SAMPLE STUDY MATERIAL

GATE SOLUTION

2000 to 2015

Detailed solution of each question

SAMPLE ★ SAMPLE ★ SAMPLE ★ SAMPLE ★

CHEMICAL ENGINEERING

GATE SOLUTION

Subject-wise reducing year

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GATE Solution

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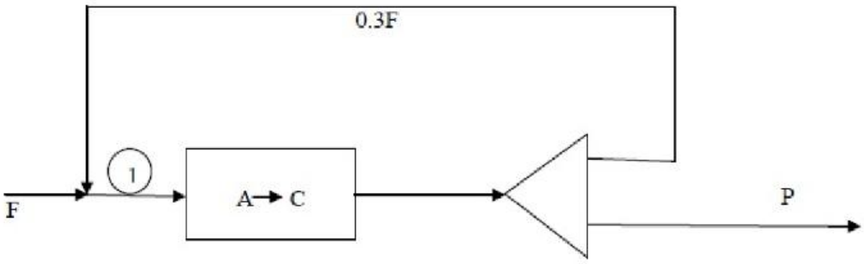
1. PROCESS CALCULATIONS

(GATE 2000 to 2015 Question Papers)

GATE-2015

Q. **1** 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 in A → C. A part of the reactor effluent is recycled. The molar flow rate of the recycle stream is 0.3F. 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 _______________



Q. **2** Adsorption on activated carbon is to be used for reducing phenol concentration in wastewater from 0.04mol/1 to 0.008 mol/1. The adsorption isotherm at the operating temperature can be expressed as q = $0.025C^{1/3}$; where q is the phenol concentration in solid (mol/g solid) and C is the phenol concentration in water (mol/1). The minimum amount of solid (in grams) required per liter of wastewater (up to one decimal place) is _______________

GATE-2014

Q. 3 A wet solid of 100 kg is dried from a moisture content of 40 wt% to 10 wt%. The critical moisture content is 15 wt% and the equilibrium moisture content is negligible. All moisture contents are on dry basis. The falling rate is considered to be linear. It takes 5 hours to dry the material in the constant rate period. The duration (in hours) of the falling rate period is

Q.4 Two elemental gases (*A* and *B*) are reacting to form a liquid (*C*) in a steady state process as per the reaction A + B → 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 ___________

Q.5 Carbon dioxide (CO) is burnt is presence of 200% excess pure oxygen and the flame temperature achieved is 2298K. The inlet streams are at 25ºC. The standard heat of formation (at 25ºC) of CO and CO_2 are – 110kJ mol^{-1} and -390kJ mol^{-1}, respectively. The heat capacities (in J mol^{-1} K^{-1}) of the components are

$$C_{po_2} = 25 + 14\times10^{-3}T$$

$$C_{Pco_2} = 25 + 42\times10^{-3}T$$

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

____

GATE-2013

Common Data for Questions 6 and 7:

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.

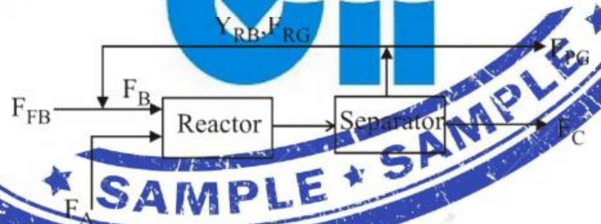
Q.6 The value of C_R in mg/L, up to one digit after the decimal point, is ________ **(2-Marks)**

Q.7 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 __________ **(2-Marks)**

GATE-2012

Common Data for Questions for 8 and 9 :

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 recycle gas is F_{RG}

Molar flow rate of purge gas is F_{PG}

Molar flow rate of A is F_A

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

Molar flow rate of C is F_C

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

Q. 8 If $Y_{RB} = 0.3$, the ratio of recycle gas to, purge gas $\left(F_{RG} / F_{PG}\right)$ is **(2-Marks)**

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

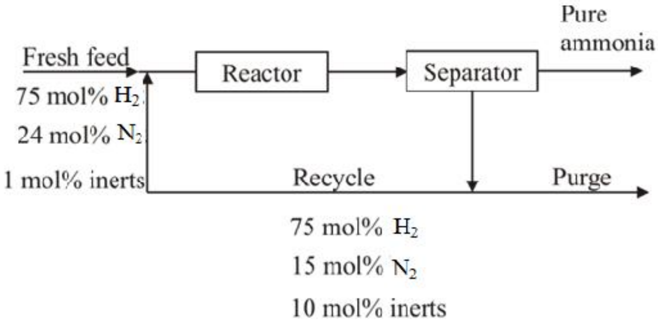
Q. 9 If the ratio of recycle gas to purge gas $\left(F_{RG} / F_{RB}\right)$ is 4 then Y_{RB} is **(2-Marks)**

