Ranjan e-institute

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Gate Solution

30 year

Process calculation

Quick link: year wise

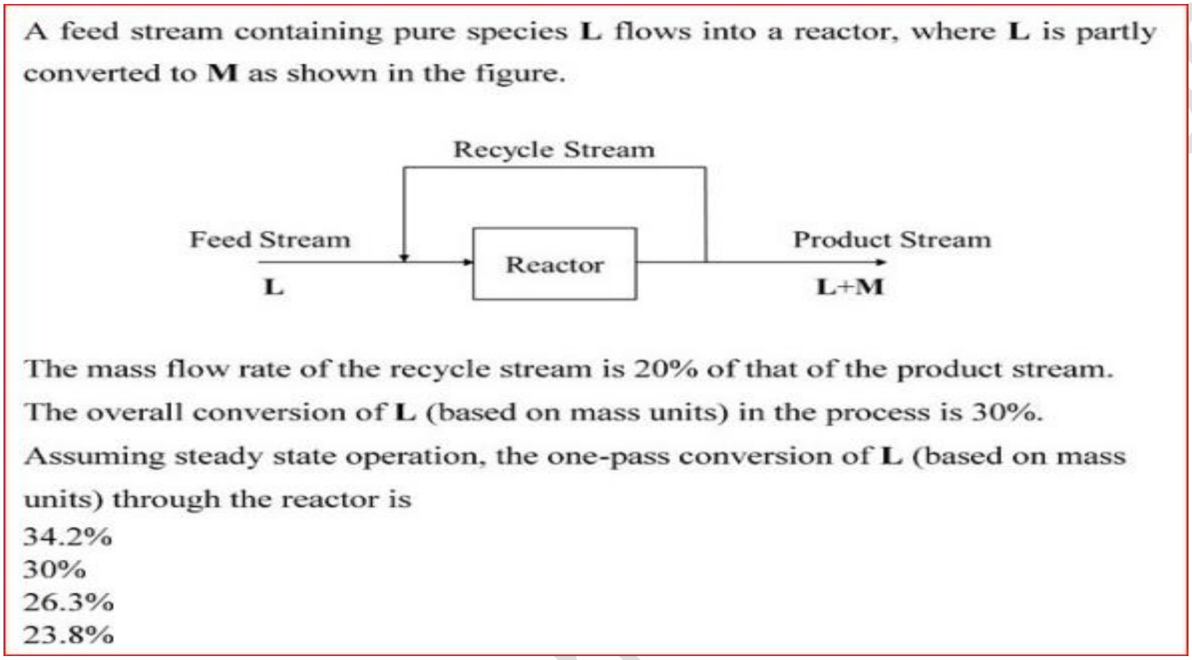
2020	2019	2018	2017	2016	2015	2014	2013	2012	2011
2010	**2009**	**2008**	**2007**	**2006**	**2005**	**2004**	**2003**	**2002**	**2001**
2000	**1999**	**1998**	**1997**	**1996**	**1995**	1994	**1993**	**1992**	**1991**
1990									
Answer Key									

- **This Pdf file is internally hyper linked.**
- **To see the solution of question plz click on the link given at the end of question "solution". To return again on question click on upward arrow link "↑".**
- **We tried to make 100 % mistake free solution of GATE Chemical egg questions, however if you find any inappropriate solution, please report to ' ranjaneinstitute@gmail.com'.**

Gate-2020

1.

solution



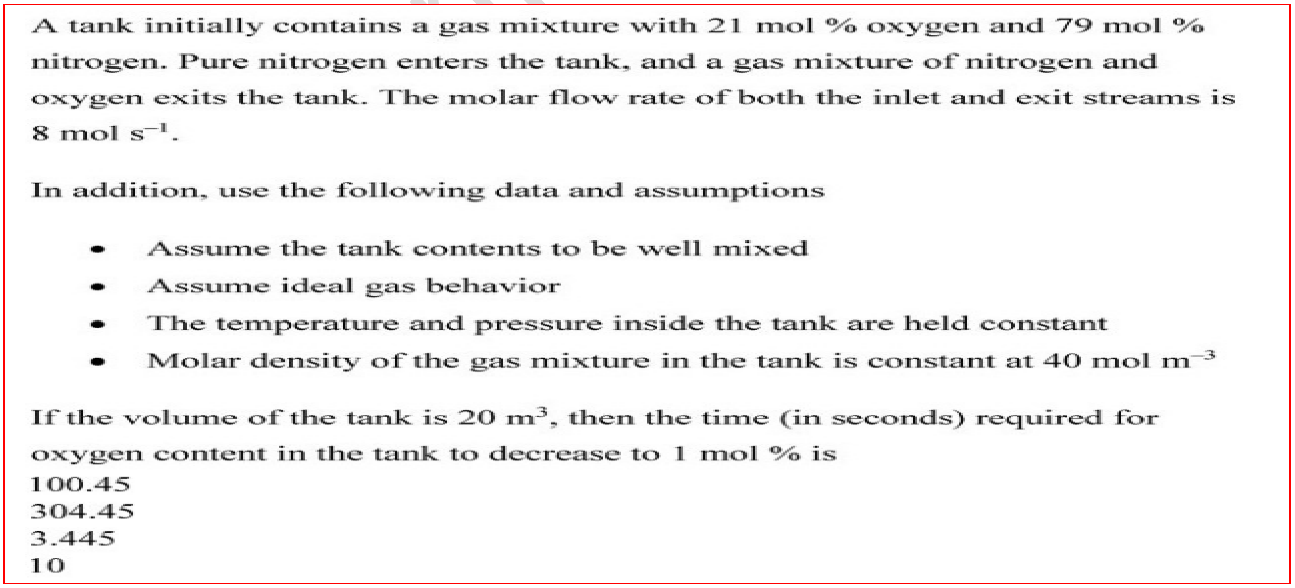
A feed stream containing pure species **L** flows into a reactor, where **L** is partly converted to **M** as shown in the figure.

The mass flow rate of the recycle stream is 20% of that of the product stream. The overall conversion of **L** (based on mass units) in the process is 30%. Assuming steady state operation, the one-pass conversion of **L** (based on mass units) through the reactor is

34.2%
30%
26.3%
23.8%

2.

Solution



A tank initially contains a gas mixture with 21 mol % oxygen and 79 mol % nitrogen. Pure nitrogen enters the tank, and a gas mixture of nitrogen and oxygen exits the tank. The molar flow rate of both the inlet and exit streams is 8 mol s^{-1}.

In addition, use the following data and assumptions

- Assume the tank contents to be well mixed
- Assume ideal gas behavior
- The temperature and pressure inside the tank are held constant
- Molar density of the gas mixture in the tank is constant at 40 mol m^{-3}

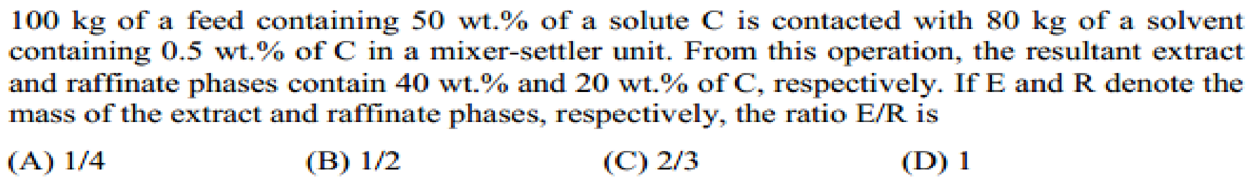
If the volume of the tank is 20 m^3, then the time (in seconds) required for oxygen content in the tank to decrease to 1 mol % is

100.45
304.45
3.445
10

Gate-2019

1.

solution

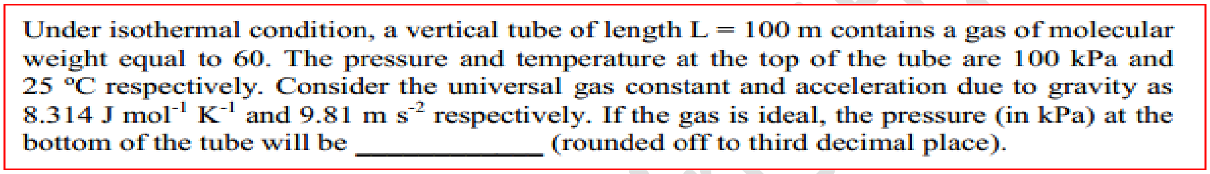


100 kg of a feed containing 50 wt.% of a solute C is contacted with 80 kg of a solvent containing 0.5 wt.% of C in a mixer-settler unit. From this operation, the resultant extract and raffinate phases contain 40 wt.% and 20 wt.% of C, respectively. If E and R denote the mass of the extract and raffinate phases, respectively, the ratio E/R is

(A) 1/4 (B) 1/2 (C) 2/3 (D) 1

Gate-2018

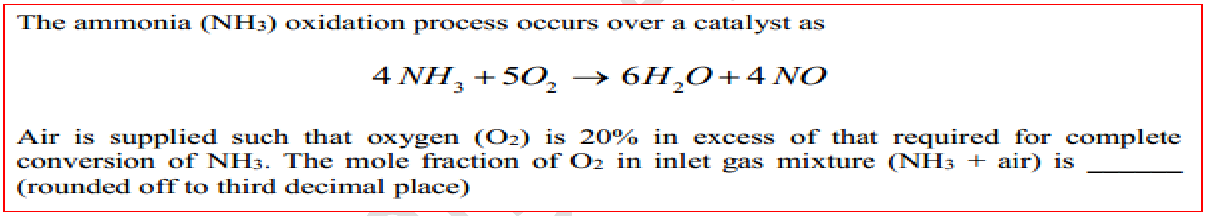
1.



Under isothermal condition, a vertical tube of length L = 100 m contains a gas of molecular weight equal to 60. The pressure and temperature at the top of the tube are 100 kPa and 25 °C respectively. Consider the universal gas constant and acceleration due to gravity as 8.314 J mol^{-1} K^{-1} and 9.81 m s^{-2} respectively. If the gas is ideal, the pressure (in kPa) at the bottom of the tube will be ____________ (rounded off to third decimal place).

Solution

2.



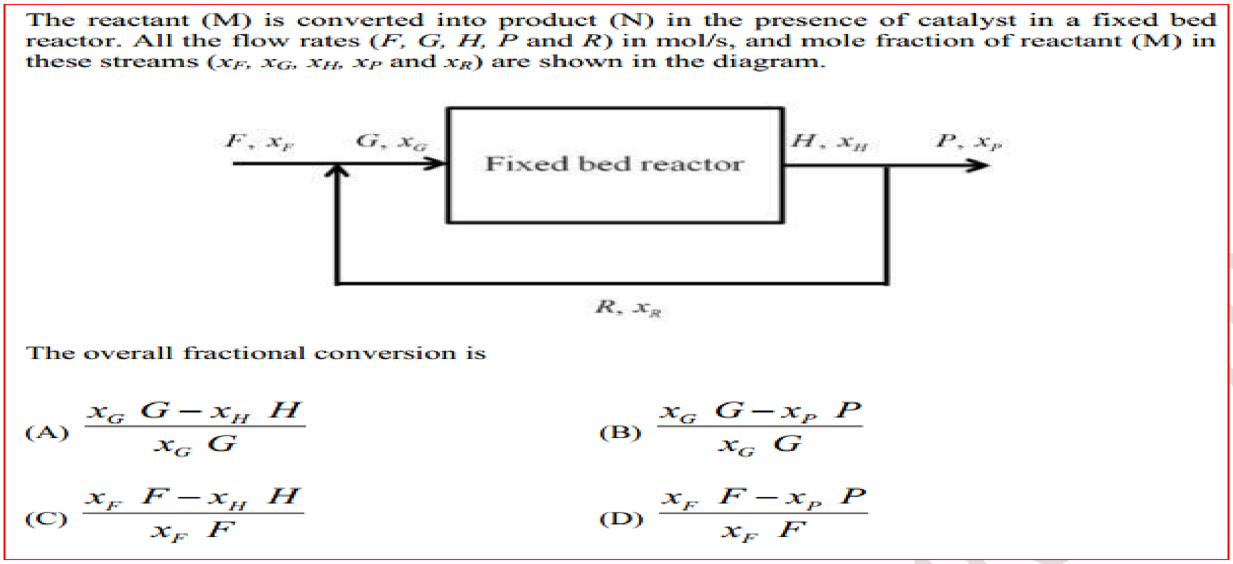
The ammonia (NH_3) oxidation process occurs over a catalyst as

$$4\,NH_3 + 5O_2 \rightarrow 6H_2O + 4\,NO$$

Air is supplied such that oxygen (O_2) is 20% in excess of that required for complete conversion of NH_3. The mole fraction of O_2 in inlet gas mixture (NH_3 + air) is ______ (rounded off to third decimal place)

Solution

3.



The reactant (M) is converted into product (N) in the presence of catalyst in a fixed bed reactor. All the flow rates (F, G, H, P and R) in mol/s, and mole fraction of reactant (M) in these streams (x_F, x_G, x_H, x_P and x_R) are shown in the diagram.

The overall fractional conversion is

(A) $\dfrac{x_G\ G - x_H\ H}{x_G\ G}$

(B) $\dfrac{x_G\ G - x_P\ P}{x_G\ G}$

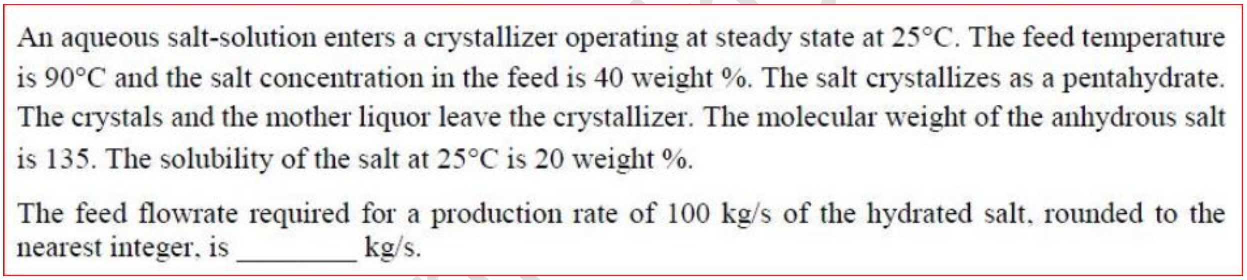
(C) $\dfrac{x_F\ F - x_H\ H}{x_F\ F}$

(D) $\dfrac{x_F\ F - x_P\ P}{x_F\ F}$

Solution

Gate-2017

1.



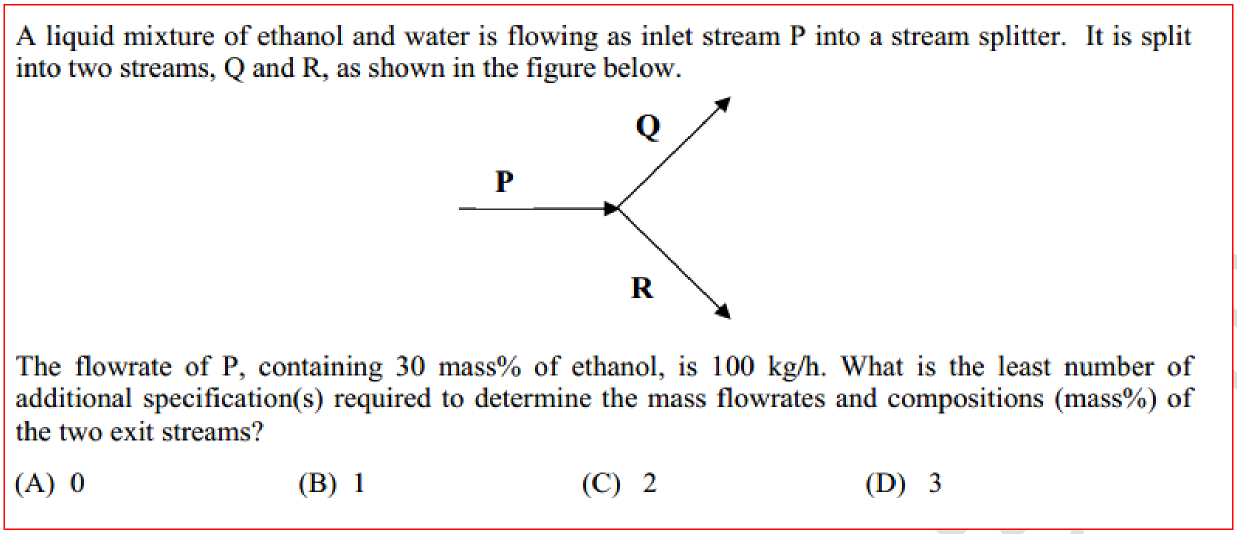
An aqueous salt-solution enters a crystallizer operating at steady state at 25°C. The feed temperature is 90°C and the salt concentration in the feed is 40 weight %. The salt crystallizes as a pentahydrate. The crystals and the mother liquor leave the crystallizer. The molecular weight of the anhydrous salt is 135. The solubility of the salt at 25°C is 20 weight %.

The feed flowrate required for a production rate of 100 kg/s of the hydrated salt, rounded to the nearest integer, is ________ kg/s.

Solution

Gate-2016

1.



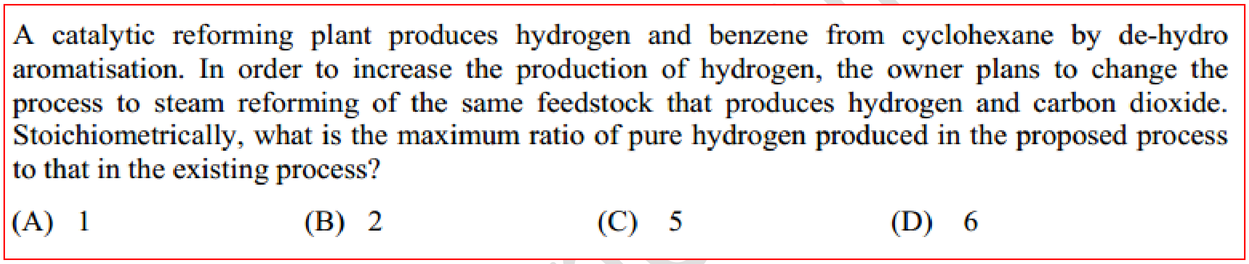
A liquid mixture of ethanol and water is flowing as inlet stream P into a stream splitter. It is split into two streams, Q and R, as shown in the figure below.

The flowrate of P, containing 30 mass% of ethanol, is 100 kg/h. What is the least number of additional specification(s) required to determine the mass flowrates and compositions (mass%) of the two exit streams?

(A) 0 (B) 1 (C) 2 (D) 3

Solution

2.



A catalytic reforming plant produces hydrogen and benzene from cyclohexane by de-hydro aromatisation. In order to increase the production of hydrogen, the owner plans to change the process to steam reforming of the same feedstock that produces hydrogen and carbon dioxide. Stoichiometrically, what is the maximum ratio of pure hydrogen produced in the proposed process to that in the existing process?

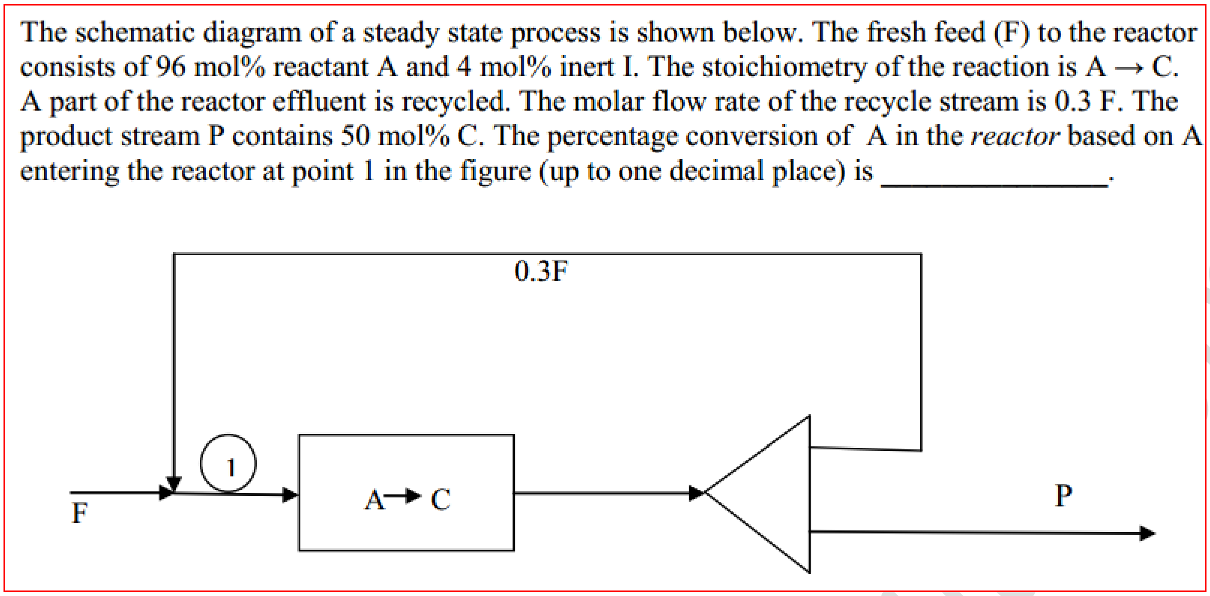
(A) 1 (B) 2 (C) 5 (D) 6

Solution

Gate-2015

1.

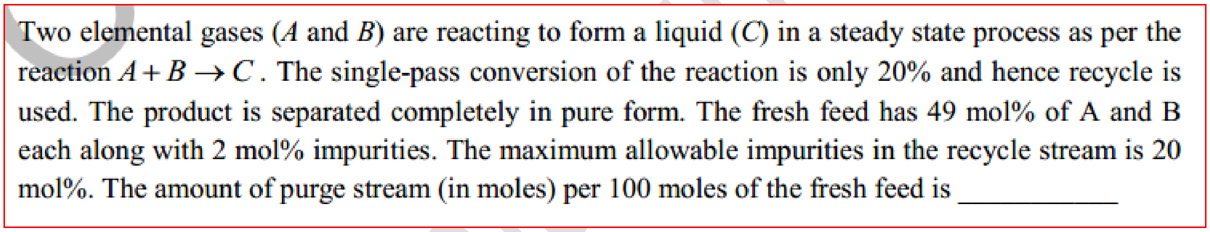
solution



The schematic diagram of a steady state process is shown below. The fresh feed (F) to the reactor consists of 96 mol% reactant A and 4 mol% inert I. The stoichiometry of the reaction is A → C. A part of the reactor effluent is recycled. The molar flow rate of the recycle stream is 0.3 F. The product stream P contains 50 mol% C. The percentage conversion of A in the *reactor* based on A entering the reactor at point 1 in the figure (up to one decimal place) is _______________.

Gate-2014

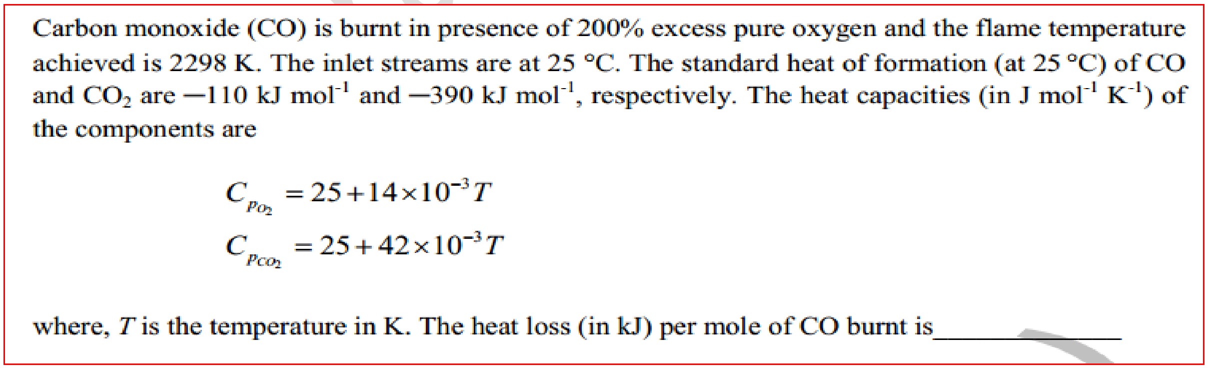
1.



Two elemental gases (A and B) are reacting to form a liquid (C) in a steady state process as per the reaction $A + B \rightarrow C$. The single-pass conversion of the reaction is only 20% and hence recycle is used. The product is separated completely in pure form. The fresh feed has 49 mol% of A and B each along with 2 mol% impurities. The maximum allowable impurities in the recycle stream is 20 mol%. The amount of purge stream (in moles) per 100 moles of the fresh feed is ___________

Solution

2.



Carbon monoxide (CO) is burnt in presence of 200% excess pure oxygen and the flame temperature achieved is 2298 K. The inlet streams are at 25 °C. The standard heat of formation (at 25 °C) of CO and CO_2 are −110 kJ mol^{-1} and −390 kJ mol^{-1}, respectively. The heat capacities (in J mol^{-1} K^{-1}) of the components are

$$C_{P_{O_2}} = 25 + 14\times10^{-3}T$$

$$C_{P_{CO_2}} = 25 + 42\times10^{-3}T$$

where, T is the temperature in K. The heat loss (in kJ) per mole of CO burnt is_____________

Solution

Gate-2013

1.

A reverse osmosis unit treats feed water (F) containing fluoride and its output consists of a permeate stream (P) and a reject stream (R). Let C_F, C_P, and C_R denote the fluoride concentrations in the feed, permeate, and reject streams, respectively. Under steady state conditions, the volumetric flow rate of the reject is 60 % of the volumetric flow rate of the inlet stream, and $C_F = 2$ mg/L and $C_P = 0.1$ mg/L.

Q.48 The value of C_R in mg/L, up to one digit after the decimal point, is _________

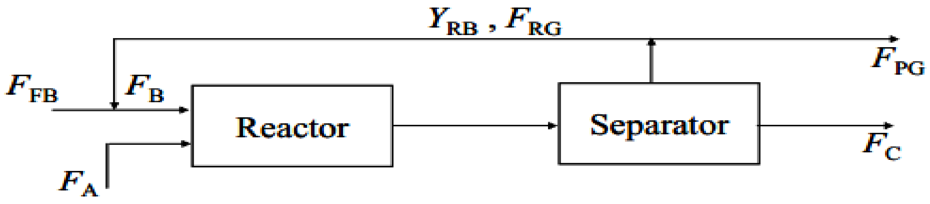
Q.49 A fraction f of the feed is bypassed and mixed with the permeate to obtain treated water having a fluoride concentration of 1 mg/L. Here also the flow rate of the reject stream is 60% of the flow rate entering the reverse osmosis unit (after the bypass). The value of f, up to 2 digits after the decimal point, is __________

Solution

Gate-2012

1.

