University of Eswatini

Faculty of Science and Engineering

Department of Chemistry

Re-sit Examination 2018/2019

Title of Paper	:	Applied thermodynamics
Course code	:	CHE 242
Time	:	3 hours
Instructions	:	Each question is worth 25% Answer question 1 and any other 3 questions Data sheets are provided with this examination

Do not open this paper until permission has been given by the invigilator

Question 1 – Compulsory [25 Marks]

a) Write short notes on the following

   i. Partial molar volume [2]

   ii. Raoult's Law [3]

b) What is the approximate osmotic pressure of a 0.118 molal and 1.00 g/mL solution of LiCl at 10.0 °C? The freezing point of this solution is -0.415 °C. [8]

c) Solid $CaCO_3$ degenerates into CaO and CO_2 at certain conditions, determine if this reaction will proceed under standard conditions given that $\Delta G°$ of $CaCO_3$, CaO and CO_2 are -1128, -603.5 and -137.2 kJ mol-1, respectively. [6]

d) The analysis of gases is done under real or perfect conditions. Derive an expressions $\Delta_r G$ for real gases [6]

Question 2 [25 Marks]

a) Write short notes on the following;

   i. Triple point [2]

   ii. van't Hoff factor [2]

   iii. Standard chemical potential [4]

b) Show your understanding of colligative properties by using 2 real life examples to show the use of any two scenarios of your choice. [6]

c) The vapour pressure of pure acetone is 4.00 x 10^3 mmHg. A solution is prepared by dissolving 1.00g of a non-volatile compound sulfanilamide ($C_6H_8O_2N_2S$) in 10.00 g of acetone (CH_3COCH_3)

   i. Find the vapour pressure of acetone in the solution [7]

   ii. Given that the solution is prepared in a 200ml container, what is the osmotic pressure of the solution at 0°C. [4]

Question 3 [25 Marks]

a) Write short notes on the following;

i. Henry's law [3]

ii. Osmotic pressure [3]

iii. Vapour pressure lowering [3]

b) Calculate the partial molar volume of pure liquid water when the density is given by 0,997 g/cm^3 at 25°C. By how much would the molar volume change if the sample is increased by 2g. [4]

c) What mass of urea CON_2H_4, must be added to 450g H_2O to get a solution with a vapour pressure of 298 mmHg given that the vapour pressure of pure H_2O is 31.8 mmHg at this temperature. [4]

d) Derive the vapor pressure of a pressurized liquid, with an aid of diagrams where necessary. [8]

Question 4 [25 Marks]

a) At 286 K, the osmotic pressure of a glucose solution is 9.97 atm. What is the freezing point depression (given the density of the solution is 1.12 g/mL) given that Kf = 1.86°C kg/mol ? [10]

b) Using a rough sketch, show the important components of a phase diagram. [5]

c) Estimate the vapour pressure of a liquid benzene at 20°C when its normal boiling point is 80°C at a vapour pressure of is 101kPa, given that $\Delta_{vap}H$=30,8kJ/mol. [5]

d) Explain how Raoults law and Henry's law are used to specify the chemical potential of a component of a mixture [5]

Question 5 [25 Marks]

a) Illustrate the schematic temperature dependence of the chemical potential with temperature for the three phases of a chemical substance [8]

b) Derive the equation for the vapor pressure lowering [4]

c) Give brief explanation of the following observations;

i. Freezing –point constants are typically larger than boiling point constants of a solvent,

ii. There is a difference in the boiling point constants of water and benzene.

[6]

d) Derive that equation of the equilibrium constant for the generic chemical equation

$aA(g) + bB(g) \rightarrow cC(g) + dD(g)$ [7]

Question 6 [25 Marks]

a) Determine the molecular formula of a compound given that when 7.85 g sample of the compound having an empirical formula C_5H_4 is dissolved in 301 g of benzene, the freezing point of the solution is 1.04 °C below that of pure benzene. K_f is given by 5.12 °C kg/mol [6]

b) For the chemical equation (Question 5d), derive 4 equations for the chemical potential and use them with Hess' law to find an equation for $\Delta_r G$ (given that $\Delta_r G = \Delta\mu$) [9]

c) Calculate the difference in slope of the chemical potential against pressure on either side of (a) the normal freezing point of water and (b) the normal boiling point of water. Given that the densities of ice and water at 0°C are 0.917 gcm^{-3} and 1.00 gcm^{-3} and those of water and water vapour at 100°C are 0.958 gcm^{-3} and 0.598 gcm^{-3}, respectively. By how much does the chemical potential of water exceed that of liquid water at 1.2 atm and 100°C? [10]

