Name : .....

Roll No. : .....

Invigilator's Signature : .....

CS/B.TECH/CHE/NEW/SEM-6/CHE-602/2013

2013

CHEMICAL ENGINEERING THERMODYNAMICS

Time Allotted : 3 Hours *Full Marks* : 70

The figures in the margin indicate full marks.

Candidates are required to give their answers in their own words as far as practicable.

GROUP – A
(Multiple Choice Type Questions)

1. Choose the correct alternatives for any *ten* of the following :

$10 \times 1 = 10$

i) Thermal efficiency of a heat engine is the ratio of

a) the total heat input to the net work output

b) the net work output to the total heat input

c) the net work input to the total heat output

d) none of these.

ii) For an ideal gas, the compressibility factor at all temperatures and pressures is

a) 1 b) 0

c) –1 d) ∞ .

iii) A liquid at a temperature below its saturation temperature is called a

a) sub-cooled liquid b) compressed liquid

c) superheated liquid d) both (a) and (b).

iv) A gas shows deviation from ideal gas behaviour at

a) low pressure and high temperature

b) low pressure and low temperature

c) low temperature and high pressure

d) high temperature and high pressure.

v) Fugacity coefficient of a substance is the ratio of its fugacity to

a) mole fraction b) activity

c) pressure d) activity coefficient.

vi) For the reversible isothermal change of an ideal gas undergoing a process, the change in entropy is given by

a) $(\Delta S)_T = R\,ln\,(V_1 / V_2)$ b) $(\Delta S)_T = R\,ln\,(P_1 / P_2)$

c) $(\Delta S)_T = R\,ln\,(P_2 / P_1)$ d) none of these.

vii) The excess volume of liquid benzene at 35°C and 1 atm is

a) 0 b) 1

c) always positive d) always negative.

viii) For an ideal solution comprising two components A and B, the activity coefficient of A (γ_A) is

a) 0 b) 1

c) always positive d) always negative.

ix) The K factor of a species in ideal solution is the ratio of

a) partial pressure of the component to its vapour pressure

b) partial pressure of the component to the total pressure of the solution

c) vapour pressure of the component to the total pressure of the solution

d) none of these.

x) Solution in which intermolecular forces between like molecules are greater than those between unlike molecules

a) is an ideal solution

b) shows negative deviation from ideality

c) shows positive deviation from ideality

d) none of these.

xi) The enthalpy of a binary liquid system at a fixed T and P is represented by the equation $H = 600 - 180x_1 - 20x_1^3$ J/mol. The partial molar enthalpy of the component 1 is given by

a) $420 - 60x_1^2 - +40x_1^3$ b) $420 + 60x_1^2 - -40x_1^3$

c) $40 - 60x_1^2 - +420x_1^3$ d) $60 - 40x_1^2 - +20x_1^3$.

xii) For the reaction $A + B = R + S$, the equilibrium constant is

a) independent of total pressure of the system

b) directly proportional to the total pressure

c) inversely proportional to the total pressure

d) none of these.

GROUP – B
(Short Answer Type Questions)

Answer any *three* of the following $3 \times 5 = 15$

2. How the concept of entropy can be derived from Carnot cycle ? Represent the ideal Carnot cycle in a Temperature (T)-Entropy (S) diagram. 3 + 2

3. Prove that $C_P - C_V = \frac{TV\beta^2}{\alpha}$, where α is isothermal compressibility and β is thermal expansion coefficient. Other symbols bear the usual significance.

4. A horizontal piston-cylinder arrangement contains an ideal gas of volume 0·03 m^3. An external force holding the frictionless piston is placed against an initial gas pressure of 14 bar. The external force on the piston is reduced gradually, and the gas expands isothermally as its volume doubles. What is the work done by the gas in moving the external force ? How much work would be done if the external force were suddenly reduced to half its initial value instead of being gradually reduced ? 3 + 2

5. The azeotrope of the ethanol-benzene system has a composition of 44·8 mol% ethanol with a boiling point of 341·4 K. At this temperature the vapour pressures of benzene and ethanol are respectively 68·9 kPa and 67·4 kPa. Find the vapour composition of benzene in equilibrium with a solution containing 10 mol% ethanol and rest benzene at 341·4 K.

6. Deduce the Gibbs-Duhem equation.

GROUP – C

(Long Answer Type Questions)

Answer any *three* of the following. $3 \times 15 = 45$

7. a) What are the criteria based on which refrigerant is chosen for refrigeration ? Explain the absorption refrigeration with a flow diagram. Determine the expression of performance efficiency of an ideal absorption refrigeration cycle. 3 + 3 + 2

   b) What is the difference between lined and Claude liquefaction process ? 2

   c) A rigid insulated tank of volume $3m^3$ is divided into two compartments by a removable partition of negligible volume. One component of volume 1 m^3 contains Oxygen at 500 K and 10 bar while 2nd one contains Nitrogen at 800 K and 20 bar. The partition is removed and the gas is allowed to mix. After mixing calculate total change of entropy of the process. Assume both gases to be ideal with $\gamma = 1 \cdot 4$. 5

8. a) Hydrocarbon oil is to be cooled from 425 K to 320 K at a rate of 5000 kg/hr in a parallel flow heat exchanger. Cooling water at a rate of 10000 kg/hr at 295 K is available. The mean specific heats of the oil and water are respectively 2·5 kJ/kg-K and 4·2 kJ/kg-K. Determine the total change in entropy. Is the process reversible ?

b) If a reversible Carnot engine is to be operated receiving the heat from the oil and rejecting the heat to the surrounding at 295 K, how much work would be available ? Calculate the vapour pressure of water at 363 K, if the vapour pressure at 373 K is 101·3 kPa. The mean heat of vaporization in this temperature range is 2275 kJ/kg. 10 + 5

9. a) Prove the following relation :

$$ln\ f / P = \int_0^P (z-1)\,dP / P$$

b) From the following compressibility data for hydrogen at 0°C determine the fugacity of hydrogen at 1000 atm :

P (atm)	Z	P (atm)	Z
100	1·069	600	1·431
200	1·138	700	1·504
300	1·209	800	1·577
400	1·283	900	1·649
500	1·356	1000	1·720

7 + 8

10. a) Prove that $\Delta G^0 = -RT \ln K_a$.

b) Estimate the maximum conversion of ethylene to ethanol by the vapour phase dehydration at 250°C and 35 bars for an initial steam to ethylene ratio of 5. The system is non-ideal.

Data : The reaction is $C_2H_4(g) + H_2O(g) = C_2H_5OH(g)$

At 250°C, the equilibrium constant $(K_a) = 9 \cdot 841 \times 10^{-3}$

The fugacity coefficients of ethylene gas, steam and ethanol vapour are respectively 0·977, 0·896 and 0·837.

7 + 8

11. a) For a binary liquid mixture at constant temperature and pressure excess Gibbs energy is given by

$G^E / RT = (0 \cdot 198x_1 + 0 \cdot 372x_2)x_1x_2$

Find the value of $\ln \gamma_1$ at infinite dilution.

b) Discuss how partial molar properties can be evaluated using graphical technique. 8 + 7

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