मोतीलाल नेहरू राष्ट्रीय प्रौद्योगिकी संस्थान इलाहाबाद
प्रयागराज-211004 [भारत]

Motilal Nehru National Institute of Technology Allahabad
Prayagraj-211004 [India]

Department of Chemical Engineering
Mid Semester (Odd) Examination 2023-24

Programme Name: B.Tech | **Semester:** III[rd]

Course Code: CHN-13103 | **Course Name:** Chemical Engineering Thermodynamics

Branch: Chemical Engineering | **Student Reg. No.:** 2 0 2 2 2 0 6 8

Duration: 90 Minutes | **Max. Marks:** 25

Instructions: (Related to Questions)

1. *Figures to the right indicate the full marks.*
2. *All questions are compulsory. Be precise in your answers*

			Marks	CO
Q 1	**a**	What are the limitations of first law of thermodynamics? Is enthalpy a true energy? Is it conserved? If not, why?	**(4)**	CO.1
	b	State the difference between extensive and intensive properties. Molar enthalpy and partial molar property are intensive/extensive?	**(3)**	CO.1
	c	Define Gibbs Phase Rule for reacting and non-reacting systems. What is the degree of freedom for a system containing liquid water and liquid benzene in equilibrium with their vapors?	**(3)**	CO.1
Q 2	**a**	For a given reaction we have $\Delta H > 0$ and $\Delta S < 0$. When will the reaction will be spontaneous? (a) Never (b) when $T > \Delta H/\Delta S$ (c) always (d) when $T < \Delta H/\Delta S$	**(1)**	CO.2
	b	The statement $dA \leq 0$ means: (a) The condition for equilibrium is $dA = 0$ (b) Processes are not spontaneous if $dA \leq 0$ (c) dA cannot be greater than 0 (d) all of the above	**(1)**	CO.2
	c	Starting from first and second law of thermodynamics, derive Maxwell equation. Clearly mention the assumptions.	**(5)**	CO.2
Q 3	**a**	What is the definition of "partial molar property"? Try saying it in words rather than equation.	**(3)**	CO.3

Q 4 b The enthalpy of a binary liquid system of species 1 and 2 at fixed T & P is represented by the following equation: **(5)** CO.3

$$H = 400x_1 + 600x_2 + x_1x_2(40x_1 + 20x_2)$$

Where, H is in J/mol. Determine expression for $\overline{H_1}$ and $\overline{H_2}$ as functions of x_1, numerical values for the pure species enthalpies H_1 and H_2, numerical values for the partial enthalpies at infinite dilution $\overline{H_1}^{\infty}$ and $\overline{H_2}^{\infty}$.

COURSE OUTCOMES:

On successful completion of this course, the abilities of the students will be:

CO. No.	COURSE OUTCOMES (COs)
1	Ability to apply fundamental laws of thermodynamics to various processes, learning thermodynamic aspects of refrigeration and liquefaction processes
2	Ability to correlate the property changes for real fluids in terms of easily measurable macroscopic properties
3	Ability to apply the fundamentals of solution thermodynamics to gas-liquid mixtures and to correlate phase equilibrium of binary/multi component systems using various models
4	Ability to calculate the equilibrium conversion and compositions for single and multi-reaction schemes in different types of fluid mixtures

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End Semester Examination 2023-24 (29.5)

Programme Name: B.Tech **Semester:** III[rd]

Course Code: CHN-13103 **Course Name:** Chemical Engineering Thermodynamics

Branch: Chemical Engineering **Student Reg. No.:** 2022220688

Duration: 2.5 hours **Max. Marks:** 50

Instructions: *All questions are compulsory. Assume any missing data.*

			Marks	CO
Q 1	a	State third law of thermodynamics? What is the significance of absolute zero? Is it possible to achieve zero kelvin temperature in laboratory? If not, what is the value of lowest possible temperature in kelvin that can be achieved practically?	(4)	
	b	Determine the degree of freedom at a quadruple point for a given hypothetical one-component system.	(2)	CO.1
	c	Draw neat diagram of a vapor compression refrigeration cycle. Explain the working details and basic principles involved. Plot each cycle on a T-S diagram.	(4)	
Q 2	a	Calculate the volume occupied by 1 mol of CH_4 gas at 500°C and 15 atm using the following Virial equation of state $Z = 1 + \frac{PB}{RT}$, where, $B = \frac{RT_c}{P_c}\left(B^0 + \omega B^1\right)$ Given that: $B^0 = 0.038089$; $B^1 = 0.138520$ $T_c = 190.6$ K; $P_c = 45.99$ bar; Accentric factor, $\omega = 0.012$	(4)	CO.
	b	What is the definition of "Chemical Potential"? Write it in terms of four free energies. Show that the multiple phases at the same temperature and pressure are in equilibrium when the chemical potential of each species is the same in all the phases.	(6)	
Q 3	a	Define Gibb's theorem for ideal mixtures. Determine the enthalpy and entropy change of mixing for the same.	(5)	CO

b Calculate the fugacity of pure gas at 500 K and 30 bar. (a) Calculate the fugacity of pure liquid which is in equilibrium with the gas at 500 K and 30 bar. (b) Also, calculate the liquid fugacity at 500 K and 60 bar. (5)

Given that:
Molar liquid volume, V^L = 25 cm^3/mol
Compressibility factor of gas between 0 and 30 bar is : Z = 1 – (0.01)P
R = 83.1447 cm^3 bar/mol K

Q 4 a Differentiate between residual and excess properties. Why the concept of residual properties for real gases cannot be extended for real liquids? (5)

b In a binary mixture, the activity coefficient of component (1), in the entire range of composition, is given by $R \ln \gamma_1 = Ax_2^2 + Bx_1^2$. Where R, A and B are constants. Derive expression for the activity coefficient of component (2). (5) CO.

Q 5 a Develop the expression to relate the standard Gibbs free energy change with equilibrium constant and then deduce it for liquid phase reactions. (5)

b The reaction $N_2 + O_2 \rightleftharpoons 2NO$ takes place in the gas phase at 2975 K and 2025 kPa. The reaction mixture initially comprises 15 mol % O_2, 77 mol % N_2 and the rest inerts. The standard Gibbs free energy change for the reaction is 113.83 kJ/mol at this temperature. Assuming ideal gas behaviour, calculate the partial pressures of all species at equilibrium. How is the conversion of oxygen affected when the initial mixture was free of inerts? (5) CO.

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End