

JK LAKSHMIPAT UNIVERSITY, JAIPUR

INSTITUTE OF ENGINEERING AND TECHNOLOGY

End Term Examination (Regular), April-May, 2016

B. Tech in Chemical Engineering, IV Semester

Roll No.....

CHE403: CHEMICAL ENGINEERING THERMODYNAMICS

Time: 3 hours

Max. Marks: 100

Instructions to students:

1. Do not write anything other than your roll number on question paper.
2. Assume suitable data wherever required and mention it clearly.
3. Writing appropriate units, nomenclature, and drawing neat sketches/schematics/ flow chart wherever, required are an integral part of the answer.

Q.1A Objective type multiple choice questions (10 questions @ 1 mark)

10

i. The major limitation of the first law of thermodynamics is that it does not consider

- (a) Heat as a form of energy (b) Rate of change of the process
(c) Direction of change (d) Spontaneous process

ii. Maxwell's equation corresponding to the identity,

$$dH = TdS + VdP + \sum \mu_i dn_i \text{ is}$$

(a) $\left(\frac{\partial T}{\partial V}\right)_{S, n_i} = -\left(\frac{\partial P}{\partial S}\right)_{V, n_i}$

(b) $\left(\frac{\partial V}{\partial T}\right)_{P, n_i} = -\left(\frac{\partial S}{\partial P}\right)_{T, n_i}$

(c) $\left(\frac{\partial P}{\partial T}\right)_{V, n_i} = \left(\frac{\partial S}{\partial V}\right)_{T, n_i}$

(d) $\left(\frac{\partial P}{\partial T}\right)_{S, n_i} = \left(\frac{\partial S}{\partial V}\right)_{P, n_i}$

iii. As pressure approaches zero, the ratio of fugacity to pressure (f/P) for a gas approaches

- (a) Zero, (b) Unity, (c) Infinity (d) an indeterminate value

iv. Helmholtz function(A) is given as

- (a) $A = U - TS$ (c) $A = U - TS$
(b) $A = TS - U$ (d) $A = U - S/T$

v. When an ideal gas ($\gamma = 5/3$) is heated under constant pressure, then what percentage of given heat energy will be utilised in doing external work

- (a) 40% (b) 30% (c) 60% (d) 20%

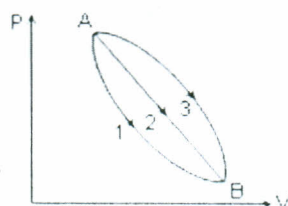


- vi. All but one of the following represent the chemical potential of components i in the solution.

$$(a) \mu_i = \left(\frac{\partial G^i}{\partial n_i} \right)_{T, P, n_{j \neq i}} \quad (b) \mu_i = \left(\frac{\partial U^i}{\partial n_i} \right)_{T, P, n_{j \neq i}} \quad (c) \mu_i = \left(\frac{\partial A^i}{\partial n_i} \right)_{T, P, n_{j \neq i}} \quad (d) \mu_i = \left(\frac{\partial H^i}{\partial n_i} \right)_{T, P, n_{j \neq i}}$$

- vii. An ideal gas of mass m in a state A goes to another state B via three different processes as shown in figure. If Q_1, Q_2 and Q_3 denote the heat absorbed by the gas along the three paths, then

- (a) $Q_1 < Q_2 < Q_3$
 (b) $Q_1 < Q_2 = Q_3$
 (c) $Q_1 = Q_2 > Q_3$
 (d) $Q_1 > Q_2 > Q_3$



- viii. The units of the isothermal compressibility are

- (a) m^{-3} (b) Pa^{-1} (c) $m^3 Pa^{-1}$ (d) $m^{-3} Pa^{-1}$

- ix. When an ideal diatomic gas is heated at constant pressure, the fraction of the heat energy supplied which increases the internal energy of the gas, is

- (a) $\frac{2}{5}$ (b) $\frac{3}{5}$ (c) $\frac{3}{7}$ (d) $\frac{5}{7}$

- x. The second law of thermodynamics states that

- (a) Heat is neither created nor destroyed
 (b) Heat can be converted into other forms of energy
 (c) Heat flows from a hot object to a cold one
 (d) The mechanical equivalent of heat is the amount of energy that must be expended in order to produce heat

Q.2 Short answer type questions (4 questions @ 2.5 marks)

10

- What do you mean by the term 'Entropy'? Prove that entropy is a property of a system.
- What are point and path properties? Explain with examples.
- Define fugacity and fugacity coefficient?
- Write clausius-clapeyron equation and give its physical significance.

