BACHELOR OF TECHNOLOGY (C.B.C.S.) (2021-COURSE)

B. Tech. Sem - II CHEMICAL :SUMMER- 2022

SUBJECT : MATERIAL & ENERGY BALANCE CALCULATIONS

Day : Friday | Time : 10:00 AM-01:00 PM

Date : 5/8/2022 | **S-24055-2022** | Max. Marks : 60

N.B.:

1) All questions are **COMPULSORY**.
2) Figures to the right indicate **FULL** marks.
3) Use of non-programmable **CALCULATOR** is allowed.
4) Draw neat and labeled diagram **WHEREVER** necessary.
5) Assume suitable data if necessary.

Q.1 **a)** State and explain Dalton's law. **[04]**

b) A solution of caustic soda contains 20% NaOH by weight. The density of solution is 1.196 kg/lit. Find the normality, molarity and molality of the solution. **[06]**

OR

Q.1 **a)** Prove that, for ideal gas $P_A = y_A P$, where y_A = mole fraction of component A in gas mixture, P_A = partial pressure of component A, P = total pressure. **[04]**

b) The analysis of gas sample on mole basis is given below: **[06]**
CH_4 = 66%, CO_2 = 30% and NH_3 = 4%. Calculate :

i) average molecular weight of gas

ii) density of gas at a temperature of 303K and 303.975 kPa

iii) composition in weight percent.

Q.2 **a)** Explain general procedure to solve problems in material balance without chemical reaction. **[04]**

b) 10,000 kg/hr of solution containing 20% methanol is continuously fed to a distillation column. The distillate contains 98% methanol and waste solution (bottom product) from the column carries 1% methanol. All percentages are by weight. Calculate : **i)** the mass flow rates of distillate and bottom product **ii)** the percent loss of methanol. **[06]**

OR

Q.2 **a)** Explain solid-liquid extraction (leaching) operation used in chemical industry with its block diagram and material balance. **[04]**

b) An evaporator is fed with 15,000 kg/hr of a solution containing 10% NaCl, 15% NaOH and rest water. In this operation, water is evaporated and NaCl is precipitated as crystals. The thick liquor leaving the evaporator contains 45% NaOH, 2% NaCl and rest water. Calculate: **i)** kg/hr of water evaporated **ii)** kg/hr of NaCl preciptated **iii)** kg/hr of thick liquor obtained. **[06]**

Q.3 **a)** A feed containing 60 mole% A, 30 mole% B and 10 mole% inerts enters into a reactor. 80% of original A reacts according to the reaction $2A + B \rightarrow C$. Find the composition of product stream on mole basis. **[04]**

b) Explain limiting reactant and excess reactant with suitable example. **[06]**

OR

Q.3 A mixture of pure carbon dioxide and hydrogen is passed over a nickel catalyst. The temperature of catalyst is 588K and the reactor pressure is 2.02 MPa.g. The gases leaving the reactor contain 57.1% CO_2, 41.1% H_2, 1.68% CH_4 and 0.12% CO by mole on a dry basis. The reaction taking place in the reactor are: **[10]**

$CO_2 + 4H_2 \rightarrow CH_4 + 2H_2O$

$CO_2 + H_2 \rightarrow CO + H_2O$

Find : **i)** The conversion of CO_2 per pass.

ii) The yield of CH_4 in terms of CO_2 reacted.

iii) The composition of feed on mole basis.

Q.4 **a)** Explain in detail recycle and purge operation used in chemical industry with their industrial importance and block diagram. **[04]**

b) Explain in detail humid heat and humid volume. **[06]**

OR

P.T.O.

Q.4 In a drying operation, it is necessary to maintain moisture content of feed to a calciner at 15% by weight to prevent lumping and sticking. This is achieved by mixing the feed having 30% by weight moisture and with a recycle stream of dried material having 3% moisture by weight. The drying operation is shown in figure 1 given below: **[10]**

Calculate : **i)** The fraction of dried product to be recycle.
ii) Water removed from Calciner.
iii) Product obtained.