The reaction $A_{(liq)} + B_{(gas)} \rightarrow C_{(liq)} + D_{(gas)}$, is carried out in a reactor followed by a separator as shown below



Notation:

Molar flow rate of fresh B is F_{FB}

Molar flow rate of A is F_A

Molar flow rate of recycle gas is F_{RG}

Mole fraction of B in recycle gas is Y_{RB}

Molar flow rate of purge gas is F_{PG}

Molar flow rate of C is F_C

Here, $F_{FB} = 2$ mol/s; $F_A = 1$ mol/s, $F_B / F_A = 5$ and A is completely converted.

Q.50 If $Y_{RB} = 0.3$, the ratio of recycle gas to purge gas (F_{RG}/F_{PG}) is

(A) 2 (B) 5 (C) 7 (D) 10

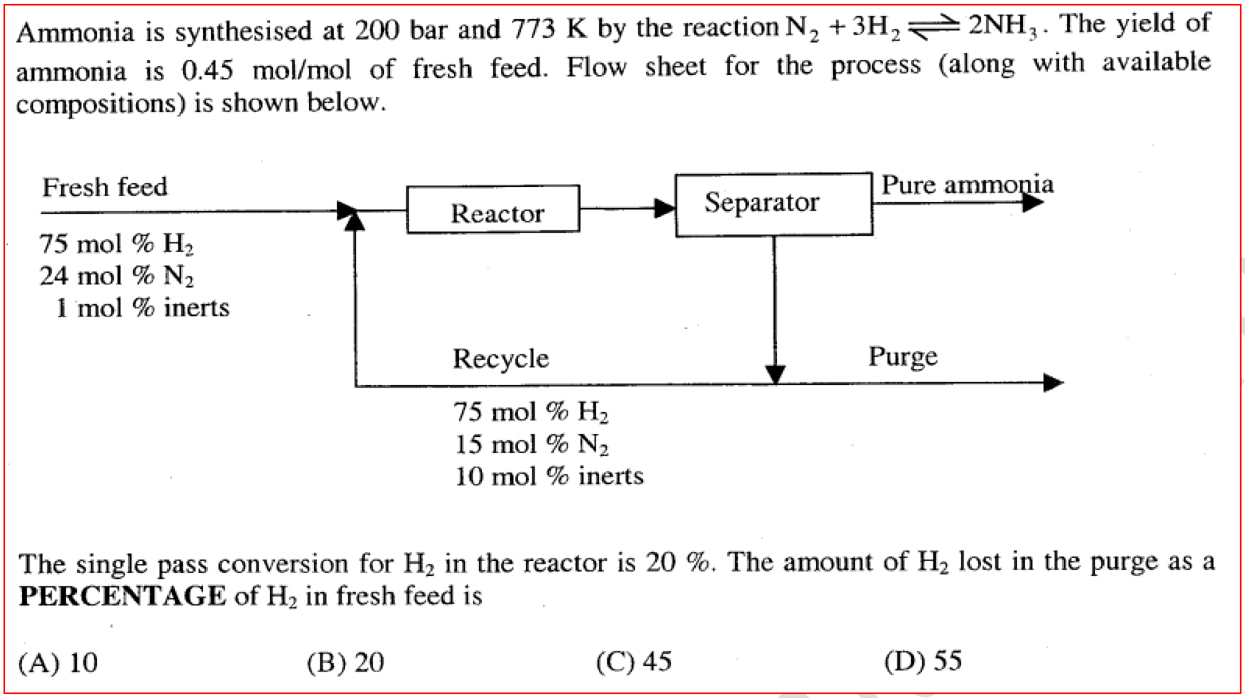
Q.51 If the ratio of recycle gas to purge gas (F_{RG}/F_{PG}) is 4 then Y_{RB} is

(A) 3/8 (B) 2/5 (C) 1/2 (D) 3/4

Solution

Gate-2011

1.



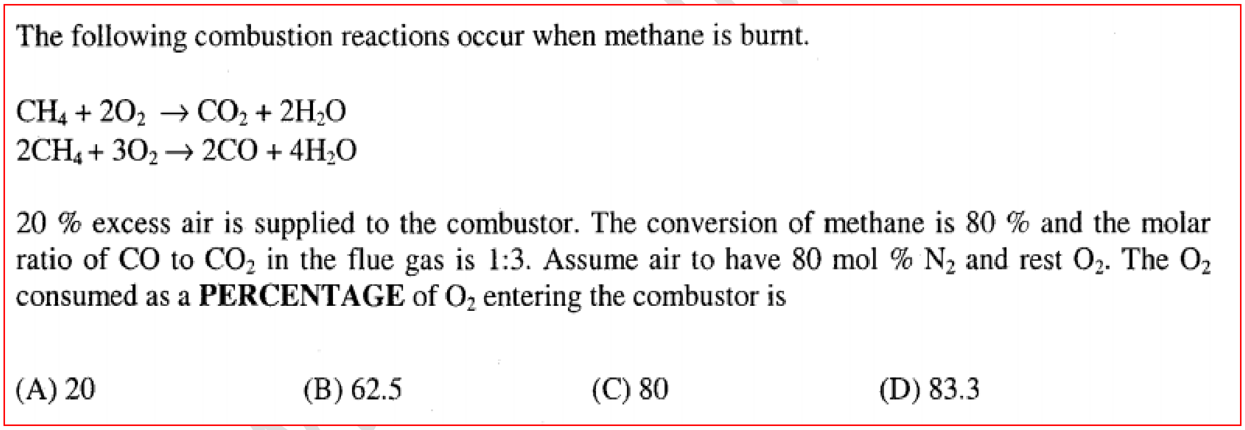
Ammonia is synthesised at 200 bar and 773 K by the reaction $N_2 + 3H_2 \rightleftharpoons 2NH_3$. The yield of ammonia is 0.45 mol/mol of fresh feed. Flow sheet for the process (along with available compositions) is shown below.

The single pass conversion for H_2 in the reactor is 20 %. The amount of H_2 lost in the purge as a **PERCENTAGE** of H_2 in fresh feed is

(A) 10 (B) 20 (C) 45 (D) 55

Solution

2.



The following combustion reactions occur when methane is burnt.

$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$
$2CH_4 + 3O_2 \rightarrow 2CO + 4H_2O$

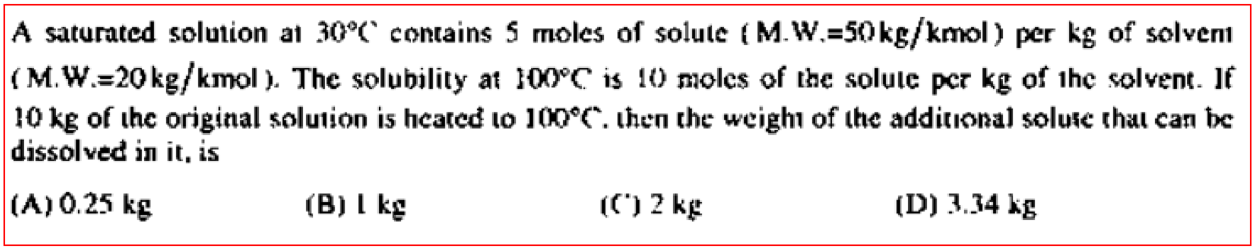
20 % excess air is supplied to the combustor. The conversion of methane is 80 % and the molar ratio of CO to CO_2 in the flue gas is 1:3. Assume air to have 80 mol % N_2 and rest O_2. The O_2 consumed as a **PERCENTAGE** of O_2 entering the combustor is

(A) 20 (B) 62.5 (C) 80 (D) 83.3

Solution

Gate-2010

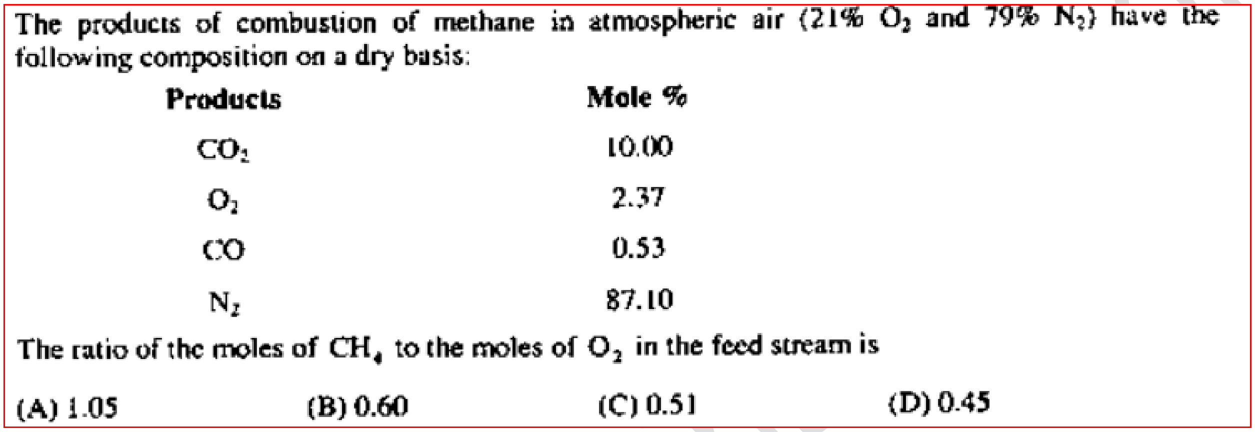
1.


A saturated solution at 30°C contains 5 moles of solute (M.W.=50 kg/kmol) per kg of solvent (M.W.=20 kg/kmol). The solubility at 100°C is 10 moles of the solute per kg of the solvent. If 10 kg of the original solution is heated to 100°C, then the weight of the additional solute that can be dissolved in it, is

(A) 0.25 kg (B) 1 kg (C) 2 kg (D) 3.34 kg

Solution

2.


The products of combustion of methane in atmospheric air (21% O_2 and 79% N_2) have the following composition on a dry basis:

Products	Mole %
CO_2	10.00
O_2	2.37
CO	0.53
N_2	87.10

The ratio of the moles of CH_4 to the moles of O_2 in the feed stream is

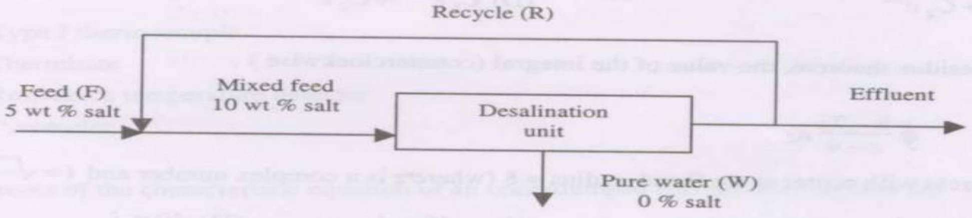
(A) 1.05 (B) 0.60 (C) 0.51 (D) 0.45

Solution

Gate-2009

1.

Pure water (stream W) is to be obtained from a feed containing 5 wt % salt using a desalination unit as shown below.



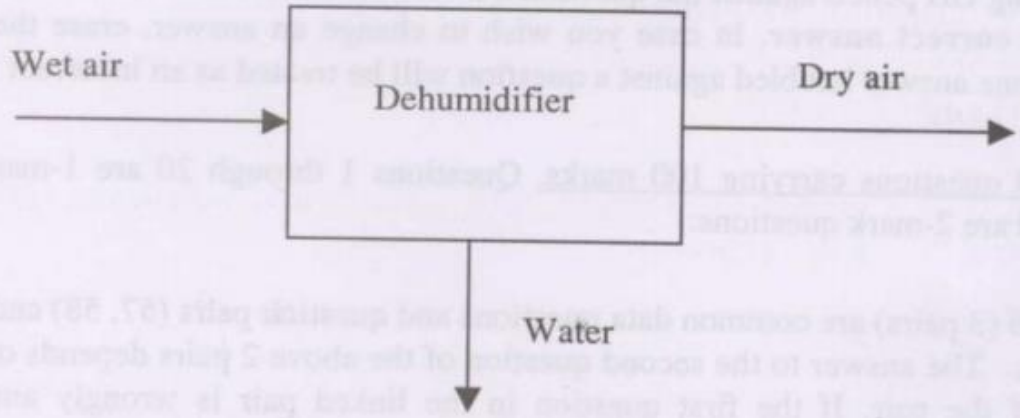
If the overall recovery of pure water (through stream W) is 0.75 kg/kg feed, then the recycle ratio (R/F) is

(A) 0.25 (B) 0.5 (C) 0.75 (D) 1.0

Solution

2.

A dehumidifier (shown below) is used to completely remove water vapor from air.



Which **ONE** of the following statements is **TRUE** ?

(A) Water is the ONLY tie component.
(B) Air is the ONLY tie component
(C) BOTH water and air are tie components
(D) There are NO tie components

Solution

Gate-2008

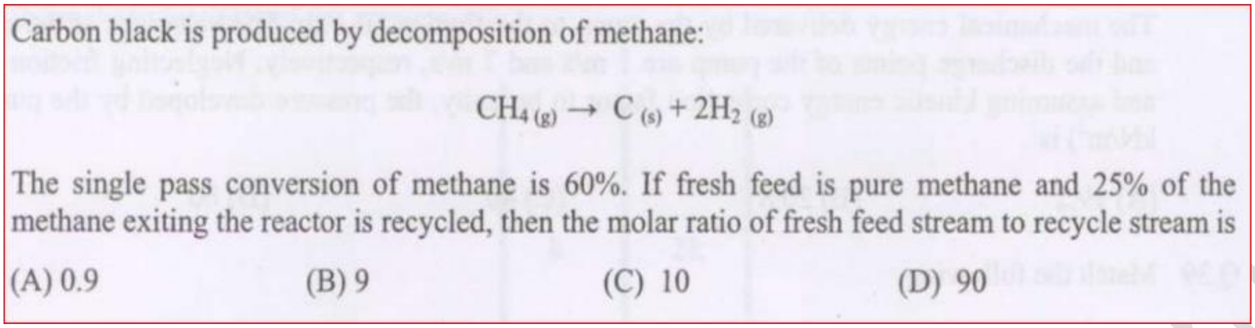
1.

A 35 wt% Na_2SO_4 solution in water, initially at 50°C, is fed to a crystallizer at 20°C. The product stream contains hydrated crystals $Na_2SO_4 \cdot 10H_2O$ in equilibrium with a 20 wt% Na_2SO_4 solution. The molecular weights of Na_2SO_4 and $Na_2SO_4 \cdot 10H_2O$ are 142 and 322, respectively. The feed rate of the 35% solution required to produce 500 kg/hr of hydrated crystals is

(A) 403 kg/hr (B) 603 kg/hr (C) 803 kg/hr (D) 1103 kg/hr

Solution

2.



Carbon black is produced by decomposition of methane:

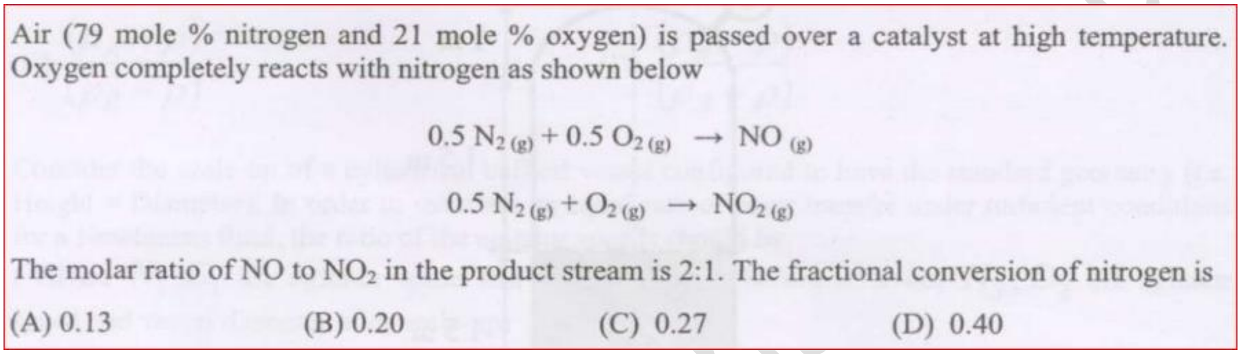
$$CH_{4\,(g)} \rightarrow C_{(s)} + 2H_{2\,(g)}$$

The single pass conversion of methane is 60%. If fresh feed is pure methane and 25% of the methane exiting the reactor is recycled, then the molar ratio of fresh feed stream to recycle stream is

(A) 0.9 (B) 9 (C) 10 (D) 90

Solution

3.



Air (79 mole % nitrogen and 21 mole % oxygen) is passed over a catalyst at high temperature. Oxygen completely reacts with nitrogen as shown below

$$0.5\,N_{2\,(g)} + 0.5\,O_{2\,(g)} \rightarrow NO_{(g)}$$

$$0.5\,N_{2\,(g)} + O_{2\,(g)} \rightarrow NO_{2\,(g)}$$

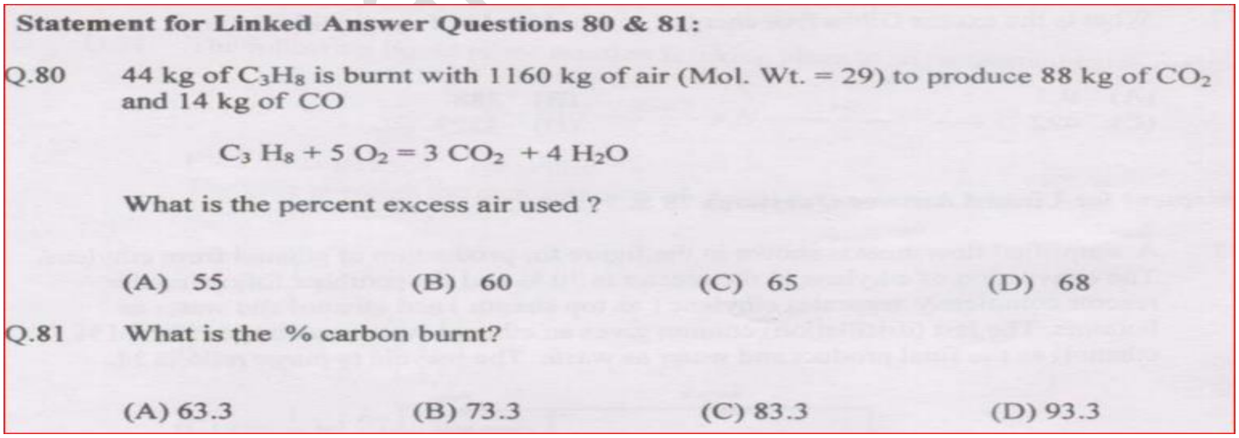
The molar ratio of NO to NO_2 in the product stream is 2:1. The fractional conversion of nitrogen is

(A) 0.13 (B) 0.20 (C) 0.27 (D) 0.40

Solution

Gate-2007

1.



Statement for Linked Answer Questions 80 & 81:

Q.80 44 kg of C_3H_8 is burnt with 1160 kg of air (Mol. Wt. = 29) to produce 88 kg of CO_2 and 14 kg of CO

$$C_3H_8 + 5\,O_2 = 3\,CO_2 + 4\,H_2O$$

What is the percent excess air used ?

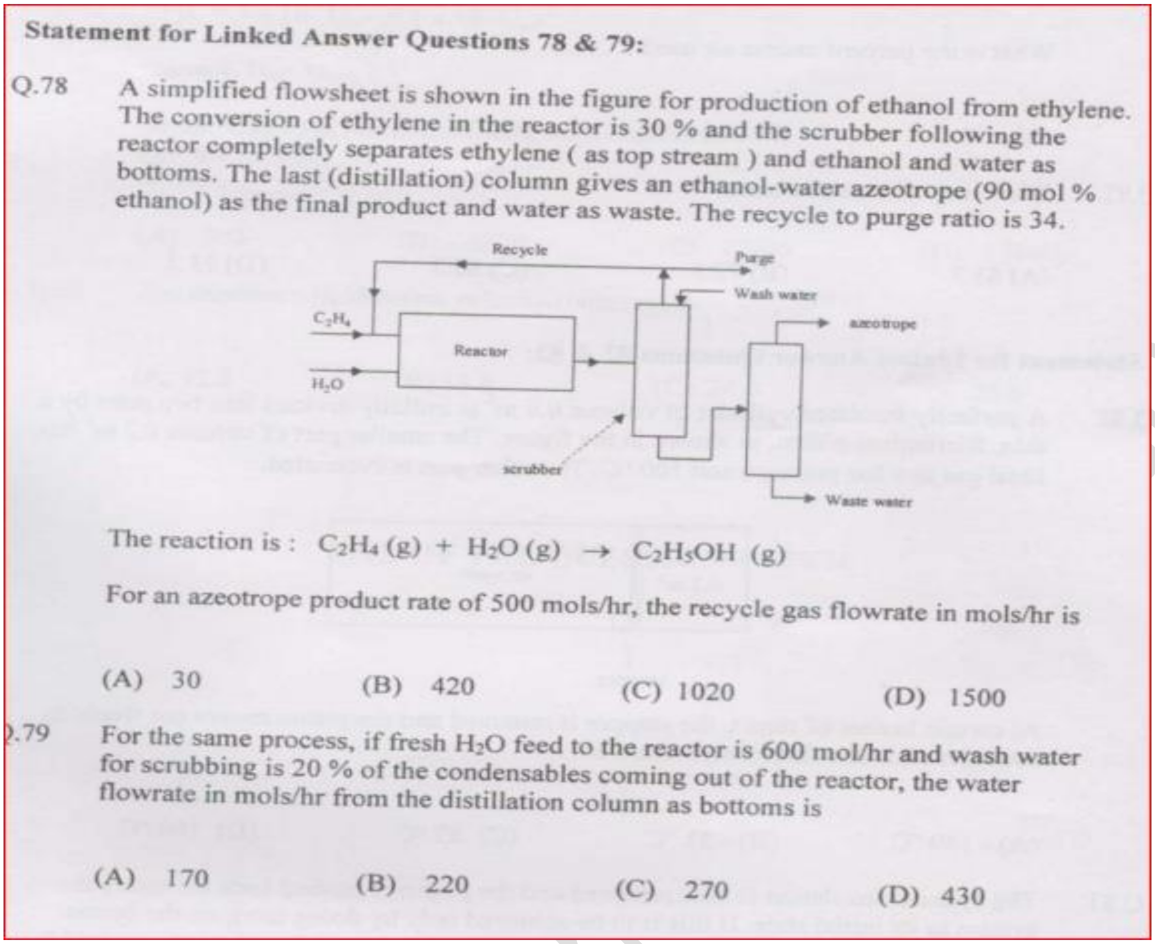
(A) 55 (B) 60 (C) 65 (D) 68

Q.81 What is the % carbon burnt?

(A) 63.3 (B) 73.3 (C) 83.3 (D) 93.3

Solution

2.



Statement for Linked Answer Questions 78 & 79:

Q.78 A simplified flowsheet is shown in the figure for production of ethanol from ethylene. The conversion of ethylene in the reactor is 30 % and the scrubber following the reactor completely separates ethylene (as top stream) and ethanol and water as bottoms. The last (distillation) column gives an ethanol-water azeotrope (90 mol % ethanol) as the final product and water as waste. The recycle to purge ratio is 34.

The reaction is : $C_2H_4\,(g) + H_2O\,(g) \rightarrow C_2H_5OH\,(g)$

For an azeotrope product rate of 500 mols/hr, the recycle gas flowrate in mols/hr is

(A) 30 (B) 420 (C) 1020 (D) 1500

.79 For the same process, if fresh H_2O feed to the reactor is 600 mol/hr and wash water for scrubbing is 20 % of the condensables coming out of the reactor, the water flowrate in mols/hr from the distillation column as bottoms is

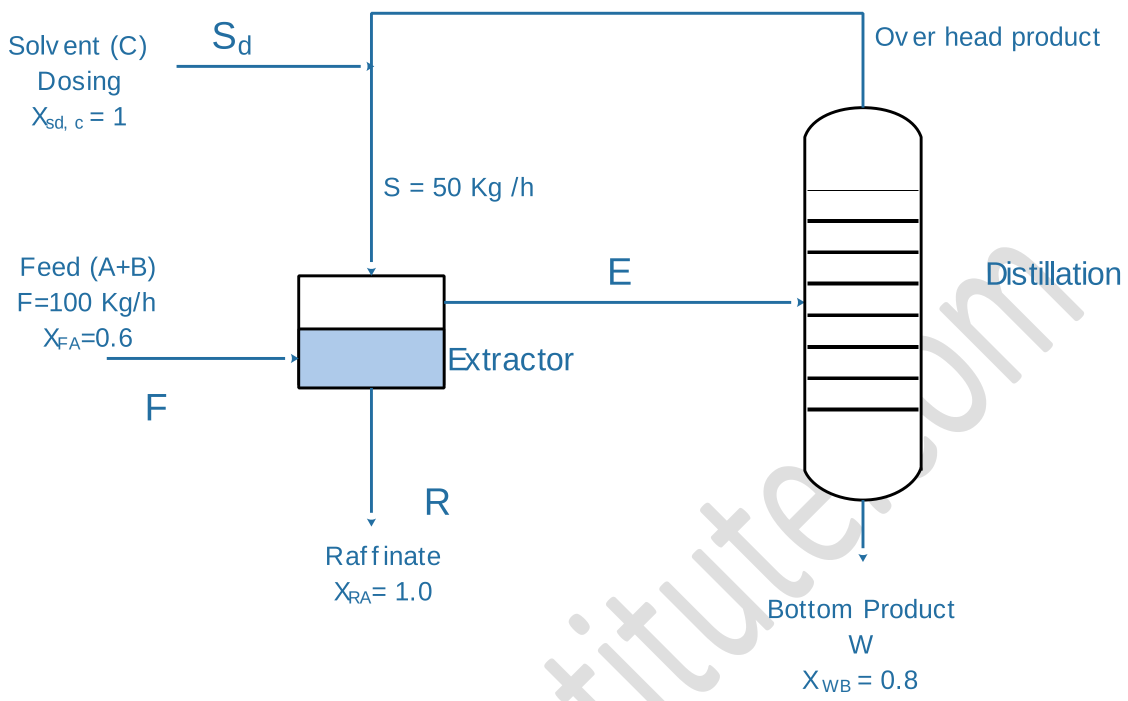
(A) 170 (B) 220 (C) 270 (D) 430

Solution

Gate-2006

1. Statement for Linked Answer Questions

Solvent C is used to extract solute B selectively from, 100 kg/hr feed mixture A+B in a steady state continuous process shown below. The solubility of C in the raffinate and the solubility of A in the extract are negligible. The extract is distilled to recover B in the bottom product. The overhead product is recycled to the extractor. The loss of solvent in the bottoms is compensated by make up solvent S_d. The total flow rate of the solvent stream S going to the extractor is 50 kg/hr. The mass fractions (X_i's) of some selected streams are indicated in the figure below.



a. Distillation bottoms flow rate W and solvent dosing rate S_d in kg/hr are

(A) W = 50, S_d = 50	(B) W = 100, S_d = 20
(C) W = 10, S_d = 50	(D) W = 50, S_d = 10

Solution

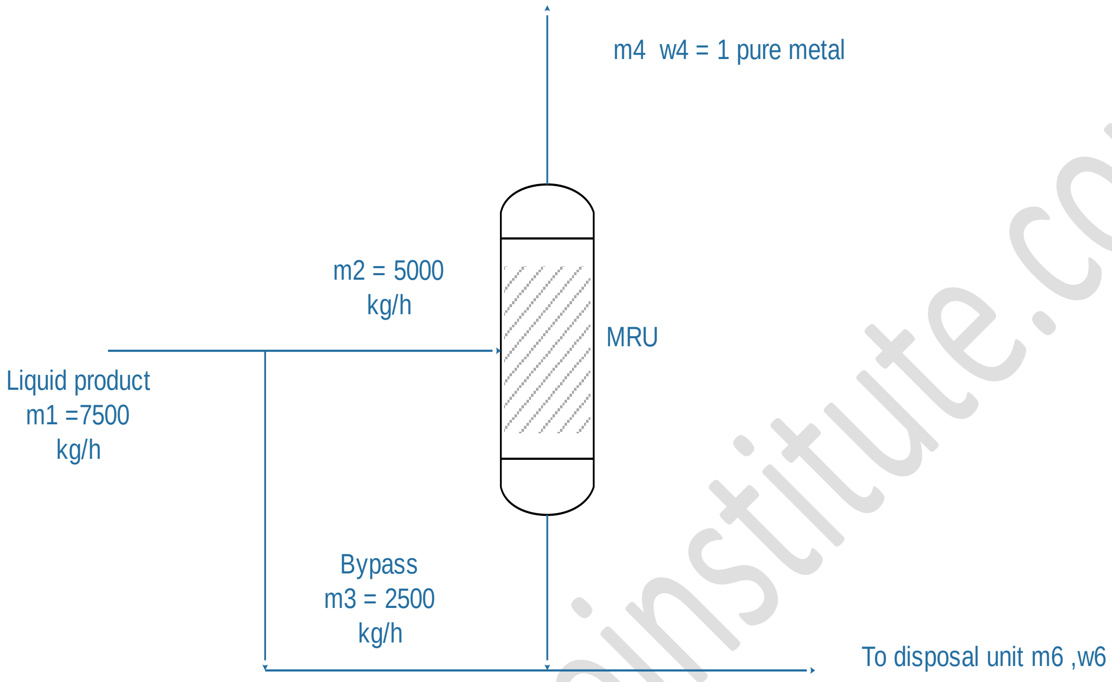
b. Feed rate E to the distillation column and overhead product rate T in kg/hr are

(A) E = 90, T = 40	(B) E = 80, T = 40
(A) E = 90, T = 50	(B) E = 45, T = 20

Solution

Gate-2005

1. A metal recovery unit (MRU) of intake capacity 5000 kg/hr treats a liquid product from a plant and recovers 90% of the metal in the metal in the pure form. The unrecovered metal and its associated liquid are sent to a disposal unit along with the untreated product from the plant (see figure below). Find the flow rate (m6) and the weight fraction of the metal (w6). The liquid product flow rate is 7500 higher of composition 0.1 (wt fraction), Assume steady state.

