Seat No.: _____ Enrolment No._____

GUJARAT TECHNOLOGICAL UNIVERSITY

ME - SEMESTER– I• EXAMINATION – WINTER 2014

Subject Code: 2711601 **Date:07/01/ 2015**

Subject Name: Advanced Thermodynamics

Time: 02:30 p.m. to 05:00 p.m. **Total Marks: 70**

Instructions:

1. **Attempt all questions.**
2. **Make suitable assumptions wherever necessary.**
3. **Figures to the right indicate full marks.**

Q.1 **(a)** Starting from first principles, derive an expression for Heat of Reaction for a reaction of type a A + b B c C + d D occurring at any temperature (T) and any pressure (p) **under non-ideal conditions** following step wise procedure. Hence or otherwise with suitable assumptions, derive the following equation. **07**

$$\Delta H_R = \Delta H_0^0 + \Delta a T + \frac{\Delta b}{2} T^2 + \frac{\Delta c}{3} T^3$$

(b) Production of methanol proceeds as follows: **07**

$$CO + 2H_2 \rightarrow CH_3OH.$$

The reaction under consideration is carried out at temperature (t) = 390 ^oC and pressure (p) = 300 atm. The value of ratios of activity coefficients (K_r) is 0.434 and the value of free energy change for reaction under standard conditions at temperature 663.2 K is + 14,700 Cal/gmole. Show that the values of yield of methanol and equilibrium conversion are 21% and 45% respectively.

Q.2 **(a)** What is criteria for Chemical Reaction Equilibria ? **07**
With special reference to above, discuss in detail the ranges of $\Delta \overline{G}$, $\Delta G°$, K and Xe for a generalized reaction of type
a A + b B == c C +d D
occurring under any pressure (P) and any temperature (T).

(b) Describe with the help of appropriate data and equations and relevant graphs, the calculation of equilibrium conversion **under adiabatic conditions** for a reaction of type A== B being highly reversible and **exothermic in nature.** **07**

OR

(b) Explain the adiabatic flash calculations with block diagram and supporting equations. **07**

Q.3 Explain with neat sketch the working of Ammonia Vapour absorption refrigeration cycle. **14**
Also discuss the importance of ñEconomizerò in the same cycle.

OR

Q.3 Given a plant process that requires cooling of 54.5 m³/h of water from 12.6 to 7°C, assume that the cooler heat transfer area will enable a 5°C differential between the chilled water leaving the cooler and the R-12 evaporating temperature. **14**
Also assume that the condenser heat transfer area enable a 5°C differential between the condenser water out and R-12 condensing temperature.
Water is available for the condensing medium at 30°C inlet and 35°C outlet. Assume no liquid sub cooling or suction gas superheating.
Find.

(a) Tons of refrigeration.
(b) Evaporator pressure.
(c) Condenser operating pressure.
(d) Refrigeration effect.
(e) Mass flow rate of R-12 circulated.
(f) Compression ratio.
(g) Coefficient of performance.
(h) Condenser water quantity.

Exponential Coefficient for isentropic compression of R-12 is n = 1.19.
Properties of R-12

T, K	P, bar	h_L, kJ/kg	h_G, kJ/kg
260	1.959	387.7	546.1
270	2.784	397	550.7
280	3.825	406.5	555.1
290	5.184	416.1	559.4
300	6.84	426	563.5
310	8.86	436	567.3
320	11.29	446.2	570.9

Specific heat of water = 4.1868 kJ / (kg.^{0}C)

Specific heat of R-12 in gas phase = 0.25 kJ / (kg.^{0}C)

Q.4 (a) A feed to a column has the composition given in the table below, and is a pressure of 14 bar and a temperature 60° C. Based on calculations verify that the given mixture is a Vapour-liquid mixture at given conditions. **07**

Feed	kmol/h	Ki
ethane	20	3.8
propane	20	1.3
isobutene	20	0.43
n-pentane	20	0.16
	80	

Also determined the flow rates and composition of vapour and liquid phases.

(b) Explain the BUBLT Calculations with block diagram and supporting equations **07**

OR

Q.4 Acetic acid is manufactured by carbonylation of methanol by following reaction. **14**

$CH_3OH(l) + CO(g) = CH_3 COOH(l)$

Continuous reaction is carried out at 180°C (453.15 K) and 50 atm in presence of a catalyst. Composition of liquid within the reactor remains uniform throughout and does not change with time. Liquid within the reactor contains 85% methanol and 15% acetic acid (by mole). Gas mixture leaves from the top of the reactor contains 65 kmol/h of carbon monoxide and 35 kmol/h of hydrogen and are accompanied by vapours of acetic acid and methanol. Calculate the flow rate of organic vapours in the real gas mixture (i.e. non-deal behaviour of gas mixture) and in ideal gas mixture.

Data : Vapour pressures of acetic acid and methanol at 180°C (453.15 K) are 5 bar and 27 bar, respectively. Critical pressures of acetic acid and methanol are 57.86 bar and 80.92 bar, respectively. Critical temperatures of acetic acid and methanol are 592.7 K and 512.64 K, respectively.

Acentric factor (ɤ) for acetic acid and methanol are 0.467 and 0564, respectively.

For evaluation of ʌ and ʌ ^{sat} : generalized correlation in the form of virial equation

$$ʌ = \exp \{ (p_{r/} T_r) (B^0 + ɤ B^1) \}$$

where p_r = reduced pressure

T_r = reduced temperature

ɤ = acentric factor (Pitzer correlation)

B^0 and B^1 are function of generalized reduced second virial coefficient correlation and are dependent on temperature only.

$$B^0 = 0.083 ï (0.422/ T_r^{1.6})$$

$$B^1 = 0.139 - (0.172/ T_r^{4.2})$$

Q.5 **(a)** Explain calculations of equilibrium conversion values under isothermal conditions for the following **two reactions proceeding simultaneously:** A → B+C & A → D+E. Derive relevant equations for equilibrium constant (K) as a function of P, n_t & x_e. Also briefly decribe stepwise procedure for calculation of values of x_e **when both reactions proceed simultaneously.** **07**

(b) What are equilibrium conversion charts? **07**

Elaborate the procedure for obtaining equilibrium conversion charts.

Depict and discuss generalized nature of these charts for reaction of type A → B+C being **exothermic in nature** and occurring under different sets of conditions

OR

14

Q.5 Synthesis gas for methanol may be produced by the catalytic reforming of methane with steam.

$CH_{4(g)} + H_2O_{(g)}$ Ÿ $CO_{(g)} + 3H_{2(g)}$ (I)

$CO_{(g)} + H_2O_{(g)}$ Ÿ $CO_{2(g)} + H_{2(g)}$ (II)

K_I at 1300 K = 13.845
K_{II} at 1300 K = 0.5798

Assume equilibrium is attained for both reactions at 1 bar and 1300 k.

(i) Would it be better to carry out the reaction at pressure above 1 bar?

(ii) Would it better to carry out the reaction at a temperature below 1300 K. Reaction (I) is endothermic and reaction (II) is exhothermic.

(iii) Repeat part (iii) for a steam to methane mole ratio in the feed of 2.

****