ASSIGNMENT-3

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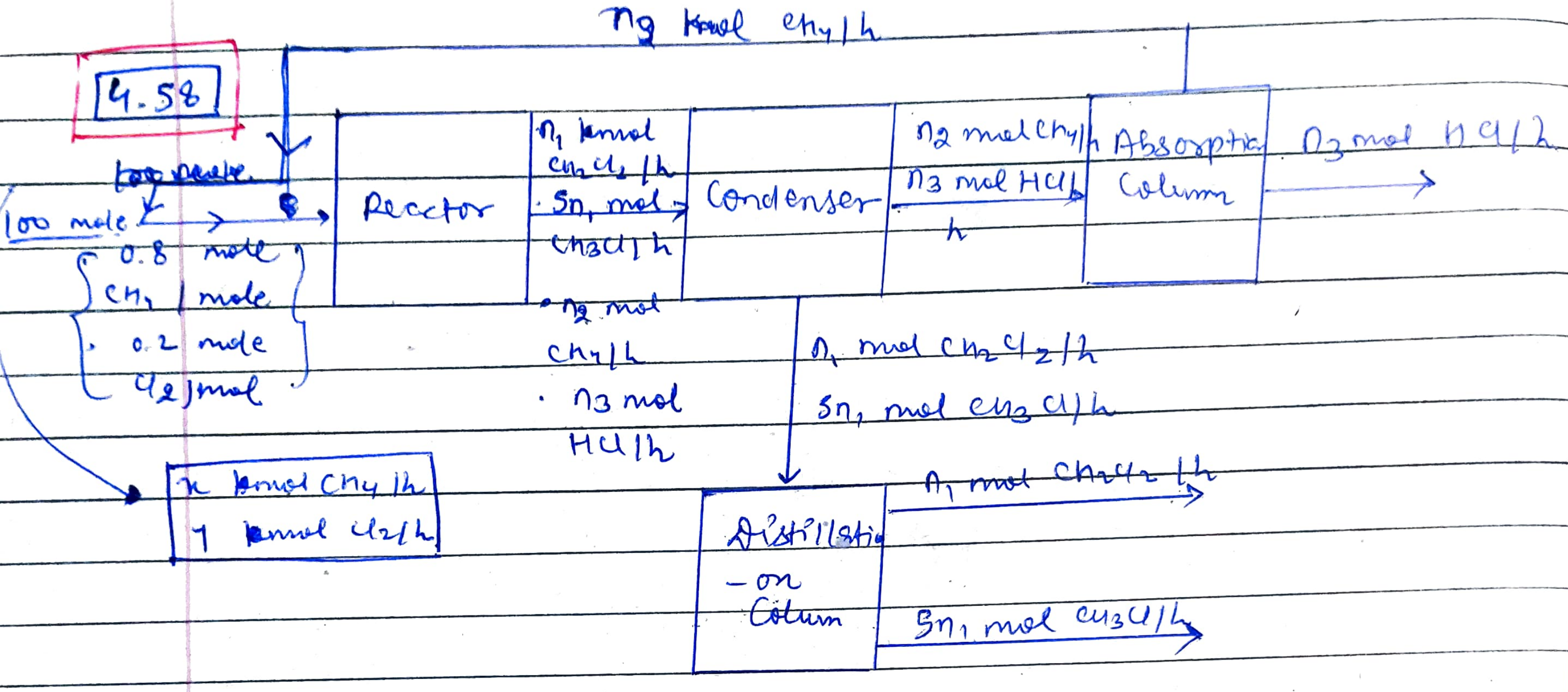
200457



(a) Let 100 mole of reactor feed be a basis of calculation

i) at the mixing point of fresh feed.

