GATE SOLUTION
2000 to 2015
Detailed solution of each question

CHEMICAL ENGINEERING
GATE SOLUTION
Subject-wise reducing year

CONTENTS
## GATE Solution

1. Process Calculations .................................. 1-19  
2. Thermodynamics Engineering ..................... 20-55  
3. Fluid Mechanics ........................................ 56-110  
4. Mechanical Operations ............................... 111-116  
5. Heat Transfer .......................................... 117-161  
6. Mass Transfer .......................................... 162-218  
7. Chemical Reaction Engineering .................... 219-277  
8. Instrumentation and Process Control ............ 278-323  
10. Chemical Technology .................................. 340-364  
12. Verbal Ability (General Aptitude) ............... 430-433
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 $A \rightarrow C$. 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 0.04 mol/l to 0.008 mol/l. 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/l). 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 $A + B \rightarrow C$. 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 ____________

Q. 5 Carbon dioxide (CO) is burnt in presence of 200% excess pure oxygen and the flame temperature achieved is 2298K. 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

$$C_{p\text{O}_2} = 25 + 14 \times 10^{-3}T$$
$$C_{p\text{CO}_2} = 25 + 42 \times 10^{-3}T$$
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 \( A_{(liq)} + B_{(liq)} \rightarrow C_{(liq)} + D_{(g)} \) 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 $F_{RG}$
Molar 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. 8** 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. 9** If the ratio of recycle gas to purge gas \( (F_{RG} / F_{RB}) \) is 4 then $Y_{RB}$ is

(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 \( N_2 + 3H_2 \rightarrow 2NH_3 \). 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.  

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.  

Q. 12 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.  

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:

<table>
<thead>
<tr>
<th>Products</th>
<th>Mole%</th>
</tr>
</thead>
<tbody>
<tr>
<td>CO$_2$</td>
<td>10.00</td>
</tr>
<tr>
<td>O$_2$</td>
<td>2.37</td>
</tr>
<tr>
<td>CO</td>
<td>0.53</td>
</tr>
<tr>
<td>N$_2$</td>
<td>87.10</td>
</tr>
</tbody>
</table>

The ratio of the moles of CH$_4$ to the moles of O$_2$ in the feed stream is.
Q. 14 Dehydrogenation of ethane, \( \text{C}_2\text{H}_6(g) \rightarrow \text{C}_2\text{H}_4(g) + \text{H}_2(g) \), 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

\[(1-\text{Mark})\]

\(\text{(A) 1 \hspace{1cm} (B) 2 \hspace{1cm} (C) 3 \hspace{1cm} (D) 4}\)

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 ratio of distillate to feed flow rate is 0.5

Q. 15 The mole fraction of methanol in the distillate is

\[\text{(2-Marks)}\]

\(\text{(A) 0.2 \hspace{1cm} (B) 0.7 \hspace{1cm} (C) 0.8 \hspace{1cm} (D) 0.9}\)

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

\[\text{(2-Marks)}\]

\(\text{(A) \(-2 \times 10^6\) \hspace{1cm} (B) \(-1 \times 10^6\) \hspace{1cm} (C) \(1 \times 10^6\) \hspace{1cm} (D) \(2 \times 10^6\)}\)

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.

\[\text{(2-Marks)}\]

\(\text{(A) 0.25 \hspace{1cm} (B) 0.5 \hspace{1cm} (C) 0.75 \hspace{1cm} (D) 1.0}\)
Q. 18 Air (79 mole% nitrogen and 21 mole% oxygen) is passed over a catalyst at high temperature. Oxygen completely reacts with nitrogen as shown below.

\[ 0.5N_2(g) + 0.5O_2(g) \rightarrow NO(g) \]
\[ 0.5N_2(g) + O_2(g) \rightarrow NO_2(g) \]

The molar ratio of NO to NO\(_2\) in the product stream is 2:1. The fractional conversion of nitrogen is.

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

(2-Marks)

Q. 19 A 35 wt % Na\(_2\)SO\(_4\) solution in water, initially at 50ºC, is fed to a crystallizer at 20ºC. The product stream contains hydrate crystals Na2SO\(_4\)\(\cdot\)10H\(_2\)O in equilibrium with a 20 wt % Na\(_2\)SO\(_4\) solution. The molecular weights of Na\(_2\)SO\(_4\) and Na\(_2\)SO\(_4\)\(\cdot\)10H\(_2\)O are 142 and 322, respectively. The feed rate of 35% solution required to produce 500kg/hr of hydrated crystals is.

