Department of Chemistry
Memorial University
Chemistry 1050

Fall 2014 Final Examination
Time 3 hours

NAME:______________________________ MUN Student Number:_____________________

Instructor's Name: ______________________

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.**

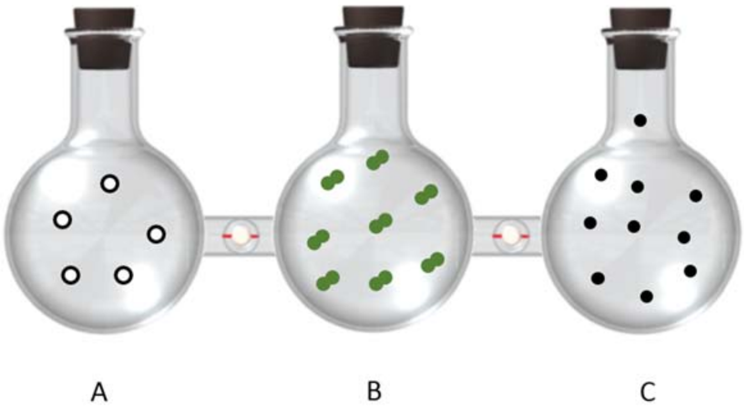
3. **Read each question carefully** and answer each question in the space provided.

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
1-2	9	
3-5	8	
6-7	8	
8	3	
9-11	13	
12-16	11	
17-18	11	
19-20	9	
21-22	7	
23-25	9	
26-27	9	
28	3	
total	100	

1. The figure below shows a vessel in which three chambers all have equal volumes and all are at the same temperature. Each chamber contains an ideal gas with molar amounts proportional to the number of atoms or molecules.



a) Which one has the highest pressure? Explain your answer in terms of the kinetic molecular theory! **(1 mark)**

b) If the pressure of container B is 1.50 bar, what is the pressure in container C? **(2 marks)**

c) If the pressure of container B is 1.50 bar, what is the total pressure in the containers if the stopcocks separating each of the containers is opened so that the gases mix. **(2 marks)**

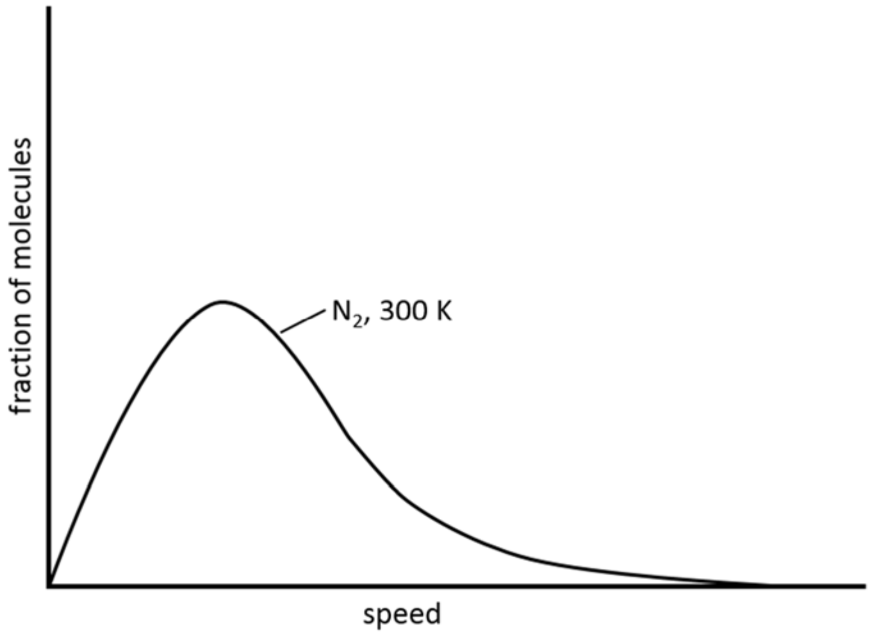
2. Calcium carbide (CaC_2) is used in many industrial applications such as the production of acetylene, fertilizer, and steel. It is formed along with CO, a poisonous gaseous by-product, in an electric arc furnace according to the following reaction:

$$CaO(s) + 3\ C(s) \rightarrow CaC_2(s) + CO(g)$$

If 100.0 g of solid carbon is reacted with an unlimited supply of CaO, what volume of CO is formed at 298 K and 1.02 bar pressure? **(4 marks)**

