B.TECH/ BT/4TH SEM/ BIOT 2201/2018

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) For heat transfer in steady flow processes, where ΔE_k and ΔE_p are negligible, shaft work, $W_s = 0$ and mass flow rate is $\dot{m}$, which of the following is true?
(a) $Q=\Delta U\,\dot{m}$ (b) $Q=\Delta U\,\dot{m}$ (c) $\Delta U=0$ (d) $\Delta H=0$.

(ii) Which of the following best describes the PVT behaviour of both gases and liquids?
(a) Viral Equation of state (b) Ideal gas law
(c) van der Waal's equation (d) None of the above.

(iii) For a pure substance, the region to the right of critical temperature T_c and above the critical pressure P_c is known as the
(a) saturated vapour region (b) saturated liquid region
(c) solid region (d) supercritical region.

(iv) 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.

(v) A 10 minute experimental run shows that 75% of liquid reactant is converted to product by a ½ order rate. What would be the percentage conversion in a 20 minute run?
(a) 50 (b)80 (c)100
(d)Reaction completed before 20minutes.

(vi) For an ideal gas the fugacity coefficient
(a) $\varphi > 1$ (b) $\varphi < 1$ (c) $\varphi = 0$ (d) $\varphi = 1$.

(vii) Secondary active transport requires
(a) concentration gradient
(b) an electrical potential difference
(c) a partial pressure difference
(d) all of the above.

(viii) What is the unit of rate constant for a 1/4 order reaction?
(a) $(\text{time})^{-1}(\text{concentration})^{1/2}$
(b) $(\text{time})^{-1}(\text{concentration})^{3/4}$
(c) $(\text{time})^{-1}(\text{concentration})^{-3/4}$
(d) $(\text{time})^{-1}$.

(ix) k_m remains unchanged in value in presence of inhibitor for
(a) competitive inhibition
(b) uncompetitive inhibition
(c) non-competitive inhibition
(d) all the above.

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

Group – B

2. (a) Water at 95°C is pumped from a storage tank at the rate of $1\text{m}^3/\text{min}$. The motor for the pump supplies work at the rate of 1.48 kW. The water goes through a heat exchanger, giving up heat at the rate of 42,000 kJ/min and is delivered to a second storage tank at an elevation of 15.24 m above the first tank. What is the temperature of the water delivered to the second tank?

Given: density of water at 95°C = $975.5\ \text{kg/m}^3$
Enthalpy of water at 95°C = 397.96 kJ/kg
Enthalpy of water at 36°C =150.86 kJ/kg
Enthalpy of water at 40°C = 167.57 kJ/kg
Accelaration due to gravity , g = $9.81\ \text{m/sec}^2$

(b) When a system is taken from state a to state b along the path acb, 100 J of heat flows into the system and the system does 40 J of work.
(i) How much heat flows into the system along path acb if work done by the system is 20 J?
(ii) Again if the system returns from b to a along path bda and if work done on the system is 30 J, does the system liberate or absorb heat during the process? How much?

8 +4 =12

3. (a) Draw a PT diagram and a PV diagram for a pure substance and explain their physical significance.

(b) What do you understand by (i) Triple point (ii) Critical point and (iii) fluid region?

(c) For complete oxidation of glucose ($C_6H_{12}O_6$)and palmitic acid($C_{16}H_{32}O_2$) to carbon dioxide and water at 310K the values of ΔU are respectively -2810 kJ/mol and -10012 kJ/mol. Calculate ΔH for the two processes.

5 + 3 + 4 = 12

Group – C

4. (a) How does the standard Gibbs energy change of a reaction is related to the respective equilibrium constant?

(b) Given:

Glucose-6-phosphate + H_2O → Glucose + Pi $K'_{eq} = 270$

ATP + Glucose → glucose-6-phosphate + ADP $K'_{eq} = 890$

Using this information calculate the standard free energy of hydrolysis of ATP. Assume a temperature of 25°C.

(c) Glucose-6-phosphate was hydrolysed enzymatically (at pH7 and 25°C) to glucose and inorganic phosphate. The concentration of glucose-6-phosphate (G-6-P) was 0.5M at the start. At equilibrium only 0.01% of the original glucose-6-phosphate remained. Calculate (i) K'_{eq} for the hydrolysis of G-6-P (ii) ΔG' for the hydrolysis reaction (iii) K'_{eq} for the reaction by which G-6-P is synthesized from inorganic phosphate and glucose and (iv) ΔG' for the synthesis reaction.

2 + 4 + 6 = 12

5. (a) What is active and passive transport?

(b) Explain primary and secondary active transport in biological systems with example.

(c) The concentration of chloride ion in blood serum is about 0.10M. The concentration of chloride ion in urine is about 0.16M. (a) Calculate the energy expended by the kidneys in transporting chloride from plasma to urine. (b) How many moles of Cl^- ions could be transported per mole of ATP hydrolyzed?

2 + 6 + 4 = 12

Group – D

6. (a) Large central power stations, using fluidized bed combustors may be built some day. These giants would be fed 240 tons of coal/h (90% C, 10%H_2), 50% of which would burn within the battery of primary fluidized beds, whereas the other 50% elsewhere in the system. One suggested design would use a battery of 10 fluidized beds, each 20 m long, 4 m wide and containing solids to a depth of 1m. Find the rate of reaction within the beds, based on the oxygen used.

(b) The maximum allowable temperature for a reactor is 800 K. At present our operating set point is 780 K, the 20 K margin of safety to account for fluctuating feed,

sluggish controls etc. Now with a more sophisticated control system we would be able to raise our set point to 792 K with the same margin of safety that we now have. By how much can the reaction rate, be raised by this change if the reaction taking place in the reactor has activation energy of 175 kJ/mol?

6 + 6 = 12

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

Time, min	0	2	4	6	8	10	12	14	∞
Partial pressure of A, mm of mercury	760	600	475	390	320	275	240	215	150

The stoichiometry of the decomposition is A→2.5R. Find a rate equation, which satisfactorily represents this decomposition.($C_A=p_A/RT$, where C_A is molar concentration of A and p_A is partial pressure of A)

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Group – E

8. (a) Enzyme E catalyzes the transformation of reactant A to product R as follows:

A+ E→R+E,

$$-r_A(\text{ mol/L.min}) = \frac{200 C_A C_{E0}}{2 + C_A}$$

If we introduce enzyme (C_{E0}= 0.001 mol/L) and reactant (C_{A0}= 10 mol/L) into a batch reactor and let the reaction proceed, find the time needed for the concentration of reactant to drop to 0.025 mol/L. Note that the concentration of the enzyme remains unchanged during the reaction.

(b) Find a rate equation to represent the breakdown of cellulose by cellulose in the absence of inhibitor.

6 + 6 = 12

9. At room temperature sucrose is hydrolyzed by the enzyme sucrose as follows:

Sucrose + sucrose → products + sucrase.

Starting with sucrose (C_{A0}= 1mol/m^3) and sucrase (C_{E0}= 0.01 mol/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**