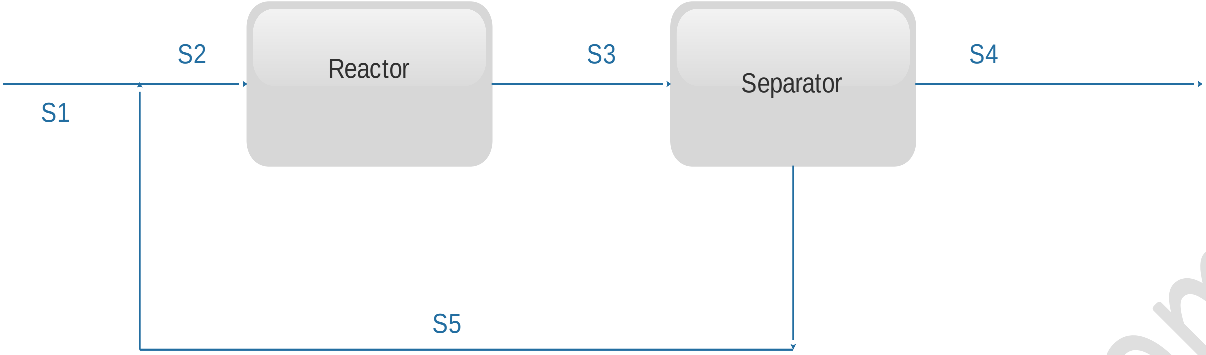


(a) m_6 = 7500 kg/hr, w_6 = 0.0 (b) m_6 = 7050 kg/hr, w_6 = 0.04255

(c) m_6 = 4500 kg/hr, w_6 = 0.1712 (d) m_6 = 5600 kg/hr, w_6 = 0.0314

Solution

2. A feed stream (S1) at 100 kg/hr and containing only A mixes with recycle stream S5 before entering the reactor (see figure below), where the reaction A → B takes place. The operation is at steady state. The stream S3 leaving the reactor is separated, without either phase or composition change, into two streams S4 and S5. If the mass fraction of B in S4 is 0.95 and total flow rate of S5 is 10 kg/hr, then the ratio of flow rates of streams (S3/S5), and the flow rate of A in S3 are, respectively.



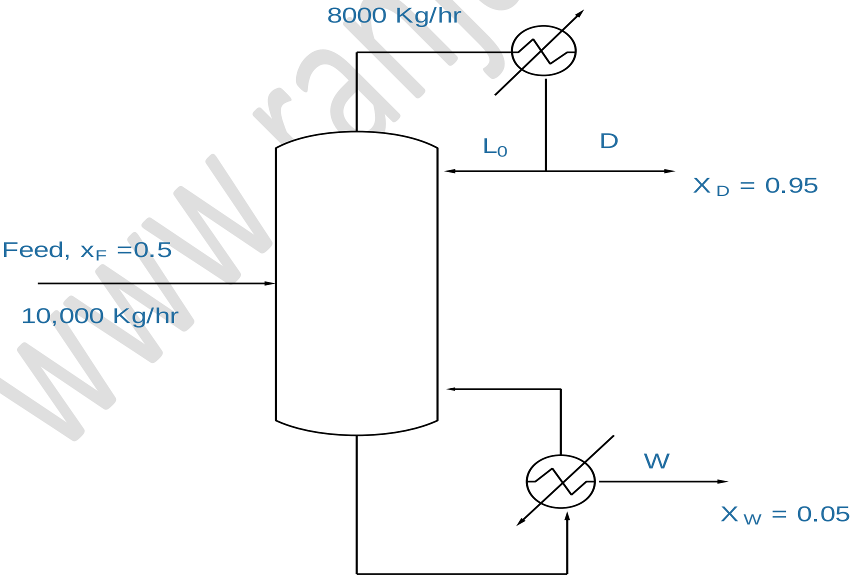
(a) 11 and 110 kg/hr (b) 24 and 240 kg/hr

(c) 11 and 5.5 kg/hr (d) 70 and 330 kg/hr

Solution

Gate-2004

1. A distillation column separates 10,000 kg/h of a benzene-toluene mixture as shown in the figure below. In the figure, X_F, X_D, and X_W represent the weight fraction of benzene in the feed, distillate, and residue, respectively.



The reflux ratio is –

(a) 0.5 (B) 0.6 (C) 1.0 (D) 2.0

Solution

2. The weight fraction of methanol in an aqueous solution is 0.64. The mole fraction of methanol X_M satisfies.

(A) $X_M < 0.5$ (B) $X_M = 0.5$

(C) $0.5 < X_M < 0.64$ (D) $X_M \geq 0.64$

Solution

3. 80 kg of Na_2SO_4 (molecular weight = 142) is present in 330 kg of an aqueous solution. The solution is cooled such that 80 kg of Na_2SO_4. 10 H_2O crystals separate out. The weight fraction of Na_2SO_4 in the remaining solution is

(A) 0.00 (B) 0.18 (C) 0.24 (D) 1.00

Solution

Common Data Question 4&5

One mole of methane undergoes complete combustion in a stoichiometric amount of air. The reaction proceeds as $CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$. Both the reactants and the products are in gas phase.

$\Delta H^0 298 = -730$ kJ/mol of methane.

4. Mole fraction of water vapour in the product gases is about

(A) 0.19 (B) 0.33 (C) 0.40 (D) 0.67

Solution

5. If the average specific heat of all the gases/vapour is 40 J/(mol k), the maximum temperature rise of the exhaust gases in ^{0}C would be approximately equal to

(A) 1225 (B) 1335 (C) 1525 (D) 1735

Solution

Gate-2003

1. 6 g of carbon is burnt with an amount of air containing 18 g oxygen. The product contain 16.5 g CO_2 and 2.8 g CO besides other constituents. What is the degree of conversion on the basis of disappearance of the limiting reactant ?

a) 100% b) 95 % c) 75 % d) 20 % solution

2. An aqueous solution of 2.45% by weight H_2SO_4 has a specific gravity of 1.011. The composition expressed in normality is

a) 0.2500 b) 0.2528 c) 0.5000 d) 0.5055

Solution

3. Na_2SO_4, 10 H_2O crystals are formed by cooling 100 kg of 30% by weight aqueous solution of Na_2SO_4. The final concentration of the solute in the solution is 10%. The weight of crystals is

a) 20 b) 32.2 c) 45.35 d) 58.65

Solution

4. A sample of natural gas containing 80% Methane (CH_4) and the rest Nitrogen (N_2) is burnt with 20% excess air. With 80% of the combustibles producing CO_2 and the remainder going to CO the Orsat analysis in volume percent is

a) CO_2 : 6.26 CO : 1.56 O_2 : 3.91 H_20 : 15.66 N_2 : 72.60

b) CO_2 : 7.42 CO : 1.86 O_2 : 4.64 N_2 : 86.02

c) CO_2 : 6.39 CO : 1.60 O_2 : 3.99 H_20 : 15.96 N_2 : 72.06

d) CO_2 : 7.60 CO : 1.90 O_2 : 4.75 N_2 : 85.74

Solution

Gate-2002

1. Methane is mixed with stoichiometric proportion of oxygen and completely combusted. The number of additional specifications required to determine the product flow rate and composition is

A) 0 B) 1 C) 2 D) 3

Solution

2. Fresh orange juice contains 12% (by weight) solids and the rest water. 90% of the fresh juice is sent to an evaporator to remove water and subsequently mixed with the remaining 10% of fresh juice. The resultant product contains 40% solids. The kg of water removed from 1 kg fresh juice is

A) 0.4 B) 0.5 C) 0.6 D) 0.7

Solution

3. 1 kg of saturated aqueous solution of a highly soluble component A at 60^0C is cooled to 25^0C. The solubility limits of A are (0.6 kg A)/(kg water) at 60^0C and (0.2 kg A)/(kg water) at 25^0C. The amount, is kgs, of the crystals formed is

A) 0.4 B) 0.25 C) 0.2 D) 0.175

Solution

Gate-2001

1. For the case of a fuel gas undergoing combustion with air, if the air/fuel ratio is increased, the adiabatic flame temperature will

A) increase B) decrease

C) increase or decrease depending on the fuel type D) not change

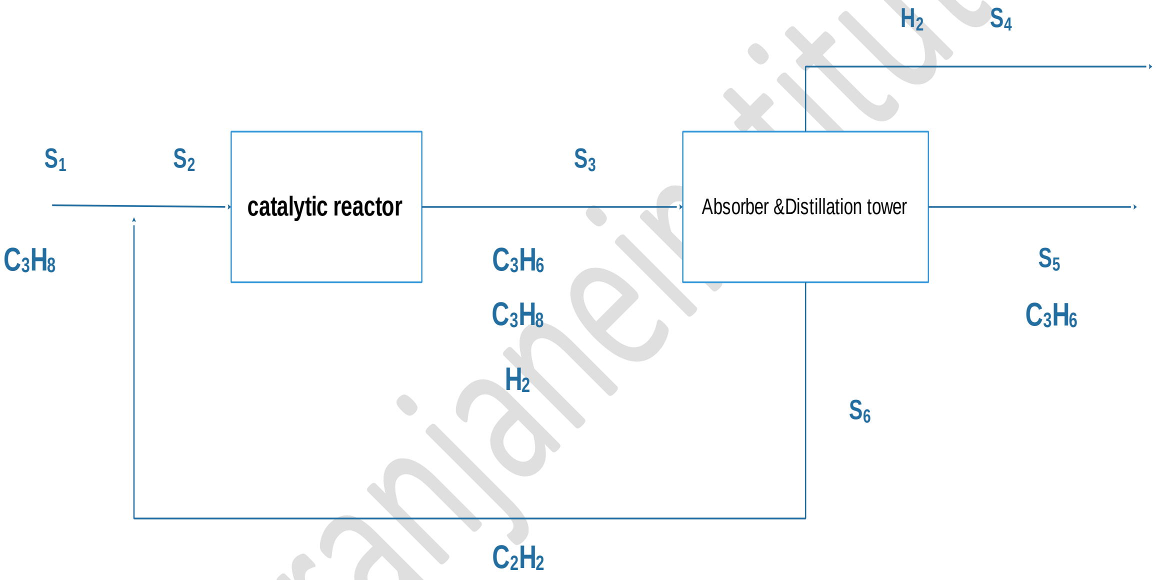
Solution

2. A butane isomerization process produces 70 kmol/h of pure isobutane. A purge stream removed continuously contains 85% n butane and 15% impurity (mole %). The feed stream is n-butane containing 1% impurity (mole %). The flow rate of the purge stream will be

A) 3 kmol/h B) 4 kmol/h C) 5 kmol/h D) 6 kmol/h

Solution

3. The process schematic of a propane dehydrogenation plant is shown below. It is desired to set up a simplified version of the material balance for this plant. Assume that the only reaction is the dehydrogenation of propane (C_3H_8) to propylene (C_3H_6) there are no side reactions. The yield of propylene per pass is 30% (i.e., 30% of the propane entering the reactor is converted to propylene). Assume that the amount of carbon formed on the catalyst is negligible. The product flow rate (stream S_5) is 50 kmol/h. Calculate the flow rates of all the other streams. Notice that all streams except stream S_3, are pure.



Solution

Gate-2000

1. The molar composition of a gas is 10% H_2, 10% O_2, 30% CO_2 and balance H_2O. If 50% H_2O condenses, the final mole percent of H_2 in the gas on a dry basis will be

A) 10 %, B) 5 %, C) 18.18 %, D) 20 %,

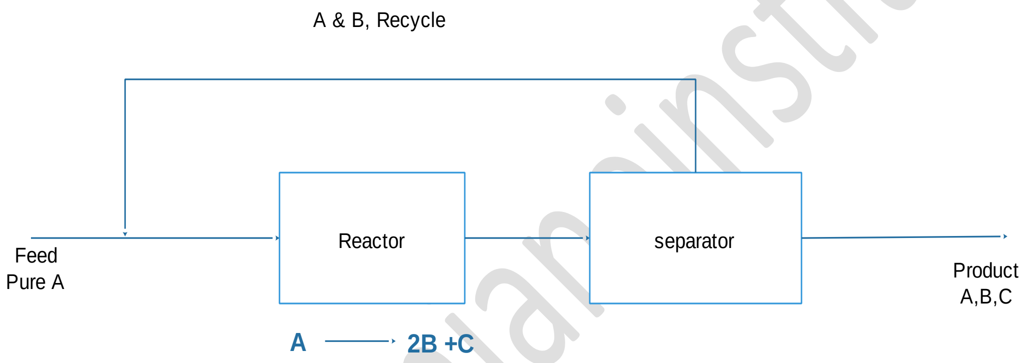
Solution

2. The reaction A→2B + C takes place in a catalytic reactor (see diagram 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 the

a) single pass conversion of A in the reactor.

b) molar ratio of recycle to feed.



Solution

Gate-1999

1. It is proposed to produce acetaldehyde by oxidation of ethanol in gas phase: C_2H_5OH (g) + ½ O_2 (g)→CH_3CHO (g) + H_2O (g). The ratio of air to ethanol in the fresh feed (before it is mixed with recycle stream) is 10 to 1. The conversion of ethanol on a single pass through the reactor is 25%. The unreacted ethanol is completely separated from the reaction products and recycled. What is the ratio of recycle stream to the fresh feed stream ? What is the composition of the outlet stream from the reactor in mass fraction and mole fraction ?

Solution

2. A solution of specific gravity 1.0 consists of 35% A by weight and the remaining B. If the specific gravity; of A is 0.7, the specific gravity of B is

A) 1.25 B) 1.3 C) 1.35 D) 1.2

Solution

3. Pure A in gas phase enters a reactor. 50% of this A is converted to B through the reaction A →3B. Mole fraction of A in the exit stream is

A) 1/2 B) 1/3 C) 1/4 D) 1/5

Solution

Gate-1998

1. Pure ethanol vapour is fed to a reactor packed with Alumina catalyst, at the rate of 100k.mol/h. The reactor products comprise : Ethylene: 95 kmol/h, water vapour : 97.5 kmol/h and diethylene either : 2.5 kmol/h. The reactions occurring can be represented by :

$$C_2H_5OH \rightarrow C_2H_4 + H_2O$$

$$2C_2H_5OH \rightarrow C_2H_5\text{-}O\text{-}C_2H_5 + H_2O$$

The percent conversion of ethanol in the reactor is :

A) 100.0 B) 97.5 C) 95.0 D) 2.5

solution

2. For reaction P + 2Q → 3R, molar rate of consumption of P is

A) double of that of Q
B) same as that of Q
C) half of that of Q
D) 2/3 of that of Q

Solution

3. Ethylene Oxide is produced by the oxidation of Ethylene over a catalyst. Safety considerations dictate that the gaseous mixture entering the reactor should contain 10 mol Air per mol Ethylene. The conversion per pass is 22%. The Ethylene oxide formed is completely condensed out and the remaining gases recycled. Make up oxygen is added to maintain the requisite oxygen levels. For a plant producing 440 kg/h of ethylene oxide.

(i) Calculate the quantity of pure makeup oxygen to be supplied, in kg/h, in steady; state operation

(ii) Draw a neat block diagram showing the major units, flows and compositions, and indicate the envelope / boundary around which the requisite mass balance(s) is/are being made.

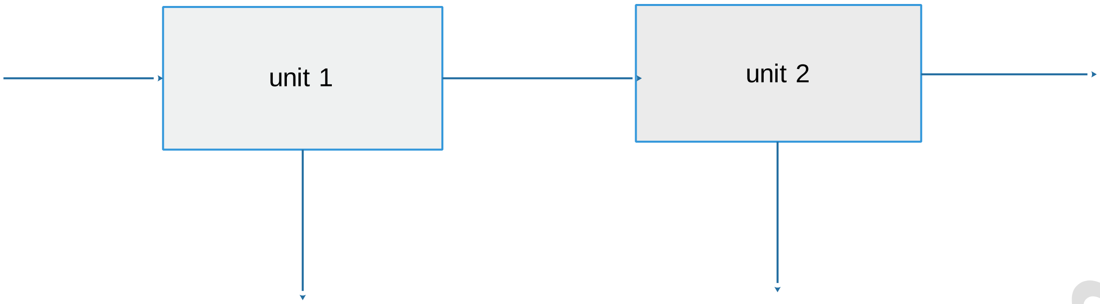
The relevant reaction is represented by – $2\ C_2H_4\ (g) + O_2(g) \rightarrow 2\ C_2H_4O\ (g)$

[Assume atomic masses as : C = 12, 0 = 16, H = 1]

Solution

Gate-1997

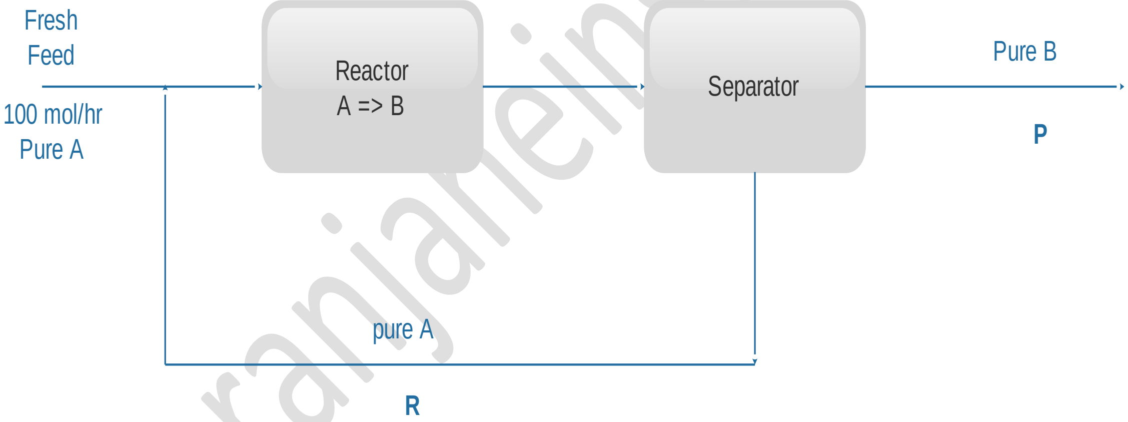
1. In the system as shown in Fig. each stream contains three components.



The maximum number of independent material balances is [solution]

A)	3	B)	4
C)	6	D)	9

2. A flow sheet is given in Figure

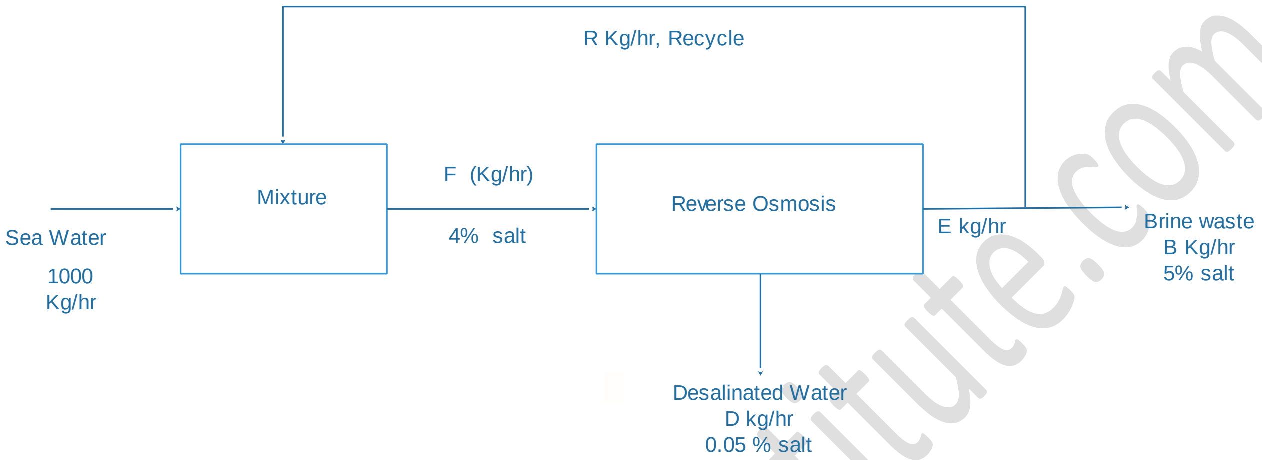


If the single-pass (once-through) conversion of A to B is 20%. Then the rate of recycle R (moles/hr) is

A) 300 B) 400 C) 500 D) 600

solution

3. Sea water is desalinated by reverse osmosis as shown in Fig. 12. Feed is 1000 Kg/hr sea water salt containing 3 % salt. All other streams concentrations are given in figure below



All compositions are on mass basis. Calculate R/E. solution

4. A feed at 1298 K, consisting of flue gas (CO_2, O_2 and N_2) and air, is passed through a bed of pure carbon. The two reactions that occur both go to completion

$$CO_2\,(g) + C(s) \rightarrow 2CO\,(g), \quad \Delta H_R^0 \text{ at } 298\text{ K} = 170\text{ kJ/mol}$$

$$O_2\,(g) + 2C(s) \rightarrow 2CO\,(g), \quad \Delta H_R^0 \text{ at } 298\text{ K} = -220.4\text{ kJ/mol}$$

The combustor is adiabatic and the product gases exit at 1298 K. Calculate the required moles of CO_2 per mol of O_2 in the feed stream, so that the net heat generated is zero and the bed temperature remains constant at 1298 K.

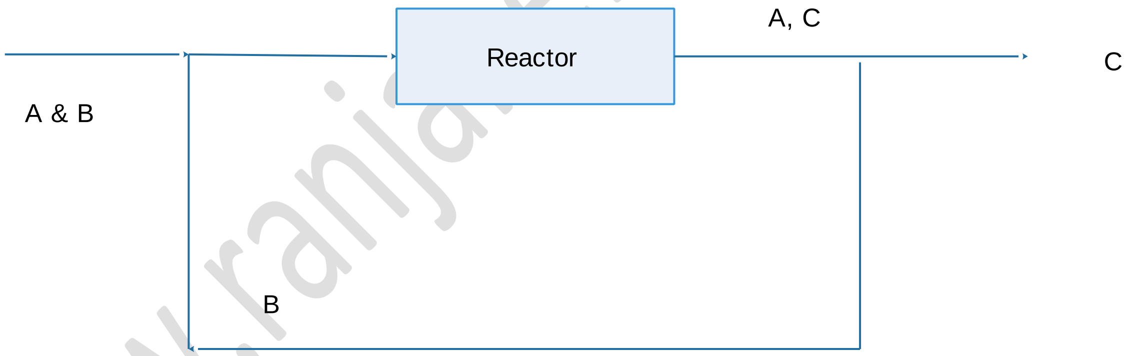
Data : Mean Molar Heat Capacities, Cpm

Substance	Cpm, kJ/(mol)(K)
C	0.02
O_2	0.03
CO	0.03
CO_2	0.05

solution

Gate-1996

1. The reaction A + B→C has been conducted in a reactor as shown



I. The number of boundaries around which material balances can be written are –

a. 1

b. 6

c. 3

d. 4

solution

II. The number of independent balances (material) that can be made around the reactor are –

a.	1	b.	2
c.	3	d.	4

solution

2. A hydrocarbon is burnt with excess air. The Orsat analysis of the flue gas shows 10.81 % CO_2, 3.78 % O_2 and 85.45 % N_2. Calculate the atomic ratio of C : H in the hydrocarbon and the % excess air.

solution

3. Methanol vapour can be converted into formaldehyde by the following reaction scheme

$$CH_3OH + \tfrac{1}{2} O_2 \rightarrow HCHO + H_2O$$

$$CH_3OH \rightarrow HCHO + H_2$$

The fresh feed to the process was 0.5 kg mol/ h O_2 and an excess methanol. All of the O_2 reacts in the reactor. Formaldehyde and water are removed from the product stream first, after which H_2 is removed from the recycled methanol. The recycle flow rate of methanol was 1 kg mol/h. The ratio of methanol reacting by decomposition to that by oxidation was 3. Draw the flow diagram and then calculate the per pass conversion of methanol in the reactor and the fresh feed rate of methanol.

solution

Gate-1995

1. 1000 kg of wet solids are to be dried from 60% to 20% moisture (by weight). The mass of moisture removed in kg is – solution

(A) 520 (B) 200

(C) 400 (D) 500

2. Assuming that CO_2 obeys perfect gas low, calculate the density of CO_2 (in kg/m^3, at and 2 atm & 536 K.)

(A) 1 (B) 2

(C) 3 (D) 4

Solution

3. Pure O_2 is mixed with air to produce an enriched air containing 50 volume % of O_2. The ratio of moles of air to O_2 used is –

(A) 1.72 (B) 0.58

(C) 0.5 (D) 0.2

Solution

4. Methanol is produced by the reaction of CO with H_2 : $CO + 2H_2 \rightarrow CH_3OH$. Only 15% of carbon monoxide entering the reactor is converted to methanol. The methanol formed is condensed and recovered completely. The unreacted CO and H_2 are recycled back to the reactor. The feed will contain H_2 and CO in the ratio of 2 : 1. For 3200 kg/hr of methanol produced, calculate –

(i) kg mole/hr of fresh feed
(ii) kg mole/hr of recycle gas
Mol Weight of CH_3OH = 32

solution

5. The Orsat analysis of a flue gas is

CO_2	12.7%
O_2	7.1%
N_2	80.2%

Determine the percent excess air used in the combustion. The nitrogen present in the flue gas is contributed by air only.

solution

6. Pure CO is mixed with 100% excess air and burnt. Only 80% of CO burns. The reactants are at 100^0C and the products are at 300^0C. Calculate the amount of heat added or removed per kg mole of CO fed to the reactor.