$n_{unknowns} = 3 \; (n_g)$

$n_{ind.eqs} = 2$ (~~for CH_4~~) (atomic balance for C & H)

$n_{df} = 3 - 2 = 1$

degree of freedom = 1

ii) for reactor

$n_{unknowns} = 3 \; (n_1, n_2, n_3)$

$n_{balances} = 3$ (atomic balances for C, Cl & H)

$n_{df} = 3-3 = 0$ Isham Singh

Degree of freedom $= 0$. 200457 (2)

iii) for condenser

$n_{unknown} = 3\ (n_1, n_2, n_3)$

$n_{ind.\ eq} = 0$

$n_{df} = 3-0 = 3$

Degree of freedom $= 3$

iv) for distillation column

$n_{unknown} = 1$ $n_{ind\ eq} = 0$

$n_{df} = 1-0$

Degree of freedom $= 1$

v) Absorption Column

$n_{unknown} = 2\ (n_2, n_3)$ | $n_{ind.\ eq.} = 0$

$n_{df} = 2-0 = 2$

Degree of freedom $= 2$

vi) for overall process

$n_{unknown} = 2\ (n_1, n_3)$ | $n_{ind.\ eq} = 1$

$n_{df} = 2-1 = 1$

Degree of freedom $= 1$.

• for overall reactor :-

C balance :- $80(1) + n_2(\cancel{1}) = n_1(1) + 5n_1(1) + \cancel{n_2}(1)$

$80 = 6n_1 + n_2$ — (1)

H balance :- $80(4) + \cancel{\ldots} = n_1(2) + 5n_1(3) + \cancel{4n_2}\ 4n_2 + n_3$

$320 = 17n_1 + n_3 + 4n_2$ — (2)

Cl balance :- $20(2) = n_1(2) + 5n_1 + n_3$

$40 = 7n_1 + n_3$ — (3)

Eq (2) − Eq (3) ⇒ $280 = 10n_1 + 4n_2$ — (4)

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Eq (4) − 4× Eq (1)

$280 = 10n_1 + 4n_2$

$- \quad 320 = 24n_1 + 4n_2$

$-40 = -14n_1$

$$\boxed{n_1 = \frac{40}{14} = 2.85 \text{ mol } CH_2Cl_2 / h}$$

$$\boxed{n_2 = 62.9 \text{ mol } CH_4 / h} \quad \boxed{n_3 = 20 \text{ mol } HCl / h}$$

rate at which HCl is removed from absorber.

- at mixing :- $x + n_2 = 80$

$$\boxed{x = 17.1 \text{ mol } CH_4/h}$$

$$\boxed{y = 20 \text{ mol } Cl_2 / h}$$

- Methyl chloride prodn rate = $5n_1$ = 14.5 kmol CH_3Cl/h.
- Molar flow rate of recycle stream = n_2 = 62.9 mol CH_4/h
- Rate at which HCl is removed from absorber = n_3 = 20 mol HCl/h

b) The values have been calculated in step (4)

$x = 17.1$ mol CH_4/h | $n_2 = 62.9$ mol CH_4/h

$y = 20$ mol Cl_2/h | $n_3 = 20$ mol HCl/h

$n_1 = 2.85$ mol CH_2Cl_2/h

c) Required production = 1000 kg CH_3Cl/h.

No. of moles = ~~1000 kg / $CHCl_3$~~

$$= \frac{1000 \text{ kg } CH_3Cl}{h} \cdot \frac{1 \text{ mol}}{50.49 \text{ g}} = 19.81 \text{ mol } CH_3Cl/h$$

$$\text{Scale} = \frac{19.81}{14.5} = 1.366$$

For fresh feed

$x = (17.1)(1.366) = 23.3$ mol CH_4/h

$y = (20)(1.366) = 27.3$ mol Cl_2/h

total no. of moles = 50.6 mol/h

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% mole of $CH_4 = \frac{23.3}{50.6} \times 100$

