BIRLA INSTITUTE OF TECHNOLOGY, MESRA, RANCHI
(END SEMESTER EXAMINATION)

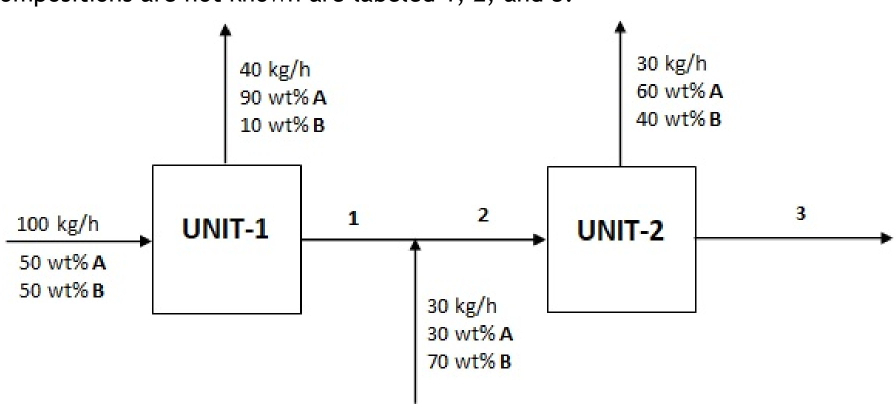
CLASS: BTECH | **SEMESTER : III**
BRANCH: CHEMICAL | **SESSION : MO/2022**

SUBJECT: CL217 CHEMICAL PROCESS CALCULATIONS

TIME: 3:00 Hours | **FULL MARKS: 50**

INSTRUCTIONS:
1. The question paper contains 5 questions each of 10 marks and total 50 marks.
2. Attempt all questions.
3. The missing data, if any, may be assumed suitably.
***4*. Before attempting the question paper, be sure that you have got the correct question paper.**
5. Tables/Data hand book/Graph paper etc. to be supplied to the candidates in the examination hall.

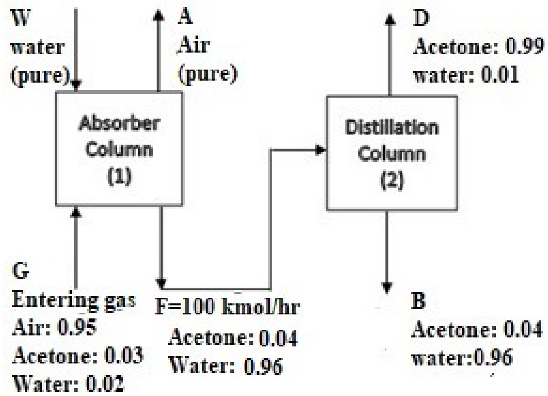
Q.1(a)	A mixture is 10 mole% ethyl alcohol, 75 mole% ethyl acetate ($C_4H_8O_2$), and 15 mole% acetic acid. (i) Calculate the mass fractions of each compound. (ii) What is the average molecular weight of the mixture?	2	CO1 BL3
Q.1(b)	A seed crystal of diameter ***D*** (mm) is placed in a solution of dissolved salt, and new crystals are observed to nucleate (form) at a constant rate ***r*** (crystals/min). Experiments with seed crystals of different sizes show that the rate of nucleation varies with the seed crystal diameter as ***r*** (crystals/min) = 200***D*** – 10***D***^{2} (***D*** in mm) (i) What are the units of the constants 200 and 10? (ii) Derive a formula for ***R*** (crystals/s) in terms of ***d*** (inches). (iii) Calculate the crystal nucleation rate in crystals/s corresponding to a crystal diameter of 0.050 inch.	3	CO1 BL3
Q.1(c)	Determine units of *C* for the following equation to be dimensionally consistent, which is used for calculating the volumetric flowrate *q* (m^3/s) of a liquid in a device: $q = CA_1\sqrt{\frac{2V(p_1-p_2)}{1-(A_1/A_2)^2}}$, where A_1 and A_2 are cross sectional area in m^2, *V* is specific volume in $m^3.kg^{-1}$, and $(p_1 - p_2)$ is pressure drop in Pa.	2	CO1 BL3
Q.1(d)	Heat capacity C_p of a substance in BTU. lb^{-1}. $^oR^{-1}$ is given by: $C_p = 10 + 0.2T$, where *T*= temperature in ^oR. Convert the equation in J. kg^{-1}. K^{-1} with *T*= temperature in K.	3	CO1 BL3
Q.2(a)	Define the equation of state for a real gas with an example.	2	CO2 BL1
Q.2(b)	A sample of gas mixture at 2000 kPa absolute and 400 K composed of CH_4(0.1 kg); C_2H_6(0.2 kg); N_2(0.05 kg). Calculate the density of the gas sample in kg/m^3?	3	CO2 BL3
Q.2(c)	Humid air at 75 °C, 825 mmHg, and 30% relative humidity is fed into a process unit at a rate of 1000 m^3/h. Determine (i) the molar flow rates of water, dry air, and oxygen entering the process unit, (ii) the molal humidity and, absolute humidity of the air. Vapor pressure of water at 75 °C is 289 mmHg.	5	CO2 BL3
Q.3(a)	A labeled flowchart of a continuous steady-state two-unit process is shown below. Each stream contains two components, **A** and **B**, in different proportions. Three streams whose flow rates and/or compositions are not known are labeled 1, 2, and 3.	5	CO3 BL3 BL4



(i) Perform the degree-of-freedom analysis of the following: overall system, Unit 1, mixing point, and Unit 2.
(ii) Calculate the unknown flow rates and compositions of stream 1, 2, and 3.