(A) $\frac{3}{8}$ (B) $\frac{2}{5}$ (C) $\frac{1}{2}$ (D) $\frac{3}{4}$

GATE-2011

Q. 10 Ammonia is synthesized 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_2lost in the purge as a PERCENTAGE of H_2in fresh feed is. **(2-Marks)**



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

Q. 11 The following combustion reactions occur when methane is burnt.

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

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

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. **(2-Marks)**

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

GATE-2010

Q. 12 A saturated solution at $30^\circ C$ contains 5 moles of solute (M.W.=50kg/kmol) per kg of solvent (M.W.=20kg/kmol). The solubility at $100^\circ C$ is 10 moles of the solute per kg of the solvent. If 10 kg of the original solution is heated to $100^\circ C$, then the weight of the additional solute that can be dissolved in it, is **(2-Marks)**

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

Q. 13 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 **(2-Marks)**

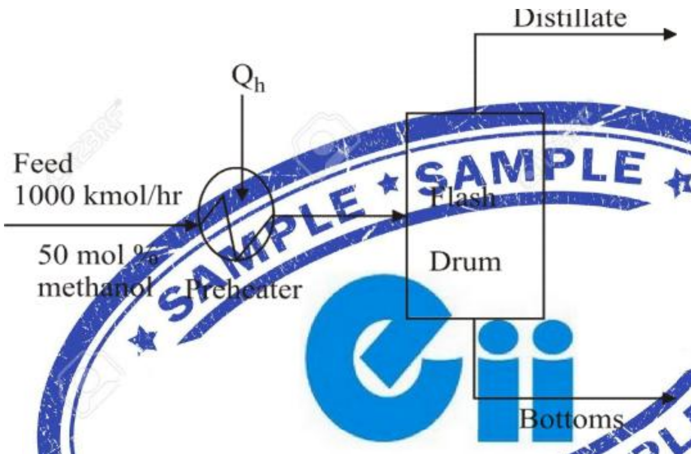
(A) 1.05 (B) 0.60 (C) 0.51 (D) 0.4

Q. 14 Dehydrogenation of ethane, $C_2H_6(g) \rightarrow C_2H_4(g) + H_2(g)$, is carried out in a continuous stirred tank reactor (CSTR). The feed is pure ethane. If the reactor exit stream contains unconverted ethane along with the products, then the number of degrees of freedom for the CSTR is **(1-Mark)**

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

Common Data for Question 15 and 16:

A flash distillation drum (see figure below) is used to separate a methanol-water mixture. The mole fraction of methanol in the feed is 0.5, and the feed flow rate is 1000 kmol/hr. the feed is preheated in a heater with heat duty Q_h and is subsequently flashed in the drum. The flash drum can be assumed to be an equilibrium stage, operating adiabatically. The equilibrium relation between the mole fractions of methanol in the vapor and liquid phases is y=4x. The ration of distillate to feed flow rate is 0.5



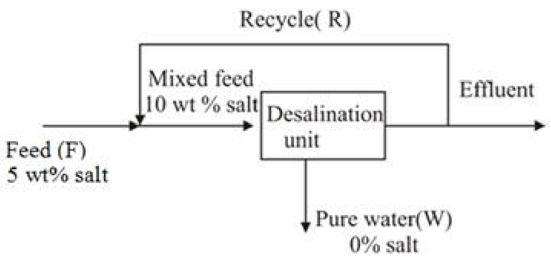
Q. 15 The mole fraction of methanol in the distillate is **(2-Marks)**

(A) 0.2 (B) 0.7 (C) 0.8 (D) 0.9

Q. 16 If the enthalpy of the distillate with reference to the feed in 3000 kJ/kmol, and the enthalpy of the bottoms with reference to feed is –1000kJ/ kmol, the heat duty of the preheater (Q_h in kJ/hr) is **(2-Marks)**

(A) -2×10^6 (B) -1×10^6 (C) 1×10^6 (D) 2×10^6

Q. 17 Pure water (stream W) is to be obtained from a feed containing 5wt % 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. **(2-Marks)**

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

GATE-2008

Q. 18 Air (79mole% nitrogen and 21 mole% oxygen) is passed over a catalyst at high temperature. Oxygen completely reacts with nitrogen as shown below.

