

UNIVERSITY OF TECHNOLOGY, JAMAICA

DEPARTMENT OF SCIENCE AND MATHEMATICS

SEMESTER II FINAL EXAMINATION

GROUP: Sci. Ed. 2

DATE: APRIL, 2008

MODULE: PHYSICAL CHEMISTRY (CHY2007)

DURATION: 2 HRS

INSTRUCTIONS: ANSWER **FOUR** (4) QUESTIONS

$R = 0.08206 \text{ L atm mol}^{-1} \text{ K}^{-1} = 8.314 \text{ J K}^{-1} \text{ mol}^{-1}$; $1 \text{ atm} = 760 \text{ mm Hg} = 760 \text{ bar} = 101325 \text{ Pa} = 1.01325 \times 10^5 \text{ N m}^{-2}$; $1 \text{ J} = 1 \text{ N m}$

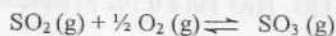
QUESTION NO. 1

- (a) Three gases – H_2 , CO_2 and Ar each weighing 50 g, are contained in a 1.0 L flask at 25.0°C .
- Calculate the number of moles of each gas and hence the mole fraction of each gas in the mixture. [4]
 - Calculate the total pressure of the mixture and hence the partial pressure exerted by each gas. [3]
- (b) (i) State which assumptions of the kinetic molecular theory for an ideal gas become invalid under conditions of extremely high pressure and extremely low temperatures. [2]
- (ii) Explain why these assumptions become invalid at conditions of extremely high pressures and extremely low temperatures. [6]
- (c) Using the assumptions of the kinetic molecular theory explain, the following:
- Charles' Law
 - Avogadro's Law [2.5 × 2 = 5]

Total = 20 marks

QUESTION NO. 2

- (a) The following reaction is important in the manufacture of sulphuric acid:



At 900 K, 0.0216 mol of SO_2 and 0.0148 mol of O_2 are sealed in a 1.00 dm^3 reaction vessel. When equilibrium is reached, the concentration of SO_3 is determined to be 0.0175 M. Calculate K_c and K_p for the reaction. [6]

- (b) The solubility product K_{sp} for lead(II) iodide, PbI_2 , is $7.9 \times 10^{-8} \text{ mol}^3 \text{ dm}^{-9}$. Calculate the solubility (in mol dm^{-3} and g dm^{-3}) of PbI_2 in:
- pure water and, [3]
 - 0.10 mol dm^{-3} sodium iodide (NaI) solution. [4]
 - Why is your answer in b (ii) so different from that obtained in b (i)? [2]
- (c) (i) Explain why an aqueous solution containing equal concentrations of propanoic acid ($\text{CH}_3\text{CH}_2\text{COOH}$) and its sodium salt constitutes a buffer system. [3]
- (ii) Briefly explain how the buffer system in (i) is able to minimise the effect of added H_3O^+ ions. [2]

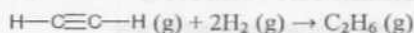
Total = 20 marks

QUESTION NO. 3

- (a) Explain how Hess's Law of heat summation depend on the fact that enthalpy is a state function. [3]
- (b) (i) Determine the heat absorbed during the complete reaction of 2.614 moles of carbon with $\text{SO}_2(\text{g})$ to form $\text{CS}_2(\text{l})$ and $\text{CO}(\text{g})$ at constant pressure?



- (ii) If the reaction occurs at STP, what is the internal energy change ΔU for the reaction? Assume volume change, due to solid and liquid reactants, to be constant. [5]
- (c) Use the given average bond dissociation energies (BE) to estimate ΔH for the hydrogenation of ethyne, $\text{C}_2\text{H}_2(\text{g})$:



Bond	BE/ kJ mol^{-1}
$\text{C}\equiv\text{C}$	835
$\text{C}-\text{H}$	410
$\text{C}-\text{C}$	350
$\text{H}-\text{H}$	436

 [4]