3. Charles's Law states that the volume of a gas is proportional to the temperature of the gas. Explain Charles's Law in terms of the kinetic molecular theory. **(2 marks)**

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



On this plot, sketch the distribution for Cl_2 at 300 K and the one for N_2 at 500 K. **(2 marks)**

5. A 29.8 g steel spoon at 18.5 °C is dipped into 180. g of hot coffee at 90.3 °C. Assuming that coffee has the same heat capacity as water and the heat capacity of steel is 0.420 J g^{-1} $^{o}C^{-1}$ what is the final temperature of the spoon and coffee? **(4 marks)**

6. Palmitic acid is the main component of body fat and burns according to the following balanced chemical reaction.

$$\mathrm{C_{16}H_{32}O_2}(s) \ + \ 23\ \mathrm{O_2}(g) \ \rightarrow \ 16\ \mathrm{CO_2}(g) \ + \ 16\ \mathrm{H_2O}(l)$$

In a bomb calorimetry experiment 0.7081 g of palmitic acid (molar mass = 256.42 g $\mathrm{mol^{-1}}$) was combusted in a bomb calorimeter with a heat capacity of 10.26 kJ $°\mathrm{C}^{-1}$. The temperature of the calorimeter was observed to rise by 2.599 °C. Determine the $\Delta_r U°$ and $\Delta_r H°$ (at 298 K) for the combustion of palmitic acid. **(5 marks)**

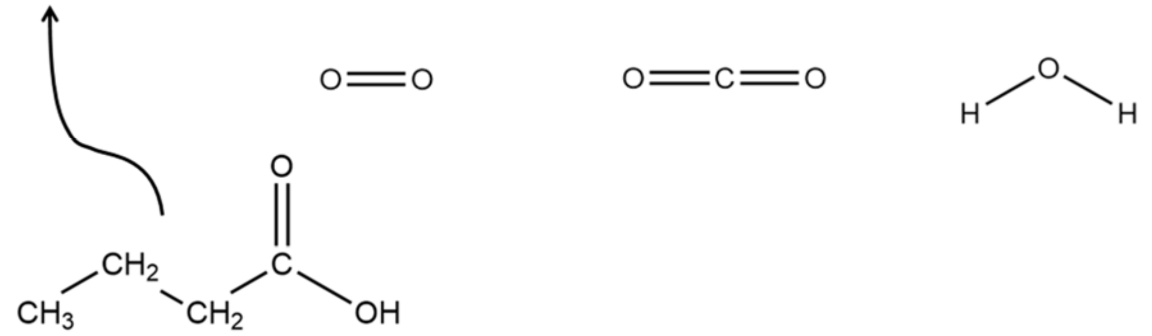
7. The heats of formation for the reactants and products in the combustion of palmitic acid are provided below.

	$\mathrm{C_{16}H_{32}O_2}(s)$	+	$23\ \mathrm{O_2}(g)$	$\rightarrow$	$16\ \mathrm{CO_2}(g)$	+	$16\ \mathrm{H_2O}(l)$
$\Delta_f H°$ / kJ $\mathrm{mol^{-1}}$	-892				-393.5		-285.8

Compute $\Delta_r H°$ for the combustion of palmitic acid. **(3 marks)**

8. The structures of the reactants and products for the combustion of butanoic acid are provided below the equation.

$$C_4H_8O_2(s) \quad + \quad 5\,O_2(g) \quad \rightarrow \quad 4\,CO_2(g) \quad + \quad 4\,H_2O(l)$$



