

KATHMANDU UNIVERSITY
End Semester Examination
January/February 2024

Marks Scored:

Level : B.E.

Year : II

Exam Roll No. :

01 FEB 2024

Time: 30 mins.

Course : CHEG 211

Semester : II

F. M. : 10

Registration No.:

Date :

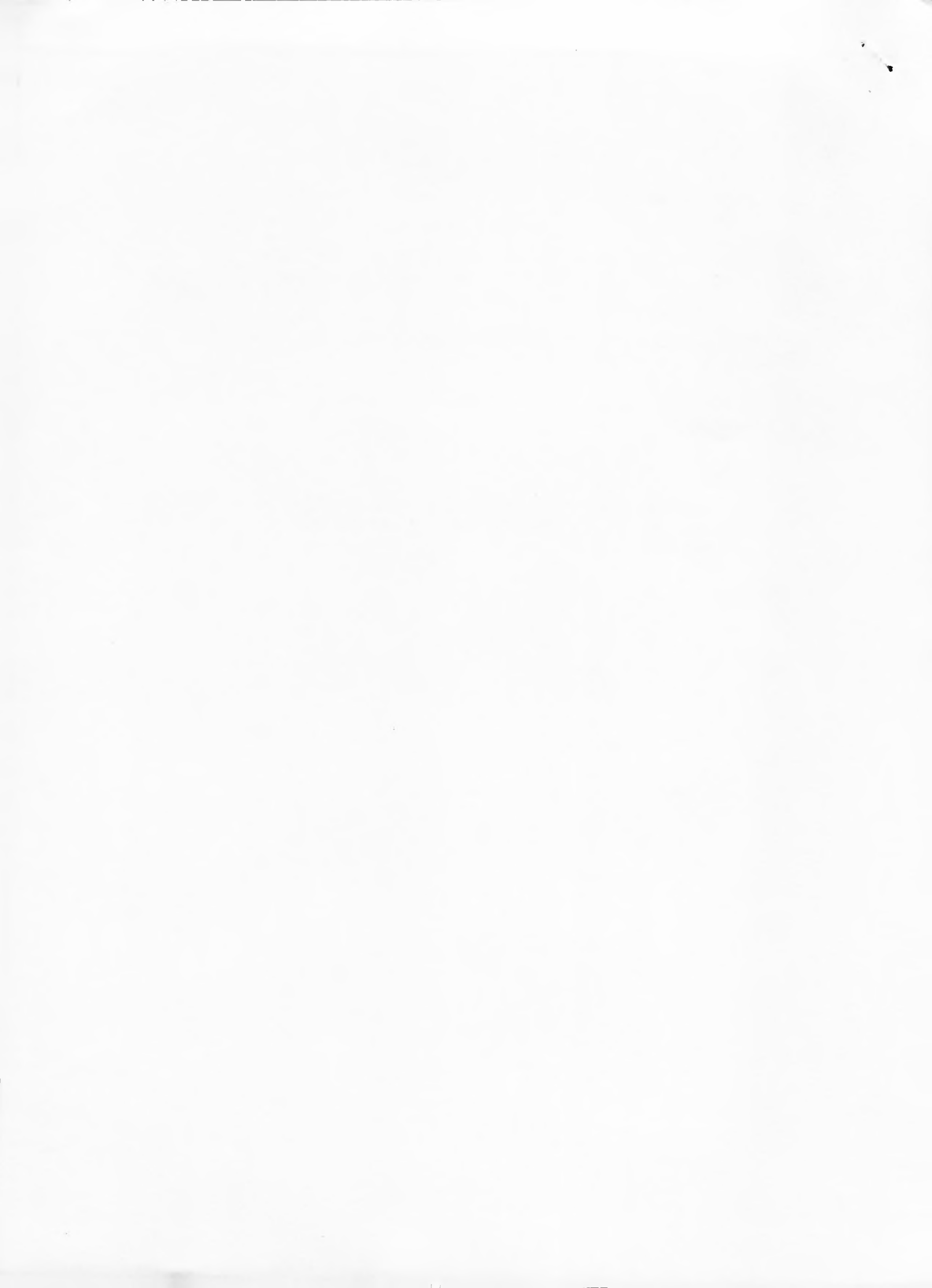
SECTION "A"

[20Q. \times 0.5 = 10 marks]

Choose and encircle the most appropriate option from each set of choices.

1. A system undergoes a process where 150 kJ of heat is added and 100 kJ of work is done on the system. What is the change in internal energy?
a. 0 kJ b. 50 kJ c. 250 kJ d. -250 kJ
2. For a steady-flow process involving a control volume, the rate of change of total energy within the control volume is equal to:
a. the net rate of energy transfer into the control volume
b. the net rate of energy transfer out of the control volume
c. the sum of energy transfers into and out of the control volume
d. zero
3. The efficiency of an ideal Rankine cycle is closest to:
a. 100% b. 80% c. 60% d. 50%
4. The Clausius statement of the Second Law of Thermodynamics refers to:
a. Heat cannot spontaneously flow from a colder body to a hotter body
b. No cyclic process can have a higher efficiency than a reversible process operating between the same temperature limits
c. Energy cannot be created nor destroyed
d. Entropy of an isolated system always increases
5. Which process is reversible according to the Second Law of Thermodynamics?
a. Friction between surfaces
b. Heat transfer from a hot object to a cold object
c. Adiabatic expansion of an ideal gas
d. Irreversible expansion of a gas against a constant external pressure
6. Which statement regarding entropy is **CORRECT**?
a. Entropy of a perfect crystal at absolute zero is zero
b. Entropy is not a state function
c. Entropy decreases in an irreversible process
d. Entropy change is independent of temperature