- (d) (i) Define the terms "lattice energy" and "enthalpy of ionisation". [2]
- (ii) Using the following data, construct a Born-Haber cycle for potassium chloride and use it to calculate the electron affinity of chlorine. [5]

	$\Delta H/\text{kJ mol}^{-1}$
1 st ionisation energy of potassium	+ 419
Enthalpy of atomisation of potassium	+ 89.2
Enthalpy of atomisation of chlorine	+ 121.7
Enthalpy of formation of $\text{KCl}(\text{s})$	- 436.7
Lattice enthalpy of potassium chloride	- 711

Total = 20 marks

QUESTION NO. 4

- (a) Explain how the following affect the solubility of sparingly soluble salts:
(i) pH
(ii) addition of a common ion [3 + 3]
- (b) State Lewis' definition of acids. [2]
- (c) The pK_a for acetic acid is 4.74. Calculate the pH and the concentration of all species present (CH_3COOH , CH_3COO^- , H_3O^+) in a 0.102 M aqueous solution of acetic acid. [7]
- (d) Several commercial drain cleaners contain $\text{NaOH}(\text{s})$ and small amounts of $\text{Al}(\text{s})$. When one of these cleaners is added to water a reaction occurs resulting in the formation of H_2 bubbles:



The purpose of the H_2 bubbles is to agitate the solution and thereby increase the cleansing action. According to this equation, how many liters of $\text{H}_2(\text{g})$ are released when 0.200 g Al are dissolved in an excess of OH^- at 25 °C and 1.00 atm pressure? [5]

Total = 20 marks

QUESTION NO. 5

(a) Discuss two (2) factors that affect the rate of a reaction. [4]

(b) The first-order gas phase reaction, $\text{SO}_2\text{Cl}_2(\text{g}) \rightarrow \text{SO}_2(\text{g}) + \text{Cl}_2(\text{g})$, has a rate constant, $k = 2.20 \times 10^{-5} \text{ s}^{-1}$ at 593 K. What percent of a sample of SO_2Cl_2 would be decomposed by heating (at 593 K) for

- (i) 1 hr,
(ii) 3 hrs?

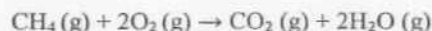
[5]

(c) The following data relates to the hydrolysis of t-butyl bromide (A) in a 10:90 water-acetone solution.

time/min	9.0	27.0	54.0	72.0	105.0
[A]/mol dm ⁻³	0.0961	0.0767	0.0536	0.0432	0.0270

- (i) Prove that this reaction is first-order and not second-order reaction. [8]
(ii) Calculate the rate constant of the reaction. [1]

(d) Consider the reaction for the combustion of methane, CH_4 ,

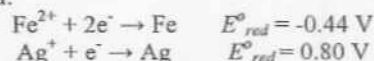


If methane burns at a rate of $0.16 \text{ mol dm}^{-3} \text{ s}^{-1}$, at what rates are CO_2 and H_2O formed? [2]

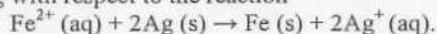
Total = 20 marks

QUESTION NO. 6

(a) Given the following data:



Answer the following with respect to the reaction



- (i) Calculate E° for the above reaction. [1]
(ii) Indicate whether E° for the reaction is spontaneous or not, at standard states. [1]
(iii) What is the value of E at equilibrium? [1]
(iv) What is the value of the equilibrium constant at 25 °C? [2]
(v) If $[\text{Fe}^{2+}] = 0.001 \text{ M}$ and $[\text{Ag}^+] = 0.0100 \text{ M}$, what is the magnitude of E at 25 °C? [2]
(vi) For the reaction that is spontaneous, what is the maximum amount of work than can be performed? [2]

(b) How many grams of cadmium are consumed in a nickel-cadmium battery if it operates at a constant current of 0.2 amp for 30.00 sec? The half-reaction of interest is



(d) A mixture of gaseous hydrocarbons is produced by catalytic cracking. Three of these gases: CH_4 , C_2H_6 , and C_3H_8 move through a hole into a vacuum area housing a detector. Calculate the rates at which C_2H_6 , and C_3H_8 reach the detector relative to CH_4 . [3]

