Register Number:……..

KUMARAGURU college of technology
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B.TECH. DEGREE EXAMINATIONS: NOV/DEC 2023

(Regulation 2018)

Third Semester

BIOTECHNOLOGY

U18BTT3102: Bioprocess Calculations

COURSE OUTCOMES

CO1: Apply the unit conversion and basic calculations
CO2: Solve the material balance without and with involving chemical reactions
CO3: Analyze the energy balance involving chemical reactions
CO4: Conceptualize energy balance without involving chemical reactions
CO5: Elucidate the concept of thermodynamic preliminaries
CO6: Elaborate the stoichiometry for growth and product formation

Time: Three Hours **Maximum Marks: 100**

Answer all the Questions

PART A (10 x 1 = 10 Marks)

1. A temperature of 356.4 °F increases by 8°. What is the temperature in °C? CO1 [K1]
   a) 356.4 b) 364.4
   c) 332.4 d) 184.7
2. Assertion (A): The ideal gas law describes the behavior of real gases under all conditions. CO1 [K1]
   Reason (R): The ideal gas law assumes that gas particles have zero volume and do not interact with each other.
   a) Both A and R are true, and R is the correct explanation of A b) Both A and R are true, but R is not the correct explanation of A
   c) A is true, but R is false d) A is false, but R is true
3. Match the following: CO2 [K1]

	Term		Expressions
A	Selectivity	I	$\frac{\text{moles of reactant supplied} - \text{moles of reactant theoretically required}}{\text{moles of B theoretically required}}$
B	Yield	II	$\frac{\text{moles of desired product fromed}}{\text{moles of undesired product fromed}}$
C	Conversion	III	$\frac{\text{moles of reactant reacted to produce desired product}}{\text{moles of reactant totally reacted}}$
D	Precent Excess	IV	$\frac{\text{moles (or mass) of reactant reacted}}{\text{moles (or mass)of reactant charged or fed}}$

   a) A-I B-II C-III D-IV b)
   c) A-III B-IV C-I D-II d) A-IV B-I C-II D-III
4. Consider the following statement with respect to steady state: CO2 [K1]
   1. In an equilibrium state, there is a balance between opposing factors, resulting in a stable and unchanging overall state.
   2. There is no net accumulation of mass, energy, or other relevant quantities within the system.
   3. Any changes are occurring at a rate such that the overall state of the system vary.
   4. It may be reached when the rates of material entering and leaving a system are unequal.

5. System has reached a unstable equilibrium, and its state variables remain changing over time.

Which of these above statements are correct?

a) 1,2 b) 2,3
c) 3,4 d) 4,5

5. An exothermic reaction takes place in an adiabatic reactor. The product temperature ..... the reactor feed temperature. CO3 [K_2]

a) Is always greater than b) Is always equal to
c) Is always less than d) May be greater or less than

6. Assertion (A): The total energy flow across a system boundary that is caused by a temperature difference between the system and the surroundings. CO4 [K_1]

Reason (R): The net amount of heat transferred to or from the system over a fixed time interval.

a) Both A and R are true, and R is the correct explanation of A
b) Both A and R are true, but R is not the correct explanation of A
c) A is true, but R is false
d) A is false, but R is true

7. Match the list I (Term) with list II (Definition) CO5 [K_1]

List - I		List II	
A	Adiabatic system	I	A system in which the volume is invariant during a process
B	Isobaric system	II	A system in which the temperature is invariant during a process
C	Isochoric system	III	A system that does not exchange heat with the surroundings
D	Isothermal system	IV	A system in which the pressure is constant during a process

a) A-I B-II C-III D-IV b) A-II B-III C-IV D-I
c) A-III B-IV C-I D-II d) A-IV B-I C-II D-III

8. Arrange the following processes in order of increasing entropy change: CO5 [K_2]

1. Evaporation of water at room temperature.
2. Mixing two gases in a closed container.
3. Combustion of gasoline in a car engine.
4. Freezing of liquid water to form ice at 0°C.

