NATIONAL UNIVERSITY OF SCIENCE AND TECHNOLOGY
DEPARTMENT OF APPLIED CHEMISTRY
END OF SEMESTER EXAMINATIONS – DECEMBER 2002
PHYSICAL CHEMISTRY I - SCH 2104
TIME – (3) THREE HOURS

SECTION A: Answer **ALL** questions – 40 marks.

1. (a) Write both Kc and Kp expressions for the following reversible reactions:

(i) $2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$

(ii) $CaCO_3(s) \rightleftharpoons CaO(s) + CO_2(g)$

(iii) $S(s) + H_2SO_3(aq) \rightleftharpoons H_2S_2O_3(aq)$ (6 marks)

(b) If 200g of water at 40°C is mixed with 100g of water at 80°C in an insulated container, what will be the temperature of the mixture. (4 marks)

2. (a) The refractive index of water at 20°C is 1.330 for light of wavelength 589cm. Calculate the polarizability volume of the molecule at this frequency.

$Rm = (Mm/\rho)\{(n^2_r - 1) / (n^2_r + 2)\}$
$\rho = 0,9892gcm^{-3}$, $Na = 6.022 \times 10^{23}mol^{-1}$
$\alpha^1 = (¾\pi Na)Rm$ (6 marks)

(b) The molar heat capacity of CH_4 gas may be expressed by $Cp = a + bT + cT^2$.
where: $a = 30.5JK^{-1}mol^{-1}$
$b = 8.72 \times 10^{-3}JK^{-1}mol^{-1}$
$c = -4.53 \times 10^{-5}JK^{-1}mol^{-1}$

Calculate how much heat is required to heat one mole of CH_4 gas from 250K to 950K. (4 marks)

3 (a) Calculate the osmotic pressure of a certain aqueous solution at 55°C, using the following formulae.

$\Pi V^*_1 = -RT\ln a_1$ and using the following data all at 55°C.

Vapor pressure of solution: 5.325kPa
Vapor pressure of pure water: 5.538kPa
Density of pure water: $0.9875gcm^{-1}$ (5 marks)

3. (b) If Kp = 4.6×10^{-31} at 25°C and ΔH° = 180.5kJ for the following reaction:

$N_2(g) + O_2(g) \rightleftharpoons 2NO(g)$

Evaluate the equilibrium constant of this reaction at 2 400K and give your observations in relation to these two values. R = 8.314J/mol K.

(5 marks)

4 (a) Use the thermodynamic data to estimate the normal boiling temperature of liquid bromine, Br_2. Assume that ΔH and ΔS do not change with temperature $Br_2(l) \longrightarrow Br_2(g)$

	ΔH° kJ/mol	S° J/mol K	ΔG° kJ/mol
$Br_2(l)$	0	152.23	0
$Br_2(g)$	30.91	245.4	3.14

(4 marks)

(b) An electron is confined to a molecule of length 1nm (≈ 5 atoms). What is:

(i) its minimum energy.
(ii) Its minimum excitation energy, from that state. (6 marks)

SECTION B – Answer **only 3** questions – 60 marks.

5. (a) Calculate, Q, W and ΔE for the vaporization of 2.5g of liquid water at 2.1 atm and 100°C. Make the following assumptioms:

(i) density of liquid water at 100°C is 1g/mL.
(ii) Water vapor is described by the ideal gas equation.
(iii) External pressure is constant at 2.1 atm.

Heat of vaporization of water is 3.36kJ/g

(15 marks)

(b) Mercury (II) sulfide is found in a dark red mineral called cinnabar. Metallic mercury is obtained by roasting the sulfide in a limited amount of air. Determine the temperature range in which the reaction is spontaneous.

$HgS(s) + O_2(g) \longrightarrow Hg(l) + SO_2(g)$

	ΔH°_f kJ/mol	S° J/mol K	ΔG° kJ/mol
Hg(l)	0	76.02	0
$SO_2(g)$	-296.8	248	-300.2
$O_2(g)$	0	205	0
HgS(s)	-58.2	82.4	-50.6

(5 marks)

6. 350l/min of water at 85°C and 98.1kPa is pumped from a tank by a pump having a motor with a potential energy of 2.53kW. The water is passed through a heat-exchanger, where if transfers 43 787kJ/min of heat to another fluid and is kept in another tank elevated to 20m from the first tank. What will be the temperature of water kept in the second tank. To help solve the problem draw a fully labeled sketch diagram depicting the process.

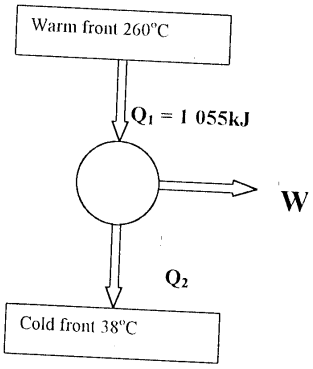
Data: Density of water at 85°C and 98.1kPa = 0.962 kg/L

H_2O, kJ/kg	125.6	167.5	209.5	251.2	397.3
T°C	30	40	50	60	85

(20 marks)

7. (a) If you have a heating pump of Carnot as in Fig 1 that work between two fronts at 260°C and 38°C respectively, and receive from the warm from 1 055kJ. Determine:

(i) the entropy change of the warm front.
(ii) the entropy change of the cold front.
(iii) the total entropy change of the process.



(15 marks)

(b) Evaluate ΔG^o for the reaction in which diatomic hydrogen and oxygen gases react to form water vapor at 298K, using values of ΔH_f^o and S^o. Is the reaction spontaneous at 298K? $2H_2(g) + O_2(g) \longrightarrow 2H_2O(g)$.

	ΔH_f^o kJ/mol	S^o J/mol K
$H_2(g)$	0	130.6
$O_2(g)$	0	205
$H_2O(g)$	-241.8	188.7

(5 marks)

8. (a) One liter of saturated barium sulfate contains 0.0025 grams of dissolved $BaSO_4$. Calculate the solubility product constant (K_{sp}) for $BaSO_4$.

$BaSO_4(s) \rightleftharpoons Ba^{2+}(aq) + SO_4^{2-}(aq)$ (8 marks)

(b) Calculate the concentration of OH^- and the pH of a solution that is 0.20M in aqueous NH_3 and 0.10M in NH_4Cl. (8 marks)

(c) Derive the mathematical expression for the partial molar volume of component A and B, then the total volume of the mixture in question. (4 marks)

9. Calculate the equilibrium constant, K and ΔG at 25°C for the following reaction.

$2Cu + PtCl_6^{2-} \longrightarrow 2Cu^+ PtCl_4^{2-} + 2Cl^-$ E^o

$2(Cu \longrightarrow Cu^+ + \bar{e})$ - 0.521V

$PtCl_6^{2-} + 2\bar{e} \longrightarrow PtCl_4^{2-} + 2Cl$ + 0.68V

at the following concentrations:

$[PtCl^{2-}] = 1.00 \times 10^{-2}M$
$[Cu^+] = 1.00 \times 10^{-3}M$
$[PtCl_4^{2-}] = 2.00 \times 10^{-5}M$
$[Cl^-] = 1.00 \times 10^{-3}M$

In terms of K, comment about the forward reaction. (20 marks)

END OF QUESTION PAPER!!!