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

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

The molar ratio of NO to NO_2 in the product stream is 2:1. The fractional conversion of nitrogen is. **(2-Marks)**

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

Q. 19 A 35 wt % Na_2 SO_4 solution in water, initially at 50^oC, is fed to a crystallizer at 20^oC. The product stream contains hydrate crystals $Na2SO_4.10H_2O$ in equilibrium with a 20 wt % Na_2SO_4 solution. The molecular weights of Na_2SO_4 and Na_2 SO_4 $10H_2O$ are 142 and 322, respectively. The feed rate of 35% solution required to produce 500kg/hr of hydrated crystals is. **(2-Marks)**

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

Q. 20 600 kg/hr of saturated steam at 1 bar (enthalpy 2675.4 kJ/kg) is mixed adiabatically with superheated steam at 450^oC and 1 bar (enthalpy 3382.4 kJ/kg). The product is superheated steam at $350^\circ C$ and 1 bar (enthalpy 3175.6 kJ/kg). The flow rate of the product is.

(A) 711 kg/hr (B) 1111 kg/hr (C)1451 kg/hr (D) 2051 kg/hr **(2-Marks)**

Q. 21 Carbon black is produced by decomposition of methane:

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

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 **(2-Marks)**

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

Common Data for Question 22, 23, 24:

Methane and stream are fed to a reactor in molar ratio 1:2. The flowing reactions take place,

$$CH_{4(g)} + 2H_2O_{(g)} \rightarrow CO_{2(g)} + 4H_{2(g)}$$

$$CH_{4(g)} + H_2O_{(g)} \rightarrow CO_{(g)} + 3H_{2(g)}$$

Where CO_2 is the desired product, CO is the undesired product and H_2 is a byproduct the exit stream has the following composition

Species	CH_4	H_2O	CO_2	H_2	CO
Mole %	4.35	10.88	15.21	67.39	2.17

Q. 22. The selectivity for desired product relative to undesired product is **(2-Marks)**

(A) 2.3 (B) 3.5 (C) 7 (D) 8

Q. 23 The fractional yield of CO_2 is(where fractional yield is defined as the ratio of moles of the desired product formed to the moles that would have been formed if there were no side reactions and the limiting reactant had reacted completely) **(2-Marks)**

(A) 0.7 (B) 0.88 (C) 1 (D) 3.5

Q. 24 The fractional conversion of methane is **(2-Marks)**

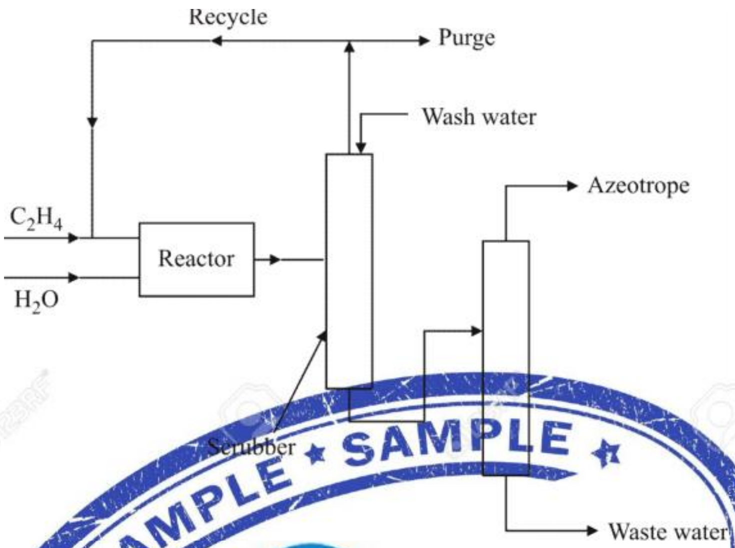
(A) 0.4 (B) 0.5 (C) 0.7 (D) 0.8

GATE-2007

Linked Answer Questions 25 and 26:

A simplified flow sheet 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 (90mol% ethanol) as the final product and water as waste. The recycle to purge ratio is 34.