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

(2-Marks)

Q. 20 600 kg/hr of saturated steam at 1 bar (enthalpy 2675.4 kJ/kg) is mixed adiabatically with superheated steam at 450ºC and 1 bar (enthalpy 3382.4 kJ/kg). The product is superheated steam at 350ºC 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:

\[ CH_4(g) \rightarrow C(s) + 2H_2(g) \]

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

(2-Marks)

Common Data for Question 22, 23, 24:

Methane and stream are fed to a reactor in molar ratio 1:2. The following 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

<table>
<thead>
<tr>
<th>Species</th>
<th>CH(_4)</th>
<th>H(_2)O</th>
<th>CO(_2)</th>
<th>H(_2)</th>
<th>CO</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mole %</td>
<td>4.35</td>
<td>10.88</td>
<td>15.21</td>
<td>67.39</td>
<td>2.17</td>
</tr>
</tbody>
</table>

Q. 22. The selectivity for desired product relative to undesired product is.

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

(2-Marks)

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)

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

(2-Marks)

Q. 24 The fractional conversion of methane is.

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

(2-Marks)
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.

The reaction is: 

\[ \text{C}_2\text{H}_4(g) + \text{H}_2\text{O}(g) \rightarrow \text{C}_2\text{H}_5\text{OH}(g) \]

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\text{2O} feed to the reactor is 600 mols/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

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

Statement for Linked Answer Question 27 and 28:

Q. 27 44kg of \( \text{C}_3\text{H}_8 \) is burnt with 1160kg of air (Mol. Wt. = 29) to produce 88kg CO\text{2} and 14kg CO

\[ \text{C}_3\text{H}_8 + 5\text{O}_2 = 3\text{CO}_2 + 4\text{H}_2\text{O} \]

What is the percent excess air used?

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

Q. 28 What is the % carbon burnt?

(A) 63.3  (B) 73.3  (C) 83.3  (D) 93.3
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 ($m_b$) 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) $m_b = 7500$ kg/hr, $w_6 = 0.0$
(B) $m_b = 7050$ kg/hr, $w_6 = 0.04255$
(C) $m_b = 4500$ kg/hr, $w_6 = 0.1712$
(D) $m_b = 5600$ kg/hr, $w_6 = 0.0314$
### Detailed Solutions & Explanations

**ANS - 1 : 45.5%**

**EXP:**

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

\[
\begin{align*}
0.3F &= 0.3 \times 100 = 30 \\
A &= 46\% = 13.8 \text{ kmol} \\
I &= 4\% = 1.2 \text{ kmol} \\
C &= 50\% = 15 \text{ kmol}
\end{align*}
\]

\[100 = F, \quad A = 96, \quad I = 4\]

**Diagram:**

A reactor diagram showing the flow of materials and reactions.

\[
\begin{align*}
\text{At point (1)} & \\
A &= 96 + 13.8 = 109.8 \\
I &= 4 + 1.2 = 5.2 \\
C &= 15
\end{align*}
\]

\[P = 100 \text{ kmol (by overall balance)}\]

\[I = 4 \text{ (by inert balance) (4%)}\]

Inert in feed = Inert in product

\[C = 50\% \text{ of } P = 50 \text{ kmol}\]

\[A = P - C - I = 46 \text{ kmol (46%)}\]

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

\[= 13.8 + 46 = 59.8\]
% conversion of A = \frac{A \text{ in to the reactor at point (1)} - A \text{ in outlet of reactor}}{A \text{ in to the reactor at point (1)}} \times 100

So,

\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.

