

THERMODYNAMICS & KINETICS
(BIOT 2201)

Time Allotted : 2½ hrs

Full Marks : 60

Figures out of the right margin indicate full marks.

Candidates are required to answer Group A and any 4 (four) from Group B to E, taking one from each group.

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

Group – A

1. Answer any twelve:

12 × 1 = 12

Choose the correct alternative for the following

- (i) The work done by a closed system in a reversible process is always ____ that done in an irreversible process.
(a) less than or more than (b) equal to
(c) less than (d) more than
- (ii) Which among the following is correct relation between COP of heat pump and COP of refrigerator?
(a) $[\text{COP}]_{\text{H.P.}} = 1 + [\text{COP}]_{\text{ref}}$ (b) $[\text{COP}]_{\text{H.P.}} = 1 - [\text{COP}]_{\text{ref}}$
(c) $[\text{COP}]_{\text{H.P.}} = [\text{COP}]_{\text{ref}}$ (d) None of the above.
- (iii) Changes in enthalpy in an exothermic reaction is
(a) positive (b) negative (c) constant (d) neutral.
- (iv) The locus of standard liquid line and standard vapour line meets at
(a) Boiling point (b) Critical point
(c) Ice point (d) Triple point.
- (v) First law of thermodynamics deals with _____
(a) conservation of mass (b) conservation of momentum
(c) conservation of energy (d) conservation of pressure.
- (vi) At constant pressure and temperature, the direction of any chemical reaction is one where, the decrease.
(a) entropy (b) enthalpy
(c) Gibbs energy (d) none of these
- (vii) Conversion of a reactant is independent of initial concentration of the reactant for
(a) First order reaction (b) Second order reaction
(c) Half order reaction (d) Zero order reaction.

- (viii) An elementary reaction has the kinetic equation $-r_A = kC_A^{2.5}C_B^{-2.5}$. What is the order of reaction?
 (a) 0 (b) 5 (c) 2.5 (d) None of these.
- (ix) What is the unit of rate constant for a first order reaction?
 (a) $(\text{time})^{-1}$ (b) $(\text{time})^{-1}(\text{concentration})^{3/4}$
 (c) $(\text{time})^{-1}(\text{concentration})^{-3/4}$ (d) $(\text{time})^{-1}(\text{concentration})^{1/2}$.
- (x) When the inhibitor factor affects both the maximum forward velocity and Michaelis constant in an enzyme substrate reaction, the resulting inhibition is
 (a) Competitive (b) Uncompetitive
 (c) Noncompetitive (d) Substrate inhibition.

Fill in the blanks with the correct word

- (xi) The entropy of universe is always increasing _____.
- (xii) Milk is pastuerized if it is heated to 63°C for 30 min, but if it is heated to 74°C it only needs 15s for the same result. Find the activation energy? (R=8.314J/mol.K) _____.
- (xiii) Multisubstrate enzyme reaction can follow a mechanism called _____.
- (xiv) Heat engine efficiency formula is _____.
- (xv) Double reciprocal plot is also known as _____.

Group - B

2. (a) State the criteria for a system to be in equilibrium. [[CO1](Remember/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 m³/kg volume and leaving at 5 m/sec, 700 KPa and 0.19 m³/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. Compute the rate of shaft work input in the air in KW. [[CO1](Comopute/IOCQ)]
3 + 9 = 12
3. (a) Describes the working principle of a refrigeration cycle, with the cycle diagram. How the performance of refrigeration system is calculated? [[CO2](Underatand/LOCQ)]
 (b) State the 2nd law of thermodynamics. [[CO2](Remember/LOCQ)]
 (c) Mathematically prove that entropy of the universe is increasing. [[CO2](Compute/HOCQ)]
5 + 2 + 5 = 12

Group - C

4. (a) Calculate the standard free-energy change (ΔG°) at 25°C and ΔG_{300} for the reaction
 $3H_2(g) + N_2(g) \rightleftharpoons 2NH_3(g)$
 Assuming that ΔH and ΔS do not change between 25°C and 300°C.

Given, $\Delta H^\circ = -45.9 \text{ KJ/mol}$

$S(\text{N}_2) = 191.6 \text{ J/(mol.K)}$

$S(\text{H}_2) = 130.7 \text{ J/(mol.K)}$

$S(\text{NH}_3) = 192.8 \text{ J/(mol.K)}$

Is the reaction spontaneous as written?

[[CO3](Analyse/IOCQ)]

(b) Write down the following equation with explanation of each term.

(i) Virial equation

(ii) Van-der-Walls equation.

[[CO3](Remember/LOCQ)]

6 + 6 = 12

5. (a) Write a short note on active transport of Na^+/K^+ across cell membrane.

[[CO3](Remember/LOCQ)]

(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)]

6 + 6 = 12

Group - D

6. The following data are obtained at 0°C in a constant volume batch reactor using pure gaseous A:

$C_A, \text{ mol/L}$	1	2	4	6	7	9	12
$-r_A, \text{ Mol/L.h}$	0.06	0.1	0.25	1	2	1	0.5

The stoichiometry of the decomposition is $\text{A} \rightarrow 2.5\text{R}$. Find a rate equation which satisfactorily represents this decomposition.

[[CO5](Analyse/HOCQ)]

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7. (a) Derive an equation for rate of product formation in an enzyme reaction with competitive inhibition.

[[CO5](Analyse/LOCQ)]

(b) What is enzyme inhibition? What are the different types of enzyme inhibitions are there?

[[CO4](Remember/LOCQ)]

(c) Derive Michaelis- Menten equation for enzyme reaction.

[[CO5](Apply/IOCQ)]

5 + (1 + 1) + 5 = 12

Group - E

8. (a) Derive Briggs and Haldane equation for enzyme substrate reaction.

[[CO6](Analyse/HOCQ)]

(b) Graphically differentiate among the different types of inhibition reactions.

[[CO64](Differentiate/IOCQ)]

6 + 6 = 12

9. At room temperature sucrose is hydrolyzed by the catalytic action of the enzyme sucrose as follows: sucrose + sucrase \rightarrow products+ sucrase.

Starting with a sucrose concentration $C_{A0} = 1 \text{ mM}$ and enzyme concentration $C_{E0} = 0.01 \text{ mM}$, the following kinetic data are obtained in a batch reactor.

C_A , mM	0.84	0.68	0.53	0.38	0.27	0.16	0.09	0.04	0.018	0.006	0.0025
t, h	1	2	3	4	5	6	7	8	9	10	11

Determine whether these data can be reasonably fitted by the kinetic equation $-r_A = \frac{k_2 \cdot C_{E0} \cdot C_A}{C_A + C_M}$, where k_2 and C_M are kinetic constants. If the fit is reasonable find the value of k_2 and C_M .

[[CO6](Compute/HOCQ)]

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Cognition Level	LOCQ	IOCQ	HOCQ
Percentage distribution	30.20	33.33	36.45

Course Outcome (CO):

After the completion of the course 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.