Data : Mean molal specific heats between 25^0C and T^0C (given below) in KJ/kg.mole.K are –

Gas	$T = 100^0C$	$T = 300^0C$
CO	20.22	30.61
CO_2	--	43.77

O_2	29.64	30.99
N_2	29.17	29.66

Standard heat of formation at 250^0C in KJ/kg mole are –

CO : -110524 CO_2 : -393514

solution

7. Bituminous coal with a calorific value of 20000 kJ/kg is used for generating steam in a boiler. How much coal has to be burnt to generate 1 MW of energy. Efficiency of combustion is 0.75. How much air is needed if 50% excess air is to be used. Assume that coal contains 67% carbon and 33% ash.

solution

Gate-1993

1. 1000 kg of a solution containing 50% by weight of a salt dissolved in it is cooled. 400 kg of anhydrous salt is separated out. The solubility of the salt at the lower temperature per 100 kg of water is,

I. 80

II. 50

III. 40

IV. 20 solution

2. Methane is completely burned with air. The maximum possible volume percen of carbon dioxide (on dry basis) in the flue gases is,

I. 11.7

II. 21.0

III. 44.0

IV. 28.0 solution

3. Iron pyrites (FeS2) is burned with air in 100% excess of that required to oxidize all iron to Fe2O3 and all sulphur to sulphur dioxide. Calculate the composition of exit gases, if 80% of sulphur is oxidized to sulphur trioxide and the rest to sulphur dioxide. All iron is oxidized to Fe2O3

solution

Gate-1992

1. It is a desired to make 100 kg of a solution containing 40% salt by mixing solution A containing 25% salt and solution B containing 50% salt. The mass in kg of solution A required is ________________

solution

2. 1.2 g atoms of carbon and 1.5 g moles of oxygen are reacted to give 1 g mole of carbon dioxide. the limiting reactant is______________ the percent excess reactant supplied is

solution

3. The concentration of SO_2 in flue gases from a boiler was found to be 0.2 kg/ m$^{3.}$ at NTP determine the concentration of SO_2 in part per million by volume at NTP assume that the gases are perfect solution

4. The analysis of the gas entering the secondary converter in a contacts sulphuric acid plant is 4% SO_2, 13% O_2, 83% N_2 (by volume) . In the converter

SO_2 is oxidised to SO_3 the gases leaving the converter contains 0.45% SO_2 on SO_3 free basis . Calculate the percent conversion of SO_2.

solution

5. Dry Methane is burnt with dry air both are at 25 °C .initially the flame temperature is 1300 °C if the complete combustion is assumed how much excess air is being used .the reaction is

$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$

Standard heat of reaction = -8.028 10^5 J/g mole of CH_4 reacted, mean mol at specific heat of gases between 25°C and 1300°C are in J/(g.mole °K)

$CO_2 = 51.88$

$H_2O = 40.45$

$O_2 = 34.01$

$N_2 = 32.21$

solution

Gate-1991

1. A wet paper pulp contains 75% water after 100 kg of water is removed in a dryer, it is found that the pulb is now containing 30% of water. the weight of original pulp is solution

2. H_2S is Produced from the reaction

$Fes + 2HCL \rightarrow Fecl_2 + H_2S$

120 kg of Fes react with 150 kg of HCL and 0.5 k mole of H_2S has has been Produc
The degree of completion of the reaction is and the limiting reactant is_________ in
the limiting reactant is___________

Solution

3. The heat absorbed for isothermal reaction

$C_4H_{10}(g) \rightarrow C_2H_4(g) + C_2H_6(g)$

at 298 K and 1 ATM pressure is__________standard heat of combustion kg/ mo

$C_2H_{10}(g) = -2873.5$

$C_2H_4(g) = -1411.9$

$C_2H_6(g) = -1561.0$

Solution

4. Limestone mixed with Coke is being burnt in a kiln an average analysis of the limestone is $CaCO_3$ 84.5 % $MgCO_3$ 11.5% and the rest inert the coke contain 76% carbon 21% ash and 3% moisture the The calcination of $CaCO_3$ is only 95% complete and that of $MgCO_3$ 90% the carbon in the Coke is completely burnt to CO_2 the kiln is fed with 1 kg of Coke per 5 kg limestone calculate weight percent CaOin the product leaving the kiln.

Solution

GATE- 1990

1. The following data on heats of combustion at 25°C are given

Compound Heat of combustion at 25°C

n-Heptane C_7H_{16} (g)	- 4850 kJ / mol
Ethyl Alcohol C_2H_5OH (g)	- 1410 kJ / mol

Heats of formation of CO_2 (g) and H_2O (l) are -380 kJ / mol and –280 kJ / respectively.

I. The heat of formation of gaseous n-Heptane at 25°C is ________

II. The heat of formation of gaseous Ethyl Alcohol at 25°C is ________

solution

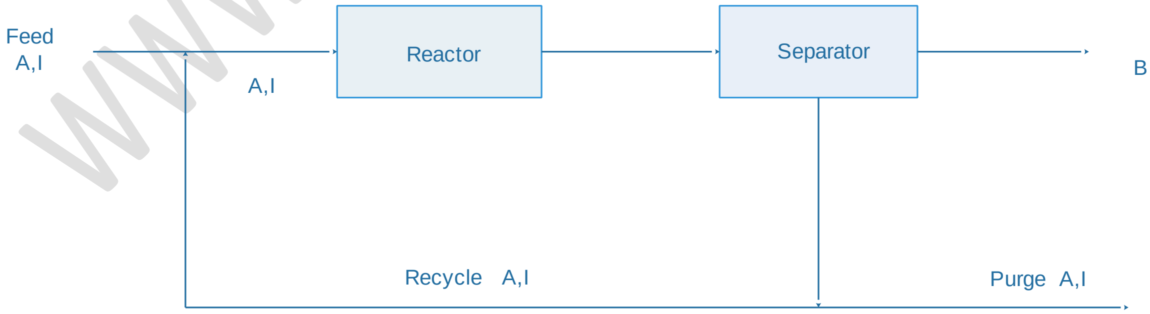
2. Pure propane (C_3H_8) is burnt in an excess of air to give following analysis of combustion products in volume percent:

$CO_2 = 5.0$, $CO = 3.5$, $H_2O = 11.4$, $O_2 = 7.0$ and $N_2 = 73.1$

Calculate the percentage of excess air used.

solution

3. For the reaction A → B, the process flow diagram is shown in figure.1.The fresh feed of A contains 0.5 % of inert by volume. 60% conversion per pass of A fed to the reactor is obtained. The concentration of inert going into the reactor (after mixing with the recycle stream) must be held at 2% by volume. All streams are ideal gases and the process is at steady state. How many moles need to be recycled per mole of total feed to the reactor at (1).



solution

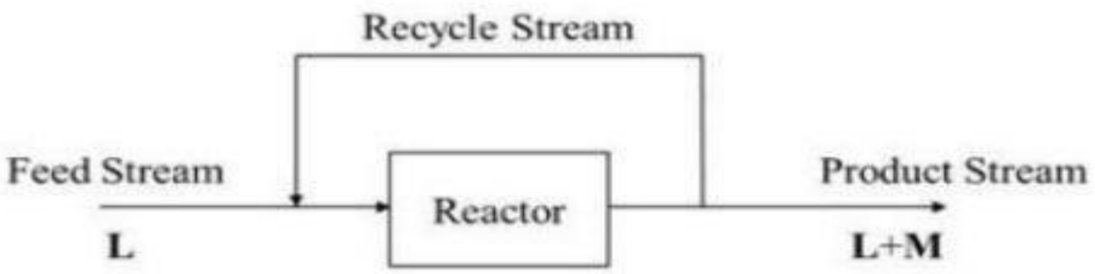
Answer Key

	Question No						
	1	2	3	4	5	6	7
90	-190	37.32	0.344				
91	155.55	36.76	99.4	71.39%			
92	A	25	70,000	89.35	82.064		
93	D	A	——				
94							
95	D	B	A	R=1700 300	49.93	191926.35	coal=0.066 Air= 0.771
96	1.1 –D 1.2 -B	C/H=0.33 %exc=19.97%	Feed rate= 4 Conversion=80%				
97	A	B	0.626	1.44			
98	A	B	160 kg/hr				
99	RR=0.272	B	C				
00	D	A – 8.65 B – 9.96					
01	B	C	———				
02	C	D	B				
03	B	D	D	B			
04	B	B	B	A	D		
05	B	C					
06	a – D b - A						
07	a – D b - C	a – C b – B					
08	C	B	B				
09	B	C					
10	C	D					
11	A	B					
12	a – B b - A						
13	1 – 3.2 to 3.4 2 – 0.266						
14	10	34.66					
15	45.53						
16	B	D					
17	200						

18	**102.40**	**0.184**	**D**				
19	**C**						
20	**26.3%**						

Solution G-2020

1)



Basis: L = 100 Kg/hr fresh feed

At steady- state:

Overall material balance: Mass flow rate of feed stream = Mass flow rate of product stream

Feed stream (L) = 100 Kg/hr

$$\Rightarrow Mass\ flow\ rate\ of\ \ Product\ stream\ =\ 100\ kg/hr$$

$$\Rightarrow Mass\ flow\ rate\ of\ \ Recycle\ stream\ =\ 100\times 0.20\ = 20\ kg/hr$$

$$\Rightarrow Mass\ flow\ rate\ of\ stream\ just\ after\ the\ reactor\ =\ \ product\ stream\ +\ recycle\ stream$$

$$=\ 100\ kg/hr\ +\ \ 20\ kg/hr\ \ = 120\ kg/hr$$

$$Overall\ conversion\ =$$

$$\frac{mass\ of\ the\ reactant\ (L)\ in\ the\ fresh\ feed\ -\ mass\ of\ the\ reactant\ (L)\ in\ the\ output\ of\ the\ overall\ process}{mass\ of\ reactant\ (L)\ in\ the\ fresh\ feed}$$

$$0.30\ =\ \frac{100\ -\ mass\ of\ rectant\ in\ the\ product\ stream}{100}$$

$$\Rightarrow\ mass\ of\ reactant\ (L)\ in\ the\ product\ stream\ =\ 70$$

$$\Rightarrow\ mass\ of\ \ M\ in\ the\ product\ stream\ =\ 30$$

This percentage of L(70%) and M (30%) will remain the same in the stream just after the reactor and in the recycle stream.

↑

$$\Rightarrow Mass\ flow\ rate\ of\ L\ just\ after\ the\ reactor\ =\ 120 \times 0.70\ =\ 84$$

$$\Rightarrow Mass\ flow\ rate\ of\ M\ just\ after\ the\ reactor\ =\ 120 \times 0.30\ =\ 36$$

$$\Rightarrow Mass\ flow\ rate\ of\ L\ in\ recycle\ stream\ =\ 20 \times 0.70\ =\ 14$$

$$\Rightarrow Mass\ flow\ rate\ of\ M\ in\ recycle\ stream\ =\ 20 \times 0.30\ =\ 6$$

$$\Rightarrow Mass\ flow\ rate\ of\ L\ entering\ in\ the\ reactor$$
$$=\ L\ (from\ fresh\ feed)\ +\ L(from\ recycle\ stream)$$

$$= 100\ +\ 14\ =\ 114$$

Amount of L converted inside the reactor = Amount of L entering into the reactor - Amount of L exiting through the reactor

Amount of L converted inside the reactor = 114 - 84 = 30 $Single - pass\ conversion\ (one - pass\ conversion):$

$$= \frac{mass\ of\ the\ reactant(L)\ fed\ into\ the\ reactor - mass\ of\ the\ reactant(L)\ exiting\ the\ reactor}{mass\ of\ reactant(L)\ fed\ into\ the\ reactor}$$

$$= \frac{114\ -\ 84}{114} = \frac{30}{114} = 0.263$$

Therefore, one-pass conversion of L (based on mass unit) through the reactor is 26.3 %.

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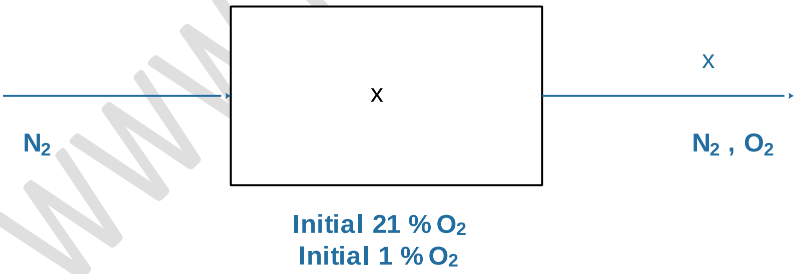
2)



Unsteady-state mole balance:

Rate of mole of oxygen entering into the tank - rate of mole of oxygen exiting the tank = rate of accumulation of oxygen in the tank

Let ‘x’ is the mole % of oxygen at any time ‘t’ inside the tank.

$$x \times molar\ flow\ rate\ of\ entering\ feed\ - x \times molar\ flow\ rate\ of\ exiting\ feed$$

$$= \frac{\partial(x \times\ molar\ density\ of\ mixture \times volume\ of\ tank)}{\partial t}$$

$$0 \times molar\ flow\ rate\ of\ entering\ feed\ - x \times 8\ = \frac{\partial(x\ \times\ \ 40\ \times\ 20)}{\partial t}$$

$$0\ - 8x\ = \frac{800\partial x}{\partial t}$$

$$\partial t\ =\ -100\frac{\partial x}{x}$$

$$t\ =\ -100\int_{0.21}^{0.01}\frac{\partial x}{x}$$

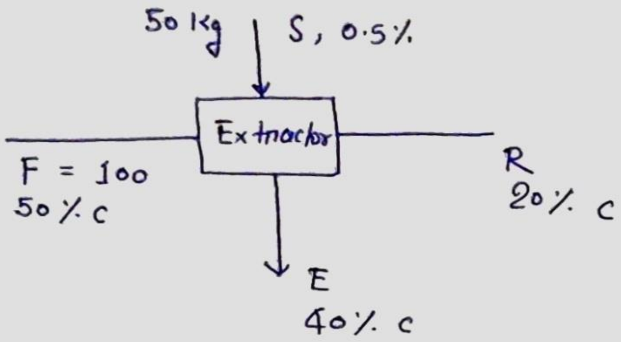
$$\Rightarrow\ t\ =\ -100 * ln\ \frac{0.01}{0.21}$$

$$\Rightarrow\quad t\ =\ -100 \times (-3.0445)\ = 304.5\ seconds$$

Therefore, the time required (in seconds) for oxygen content in the tank to decrease to 1% is 304.5 seconds.

G- 2019

①



→ overall material balance —

$$F + S = E + R$$

$$E + R = 180 \quad — \text{(I)}$$

→ c material balance —

$$50 \times \frac{0.5}{100} + 100 \times \frac{50}{100} = E \times \frac{40}{100} + R \times \frac{20}{100}$$

$$2E + R = 251.25 \quad — \text{(II)}$$

→ solving equation (I) & (II)

~~E = 101.25~~

~~R = 48.75~~

~~→ E/R = 101.25/48.75~~

$$E = 71.25$$

$$R = 108.75$$

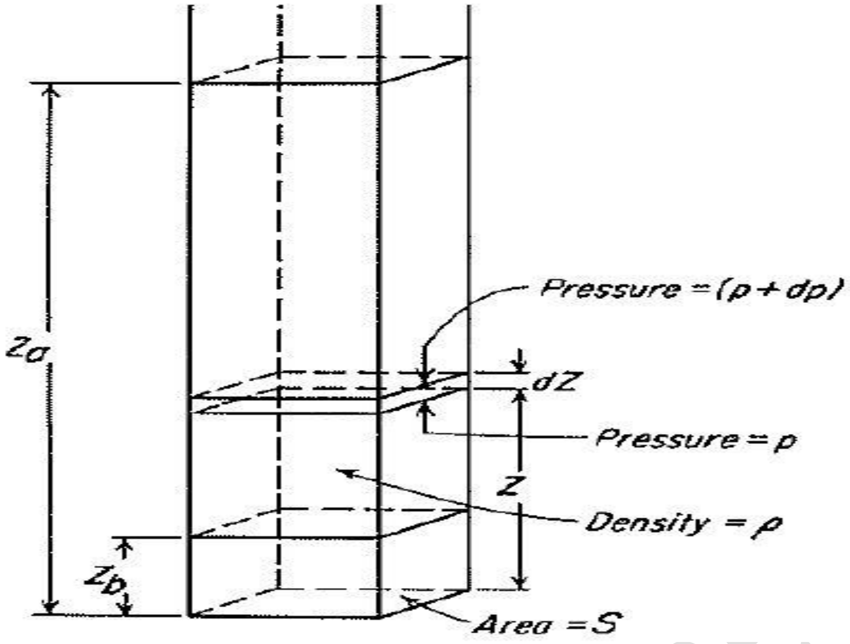
$$\rightarrow E/R = \frac{71.25}{108.75} = 0.66 \simeq \frac{2}{3}$$

Ans: C

Solution G-2018

1)

Consider the vertical column of gas shown in the figure. Assume the cross- sectional area of the column is S. At a height Z above the base of the column let the pressure be p and density be row. Now apply force balance on the small volume of gas of height dz and cross- sectional area S.



$$pS = (pgh + dp)S + \rho \times (S \times dL) \times g$$

$-dpS = \rho \times (S \times dL) \times g$ ------------------ (i)

For an ideal gas density and pressure are related by the equation :

$$\rho = \frac{pM}{RT} \qquad \text{------------------ (ii)}$$

M: Molecular weight

T: Absolute temperature

Substitution from (ii) into (i), gives

$$-dpS = \frac{pM}{RT} \times (S \times dL) \times g$$

$$-\frac{dp}{p} = \frac{Mg}{RT} \times dL$$

Integrating between levels a and b, Given T is constant.

$$\int_a^b -\frac{dp}{p} = -\frac{Mg}{RT}\int_a^b (La - Lb)\, dL$$

$$\ln\frac{p_a}{p_b} = -\frac{Mg}{RT}(L_a - L_b)\ :\ Barometric\ Equation$$

Here, $L_a = 0, L_b = 100$

On substituting the given values,

$$\boldsymbol{\ln\frac{p_a}{100\ kPa} = -\frac{60 \times 9.81}{1000 \times 8.314 \times 298.15}(0 - 100)}$$

$$\boldsymbol{\Rightarrow p_a = 102.40\ kPa}$$

Therefore, pressure at the bottom of the tube will be 102.40 kPa.

2)

Basis:

Let NH_3fed into the reactor = 100 mole

$$4NH_3 + 5O_2 \rightarrow 6H_2O + 4NO$$

Stoichiometric numbers represent the quantity of any reactant that is theoretically required for complete conversion of other reactants**.**

Theoretical O_2required for complete conversion of NH_3 = $\frac{5}{4} \times 100 = 125$

Excess O_2supplied = 125 (1.2) = 150

Theoretical air required for complete conversion of NH_3 = $\frac{125}{0.21} = 595.238$

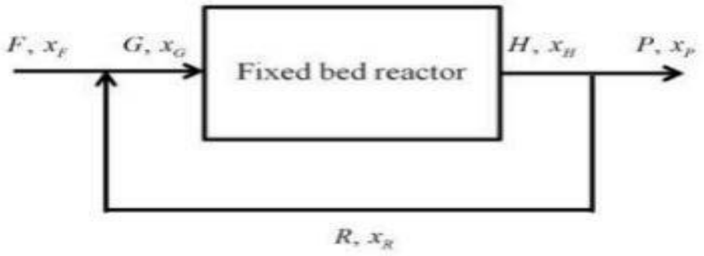
Excess air supplied = 595.238 (1.2) = 714.285

$$\boldsymbol{Mole\ fraction\ of\ O_2 = \frac{Number\ of\ moles\ of\ O_2\ in\ the\ inlet\ gas\ mixture}{Total\ Number\ of\ moles\ of\ Air\ and\ NH_3}}$$

$$\boldsymbol{Mole\ fraction\ of\ O_2 = \frac{150}{(714.285\ +\ 100)} = \frac{150}{814.285} = 0.184}$$

Therefore, the mole fraction of O_2 in the inlet gas mixture $(NH_3 + air)$ is 0.184 .

3)



$$\mathit{Overall\ frcational\ conversion} = \frac{\mathit{moles\ of\ the\ reactant\ (M)\ in\ the\ fresh\ feed} - \mathit{moles\ of\ the\ reactant\ (M)\ in\ the\ output\ of\ the\ overall\ process}}{\mathit{moles\ of\ reactant\ (M)\ in\ the\ fresh\ feed}}$$

Moles of the reactant (M) in the fresh feed $=Fx_F$

Moles of the reactant (M) in the output of the overall process $=Px_P$

Moles of M converted on the basis of fresh feed = Moles of the reactant (M) in the fresh feed - Moles of the reactant (M) in the output of the overall process

⇒ Moles of M converted on the basis of fresh feed $=Fx_F - Px_P$

$$\Rightarrow \quad \mathit{Overall\ fractional\ conversion} = \frac{Fx_F - Px_P}{Fx_F}$$

Therefore, overall fractional conversion is $\frac{Fx_F - Px_P}{Fx_F}$.

Solution G-2017

1)

Let the feed flow rate for a production of 100kg/s of the hydrated salt = F kg/s

And let mother liquor flow rate = M kg/s

$$m_s: \mathit{mass\ fraction\ of\ salt\ in\ the\ crystals}$$

Overall mass balance at steady-state:

F = 100 + M -- (i)

Salt balance:

$$F \times (solubility\ at\ 60℃)\ = 100 \times m_s + M \times (solubility\ at\ 20℃)\ \text{--------------------}\quad \text{(ii)}$$

$$Mass\ fraction\ of\ salt\ in\ the\ one\ molecule\ of\ crystal\ (m_s)$$

$$= \frac{Molecular\ weight\ of\ salt}{Molecular\ weight\ of\ salt\ + total\ weight\ of\ water\ in\ the\ crytstal}$$

$$\Rightarrow\ m_s = \frac{135}{135\ +\ 5 \times 18} = \frac{135}{225} = 0.60$$

$$solubility\ at\ 60℃\ = 40\ wt\%$$

$$solubility\ at\ 25℃\ = 20\ wt\%$$

On substituting all the values in (ii)

$$F \times 0.40\ = 100 \times 0.60 + M \times 0.20\ \text{------------------------}\quad \text{(iii)}$$

From (i) and (iii)

$$F \times 0.40\ = 100 \times 0.60 + (F - 100) \times 0.20$$

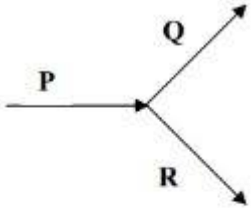
$$0.40F\ = 60\ + 0.20F\ - 20$$

$$F\ = \frac{40}{0.20} = 200$$

Therefore, the feed flow rate required for a production rate of 100 kg/s of the hydrated salt is 200 kg/s.

Solution G-2016

1)



Overall mass-balance:

P = Q + R

On substituting the given values:

100 = Q +R -------------------- (i)

Ethanol- balance:

$$P \times x_P = Q \times x_Q + R \times x_R$$

On substituting the given values:

On substituting the given values:

$P \times 0.30 = Q \times x_Q + R \times x_R$ ------------- (ii)

$$P \times y_P = Q \times y_Q + R \times y_R$$

Here, mole fraction x_Q and x_R will be same

2)

Stoichiometrically means write down the balanced chemical equations for both the processes.

Balanced chemical equation for de-hydro aromatisation of cyclohexane:

$C_6H_{12} \rightarrow 3H_2 + C_6H_6$ ------------------------------------ (i)

(Cyclohexane) (Hydrogen) (Benzene)

Balanced chemical equation for steam reforming of cyclohexane:

$C_6H_{12} + 12H_2O \rightarrow 18H_2 + 6CO_2$ ----------- (ii)

(Cyclohexane) (steam) (Hydrogen) (Carbon dioxide))

In equation (i) 1 mole of cyclohexane produces 3 moles of H_2 , that is the maximum amount of hydrogen produced at complete conversion of C_6H_{12}.

In equation (ii) 1 mole of cyclohexane produces 18 moles of H_2 , that is the maximum amount of hydrogen produced at complete conversion of C_6H_{12}.

Maximum ratio of hydrogen produced in the proposed process to that in the existing process $= \frac{18}{3} = 6$.

Therefore, maximum ratio of hydrogen produced in the proposed process to that in the existing process $= \frac{⍰⍰}{⍰} = ⍰$.

