Registration No : | | | | | | | | | | |

Total number of pages : 04 **B.Tech.**
PCE4I003

4th Semester Regular / Back Examination 2017-18
CHEMICAL ENGINEERING THERMODYNAMICS
BRANCH : CHEM
Time : 3 Hours
Max Marks : 100
Q.CODE : C768

Answer Part-A which is compulsory and any four from Part-B.
The figures in the right-hand margin indicate marks.
Assume suitable notations and any missing data wherever necessary.
Use of Steam Table is permitted. Answer all parts of a question at a place.

Part – A (Answer all the questions)

Q1. Answer the following questions : **(2 x 10)**

(a) Which of the following systems is an open system (A) and closed system (B) respectively?
A. Water contained in a Dewar flask
B. Water contained in a sealed container is being heated
C. Water contained in a beaker open to atmosphere is being heated
i. A and B
ii. A and C
iii. B and C
iv. C and B

(b) What is the amount of work done by a compressor (kJ/kmol) to compress an ideal gas isothermally at a temperature of 25°C from 1 bar to 10 bars?
i. 5707.7
ii. 3293
iii. 57.07
iv. 560.8

(c) In the P-T diagram at triple point which of the following lines has the highest slope?
i. S-L
ii. L-V
iii. S-V
iv. None of these

(d) The P-V isotherm of a real gas goes through an inflexion at the
i. Critical pressure
ii. Vapor pressure of the liquid
iii. Triple point
iv. None of these

(e) Absolute value of entropy for perfect crystalline substances can be calculated by using
i. First law of thermodynamics
ii. Second law of thermodynamics
iii. Third law of thermodynamics
iv. None of these

(f) For an ideal gas
   i. Fugacity is equal to pressure
   ii. Fugacity coefficient is equal to pressure
   iii. Fugacity is always equal to 1
   iv. None of these

(g) The chemical potential of a species in an ideal solution depends on
   i. Temperature
   ii. Pressure
   iii. Composition
   iv. All of these

(h) For an ideal gas specific internal energy is a function of
   i. Temperature only
   ii. Temperature and pressure
   iii. Temperature, pressure, and Gibbs free energy
   iv. None of these

(i) The Gibbs Duhem equation is applicable for
   i. Molar Gibbs free energy only
   ii. Molar Gibbs free energy and excess Gibbs free energy only
   iii. Chemical potential, molar Gibbs free energy, and excess Gibbs free energy only
   iv. Any partial molar property

(j) The activity coefficient of benzene in a benzene-toluenemixture can be assumed to be equal to
   i. Vapour pressure of benzene
   ii. Critical temperature of benzene
   iii. Mole fraction of benzene in the mixture
   iv. Unity

Q2. Answer the following questions : (2 x 10)

(a) Write the limitations of first law of thermodynamics.

(b) Differentiate between ideal gas and real gas.

(c) An equilibrium liquid/vapor system described by Raoult's lawcan't exhibit an azeotrope. Justify.

(d) Steam at 400 bar and 500°C is throttled through an adiabatic pressure relief valve to atmospheric pressure. What is the temperature of steam after expansion?

(e) Helium-laced gases are used as breathing media for deep sea divers.Why?

(f) Define Excess Properties.How Excess Gibb's energy is related with activity coefficient?

(g) What do you mean by reaction coordinate?

(h) Express partial molar temperature and partial molar pressure in terms of T and P of the mixture.

(i) Define Raoult's law. Write the limitations of this law.

(j) What are the values of total Gibbs energy and its differential for a chemical reaction at equilibrium?

Part – B (Answer any four questions)

Q3. **(a)** A closed non-reactive system contains species 1 and 2 in vapor/liquid equilibrium. Species 2 is very light gas, essentially insoluble in liquid phase. The vapor phase contains both species 1 and 2. Some additional moles of species are added to the system, which is then restored to its initial T and P. As a result of the process, does the total number of moles of liquid increase, decrease, or remain unchanged? Explain it. **(4)**

(b) Heat in the amount of 7.5 kJ is added to a closed system while its internal energy decreases by 12 kJ. How much energy is transferred as work? For a process causing the same change of state but for which the work is zero, how much heat is transferred? **(3)**

(c) Liquid water at 180°C and 1002.7 kPa has an internal energy (of an arbitrary scale) of 762.0 kJ/kg and specific volume of 1.128 cm^3/g. **(8)**

i. What is its enthalpy?

ii. The water is brought to the vapor state at 300°C and 1500 kPa, where its internal energy is 2784.4 kJ/kg and its specific volume is 169.7 cm^3/g. Calculate ΔU and ΔH.

Q4. **(a)** Reported values of virial coefficient of isopropanol vapour at 200°C are B= -388 cm^3/mol.Calculate molar volume (V) and compressibility factor (Z) for isopropanol vapor at 200°C and 10 bar by using **(5)**

i. Ideal gas equation and

ii. $Z = \frac{PV}{RT} = 1 + \frac{B}{V}$.

(b) Express the volume expansivity and isothermal compressibility as function of density ρ and its partial derivatives. For water at 50°C and 1 bar, $\kappa = 44.18 \times 10^{-6}$ bar^{-1}. To what pressure must water be compressed at 50°C to change its density by 1%? Assume that κ is independent of P. **(10)**

Q5. **(a)** The following heat engines produce power of 95000kW. Determine in each case the rates at which heat is absorbedfrom the hot reservoir and discarded to the cold reservoir. **(10)**

i. A Carnot engine operates between heat reservoirs at 750 K and 300 K.

ii. A practical engine operates between the same heat reservoirs but with a thermal efficiency η = 0.35.

(b) Derive the expression for entropy changes of an ideal gas. **(5)**

Q6. Assuming validity of Raoult's law, do the following calculations for the benzene(1)/toluene(2) system: **(15)**

i. Given $x_1 = 0.33$ and T=100°C, find y_1 and P

ii. Given $x_1 = 0.33$ and P =120 kPa, find y_1 and T

Vapor pressure of benzene and toluene can be calculated by Antoine equation

For benzene, $ln\ P^s/kPa = 13.7819 - \frac{2726.81}{T/K - 55.578}$

For toluene, $ln\ P^s/kPa = 13.9320 - \frac{3056.96}{T/K - 55.525}$

Q7. An ideal gas initially at 600 K and 10 bar undergoes a four step mechanically reversible cycle in a closed system. In step 1-2, pressure decreases isothermally to 3 bar; in step 2-3, pressure decreases at constant volume to 2 bar; in step 3-4, volume decreases at constant pressure; and in step 4-1, the gas returns adiabatically to its initial state. Take $C_p = (7/2)R$ and $C_v = (5/2)R$. **(15)**

i. Sketch the cycle on PV diagram,

ii. Determine (where unknown) both T and P for states 1, 2, 3, and 4, and

iii. Calculate Q, W, ΔU, and ΔH for each step of the cycle.

Q8. Derive the expression relating standard Gibb's energy change and equilibrium constant. Explain the effect of temperature on equilibrium constant by using this expression for exothermic and endothermic reaction. **(15)**

Q9. **(a)** Write a short note on Theorem of corresponding states. **(5)**

(b) Develop expression for the mole fraction of reacting species as a function of reaction coordinate for a system initially containing 2 mol NH_3 and 5 mol O_2 and undergoing the reaction **(5)**

$$4NH_3(g)+5O_2(g)\rightarrow 4NO(g) +6\ H_2O(g)$$

(c) Write a short note on Lewis/Randal rule. **(5)**