(2-Marks)



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

Q.25 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

Q.26 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 condensable coming out of the reactor, the water flowrate in mols/hr from the distillation column as bottoms is **(2-Marks)**

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

Statement for Linked Answer Question 27 and 28:

Q.27 44kg of C_3H_8 is burnt with 1160kg of air (Mol. Wt. = 29) to produce 88kg CO_2 and

14kg CO $\quad C_3H_8 + 5O_2 = 3CO_2 + 4H_2O$

What is the percent excess air used?

(A) 55 (B) 60 (C) 65 (D) 68 **(2-Marks)**

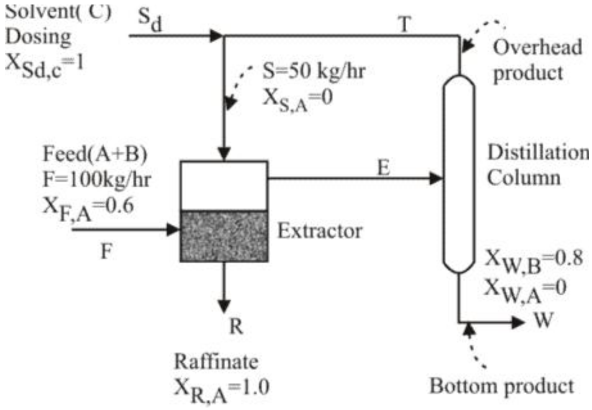
Q.28 What is the % carbon burnt?

(A) 63.3 (B) 73.3 (C) 83.3 (D) 93.3 **(2-Marks)**

GATE-2006

Statement for Linked Answer Question 29 and 30:

Solvent C is used to extract solute B selectively form 100kh/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 bottom is compensated by make up solvent $S_{d.}$. The total flow rate of the solvent stream S going to the extractor is 50kg/hr. the mass fractions (X_i's) of some selected streams are indicated in the figure below.



Q.29 Distillation bottoms flow rate W and solvent dosing rate S_d in kg/hr are **(2-Marks)**

(A) W = 50, S_d = 50 (B) W = 100, S_d = 20

(C) W = 10, S_d = 50 (D) W = 50, S_d = 10

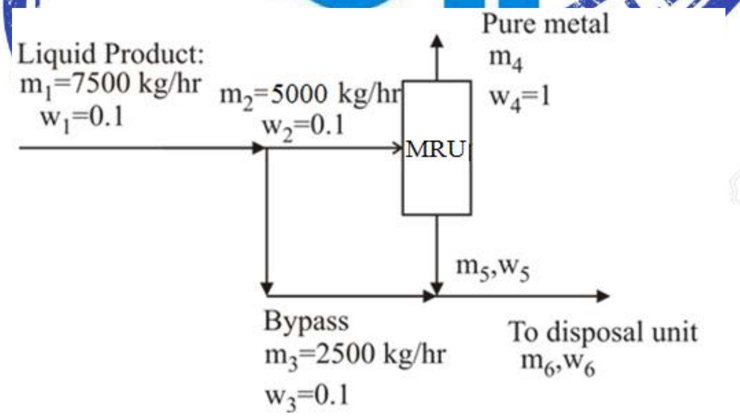
Q.30 Feed rate E to the distillation column and overhead product rate T in kg/hr are **(2-Marks)**

(A) E = 90, T = 40 (B) E = 80, T = 40

(C) E = 90, T 50 (D) E = 45, T = 20

GATE-2005

Q.31 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 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 (m_6) and the weight fraction of the metal (w_6). The liquid product flow rate is 7500 kg/hr of composition 0.1 (wt fraction). Assume steady state. **(2-Marks)**



(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) $m_6 = 5600\,kg/hr, w_6 = 0.0314$

::::::::::::::::::::::Sample File Continue::::::::::::::::::::::::

