen gases have molar masses of 32.0 g mol^{-1} and 2.0 g mol^{-1}, respectively. If 4.0×10^{-3} mol of oxygen effuses through a tiny hole in 1.5 days, how much hydrogen will effuse in the same amount of time? **(2 marks)**

7. At moderately high pressure and low temperature, the volume of a sample of xenon was determined to be slightly less than that predicted by the ideal gas law. Explain in terms of the properties of a real gas and the kinetic molecular theory. **(2 marks)**

8. A 1133 g steel horseshoe at 1265 ^{o}C is dipped into a bucket containing 4.50×10^{3} g of water at 25 ^{o}C. The heat capacity of steel is 0.420 J g^{-1} ^{o}C^{-1}. What is the final temperature of the horseshoe and water assuming no heat escapes? **(4 marks)**

9. Oleic acid is one of the main components of fats in scrunchions, a delectable Newfoundland treat.

$$C_{18}H_{34}O_2(s) + \frac{51}{2} O_2(g) \rightarrow 18\, CO_2(g) + 17\, H_2O(l)$$

In a bomb calorimetry experiment 0.7081 g of oleic acid (molar mass = 282.46 g mol^{-1}) was combusted in a bomb calorimeter with a heat capacity of 10.66 kJ ^{o}C^{-1}. The temperature of the calorimeter was observed to rise by 2.620 ^{o}C. Determine the $\Delta_r U$ and $\Delta_r H$ (at 298 K) for the combustion of oleic acid. **(4 marks)**

10. a) The heats of formation for the reactants and products in the combustion of oleic acid are provided below.

$$C_{18}H_{34}O_2(s) + \frac{51}{2} O_2(g) \rightarrow 18\ CO_2(g) + 17\ H_2O(l)$$

$\Delta_f H^\circ$ / kJ mol^{-1}	-781	-393.5	-285.8

Compute $\Delta_r H^o$ for the combustion of oleic acid using the heats of formation provided. **(3 marks)**

b) Use the $\Delta_r H^o$ computed in a) to determine how many "food calories" would be had by eating 50.0 g of oleic acid (1 food calorie = 4.184 kJ). **(2 marks)**

11. Find $\Delta_r H$ for the following reaction: **(3 marks)**

$$N_2O(g) + NO_2(g) \rightarrow 3\ NO(g)$$

Use these reactions with known $\Delta_r H$'s:

$$2\ NO(g) + O_2(g) \rightarrow 2\ NO_2(g) \qquad \Delta_r H = -113.1\ \text{kJ mol}^{-1}$$

$$N_2(g) + O_2(g) \rightarrow 2\ NO(g) \qquad \Delta_r H = 182.6\ \text{kJ mol}^{-1}$$

$$2\ N_2O(g) \rightarrow 2N_2(g) + O_2(g) \qquad \Delta_r H = -163.2\ \text{kJ mol}^{-1}$$

12. State whether you think each of the following processes are exothermic or endothermic. **(4 marks)**

$18\,CO_2(g) + 17\,H_2O(l) \rightarrow C_{18}H_{34}O_2(s) + \frac{51}{2}\,O_2(g)$ _____

