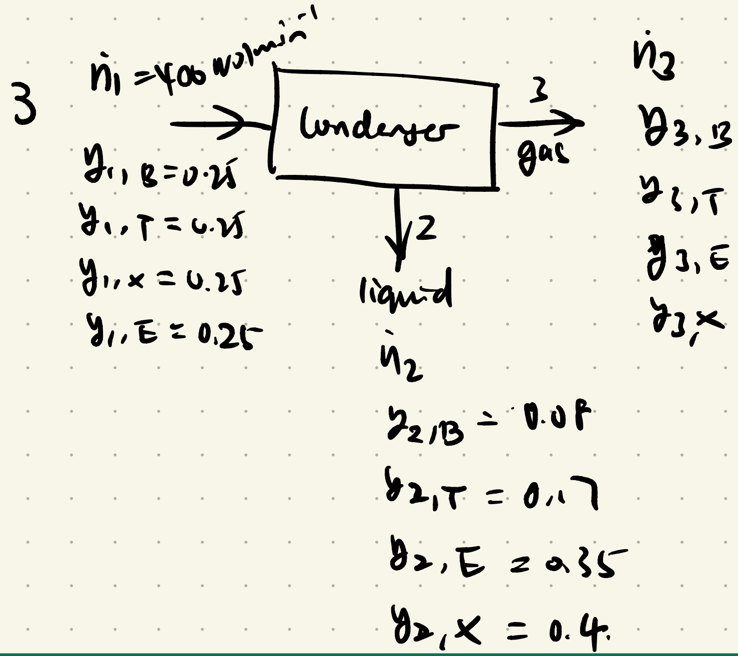
PS7

Problem 2

3



Material balance

$n_{3,B} = 100 - 0.08 n_2$ $\qquad$ $n_{3,E} = 100 - 0.35 n_2$

$n_{3,T} = 100 - 0.17 n_2$ $\qquad$ $n_{3x} = 100 - 0.4 n_2$

Energy balance

$$\sum nH + \cancel{Q}^{?} + \cancel{W}^{?} = 0$$

$$\Rightarrow \Delta H_{vap.} = \sum c_p \Delta T$$

$$\Rightarrow 30.765 \, n_{3,B} + 33.47 \, n_{3,T} + 35.98 \, n_{3,e} + 36.07 \, n_{3,x}$$

average cp? $\qquad$ each totals to 100 mol.

$$= (250-125) \frac{1}{1000} \big(\underline{135 + 160 + 185 + 181} \big) \, \underline{100}$$

Combine:

