THERMODYNAMICS AND KINETICS
(BIOT 2201)

Time Allotted: 3 hrs **Full Marks: 70**

Figures out of the right margin indicate full marks.

Candidates are required to answer Group A and any 5 (five) from Group B to E, taking at least one from each group.

Candidates are required to give answer in their own words as far as practicable.

Group – A
(Multiple Choice Type Questions)

1. Choose the correct alternatives for the following: **10×1=10**

(i) Cubic equation of state can calculate molar volume of
(a) gas (b) liquid
(c) both (a) and (b) (d) none of these.

(ii) Example of an isoenthalpic process is
(a) compression (b) condensation
(c) throttling (d) heat exchang.

(iii) The ratio of pressure to fugacity at standard state is called the
(a) activity (b) activity coefficient
(c) fugacity coefficient (d) energy coefficient.

(iv) The combined First and Second law of thermodynamics is represented by
(a) dU = TdS – PdV (b) dU = TdS + PdV
(c) dU = TdS –VdP (d) dU= TdS+VdP.

(v) 1 ton refrigeration is equal to
(a) 3.517 kW (b) 35.17 kW (c) 351.7 kW (d) 3517 kW.

(vi) What is the degree of freedom for a liquid water in equilibrium with its vapor?
(a) 1 (b) 2 (c) 3 (d) 0.

(vii) A second order reaction becomes a pseudo first order reaction when
(a) $C_{B0} >> C_{A0}$ (b) $C_{B0} = C_{A0}$ (c) $C_{B0} << C_{A0}$ (d) none.

(viii) For the enzyme substrate reaction, the rate of disappearance of substrate is given by
$-r_A = \frac{1760[A][E_0]}{6+[A]}$, mol/m^3.s. What are the units of the two constants?
(a) s^{-1}, mol/m3 (b) mol/L, s^{-1}
(c) mol/m^3.s, mol/m^3 (d) none

(ix) Higher value of Michaelis constant signifies
(a) increased substrate affinity of the enzyme
(b) reduced substrate affinity of the enzyme
(c) decreased enzyme reaction rate
(d) none of the above

(x) Reactions with order n>1
(a) can go to completion within a finite time
(b) never go to completion within a finite time
(c) do not have any limiting reactant
(d) none of the above

Group - B

2. (a) What will you observe in terms of volume change for acetone when the temperature and pressure change from 20 °C, 1 bar to 0°C, and 10 bar? Given
$V_1 = 1.3\times10^{-3}$ m^3.kg^{-1}, $\beta = 1.5\times10^{-3}$ K^{-1}, $\kappa = 62\times10^{-6}$ bar^{-1}.

(b) Describe the Claude process of liquefaction.

(c) Define Fugacity, Fugacity coefficient. How is fugacity different from pressure?

4 + 4 + 4 = 12

3. (a) Liquid water at 453.15 K and 1002.7 kPa has an internal energy of 762kJ.kg^{-1} and a specific volume of 1.128 cm^3.g^{-1}. What is its enthalpy? The same water is brought to the vapor state at 573.15 K and 1500 kPa, where its internal energy is 2784.4 kJ.kg^{-1} and its specific volume is 169.7 cm^3.g^{-1}. Calculate ΔU and ΔH for the process.

(b) Draw a labelled diagram of vapor-compression refrigeration cycle.

(c) Define chemical potential. Why it is important?

7 + 3 + 2 = 12

Group - C

4. (a) Briefly describe the protein folding with respect to free energy funnel.

(b) For the following reaction:
Glucose → 2 Lactic acid; ΔG = – 52000 cal/mole
Glucose+ $6O_2 \rightarrow 6CO_2 + 6H_2O$; ΔG = – 686000 cal/mole

(i) Calculate the ΔG for the complete oxidation of lactic acid to CO_2 and H_2O

(ii) How many ATP (moles) could be synthesized in the process of 40% efficiency?

12

5. (a) The pH of the gastric juice is about 1.5. Assuming that pH inside the cell of gastric mucosa is 6.8. Calculate the amount of energy required to secrete one mole of H^+ ion. T = 37 °C.

(b) The K_{eq} of a deamination reaction at 20°C and 37°C are 185 and 65 respectively.
Calculate ΔH, ΔG, and ΔS at 37 °C.

5 + 7 = 12

Group – D

6. (a) For the decomposition A→ R, C_{A0}= 1mol/L, in a batch reactor conversion is 75% after 1h, and is just complete after 2h. Find a rate equation to represent these kinetics.

   (b) An ampoule of radioactive Kr-89 (half life=76min) is set aside for a day. What does this do to the activity of the ampoule? Note that radioactive decay is a first order process.

5 + 7 = 12

7. Aqueous A at a concentration C_{A0}= 1mol/L is introduced into a batch reactor where it reacts away to form product R according to stoichiometry A→R. The concentration of A in the reactor is monitored at various times, as shown below:

t, min	0	100	200	300	400
C_A, mol/m^3	1000	500	333	250	200

For C_{A0}= 500 mol/m^3, find the conversion of reactant after 5 h in the batch reactor.

12

Group - E

8. At room temperature sucrose is hydrolyzed by the enzyme sucrase as follows:
   Sucrose + sucrase → products + sucrase.
   Starting with sucrose (C_{A0}= 1mol/m^3) and sucrase (C_{E0}= 0.01mol/m^3) the following data are obtained in a batch reactor.

C_A, mol/m^3	0.68	0.16	0.006
t, h	2	6	10

Find a rate equation to represent the kinetics of this reaction.

12

9. An inhibitor I is added to the enzymatic reaction at a level of 1.0g/L. The following data were obtained for K_m= 9.2g/L

v, g/(L.min)	0.909	0.658	0.493	0.40	0.333	0.289	0.227
S, g/L	20	10	6.67	5	4	3.33	2.5

   (a) Is the inhibitor competitive or non-competitive?
   (b) Find K_I

12