Solution G-2015

1)

First of all see the stoichiometry of reaction, $A \rightarrow B$ Here the number of moles will not change at any conversion.

$$\therefore \; \boldsymbol{F(moles\ entering\ into\ the\ process)} = \boldsymbol{P(moles\ exiting\ the\ process)}$$

For avoiding any accumulation of inerts,

Mole of inerts entering into the process = mole of inerts exiting the process

$$\boldsymbol{F \times 0.04 = P \times x_{Pi}}$$

$\boldsymbol{x_{pi} = 0.04}$ **{ moles of inerts in the product }**

This percentage of A(46%), inerts (4%), and C(50%) will remain the same in the stream just after the reactor and in the recycle stream.

$$\Rightarrow Molar\ flow\ rate\ of\ Stream\ just\ after\ the\ reactor = F + 0.30F = 1.30F$$

$$\Rightarrow Molar\ flow\ rate\ of\ A\ just\ after\ the\ reactor = 1.3F \times 0.46 = 0.598F$$

$$\Rightarrow Molar\ flow\ rate\ of\ A\ in\ recycle\ stream = 0.30F \times 0.46 = 0.138F$$

$$\Rightarrow Mass\ flow\ rate\ of\ M\ in\ recycle\ stream = 20 \times 0.30 = 6$$

$$\Rightarrow Molar\ flow\ rate\ of\ A\ entering\ in\ the\ reactor = A\ (from\ fresh\ feed) + A(from\ recycle\ stream)$$

$$= 0.96F + 0.138F = 1.098F$$

Amount of A converted inside the reactor = Amount of A entering into the reactor - Amount of A exiting through the reactor

Amount of A converted inside the reactor = $1.098F - 0.598F = 0.50F$

$Single - pass\ conversion\ (one - pass\ conversion):$

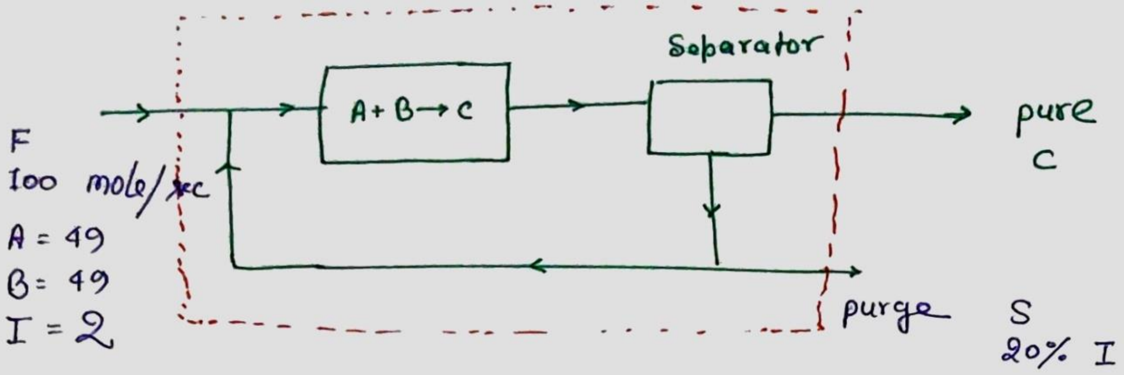
$$= \frac{moless\ of\ the\ reactant(A)\ fed\ into\ the\ reactor - moles\ of\ the\ reactant(A)\ exiting\ the\ reactor}{moles\ of\ reactant(A)\ fed\ into\ the\ reactor}$$

$$= \frac{1.098F - 0.598F}{1.098F} = \frac{0.50F}{1.098F} = 0.4553 = 45.53\%$$

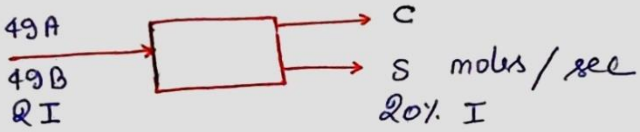
Therefore, the percentage conversion of A in the reactor based on A entering the reactor at point is 45.53 %.

G-2014

1) basis : Feed is 100 mole/sec



Inert balance over system under red box –

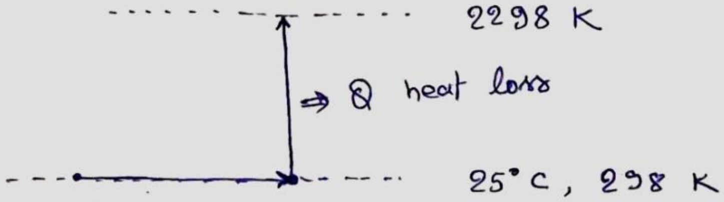


$2 = 0.2\,S$

$S = 10$ mole/sec

Ans: 10

2)



$CO + \frac{1}{2}O_2 \longrightarrow CO_2$ .... $\Delta H = -390 + 110$

$= -280$ KJ/mole

Heat generated = 280 KJ/mole CO

Heat loss = Q KJ/mole CO burnt

basis : 1 mole CO

$$CO + \frac{1}{2} O_2 \longrightarrow CO_2$$

	CO	O_2	CO_2
Required mole } →	1	0.5	
200% excess O_2 at t=0 }	1	1.5	
Reaction complion }	0	1	1

1 mole O_2 , 1 mole CO_2 will remains —

Heat balance —

$$\text{Heat generated} - \text{Heat loss} = \left[\int_{298}^{2298} m\,C_p\,dT\right]_{O_2} + \left[\int_{298}^{2298} m\,C_p\,dT\right]_{CO_2}$$

$$10^3 \times 280 - Q = \int_{298}^{2298} (25 + 14\times10^{-3}\,T)\,dT + \int_{298}^{2298} (25 + 42\times10^{-3}\,T)\,dT$$

$$280\times10^3 - Q = (36.33 + 50 + 50 + 109.032) \times 10^3$$

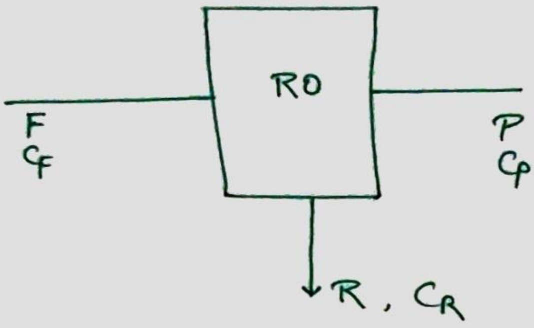
$$Q = 34.66 \times 10^3 \text{ J}$$

$$Q = 34.66 \text{ KJ}$$

34.66

GATE - 2013

1)



$C_F = 2$ mg/lit
$C_p = 0.1$ mg/L

basis : $F = 100$ lit/hr

$R = 0.6 \times 100 = 60$ lit/hr

$F = R + P \Rightarrow P = 40$ lit/hr

Fluride material balance –

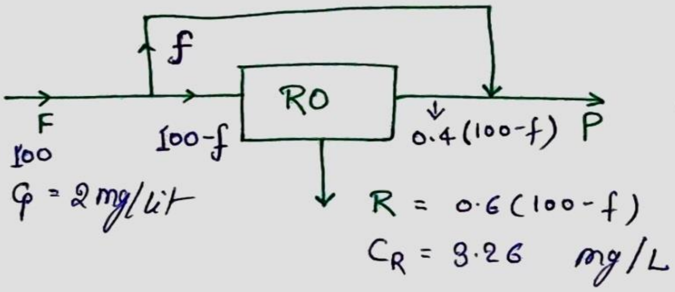
$100 \times 2 = 40 \times 0.1 + 60\, C_R$

$C_R = 3.26$ mg/lit

Ans : 3.2 to 3.4

---

2)



P
(0.4 (100-f) + f)
$C_p = 1$ mg/L

flow rate of stream just before RO unit
= 100 – f

$R = 0.6(100 - f)$
$P = f + 0.4(100 - f)$

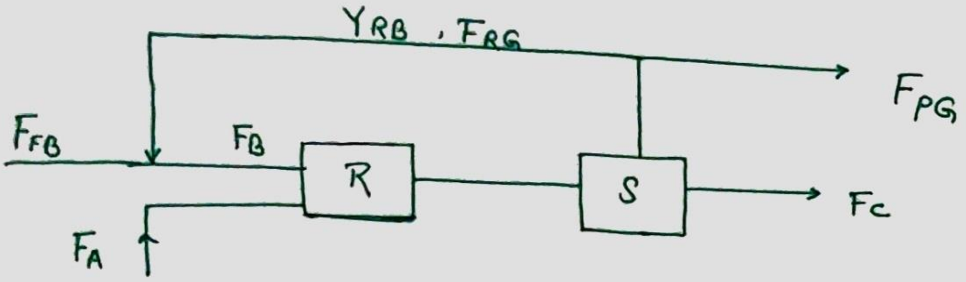
fluride material balance –

$2 \times 100 = 3.26 \times 0.6(100 - f) + [0.4(100 - f) + f]\, 1$

$\frac{f}{100} = 0.266$

Ans : 0.266

G - 2012



$A_{(L)} + B_{(g)} \longrightarrow C_{(L)} + D_{(g)}$

as A completely converted into C

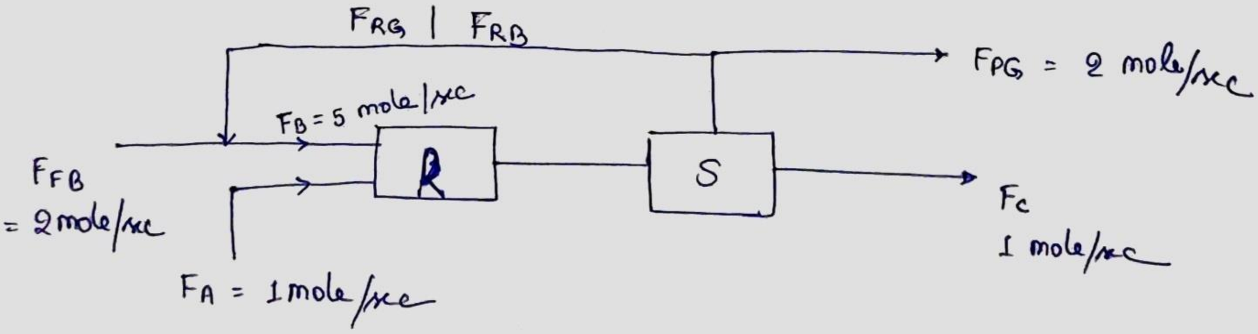
$F_A = F_C$ (separator separates liquid & gas)

$F_{FB} = F_{PG}$ (as $F_A + F_{FB} \longrightarrow F_{PG} + F_C$)

A_L +	B_g $\longrightarrow$	C_L +	D_g	
1	2	0	0	moles enitialy
0	1	1	1	moles after reaction

hence $F_C = 1$ mole / sec

$F_{PG} = F_{FB} = 2$ mole /sec



F_B = molar flow rate of B just before the reactor.

$\frac{F_B}{F_A} = 5 \Rightarrow F_B = 5$ mole/sec

F_{RB} = molar flow rate of B in recycle stream

mass balance of B @ the feed of reactor

$F_{FB} = F_{RB} + F_B$

$F_{RB} = 3$ mole/sec

and given –

$Y_{RB} = \frac{F_{RB}}{F_{RG}} = 0.3 \Rightarrow F_{RG} = 10$

hence

$\frac{F_{RG}}{F_{PG}} = \frac{10}{2} = 5$

Ans: B

now

$F_{RG} / F_{PG} = 4$

$F_{RG} = 2 \times 4 = 8$ mole/sec

$F_{RB} = 3$ mole/sec

$Y_{RB} = \frac{F_{RB}}{F_{RG}} = \frac{3}{8}$

Ans: A

G-2011

① **Basis :-**

→ Feed enlet flow rate = 100 mole/sec

H_2 = 75 m/sec

N_2 = 24 m/s

I = 1 m/s

→ Yield of NH_3 per mole fresh feed = 0.45

Hence flow rate of pure NH_3 = 45 m/s

→ $$N_2 + 3H_2 \longrightarrow \underset{45}{2NH_3}$$

Required H_2 for 45 mole NH_3 = $\frac{3}{2} \times 45$

= 67.5 m

→ conversion of H_2 is 20%

moles of H_2 entering the reactor × $\frac{20}{100}$ = 67.5

moles of H_2 entering the reactor = 337.5

→ moles of H_2 in Recycle Stream = 337.5 − 75

= 262.5

→ moles of H_2 coming out of reactor

= 337.5 − 67.5

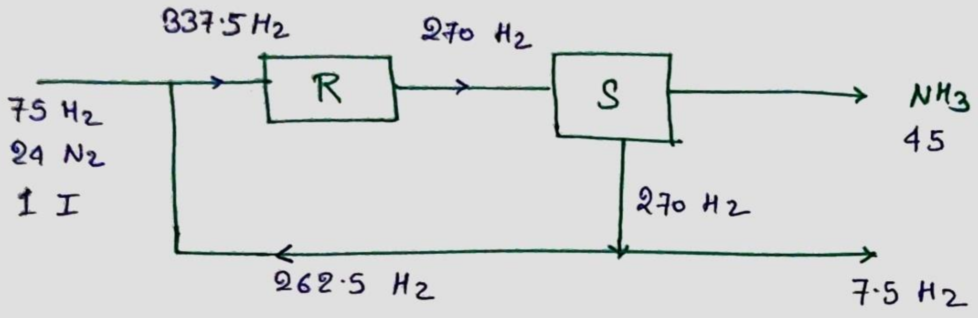
= 270

→ moles of H_2 in purge = 270 − 262.5 = 7.5

→ H_2 lost in the purge as % of H_2 in fresh feed

$$= \frac{7.5}{75} \times 100$$

$$= 10\ \%$$



Ans: A

②

$$CH_4 + 2O_2 \longrightarrow CO_2 + 2H_2O \quad — \text{(I)}$$

$$CH_4 + \frac{3}{2}O_2 \longrightarrow CO + 2H_2O \quad — \text{(II)}$$

basis :-

1 mole of CH_4 is taken initially

ratio of CO/CO_2 in flue gas is 1:3

$\frac{1}{4}$ moles will react to form CO

$\frac{3}{4}$ moles will react to form CO_2

Reaction – (I)

$$CH_4 + 2\ O_2 \longrightarrow CO_2 + 2H_2O$$

$$\frac{1}{4}$$

O_2 consumed (80% conversion) $= 2 \times \frac{3}{4} \times 0.80 = 1.2$

→ Reaction - ②

$CH_4 + \frac{3}{2} O_2 \longrightarrow CO + 2H_2O$

$\frac{1}{4}$

O_2 consumed $= \frac{3}{2} \times \frac{1}{4} \times 0.8 = 0.3$ moles

total moles of O_2 consumed $= 1.2 + 0.3$
$= 1.5$

→ theoretical O_2 required to complete conversion of O_2

$CH_4 + 2O_2 \longrightarrow CO_2 + 2H_2O$

1   2 moles

2 moles of O_2 required for complete conversion
20 % excess

O_2 supplied $= 2 \times 1.2$
$= 2.4$ moles

→ % O_2 consumed $= \frac{O_2 \text{ consumed}}{O_2 \text{ supplied}} \times 100$

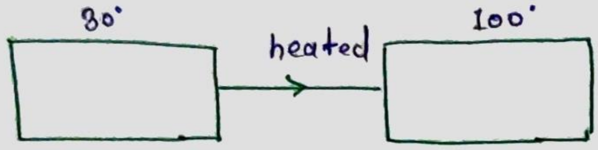
$= \frac{1.5}{2.4} \times 100$

$= 62.5$ %

Ans: B

G- 2010

①



solubility

$= \frac{5 \text{ moles solute}}{\text{Kg solvent}}$

$= \frac{5 \times 10^{-3} \times 50}{\text{Kg solvent}}$ Kg solute

$= 0.25 \ \frac{\text{Kg}}{\text{Kg}}$

↘

solubility

$= \frac{10 \text{ moles solute}}{\text{Kg solvent}}$

$= 10 \times 10^{-3} \times 50$

$= 0.5 \ \frac{\text{Kg}}{\text{Kg}}$

→ Initially 10 Kg solution is taken — 30°c

x solute Kg | y solvent Kg

$$\left.\begin{array}{l} x + y = 10 \\ \frac{x}{y} = 0.25 \end{array}\right\} \Rightarrow \begin{array}{l} 2 \text{ Kg solute} \\ 8 \text{ Kg solvent} \end{array}$$

→ after heating —

a Kg of solute is added to form saturated solution

$\boxed{\begin{array}{l} (2+a) \text{ Kg solute} \\ 8 \text{ Kg solven} \end{array}}$ 100 °C solubility 0.5 Kg / Kg

$$\frac{2+a}{8} = 0.5$$

$$a = 2 \text{ Kg}$$

Ans: c

②

$$CH_4 + 2O_2 \longrightarrow CO_2 + 2H_2O$$

$$CH_4 + \frac{3}{2}O_2 \longrightarrow CO + 2H_2O$$

basis : 100 moles of dry flue gas

CO_2 = 10 moles

CO = 0.53 moles

} CH_4 consumed = 10.53 moles

N_2 = 87.10 moles

Air supplied = $\frac{87.10}{0.79}$

O_2 supplied = $\frac{0.21}{0.79} \times 87.10$ = 23.15 moles

as there is no CH_4 in flue gas

CH_4 consumed = [CH_4 supplied] = 10.53 moles

$$\frac{CH_4 \text{ supplied}}{O_2 \text{ supplied}} = \frac{10.53}{23.15} = 0.45$$

Ans: D

G - 2009

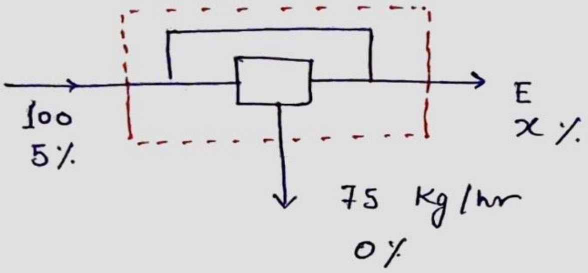
① <u>basis</u> : Feed is 100 kg/hr

pure water $= 0.75 \times 100$

$= 75$ kg/hr

Eluent flow rate E

overall mass balance



$100 = 75 + E \implies E = 25$ kg/hr

salt balance

$$100 \times \frac{5}{100} = 75 \times 0 + 25 \times \frac{x}{100}$$

$x = 20$ %

Recycle stream has flow rate R kg/hr and concentration 20 %

salt balance at junction of recycle and feed

$$100 \times \frac{5}{100} + R \times \frac{20}{100} = (R+100) \times \frac{10}{100}$$

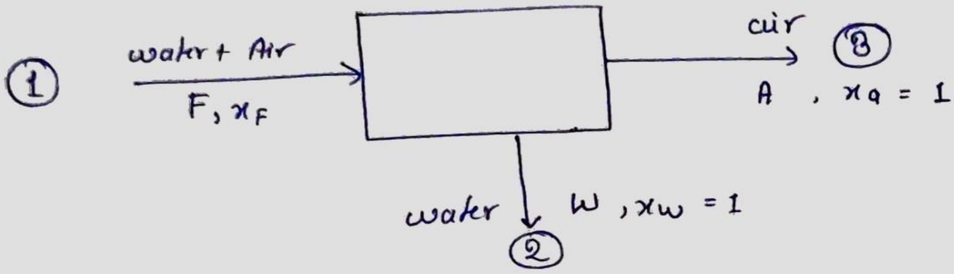
$R = 50$

$$\frac{R}{F} = \frac{50}{100} = 0.5$$

Ans : B

② Ans: c

Both water and air are tie component



→ We can apply water balance between stream ① & ② by considering air as tie component

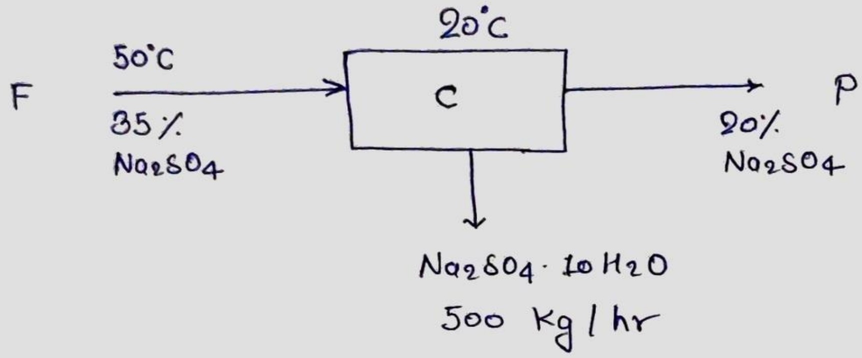
$$\boxed{F \, x_F = W}$$

→ We can apply air balance between stream ① & ③ by considering water as tie component.

$$\boxed{F(1-x_F) = A}$$

G- 2008

①



→ overall material balance

$F = 500 + P$

→ Na_2SO_4 weight % in $Na_2SO_4 \cdot 10 H_2O$ crystal

$= \frac{142}{322} \times 100$

$= 44.099$ %

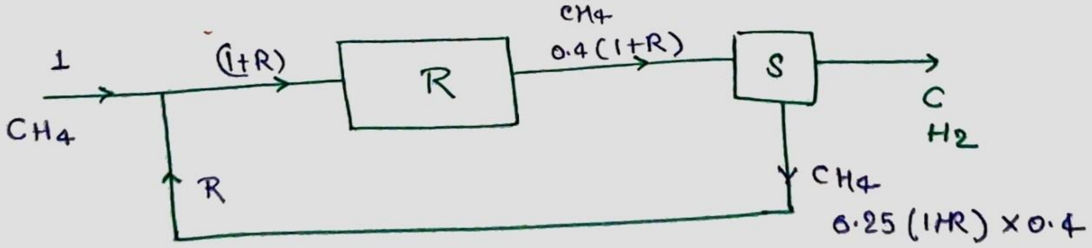
→ Na_2SO_4 balance

$35 \times F = 500 \times 44.099 + 20 P$

hence $F = 803.3$ $P = 303.3$

Ans: C

②



$CH_4 \rightarrow C + 2H_2$

basis : fresh feed methane 1 mole / sec

flow rate of recycle stream = R mole/sec

flow rate just before the reactor = 1+R

→ single pass conversion of reactor = 60%

CH_4 after reactor = 0.4 (1+R)

→ flow rate of CH_4 after separator is 25%

= 0.25 × 0.4 (1+R)

→ Recycle R = 0.4 × 0.25 (1+R)

R = 0.111

→ $\frac{F}{R} = \frac{1}{0.111} = 9$

Ans: B

---

③

$$N_2 + O_2 \longrightarrow \underset{x}{2NO} \quad — ①$$

$$N_2 + 2O_2 \longrightarrow \underset{x/2}{2NO_2} \quad — ②$$

Basis : 1 mole air is supplied

0.79 mole N_2

0.21 mole O_2

→ Oxygen is completely reacted

let NO formed is x moles

NO_2 formed is x/2 moles

→ O_2 consumed in Rxn - ① = $\frac{1}{2} \times x$

O_2 consumed in Rxn - ② = $\frac{x}{2}$

total oxygen consumed $= \frac{x}{2} + \frac{x}{2} = x$

total oxygen supplied $= 0.21 =$ consumed $= x$

→ N_2 consumed in Rxn-① $= \frac{x}{2}$

→ N_2 consumed in Rxn-② $= \frac{1}{2} \times \frac{x}{2}$

total N_2 consumed $= 0.75x = 0.1575$

conversion of $N_2 = \frac{0.1575}{0.79} \times 100$

$= 0.2$

Ans: B

G- 2007

① a) $C_3H_8 + 5O_2 \longrightarrow 3CO_2 + 4H_2O$

$C_3H_8 + \frac{7}{2}O_2 \longrightarrow 3CO + 4H_2O$

→ C_3H_8, 44 Kg taken initially = 1 K mole

88 Kg CO_2 formed = 2 K mole CO_2

14 Kg CO formed = 0.5 K mole CO

O_2 supplied = $\frac{1160}{29} \times 0.21 = 8.4$ K mole

→ for complete combution of C_3H_8 5 mole of O_2 required.

$$\% \text{ excess} = \frac{(-\text{Required} + \text{supplied})}{\text{Required}} \times 100$$

$$= \frac{8.4 - 5}{5} \times 100$$

$$= 68$$

Ans : D

b) 2 K mole CO_2 formed $\Rightarrow \frac{2}{3}$ C_3H_8 Kmoles consumed

0.5 K mole CO formed $\Rightarrow \frac{0.5}{3}$ K mole C_3H_8 consu-med

C_3H_8 total consumed = 2.5/3

$$\% \text{ C burned} = \frac{\text{consumed}}{\text{supplied}} \times 100$$

$$= \frac{2.5}{3 \times 1} \times 100 = 83.3$$

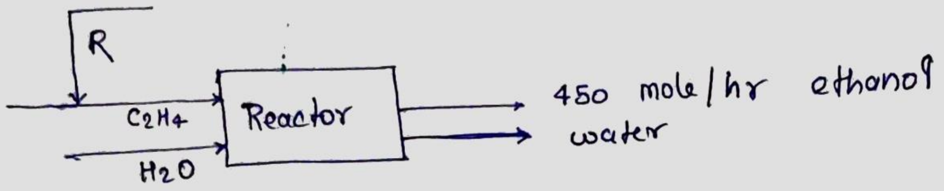
Ans : C

② a) Azeotrope product flow rate = 500 mole/h

ethanole in product = 500 × 0.9 mole/hr

→ Enanol in Azeotrope = ethanol coming out of Reactor

= 450 mole/hr



→ C_2H_4 required for 450 mol/hr ethanol = 450 mol/hr

$$C_2H_4 + 2H_2O \longrightarrow C_2H_5OH$$

as conversion is 30%, C_2H_4 feed to Reactor is –

$$= \frac{450}{0.3}$$

= 1500 mole/hr

C_2H_4 consumed in Reactor = 450 mol/hr

C_2H_4 unreacted (out of Reactor) = 1500 − 450

= 1050

→ Now $\left(\begin{matrix} C_2H_5OH \\ + \\ H_2O \end{matrix}\right)$ will be condensed. Remaining gas stream of C_2H_4 will be devided into purge & Recycle stream

$$\left.\begin{matrix} R + P = 1050 \\ R/P = 34 \end{matrix}\right\} \Rightarrow \begin{matrix} R = 1020 \text{ m/h} \\ P = 30 \text{ m/h} \end{matrix}$$

Ans: c

b) → H_2O fed to Reactor 600 mol/h·

H_2O consumed in Reactor = 450 mol/h

water unreacted = 150 mol/h

total (water + ethanol) condensable out of reactor = 150 + 450 = 600 mol/h

→ water wash rate in scrubber is 20% of condensable coming out of reactor.