The End

General data and fundamental constants

Quantity	Symbol	Value
Speed of light	c	$2.997\ 924\ 58 \times 10^{8}$ m s^{-1}
Elementary charge	e	$1.602\ 177 \times 10^{-19}$ C
Faraday constant	$F = N_A e$	9.6485×10^{4} C mol^{-1}
Boltzmann constant	k	$1.380\ 66 \times 10^{-23}$ J K^{-1}
Gas constant	$R = N_A k$	$8.314\ 51$ J K^{-1} mol^{-1}
		$8.205\ 78 \times 10^{-2}$ dm^{3} atm K^{-1} mol^{-1}
		6.2364×10 L Torr K^{-1} mol^{-1}
Planck constant	h	$6.626\ 08 \times 10^{-34}$ J s
	$\hbar = h/2\pi$	$1.054\ 57 \times 10^{-34}$ J s
Avogadro constant	N_A	$6.022\ 14 \times 10^{23}$ mol^{-1}
Atomic mass unit	u	$1.660\ 54 \times 10^{-27}$ Kg
Mass		
electron	m_e	$9.109\ 39 \times 10^{-31}$ Kg
proton	m_p	$1.672\ 62 \times 10^{-27}$ Kg
neutron	m_n	$1.674\ 93 \times 10^{-27}$ Kg
Vacuum permittivity	$\varepsilon_0 = 1/c^2\mu_0$	$8.854\ 19 \times 10^{-12}$ J^{-1} C^{2} m^{-1}
	$4\pi\varepsilon_0$	$1.112\ 65 \times 10^{-10}$ J^{-1} C^{2} m^{-1}
Vacuum permeability	μ_0	$4\pi \times 10^{-7}$ J s^{2} C^{-2} m^{-1}
		$4\pi \times 10^{-7}$ T^{2} J^{-1} m^{3}
Magneton		
Bohr	$\mu_B = e\hbar/2m_e$	$9.274\ 02 \times 10^{-24}$ J T^{-1}
nuclear	$\mu_N = e\hbar/2m_p$	$5.050\ 79 \times 10^{-27}$ J T^{-1}
g value	g_e	2.002 32
Bohr radius	$a_0 = 4\pi\varepsilon_0\hbar/m_e e^2$	$5.291\ 77 \times 10^{-11}$ m
Fine-structure constant	$\alpha = \mu_0 e^2 c/2h$	$7.297\ 35 \times 10^{-3}$
Rydberg constant	$R_\infty = m_e e^4/8h^3 c\varepsilon_0^2$	$1.097\ 37 \times 10^{7}$ m^{-1}
Standard acceleration of free fall	g	$9.806\ 65$ m s^{-2}
Gravitational constant	G	$6.672\ 59 \times 10^{-11}$ N m^{2} Kg^{-2}

Conversion factors

1 cal	=	4.184 joules (J)	1 erg	=	1×10^{-7} J
1 eV	=	$1.602\ 2 \times 10^{-19}$ J	1 eV/molecule	=	96 485 kJ mol^{-1}

Prefixes

f	p	n	μ	m	c	d	k	M	G
femto	pico	nano	micro	milli	centi	deci	kilo	mega	giga
10^{-15}	10^{-12}	10^{-9}	10^{-6}	10^{-3}	10^{-2}	10^{-1}	10^{3}	10^{6}	10^{9}

PERIODIC TABLE OF ELEMENTS

GROUPS

Atomic mass → 10.811
Symbol → B
Atomic No. → 5

TRANSITION ELEMENTS

PERIODS	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
	IA	IIA	IIIB	IVB	VB	VIB	VIIB	VIIIB			IB	IIB	IIIA	IVA	VA	VIA	VIIA	VIIIA
1	1.008 H 1																	4.003 He 2
2	6.941 Li 3	9.012 Be 4											10.811 B 5	12.011 C 6	14.007 N 7	15.999 O 8	18.998 F 9	20.180 Ne 10
3	22.990 Na 11	24.305 Mg 12											26.982 Al 13	28.086 Si 14	30.974 P 15	32.06 S 16	35.453 Cl 17	39.948 Ar 18
4	39.098 K 19	40.078 Ca 20	44.956 Sc 21	47.88 Ti 22	50.942 V 23	51.996 Cr 24	54.938 Mn 25	55.847 Fe 26	58.933 Co 27	58.69 Ni 28	63.546 Cu 29	65.39 Zn 30	69.723 Ga 31	72.61 Ge 32	74.922 As 33	78.96 Se 34	79.904 Br 35	83.80 Kr 36
5	85.468 Rb 37	87.62 Sr 38	88.906 Y 39	91.224 Zr 40	92.906 Nb 41	95.94 Mo 42	98.907 Tc 43	101.07 Ru 44	102.91 Rh 45	106.42 Pd 46	107.87 Ag 47	112.41 Cd 48	114.82 In 49	118.71 Sn 50	121.75 Sb 51	127.60 Te 52	126.90 I 53	131.29 Xe 54
6	132.91 Cs 55	137.33 Ba 56	138.91 *La 57	178.49 Hf 72	180.95 Ta 73	183.85 W 74	186.21 Re 75	190.2 Os 76	192.22 Ir 77	195.08 Pt 78	196.97 Au 79	200.59 Hg 80	204.38 Tl 81	207.2 Pb 82	208.98 Bi 83	(209) Po 84	(210) At 85	(222) Rn 86
7	223 Fr 87	226.03 Ra 88	(227) **Ac 89	(261) Rf 104	(262) Ha 105	(263) Unh 106	(262) Uns 107	(265) Uno 108	(266) Une 109	(267) Uun 110								

*Lanthanide Series	140.12 Ce 58	140.91 Pr 59	144.24 Nd 60	(145) Pm 61	150.36 Sm 62	151.96 Eu 63	157.25 Gd 64	158.93 Tb 65	162.50 Dy 66	164.93 Ho 67	167.26 Er 68	168.93 Tm 69	173.04 Yb 70	174.97 Lu 71
**Actinide Series	232.04 Th 90	231.04 Pa 91	238.03 U 92	237.05 Np 93	(244) Pu 94	(243) Am 95	(247) Cm 96	(247) Bk 97	(251) Cf 98	(252) Es 99	(257) Fm 100	(258) Md 101	(259) No 102	(260) Lr 103

( ) indicates the mass number of the isotope with the longest half-life.