Use the bond energies below to estimate Δ_rH^o. **(3 marks)**

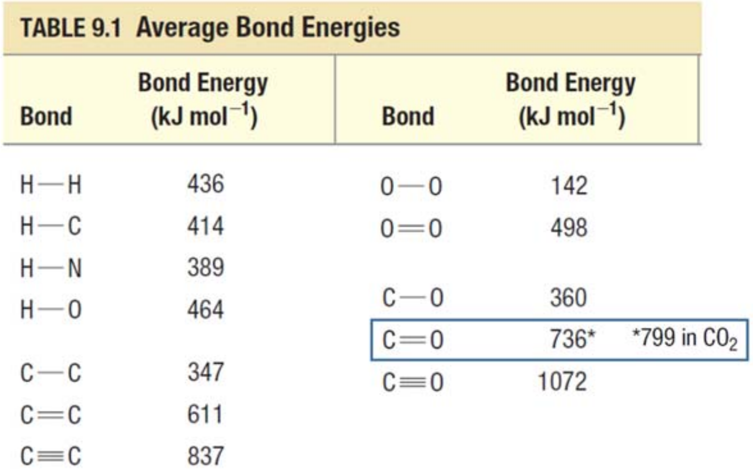


TABLE 9.1 Average Bond Energies

Bond	Bond Energy (kJ mol^{-1})	Bond	Bond Energy (kJ mol^{-1})	
H—H	436	O—O	142	
H—C	414	O=O	498	
H—N	389			
H—O	464	C—O	360	
		C=O	736*	*799 in CO_2
C—C	347	C≡O	1072	
C=C	611			
C≡C	837			

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

$6\ CO_2(g) + 6\ H_2O(l) \rightarrow C_6H_{12}O_6(s) + 6\ O_2(g)$ ____________________

$Cu(s) \rightarrow Cu(l)$ ____________________

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

$H_2O(g) \rightarrow H_2O(l)$ ____________________

$2\ F(g) \rightarrow F_2(g)$ ____________________

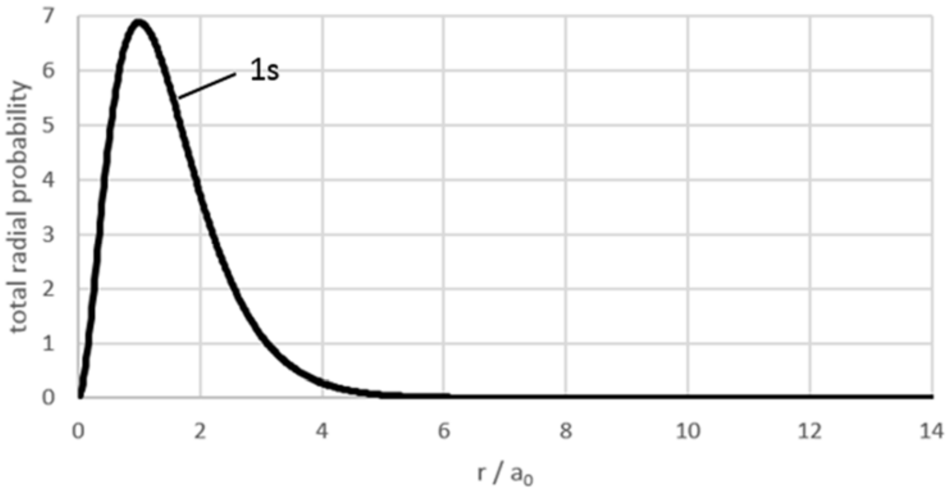
$O^-(g) + e^- \rightarrow O^{2-}(g)$ ____________________

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

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

10. 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 $1s^22s^1$ rather than $1s^22p^1$? **(1 marks)**

11. Write the condensed ground state electron configurations for the following. **(6 marks)**

S :

Cu :

Zn^{2+} :

Br :

Bi (element 83) :

Sb^{3+} :

12. How many electrons have the following sets of quantum numbers: **(2 marks)**

a) n = 3 __________

b) n = 3, ℓ = 1 __________

c) n = 3, ℓ = 1, m_ℓ = 1 __________

n = 3, ℓ = 1, m_ℓ = 1, m_s = ½ __________

13. a) Circle the **<u>largest</u>** atom in the following pairs: **(1 mark)**

Na or S

Mg or Ca

b) In the following pairs, circle the atom with **<u>largest</u>** first ionization energy **(1 mark)**

Na or Mg

Mg or Ca

c) In the following pairs, circle the ionic compound with the highest melting point. **(1 mark)**

