Department of Chemical Engineering, MNNIT Allahabad
End Semester Examination, B.Tech. (III Sem), 2018-19
SUBJECT: CHEMICAL PROCESS PRINCIPLES (CH-13101)

Max. Marks: 60

Note: *1. Solve the questions as per the given sequence*
*2. Assume suitable assumptions wherever necessary*

1. I) At 360K, the vapour pressures of n-heptane and toluene are 71.2 kPa and 48.9 kPa. Determine the composition of the liquid and vapour in equilibrium at 360K and 65kPa, If it is given that n-heptane and toluene form ideal solutions.

ii) Sulphur trioxide gas is obtained by the combustion of iron pyrites according to the reaction:
$4FeS_2 + 15O_2 \rightarrow 2Fe_2O_3 + 8SO_3$
How many kilograms of pyrites are burned to obtain 100 kg of sulphur trioxide? How many kilograms of oxygen are consumed in the production of 40 kg of SO_3?

iii) A gas confined in a cylinder is maintained at a constant pressure by means of a weight placed on the piston. The piston is frictionless. The piston is 100 mm and the mass of the piston and the weight together is 50 kg. The atm. pressure is 1.0133 bar. Determine a) the pressure of the gas and b) the work done by the gas in J if the gas is allowed to expand pushing up the piston and the weight by 500 mm.

iv) A liquid mixture containing 25% A, 30% B, and the rest C is in equilibrium with the vapour which contains 50% B. All percentages are on a mole basis. The equilibrium pressure and temperature are 200 kPa and 350 K, respectively. At 350K, the vapour pressure of C is 50 kPa. What is the % of A in the vapour?

v) What is the difference between crystallization and dissolution? A solution of sodium chloride in water is saturated at a temperature of 15°C. Calculate the weight of NaCl that can be dissolved by 100 kg of this solution if it is heated to 65°C.
Solubility of NaCl at 15°C=6.12 kgmole/1000 kg H_2O
Solubility of NaCl at 65°C=6.37 kgmole/1000 kg H_2O [10]

2. Define relative saturation and percent saturation in terms of humidity along with equations. A mixture of acetone vapour and nitrogen gas at 101.3kPa and 295K contains acetone vapour to the extent that it exerts a partial pressure of 15kPa. The vapour pressure of acetone at 295K is 26.36kPa. Determine a) the mole fraction of acetone in the mixture b) the wt. fraction of acetone in the mixture c) molal humidity d) absolute humidity e) the molal saturation humidity f) absolute saturation humidity.   [6]

3. A spherical storage tank of 3m in diameter is half filled with 12500 kg of an organic liquid at 7000 kPa. If the total internal energy in the tank is 5.3×10^6 kJ, what is the specific enthalpy of the fluid in the tank in kJ/kg?   [4]

4. Define following terms: Tie component, limiting and excess reactant, proximate and ultimate analysis.   [2]

5. It is required to make 1000 kg mixed acid containing 60% H_2SO_4, 32% HNO_3 and 8% water by blending (i) the spent acid containing 11.3% HNO_3, 44.4% H_2SO_4 and 44.3% H_2O, (ii) aqueous 90% HNO_3 and (iii) aqueous 98% H_2SO_4. All percentages are by weight. Calculate the quantities of each of the three acids required for blending.   [3]

6. 1000 kg/h of a thermic fluid, to be used as a heat transfer medium, is being indirectly heated in a heater, from 380 to 550 K. Calculate the heat load on the heater, in kW. Also estimate the mean heat capacity of the thermic fluid over the temperature range of interest. The heat capacity equation for the thermic fluid is:

$C_p = 1.436 + 0.00218\,T$

where, C_p is in kJ/kg and T is in K.   [3]

7. Chlorinated diphenyl (Diphyl A-30) is heated from 313 K to 553 K at the rate of 4000 kg/h in an indirectly fired heater. In this particular temperature range, the heat capacity of the fluid is given by the equation,

$$C_p = 0.7511 + 1.465 \times 10^{-3}\,T \text{ kJ/(kg.K)}$$

P.T.O.

Also, the heat capacity data of Diphyl A-30 at 313 K and 553 K are 1.1807 and 1.5198 kJ/(kg.K), respectively. Calculate the heat to be supplied to the fluid in the heater using the heat capacity equation. Also, calculate the % error involved in using the mean heat capacity data for the heat change calculations. [4]

8. The shift reaction is a very important reaction in the gas processing industry.

$$CO + H_2O \rightarrow CO_2 + H_2$$
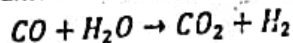
If a and b are the percent carbon monoxide in the dry and outlet gas mixtures from the shift converter respectively, prove that moles of CO converted (x) per 100 moles of inlet gas mixture can be calculated by using the formula.

[4]

$$x = \frac{100\,(a - b)}{100 + b}$$

9. A furnace is fired with fuel oil. The Orsat analysis of the flue gases indicates 10.6% CO_2, 6.0% O_2 and rest N_2 (by volume). Find (a) the percentage excess air and, (b) the C:H ratio in the fuel oil, assuming that fuel oil does not contain nitrogen. [5]

10. The reaction $A \rightarrow 2B + C$ takes place in a catalytic reactor (see in Fig. given below). The reactor effluent is sent to a separator. The overall conversion of A is 95%. The product stream from the separator consists of B, C and 0.5% of A entering the separator, while the recycle stream consists of the remainder of the unreacted A and 1% of B entering the separator. Calculate:
(a) Single pass conversion of A in the reactor.
(b) Molar ratio of feed.

[5]
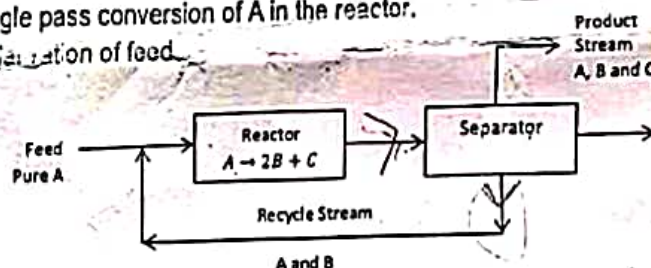
11. In the preparation of cooking liquor for a sulphite pulp mill, an absorption column is used to absorb SO_2 in a weak liquor. The weak liquor enters the top of the column at the rate of 20 l/s with SO_2 concentration of 0.5% (by weight) and leaves with SO_2 concentration of 1.0% (by weight). The gas stream entering the bottom of the column passing in the counter-current direction to the liquor stream contains 17% (by volume) SO_2. When the gas leaves the top of the column, 75% of SO_2 gets absorbed. The pressure in the column becomes 50 kPa and operates isothermally at 308 K. Assuming that the liquor has a specific gravity of 1.0, calculate:
(a) the molal flow rate of entering gas and (b) the volumetric flow rate of entering gas. [7]

12. In a particular drying operation, it is necessary to hold the moisture content of feed to a calciner to 15% (w/w) to prevent lumping and sticking. This is accomplished by mixing the feed having 30% moisture (w/w) with a recycle stream of dried material having 3% moisture (w/w). The drying operation is shown in Figure. What fraction of the dried product must be recycled?

[7]