\therefore \quad q \text{ mol phenol} = 1 \text{ g solid}

\therefore \quad 0.032 \text{ mol phenol} = \frac{0.032}{q} \text{ g solid required} \quad \ldots(i)

\Rightarrow \quad q = 0.025C^{1/3} \quad \ldots(ii)

\Rightarrow \quad q = 0.025(0.008)^{1/3} \quad \text{[Given]}

q = 0.005

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

3. Wet solid = 100kg

Initial Moisture content = 40wt% (x_i)

Final moisture content = 10wt% (x_c)

Equivalent moisture content = 0 (x_e) or (x_c)

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

\[ t_c = \frac{W_i}{AN_c} (x_i - x_c) \]

Where \( N_c \rightarrow \text{Constant drying rate from the above formula, we can calculate AN_c by putting} \]

\[ x_i = \frac{W}{W_S}, \quad x_c = \frac{.15}{W_S} \]

\[ t_c = 5hr \]

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:

\[ t_f = \frac{W}{N} \left( \frac{x - x^*}{x_f - x^*} \right) \ln \frac{x - x^*}{x_f - x^*} \]

By putting the values

\[ t_f = 1.22 \text{hr} \]

\[ t_f = (20)(0.15)\ln(1.5) \]

4. 9.99 to 10.01
5. 32.0 to 38.0

Explanations - 2013

6. Feed (F) [C\(_F\) = 2 mg/L] → RO → Reject (R) [C\(_R\) = 0.1 mg/L] → Permeate stream (P) [C\(_P\) = 0.1 mg/L]

Mass balance F = P + R

Given: \( R = 0.6 \times F \) \( \ldots (i) \)
\[ \therefore F = P + 0.6 \times F \]
\[ P = 0.4 \times F \] \( \ldots (ii) \)

Mass balance on fluoride content: \( F \times C_F = P \times C_P + R \times C_R \)

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. [Diagram]

Given: \( R = 60\% \) of volumetric flow rate of the inlet stream
Therefore, \( P = 0.4 \times F \times (1 - f) \) \( \ldots (i) \)

Fluoride content balance on by pass stream:

\[ f \times F \times 2 = [P + f \times F] \times C_P \]
\[ f \times F \times 2 = P + f \times F \]
\[ \therefore C_P = 1 \] (Given)

From equation (i)
\[ f \times F \times 2 = 0.4 \times F \times (1 - f) + f \times F \]
\[ 2 \times f = 0.4 \times (1 - f) + f \]
\[ f = 0.4 / 1.4 = 0.286 \]
8. (B)

Given: \( F_{FB} = 2 \text{ mol/sec} \) \( \frac{F_B}{F_A} = 5 \text{ mol/sec} \)

\( F_A = 1 \text{ mol/sec} \)

A is completely converted

Assume separator separates all C \( \therefore F_C = 1 \text{ mol/sec} \)

Overall Material Balance across the dotted circle

\[
F_A + F_{FB} = F_C + F_{PG}
\]

Material Balance for component B at the point (1)

\[
F_B = F_{FB} + Y_{RB} F_R \Rightarrow F_{RG} = \frac{F_B - F_{FB}}{Y_{RB}}
\]

\( Y_{RB} = 0.3 \) given \( \therefore F_{RG} = 10 \text{ mol/sec} \)

\[
\frac{F_{RG}}{F_{PG}} = 4 \text{ (given)}
\]

\( \therefore F_{PG} = 2 \text{ from Question} \) (50)

\( F_{RG} = 4 \times F_{PG} = 4 \times 2 = 8 \text{ mol/sec} \).

Material Balance at point (1)

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

\[
Y_{RB} = \frac{F_B - F_{FB}}{F_{RG}} = \frac{5 - 2}{8} = \frac{3}{8} \quad \frac{F_B = 5 \text{ mol/sec}}{F_{FB} = 2 \text{ mol/sec}} \text{ given}
\]

9. (A)

\[ \frac{F_{RG}}{F_{PG}} = 4 \text{ (given)} \]

\( \therefore F_{PG} = 2 \text{ from Question} \)

\[
F_{RG} = 4 \times F_{PG} = 4 \times 2 = 8 \text{ mol/sec}.
\]

Material Balance at point (1)

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

\[
Y_{RB} = \frac{F_B - F_{FB}}{F_{RG}} = \frac{5 - 2}{8} = \frac{3}{8} \quad \frac{F_B = 5 \text{ mol/sec}}{F_{FB} = 2 \text{ mol/sec}} \text{ given}
\]

10. (A)
\[ N_2 + 3H_2 \rightleftharpoons 2NH_3 \]

Basis: 100 moles of feed

As yield of ammonia \( =0.45 \text{ mol/mol of fresh feed} \)

\[ \therefore \text{Moles of } NH_3 \text{ Produced} = 100 \times 0.45 = 45 \text{ mol} \]

\[ \text{moles of } H_2 \text{ required} = 45 \times \frac{3}{2} = \frac{135}{2} \text{ mole} \]