NaCl or $MgCl_2$

NaCl or NaBr

14. Below are the reactions of two different alkali metal with water:

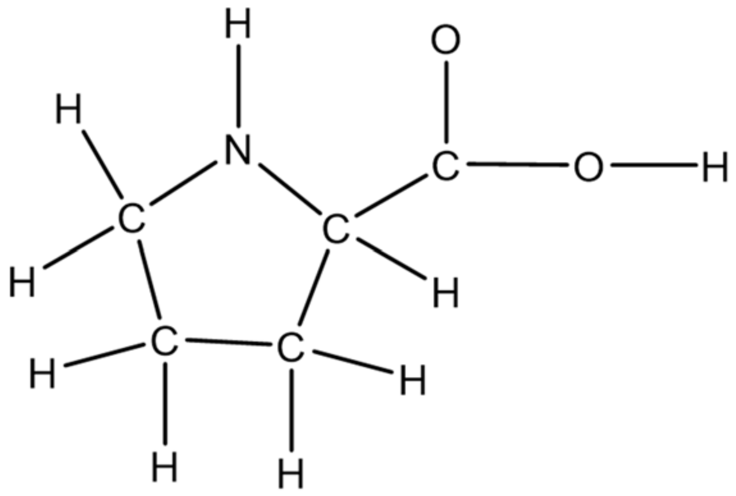
$$2\,\mathrm{Li}(s) + 2\,\mathrm{H_2O}(l) \rightarrow 2\,\mathrm{LiOH}(aq) + \mathrm{H_2}(g)$$
$$2\,\mathrm{K}(s) + 2\,\mathrm{H_2O}(l) \rightarrow 2\,\mathrm{KOH}(aq) + \mathrm{H_2}(g)$$

The reaction with potassium (K) is significantly more vigorous than the reaction with lithium (Li). Using periodic trends, explain this observation. **(2 marks)**

15. The first ionization energy of nitrogen (N) is 1402 kJ mol^{-1} and that of oxygen (O) is 1319 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 N and O to explain why O has the lower ionization energy. **(2 marks)**

16. Will the ionization energy of a hydrogen atom where the electron is in the n=2 excited state be greater or less than the ionization energy from the ground state? Use diagrams or equations to support your answer. **(2 marks)**

17. a) Below is the skeletal structure for proline, $C_5H_9NO_2$, one of the 20 proteinogenic amino acids. Complete the Lewis structure for proline by placing lone pairs and multiple bonds where required. **(2 marks)**



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

electron group geometry________________________

shape ___________________________

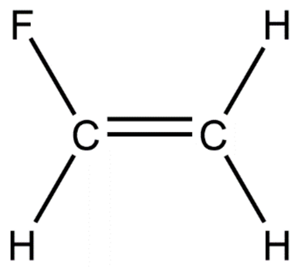
hybridization ___________________________

18. a) Draw the Lewis structure for XeF_4. **(2 marks)**

b) Draw and name the shape of XeF_4**. (2 mark)**

b) State whether XeF_4 is polar or non-polar and state the dominant intermolecular forces between molecules of XeF_4. **(2 marks)**

19. To the right is a Lewis structure for fluoroethene. Use Valence Bond and Orbital Hybridization Theories to describe the bonding in fluoroethene. Your answer should show the following steps. **(5 marks)**



i) Using the Lewis structure of fluoroethene and VSEPR theory, predict the shape around each of the C atoms.
ii) What is the hybridization of each C?
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.

20. a) Draw the molecular orbital diagram for the H_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 H_2? **(1 mark)** _______________

c) What is the bond order for H_2^+? **(1 mark)** _______________

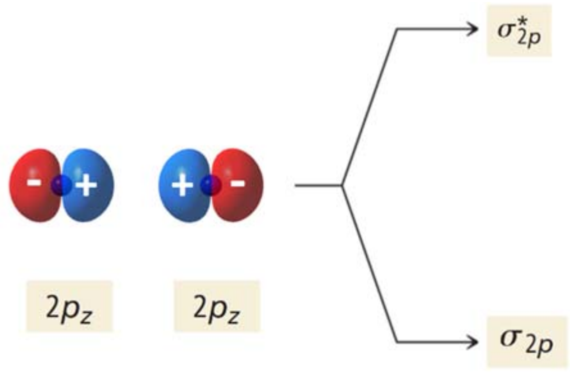
21. a) Define the term “excited state.” **(1 mark)**

b) Draw the molecular orbital diagram for an excited state of H_2 and determine the bond order. **(1 mark)**

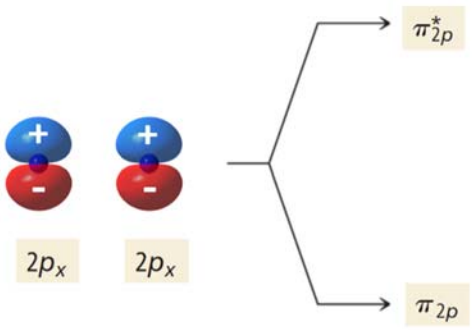
22. Sketch and correctly label the orbitals indicated below showing the phases (+ or -) and the position of the nucleus (or nuclei).