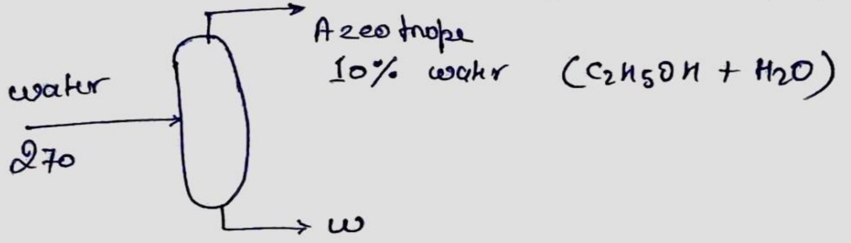
wash water = 0·2 × (600) = 120 mol/h

→ Water balance over distillation column

Inlet water to distillation = wash water + unreacted water stream coming out of reactor

= 120 + 150

= 270 mol/hr

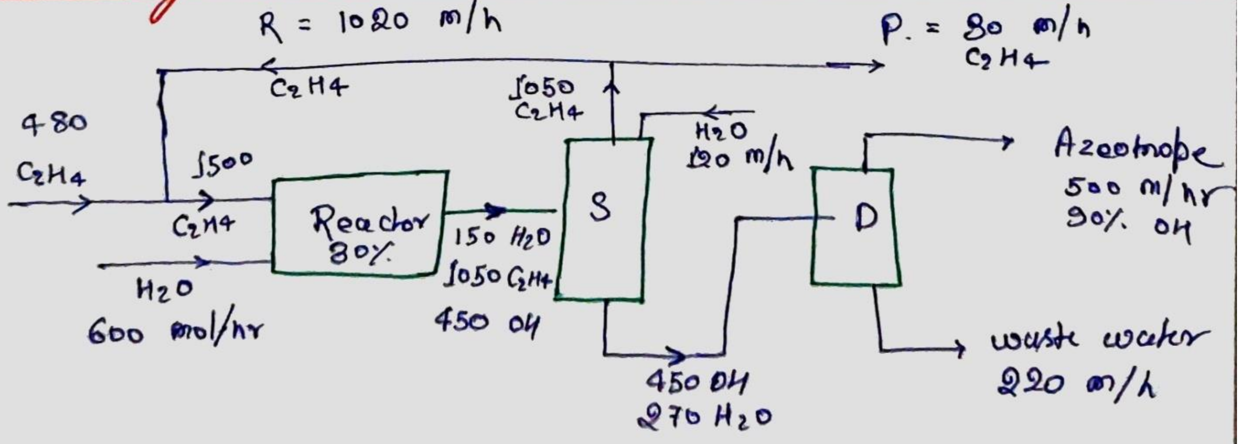


$$270 = 500 \times \frac{10}{100} + \omega$$

$$\omega = 220$$

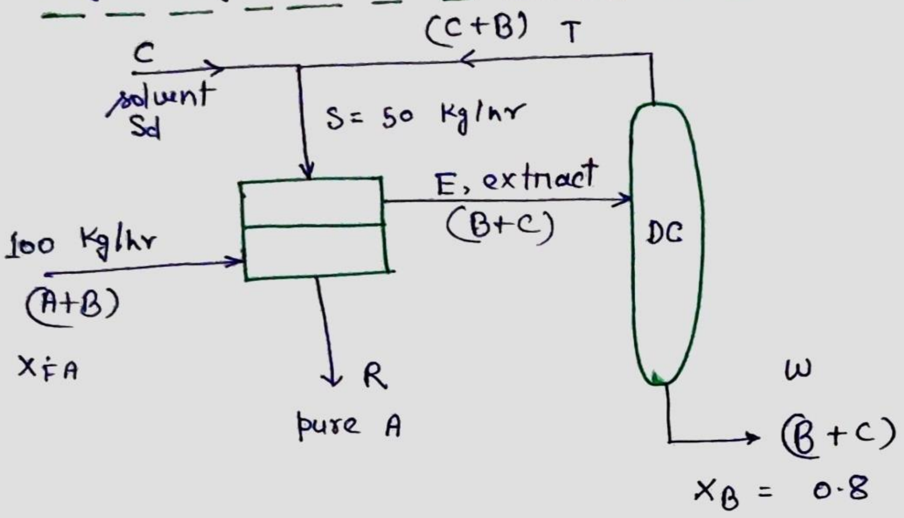
Ans: B

material flow diagram



G-2006

① As c in raffinate and solubility of A in extract are negligible, material will flow according to following diagram



→ A balance on hole unit —

$100 \times X_{FA} = R \Rightarrow R = 60$ Kg/hr

→ overall material balance on extractor —

$$\left.\begin{array}{l} 100 + 50 = 60 + E \\ F + S = R + E \end{array}\right\} \quad E = 90 \text{ Kg/hr}$$

→ C balance on hole unit —

$Sd = (1-X_B)\,W \qquad Sd = 0.2\,W$ ---- ①

→ over all balance of distillation column

$E = W + T$ .... ⑪

→ overall balance on solvent junction –

$$Sd + T = S \Rightarrow Sd + T = 50 \quad \cdots \text{(III)}$$

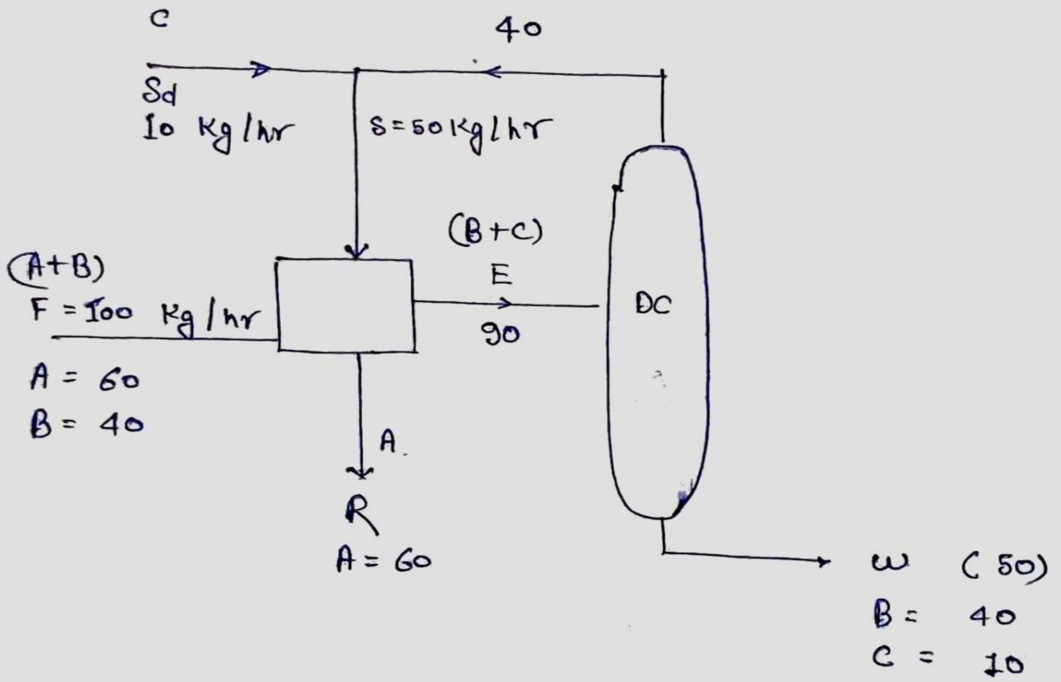
→ solving equation ①, ② & ③

$Sd = 10$ kg/hr
$W = 50$ kg/hr
$T = 40$ kg/hr

Ans

① A = d
① B = a

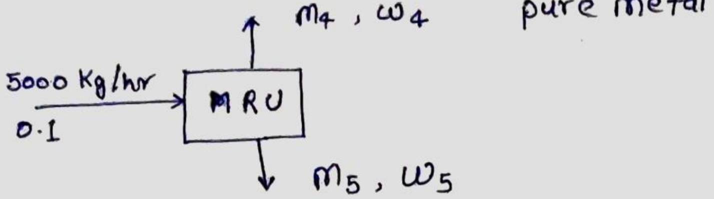
$w = 50$, $Sd = 10$
$E = 90$, $T = 40$



final material balance flow diagram

G - 2005

① material balance over MRU unit :-



metal inlet = $5000 \times 0.1 = 500$ kg/hr

90% metal recovered , hence

$m_4 = 0.9 \times 500 = 450$ Kg/hr

~~overall balance~~

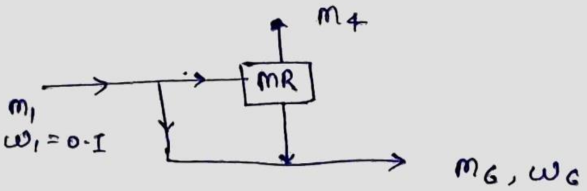
~~$5000 = m_4 + m_5 \Rightarrow m_5 = 4550$ Kg/hr~~

~~metal balance~~

~~$5000 \times 0.1 = 450 + \omega_5 \times 4550$~~

~~$\omega_5 = 0.01099$~~

overall material balance —



$m_1 = m_4 + m_6 \Rightarrow m_6 = 7500 - 450$

$m_6 = 7050$

metal balance —

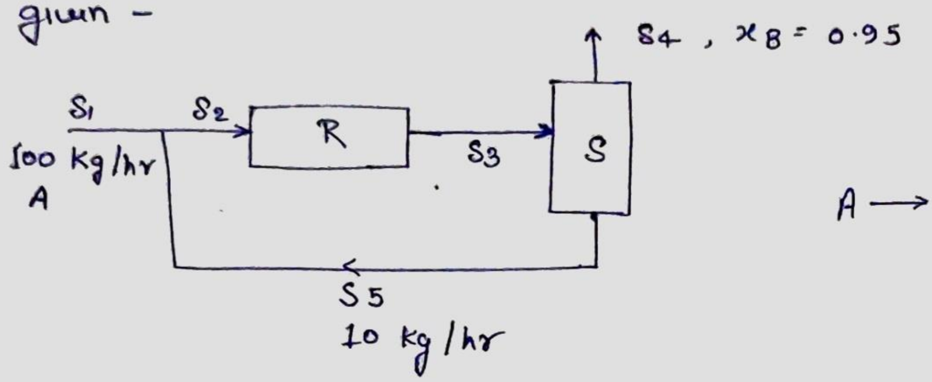
$0.1\, m_1 = m_4 + m_6 \omega_6$

$0.1 \times 7500 = 450 + 7050\ \omega_6$

$w_6 = 0.0425$

Ans: B

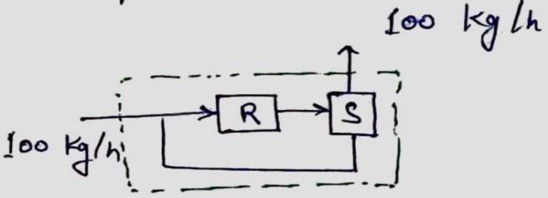
② given -



→ overall material balance on complete unit

$S_1 = S_4$

$S_4 = 100$ kg/hr

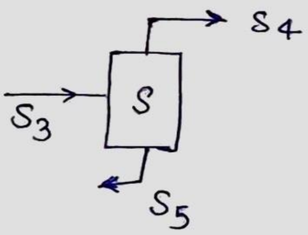


→ over all material balance on separator

$S_3 = S_4 + S_5$

$S_3 = 100 + 10$

$S_3 = 110$ kg/hr



→ $S_3/S_5 = \frac{110}{10}$

$= 11$

→ Separator separates product stream without changing the composition of stream

5% A in S3 stream, S4, S4 streams

A in $S_3 = \frac{5}{100} \times 110 = 5.5$ kg/hr

Ans: C

G- 2004

①

Material balance on complete distillation column

overall –

$10,000 = D + W$ ..... ①

benzene balance –

$0.5 \times 10,000 = 0.95\, D + 0.05\, W$ ..... (II)

solving equation ① & ②

$D = 5,000$

$W = 5,000$

$$\text{Reflux Ratio} = \frac{L_o}{D} = \frac{8,000 - 5,000}{5,000} = 0.6$$

Ans B

②

Basis : —

100 gm solution

64 gm $CH_3OH \Rightarrow \frac{64}{32}$ mole CH_3OH

2 mole CH_3OH

36 gm $H_2O \Rightarrow \frac{36}{18}$ mol H_2O

2 mol H_2O

$$\text{mole fraction} = \frac{2}{2+2}$$

$= 0.5$

Ans: B

③ given

80 Kg N_2SO_4

330 Kg total

$(330-80)$ Kg H_2O = 250 Kg

$$\boxed{\begin{array}{l}80\ Na_2SO_4\\ 250\ H_2O\end{array}}$$

→ 80 Kg $Na_2SO_4 \cdot 10\,H_2O$ separated by critallization

Na_2SO_4 % on $(Na_2SO_4 \cdot 10\,H_2O)$ crystal

$$= \frac{142}{322} \times 100$$

$$= 44.099\ \%$$

→ Na_2SO_4 separated from solution $= \dfrac{44.099 \times 80}{100}$

$$= 35.27 \text{ Kg}$$

→ Na_2SO_4 Remains on solution $= 80 - 35.27$

$$= 44.72$$

$$\boxed{\begin{array}{ll}44.72 & Na_2SO_4\\ 205.27 & H_2O\end{array}}$$

Remaining solution

% Na_2SO_4 on remaining solution $= \dfrac{44.72}{250} \times 100$

$$= 0.179 \times 100$$

weight fraction Na_2SO_4 = ·179

Ans: B

④ a) $CH_4 + 2O_2 \longrightarrow CO_2 + 2H_2O$

1 mole 2 mol. Required

→ Air supplied $= \frac{2}{0.21} = 9.52$ mol

N_2 supplied $= \frac{2}{0.21} \times 0.79 = 7.52$ mol

product CO_2 = 1 mol

H_2O = 2 mol

→ product gas

2 H_2O 1 CO_2	$N_2 = 7.52$

% H_2O $= \frac{\boxed{2}}{10.52} \times 100$ **= 19 %**

Fractional Conversion = 0.19

Ans: A

---

4 ⑤ ⓑ Heat produced by combution reaction will raise the temperature of rxn

$-\Delta H = m C_p \Delta T$

$780 \times 1000 \times 1 = 10.52 \times 40 \times \Delta T$

$\Delta T = 1735$

Ans: D

G- 2003

①

$$C + O_2 \longrightarrow CO_2$$

$$C + \frac{1}{2}O_2 \longrightarrow CO$$

moles of C $= \frac{6}{12}$

$= 0.5$

moles of O_2 = 18/32

= 0.56

$$\begin{array}{cccc} C & + O_2 & \longrightarrow & CO_2 \\ 0.5 & 1.125 & & \end{array}$$

Limiting Reactant is carbon

→ given, 16.5 g CO_2 $= \frac{16.5}{44}$ mol $= 0.375$ mol

→ 2.8 g CO $= \frac{2.8}{28} = 0.1$ mol

$$\begin{array}{ccccc} C & + O_2 & \longrightarrow & CO_2 & \\ 0.5 & 0.56 & & 0 & \text{enital} \\ (0.5-0.375) & 0.56 - 0.375 & & 0.375 & t=t \end{array}$$

$$\begin{array}{ccccc} C & + \frac{1}{2}O_2 & \longrightarrow & CO & \\ 0.5 & 0.56 & & 0 & \text{enitial} \\ 0.5-0.1 & (0.56 - 0.1/2) & & 0.1 & t=t \end{array}$$

Initial moles of C = 0.5 mole

final moles of C = 0.5 − 0.375 − 0.1

C = 0.025

$$\% \text{ conversion of } C = \frac{0.5 - 0.025}{0.5} \times 100$$

$$= \frac{47.5}{0.5} = 95\,\%$$

Ans: B

② basis : 1 L of H_2SO_4 solution

specific gravity 1.011

1 L solution H_2SO_4 contains 1011 gm solution

H_2SO_4 % = 2.45

$$= \frac{2.45 \times 1011}{100}$$

$= 24.76$ gm H_2SO_4

$= \frac{24.76}{98}$ mol H_2SO_4 = 0.2526 mol

molarity $= \frac{0.2526}{1} = 0.2526$

Normality = molarity × valancy of H_2SO_4

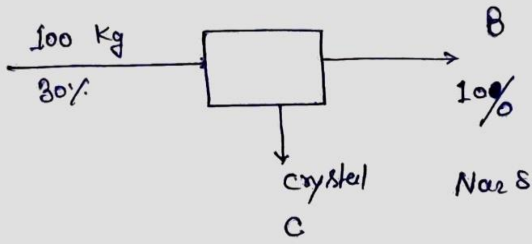
$= 2 \times 0.2526$

$= 0.5053$

Ans: D

---

③



$Na_2SO_4 \cdot 10H_2O$

% of Na_2SO_4 in crystal $= \frac{142}{322} \times 100$

$= 44.0993$

overall balance —

$100 = B + C$ — ①

Na_2SO_4 balance —

$100 \times 0.3 = B \times 0.1 + C \times 0.44099$ — (II)

Solving equation (I) & (II)

$B = 58.65$ Kg

Ans: D

---

④ basis : 100 moles of (natural gas)

$CH_4 = 80$ moles

$N_2 = 20$ moles

$$CH_4 + 2O_2 \longrightarrow CO_2 + 2H_2O$$

$$CH_4 + \frac{3}{2}O_2 \longrightarrow CO + 2H_2O$$

→ theoretical O_2 required $= 80 \times 2 = 160$ moles

theoretical air required $= \frac{160}{0.21} = 761.9$ moles

theoretical N_2 supplied $= 761.9 \times 0.79 = 601.9$ mol

→ 80% CH_4 converted into CO_2

$CO_2 = 0.8 \times 80 = 64$ moles

20% CH_4 converted into CO

$CO = 0.2 \times 80 = 16$ moles

→ 20% excess air supplied

O_2 supplied $= 1.2 \times 160 = 192$

N_2 supplied $= 1.2 \times 601.9 = 722.28$

→ O_2 consumed $= 2 \times 64 + \frac{3}{2} \times 16$

$= 152$ moles

O_2 remains $= 40$ moles

product gas will contain.

$CO_2 = 64$
$CO = 16$
$O_2 = 40$
$N_2 = 20 + 722.28$
$H_2O = 64 \times 2 + 16 \times 2$

total = 1022.28 moles

% $CO_2 = 6.26$
% $CO = 1.56$
% $O_2 = 3.91$
% $N_2 = 72.61$
% $H_2O = 15.66$

ORSAT analysis is always on dry basis —
Hence

$CO_2 = 64$
$CO = 16$
$O_2 = 40$
$N_2 = 742.28$

total = 862.28 mol

% $CO_2 = 7.42$
% $CO = 1.85$
% $O_2 = 4.63$
% $N_2 = 86.08$

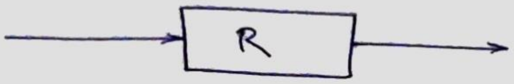
Ans: B

G-2002

Correct Answer is B =1

This question is solved by considering unknown conversion but in question complete conversion is given

①



CH_4	$+ \; 2O_2$	$\longrightarrow$	CO_2	$+ \; 2H_2O$	
1	2		0	0	t=0
0	0		1	2	complete rxn

but rxn can be incomplete

	Reactant	Product
1)	feed rate (CH_4+O_2)	conversion
2)	feed CH_4	Rate of CO_2
3)	feed O_2	Rate of H_2O

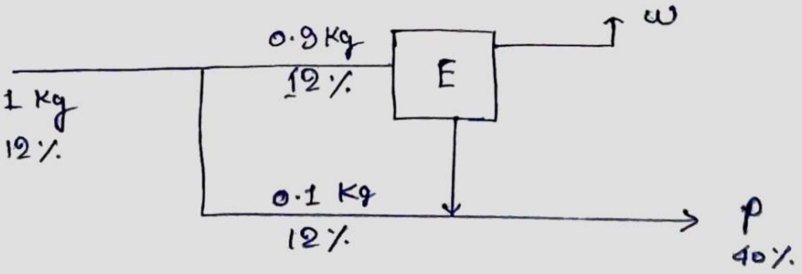
two specification required to determine product flow rate —

one from Reactant column.

other from product column.

Ans: C

②



basis : 1 Kg fresh juice

Tie component : solid

solid balance on complete unit

$0.12 \times 1 = w \times 0 + 0.4\,P \Rightarrow P = 0.3\ \text{kg/hr}$

overall balance

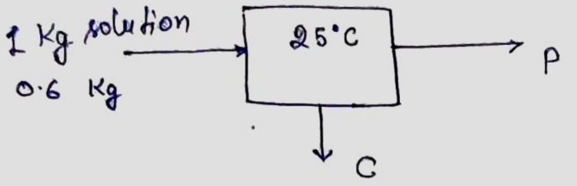
$1 = P + w$

$w = 0.7$ kg

Ans: D

---

③



→ 1 Kg of saturated solution @ 60°C

0.6 Kg / Kg of water

solution contain x kg A & w kg water

$$\left.\begin{array}{l} x + w = 1 \\ x / w = 0.6 \end{array}\right\} \quad \begin{array}{l} w = 0.625 \\ x = 0.375 \end{array}$$

% A = 87.5 %

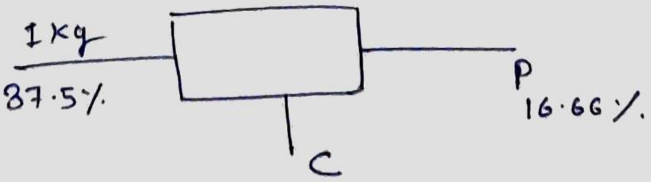
→ 1 Kg of saturated solution @ 25°C

0.2 Kg A / Kg of water

$$\left.\begin{array}{l} x + w = 1 \\ x / w = 0.2 \end{array}\right\} \quad \begin{array}{l} w = 0.8333 \\ x = 0.1666 \end{array}$$

% A = 16.66 %

hence



overall balance —

$c + p = 1$

$0.37 \times 1 = c + 0.1666\,p$

A balance —

from above equation —

$p = 0.75$

$c = 0.244$

Ans: B

G- 2001

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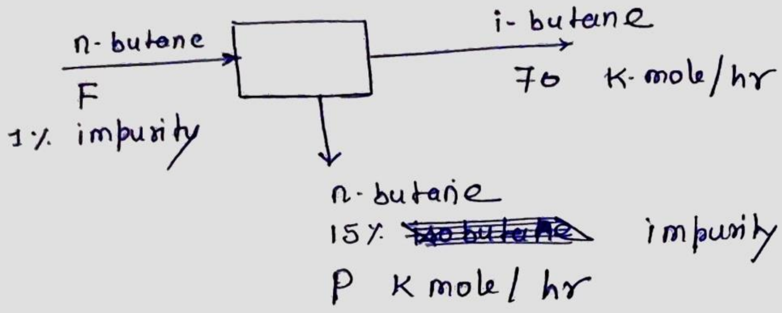
① Ans: B

②



overall balance —

$F = P + 70$

Impurity balance

$1 \times F = 15\,P$

Hence

$P = 5$ K mole/hr

Ans: C

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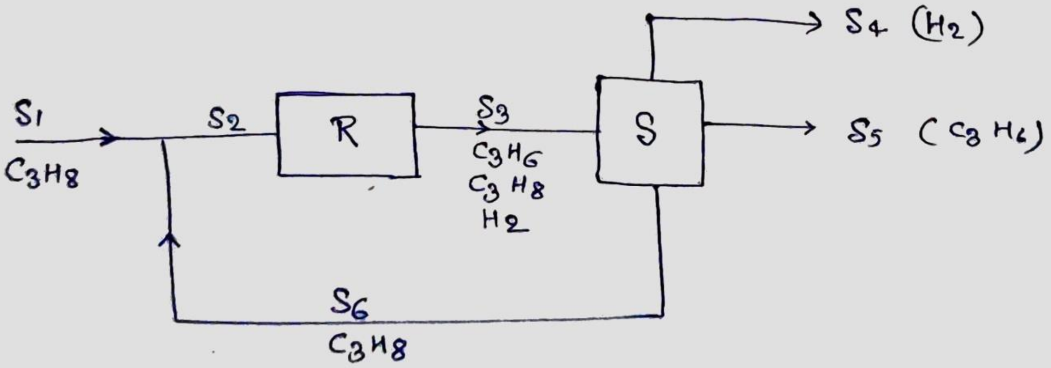
③

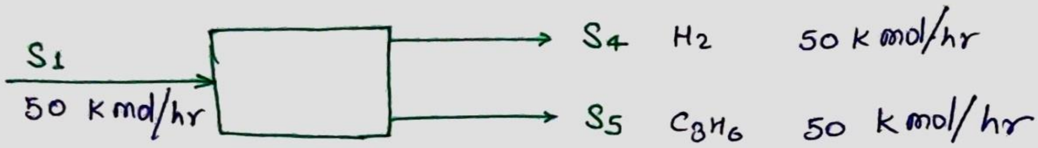


given $S_5 = 50$ Kmol/hr

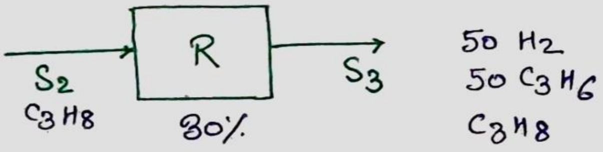
$$\underset{50}{C_3H_8} \longrightarrow \underset{50}{C_3H_6} + \underset{50}{H_2}$$

over all unit –

as 50 kmoles C_3H_6 formed, 50 k moles C_3H_8 will be consumed & 50 k moles H_2 will be formed.



Balance on Reactor



as 50 k mole C_3H_6 will formed

C_3H_8 supplied $S_2 = \frac{50}{0.3}$

$S_2 = 166.66$ K mol

C_3H_8 unreacted out of reactor $= 166.66 \times 0.7$

~~= 0.7 ×~~ 116.66 Kmol

~~= 81.66 Kmol~~

$\boxed{S_6} \rightarrow 116.66$ Kmole

$$S_3 = S_2 + S_4 + S_5$$
$$= 116.66 + 50 + 50$$
$$= 216.67 \text{ K mol}$$

G- 2000

① given
10 % H_2
10 % O_2
30% CO_2
50% H_2O

basis : 100 moles of gas mixture

H_2 = 10 m
O_2 = 10 m
CO_2 = 30 m
H_2O = 50 m

50 % H_2O condensed out
H_2O remains
25 mol

% H_2 after condensation of H_2O wet basis

$$= \frac{10}{10+10+30+25} \times 100$$

$$= 13.33\ \%$$

% H_2 on dry basis –

$$= \frac{10}{10+10+30} \times 100 = 20\ \%$$

Ans : D

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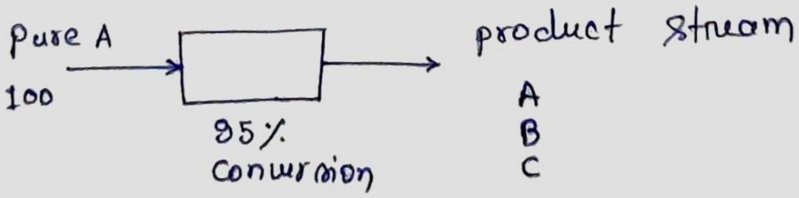
② Rxn $A \rightarrow 2B + C$

Basis : 100 mole/h pure A taken.