Please provide your answer by numbering the processes in the correct order.

a) 1-2-3-4 b) 2-3-4-1
c) 3-4-2-1 d) 4-1-2-3

9. Consider a reactor initially containing 100 moles of a reactant. The reaction follows the first-order kinetics, A → B, with a rate constant $k = 0.2\ min^{-1}$. After 5 minutes, the reactor contains 60 moles of A. CO6 [K_2]

1. The reaction rate at 5 minutes is 0.2 mol/min
2. The concentration of A at t = 5 minutes is 12 mol/L
3. The concentration of A at t = 0 is 1 mol/min
4. At t = 5 minutes, the concentration of B is 40 mol/L

Which of these above statements are correct?

a) 1,2 b) 2,3
c) 3,4 d) 4,1

10. Consider the following for biochemical processes. CO6 [K_2]

1. Product Formation: Formation of the final products of biomass conversion.
2. Substrate Formation: Formation of a substrate suitable for biomass conversion.
3. Microbial Action: Activity of specific microorganisms involved in biomass conversion.

4. Oxygen Utilization: Utilization of oxygen during the conversion process.
5. Nitrogen Incorporation: Incorporation of nitrogen into the conversion process.

Which is the correct sequence of processing?

a) 1-2-3-4-5 b) 2-3-4-5-1
c) 3-4-5-1-2 d) 4-5-1-2-3

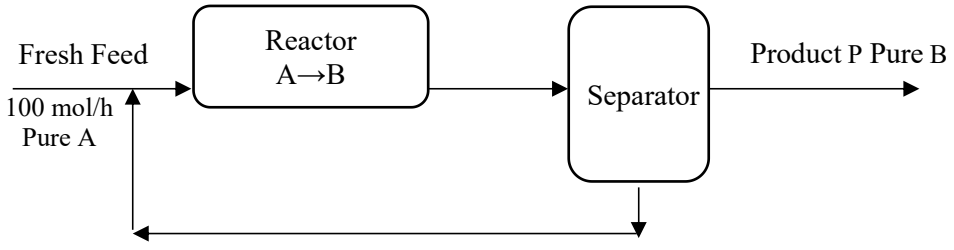
Answer any TEN Questions
PART B (10 x 4 = 40 Marks)
(Answer not more than 80 words)

11. The thermal conductivity of aluminum at 32 °F is 117 Btu h^{-1} ft^{-1}°F. Find the equivalent value in terms of cal sec^{-1} cm^{-1} $°C^{-1}$. CO1 [K_2]
12. A solution is prepared by dissolving 3 moles of hydrochloric acid (HCl) in 500 g of water. Determine the following. (a) Molarity of the HCl solution, (b) Molality of the HCl solution and (c) Normality of the HCl solution CO1 [K_2]
13. Consider a steady-state distillation column separating a binary mixture of ethanol (A) and water (B). The feed to the column is a liquid mixture containing 30 mol% ethanol and 70 mol% water. The distillate is 90 mol% ethanol, and the bottoms are 10 mol% ethanol. Determine the distillate and bottoms flow rates if the feed rate is 100 mol/h. CO2 [K_3]
14. A reaction requires 2 moles of A for every mole of B. If 10 moles of A are fed into the reactor with 6 moles of B, what is the limiting reactant? CO2 [K_3]
15. Calculate the enthalpy change between the reactants and products at standard condition if 50 mole of CO_2 is produced according to the following reaction. CO3 [K_3]