$$30.765(100 - 0.08 n_2) + 33.47(100 - 0.17 n_2) + 35.98(100 - 0.35 n_2)$$

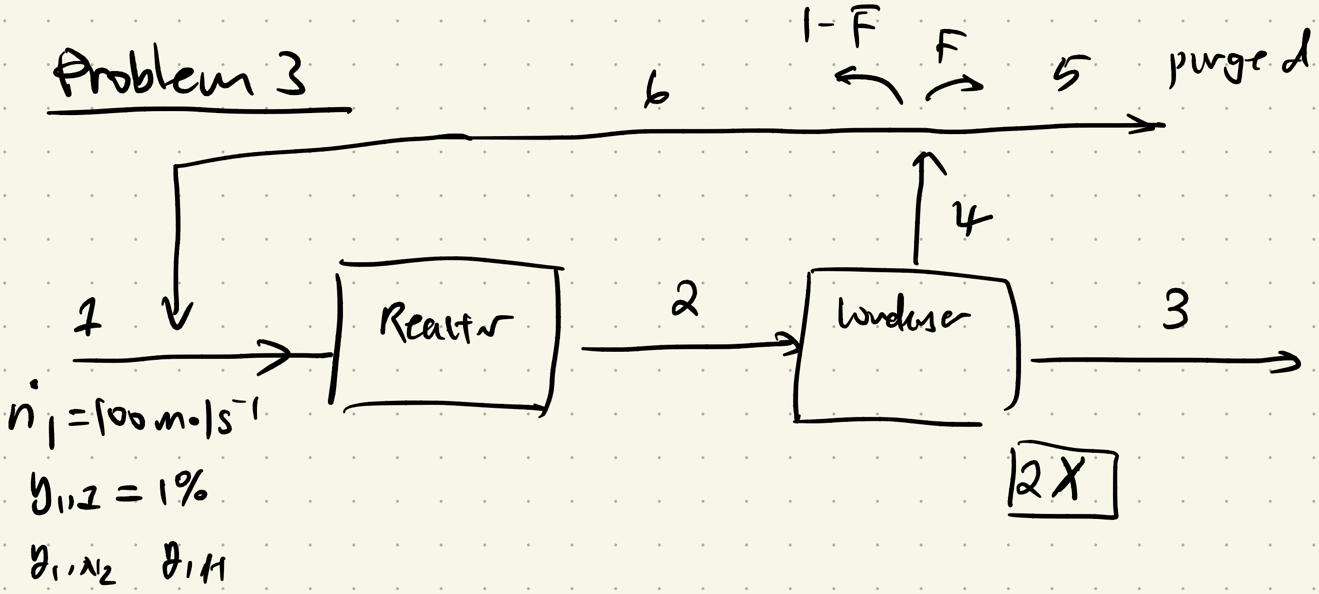
$$+ \, 36.07(100 - 0.4 n_2) = 8262.5$$

$$\Rightarrow n_2 = \frac{5466}{35.1721} = 155.4 \, mol \, s^{-1}$$

$n_3 = 400 - 155.4 = 244.6 \, mol \, s^{-1}$ $\qquad$ (almost?).

$$\Rightarrow y_{3,B} = \frac{n_{3,B}}{\cancel{244.6}} = 0.358 \quad y_{3,T} = 0.31 \quad y_{3,E} = 0.186 \quad y_{3,x} = 0.155$$

Problem 3



$\boxed{2X}$

1). ① $n_{1,N_2} = \dfrac{1-y_{1,I}}{4}$ $\quad n_{1,H_2} = \dfrac{3-3y_{1,I}}{4}$ (stoichiometric)

② Since $N_2:H_2$ mole ratio remains constant:

$$\frac{n_{i,H_2}}{n_{i,N_2}} = \frac{3}{1} \quad \forall i \in \{1,2,4,5,6\}$$

$$n_{i,I} \text{ is constant } \forall\, i \in \{4,5,6\}$$

③ Compare feed and $\dot n_6$, N_2:

$$(\dot n_{1,N_2} + \dot n_{6,N_2})\cdot(1-X)(1-F) = \dot n_{6,N_2}$$

- $\Rightarrow \dot n_{6,N_2} = \dfrac{(1-X)(1-F)}{X+F-XF} \cdot \dfrac{1-y_{1,I}}{4}$
- $\Rightarrow \dot n_{6,H_2} = 3\cdot \dot n_{6,N_2}$
- $(\dot n_{6,I} + \dot n_1 y_{1,I})(1-F) = \dot n_{6,I} \Rightarrow \dot n_{6,I} = \dfrac{\dot n_1 y_{1,I}(1-F)}{F}$

$$\Rightarrow \dot n_6 = \frac{(1-X)(1-F)}{X+F-XF}\cdot(1-y_{1,I}) + \frac{\dot n_1 y_{1,I}}{F}(1-F)$$

Represent in terms of $\dot{n}_6$

(a): $\dot{n}_1 + \dot{n}_6$

(b) $(\dot{n}_{1,N_2} + \dot{n}_{6,N_2}) \cdot 2X$

(c) $\dfrac{(\dot{n}_{1,N_2} + \dot{n}_{6,N_2})X}{\dot{n}_{1,N_2}}$

Thus:

$$\text{Let } A = \frac{(1-X)(1-F)}{X+F-XF}$$

(a) $1 + A(1-y_{1,I}) + \dfrac{F}{1-F} y_{1,I}$

(b) $\dfrac{1-y_{1,I}}{4}(1+A)(2X)$

(c) $\dfrac{1-y_{1,I}}{4}(1+A)(X)$

$y_{1,I} = 0.01, \quad X = 0.2, \quad F = 0.1$

$$A = \frac{0.8 \cdot 0.9}{0.2+0.1-0.02} = \frac{18}{7}$$

$\Rightarrow$ a): $\left[1 + \dfrac{99}{100} \times \dfrac{18}{7} + \dfrac{1}{9} \times \dfrac{99}{100}\right] 100 = 365.6 \text{ mol s}^{-1}$

b) $\left[\dfrac{0.99}{4}\left(1+\dfrac{18}{7}\right)(2)(0.2)\right] 100 = 35.4 \text{ mol s}^{-1}$

c) $\dfrac{0.99}{4}\left(1+\dfrac{18}{7}\right)(0.2) = 0.177$

2a) To improve overall yield

b) Haber.

c) i) Isolation from air through condensation.

