RAJARATA UNIVERSITY OF SRI LANKA
FACULTY OF APPLIED SCIENCES

B.Sc. in Applied Sciences
First Year - Semester II Examination – January / February 2023

# CHE 1302 – PHYSICAL CHEMISTRY I

**Time: Three (3) hours**

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Answer **all** questions.
The use of a non-programmable calculator is permitted.
Avogadro Number ($N_A$) = $6.022 \times 10^{23}$ $mol^{-1}$ Faraday's Constant (F) = 96485 C $mol^{-1}$
Universal Gas Constant (R) = 8.314 J $K^{-1}$ $mol^{-1}$

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1. a) What are the assumptions of the kinetic theory of gases?

(10 marks)

b) An ideal gas has a density of 4.5 kg $m^{-3}$ at a pressure of $9.3 \times 10^5$ Pa and a temperature of 504 K. Determine the root-mean-square (r.m.s.) speed of the gas atoms at 504 K.

(20 marks)

c) The Initial temperature of an ideal gas is 27°C. The temperature of the gas is increased to 927°C. Find the ratio of final r.m.s speed to the initial r.m.s. speed.

(10 marks)

d) The compressibility factor (Z) in terms of virial equation may be represented as

$Z = \left[1 + \frac{B}{V_m} + \frac{C}{V_m^2} + \frac{D}{V_m^3} \ldots\ldots\right]$ B, C, and D are constants and a function of temperature.

i. Show that, for a one mole of a gas:
$Z = 1 + \frac{1}{V}\left(b - \frac{a}{RT}\right) + \frac{b^2}{V^2} + \frac{b^3}{V^3} \ldots\ldots$ Where a and b are van der Walls constants.

ii. At low pressure, show that the Boyle's temperature $(T_B) = \frac{a}{Rb}$ and describe the significance of $T_B$.

(40 marks)

e) Explain the liquefaction of a gas using Joule -Thomson effect.

(20 marks)

2. a) Distinguish between a reversible and an irreversible process in thermodynamic point of view (10 marks)

   b) 5 mol of an ideal gas at 400K and 4 atm, undergo expansion isothermally to half the initial pressure. If this expansion take place;
   i. Reversibly
   ii. Irreversible against zero pressure
   iii. Irreversible against 5 atm external pressure.
   Calculate the work done on the gas in each case. (40 marks)

   c) Calculate $\Delta H$ when 10 mol of $H_2O$ at 20 atm is heated from 30 °C to 40 °C?
   $C_{p,m}(\text{liquid, } H_2O) = 75 \text{ J K}^{-1} \text{ mol}^{-1}$
   $\Delta H_{\text{Vapourization}} = 47.3 \text{ kJ mol}^{-1}$ at 373 K
   $C_{p,m}(\text{gaseuos, } H_2O) = 35.4 \text{ J K}^{-1} \text{ mol}^{-1}$
   (30 marks)

   d) With relevant equations, explain three methods, that you can apply to find out Gibbs free energy change for a reaction $Zn(s) + Cu^{2+}(aq) \rightarrow Cu(s) + Zn^{2+}(aq)$
   (20 marks)

3. a) i. Define the term "entropy" and ii. Calculate entropy change when 10 moles of an ideal gas expands reversibly and isothermally from an initial volume of 10 L to 100 L at 300K.
   (25 marks)

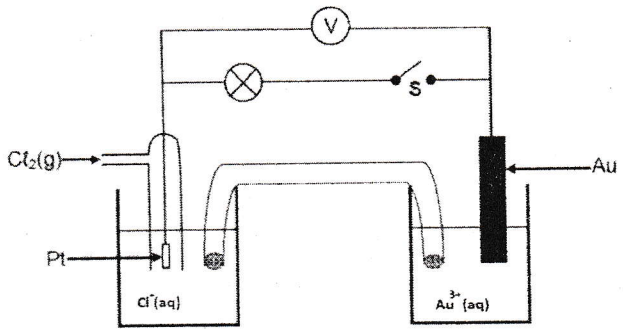
   b) Derive the relationship between $\Delta H$ and $\Delta U$ for an ideal gas. Explain each term involved in the equation.
   (25 marks)

   c) $\Delta G$ is net energy available to do useful work and is thus a measure of "free energy". Show mathematically that $\Delta G$ is a measure of free energy. Find the unit of $\Delta G$. If a reaction has positive enthalpy change and positive entropy change, under what condition will the reaction be spontaneous?
   (25 marks)

   d) The $\Delta H$ and $\Delta S$ for $2Ag_2O(s) \rightarrow 4Ag(s) + O_2(g)$ are given + 61.17 kJ $mol^{-1}$ and +132 J $K^{-1}$ $mol^{-1}$ respectively. Above what temperature will the reaction be spontaneous?
   (25 marks)

4. a) Explain what is meant by:
   i. Standard electrode potential
   ii. Electrochemical cell with transference
   (20 marks)

b) The diagram below shows a galvanic cell operating under **standard conditions.** The cell reaction taking place when the cell is functioning is:
$6Cl^-(aq) + 2Au^{3+}(aq) \rightarrow 3Cl_2(g) + 2Au(s)$
with switch S OPEN, the initial reading on the voltmeter is 0.14 V.




Write down the:

i. Half-reaction which takes place at the anode and cathode?
ii. Cell notation for this cell
iii. Calculate the standard reduction potential of Au.
iv. Predict the spontaneity of the cell reaction

(40 marks)

c) Discuss the application and salient features of Ag/AgCl electrode as a reference electrode in electrochemical measurements

(20 marks)

d) Apply the Nernst equation to explain the quinehydrone electrode as a pH sensor

(20 marks)

5 a) At 298 K, the resistance of $2.00 \times 10^{-2}$ M KCl is 195.96 Ω and that of $2.50 \times 10^{-3}$ M $K_2SO_4$ is 775.19 Ω. The conductivity (κ) of $2.00 \times 10^{-2}$ M KCl at 298 K is 0.277 S $m^{-1}$. Calculate molar conductivity of $K_2SO_4$ solution.

(30 marks)

b) Explain, with relevant equations that how you would carry out an experiment to determine the solubility product of $BaSO_4$ in water using conductivity measurements

(30 marks)

c) In an electrolysis experiment, a current was passed for 5 hours through two cells connected in series. The first cell contains a solution of gold(III) salt and the second cell contains copper sulphate solution. 9.85 g of gold was deposited in the first cell. Find the amount of copper deposited on the cathode in the second cell. Also calculate the magnitude of the current passed through the circuit. (relative atomic mass of Au = 197, Cu = 63.5)

(20 marks)

d) Explain the variation of molar conductivity of a strong electrolyte and a weak electrolyte upon dilution.

(20 marks)

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