Single pass conversion (20%)

\[ \therefore \text{moles of } H_2 \text{ entering} = \frac{135}{2} \times \frac{1}{2} = \frac{135}{4} \text{ mole} \]

Moles of \( H_2 \) Coming out from separator = \( \frac{135}{4} - 75 = 270 \text{ mole} \)

Moles of \( H_2 \) in fresh feed = \( 0.75 \times 100 = 75 \text{ mol} \)

In recycle moles of \( H_2 = 270 - 262.5 = 7.5 \text{ mol} \)

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

11. \( (B) \quad CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O \quad \text{(i) } \epsilon_1 \)

\[ 2CH_4 + 3O_2 \rightarrow 2CO_2 + 4H_2O \quad \text{(ii) } \epsilon_2 \]

\( \epsilon = \text{Extent of reaction.} \)

Let assume \( \epsilon_1 = a \quad \epsilon_2 = b \)

By Stoichiometry \( O_2 \) required = 2 mol

20% excess; \( O_2 \) Supplied = \( 2 \times 1.2 = 2.4 \text{ mol} \)

Air; 80% \( N_2 \) and 20% \( O_2 \)

So \( N_2 \) supplied = \( 2.4 \times \frac{0.8}{0.2} = 9.6 \text{ mole} \)

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

Methane mole balance;

0.2 = initial amount \( CH_4 \) - methane consumed - methane consumed at feed

\[ \downarrow \text{at feed} \quad \downarrow \text{in Reaction (i)} \quad \downarrow \text{in reaction (ii)} \]

0.2 = 1 - \epsilon_1 - 2\epsilon_2 \quad \text{(3)} \]
\[
\frac{\text{mole of CO}}{\text{mole of CO}_2} = \frac{2\varepsilon_2}{\varepsilon_1} = \frac{1}{3} \Rightarrow \varepsilon_1 = 6\varepsilon_2 \quad (4)
\]

From above two equation (3) and (4)

\[
\varepsilon_1 = 0.6 \quad \varepsilon_2 = 0.1
\]

\[
\therefore \quad \frac{O_2 \text{ consumed}}{O_2 \text{ supplied}} = \frac{2\varepsilon_2 + 3\varepsilon_1}{2.4} = \frac{2 \times 0.1 + 3 \times 0.6}{2.4} = \frac{1.5}{2.4} = 0.625
\]

**Explanations – 2010**

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

\[
C_{sol.} = \frac{5 \text{ mol solute}}{\text{kg solvent}}
\]

Means \[
C_{sol.} \left( \frac{\text{kg solute}}{\text{kg solvent}} \right) = 5 \text{mol solute} \times \frac{1 \text{k mol solute}}{1000 \text{mol solute}} \times \frac{50 \text{kg solute}}{1 \text{k mol solute}} = 0.25 \text{kg solute per kg solvent}
\]

\[
\therefore \quad C_{sol} = \frac{0.25}{125} \text{kg solute per kg solvent} = 0.20 \text{kg solute per kg solution}
\]

10 Kg solution contains = 10 \times 0.2 = 2 kg solute and 8 kg solvent

At 100ºC \[
C_{sol.} = \frac{10 \text{mol solute}}{\text{kg solvent}} = \frac{10 \text{mol solute}}{1000 \text{mol solute}} \times \frac{1 \text{k mol solute}}{1 \text{k mol solute}} \times \frac{50 \text{kg solute}}{1 \text{k mol solute}} = 4 \text{ kg solute}
\]

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

13. (D) \[\text{CH}_4 + 2\text{O}_2 \rightarrow \text{CO}_2 + 2\text{H}_2\text{O}\]

\[\text{CH}_4 + \frac{3}{2}\text{O}_2 \rightarrow \text{CO}_2 + 2\text{H}_2\text{O}\]

From above two equation

Mole of \text{CH}_4 burnt = mole of \text{CO}_2 + mole of \text{CO} = 10 + 0.53 = 10.53 moles

Moles of \text{O}_2 entered = \text{moles of } N_2 \times \frac{21 \text{ moles } O_2}{79 \text{ mol } N_2} = 87.10 \times \frac{21}{79} = 23.15 \text{ mol } O_2

\[
\text{Ratio} = \frac{10.53}{23.15} = 0.45
\]

Highest Result in GATE 2015

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