Reg. No. | | | | | | | | | | | | | | |

B.E / B.TECH. CHEMICAL ENGINEERING, MAY 2023

Fifth Semester

CH18503 – CHEMICAL ENGINEERING THERMODYNAMICS-II

(Chemical Engineering)

(Regulation 2018 / Regulation 2018A)

TIME: 3 HOURS **MAX. MARKS: 100**

CO 1	Identify the property of solutions upon mixing and also about the excess property
CO 2	Explore and generate the phase diagram data and also about the effect of temperature and pressure on azeotropic conditions
CO 3	Impart knowledge on various models used to evaluate the equilibrium data and also to test the thermodynamic consistency
CO 4	Identify and calculate the equilibrium constant for various systems and analysis of simultaneous reactions
CO 5	Apply principles of refrigeration and its application

PART- A (10 x 2 = 20 Marks)

(Answer all Questions)

		CO	RBT LEVEL
1.	State the importance of Gibbs-Duhem's equation.	1	2
2.	Highlight the various methods available for determining Partial Molar Properties.	1	2
3.	Distinguish between minimum boiling and maximum boiling azeotropes.	2	2
4.	Cite Raoults law and its applicability.	2	2
5.	Which is the most reliable method for testing the consistency of experimental VLE data?	3	2
6.	Enumerate the difference between Activity Composition models and Local composition models.	3	2
7.	Mention the effect of temperature on Reaction Equilibrium constant?	4	2
8.	Interpret the term "feasibility of a reaction"	4	2
9.	Infer the efficiency of actual refrigeration cycles is less than Carnot's cycle?	5	2
10.	Mention any two comparisons between Joule – Thomson and Isentropic cooling.	5	2

PART- B (5 x 14 = 70 Marks)

		Marks	CO	RBT LEVEL
11(a)	Derive the Gibbs Duhem equation relating the Molar and Partial Molar property and write down the significances.	(14)	1	2

(OR)

			Marks	CO	RBT LEVEL
(b)	**(i)**	Show that when Henry's law is applicable for component 1 in a binary solution over certain concentration range, Lewis- Randall rule is applicable for component 2 over the same concentration range.	(7)	1	2
	(ii)	At 300K and 1 bar the volumetric data for a liquid mixture of benzene and cyclohexane are represented by $V = 101.4 \times 10^{-6} - 15.8 \times 10^{-6} X - 2.64 \times 10^{-6} X^2$ where X is the mole fraction of the benzene and V has the units of m^3/mol. Find the expressions for the partial molar volumes of benzene and cyclohexane.	(7)	1	2

		Marks	CO	RBT LEVEL
12.(a)	Distinguish between minimum boiling and maximum boiling azeotropes with the help of phase diagrams.	(14)	2	2
	(OR)			
(b)	Compare the equilibrium diagram on ternary co-ordinates for type I and type II systems	(14)	2	2
13. (a)	A mixture contains 45% (mol) methanol (A), 30% (mol) ethanol (B) and the rest n-propanol (C). Liquid solution may be assumed to be an ideal and perfect gas law is valid for the vapour phase. Calculate at a total pressure of 101.3 kPa.	(14)	3	3

a. The bubble point and the vapour composition

b. The dew point and the liquid composition.

The vapour pressures of the pure liquids are given below

Temperature, K	333	343	353	363
P_A, kPa	81.97	133.29	186.61	266.58
P_B, kPa	49.32	73.31	106.63	166.61
P_C, kPa	39.32	62.65	93.30	133.29

(OR)

(b) For the given data check whether the system is consistent or not? **(14)** 3 3

X_1	0	0.2	0.4	0.6	0.8	1.0
γ_1	0.576	0.655	0.748	0.856	0.95	1.0
γ_2	1.0	0.985	0.930	0.814	0.626	0.379

14. (a) In the synthesis of ammonia, stoichiometric amounts of nitrogen and hydrogen are sent to a reactor where the following reaction occurs **(14)** 4 4

$N_2 + 3H_2 \rightleftharpoons 2NH_3$

The equilibrium constant for the reaction at 675 K may be taken as 2×10^{-4}.

(a) Determine the per cent conversion of nitrogen to ammonia at 675 K and 20 bar.

(b) What would be the conversion at 675 K and 200 bar?

(OR)

(b) (i) A gas mixture containing 4 mol CO_2, 6 mol H_2 and 3 mol water is undergoing the following reactions **(7)** 4 4

$CO_2+3H_2 \longrightarrow CH_3OH+H2O$

$CO_2+3H_2 \longrightarrow CO+H_2O$

Develop expressions for the mole fraction of the species in terms of the extent of reaction.

(ii) The standard heat of formation and standard free energy of formation of ammonia at 298 K are -46,100 J/mol and -16,500 J/mol respectively. Analyze the equilibrium constant for the reaction **(7)** 4 4

$N_2(g) + 3H_2(g) \longrightarrow 2NH_3(g)$

at 500 K. Assuming that the standard heat of reaction is constant in the temperature range 298 to 500 K.

15. (a) Differentiate Linde and Claude process for air liquefaction with neat sketches. **(14)** 5 2

(OR)

(b) Vapor compression refrigeration system rated at 5 tons is employed in a chemical manufacturing plant to maintain the temperature of evaporator and condenser at – 10°C and 35°C respectively. The isentropic efficiency of compressor is 85%. **(14)** 5 2

Enthalpy of saturated liquid at 35°C is 69.5 K KJ/Kg. The enthalpy of super heated vapor is 208.3 KJ/Kg.

Determine

(i) Mass flow rate of the refrigerant

(ii) Power consumption of the compressor

(iii) Amount of heat rejected in the compressor

Difference in COP between vapor-compression and Carnot cycle.

PART- C (1 x 10 = 10 Marks)

(Q.No.16 is compulsory)

Marks CO RBT LEVEL

16. Methanol is produced by the following reaction **(10)** 4 4

$CO(g) + 2H_2(g) \longrightarrow CH_3OH(g)$

The standard heat of formation of CO(g) and CH_3OH (g) at 298 K are (-110,500) J/mol and (-200,700) J/mol respectively. The standard free energies of formation are (-137,200) J/mol and 162,000 J/mol respectively.

i) Calculate the standard free energy change and determine whether the reaction is feasible at 298K.

ii) Determine the equilibrium constant at 400K assuming that the heat of reaction is constant.

iii) Derive an expression for standard free energy of reaction as function of temperature if the specific heats of the components are:

$Cp : 3.376\,R + 0.557 * 10^{-3}\,RT - 0.031 * 10^{5}\,RT^{-2}$ for CO

$Cp : 3.249\,R + 0.422 * 10^{-3}\,RT + 0.083 * 10^{5}\,RT^{-2}$ for H_2

$Cp : 2.211\,R + 12.216 * 10^{-3}\,RT - 3.450 * 10^{-6}\,RT^{2}$ for CH_3OH

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