Overall Unit :–



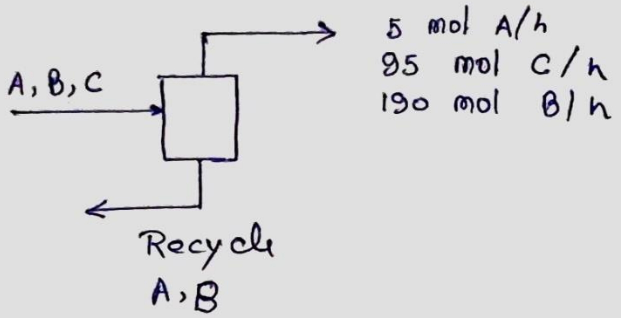
→ overall conversion 95 %

A in product stream = $100(1-0.95) = 5$ mol/h

C in product stream = $100 \times 0.95 = 95$ mol/h

B in product stream = $2 \times 0.95 \times 100 = 190$ mol/hr

→ Separator —



→ product stream from separator contains 0.5% of A entering sperator

flow rate of A entering to sparator $\times \frac{0.5}{100} = 5$

→ A entering to sperator = 1000 mol/h

A in Recycle = $1000 - 5 = 995$ mol/hr

→ C entering to seperator = C exit from separator
= 95 mol/h

→ B entering to separator = x mol/hr

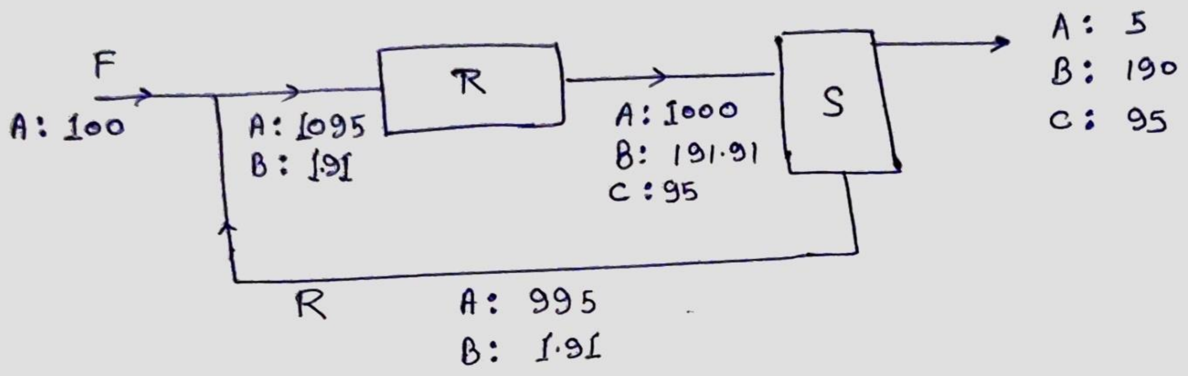
B balance on separator

$$x = \frac{x}{100} + 190$$

$$x = 191.91 \text{ mol/hr}$$

→ B in Recycle stream = $191.91 - 190$
= 1.91 mol/hr

Hence following material flow diagram will be obtained –



→ A entering to the reactor

995 + 100 = 1095 mol/hr

→ A out of reactor : 1000

conversion of $A = \dfrac{1095 - 1000}{1095} \times 100$

$\% A = 8.65 \%$

a) Ans : 8.65

→ Recycle stream = 995 + 1.91 = 996.91 mol/h

$$\frac{R}{F} = \frac{996.91}{100}$$

$$\frac{R}{F} = 9.96$$

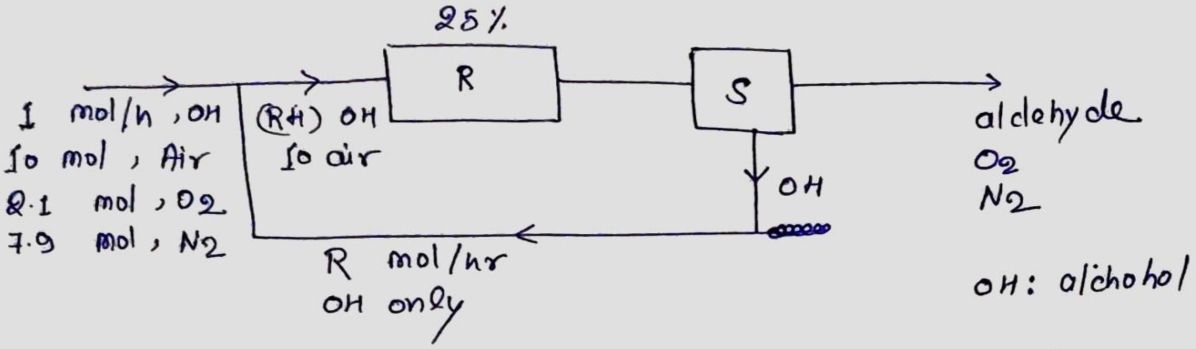
b) Ans : 9.96

G-1999

① Basis : 1 mol/h fresh enthanol feed

Air in Feed = 10 × 1 = 10 mol/h

Total Feed = 11 mol/h



→ O_2 in Feed = 0.21 × 10 = 2.1 mol/h

R pure ethanol in Recycle stream

ethanol in Feed of Reactor = (R+1)

$$C_2H_5OH + \frac{1}{2}O_2 \longrightarrow CH_3CHO + H_2O$$

→ ethanol at product stream out of Reactor = (R+1) 0.75

ethanol completly separated out by separator unit

hence

$$R = 0.75(R+1)$$

$$R = 3 \text{ mol/hr}$$

→ Recycle Ratio $= \frac{R}{F} = \frac{3}{11} = 0.272$

$$\boxed{RR = 0.272}$$

Ans

N_2 out of Reactor = 7.9 mol/hr

O_2 out of Reactor $= 2.1 - \frac{0.25(RH)}{2} = 1.62$ mol/hr

aldehyde out of Reactor = (RH) × 0.25 = 1 mol/hr

ethanol out of Reactor = 0.75 (RH) = 3 mol/hr

water out of Reactor = 1 mol/hr

mass fraction & mole fraction of each product out of reactor can be calculated from above data

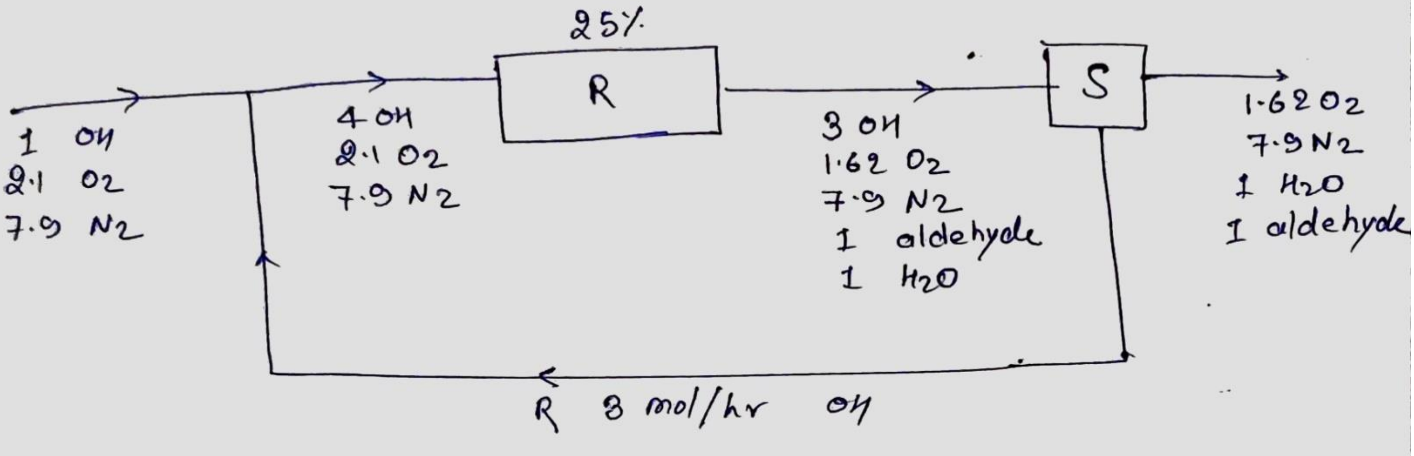


Fig: material flow diagram

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② basis 1000 gm solution — SG = 1

350 gm A SG = 0.7

650 gm B ρ_B = SG of B

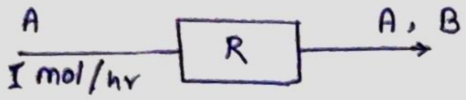
$$V = \text{total volume} = \frac{0.35}{0.7} + \frac{0.65}{\rho_B} \text{ lt}$$

$$\frac{1}{V} = 1 \Rightarrow \frac{0.35}{0.7} + \frac{0.65}{\rho_B} = 1$$

$$\rho_B = 1.3$$

Ans: B

⑧



basis : A is 1 mol/hr

$A \longrightarrow 3B$

t=0	1	0
t=t	$1 - 0.5 \times 1$ $= 0.5$	$3 \times 0.5 \times 1$ 1.5

mole fraction of A at exit stream :—

$$= \frac{0.5}{1.5 + 0.5}$$

$$= 1/4$$

Ans : C

↑

G-1998

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①.

$$C_2H_5OH \longrightarrow C_2H_4 + H_2O$$

t = 0   100

t = t   100 − 95   95   95

$$C_2H_5OH \longrightarrow \frac{1}{2}(C_2H_5-O-C_2H_5) + \frac{1}{2}H_2O$$

t = 0   100

t = t   − 5 $5 \times \frac{1}{2}$ $5 \times \frac{1}{2}$

total C_2H_5OH converted = 95 + 5 = 100 mol

percent conversion = 100

Ans: A

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② Ans : $\boxed{C}$

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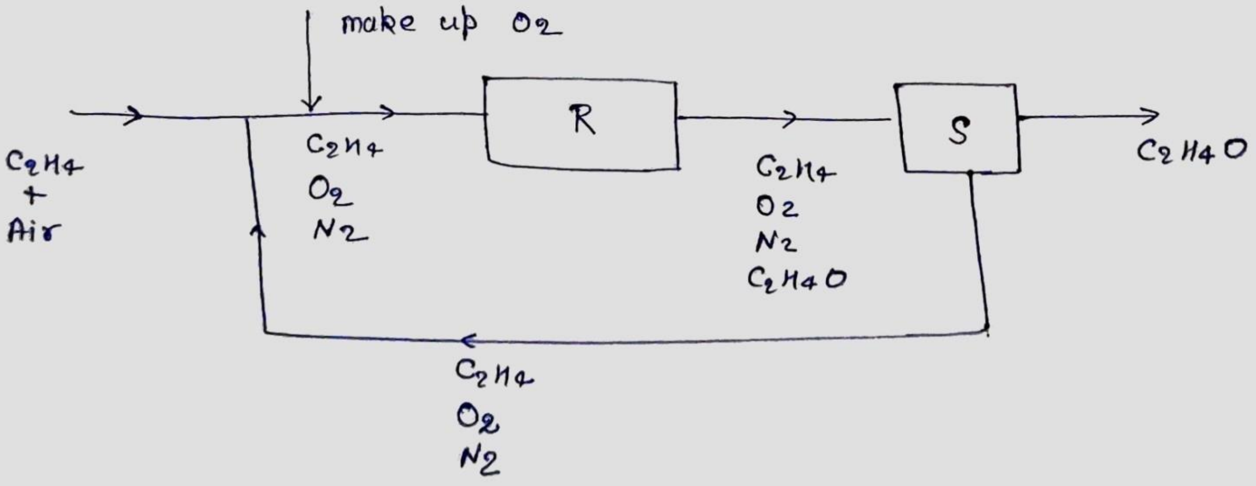
③

$$C_2H_4 + \frac{1}{2}O_2 \longrightarrow C_2H_4O$$

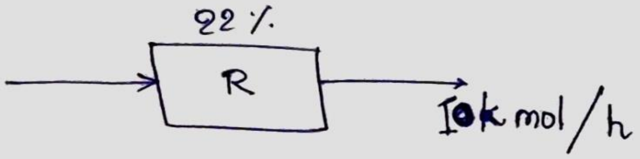


→ Production rate = 440 kg / h

$= \frac{440}{44}$ k mol / h = 10 k mol / h

→ O_2 consumed = $\frac{10}{2}$ k mol / hr

→ Reactor



ethylene in Reactor feed = $\frac{10}{0.22}$ = 45.45 k mol / hr

Air in reactor feed = 10 × 45.45 = 454.54 Kmol/hr

O_2 in reactor feed = 0.21 × 454.54 = 95.45 K mol / hr

N_2 in reactor feed = 454.54 − 95.45 = 359.09 kmol/hr

ethelene out of reactor = feed − consumed

= 45.45 − 10

= 35.45

O_2 out of the reactor = 95.45 − 5 = 90.45 mole

N_2 out of the reactor = 359.09

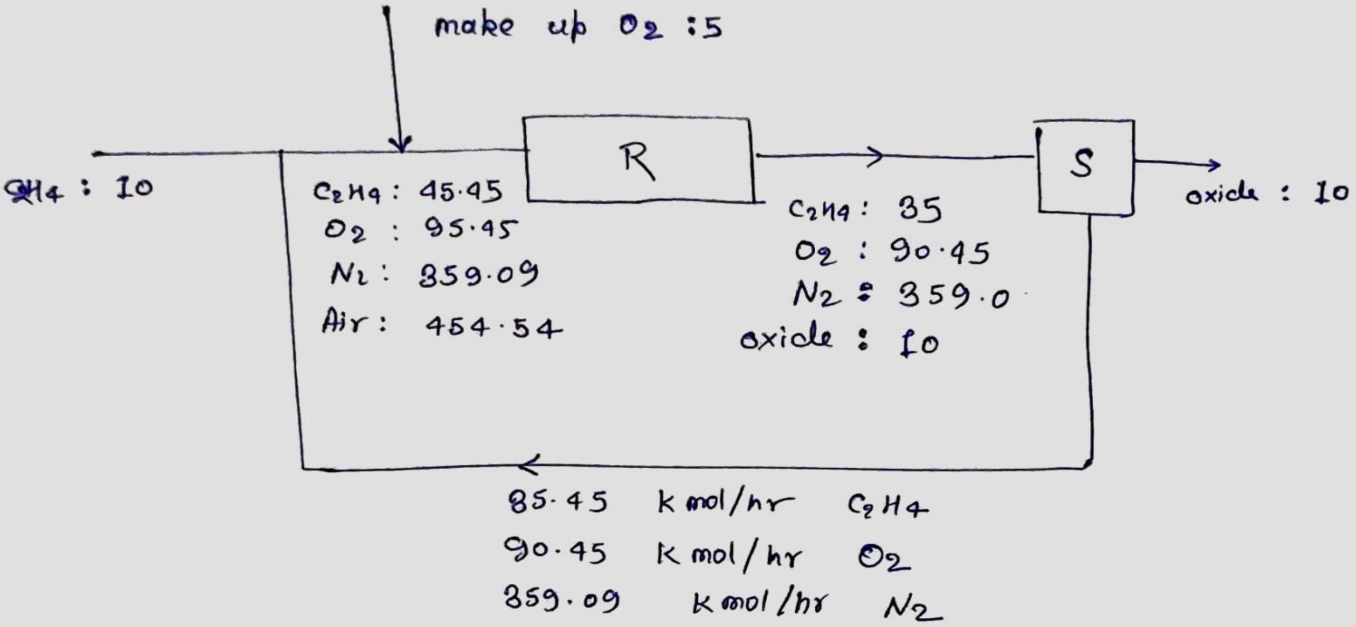
→ Recycle —

C_2H_4 = 35.45 k mol / hr

O_2 = 90.45 K mol / hr

N_2 = 359.09 k mol / hr

→ As 5 k mole / hr of O_2 consumed hence make of 5 K mole / hr O_2 to be given make up = 5 × 32 = 160 kg/hr



Ans: 160 kg/hr

G-1997

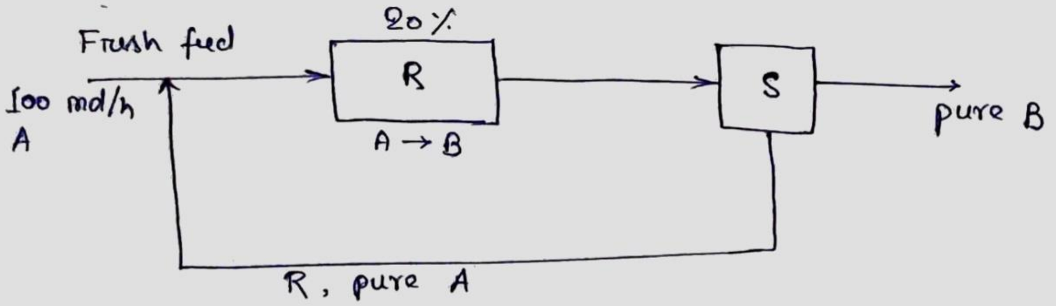
①. "The maximum number of independent equation that can be derived by writing balance equation on a non reactive system is equel to the no of chemical species in the input & output streams".

Ans: A

total three species, Hence total 3 indenpent material balance equation can be written.

---

②.



→ Feed to Reactor = 100 + R

→ A at the outlet of reactor = 0.8 (100 + R)

→ A in Recycle = A at the outlet of Reactor

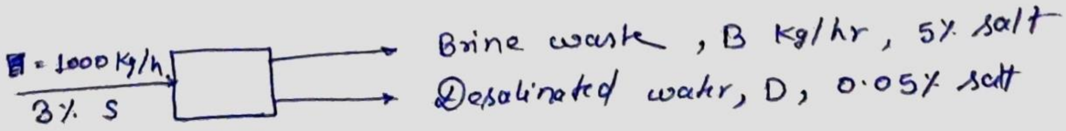
$R = 0.8\ (100 + R)$

$R = 400$

Ans: B

---

③ material balance on complete unit —



Brine waste, B kg/hr, 5% salt

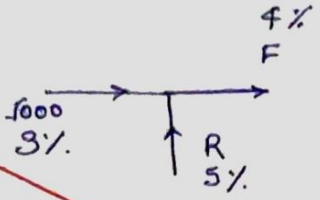
Desalinated water, D, 0.05% salt

overall balance —

$$1000 = B + D$$

salt balance —

$$1000 \times \frac{3}{100} = \frac{5}{100} \times B + \frac{0.05}{100} D$$



$B = 595.95$ Kg/hr
$D = 404.05$ Kg/hr

→ Material balance on mixed stream of Recycle & Feed —

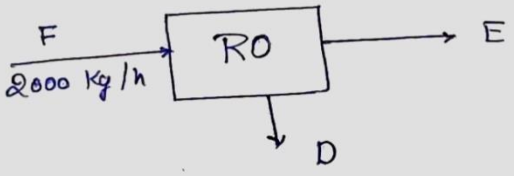
overall $F = R + 1000$

material salt $0.03 \times 1000 = 0.05 B + 0.0005 D$

hence

$F = 2000$ kg/hr
$R = 1000$ kg/hr

→ overall material on RO cell —



$F = D + E$

$2000 = 404.05 + E$

$E = 1595.95$

→ $$\frac{R}{E} = \frac{1000}{1595.95} = 0.6266$$

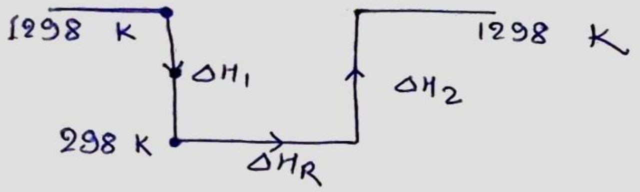
Ans: 0.626

④. let take enitial moles of reactants — @ 1298

C = c moles
N_2 = n moles
CO_2 = x moles
O_2 = y moles

Reactants

→ applying Hess Law —



As combustor is adiabatic hence total enthalpy change of Reaction is zero

$$\Delta H = \Delta H_1 + \Delta H_R + \Delta H_2 = 0 \quad \ldots\ldots ①$$

→ Reaction

	CO_2	+ C	$\longrightarrow$ $2CO$
t=0	x	c	0
completion	0	$c-x$	$2x$

	O_2	+ $2C$	$\longrightarrow$ $2CO$
t=0	y	c	0
Completion	0	$c-2y$	$2y$

Hence product stream will contain —

$(2x+2y)$ CO
$(C-x-2y)$ Carbon
n N_2

product

→ ΔH_1

$$\Delta H_1 = (0.02C + C_{pN}n + 0.05x + 0.03y)(298 - 1298)$$

→ ΔH_R

$$\Delta H_R = 170x - 220.4y$$

→ ΔH_2

$$\Delta H_2 = \left[(2x+2y)\times 0.03 + (C-x-2y)\,0.02 + C_{pn}n\right]\left[1298 - 298\right]$$

→ $\Delta H = \Delta H_1 + \Delta H_2 + \Delta H_2 = 0$

~~0.02C~~

$$-\left[20C + 50x + 30y\right] + 170x - 220.4y + 60x + 60y$$

$$-20x - 40y + 20C = 0$$

Nitrogen part will cancel out each other

$$160x = 230.4y$$

$$\frac{x}{y} = 1.44$$

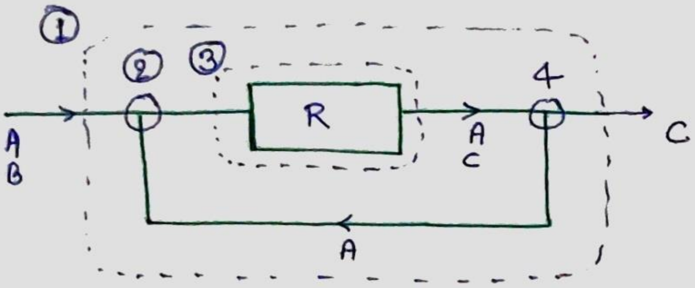
Hence ratio of CO_2 & O_2 is 1.44

Ans: 1.44

G- 1996

①.1)

1.1)



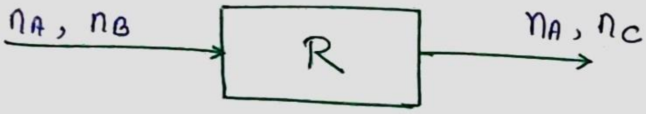
total four boundry can be drawn on which material balance can be written.

1) overall unit
2) Junction of fed & Recycle Stream
3) Reactor
4) point of separation of product and recycle

Ans: D

1.2

1.②



number of unknowns = 4 (n_A, n_B, n_A', n_B')

number of chemical rxn = 01

$$A + B \longrightarrow C$$

DOF = number of unknown − number of independent equation − addition information

Additional information = 1 = conversion of B is 100%.

↑

DOF = 4 - 1 - 1
= 2

Hence total 2 indenpendent ~~equation~~ material balance can be written.

Ans : B

---

② basis : 100 mol of flue gas

10.81 mol CO_2
3.78 mol O_2
85.40 mol N_2

Let's take hydrocarbon C_xH_y

$$C_xH_y + \left(x+\frac{y}{4}\right)O_2 \longrightarrow xCO_2 + H_2O$$

→ Air supplied = $\frac{85.40}{0.79}$ = 108.10

O_2 supplied = 0.21 × 108.10 = 22.70 moles

O_2 consumed = 22.70 - 3.78 = 18.92 moles

→ 1 mol C_xH_y consumed to form x mol CO_2

$x = 10.81$

O_2 consumed = $x + \frac{y}{4} = 18.92$

$y = 32.44$

→ Ratio of carbon and oxygen $\frac{x}{y} = \frac{10.81}{32.44}$

$\frac{x}{y} = 1/3$

Ans = 1/3

$$\% \text{ excess Oxygen} = \frac{\text{supplied} - \text{Required}}{\text{Required}} \times 100$$

$$= \frac{22.70 - 18.92}{18.92} \times 100$$

$$= 19.97 \%$$ Ans

Required O_2 for 1 mol C_xH_y $= x + \frac{y}{4}$

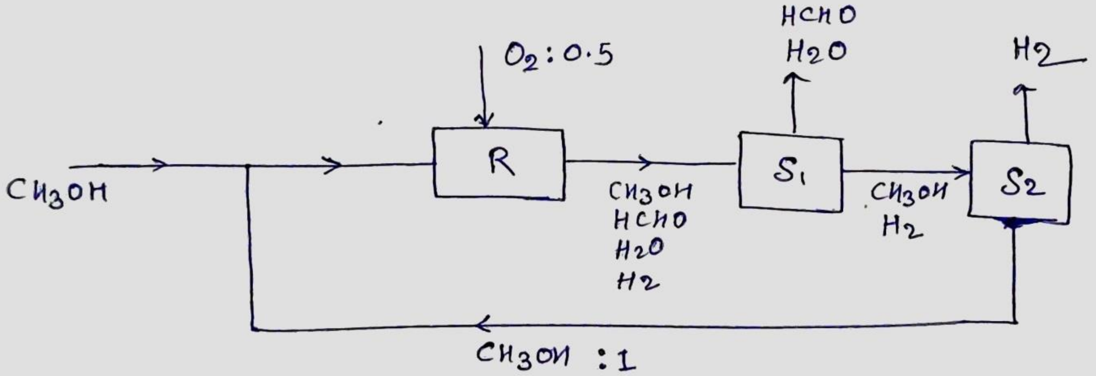
$$= 10.81 + \frac{32.44}{4}$$

$$= 18.92$$

Ans: 19.97 %

---

③



→ All O_2 reacts in the Reactor —

$$CH_3OH + \frac{1}{2} O_2 \longrightarrow HCHO + H_2O$$

methanol consumed to compeletly react with 0.5 Kmol oxygen.

= 1 K mol

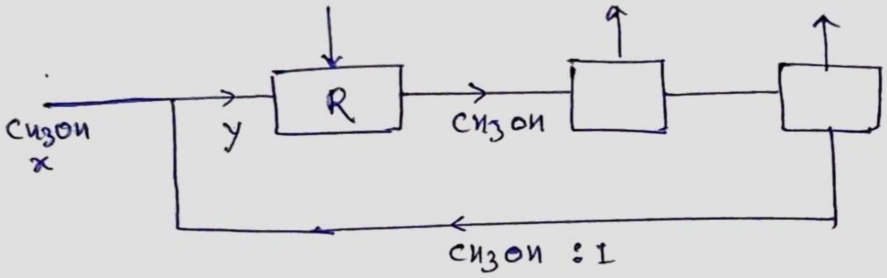
→ $$\frac{\text{Decomposition Rxn, CH}_3\text{OH consumed}}{\text{Oxydation Rxn, CH}_3\text{OH consumed}} = 3$$

CH_3OH consumed in decomposition = 3 kmol

$$CH_3OH \longrightarrow HCHO + H_2$$

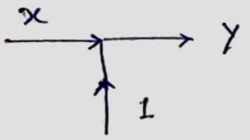
→ total CH_3OH consumed in Reactor = 3 + 1
= 4 kmol

→ Methanol balance on Reactor



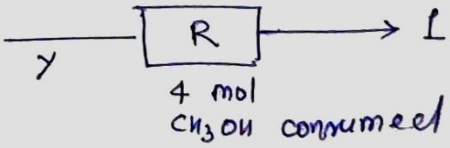
✓ CH_3OH out of Reactor = CH_3OH in recycle stream
= 1 kmol

✓ balance on junction $x + 1 = y$



✓ on Reactor

$y - 4 = 1$



hence $y = 5$ kmol
$x = 4$ kmol

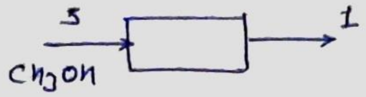
→ Fresh feed in unit CH_3OH = 4 kmol/hr

Ans: 4

→ % conversion of CH_3OH in Reactor —

$$\% \text{ conversion} = \frac{5-1}{5} \times 100$$

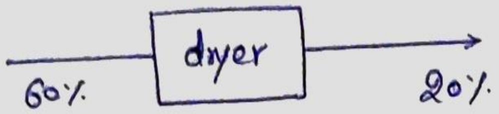
$$= 80\ \%$$



Ans : 80%

G-1995

①



1000 kg
wet
solid

!

