U.S.N.										

B.M.S. College of Engineering, Bengaluru-560019

Autonomous Institute Affiliated to VTU

June 2025 Semester End Main Examinations

Programme: B.E. **Semester: IV**
Branch: Biotechnology **Duration: 3 hrs.**
Course Code: 23BT4ESPET / 22BT4ESPET **Max Marks: 100**
Course: Process Engineering Thermodynamics

Instructions: 1. Answer any FIVE full questions, choosing one full question from each unit.
2. Missing data, if any, may be suitably assumed.

Important Note: Completing your answers, compulsorily draw diagonal cross lines on the remaining blank pages. Revealing of identification, appeal to evaluator will be treated as malpractice.

			CO	*PO*	Marks
		UNIT - I			
1	a)	A spherical balloon of diameter 0.5 m 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 expand. The pressure inside the balloon is found to vary linearly with the diameter. What would be the work done by the gas when the pressure inside reaches 5 bar.	*CO1*	*PO 2*	**10**
	b)	A turbine operating under steady state conditions receives 5000 kg of steam per hour. The steam enters the turbine at a velocity of 3000m/min at an elevation of 5m and specific enthalpy of 2777kJ/kg. It leaves the turbine at a velocity of 600m/min, at an elevation of 1m and specific enthalpy of 2252kJ/kg. Heat losses for the turbine to surroundings amounts to 16680kJ/hr. Determine the HP output of the turbine	*CO1*	*PO2*	**10**
		OR			
2	a)	Derive an expression for efficiency of carnot engine.	*CO1*	*PO2*	**10**
	b)	A reversible engine operates between two reservoirs at temperatures of 600°C and 40°C. The engine drives a refrigerator which operates between reservoirs at temperatures of 40°C and –20°C. The heat transfer to the engine is 2000 kJ and the network output of the plant if 360 kJ. (i) Evaluate the heat transfer to the refrigerator and the net heat transfer at 40°C. (ii) Reconsider (i) given that efficiency of the heat engine and COP of the refrigerator are each 40% of the maximum values	*CO1*	*PO2*	**10**
		UNIT - II			
3	a)	One mole of a gas which obeys the relation PV = RT, where R = 8.314 J/molK is initially at 300 k and 0.1 MPa. The gas is heated at constant volume till the pressure rises to 0.5 MPa and then allowed to expand at constant temperature till the pressure reduces to 0.1 MPa. Finally the gas is returned to its original state by	*CO2*	*PO2*	**10**

			compressing at constant pressure. Calculate the work done by the gas in each of the processes and also estimate the net work done by the gas.			
		b)	1kgmole of methane is compressed at constant temperature of 25°C, from 1.02 bar to 102 bar. Compute the work in a closed system required in Nm required if the gas obeys Ideal gas law and if it obeys Vanderwaals equation Data: $v_1 at\ 1\ atm = 11.1 \frac{m^3}{kgmol}$, $v_2 at\ 100\ atm = 0.089 \frac{m^3}{kg\ mol}$ $a = 2.28\ atm \left(\frac{m^3}{kgmol}\right)^2$ $b = 0.0428 \frac{m^3}{kgmol}$	*CO2*	*PO2*	**10**
			OR			
	4	a)	An ideal gas is one for which $\frac{pv}{T}$ is a constant regardless of the changes it undergoes. Such a gas has a volume of 0.02271 m^3/mol at 0^0C and 1 bar. In the following problem air may be considered an ideal gas with the constant heat capacities $C_V = 5/2$ R, $C_P = 7/2$ R where R = 8.314 J/molK. The initial conditions of the air are 1 bar and 25°C. It is compressed to 5 bar and 25^0C by two different mechanically reversible processes. Calculate the heat and work requirements and $\Delta U, \Delta H$ of the air for each path that has cooling at constant pressure followed by heating at constant volume	*CO2*	*PO2*	**10**
		b)	It is desired to compress isothermally 1 kmole of butane at 300K from initial volume of $0.5 \frac{m^3}{mol}$ to final volume of $0.1 \frac{m^3}{mol}$. Determine the amount of work to be done on the gas and the amount of energy to be removed as heat from the gas. Assume butane behaves as Vaderwaals gas. $Given, dU = C_v dT + \frac{a}{v^2} dv, \quad T_C = 425.2\ K, \quad P_C = 37.97\ bar$	*CO2*	*PO2*	**10**
			UNIT - III			
	5	a)	Prove the relation $TdS = \frac{k}{\beta} C_v dP + \frac{C_P}{v\beta} dv$, Where $\beta = \frac{1}{v}\left(\frac{\partial v}{\partial T}\right)_P$ & $k = -\frac{1}{v}\left(\frac{\partial v}{\partial P}\right)_T$	*CO3*	*PO2*	**10**
		b)	Explain the different methods to find fugacity coefficient.	*CO3*	*PO1*	**10**
			OR			
	6	a)	Derive Gibbs Duhem equation.	*CO3*	*PO2*	**10**
		b)	The need arises in a laboratory for 2000 cm^3 of an anti freeze solution consisting of 30 mol% methanol in water. What volumes of pure methanol and of pure water at 298.15K must be mixed to form 2000cm^3 of anti freeze, at 298.15K ? Partial molar volumes of methanol and water in a 30 mol% methanol solution and their pure species molar volumes, both at 298.15 K are (1) Methanol $\bar{V_1} = 38.632$ cm^3/mol, $V_1 = 40.727 \frac{cm^3}{mol}$ (2) Water $\bar{V_2} = 17.765$ cm^3/mol, $V_2 = 18.068 \frac{cm^3}{mol}$	*CO3*	*PO2*	**10**