$H_2O(s) \rightarrow H_2O(l)$ _____

$Cl(g) + e^- \rightarrow Cl^-(g)$ _____

$2\,K(s) + 2\,H_2O(l) \rightarrow 2\,K^+(aq) + 2\,OH^-(aq) + H_2(g)$ _____

$2\,F(g) \rightarrow F_2(g)$ _____

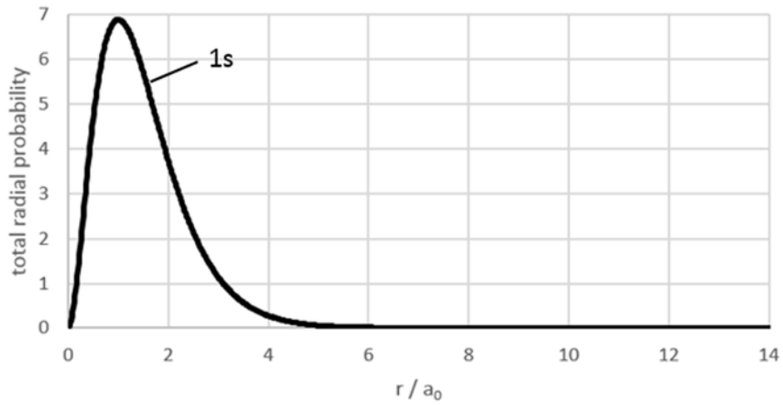
$O^-(g) + e^- \rightarrow O^{2-}(g)$ _____

$O(g) \rightarrow O^+(g) + e^-$ _____

$K^+(g) + Cl^-(g) \rightarrow KCl(s)$ _____

13. Below is a plot of the total radial probability diagram for a 1s orbital.

a) On the same plot, sketch the total radial probabilities for the 2s and the 2p orbitals **(2 marks)**.



b) Explain briefly why the 2s orbital is lower in energy than the 2p orbital. For example, why is the electron configuration of Li $1s^2 2s^1$ rather than $1s^2 2p^1$? **(1 marks)**

14. Compute the ionization energy for a hydrogen atom from its ground state in kJ mol^{-1}. **(3 marks)** (hint: what is n_i for the ground state and n_f for the ionized atom?)

15. Write the **condensed** ground state electron configurations and **condensed** orbital diagrams for the following. **(5 marks)**

Species	Condensed electron configuration	Condensed orbital diagram
P		
Co		
Fe^{2+}		
Pb (element 82)		
Sn^{2+}		

16. Consider the following condensed electron configurations and answer the questions below: **(5 marks)**

i) $[Ne]3s^1$

ii) $[Ne]3s^23p^1$

iii) $[Ne]3s^23p^3$

iv) $[Ne]3s^23p^4$

v) $[Ne]3s^13p^5$

vi) $[Ar]4s^13d^5$

vii) $[Ne]3s^23p^5$

a) Which one is the electron configuration of an excited state atom? _____

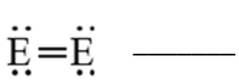
b) Which one has the following successive ionization energies (in kJ mol^{-1}): 1012, 1907, 2914, 4964, 6274, 21267, 25431, 29872? _____

c) Which one, without d electrons, has the lowest ionization energy? _____

d) Which one, without d electrons, is the smallest atom? _____

e) Which two form an ionic compound with the following formula: MX where M is the cation and X is the anion? _____ and _____

f) Which two form a covalent compound with the formula AB_2? _____ and _____

g) Which one forms a diatomic molecule with the following Lewis structure below? E just stands for element.  _____

17. Below are the reactions of two different alkali metals with water:

$$2\,\mathrm{Li}(s) + 2\,\mathrm{H_2O}(l) \rightarrow 2\,\mathrm{LiOH}(aq) + \mathrm{H_2}(g)$$
$$2\,\mathrm{K}(s) + 2\,\mathrm{H_2O}(l) \rightarrow 2\,\mathrm{KOH}(aq) + \mathrm{H_2}(g)$$

The reaction with potassium (K) is significantly more vigorous than the reaction with lithium (Li).

a) Explain this observation. **(2 marks)**

b) Write and balance the reaction between Ca(s) and water. **(1 mark)**

c) Write a balanced reaction between solid magnesium and gaseous fluorine. **(1 mark)**

18. Explain why effective nuclear charge increases as one moves across the periodic table from Li to Ne. **(2 marks)**

19. The first ionization energy of phosphorous (P) is 1012 kJ mol^{-1} and that of sulfur (S) is 1000 kJ mol^{-1} despite the general trend for ionization energies to increase going from left to right across the periodic table. Use the electron configurations for P and S to explain why S has the lower ionization energy. **(2 marks)**