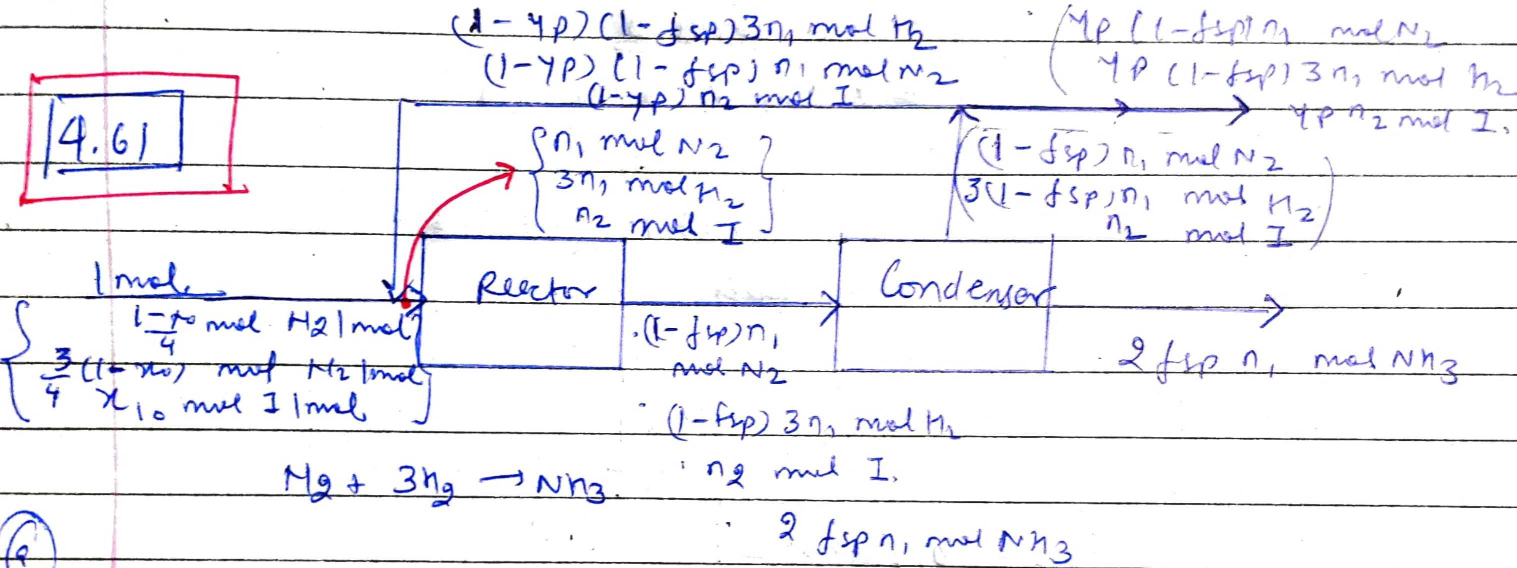
$= 46\%$

% mole of $H_2 = 54\%$

- for recycle stream

$n_2 = (62.9)(1.366) = 86$ mol CH_4/h.

4.61



- total moles $n_r = 4n_1 + n_2$

$n_p = 2 f_{sp} n_1$.

- at mixing before entering reactor

for N_2:
$$\frac{1-x_{10}}{4} + (1-y_p)(1-f_{sp})n_1 = n_1$$

$$\frac{1-x_{10}}{4} = -n_1\left[\left(1-f_{sp}\right)(1-y_p) - 1\right]$$

$$\boxed{n_1 = \frac{(1-x_{10})}{4\,(y_p + f_{sp} - y_p \cdot f_{sp})}}$$

for I:
$$x_{10} + (1-y_p)n_2 = n_2$$

$$\boxed{n_2 = \frac{x_{10}}{y_p}}$$

total moles fed $\Rightarrow 4n_1 + n_2$

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Overall N_2 conversion

$$\frac{\left(\frac{1-x_0}{4}\right) - y_p(1-f_{sp})n_1}{\left(\frac{1-x_0}{4}\right)} \times 100\ \%$$

(b) $x_0 = 0.01$, $f_{sp} = 0.2$, $y_p = 0.1$

$$n_1 = \frac{(1-x_0)}{4\,(y_p + f_{sp} - y_p f_{sp})}$$

$$n_1 = \frac{(1-0.01)}{4\,(0.1 + 0.2 - 0.02)}$$

$$n_1 = \frac{(0.99)}{4\,(0.28)}$$

$$\boxed{n_1 = 0.884 \text{ mol } N_2}$$

$$\boxed{n_2 = 0.1 \text{ mol } I}$$

$$n_r = 4n_1 + n_2$$

$$n_r = 4(0.884) + 0.1$$

$$\boxed{n_r = 3.636 \text{ moles fed}}$$

$$\boxed{n_p = 0.3536} \text{ mol } NH_3 \text{ produced}$$

$$\%\ N_2 \text{ conversion} = \frac{\left(\frac{1-0.01}{4}\right) - (0.1)\left((1-0.2)(0.884)\right)}{\left(\frac{1-0.01}{4}\right)}$$

$$= \boxed{71.3\ \%}$$

(c) Recycling is done to reuse the products and reduce wastes! It also reduces the cost of final product.
Purge is done to avoid unnecessary accumulation of I in the system!