(e) Differentiate between:

- (i) Surface tension and viscosity
(ii) Hexagonal close packing and cubic close packing of solids

[5]

Total = 20 marks

****END OF PAPER****

PERIODIC TABLE OF THE ELEMENTS

1	H Hydrogen 1.00794																	2	He Helium 4.003																																				
3	Li Lithium 6.941																	9	F Fluorine 18.9984032																																				
4	Be Beryllium 9.012182																	10	Ne Neon 20.1797																																				
11	Na Sodium 22.989770																	17	Cl Chlorine 35.4527																																				
12	Mg Magnesium 24.3050																	18	Ar Argon 39.948																																				
19	K Potassium 39.0983	20	Ca Calcium 40.078	21	Sc Scandium 44.955910	22	Ti Titanium 47.867	23	V Vanadium 50.9415	24	Cr Chromium 51.9961	25	Mn Manganese 54.938049	26	Fe Iron 55.845	27	Co Cobalt 58.933200	28	Ni Nickel 58.6934	29	Cu Copper 63.546	30	Zn Zinc 65.39	31	Ga Gallium 69.723	32	Ge Germanium 72.61	33	As Arsenic 74.92160	34	Se Selenium 78.96	35	Br Bromine 79.904	36	Kr Krypton 83.80																				
37	Rb Rubidium 85.4678	38	Sr Strontium 87.62	39	Y Yttrium 88.90585	40	Zr Zirconium 91.224	41	Nb Niobium 92.90638	42	Mo Molybdenum 95.94	43	Tc Technetium (98)	44	Ru Ruthenium 101.07	45	Rh Rhodium 102.90550	46	Pd Palladium 106.42	47	Ag Silver 107.8682	48	Cd Cadmium 112.411	49	In Indium 114.818	50	Sn Tin 118.710	51	Sb Antimony 121.760	52	Te Tellurium 127.60	53	I Iodine 126.90447	54	Xe Xenon 131.29																				
55	Cs Cesium 132.90545	56	Ba Barium 137.327	57	La Lanthanum 138.9055	72	Hf Hafnium 178.49	73	Ta Tantalum 180.9479	74	W Tungsten 183.84	75	Re Rhenium 186.207	76	Os Osmium 190.23	77	Ir Iridium 192.217	78	Pt Platinum 195.078	79	Au Gold 196.96655	80	Hg Mercury 200.59	81	Tl Thallium 204.3833	82	Pb Lead 207.2	83	Bi Bismuth 208.98038	84	Po Polonium (209)	85	At Astatine (210)	86	Rn Radon (222)																				
87	Fr Francium (223)	88	Ra Radium (226)	89	Ac Actinium (227)	104	Rf Rutherfordium (261)	105	Db Dubnium (262)	106	Sg Seaborgium (263)	107	Bh Bohrium (262)	108	Hs Hassium (265)	109	Mt Meitnerium (266)	110		111		112		113		114																													
58	Ce Cerium 140.116	59	Pr Praseodymium 140.90765	60	Nd Neodymium 144.24	61	Pm Promethium (145)	62	Sm Samarium 150.36	63	Eu Europium 151.964	64	Gd Gadolinium 157.25	65	Tb Terbium 158.92534	66	Dy Dysprosium 162.50	67	Ho Holmium 164.93032	68	Er Erbium 167.26	69	Tm Thulium 168.93421	70	Yb Ytterbium 173.04	71	Lu Lutetium 174.967	90	Th Thorium 232.0381	91	Pa Protactinium 231.03588	92	U Uranium 238.0289	93	Np Neptunium (237)	94	Pu Plutonium (244)	95	Am Americium (243)	96	Cm Curium (247)	97	Bk Berkelium (247)	98	Cf Californium (251)	99	Es Einsteinium (252)	100	Fm Fermium (257)	101	Md Mendelevium (258)	102	No Nobelium (259)	103	Lr Lawrencium (262)