ii) Electrolysis of water

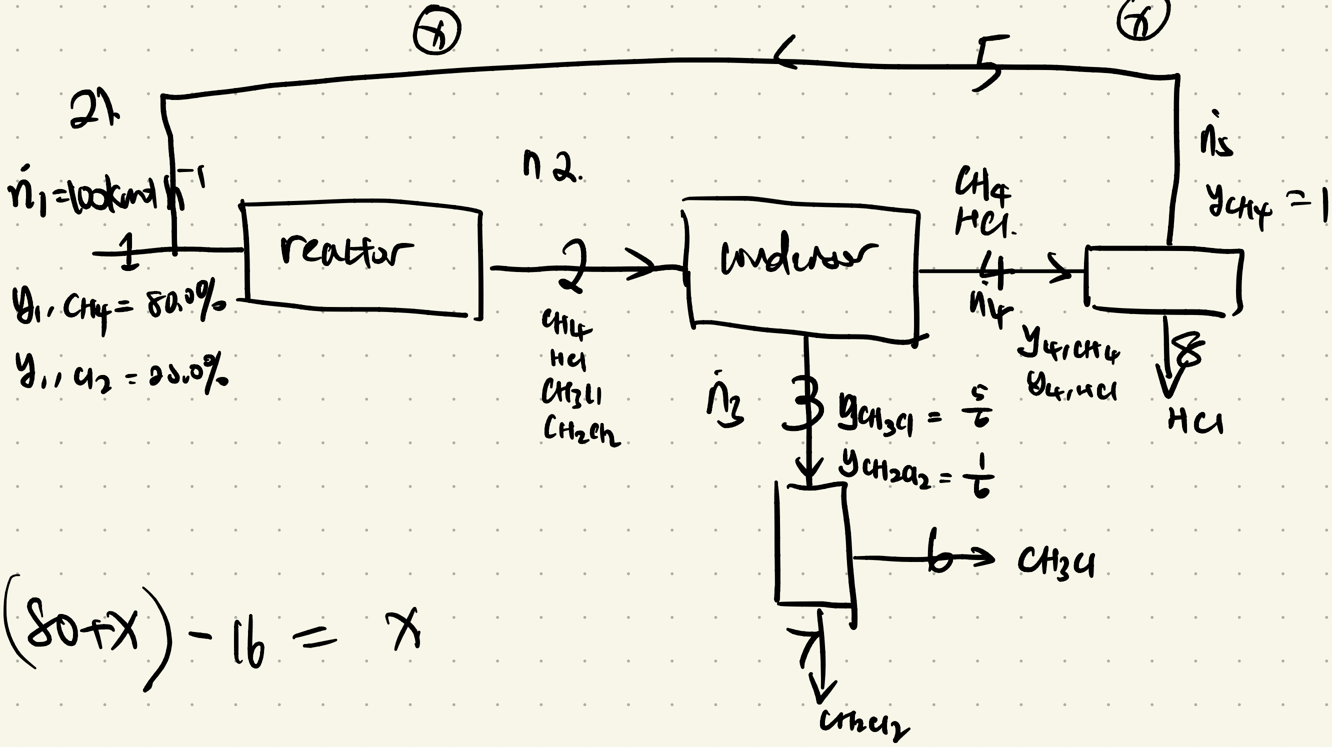
iii) Argon. Probably from air

iv) Helium. prevent explosion

Problem 4

1) a) $CH_4 + Cl_2 \rightarrow CH_3Cl + HCl.$

b) $CH_3Cl + Cl_2 \rightarrow CH_2Cl_2 + HCl.$



$(80 + x) - 16 = x$

3) $\text{conversion} = \dfrac{\dot{n}_6 + \dot{n}_7}{\dot{n}_1}$, where $\dot{n}_1 = 100\, kmol\, h^{-1}$,

$\dot{n}_6$, $\dot{n}_7$ can be measured after collection.

4) Distillation

$\dot{n}_{Cl_2} = 20.0\% \times 100 = 20\, kmol\, h^{-1}$ = total input of Cl_2 into reactor

Each Cl_2 consumed $= 1 \times CH_3Cl$ produced $= \frac{1}{2} \times CH_2Cl_2$ produced.

$\Rightarrow \dot{n}_{3,CH_3Cl} = 20 \times \dfrac{5}{5+2} = 14.3\, kmol\, h^{-1} = \dot{n}_6$

$\dot{n}_{3,CH_2Cl_2} = 20 \times \dfrac{2}{5+2} \times \dfrac{1}{2} = 2.85\, kmol\, h^{-1}. = \dot{n}_7$

All streams are solvable but:

5. The input stream is dubious

$$\text{Input} = \dot{n}_{1, CH_4} - n_{recycled, CH_4}$$

$$= \dot{n}_{1, CH_4, reacted}$$

$$= 17.1 \text{ kmol h}^{-1} < \text{recycled stream}$$

Unclear how do you initially achieve that.