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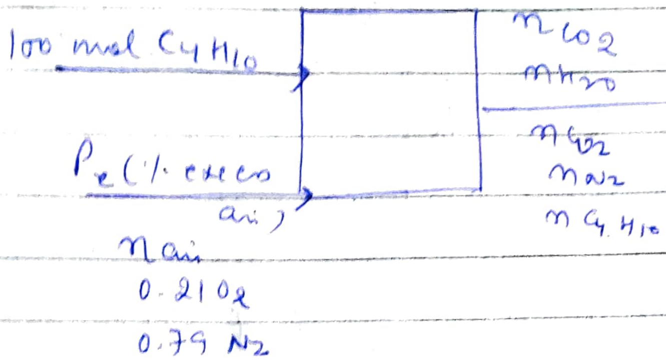
(a)



Rexn:- $C_4H_{10} + \frac{13}{2}O_2 \rightarrow 4CO_2 + 5H_2O$

6 unknowns present :- $n_{air}, n_{CO_2}, n_{N_2}, n_{O_2}, n_{H_2O}, n_{C_4H_{10}}$
- 1 N_2 balance eqn
- 1 % excess air given
- 1 % conversion given (of C_4H_{10})
- atomic balance x 3 (C, O, H)

0

Degree of freedom = 0
Hence proved!

(b) (i) theoretical air supp., 100 % conversion of C_4H_{10}.

1 mol C_4H_{10} requires $\frac{13}{2}$ mol O_2

100 mol requires $\frac{13}{2} \times 100 = 650$ mol O_2

Since 100 % conversion, $n_{C_4H_{10}} = 0$, $n_{O_2} = 0$

$n_{air} = 650 \times \left(\frac{100}{21}\right) = 3095$ mol air

$n_{N_2} = (0.79)(3095) = 2445$ moles N_2

$n_{H_2O} = 100 \times 5 = 500$ moles H_2O

$n_{CO_2} = 100 \times 4 = 400$ moles CO_2

$n_{total} = 2445 + 500 + 400 = 3345$ moles

$$\boxed{\% \; N_2 = \frac{2445}{3345} \times 100 = 73\%}$$

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$$\boxed{\%\, H_2O = \frac{500}{3345} \times 100 = 15\,\%}$$

$$\boxed{\%\, CO_2 = \frac{400}{3345} \times 100 = 12\,\%}$$

(ii) 20% excess air, 100% conversion of C_4H_{10}

$n_{C_4H_{10}} = 0$

$n_{air} = \left(1 + \frac{20}{100}\right)(3095) = 3714$ mol (780 moles O_2, 2934 mol N_2)

O_2 reacted $= \frac{13}{2} \times 100 = 650$ moles

$n_{O_2} = \cancel{\ldots} = \cancel{780}$ mol O_2

$n_{N_2} = 0.79\,(3714) = 2934$ mol N_2

$n_{CO_2} = 4 \times 100 = 400$ mol

$n_{H_2O} = 5 \times 100 = 500$ mol.

$n_{total} = \cancel{780}\,130 + 2934 + 400 + 500$

$= \cancel{4614 \text{ moles}}$ 3964 moles

$$\boxed{\begin{aligned}
\%\, O_2 &= \frac{\cancel{780}\,130}{3964} \times 100 = 3.27\,\% \\
\%\, N_2 &= \frac{2934}{3964} \times 100 = 74.01\,\% \\
\%\, CO_2 &= \frac{400}{3964} \times 100 = 10.09\,\% \\
\%\, H_2O &= \frac{500}{3964} \times 100 = 12.61\,\%
\end{aligned}}$$

iii) 90% conversion, 20% excess

$n_{C_4H_{10}} = 10$, mole of C_4H_{10} reacted $= 90$

moles of O_2 reacted $= \frac{13}{2} \times 90 = 585$

~~moles~~ $n_{air} = \left(1 + \frac{20}{100}\right)(3095) = 3714$ mol

(780 mol O_2, 2937 mol N_2)

