KUMARAGURU
college of technology
character is life

B.TECH. DEGREE EXAMINATIONS: NOV/DEC 2022

(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 2 = 20 Marks)
(Answer not more than 40 words)

1. The superficial mass velocity is found to be 200 lb/h.ft^2. Find its equivalent in kg/s.m^2.   CO1 [K$_2$]

2. What is the volume of 25 kg of chlorine at standard condition?   CO1 [K$_2$]

3. A water-soaked fabric is dried from 44% moisture to a final moisture of 91%. Calculate the weight   CO2 [K$_3$]
    of water removed per 200 kg of dried fabric.

4. Recall the process of recycle and bypass with its flow diagram.   CO2 [K$_1$]

5. For the following reaction,   CO3 [K$_3$]
    estimate the heat of reaction
    at 298 K.

    A + B → C + D

Compound	ΔH_f° (kcal/g mole)
A	-269.8
B	-195.2
C	-337.3
D	-29.05

6. 2 gm moles of nitrogen are heated from 50°C to 250°C in a cylinder. What is ΔH for the process?   CO4 [K$_3$]
    The heat capacity equation is $C_P = 27.32 + 0.6226 \times 10^{-2}T - 0.0950 \times 10^{-5} \, T^2$
    where C_P is in J/g mol °C and T is in K.

7. A system consisting of some fluid is stirred in a tank. The rate of work done on the system by the   CO5 [K$_4$]
    stirrer is 2.25 hp. The heat generated due to stirring is dissipated to the surroundings. If the heat
    transferred to the surroundings is 3400 kJ/h, determine the change in internal energy.

8. Define specific heat capacity with its units.   CO5 [K$_1$]

9. What is meant by theoretical oxygen demand?   CO6 [K$_1$]

10. Distinguish between the steady state and unsteady state with its equation.   CO6 [K$_1$]

Answer any FIVE Questions
PART B (5 x 4 = 20 Marks)
(Answer not more than 80 words)

11. An aqueous solution of K_2CO_3 is prepared by dissolving 43 kg of K_2CO_3 in 100 kg of water at 293 K. Calculate molarity, normality, and molality of solution. Density of solution is 1.3 kg/l.   CO1 [K₃]

12. A mixture containing 47.5% of acetic acid is being separated by extraction in a counter current multistage unit. The operating temperature is 24°C and the solvent used is iso-propyl ether. Using the solvent in the ratio of 1.3 kg/kg of feed, the 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?   CO2 [K₃]

13. Find the heat of reaction at 1200 K.   CO3 [K₃]

    $C_2H_6 \rightarrow C_2H_4 + H_2$

    $\Delta H_{f,C_2H_6} = -84720$ kJ/k mol

    $\Delta H_{f,C_2H_4} = 52280$ kJ/k mol

14. Calculate the amount of heat given off when 1 m³ of air at standard conditions cools from 500°C to –100°C at constant pressure. C_P air $= 6.386 + 1.762 \times 10^{-3}\,T – 0.2656 \times 10^{-6}\,T^2$, where C_P is in kcal/k mole K and T in K.   CO4 [K₃]

15. Summarize the following: CO5 [K₂]

    (i)   Homogeneous and Heterogeneous

    (ii)   Intensive and Extensive

    (iii)   Isobaric and Isochoric

    (iv)   Enthalpy and Entropy

16. A bioreactor was charged with 5000 kg/h of an aqueous solution of fermented grain containing 15% by weight glucose (C6H12O6). Yeast digests the glucose to form ethanol and acrylic acid (C₂H₃COOH).   CO6 [K₄]

    $C_6H_{12}O_6 \rightarrow 2C_2H_5OH + 2CO_2$

    $C_6H_{12}O_6 \rightarrow 2C_2H_3COOH + 2H_2O$

    If 150 kg CO_2 is produced and 110 kg unreacted glucose remains in the broth, determine the percent composition by weight of the products in the broth.

