Chemical Engineering Department
King Saud University
Fall Semester 1427/1428

Final Exam

Q.1

For a 30 mol% n-pentane and 70 mol% n-hexane, calculate:

a- The dew-point temperature at 1 atm.
b- The bubble-point temperature at 1 atm.
c- The dew-point pressure at 55 ^{o}C.
d- The vapor fraction at 60 ^{o}C and 1 atm, and the mole fractions of the vapor and liquid phases.
e- Calculate the adiabatic flame temperature of the mixture at 60 ^{o}C and 1 atm being burned with 30% excess oxygen (not air) at 75 ^{o}C.

Q.2

A distillation tower is needed to separate an equimolar mixture, at 25 ^{o}C and 1 atm, of benzene from styrene. The distillate should contain 99 mol% benzene and 95% of the benzene fed to the tower. If $R = 1.3\ R_{min}$, determine:

a- The minimum number of stages at a total condenser.
b- The theoretical number of stages.
c- The optimum feed stage.
d- The reflux ratio.

Q.3

In the nitric acid process, ammonia oxidation is carried out in a catalytic reactor. Two reactions are possible:

$$\mathbf{4NH_3 + 5O_2 \longrightarrow 4NO + 6H_2O} \qquad \mathbf{(1)}$$

$$\mathbf{4NH_3 + 3O_2 \longrightarrow 2N_2 + 6H_2O} \qquad \mathbf{(2)}$$

At 1000 ^{o}C, 92% of the NH_3 can be converted into NO while the remainder goes by reaction (2). What is the heat of reaction at 1000 ^{o}C per kg of NH_3 supplied to the reactor if the catalytic burning is with the stoichiometric amount of pure oxygen? What would be the change in the heat of reaction if 10% excess oxygen at 1000 ^{o}C [based on reaction (1)] were used? Assume that ammonia and oxygen are fed at 25 ^{o}C and 1 atm.

Q.4

Ethylbenzene is converted to styrene by catalytic dehydrogenation reaction

$$C_8H_{10} \longrightarrow C_8H_8 + H_2$$

A flow chart of a simplified commercial process is shown below. Fresh and recycled liquid ethylbenzene combine and are heated from 25 ^oC to 500 ^oC. The heated ethylbenzene is mixed adiabatically with steam at 700 ^oC to produce the feed to the reactor at 600 ^oC. (The steam does not react but used to reduce side reactions and to remove carbon deposited on the catalyst surfaces).
A single-pass conversion of 35% is achieved in the reactor and the products exit at 560 ^oC. The product stream is cooled to 25 ^oC, allowing hydrogen to pass out from the flash drum. The water and hydrocarbon liquids are immiscible and are separated completely in a settling tank-decanter. The water is vaporized and heated and then steam is recycled to mix with the ethylbenzene feed to the reactor. The hydrocarbon stream is fed to a distillation tower in which the mixture is separated into essentially pure styrene and ethylbenzene. The ethylbenzene is recycled and cooled to 25 ^oC before mixing with the fresh feed.

a- Calculate on the basis of 100 kg/hr styrene produced, the required fresh ethylbenzene feed rate, flow rate of recycled ethylbenzene, and circulation rate of water all in mols/hr. (assume atmospheric pressure for the process)
b- Calculate the required rates of heat input or withdrawal in kJ/hr for the ethylbenzene preheater (A), steam generator (G), reactor (C), condenser (D) and distillation reboiler and condenser.