$2\ C_4H_{10}\,(g) + 13\ O_2\,(g) \rightarrow 8\ CO_2\,(g) + 10\ H_2O\,(l)$

Component	ΔH_f°
C_4H_{10} (g)	-30.04
CO_2 (g)	-93.98
H_2O (l)	-68.27
O_2 (g)	0.0

16. Calculate the heat needed to raise the temperature of 2 k mol of NH_3 for 350 K to 450 K using mean molal heat capacity. CO3 [K_3]
$C_{Pm_1}^\circ$ for NH_3 between 298 K to 350 K = 36.86 kJ/k mol K
$C_{Pm_2}^\circ$ for NH_3 between 298 K to 450 K = 38.71 kJ/k mol K
17. What is the change in internal energy when 10 kg mol of air are cooled from 60°C to 30°C in a constant volume process? C_v = 2.1 x 10^4 J/ (kg mol) (°C) CO4 [K_3]
18. Calculate the difference between heats of reaction at constant pressure and constant volume for the reaction, $2\ C_6H_6\,(l) + 15\ O_2\,(g) \rightarrow 12\ CO_2\,(g) + 6\ H_2O\,(l)$ at 25°C in kJ. CO4 [K_4]
19. Define of Internal Energy and Enthalpy. CO5 [K_1]
20. Recall the first and second law of thermodynamics. CO5 [K_1]
21. In a microbial fermentation experiment, it is found that 0.8 grams of biomass (dry weight of cells) is produced for every 1 gram of glucose consumed. Calculate the yield coefficient ($Y_{X/S}$). CO6 [K_2]
22. If the single-pass (once-through) conversion of A to B is 20%. Calculate the rate of recycle R (moles/hr). CO6 [K_4]



Answer any FIVE Questions
PART C (5 x 10 = 50 Marks)
(Answer not more than 250 words)

23. a) (i) A vacuum processing system removes dissolved gases from steel. The dial on the thermocouple vacuum gage inserted into the vessel reads 18.3 microns Hg pressure. Calculate the absolute pressure inside the vessel in Pa. — 2.5 CO1 [K3]

(ii) Calculate the work in kWh required to raise 1 ton of iron ore (1000 kg) a distance of 30 m at the standard location. The force in this case is the acceleration of gravity times the mass = 9.8 m/s^2. — 2.5 CO1 [K3]

b) Stainless steel is made by melting 2000 *lb* of iron, 506 *lb* of chromium, 225 *lb* of nickel, and 85 *lb* of molybdenum. The iron was not pure but contained 0.5 %C. Calculate the mass fraction (%) and amount of substance fraction of carbon in the stainless steel. — 5 CO1 [K3]

24. a) A 1 kg of feed contains mixture of 47.5% of acetic acid and rest water is being separated by extraction in a counter current multistage unit and the solvent used is iso-propyl ether. Final extract composition on a solvent free basis is found to be 82% of acid. The raffinate is found to contain 14% of acid on solvent free basis. Find the percentage of acid unextracted? — 5 CO2 [K4]

b) Pure A in gas phase enters a reactor. Fifty percent (50%) of this A is converted to B through the reaction A → 3B. What is the mole fraction of A in the exit stream? What is the extent of reaction? — 5 CO2 [K4]

25. a) Calculate the standard heat of formation of liquid ethyl acetate with equation using following data. — 10 CO3 [K3]

$\Delta H^{\circ}_{f(CO_2)}$ = - 93.98 kcal / mol

$\Delta H^{\circ}_{f(H_2O)}$ = - 68.26 kcal / mol

$\Delta H^{\circ}_{f(C_2H_8O_2)}$ = - 532.82 kcal / mol

26. Flue gases leaving the stack of a boiler at 520 K have the following data. — 10 CO4 [K3]

Component	Composition (%)	C_P (kJ/k mol K)
CO_2	11.4	41.62
H_2O	13.0	34.33
O_2	2.3	30.14
N_2	73.3	29.31

Calculate the heat lost in 1 k mol of gas mixture above 298 K.

27. How do the Maxwell equations relate different thermodynamic properties? Derive it. — 10 CO5 [K2]

28. a) Determine the stoichiometric coefficients for this equation. — 5 CO6 [K3]

$C_3H_8 + a\ O_2 \rightarrow b\ CO_2 + c\ H_2O$

b) A tank initially contains 100 kg of water at 50°C. Hot water at 80°C is continuously fed into the tank at a rate of 5 kg/min. The tank is well mixed, and water is drained from the tank at a rate of 2 kg/min. The heat transfer from the tank to the surroundings is 500 W. Calculate the temperature of the water in the tank after 10 minutes. — 5 CO6 [K4]

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