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

b) the σ_{2p} and σ^*_{2p} molecular orbitals **(2 marks)**



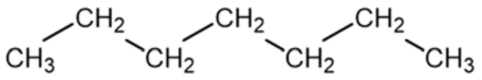
c) the π_{2p} and π^*_{2p} molecular orbitals **(2 marks)**



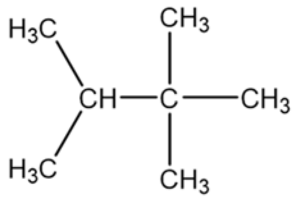
23. For the following pairs of compounds, circle the one with the highest boiling point. Briefly explain your choice. **(5 marks)**

a) $CH_3{-}SH$ or $CH_3{-}SeH$

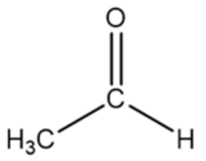
b)



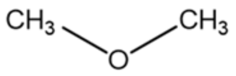
or



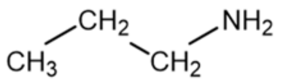
c)



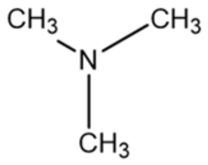
or



d)



or



e) HCl or NaCl

24. The heats of vaporization and fusion for water are 40.7 and 6.02 kJ mol^{-1}. Briefly explain why the heat of vaporization is so much higher than the heat of fusion of a substance. **(2 marks)**

25. Which of the following solutes (propanol) $CH_3CH_2CH_2OH$ or pentanol ($CH_3CH_2CH_2CH_2CH_2OH$) would you expect to be more soluble in water? Explain your answer in terms of intermolecular forces within the pure solutes and within pure water, as well as between the solutes and water in the mixture. **(2 marks)**

26. In an experiment designed to determine the heat of vaporization of carbon tetrachloride (CCl_4), the vapour pressure of CCl_4 was found to be 213 Torr at 40.1 ^{o}C and its normal boiling point (at 760. Torr) was found to be 76.7 ^{o}C. Calculate $\Delta_{vap}H^{o}$. **(4 marks)**

27. a) The vapour pressure of water at 70.0 ^{o}C is 31.2 kPa. What is the vapour pressure of a solution containing 200. g of water and 25 g of urea ($CH_4N_2O_2$, MM = 60.06 g mol^{-1})? **(3 marks)**

b) How would the vapour pressure change if, instead of urea, the same number of ***moles*** of $CaCl_2$ were added to the same amount of water in part a)? Be specific and provide a brief explanation of your answer. **(2 marks)**

28. Hemoglobin is a globular iron containing protein responsible for the transport of oxygen in the body. In an experiment, 0.5515 g of hemoglobin was dissolved in 100.00 mL of solution at 25.0 ^{o}C. The osmotic pressure was measured to be 1.985 x 10^{-3} bar. Determine the molar mass of hemoglobin. **(3 marks)**

Chemistry 1050

PERIODIC TABLE OF THE ELEMENTS

	6 **C** 12.0107	atomic number
atomic mass	**KEY**	

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1 **H** 1.0079																	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											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 L = 1 dm^3 (exactly) 1 bar L = 100 J

1 cal = 4.184 J (exactly)

SOME USEFUL FORMULAS

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

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

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

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

$$\Delta_rH = \Delta_rU + RT\Delta n_{gases}$$

$$\Delta T_f = iK_fm \qquad \Delta T_b = iK_bm \qquad P_A = x_AP^o_A$$

$$\Delta_rH^o=\sum\nu_p\Delta_fH^o\text{ (products) }-\sum\nu_r\Delta_fH^o\text{ (reactants)} \qquad P_{Tot} = X_AP^o_A + x_bP^o_b \text{ (mixture of volatile liquids)}$$