UNIT - IV

7 a) With a neat sketch explain P-x-y and T-x-y diagram. *CO3* *PO2* **10**

b) Construct P-x-y diagram for cyclohexane (1) / benzene (2) system at 40°C. Use the following expression for the liquid phase activity coefficient. $ln\gamma_1 = 0.458x_2^2$ $ln\gamma_2 = 0.1458x_1^2$. At 40°C $p_1^s = 0.243\ atm, p_2^s = 0.240\ atm$ *CO3* *PO2* **10**

OR

8 a) Chloroform A $(CHCl_3)$ and Acetone B (CH_3CO_3) forms an azeotrope at 64.5°C with $64.5\%\ A\ (weight)$ at $1\ atm$ pressure. Find the vapor composition in equilibrium with liquid containing $40\%\ A\ (weight)$ at $64.5°C\ and\ 1\ atm.$ Vapor pressure of chloroform and acetone at $64.5°C\ and\ 860\ mm\ Hg\ and\ 1000\ mm\ Hg.$

$$Mol\ Wt\ of\ Cl = 35.5, C = 12, \quad O = 16, \quad H = 1$$

CO3 *PO2* **10**

b) Verify whether the following data are thermodynamically consistent or not *CO3* *PO2* **10**

Mole fraction of component x_i	γ_1	γ_2
0.0	0.576	1.000
0.2	0.655	0.986
0.4	0.748	0.930
0.6	0.856	0.814
0.8	0.950	0.626
1.0	1.000	0.379

UNIT - V

9 a) The following equilibrium data have been reported for the vapor phase hydration of ethaline. *CO3* *PO2* **10**

$$C_2H_4 + H_2O \rightarrow C_2H_5OH$$

T°C	K
145	6.8×10^{-2}
320	1.9×10^{-2}

Heat capacity data $C_p = a + bT$

Components	a	b$\times 10^3$
C_2H_4	2.83	28.60
H_2O	7.30	2.46
C_2H_5OH	6.99	39.74

Develop the general expression for the equilibrium as function of temperature T in K $C_p\ in\ {}^{cal}/_{g.mol.K}$

b) The standard heat of formation and standard free energy formation of Ammonia is given as – *CO3* *PO2* **10**

$$\Delta G^{\circ}_{298K}\ NH_3 = -16500\ J/gmol$$
$$\Delta H^{\circ}_{298}\ for\ NH_3 = -46100\ J/gmol$$
$$N_2 + 3H_2 \rightarrow 2NH_3$$

Calculate K at 460 K assuming that standard heat of reaction is constant in the range 205 K to 500 K

			OR			
	10	a)	Benzene is introduced in the liquid phase to nitric acid to produce nitrobenzene. What is the maximum conversion of benzene at25℃ and 1 atm, If the stoichiometric amounts of reactants are taken in the reactor? At this existing condition the following data are available.	*CO3*	*PO2*	**10**
		b)	Explain heat generation in aerobic cultures with example.	*CO4*	*PO2*	**10**

Components	$\Delta H_f^o \frac{kCal}{kg\ mol}$	$\Delta S_f^o \frac{kCal}{kg\ mol}$
C_2H_6	11718	41.30
HNO_3	41404	37.19
H_2O	68371	16.72
$C_6H_5NO_2$	38000	53.60

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