PROCESS CALCULATIONS: Answer key & Detailed explanations

1	2	3	4	5	6	7	8	9	10
45%	6.4g	1.22	9.99 to 10.01	32.0 to 38.0	3.27mg/L	0.286	B	A	A
11	12	13	14	15	16	17	18	19	20
B	C	D	C	C	D	B	B	C	D
21	22	23	24	25	26	27	28	29	30
B	C	A	C	C	D	D	C	D	A
21	22	23	24	25	26	27	28	29	30
A	C	C	D	D	C	D	A	B	C
31	32	33	34	35	36	37	38	39	40
-------------------------------SAMPLE--------------------									
41	42	43	44	45	46	47	48	49	50
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51	52	53	54	55	56	57	58	59	60
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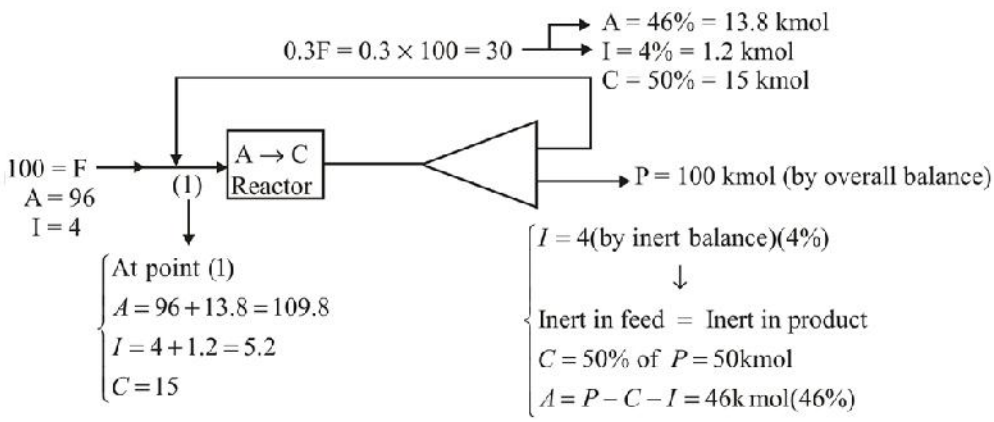
Detailed Solutions & Explanations

Explanations-2015

ANS -1 : 45.5%

EXP:

Basis: 100 kmol of fresh feed (F). It contains 96 kmol A and 4 kmol inert.



A in outlet of reactor = A outlet from separator =Sum of A in product and recycle

$$= 13.8 + 46 = 59.8$$

So,
$$\% \text{ conversion of A} = \frac{\text{A in to the reactor at point (1) - A in outlet of reactor}}{\text{A in to the reactor at point (1)}} \times 100$$
$$= \frac{109.8 - 59.8}{109.8} \times 100 = 45.53\%$$

ANS-2 : 6.4g

EXP: Phenol removed from warts water = 0.04 – 0.008 = 0.032 mol

Let q be the mol of phenol in 1 g solid in saturation.

$\because$ q mol phenol = 1 g solid

$\therefore$ 0.032 mol phenol $= \frac{0.032}{q} g$ solid required …(i)

$\Rightarrow$ $q = 0.025C^{1/3}$

$q = 0.025(0.008)^{1/3}$ [Given]

$q = 0.005$

By equation (1), solid required $= \frac{0.032}{q} = \frac{0.032}{0.005} = 6.4g$

Explanations-2014

3. Wet solid = 100kg

Initial Moisture content = 40wt%
(x_i)

Final moisture content = 10wt%
(x_c)

Equivalent moisture content = 0
(x^*) or (x_e)

All the moisture contents are on dry basis. (Given)

Let 'Ws' be the weight of bone dry solid.

Moisture content is defined as $= \frac{\text{kg moisture}}{\text{kg dry solid}}$

To make all the moisture contents satisfy the above form, they must be divided form Ws.

Constant drying time = 5hr (Given)

For the constant drying rate Regime

$$t_c = \frac{W_s}{AN_c}(x_i - x_c)$$

Where $N_C \rightarrow$ Constant drying rate from the above formula, we can calculate AN_C by putting

$x_i = \frac{.u}{ws}$, $x_C = \frac{.15}{ws}$

t_c = 5hr

AN_C = 1/20 (calculated value)

For the falling rate regime, drying rate is linear (Given)

We can use the formula for falling rate period

$$t_f = \frac{Ws}{AN_C}(x_C - x^*) Ln \frac{x_C - x^*}{x_f - x^*}$$

By putting the values

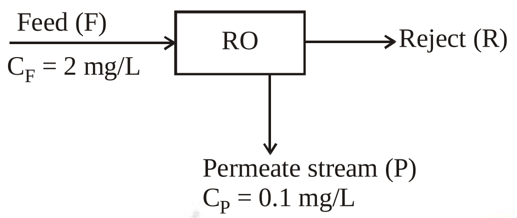
$\boxed{t_f = 1.22hr}$ $\qquad\qquad t_f = (20)(.15)Ln(1.5)$

4. 9.99 to 10.01

5. 32.0 to 38.0

Explanations-2013

6.