- Q.3A Two Carnot engines work in series between the source and sink temperatures of 550 K and 350 K. If both engines develop equal power, determine the intermediate temperature.

05

- Q.3B Prove the maxwell relationships:

05

$$\left(\frac{\partial T}{\partial V} \right)_S = - \left(\frac{\partial P}{\partial S} \right)_T, \quad \left(\frac{\partial T}{\partial P} \right)_S = \left(\frac{\partial V}{\partial S} \right)_P, \quad \left(\frac{\partial P}{\partial T} \right)_V = \left(\frac{\partial S}{\partial V} \right)_T, \quad \left(\frac{\partial V}{\partial T} \right)_P = - \left(\frac{\partial S}{\partial P} \right)_T$$

Q.4A Defined the chemical potential. Derive the expression for effect of temperature and pressure on chemical potential. 05

Q.4B Prove that 05

$$dH = C_p dT + \left[V - T \left(\frac{\partial V}{\partial T} \right)_P \right] dP$$

Q.5A An iron cube at a temperature of 400°C is dropped into an insulated bath containing 10 kg water at 25°C. The water finally reaches a temperature of 50°C at steady state. Given that the specific heat of water is equal to 4186 J/kg K. Find the entropy changes for the iron cube and the water. Is the process reversible? If so why? 05

Q.5B Explain T-x-y and P-x-y diagram with neat sketches 05

Q.6A Explain the thermodynamic chemical equilibrium and derive the expression for $(dG)_{T,P} \leq 0$ (G is Gibbs free energy). 05

Q.6B Define the residual property. Derive the expression for generating function 05

$$\frac{I^R}{RT} = \left[\frac{\partial (G^R / RT)}{\partial P} \right]_T, \quad \frac{H^R}{RT} = -T \left[\frac{\partial (G^R / RT)}{\partial T} \right]_P$$

OR

Q.6B Define the Partial Molar Property of multi component system. Derive the expression for Partial Properties for Binary Solutions 05

$$\bar{M}_1 = M + x_2 \frac{dM}{dx_1}, \quad \bar{M}_2 = M - x_1 \frac{dM}{dx_1}$$

Where $\bar{M}$ partial molar property of components, M molar property of mixture and x_1 and x_2 mole fraction of the components.

Q.7A Explain the following terms(with neat sketches) 05
(a) zeroth law of thermodynamics,

(b) Quasi-static process.

Q.7B Explain the 'Clausius inequality'? Does a cycle for which violates the Clausius inequality? Why? 05

OR

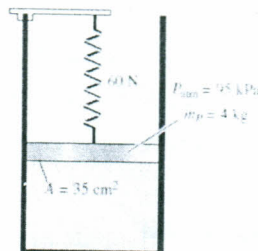
Q.7B A fluid is contained in a cylinder by a spring-loaded, frictionless piston so that the pressure in the fluid is linear function of the volume ($p = a + bV$). The internal energy of the fluid is given by the following equation 05

$$U = 34 + 3.15 pV$$

where U is in kJ, p in kPa and V in cubic metre. If the fluid changes from an initial state of 170 kPa, 0.03 m³ to a final state of 400 kPa, 0.06 m³, with no work other than that done on the piston, find the direction and magnitude of the work and heat transfer.



- Q.8A A gas is contained in a vertical, frictionless piston-cylinder device. The piston has a mass of 4 kg and a cross-sectional area of 35 cm². A compressed spring above the piston exerts a force of 60 N on the piston. If the atmospheric pressure is 95 kPa, determine the pressure inside the cylinder. 10



- Q.9A Derive an expression for enthalpy change of a gas during an isothermal process assuming using the following EOS 10

- Q.9B The enthalpy of a binary liquid mixture of species 1 and 2 at fixed T and P is represented by the equation: 10

$$H = 400x_1 + 600x_2 + x_1x_2(40x_1 + 20x_2) \quad \text{Where } H \text{ is in J mol}^{-1}$$

Calculate values of H_1 , H_2 , $\bar{H}_1^E$, $\bar{H}_2^E$.

OR

- Q.9B An insulated vessel of 0.5 m³ capacity is divided by a rigid conducting diaphragm into two chambers A and B, each having a capacity of 0.25 m³. Chamber A contains air at 1.4 bar pressure and 290 K temperature and the corresponding parameters for air in chamber B are 4.2 bar and 440 K. Calculate : 10

- Final equilibrium temperature,
- Final pressure on each side of the diaphragm, and
- Entropy change of system.

For air take $c_v = 0.715$ kJ/kg K and $R = 0.287$ kJ/kg K.

