



B.TECH DEGREE EXAMINATIONS: MAY 2017

(Regulation 2015)

Fourth Semester

BIOTECHNOLOGY

U15BT405 : Biothermodynamics

COURSE OUTCOMES

- CO1** Outline the applications of thermodynamic law and properties of fluids
CO2 Discuss the principles of partial molar properties and their applications in bioprocess engineering
CO3 Explain the principles of solution thermodynamics and their applications in bioprocess engineering
CO4 Explain the principles of phase equilibria problems and their applications in industrial biotechnology
CO5 Describe the basics principles of chemical reaction equilibria problems and their applications in industrial biotechnology
CO6 Illustrate the thermodynamic description of microbial growth and product formation

Time: Three Hours

Maximum Marks: 100

Answer all the Questions:-

PART A (10 x 1 = 10 Marks)

1. Match the Property(List I) with its factor (List II)

CO1 [K₂]

List I	List II
A. Intensive	i. boiling mixtures
B. Dew point	ii. specific volume
C. Azeotropes	iii. chemical potential
D. Gibbs free energy	iv. vapor

- | | A | B | C | D |
|----|-----|----|-----|-----|
| a) | ii | i | iii | iv |
| b) | iii | iv | ii | i |
| c) | ii | iv | i | iii |
| d) | iii | i | ii | iv |

2. Entropy change of a system is zero in

CO1 [K₂]

- | | |
|---------------------------------|-----------------------|
| a) Reversible process | b) Adiabatic process |
| c) Reversible adiabatic process | d) Isothermal process |

10. Typical cellular material formula is represented by CO6 [K₂]
- a) $\text{CH}_{1.8}\text{O}_{0.5}\text{N}_{0.2}$ b) $\text{CH}_{0.8}\text{O}_{0.7}\text{N}_{0.5}$
- c) $\text{CH}_{1.8}\text{O}_{0.4}\text{N}_{0.4}$ d) $\text{CH}_{1.8}\text{O}_{1.5}\text{N}_{0.5}$

PART B (10 x 2 = 20 Marks)

(Answer not more than 40 words)

11. Predict the mathematical expression of first law for non-cyclic process. CO1 [K₂]
12. Calculate the rate of increase in internal energy if the work done on and heat transferred from a fluid are 300 J and 3400 J/s respectively. CO1 [K₄]
13. Develop the relation to prove that the rate of change of chemical potential with pressure is equal to the partial volume of the constituent. CO3 [K₂]
14. Differentiate between ideal and real gases with respect to their characteristics. CO3 [K₂]
15. List the three criteria's of phase equilibrium with their expression. CO3 [K₁]
16. Using the criterion of equilibrium, show that the change in entropy during phase changes can be calculated from the latent heat of phase change and the absolute temperature as $\Delta S = \Delta H/T$. CO5 [K₂]
17. Calculate the equilibrium constant at 298 K of the reaction, $\text{N}_2\text{O}_4 (\text{g}) \rightarrow 2\text{NO}_2 (\text{g})$ given that the standard free energies of formation at 298 K are 97,540 J/mol for N_2O_4 and 51,310 J/mol for NO_2 . CO4 [K₃]
18. Predict the feasibility of reaction from the value of the standard free energy change. CO5 [K₂]
19. Define the term maintenance coefficient. CO6 [K₁]
20. Calculate the degree of reduction for the methane (CH_4) and ethanol ($\text{C}_2\text{H}_5\text{OH}$) CO6 [K₃]

Answer any FIVE Questions:-

PART C (5 x 14 = 70 Marks)

(Answer not more than 300 words)

Q. No. 21 is Compulsory

21. Develop the Maxwell's equation which relates the various thermodynamic properties CO1 [K₄]
22. (i) A spherical balloon of diameter 0.5m contains a gas at 1 bar and 300 k. The gas is heated and the balloon is allowed to expand. The pressure inside the balloon is found to vary linearly with diameter. What would be the work done by the gas when the pressure inside reaches 5 bar? (7) CO1 [K₄]
- (ii) Deduce any two Maxwell equations from fundamental property relations. (7) CO1 [K₃]

23. (i) At 300K and 1bar, the volumetric data for a liquid mixture of benzene and cyclohexane are represented by $V = 109.4 \times 10^{-6} - 16.8 \times 10^{-6}x - 2.64 \times 10^{-6}x^2$, where x is the mole fraction of benzene and V has the units of m^3/mol . Develop expressions for the partial molar volumes of benzene and cyclohexane. (7) CO2 [K₄]
- (ii) Develop the Gibbs Duhem equation in terms of chemical potential and fugacity. (7) CO2 [K₄]
24. The vapor pressures of ideal solutions of acetone (1) and acetonitrile (2) can be evaluated by the two Antoine equations : $\ln p_1^s = (14.5463) - (2940.46/T-35.93)$ and $\ln p_2^s = (14.2724) - (2945.47/T-49.15)$ where T is in K and P is in kPa. Determine: CO4 [K₄]
- x_1 and y_1 at 327 K and 65 kPa
 - T and y_1 at 65 kPa and $x_1 = 0.4$
 - P and y_1 at 327 k and $x_1 = 0.4$
 - T and x_1 at 65 kPa and $y_1 = 0.4$
 - P and x_1 at 327 K and $y_1 = 0.4$
 - The fraction of the system such as liquid and vapor in equilibrium at 327 K 65kPa when the overall composition of the system is 70 mole percent.
25. A mixture of 1 mol CO and 1mol water vapor is undergoing the water-gas shift reaction at a temperature of 1100K, pressure of 1bar where the equilibrium constant for the reaction is 1(assume ideal gas) CO4 [K₄]
- $$\text{CO}_{(g)} + \text{H}_2\text{O}_{(g)} \rightarrow \text{CO}_2_{(g)} + \text{H}_2_{(g)}$$
- Calculate
- The fractional dissociation of steam
 - The fractional dissociation of steam if the reactant stream is diluted with 3 mol nitrogen.
26. (i) Solve the criterion of chemical reaction equilibrium and construct the curve for the Gibbs free energy of the reaction mixture versus extent of reaction. (7) CO5 [K₄]
- (ii) Formulate the relation for the effect of temperature and pressure on equilibrium constant (7) CO5 [K₃]
27. Aerobic growth of *S.cerevisiae* on ethanol is simply described by the following overall reaction: $\text{C}_2\text{H}_5\text{OH} + a\text{O}_2 + b\text{NH}_3 \rightarrow c\text{C}_5\text{H}_7\text{NO}_2 + d\text{H}_2\text{O} + e\text{CO}_2$ CO6 [K₄]
- Determine a, b, c, d and e , where $RQ = 0.66$
 - Determine the biomass yield coefficient, $Y_{X/S}$, and oxygen yield coefficient, $Y_{X/O_2}(\text{gdw/gO}_2)$

1*****