Mass balance F = P + R

Given: R = 0.6 F …(*i*)

∴ F = P + 0.6 F

P = 0.4F …(*ii*)

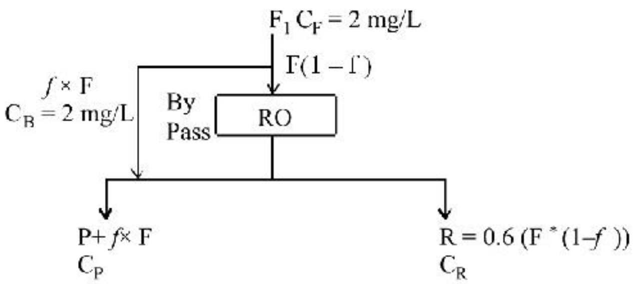
Mass balance on fluoride content : $FC_F = PC_P + RC_R$

From equation (*i*) and (*ii*)

$$F \times 2 = 0.4 \times F \times 0.1 + 0.6 \times F \times C_R$$

$$C_R = \frac{2 - 0.04}{0.6} = 3.27 \text{ mg/L}$$

7.



Given: R = 60% of volumetric flow rate of the inlet stream

Therefore, $P = 0.4 \times F(1 - f)$ …(*i*)

Fluoride content balance on by pass stream;

$$f \times F \times 2 = [P + f \times F] \times C_P$$

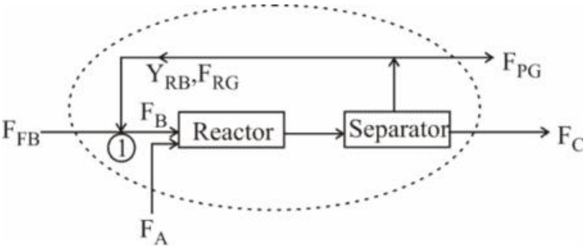
$$f \times F \times 2 = P + f \times F \qquad \because \quad C_P = 1 \quad \text{(Given)}$$

From equation (*i*)

$$f \times F \times 2 = 0.4 \times F(1 - f) + f \times F$$

$$2 \times f = 0.4 \times (1 - f) + f \qquad f = 0.4/1.4 = 0.286$$

8. (B)



Given: $F_{FB} = 2 mol/\sec$ $\qquad \frac{F_B}{F_A} = 5 mol/\sec$

$F_A = 1 mol/\sec$

A is completely converted

Assume separator separatesall C $\therefore F_C = 1 mol/\sec$

Overall Material Balance across the dotted circle

$F_A + F_{FB} = F_C + F_{PG} \qquad F_{PG} = F_A + F_{FB} - F_C = 1 + 2 - 1 = 2 mol/\sec$

Material Balance for component B at the point (1)

$F_B = F_{FB} + Y_{RB} F_{RG} \qquad \Rightarrow F_{RG} = \frac{F_B - F_{FB}}{Y_{RB}}$

$Y_{RB} = 0.3 \; given \quad so \quad F_{RG} = 10 mol/\sec$

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

9. (A) $\qquad \frac{F_{RG}}{F_{PG}} = 4(given)$

$\because F_{PG} = 2 \quad from \; Question \quad (50)$

$F_{RG} = 4 \times F_{PG} = 4 \times 2 = 8 \, mol/\sec.$

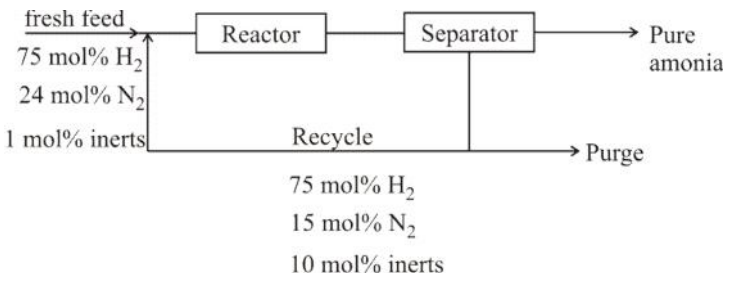
Material Balance at point (1)

$F_B = F_{FB} + Y_{RB} \times F_{RG}$

$Y_{RB} = \frac{F_B - F_{FB}}{F_{RG}} = \frac{5-2}{8} = \frac{3}{8} \qquad \left. \begin{array}{l} F_B = 5 mol/\sec \\ F_{FB} = 2 mol/\sec \end{array} \right\} given$