PTO

Q.3(b) An acetone recovery system recovers 99 mole% acetone given in the figure below. Calculate the unknown flow rates W, G, A, B, D in kmol/hr for F=100 kmol/hr. 5 CO3 BL3



Q.4(a) A gas with the following composition is burned with 30% excess air in a furnace. What is the composition of the flue gas for complete combustion? Feed gas mixture: CH_4 50%, C_2H_6 30%, CO 6%, O_2 4%, N_2 10%. 5 CO4 BL3

Q.4(b) Methanol is synthesized from carbon monoxide and hydrogen in a catalytic reactor. The fresh feed to the process contains 32 mole% CO, 64% H_2 and 4% N_2. This stream is mixed with a recycle stream in a ratio 5 mol recycle/1 mol fresh feed to produce the feed to the reactor, which contains 13 mole% N_2. A low single-pass conversion is attained in the reactor. The reactor effluent goes to a condenser from which two stream emerge: a liquid product stream containing essentially all the methanol formed in the reactor, and a gas stream containing all the CO, H_2 and N_2 leaving the reactor. The gas stream is split into two fractions: one is removed from the process as purge stream, and the other is the recycle stream that combines with the fresh feed to the reactor. For a basis of 100 mol fresh feed/h, calculate the production rate of methanol (mol/h), the molar flow rate and compositions of the purge gas, and the overall and single-pass conversions. 5 CO4 BL3 BL4

Q.5(a) 40 gm mol of ferric sulfide (FeS_2) is oxidized with 140 gm mol of O_2 in the following reaction: $4FeS_2(s) + 11O_2(g) \rightarrow 2Fe_2O_3(s) + 8SO_2(g)$. The conversion of $FeS_2(s)$ to $Fe_2O_3(s)$ is 80%. Calculate the heat of reaction at standard state in kJ. The standard heat of reaction data: 5 CO5 BL3

$\Delta H^o_{f,FeS2} = -177.9$ kJ/gm mol; $\Delta H^o_{f,Fe2O3} = -822.156$ kJ/gm mol; $\Delta H^o_{f,SO2} = -296.90$ kJ/g mol

Q.5(b) Methane is oxidized with air to produce formaldehyde in a continuous reactor. A competing reaction is the combustion of methane to form CO_2. 5 CO5 BL3

Rxn-1 $CH_4 (g) + O_2 (g) \rightarrow HCHO (g) + H_2O (v)$

Rxn-2 $CH_4 (g) + 2O_2 (g) \rightarrow CO_2 (g) + 2H_2O (v)$

Reactants: 100 mol/s CH_4 (25 °C and 1 atm); 100 mol/s O_2 (100 °C and 1 atm); 376 mol/s N_2 (100 °C and 1 atm).

Products: 60 mol/s CH_4 (150 °C and 1 atm); 30 mol/s HCHO (150 °C and 1 atm); 10 mol/s CO_2 (150 °C and 1 atm); 50 mol/s H_2O (150 °C and 1 atm); 50 mol/s O_2 (150 °C and 1 atm); 376 mol/s N_2 (150 °C and 1 atm).

(1) Determine the standard heat of reaction for Rxn-1 and Rxn-2. (2) Determine the total enthalpy of the inlet stream. (3) Determine the total enthalpy of the outlet stream. (4) Determine the rate at which heat must be transferred to or from the reactor.

Given: $(\Delta H_f)_{CH4(g)}$= -74.85 kJ/mol, $(\Delta H_f)_{HCHO(g)}$ = -115.90 kJ/mol, $(\Delta H_f)_{H2O(v)}$ = -241.83 kJ/mol, $(\Delta H_f)_{CO2(g)}$ = -393.5 kJ/mol.

Specific Enthalpies of gases (kJ/mol)
[Reference state: P_{ref} = 1 atm, T_{ref} =25 °C]

T	O_2	N_2	CO_2	H_2O
100	2.24	2.19	2.90	2.54
200	5.31	5.13	7.08	6.01

Specific enthalpy of CH_4 at 150°C = 4.890 kJ/mol.
The specific heat (kJ/mol K) of HCHO is given by:
C_P (HCHO) = $34.28 \times 10^{-3} + 4.268 \times 10^{-5}\, T - 8.694 \times 10^{-12}\, T^3$ [T in °C]

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