Answer any FIVE Question
PART C (5 x 12 = 60 Marks)
(Answer not more than 300 words)

17. a)   (i) In a multiple effect evaporator system, the second effect is maintained under vacuum of 475 torr (mm Hg). Find the absolute pressure in kPa.   3   CO1 [K₃]

    (ii) A force of 19.635 kgf is applied on a piston of diameter 5 cm. Find the pressure exerted on the piston in kPa.   3

b) A gaseous mixture analyzing CH_4: 10%, C_2H_6: 30% and rest H_2 at 15°C and 1.5 atm is flowing through an equipment at the rate of 2.5 m³/min. Find (i) the average molecular weight of the gas mixture, (ii) weight % and (iii) the mass flow rate.   6   CO1   [K₃]

18. a) 1000 kg of a 30% aqueous solution of Na_2CO_3 is slowly cooled to 20°C. During cooling, 10% water originally present evaporates. The crystal is Na_2CO_3 $10H_2O$. If the solubility of anhydrous Na_2CO_3 at 20°C is 21.5 kg/100 kg of water, Calculate weight of salt crystallizes out.   6   CO2   [K₄]

b) The gas phase reaction A → 2 B + C takes place isothermally in a constant pressure reactor. Starting with a mixture of 75% A and 25% inerts (both on volume basis), in a specified time the volume doubles [i.e., final volume = 2 (initial volume)]. Compute the % conversion of A achieved.   6   CO2   [K₃]

19. a) Calculate the heat of formation of benzoic acid crystals $C_7H_6O_2$ at 298 K using the following data.   6   CO3   [K₄]

$\Delta H^\circ_{f(CO_2)}$ = - 93.98 k cal/mol

$\Delta H^\circ_{f(H_2O)}$ = - 68.26 k cal/mol

$\Delta H^\circ_{C(C_7H_6O_2)}$ = - 770.71 k cal/mol

b) 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.   6   CO3   [K₃]

$2C_4H_{10}(g) + 13O_2(g) \rightarrow 8CO_2(g) + 10H_2O(l)$
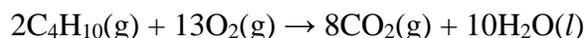
Component	ΔH°_f (k cal/mol)
C_4H_{10} (g)	-30.04
CO_2 (g)	-93.98
H_2O (l)	-68.27
O_2 (g)	0.0

20. A natural gas has the following composition on mole basis.   CO4   [K₃]

CH_4 = 83%, C_2H_6 = 15%, and N_2 = 2%. Calculate the heat to be added to heat 20 k mol of natural gas from 300 K to 520 K using the heat capacity data given below

$C_P = a + bT + cT^2$ kJ/k mol K

Component	a	b x 10^3	c x 10^6
CH_4 (g)	19.26	52.12	11.98
C_2H_6 (g)	5.41	178.09	- 67.38
N_2 (g)	29.60	-5.15	13.19

21. Derive the Maxwell's equation for the four fundamental property relations with Mnemonic CO5 [K4] diagram.

22. a) Assume that experimental measurements for a certain organism have shown that cells can 6 CO6 [K3] convert two-third (wt/wt) of the substrate carbon to biomass. Calculate the stoichiometric coefficients and yield coefficients,
    $Y_{X/S}$ (g dw cell/ g substrate) for the following biological reaction.
    $$C_6H_{12}O_6 + a\ O_2 + b\ NH_3 \rightarrow c\ (C_{4.4}\ H_{7.3}\ N_{0.86}\ O_{1.2}) + d\ H_2O + e\ CO_2$$

    b) In a sewage treatment plant, a large concrete tank initially contains 440,000 L liquid and 6 CO6 [K4] 10,000 kg fine suspended solids. To flush this material out of the tank, water is pumped into the vessel at a rate of 40,000 L/h, and liquid containing solids leave at the same rate. Estimate the concentration of suspended solids in the tank at the end of 4 h.

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