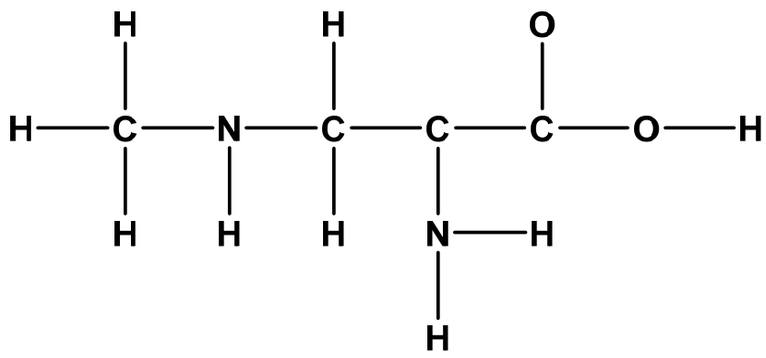
20. The ions Mg^{2+} and Al^{3+} are isoelectronic.

a) The ionization energies for these two ions are 7730 kJ mol^{-1} and 11600 kJ mol^{-1}, respectively. Explain the difference in ionization energies. **(1 mark)**

b) Which one is the largest, Mg^{2+} or Al^{3+}? **(1 mark)**

c) Write the symbol (with charge) for a negative ion that is isoelectronic with Mg^{2+} or Al^{3+}. **(1 mark)**

21. a) Below is the skeletal structure for β-methylaminoalanine (BMAA), $C_4H_9N_2O_2$, a nonproteinogenic amino acid that has been implicated in neurogenerative diseases such as ALS. Complete the Lewis structure for BMAA by placing lone pairs and multiple bonds where required. **(2 marks)**



b) For the N atoms in BMAA, what is the electron group geometry, shape, and hybridization? **(1.5 marks)**

electron group geometry_____

shape _____

hybridization _____

c) For the C atom that is attached to two oxygen atoms in BMAA, what is the electron group geometry, shape, and hybridization? **(1.5 marks)**

electron group geometry_____

shape _____

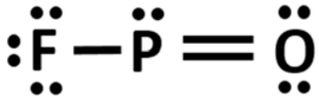
hybridization _____

22. a) Draw the Lewis structure for ICl_3 (iodine trichloride). **(2 marks)**

b) Draw and name the shape of ICl_3**. (2 mark)**

c) State whether ICl_3 (iodine trichloride) is polar or non-polar and state the dominant intermolecular forces between molecules of ICl_3. **(2 marks)**

23. To the right is a Lewis structure for phosphorous oxyfluoride. Use Valence Bond and Orbital Hybridization Theories to describe the bonding in this molecule. Your answer should show the following steps. **(4 marks)**



i) Using the Lewis structure of phosphorous oxyfluoride and VSEPR theory, predict the shape around the P atom.
ii) What is the hybridization of P?
iii) Provide a sketch, illustrating and labelling the types of **all** the bonds in the molecule, sigma (σ) or pi (π), and the atomic and/or hybrid orbitals that overlap to form these bonds.

24. a) Draw a Lewis structure for the hydrogen phosphate ion, HPO_4^{2-}, that obeys the octet rule. Assign formal charges. All oxygen atoms are attached to P and the H is attached to one O. **(2 marks)**

b) Draw another Lewis structure where the formal charges are minimized as much as possible, and any remaining formal charge resides with the correct atom(s). Assign formal charges to all the atoms. **(1 mark)**

c) Draw ALL the other resonance structures besides the one in b). **(1 marks)**

d) Use one of these Lewis structures to determine the phosphorous-oxygen bond orders; not the one attached to H. **(1 marks)**

25. a) Draw the molecular orbital diagram for the He_2^+ molecule. Don't forget to label the atomic and molecular orbitals and populate the MOs with the correct number of electrons. **(2 marks)**

