THERMODYNAMICS & 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 alternative for the following: **10 × 1 = 10**

(i) Rate of a reaction is a function of
(a) reaction time (b) concentration, reaction time
(c) concentration, temperature (d) temperature.

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

(iii) 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.

(iv) What is the balanced half-reaction for the reduction of nicotinamide adenine dinucleotide (NAD+)?
(a) $NAD^+ + 2e^- \rightarrow NADH$ (b) $NADH \rightarrow NAD^+ + H^+ + 2e^-$
(c) $NAD^+ + H^+ \rightarrow NADH$ (d) $NAD^+ + H^+ + 2e^- \rightarrow NADH$

(v) A batch reactor is a reactor
(a) at steady state
(b) where composition changes with location and time
(c) at an unsteady state
(d) none.

(vi) Efficiency of heat engine cycle is the ratio of
(a) total heat input to the cycle (Q_{in}) to net work output of the cycle (W_{net})
(b) net work output of the cycle (W_{net}) to total heat input to the cycle (Q_{in})
(c) net work output of the cycle (W_{net}) to heat rejected from the system (Q_{out})
(d) none of the above.

(vii) Which among the following is correct relation between COP of heat pump and COP of refrigerator?
(a) [COP]H.P. = 1 + [COP]ref (b) [COP]H.P. = 1 – [COP]ref
(c) [COP]H.P. = [COP]ref (d) None of the above.

(viii) Changes in enthalpy in an exothermic reaction is
(a) positive (b) negative (c) constant (d) neutral.

(ix) The locus of standard liquid line and standard vapour line meets at
(a) Boiling point (b) Critical point (c) Ice point (d) Triple point.

(x) First law of thermodynamics deals with _____
(a) conservation of mass (b) conservation of momentum
(c) conservation of energy (d) conservation of pressure.

Group- B

2. (a) State the criteria for a system to be in equilibrium. [(CO1)(Understand/LOCQ)]

(b) Air flows steadily at a rate of 0.5 kg/sec through an air compressor entering 7 m/sec velocity, 100 KPa pressure and 0.95 m^3/kg volume and leaving at 5 m/sec, 700 KPa and 0.19 m^3/kg. The internal energy of the air leaving is 90 KJ/kg greater than that of air entering. Cooling water in the compressor jacket absorbs heat from the air at the rate of 58 KW. (i) Compute the rate of shaft work input in the air in KW. (ii) Find the ratio of input pipe diameter to output pipe diameter. [(CO1)(Analyze/IOCQ)]

4 + 8 = 12

3. (a) Give an example of heat engine. Describes the working principle of a heat engine, with the cycle diagram. How is the efficiency of heat engine calculated? [(CO1)(Understand/LOCQ)]

(b) The food freezer maintain a temperature of -15°C. The ambient air temperature is 30°C. If the heat leaks into the refrigerator at a continuous rate of 1.75 kJ/sec, what is the least power necessary to pump this heat out continuously? [(CO2)(Evaluate/IOCQ)]

(1 + 5 + 1) + 5 = 12

Group - C

4. (a) What is the osmotic work A for transfer of 1 mole of protons by respiratory chain complexes through the inner mitochondrial membrane, from matrix side (pH = 7) to the inter-membrane space (pH = 6) at 37°C? What is the corresponding difference in membrane potential ΔE (expressed in V)? (R = 8.3143 J $K^{-1}mol^{-1}$, F = 96 487 J V^{-1} mol^{-1}). [(CO3)(Analyse/IOCQ)]

(b) Write a short note on active transport of Na^+/K^+ across cell membrane. [(CO3)(Analyser/IOCQ)]

6 + 6 = 12

5. (a) Calculate the electromotive force (in volts) registered by an electrode immersed in a solution containing the following mixtures of NAD+ and NADH at pH 70 and 25°C with reference to half cell of Eo = 0.01 volt.
(i) 1.0 mM NAD= and 1.0 mM MADH
(ii) 10 mM NAD+ and 1.0 mM NADH. [(CO3)(Calculate/HOCQ)]

(b) Draw the P-V diagram of a pure substance *other than water* and show the saturated liquid line, triple point line and saturated vapor line.
[(CO2)(Analyse/IOCQ)]

(3 + 3) + 6 = 12

Group - D

6. In the mid-nineteenth century the entomologist Henri Fabre noted that French ants busily bustled about their business on hot days but were rather sluggish on cool days. Checking his results with Oregon ants, I find

Running speed, m/h	150	160	230	295	370
Temperature, ˚C	13	16	22	24	28

What activation energy represents this change in bustliness?
[(CO1)(Analyze/IOCQ)]

12

7. (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 this kinetics. [(CO4)(Calculate/HOCQ)]

(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. [(CO3)(Understand/LOCQ)]

6 + 6 = 12

Group - E

8. (a) Find a rate equation to represent the breakdown of cellulose by cellulase in the absence of inhibitor. [(CO4)(Remember/LOCQ)]

(b) Enzyme E catalyzes the transformation of reactant A to product R as follows:
A+ E→R+E,
$-r_A = (200C_AC_{E0})/(2 + C_A)$, mol/L.min)
If we introduce enzyme (C_{E0}= 0.001mol/L) and reactant (C_{A0}= 10mol/L) into a batch reactor and let the reaction proceed, find the time needed for the concentration of reactant to drop to 0.025mol/L. Note that the concentration of the enzyme remains unchanged during the reaction.
[(CO5)(Understand/LOCQ)]

6 + 6 = 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

(i) Is the inhibitor competitive or non-competitive?
(ii) Find K_I. [(CO4)(Analyze/IOCQ)] **12**

Cognition Level	LOCQ	IOCQ	HOCQ
Percentage distribution	30.21	57.29	12.5

Course Outcome (CO):

After completion of this course, the students will be able to:

1. Comprehend the thermodynamic properties and functions of different systems and processes.
2. Apply the thermodynamic laws in practical problems.
3. Relate the thermodynamic properties and functions to biological systems.
4. Explain effect of temperature on rate of reaction.
5. Determine the order of a reaction using different suitable analytical methods.
6. Understand the kinetic mechanism of enzyme-substrate reactions with/without the presence of inhibitor and solve related problems.

*LOCQ: Lower Order Cognitive Question; IOCQ: Intermediate Order Cognitive Question; HOCQ: Higher Order Cognitive Question