Q/K/TY

VIT

Vellore Institute of Technology

Final Assessment Test – November 2025

Course: BACHE101 - Chemical Engineering Thermodynamics

Class NBR(s): 7117 / 7121 Slot: A1+TA1+TAA1

Time: Three Hours Max. Marks: 100

- KEEPING MOBILE PHONE/ANY ELECTRONIC GADGETS, EVEN IN 'OFF' POSITION IS TREATED AS EXAM MALPRACTICE
- DON'T WRITE ANYTHING ON THE QUESTION PAPER

General Instruction: Data sheet are allowed

COs	CO Statements
CO1	Define and illustrate thermodynamic equilibrium state and equations of state
CO2	Relate properties such as change in enthalpy, entropy, free energy, heat and work requirements for batch and flow processes occurring in chemical industries
CO3	Construct and analyse phase equilibrium data, P-x-y, T-x-y diagrams for ideal, binary, miscible vapour-liquid systems
CO4	Device methodologies for qualitative and quantitative analysis of VLE data for non-ideal, binary, miscible systems using van Laar, Margules, and property estimation models
CO5	Analyse the feasibility of a chemical reaction and determine the equilibrium rate constant for chemical reactions

BL – Blooms Taxonomy Level (1 – Remember, 2 – Understand, 3 – Apply, 4 – Analyse, 5 – Evaluate, 6 – Create)

Answer ALL Questions

(10 X 10 = 100 Marks)

1. (i) Calculate the number of degrees of freedom variables when a binary liquid mixture is in equilibrium with its vapour? [2] CO1 BL2

   (ii) Define extensive and intensive properties Identify the following properties are intensive or extensive properties: (a) volume, (b) density, (c) specific volume, (d) heat capacity, (e) specific heat, (f) potential energy, (g) pressure, (h) temperature [5]

   (iii) Distinguish between state function and path function with examples. A cyclic process may be defined as the one in which, after a series of changes, the system is brought back to its initial conditions. What would be the change in a state function in a cyclic process? [3]

2. Determine the mass of N_2 contained in a 30 m^3 vessel at 20 MPa and 200 K by using (a) the ideal gas equation (b) the generalized compressibility chart CO1 BL3

3. a) Derive an expression for fugacity co-efficient for a gas that follows PV=RT-aP, where "a" is a constant CO2 BL3

   b) Estimate the fugacity of ammonia at 12 bar and 298 K, a = 3.707 x 10^{-5} m^3/mol

4. The partial pressure of Acetone (A) and Chloroform (B) were measured at 298 K and reported as below: CO2 BL3

X_B	X_A	P_A, bar	P_B, bar
0	1	0.457	0
0.2	0.8	0.355	0.046
0.4	0.6	0.243	0.108
0.6	0.4	0.134	0.187
0.8	0.2	0.049	0.288
1	0	0	0.386

Estimate the activity and activity coefficient of chloroform in acetone at 298 K for $X_A = 0.2$ and 0.6.

(a) Based on the standard state as per Lewis-Randall rule

(b) Based on Henry's Law.

5. a) Discuss the azeotrope formation, types of azeotropes with appropriate phase diagrams and suggest some separation processes for azeotropic mixture separations. [8] CO3 BL2

b) Discuss the selection criterion of thermodynamic models for any component system. [2]

6. Mixtures of n-Heptane (A) and n-Octane (B) are expected to behave ideally. The total pressure over the system is 101.3 kPa. Using the vapour pressure data given below, construct the (a) T-x-y diagram and (b) equilibrium diagram CO3 BL3

T, K	371.4	378	383	388	393	398.6
P_A^S, kPa	101.3	125.3	140	160	179.9	205.3
P_B^S, kPa	44.4	55.6	64.5	74.8	86.6	101.3

7. The standard free energy change for the reaction CO5 BL3

$$C_4H_8(g) \rightarrow C_4H_6(g) + H_2(g)$$

is given by

$$\Delta G_T^0 = 1.03665 \times 10^5 - 20.9759T \ln T - 12.9372T$$

Where ΔG_T° is in J / mol and T is in K.

a) Over what range of T, is the reaction promising from thermodynamic view point? [2]

b) A reaction of pure butene at 800K, calculate equilibrium conversion at 1.0 bar & 5.0 bar. [4]

c) Repeat part (b) for the feed with the 50 mol% butene and the rest inert [4]

8. Molar values of ΔH and ΔS for the reaction of dissolving of NH_4Cl in water at standard conditions (P=1 bar, T=298 K) are 34.7 kJ/mol and 0.167 kJ/(k·mol), respectively. CO5 BL3

(i) Does the reaction proceed spontaneously under these conditions? [6]

(ii) How does the entropy of the environment and the universe change in this reversible process? [4]

9.a) The azeotrope of the *n*-propanol–water system has 56.9% (mol) water with a boiling point of 362 K at a pressure of 101.3 kPa. At this temperature, the vapour pressures of water and propanol are respectively 64.15 kPa and 69.61 kPa. Evaluate the activity coefficients for a solution containing 30% water through the van Laar equation. CO4 BL3

OR

9.b) Estimate the dew point temperature and liquid composition for an Acetone (1) and Water (2) liquid mixture with y_1=0.01 at a total pressure of 101.3 kPa by considering the non-ideal system behaviour. Use the Wilson model with the parameters Λ_{12}=0.1173; and Λ_{21}=0.4227 CO4 BL3

Antoine equations data:

Vapour pressure (p_1^s, p_2^s) in kPa, Temperature in K

$$\ln p_1^s = 14.717 - \frac{2975.95}{T-34.52}$$

$$\ln p_2^s = 16.536 - \frac{3985.44}{T-38.99}$$

10.a) A hydrocarbon mixture contains 25% (mol) propane, 40% (mol) n-butane and 35% (mol) n-pentane at 1447.14 kPa. Assume ideal solution behaviour and calculate the temperature and the composition of the liquid and vapour in equilibrium when 45% (mol) of the initial mixture is vaporised CO3 BL3

Component	K_i at =355.4 K	K_i at =376.6 K	K_i at =388.8 K
Propane	2.0	2.6	2.9
n-Butane	0.78	1.1	1.3
n-Pentane	0.330	0.5	0.61

OR

10.b) Assuming Raoult's law to be valid for the system benzene 1)–ethyl benzene 2) and the vapour pressures are given by the Antoine equations CO3 BL3

$$\ln p_1^s = 13.8858 - \frac{2788.51}{T-52.41}$$

$$\ln p_2^s = 14.0045 - \frac{3279.47}{T-60.00}$$

Where, P is in kPa and T is in K.

1) Construct the P-X-Y diagram at 375 K [7]

2) What is the composition of liquid and vapour at 100 kPa from the P-x-y plot [3]

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