INDIAN INSTITUTE OF TECHNOLOGY PATNA
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Course : **CH103 Introductory Chemistry** Date: **25th April 2017**
Exam : **End-Sem** Max. Marks: **60** Time: **3 Hours**

Instructions:

a) Use **data at the end** of the question paper.
b) Answer the reasoning questions in **one line (not more than 20 words)**
c) Unless mentioned **assume ideal gas behaviour**.

I . Answer all the questions (10 × 05 M = 50 M).

1) A fluorocarbon gas was allowed to expand reversibly and adiabatically to twice its volume. As a result, the temperature fell from 298.15 K to 248.4 K and its pressure fell from 202.94 kPa to 81.840 kPa. Evaluate $C_{p,m}$.

2) A block of copper of mass 2 kg and at temperature 0^0C is introduced into an insulated container in which there is 1 mole H_2O (g) at 100^0C and at 1.0 atm pressure. Assuming all the steam is condensed to water find the final temperature of the system. Find the entropy change in the total system (water + copper block).

3) At 298 K the standard enthalpy of combustion of sucrose is -5797 kJ/mole and standard Gibbs free energy is -6333 kJ/mole. Estimate the additional non-expansion work that may be obtained by raising the temperature to blood temperature, 37^0C.

4) The variation of pressure with the altitude, h, is given by the barometric formula $p = p_0 e^{\frac{-Mgh}{RT}}$, where p_0 is the pressure at sea level, p is the pressure at altitude h, M = 30.9 g /mole is the average molar mass of air and T= 20 ^{0}C is the ambient temperature. Combine this barometric formula with the Clausius-Clapeyron equation (exponential form) and predict the boiling point of water on the top of mount Everest which is about 8848 m above sea level. Also find the vapour pressure of water at this (boiling) temperature.

5) Vapour pressure of pure water at 293K is 0.02308 atm. The partial pressure of water is observed to be 0.02239 in a solution containing 0.122 kg of non-volatile solute (M=214 g/mole) dissolved in 0.920 kg water at 293 K. Find the difference of chemical potential of pure water and the chemical potential of water in the solution (a) assuming the solution is ideal and (b) assuming the solution is real.

6) In an industrial process N_2 at 1.0 bar is mixed with H_2 at 3.0 bar and the two gasses are allowed to come to equilibrium with the product ammonia in a reactor of constant volume. At the temperature of the reaction, it has been determined experimentally that K=977 for the reaction. Find the partial pressures of the three gases.

7) Consider the cell, Zn(s)|$ZnCl_2$ (0.005 mol/kg)|Hg_2Cl_2(s)|Hg(l) with measured cell potential 1.2272 V. The standard electrode potential for Zn^{2+}/Zn and Hg_2Cl_2/Hg are -0.7628 V and 0.22676 V respectively. Determine the mean ionic activity coefficient of $ZnCl_2$ (a) using the measured cell potential and (b) using Debye-Huckel limiting law.

8) The half-life for the (first order) radioactive decay of ^{14}C is 5730 years. An archaeological sample contained wood that had only 70% of the ^{14}C found in living trees. What is its age of the sample? If the sample contains 1 micro grams of ^{14}C, after how many years it will reduce to 1 nano gram.

9) Devise the rate law for the decomposition of N_2O_5 on the basis of the following mechanism: $N_2O_5 \rightarrow NO_2 + NO_3$, $NO_2 + NO_3 \rightarrow N_2O_5$, $NO_2 + NO_3 \rightarrow NO_2 + O_2 + NO$, $NO + N_2O_5 \rightarrow 3NO_2$.

10) Answer the following (**5 × 1M = 5M**)

(a) Assuming ideal behaviour calculate $C_{p,m}$ of air.

(b) Normal boiling point of hexane is 69°C. Find standard enthalpy of vaporization.

(c) What is the residual entropy of CO.

(d) Why solid CO_2 sublimes at atmospheric pressure without melting.

(e) Sketch a reaction profile for an exothermic reaction and identify the activation energy. In a reaction mixture at temperature, T, what fraction of collisions will have the kinetic energy greater than or equal to the activation energy.

II. **Fill in the blanks**. Each write answer will give you half mark (**0.5 × 20 = 10M**) and wrong answer will give you negative marks (**each wrong answer = -0.5 M**). Write only the answer in the answer script. No need to write the full statement.

a) _____ is the study of the interaction between matter and electromagnetic radiation.

b) A _____ is that part of a molecule that absorbs UV or visible light.

c) In the context of UV-Vis spectroscopy, _____ raises the energy of the HOMO and lowers the energy of the LUMO.

d) Electromagnetic radiation corresponding to bond vibrations of organic molecules is known as _____ radiation.

e) _____ (stronger/weaker) bonds and _____(heavier/lighter) atoms give rise to higher frequencies in its corresponding FTIR spectrum.

f) ^1H NMR spectrum of chlorocyclobutane has _____ number of signals.

g) The most commonly used reference compound in proton NMR spectroscopy is _____.

h) The right-hand side of a NMR spectrum is the _____ (high/low) -frequency side, where protons in electron- _____ (poor/dense) environments show a signal.

i) _____ and _____ are two methods used to determine the rate law experimentally.

j) MX and MX_2 are two strong electrolytes. Which shows more deviation from ideal behaviour 0.001 molar MX solution or 0.001 molar MX_2 solution. _____.

k) When cell reaction reaches equilibrium, the cell potential is _____.

l) Mean activity coefficient of a salt M_pX_q is _____.

m) At constant temperature, the rate of change of equilibrium constant with pressure, $\left(\frac{\partial K}{\partial p}\right)_T$ = _____.

n) A container is divided in to two equal compartments. Each contains one mole of H_2 gas at 25°c. If you remove the partition, the entropy of mixing = _____.

o) Chemical potential is the partial molar Helmholtz free energy at constant temperature, composition and _____.

p) _____ and _____ determine the lowest and highest pressure at which a liquid state can exist.

Data:

$C_{p,m}(H_2O,l)$ = 75.3 J/K/mole	$\Delta_{vap}H(H_2O, p=1\,atm)$ =40656 J/mole	1 atm = 101325 Pa
$C_s(Cu,s)$ = 0.385 J/K/g	k =1.38065 X 10^{-23} J/K	R =8.314 J/K/mole
F = 96485 C/mole	A = 0.509	g =9.81 m/s^2