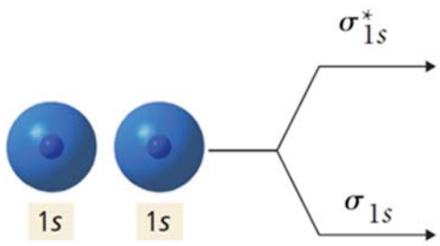
b) What is the bond order for He_2^+? **(1 mark)**

c) What is the bond order for He_2? **(1 mark)**

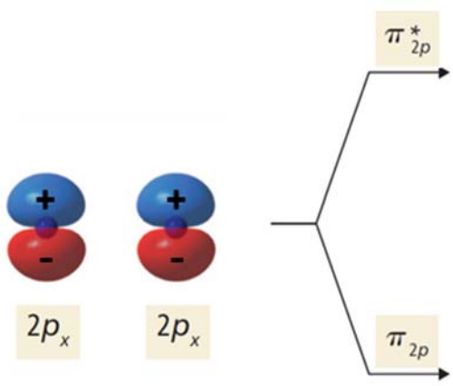
26. Sketch and correctly label the orbitals indicated below showing the phases (+ or -) and the position of the nucleus (or nuclei).

a) any d orbital **(1 mark)**.

b) the σ_{1s} and σ_{1s}^* molecular orbitals **(2 marks)**.



c) the π_{2p} and π_{2p}^* molecular orbitals **(2 marks)**.



27. State the dominant intermolecular forces within the following substances: **(2 marks)**

a) CH_3OH _____

b) CH_4 _____

c) HBr _____

d) CO_2 _____

28. On the phase diagram to the right, label the following six (6) regions or points: **(3 marks)**

Liquid

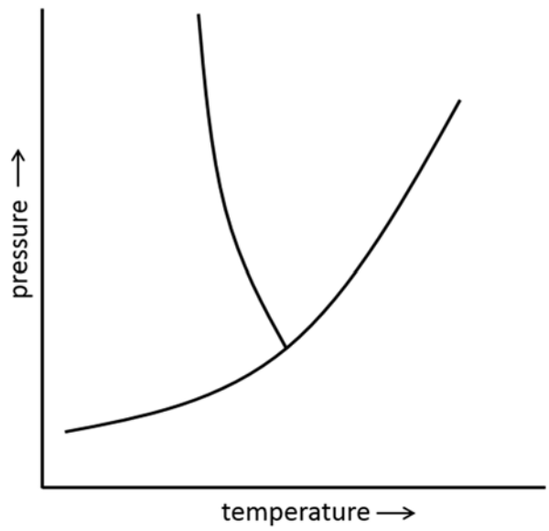
Solid

Gas

Supercritical Fluid

Triple point

Critical point



29. For the following pairs of compounds, circle the one with the highest boiling point. Briefly explain your choice. **(4 marks)**

a) O=C=O or S=C=S

b) $CH_3CH_2CH_3$ or CH_3OCH_3

c) CH_3OH or $CH_3CH_2CH_2OH$

d) CH_3CH_2OH or CH_3OCH_3

30. The normal boiling point (at 760.0 Torr) of mercury is 356.7 ^{o}C and $\Delta_{vap}H^{o}$ = 59.11 kJ mol^{-1}. Determine the vapour pressure of mercury at 200.0 ^{o}C? **(4 marks)**