→ 60% moisture content initially

hence (600 kg water + 400 kg dry solid)

→ After drying (x kg water + 400 kg dry solid)

$$\frac{x}{x+400} = 0.20$$

$0.8x = 80$

$x = 100$ kg

moisture removed —

$= 600 - 100$

$=$ [illegible] kg

500

Ans: D

②

$$\rho = \frac{PM}{RT}$$

$$\rho = \frac{2 \times 1.01 \times 10^5 \times 44}{8.314 \times 536.14}$$

$$\rho = 0.019939 \times 10^5 \ \frac{g}{m^3}$$

$$\rho = 1.993 \ \frac{Kg}{m^3}$$

Ans: B

3

Let x is molar flow rate of O_2
y " " " Air

at outlet $O_2 = x + 0.21y$
$N_2 = 0.79 N_2$

$$\frac{x+0.21y}{x+y} = 0.5$$

$$0.5x = 0.29y$$

$$\left[y/x\right] = \frac{0.5}{0.29} = 1.72$$

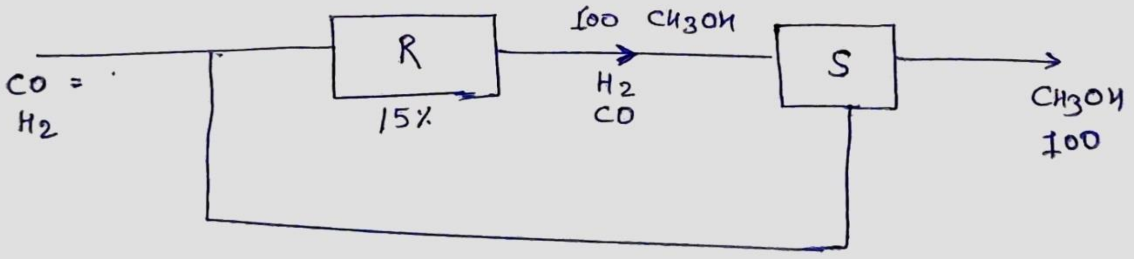
Ans : A

---

④ methanol production rate $= 3200$ Kg/h
$= \frac{3200}{32}$ K mol/h
$= 100$ K mol/h

$$CO + 2H_2 \longrightarrow CH_3OH$$

CO consumed = 100 K mol/hr
H_2 consumed = 200 K mol/hr



→ conversion 15%

CO fed to Reactor $= \frac{100}{0.15} = 666.66$

H_2 fed to Reactor $= \frac{200}{0.15} = 1333.33$

fresh CO feed = 100 k mol / hr

fresh H_2 feed = 200 Kmol/hr k mol / hr

CO out of Reactor = $\frac{100}{0.15}(1-0.15)$ = 566.66

H_2 out of Reactor = $\frac{200}{0.15}(1-0.15)$ = 1133.33

→ Material balance for separator —

CH_3OH Removed from Rxn mixture

Recycle stream will contain CO & H_2 —

= 566.66 + 1133.33

= 1700 K mol / hr

Ans
R = 1700

→ fresh feed rate = CO + H_2

= 100 + 200 K mol/hr

= 300 K mol/hr

Ans : 300

---

⑤ Basis : 100 mol flue gas —

N_2 in flue gas = 80.2 mol

N_2 supplied in feed = 80.2 mol

Air supplied in feed = $\frac{80.2}{0.79}$ = 101.518 mol

O_2 supplied in feed = 101.518 × 0.21

= 21.318 mol

O_2 consumed $= 21.318 - 7.1$
$= 14.21$ mol

Hence theoretical air required $= \frac{14.21}{0.21}$ mol
$= 67.709$ mol

$$\% \text{ excess} = \frac{\text{Supplied} - \text{Required}}{\text{Required}} \times 100$$

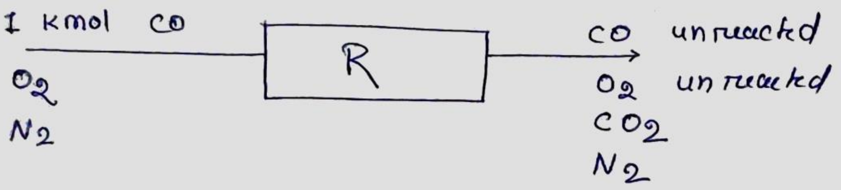
$$= \frac{101.518 - 67.709}{65.709} \times 100$$

$$= 49.93 \%$$

Ans : 49.93

---

⑥. basis : 1 K mol CO fed to combustor



$$CO + \frac{1}{2} O_2 \longrightarrow CO_2$$

→ 80% conversion of CO

CO_2 formed $= 1(0.8) = 0.8$ K mol

CO unreacted $= 1(1-0.8) = 0.2$ K mol

→ Required O_2 for 1 Kmol CO $= 0.5$ Kmol

100% excess air supplied

Supplied $O_2 = 1$ K mol

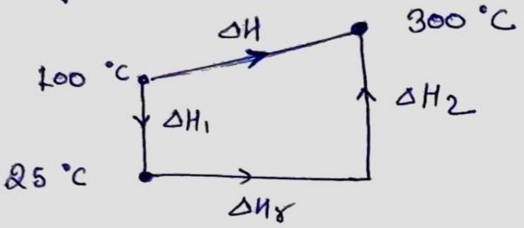
O_2 consumed in Reactor = $\frac{1}{2} \times 1 \times 0.8 = 0.4$

O_2 out of Reactor = $1 - 0.4 = 0.6$ kmol

N_2 supplied = $\frac{1}{0.21} \times 0.79 = 3.7619$ kmol

N_2 out of Reactor = 3.7619 kmol

→ Applying Hess Law —



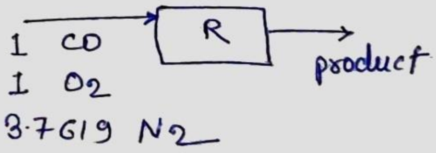
Enthalpy change for rxn ΔH

$= \Delta H_1 + \Delta H_r + \Delta H_2$

→ ΔH_1 : Reactant mixture is cooled to 25° C

$\Delta H_1 = (1 \times 29.22 + 1 \times 29.64 + 3.761 \times 29.17)(25-100)$

$\Delta H_1 = -12644.59753$ kJ

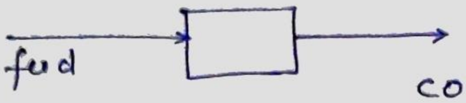


→ ΔH_r = Heat of formation of product − Heat of formation of reactant

$= (-393514) - (-110524) - 0$

$= -226392$ KJ

→ ΔH_2: PRoduct stream temp increased to 300°C



product

CO : 0.2 K mol
O_2 : 0.6 K mol
CO_2 : 0.8 K mol
N_2 : 3.7619 K mol

$$\Delta H_2 = (0.2 \times 30.61 + 0.8 \times 43.77 + 0.6 \times 30.99 + 3.7619 \times 29.66)(300 - 25)$$

$$= 47110.23$$

→ $\Delta H_{net} = \Delta H_1 + \Delta H_r + \Delta H_2$

$$= -191926.35 \text{ KJ / Kmol CO fed}$$

Heat added to Reactor = 191926.35 KJ

Ans : 191926.35

---

⑦ Calorific value = 20000 KJ/kg

Coal required = C $\frac{kg}{sec}$

→ heat produced by coal to produce 1 MW energy generation –

$$C \times 20000 \times 0.75 \times 10^3 = 1000,000$$

$$C = \frac{1}{15} \text{ kg/sec} = 0.066 \text{ kg/sec}$$

→ 67% carbon in coal

$$\text{Carbon} = \frac{0.67}{15} \ \frac{\text{Kg}}{\text{sec}}$$

$$\text{Carbon} = \frac{0.67}{15 \times 12} \ \frac{\text{kmol}}{\text{sec}}$$

$$C + O_2 \longrightarrow CO_2$$

$$\text{Oxygen required} = \frac{0.67}{15 \times 12} \ \frac{\text{kmol}}{\text{sec}}$$

$$\text{Air required} = \frac{0.67}{15 \times 12 \times 0.21} \ \frac{\text{kmol}}{\text{sec}}$$

50% excess air supplied —

$$\text{Air supplied} = \frac{1.5 \times 0.67}{15 \times 12 \times 0.21} \ \frac{\text{Kmol}}{\text{sec}}$$

$$= \frac{1.5 \times 0.67 \times 29}{15 \times 12 \times 0.21} \ \frac{\text{Kg}}{\text{sec}}$$

$$= 0.771 \ \frac{\text{Kg}}{\text{sec}}$$

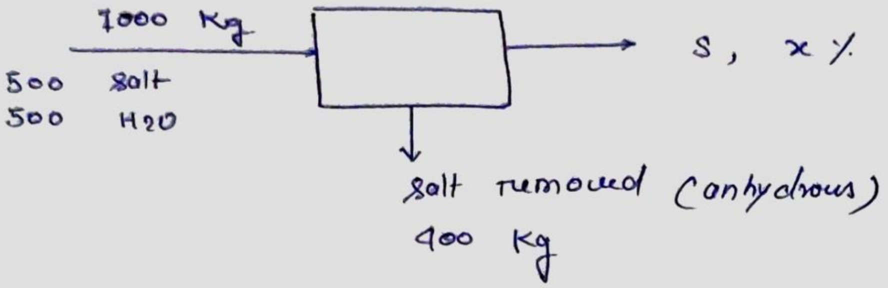
Ans:

Coal required = 0.066 Kg / sec

Air used = 0.771 Kg / sec

G- 1993

①



overall balance

$1000 = 400 + S \Rightarrow S = 600$ Kg

salt balance

$500 = 400 + S \times \frac{x}{100} \Rightarrow x = \frac{100}{6}$. $x = 16.66\,\%$

final solution will contain $= 600 \times 0.1666$ Kg salt

$= 100$ Kg salt

& 500 Kg water

Solubility of salt in kg / 100 kg of water is

$$= \frac{100}{500} \times 100$$

$$= 20$$

Ans: D

②

$$CH_4 + 2O_2 \longrightarrow CO_2 + 2H_2O$$

$$CH_4 + \frac{3}{2}O_2 \longrightarrow CO + 2H_2O$$

maximum volume per cent of CO_2 possible when flue gas contain only N_2, CO_2 & H_2O

→ above condition holds when all CH_4 converts according to reaction ①. CH_4 & O_2 are in stoichiometric ratio. conversion of rxn is 100% as flue gas does not contain any CH_4 or O_2 unreacted.

basis : 1 mol methane

required O_2 = 2 mol

Air supplied = $\frac{2}{0.21}$ mol

N_2 supplied = $0.79 \times \frac{2}{0.21} = 7.523$ mol

flue gas will contain

1 mol CO_2
2 mol H_2O
7.523 mol N_2

Volume percent of $CO_2 = \frac{1}{1+2+7.523} \times 100$

$= 9.5$ wet basis

Dry basis

$\% \; CO_2 = \frac{1}{1+7.523} \times 100$

$= 11.73 \%$

Ans: A

③. • $FeS_2 + 2.75\,O_2 \longrightarrow \frac{1}{2}Fe_2O_3 + 2\,SO_2$

$\downarrow$ 80%

SO_3

basis : 1 mol FeS_2

Required O_2 = 2.75 mol

100% excess air supplied –

O_2 supplied = 2×2.75 = 5.5 mol

N_2 supplied = $\frac{5.5}{0.21} \times 0.79$ = 20.6904 mol

SO_2 formed = 2 mol

SO_3 formed = 2×0.8 = 1.6 mol

SO_2 remains = $2 \times (1-0.8)$ = 0.4 mol

$$SO_2 + \frac{1}{2}O_2 \longrightarrow SO_3$$

O_2 consumed to form SO_3 = $\frac{1}{2} \times 0.8 \times 2$

= 0.8 mol

O_2 consumed for oxydation of FeS_2 = 2.75 mol

O_2 remains in flue gases = supplied – consumed

= 5.5 – 0.8 – 2.75

= 1.95 mol

Hence flue gas will contains

O_2 = 1.95 mol

N_2 = 20.69 mol

SO_2 = 0.4 mol

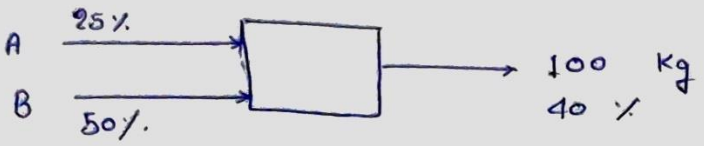
SO_3 = 1.6 mol

% of each gas can be calculated.

↑

G- 1992

①



overall balance —

$A + B = 100$

salt balance

$0.25\,A + 0.50\,B = 40$

$A = 40$ Kg

$B = 60$ Kg

Ans **40 Kg**

②

$C + O_2 \longrightarrow CO_2$

1.2 m   1.5 m

1.2 mol carbon require only 1.2 mol O_2

hence O_2 is in excess

$$\%\ \text{excess} = \frac{\text{supplied} - \text{Required}}{\text{Required}} \times 100$$

$$= \frac{1.5 - 1.2}{1.2} \times 100$$

$$= 25\,\%$$

Ans: 25

③.

[illegible]

basis : 10^6 m^3 flue gas

SO_2 present = 0.2×10^6 kg in flue gas

$= \frac{0.2}{64} \times 10^6$ kmol SO_2

$= 22.4 \times \frac{0.2}{64} \times 10^6$ m^3 SO_2

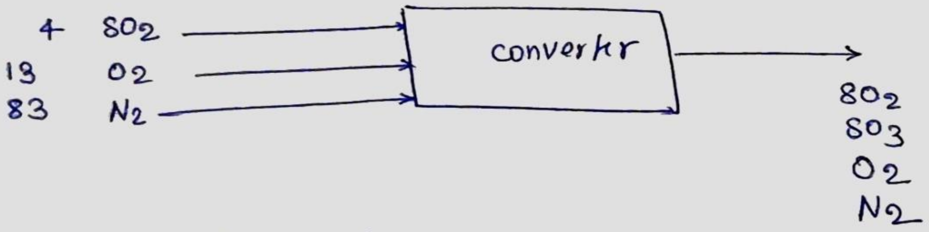
present in 10^6 m^3 gas

SO_2 ≈ 70,000 ppm

Ans: 70,000

---

④. basis : 100 mol enters the secondry converter



Let fractional conversion of SO_2 = x

$$\begin{array}{lccc} & SO_2 & + \ \frac{1}{2}O_2 & \longrightarrow \ SO_3 \\ t=0 & 4 & 13 & 0 \\ t=t & (4 - x \times 4) & (13 - \frac{x}{2} \times 4) & 4x \end{array}$$

Composition of gases out of converter –

$SO_2 = 4 - 4x$

$SO_3 = 4x$

$O_2 = 13 - 2x$

$N_2 = 83$

0.45 % SO_2 on SO_3 free basis :—

$$\frac{0.45}{100} = \frac{4-4x}{(4-4x)+(13-2x)+83}$$

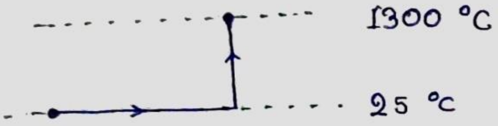
$$x = 0.8935$$

% conversion = 89.35 %

Ans: 89.35

---

⑤. basis : 1 mol CH_4



→ Reaction starts @ 25°c. Heat generated by Rxn will increase the temperature of reaction mixture. final product temp is 1300°C

→ Let oxygen supplied is x mol

	CH_4	+ $2O_2$	$\longrightarrow$ CO_2	+ $2H_2O$
$t=0$	1	x		
$t=t$	0	$x-2$	1	2

→ flue gases will contain

0 mol CH_4

$x-2$ mol O_2

1 mol CO_2

2 mol H_2O

$0.79 \times \frac{x}{0.21}$ mol N_2

Heat generated = Energy required to raise rxn mixture temperature to 1300 °C

$$8.028\times10^{5} = [(x-2)\,34.1 + 1\times51.88 + 2\times40.45 + 32.21\times3.7619\,x]\times(1300-25)$$

$$155.143x + 64.76 = 629.647$$

$x = 3.641$ mol

Air supplied $= \dfrac{3.64}{0.21}$

$= 17.338$ mol

Air required $= \dfrac{2}{0.21}$

$= 9.523$ mol

% excess air $= \dfrac{17.338 - 9.523}{9.523}\times100$

$= 82.064$

Ans : 82.064

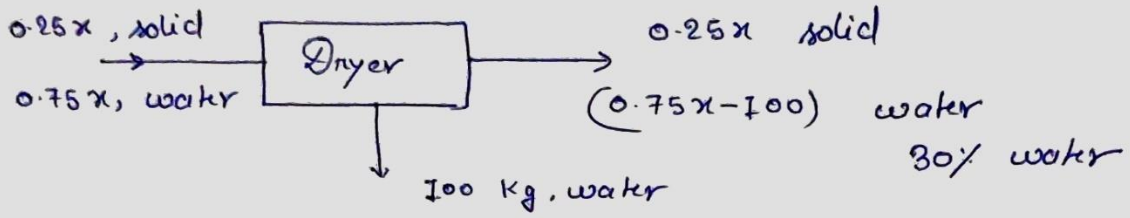
~~excess~~ air ~~used = 17.338 - 9.523~~

~~= 7.815 mol~~

~~Ans : 7.81~~

G-1991

① . basis : x kg pulp initially



pulp after drying contains 30% water —

hence —

$$\frac{0.75x - 100}{[0.25x + 0.75x - 100]} = 0.3$$

$$0.75x - 100 = 0.3x - 30$$

$$0.45x = 70 \quad \Rightarrow \quad x = 155.55 \text{ kg}$$

Ans : 155.55

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② . $FeS + 2HCl \longrightarrow FeCl_2 + H_2S$

$t=0$ 120 kg   150 kg

$\frac{120}{88}$ kmol $\frac{150}{36.5}$ kmol

= 1.36 kmol   4.1095 kmol   initially taken —

Now devide by stoichiometric coefficient

$\Rightarrow$ 1.36 $\frac{4.1095}{2}$ kmol

$1.36 < \frac{4.1095}{2}$ hence FeS is an Limiting element

$$FeS + 2HCl \longrightarrow FeCl_2 + H_2S$$

$t = 0$ 1.36 ~~2.05~~ 4.1095 0 0

$t = t$ $1.36 - 0.5$ $4.1095 - 0.5 \times 2$ 0.5 0.5

0.86 Kmol

$$\text{degree of reaction of limiting reactant} = \frac{\text{feed} - \text{out of reacted}}{\text{feed}} \times 100$$

$$= \frac{1.36 - 0.86}{1.36} \times 100$$

$$= 36.76\ \%$$

Ans: 36.76

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③. $C_4H_{10} \longrightarrow C_2H_4 + C_2H_6$

$$\Delta H_r = \sum \Delta H(\text{combution, reactant}) - \sum \Delta H(\text{com, produ}$$

$$= -2873.5 - (-1411.9) - (-1561.0)$$

$$= 99.4 \quad KJ/mol$$

Ans: 99.4

Alternate method –

$$C_4H_{10} + \frac{13}{2}O_2 \longrightarrow 4CO_2 + 5H_2O \qquad -2873.5$$

$$C_2H_4 + 3O_2 \longrightarrow 2CO_2 + 2H_2O \qquad -1411.9$$

$$C_2H_6 + \frac{7}{2}O_2 \longrightarrow 2CO_2 + 3H_2O \qquad -1561.0$$

substract 1st rxn with other two rxns —

$C_4H_{10} - C_2H_4 - C_2H_6 \longrightarrow 4CO_2 - 4CO_2 + 5H_2O - 5H_2O$

$\Delta H = 1411.9 + 1561 - 2873.5$

$C_4H_{10} \longrightarrow C_2H_4 + C_2H_6 \qquad \Delta H = 99.4$

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④. Basis : 5 Kg lime stone is calcined

Coak fed = 1 Kg

→ Reactions :—

$CaCO_3 \longrightarrow CaO + CO_2$

$MgCO_3 \longrightarrow MgO + CO_2$

$C + O_2 \longrightarrow CO_2$

Molecular mass

$CaCO_3 = 100$

$MgCO_3 = 84$

$CaO = 56$

$MgO = 40$

→ Lime stone contains —

5× 0.845 Kg $CaCO_3$ ⇒ 4.225 Kg $CaCO_3$

5× 0.115 Kg $MgCO_3$ ⇒ 0.575 Kg $MgCO_3$

5 × (1−0.845−0.115) Kg enert ⇒ 0.2 Kg Inert

→ In mols

$CaCO_3 = 4.225/100 = 0.04225$ K mol

$MgCO_3 = 0.575/84 = 0.0061607$ K mol

→ CaO formed = 0.95 × 0.04225 K mol

= 0.04013 K mol

= 0.04013 × 56 Kg

= 2.2477 Kg

MgO formed = 0·90 × 0·0061607 kmol

= 0·90 × 0·0061607 × 40 ~~kmol~~ kg

= ~~0·4657~~ 0·2217 kg

$MgCO_3$ remains = (1 − 0·9) × 0·575 kg

= 0·0575 kg

$CaCO_3$ remains = (1 − 0·95) × 4·225 kg

= 0·21125 kg

→ Remains of coak is ash only as carbon burn completly and moisture will escape in off gas

Remain ash = 0·21 × 1 kg

= 0·21 kg

→ Hence calcined mass will contein —

Ash	0·21
$CaCO_3$	0·21125
$MgCO_3$	0·0575
MgO	~~0·4657~~ 0·2217
CaO	2·2477
Inert	0·2

*All in kg

total = 3·14823

$$\text{Weight percent of CaO} = \frac{2·2477}{3·14823} \times 100$$

= 71·3955

Ans: 71·39 %

G-1990

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①

$C_7H_{16} + 11\,O_2 \longrightarrow 7\,CO_2 + 8\,H_2O \qquad \Delta H = -4850$

$\Delta H = \Sigma \Delta H_f\,[\text{products}] - \Sigma\,\Delta H_f\,[\text{Reactants}]$

$-4850 = 7 \times (-380) + 8\,(-280) - \Delta H_f\,C_7H_{16} - 0$

$\Delta H_{f,C_7H_{16}} = 4850 - 2660 - 2240$

$\Delta H_{f,C_7H_{16}} = -50 \quad KJ/mol$ **Ans : -50**

$C_2H_5OH + 3\,O_2 \longrightarrow 2\,CO_2 + 3\,H_2O \qquad \Delta H = -1410$

$\Delta H = \Sigma\,\Delta H_f\,[\text{products}] - \Sigma\,\Delta H_f\,[\text{Reactants}]$

$-1410 = 2 \times (-380) + 3 \times (-280) - \Delta H_{f,\,C_2H_5OH} - 0$

$\Delta H_{f,\,C_2H_5OH} = 1410 - 760 - 840$

$\Delta H_{f,\,C_2H_5OH} = -190 \quad KJ/Kg$ **Ans: -190**

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②

→ Basis : 100 moles flue gases

$CO_2 = 5.0$
$CO = 3.5$
$H_2O = 11.4$
$O_2 = 7.0$
$N_2 = 73.1$

→ $C_3H_8 + 5O_2 \longrightarrow 3CO_2 + 4\,H_2O$

5 moles CO_2 formed

$\frac{5}{3}$ moles of C_3H_8 consumed — in above rxn

$$C_3H_8 + \frac{7}{2} O_2 \longrightarrow 3CO + 4H_2O$$

→ CO formed 3.5 moles

$\frac{3.5}{3}$ moles of C_3H_8 consumed in abov rxn

→ total C_3H_8 @ feed $= \frac{5+3.5}{3} = 2.83$ mol

→ Air supplied

$$\frac{73.1}{0.79} = 92.53 \text{ mol}$$

→ O_2 supplied $= 0.21 \times 92.53 = 19.431$ mol

→ O_2 Required for complete combution of 2.83 mol of propane according to 1st Rxn —

$$= 5 \times 2.83$$
$$= 14.15 \text{ mol}$$

→ Required air $= \frac{14.15}{0.21} = 67.3809$ mol

$$\% \text{ excess air} = \frac{\text{Supplied} - \text{Required}}{\text{Required}} \times 100$$

$$= \frac{92.53 - 67.3809}{67.3809} \times 100$$

= ~~27.179~~ %

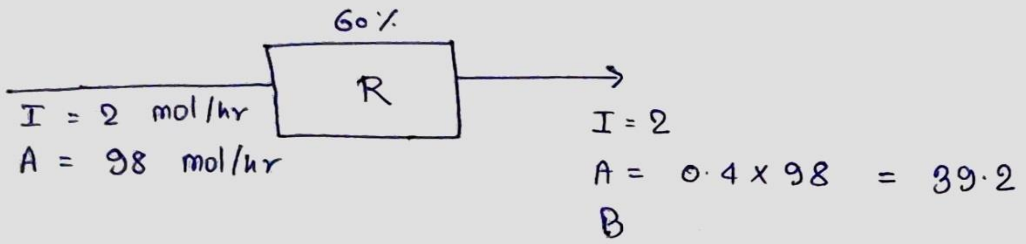
$$= 37.323 \%$$

Ans: 37.32

③ Let us assume that the stream entering the reactor (mixed stream of Recycle & Feed) has flow rate = 100 mol / h

Inert = 2 mol / hr

A = 98 mol / hr



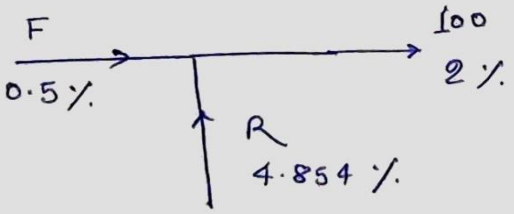
→ B is separated from product stream and divided into ~~product~~ purge and recycle stream —

composition of Recycle stream = composition of stream of separator outlet

$$\% \ I \text{ in recycle} = \frac{2}{2 + 39.2} \times 100$$

$$= 4.854 \ \%$$

→ material balance at mixed stream —



$$F + R = 100$$

$$0.5 F + 4.854 R = 2 \times 100$$

$F = 65.54$

$R = 34.45$

$$\boxed{\cancel{\frac{R}{F} = \frac{34.45}{65.54}}}$$

Recycle to total feed to Reactor Ratio —

total Feed to reactor = 100 mol/hr

$$\frac{\text{Recycle}}{\text{total feed to Reactor}} = \frac{34.45}{100}$$

$$= 0.3445$$

Ans : 0.344