moles of O_2 consumed = n_{O_2} = 780 − 585

n_{O_2} = 195 moles

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$n_{C_4H_{10}} = 10$

$n_{CO_2} = 360$

$n_{O_2} = 195$

$n_{N_2} = 2934$

$n_{H_2O} = 450$

$n_{total} = 3949$

% C_4H_{10} = 0.25 %

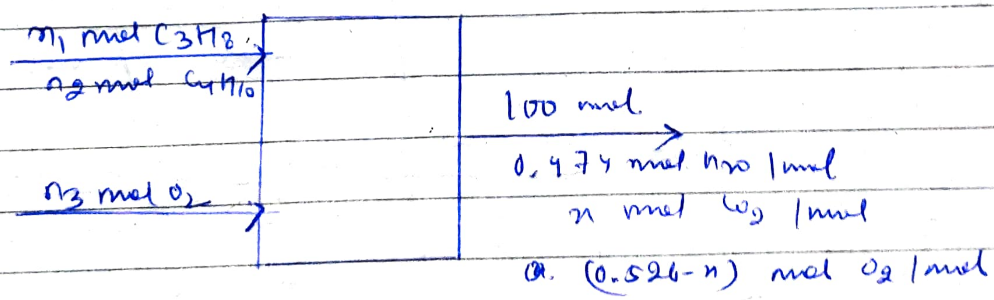
% CO_2 = 9.11 %

% O_2 = 4.93 %

% N_2 = 74.29 %

% H_2O = 11.39 %

4.73



Rean:
$C_3H_8 + 5O_2 \longrightarrow 3CO_2 + 4H_2O$

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

Dry product has 69.4% CO_2 & 30.6% O_2

$$\frac{0.526 - x}{x} = \frac{30.6}{69.4}$$

$\boxed{x = 0.365 \text{ mol } CO_2 / \text{mol}}$

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H atomic balance

$8n_1 + 10n_2 = 94.8 \quad -①$

C - atomic balance

$3n_1 + 4n_2 = x = 36.5 \quad -②$

solving ① & ②

$n_1 = 7.1$

$n_2 = 3.8$

mole % of propene $= \frac{n_1}{n_1+n_2} \times 100$

$= \frac{7.1}{10.9} \times 100 = \boxed{65.13\%}$

$\boxed{\text{Mole \% of propene} = 65.13\%}$

~~(b) $n_c/7$ 100 × 0.365 = 365 mol C~~

~~$n_H =$ 100 (0.474)~~

(b) In product

$n_c = \frac{100 \text{ mol}}{} \left| \frac{0.365 \text{ mol } CO_2}{\text{mol}} \right| \frac{1 \text{ mol C}}{\text{mol } CO_2} = 365 \text{ mol C}$

$n_H = \frac{100 \text{ mol}}{} \left| \frac{0.474 \text{ mol } H_2O}{\text{mol}} \right| \frac{2 \text{ mol H}}{\text{mol } H_2O} = 94.8 \text{ mol H}$

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$n_T = n_C + n_H$

$n_T = 36.5 + 94.8 = 131.3$

$\% \ C = \frac{36.5}{131.3} \times 100 = 27.8\%$

$\% \ H = 72.2\%$

from 9

$\frac{7.1 \text{ mol } C_3H_8}{} \left| \frac{3 \text{ mol } C}{1 \text{ mol } C_3H_8} \right| = 21.3 \text{ mol } C$

$\frac{3.8 \text{ mol } C_4H_{10}}{} \left| \frac{4 \text{ mol } C}{1 \text{ mol } C_4H_{10}} \right| = 15.2 \text{ mol } C$

total mole $C = \underline{36.5 \text{ mol } C}$

$\frac{7.10 \text{ mol } C_3H_8}{} \left| \frac{8 \text{ mol } H}{1 \text{ mol } C_3H_8} \right| = 56.8 \text{ mol } H$

$\frac{3.8 \text{ mole } C_4H_{10}}{} \left| \frac{10 \text{ mol } H}{1 \text{ mol } C_4H_{10}} \right| = 38 \text{ mol } H$

total mole $H = 94.8$ mol H

$\% \ C = \frac{36.5}{94.8 + 36.5} = \frac{36.5}{131.3}$

$\boxed{\begin{array}{l} \% \ C = 27.8\% \\ \% \ H = 72.2\% \end{array}}$

thus consistent with (a)