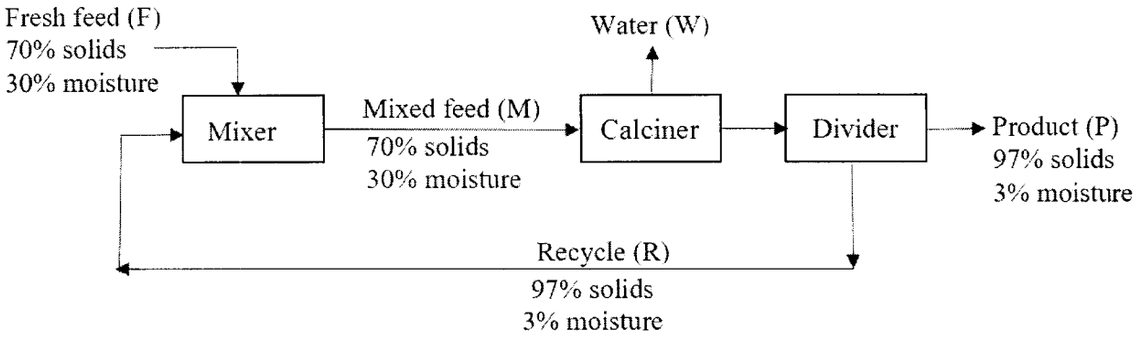

Figure 1 : Drying of solids.

Q.5 a) Calculate the standard heat of reaction at 298K of the following reaction: **[04]**

C_5H_{12} (*l*) + 8 O_2 (g) → 5 CO_2 (g) + 6 H_2O (*l*)

Data:

Component	ΔH_f^0 kJ/mol at 298 K
C_5H_{12} (*l*)	- 173.49
CO_2 (g)	- 393.51
H_2O (*l*)	- 285.83

b) What is heat capacity? Derive relation between Cp and Cv for the ideal gas. **[06]**

OR

Q.5 A natural gas has the following composition on mole basis: **[10]**

CH_4 = 84%, C_2H_6 = 13% and N_2 = 3%.

Calculate the heat to be added to heat 10 kmol of natural gas mixture from 298K to 523K using C_p^0 data given below:

$C_p^0 = a + bT + cT^2 + dT^3$ kJ/(kmol.K)

Gas	a	b × 10^3	c × 10^6	d × 10^9
CH_4	19.2494	52.1135	11.973	- 11.3173
C_2H_6	5.4129	178.0872	- 67.3749	8.7147
N_2	29.5909	- 5.141	13.1829	- 4.968

Q.6 a) Explain in detail gross and net calorific values of fuel. **[04]**

b) Calculate net calorific value at 298K for a sample of fuel oil having C/H ratio 9.33 (by weight) and containing sulphur to the extent of 1.3% by weight. **[06]**

Data: GCV of fuel oil at 298K = 41785 kJ/kg
Latent heat of water vapour at 298K = 2442.5 kJ/kg

OR

Q.6 Calculate the gross and net calorific values at 298 K in kJ/mole, kJ/kg and kJ/m^3 of the gas using following composition by mole: **[10]**

CH_4 = 74.4%, C_2H_6 = 8.4%, C_3H_8 = 7.4%, i-C_4H_{10} = 1.7%, n-C_4H_{10} = 2.0%, i-C_5H_{12} = 0.5%, n-C_5H_{12} = 0.4%, N_2 = 4.3% and CO_2 = 0.9%.

Take specific volume of gas at 298K and 101.325 kPa = 24.465 m^3/kmol.

Data:

Component	GCV, kJ/mol	NCV, kJ/mol
CH_4	890.65	802.62
C_2H_6	1560.69	1428.64
C_3H_8	2219.17	2043.11
i-C_4H_{10}	2868.20	2648.12
n-C_4H_{10}	2877.40	2657.32
i-C_5H_{12}	3528.83	3264.73
n-C_5H_{12}	3535.77	3271.67

* * * *