7. The change in Gibbs free energy for a spontaneous process at constant temperature and pressure is:
a. Positive b. Negative c. Zero d. Indeterminate
8. The equilibrium constant for a chemical reaction:
a. Depends on temperature only
b. Is affected by the initial concentration of reactants
c. Is constant at all temperatures
d. Is independent of pressure
9. The critical point on a phase diagram represents the conditions where
a. Solid and liquid phases coexist b. Liquid and gas phases coexist
c. Gas and vapor phases coexist d. All phases coexist
10. The activity coefficient of a component in a solution is:
a. Always greater than 1 for ideal solutions
b. Independent of composition and temperature
c. Always lower than 1 for non-ideal solutions
d. The ratio of the component's fugacity to its mole fraction
11. Azeotropes are best defined as:
a. Mixtures with constant boiling points at a given pressure
b. Mixtures that follow Raoult's Law accurately
c. Solutions with infinitely high boiling points
d. Mixtures that show no vapor-liquid equilibrium
12. The Gibbs-Duhem equation describes:
a. The change in Gibbs free energy during a phase transition
b. The behavior of non-ideal solutions at infinite dilution
c. The relationship between changes in chemical potential, pressure, and temperature in a system at equilibrium
d. The relationship between the composition of a mixture and its phase equilibrium conditions
13. For any closed system formed with known amounts of prescribed chemical species, equilibrium state is completely determined when any _____ independent variables are fixed.
a. 0 b. 1 c. 2 d. 3
14. The pure component thermodynamic properties _____ and _____ are equal to their partial properties in an ideal solution.
a. Volume & enthalpy b. Gibbs free energy and entropy
c. Entropy and enthalpy d. Volume and entropy
15. In the context of vapor-liquid equilibrium, the slope of the equilibrium curve on a P-x-y diagram represents the ratio of:
a. Mole fractions in the liquid phase to mole fractions in the vapor phase
b. Partial pressures of components in the liquid phase to the vapor phase
c. Vapor pressures to liquid densities
d. Enthalpies of vaporization to enthalpies of fusion



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Time : 2 hrs 30 mins

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SECTION "B"

Attempt *ALL* questions

1. A rigid vessel of 0.5 m^3 volume contains an ideal gas ($C_v = 2.5R$) at 500 K and 1 bar.
 - a. Determine the temperature change of the gas if 15 kJ of heat is extracted from the gas. [2]
 - b. Determine the entropy change of the gas if 15 kJ of heat is extracted from the gas. [2]
 - c. Determine ΔS^{total} if 15 kJ of work is done on the gas by fitting a stirrer that is rotated by a shaft. Consider this process to be adiabatic. [2]

2. Steam entering a turbine at 2000 kPa at 650°C expands reversibly and adiabatically.
 - a. What is the quality of the wet vapor at the exit stream if the discharge pressure is 200 kPa? [4]
 - b. Calculate the shaft work done by the turbine. [2]

3. For an equimolar vapor mixture of propane (1) and n-pentane (2) at 75°C and 2 bar, estimate V , H^R and S^R . Second virial coefficients, in $\text{cm}^3\text{mol}^{-1}$ are: [6]

$T/^\circ\text{C}$	B_{11}	B_{22}	B_{12}
50	-331	-980	-558
75	-276	-809	-466
100	-235	-684	-399

4. Suppose the activity coefficients of ethanol (1)/chlorobenzene (2) at 80°C is given by

$$\ln \gamma_1 = 2.2x_2^2$$

$$\ln \gamma_2 = 2.2x_1^2$$
 Is it possible to have an azeotrope of the mixture at 80°C ? If so, what is the pressure of the azeotrope and the composition of the vapor phase at the azeotrope? [5]

Given, $\log_{10} P_1^{\text{sat}} = 7.2371 - \frac{1592.864}{T(^{\circ}\text{C}) + 226.184}$

$$\log_{10} P_2^{\text{sat}} = 6.0796 - \frac{1419.045}{T(^{\circ}\text{C}) + 216.633}$$

Saturation pressure is in kPa.

5. The excess Gibbs energy for liquid argon (1)/ methane (2) mixtures have been measured at several temperatures. The results are:

$$\frac{G^E}{RT} = x_1 x_2 \{A - B(1 - 2x_1)\}$$

where A and B are independent of concentration but dependent on temperature. For the temperature range 109 K and 116 K, A and B have been fit to experimental data and show the following dependency on temperature:

$$A(T) = -3.45 \times 10^{-3}T + 0.68$$

$$B(T) = 1.00 \times 10^{-2}T - 1.12$$

- Derive the expressions for the activity coefficients for argon and methane. [4]
 - Calculate γ_1 and γ_2 at 110 K and $x_1 = 0.3$. [2]
 - Calculate γ_1^∞ and γ_2^∞ at 110 K. [2]
 - If $\frac{\Delta G^E}{RT} = \frac{\Delta H^E}{RT} + T\Delta S^E$, how can you calculate the molar enthalpy and entropy change on producing $x_1 = 0.3$ mixture from its pure components at 112 K. Write the steps only, no calculation needed. [2]
6. The production of 1,3 butadiene can be carried out by dehydrogenation of n-butane as shown in the reaction below:



Suppose side reactions are suppressed by introduction of steam. If equilibrium is attained at 498 K and 1 bar and the reactor contains 12 mol% of 1, 3 butadiene at equilibrium, calculate

- Mole fractions of other species in the reactor at equilibrium. [5]
- Mole fraction of steam required in the feed [2]

Assume ΔH_{rxn} is independent of temperature change for the given temperature.