Chemistry 1050

PERIODIC TABLE OF THE ELEMENTS

atomic mass — 6 **C** 12.0107 — atomic number

KEY

1												13	14	15	16	17	18
1 **H** 1.0079	2																2 **He** 4.0026
3 **Li** 6.941	4 **Be** 9.0122											5 **B** 10.811	6 **C** 12.0107	7 **N** 14.0067	8 **O** 15.9994	9 **F** 18.9984	10 **Ne** 20.1797
11 **Na** 22.9898	12 **Mg** 24.3050	3	4	5	6	7	8	9	10	11	12	13 **Al** 26.9815	14 **Si** 28.0855	15 **P** 30.9738	16 **S** 32.065	17 **Cl** 35.453	18 **Ar** 39.948
19 **K** 39.0983	20 **Ca** 40.078	21 **Sc** 44.9559	22 **Ti** 47.867	23 **V** 50.9415	24 **Cr** 51.9961	25 **Mn** 54.9380	26 **Fe** 55.8475	27 **Co** 58.9332	28 **Ni** 58.6934	29 **Cu** 63.546	30 **Zn** 65.409	31 **Ga** 69.723	32 **Ge** 72.61	33 **As** 74.9216	34 **Se** 78.96	35 **Br** 79.904	36 **Kr** 83.798
37 **Rb** 85.4678	38 **Sr** 87.62	39 **Y** 88.9059	40 **Zr** 91.224	41 **Nb** 92.9064	42 **Mo** 95.94	43 **Tc** (99)	44 **Ru** 101.07	45 **Rh** 102.9055	46 **Pd** 106.42	47 **Ag** 107.8682	48 **Cd** 112.411	49 **In** 114.818	50 **Sn** 118.710	51 **Sb** 121.75	52 **Te** 127.60	53 **I** 126.9045	54 **Xe** 131.29
55 **Cs** 132.9054	56 **Ba** 137.327	57 **La** 139.9055	72 **Hf** 178.49	73 **Ta** 180.9479	74 **W** 183.84	75 **Re** 186.207	76 **Os** 190.23	77 **Ir** 192.217	78 **Pt** 195.078	79 **Au** 196.9665	80 **Hg** 200.59	81 **Tl** 204.3833	82 **Pb** 207.2	83 **Bi** 208.9804	84 **Po** (210)	85 **At** (210)	86 **Rn** (222)
87 **Fr** (223)	88 **Ra** (226)	89 **Ac** (227)	104 **Rf** (261)	105 **Db** (262)	106 **Sg** (266)	107 **Bh** (264)	108 **Hs** (269)	109 **Mt** (268)									

Lanthanides	58 **Ce** 140.116	59 **Pr** 140.9077	60 **Nd** 144.24	61 **Pm** (147)	62 **Sm** 150.36	63 **Eu** 151.964	64 **Gd** 157.25	65 **Tb** 158.925	66 **Dy** 162.50	67 **Ho** 164.9303	68 **Er** 167.259	69 **Tm** 168.9342	70 **Yb** 173.04	71 **Lu** 174.967
Actinides	90 **Th** 232.0381	91 **Pa** 231.0359	92 **U** 238.0289	93 **Np** (237)	94 **Pu** (244)	95 **Am** (243)	96 **Cm** (247)	97 **Bk** (247)	98 **Cf** (251)	99 **Es** (252)	100 **Fm** (257)	101 **Md** (258)	102 **No** (259)	103 **Lr** (262)

Parenthesis Indicates the most stable isotope

SOME USEFUL CONSTANTS

Quantity and Symbol	Value	Quantity and Symbol	Value
ΔH_{fusion}, $H_2O(s)$ at 273 K	6.01 kJ mol^{-1}	Rydberg constant, R_H	1.0973 x 10^{7} m^{-1}
$\Delta H_{vaporization}$, $H_2O(\ell)$ at 373 K	40.7 kJ mol^{-1}	Velocity of light in a vacuum, c	2.998 x 10^{8} m s^{-1}
Specific Heat Capacity of $H_2O(\ell)$	4.184 J g^{-1} K^{-1}	Planck's Constant, h	6.626 x 10^{-34} J s
Specific Heat Capacity of $H_2O(s)$ at 0°C	1.960 J g^{-1} K^{-1}	Density of $H_2O(\ell)$ (near 0°C)	1.000 g mL^{-1}

Avogadro Constant, N_A 6.022 x 10^{23} mol^{-1}

Ideal Gas Constant, R 8.314 L kPa mol^{-1} K^{-1} = 8.314 J mol^{-1} K^{-1} = 0.08314 L bar mol^{-1} K^{-1} = 0.08206 L atm mol^{-1} K^{-1}

CONVERSION FACTORS

1 bar = 10^5 Pa = 100 kPa = 750.1 mmHg = 750.1 torr = 0.9869 atm

1 cal = 4.184 J (exactly)