Explanations - 2011

10.(A)



$$N_2 + 3H_2 \rightleftharpoons 2NH_3$$

Basis: 100 moles of feed

As yield of ammonia =0.45 mol/mol of fresh feed

$\therefore$ Moles of NH_3 Produced $= 100 \times 0.45 = 45\,mol$

$$moles\ of\ H_2\ required = 45 \times 3/2 = \frac{135}{2} mole$$

Single pass conversion (20%)

$$\therefore \quad moles\ of\ H_2\ entering = \frac{135}{2} \times \frac{1}{0.2} = \frac{135}{0.4} mole$$

Moles of H_2 Coming out from separator $= \frac{135}{0.4} - \frac{135}{2} = 270$

Moles of H_2 in fresh feed $= 0.75 \times 100 = 75\,mol$

In recycle moles of $H_2 = \frac{135}{0.4} - 75 = 262.5\,mol$

In purge moles of H_2= 270-262.5 = 7.5 mol

Amount of H_2 lost in the purge as a % of H_2 in fresh feed $= \frac{7.5}{75} \times 100 = 10\%$

11. **(B)** $CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O \quad ...(1);\ £_1$

$$2CH_4 + 3O_2 \rightarrow 2CO + 4H_2O \quad ...(2);\ £_2$$

ε = Extent of reaction.

Let assume $£_1 = a \qquad £_2 = b$

By Stoichiometry O_2required =2 mol

$$20\%\ excess;\ O_2\ Supplied = 2 \times 1.2 = 2.4\,mol$$

Air; 80% $N_2$and 20% O_2

So N_2 supplied $= 2.4 \times \frac{0.8}{0.2} = 9.6\,mole$

80% Conversion so, CH_4 at the exit of combustor =1(1-0.8) = 0.2

Methane mole balance;

0.2 = initial amount CH_4 (at feed) − methane consumed (in Reaction (i)) − methane consumedat feed (in reaction (ii))

$$0.2 = 1 - \varepsilon_1 - 2\varepsilon_2 \qquad (3)$$

$$\frac{mole\ of\ CO}{mole\ of\ CO_2} = \frac{2£_2}{£_1} = \frac{1}{3} \Rightarrow £_1 = 6£_2 \quad ...(4)$$

From above two equation (3) and (4)

$£_1 = 0.6 \quad £_2 = 0.1$

$$\therefore \frac{O_2\ consumed}{O_2\ supplied} = \frac{2£_2 + 3£_1}{2.4} = \frac{2\times0.1+3\times0.6}{2.4} = \frac{1.5}{2.4} = 0.625$$

Explanations – 2010

12. (C) At 30^oC solution contains 5 moles of solute

$$C_{sol.} = \frac{5\,mol\ solute}{kg\ solvent}$$

Means $C_{sol.} \frac{kg\ solute}{kg\ solvent} = \frac{5mol\ solute}{kg\ solvent} \times \frac{1k\ mol\ solute}{1000\,mol\ solute} \times \frac{50\,kg\ solute}{k\,mol\ solute} = 0.25 \frac{kg\ solute}{kg\ solvent}$

$$\therefore C_{sol} = \frac{0.25}{125}\ \frac{kg\ solute}{kg\ solvent} = 0.20 \frac{kg\ solute}{kg\ solution}$$

10 Kg solution contains $= 10\times0.2 = 2\,kg\ solute$ and 8 kg solvent

At $100^o C \quad C_{sol} = \frac{10\,mol\ solute}{kg\ solvent} = \frac{10\,mol\ solute}{kg\ solvent} \times \frac{1k\ mol\ solute}{1000\,mol\ solute} \times \frac{50\,kg\ solute}{k\ mol\ solute}$ = 4 kg solute

So the additional solute =4 – 2=2 kg solute

13. (D) $CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$

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

From above two equation

Mole of CH_4 burnt = mole of CO_2 + mole of CO = 10 + 0.53= 10.53 moles

Moles of O_2 entered $= moles\ of\ N_2 \times \frac{21\,moles\ O_2}{79\,mol\ N_2} = 87.10 \times \frac{21}{79} = 23.15\,mol\ O_2$

$$Ratio = \frac{10.53}{23.15} = 0.45$$

::Sample File::