1 L = 1 dm^3 (exactly) 1 bar L = 100 J

1 L atm = 101.3 J

SOME USEFUL FORMULAS

$$\left(P + \frac{n^2 a}{V^2}\right)(V - nb) = nRT \qquad u_{rms} = \sqrt{\frac{3RT}{M}} \qquad \ln\left(\frac{P_2}{P_1}\right) = -\frac{\Delta H_{vap}}{R}\left(\frac{1}{T_2} - \frac{1}{T_1}\right)$$

$$E_n(J) = -2.179 \times 10^{-18}\,\frac{Z^2}{n^2} \qquad r_n = \frac{n^2 a_o}{Z^2} \qquad E = h\nu$$

$$PV = nRT \qquad e_k = \frac{1}{2}mv^2 \qquad \lambda\nu = c \qquad C = k_H P_{gas} \text{ or } kP_{gas}$$

$$\lambda = \frac{h}{mv} \qquad \Delta E(J) = -Z^2 \times 2.179 \times 10^{-18}\left(\frac{1}{n_f^{\,2}} - \frac{1}{n_i^{\,2}}\right) \qquad \Delta U = q + w \qquad \pi = iCRT \text{ or } iMRT$$

$$\Delta_r H = \Delta_r U + RT\Delta n_{gases}$$

$$\Delta T_f = iK_f m \qquad \Delta T_b = iK_b m \qquad P_A = x_A P^o_A$$

$$\Delta_r H^o = \sum \nu_p \Delta_f H^o\,(\text{products}) - \sum \nu_r \Delta_f H^o\,(\text{reactants}) \qquad X_A P^o_A + x_b P^o_b \text{ (mixture of volatile liquids)}$$

Do not turn the paper over until you are told that you may do so.

You may not leave the examination room during the first half hour or during the last half hour of the examination.

At the end of the examination:
When you are told to stop writing you must do so.

ACADEMIC OFFENCES

Academic offences shall be deemed to include, but shall not be limited to, the following:

1. **Cheating on examinations, theses, assignments, work term reports, projects, internship reports, or any other tests.**
   Cheating includes copying from another student's work or allowing another student to copy from one's own work, consulting with any unauthorized person during an examination or test, or using unauthorized aids; or knowingly recording or reporting false empirical or statistical data. The work referred to includes examinations, theses, assignments, work term reports, projects, internship reports, or any other tests which are to be used in judging the student's performance in a course or programme of study, or on any special tests which the University may offer.
2. **Impersonating another student or allowing oneself to be impersonated**.
   By impersonation is meant the imitation of a student or entrance into an arrangement with another person to be impersonated for purposes of taking examinations or tests or carrying out laboratory or other assignments.
3. **Plagiarism.**
   Plagiarism is the act of presenting the ideas or works of another as one's own. This applies to all material such as essays, laboratory reports, work term reports, design projects, seminar presentations, statistical data, computer programmes and research results. The properly acknowledged use of sources is an accepted and important part of scholarship. Use of such material without acknowledgement, however, is contrary to accepted norms of academic behaviour.
4. **Theft of examination papers or other material.**
   By theft is meant obtaining by any improper means examination papers, tests, or any other such material.
5. **Use and/or distribution of stolen material.**
   The use of material which the student knows to have been improperly obtained and/or the distribution of such material is considered to be an academic offence.
6. **Submitting false information**.
   This offence includes falsifying academic forms or records, submitting false credentials, medical or other certificates, or making a false, misleading or incomplete declaration to the University.
7. **Submitting work for one course which has been or is being submitted for another course without express permission to do so.**
   This includes the presentation of an essay, report or assignment to satisfy some or all of the requirements of a course when that essay, report, or assignment has been previously submitted or is concurrently being submitted for another course without the express permission of the professor(s) involved.

NOTE: Procedures to be followed and penalties to be assessed in cases of academic dishonesty are outlined in the University Calendar.