Mass balance homework 2

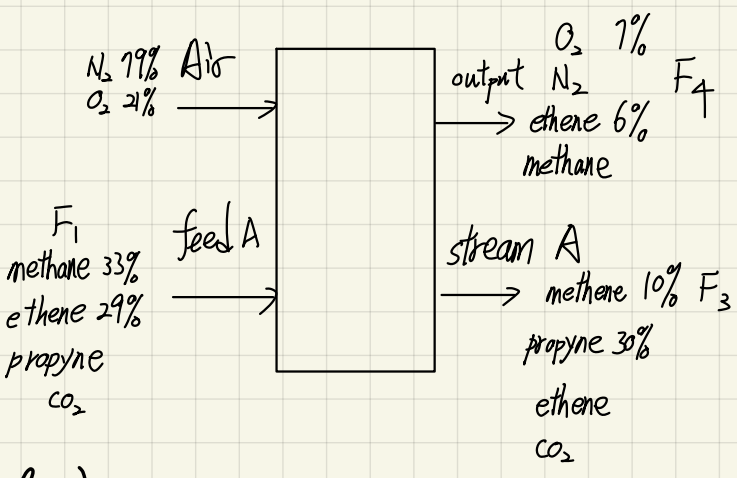
E34106010

黃偉峰

3. A separator equipped with membranes is used to continuously purify a feed gas (**feed A**) that contains Methane (33% in mole fraction), Ethene (Ethylene, 29% in mole fraction), propyne, and Carbon Dioxide. An air feed with 79% N_2 (in mole fraction) and O_2 is input as well to carry the Methane and Ethene out of the separator. The composition of the output air stream is 6% Ethene and 7% Oxygen in mole fraction. Another output stream (**stream A)** contains 10% Methane and 30% Propyne in mole fraction, and the rest are Ethene and Carbon Dioxide. Could you please calculate the flow rate (**by weight**) of **Ethene** in stream A **when the overall flow rate of feed A is 700 and 500 moles/hr,** respectively?

   a. Please show the analysis of the variables.
   b. Please list all the independent equations that you need to solve the problem.
   c. You have learned several methods to solve such problems (by hands, linear solver, and non-linear solver). Please try each of them to see if you can get the answers. If any of these is not doable, you should state the reasons.

O_2, N_2



(a)

stream	F	meth	eth	prop	N_2	O_2	CO_2
feed A 1	F_1	33%	29%	y_{1P}	X	X	y_{1C}
Air feed 2	F_2	X	X	X	79%	21%	X
streamA 3	F_3	10%	y_{3e}	30%	X	X	y_{3C}
Air out 4	F_4	y_{4m}	6%	X	y_{4N}	7%	X

$N_V = 4(6+1) - 10 = 18$

$N_d = 18 - (4+6) = 8$

⇒ 已知個小好8個可解

(b)

Mass balance

$$\begin{cases} F_1 \times 33\% = F_3 \times 10\% + F_4 y_{4m} \\ F_1 \times 29\% = F_3 \times y_{3e} + F_4 \times 6\% \\ F_1 \times y_{1P} = F_3 \times 30\% \\ F_2 \times 79\% = F_4 \times y_{4N} \\ F_2 \times 21\% = F_4 \times 7\% \\ F_1 \times y_{1C} = F_3 \times y_{3C} \end{cases}$$

fraction

$$\begin{cases} y_{1P} + y_{1C} = 38\% \\ y_{3e} + y_{3C} = 60\% \\ y_{4m} + y_{4N} = 87\% \end{cases}$$

(c) by hands

when $F_1 = 700$

$$\begin{cases} 231 = F_3 \times 0.1 + F_4 y_{4m} \\ 203 = F_3 \times y_{3e} + F_4 \times 0.06 \\ 700 \times y_{1P} = F_3 \times 0.3 \\ 700 \times y_{1C} = F_3 \times y_{3C} \\ F_2 \times 0.79 = F_4 \times y_{4N} \\ F_2 \times 0.21 = F_4 \times 0.07 \\ y_{1P} + y_{1C} = 38\% \\ y_{3e} + y_{3C} = 60\% \\ y_{4m} + y_{4N} = 87\% \end{cases}$$

$$\begin{cases} 700 \times y_{1C} = F_3 (0.6 - y_{3e}) \\ 700 \times y_{1P} = F_3 (0.3) \end{cases} \quad \Rightarrow y_{3C} = 0.2306$$

$$700 \times 0.38 = F_3 (0.9 - y_{3e})$$

$$\Rightarrow y_{3e} = 0.9 - \frac{266}{F_3} \Rightarrow 0.369$$

$$F_2 \times 0.79 = F_4 (0.87 - y_{4m})$$

$$\Rightarrow \frac{1}{3} F_4 \times 0.79 = F_4 (0.87 - y_{4m})$$

$$\Rightarrow y_{4m} = 0.6066$$

$$y_{4N} = 0.2633$$

$$\begin{cases} 469 = 0.9 F_3 + 0.06 F_4 \\ 231 = 0.1 F_3 + 0.6066 F_4 \end{cases}$$

$$\Rightarrow F_3 = 501.234 \Rightarrow F_2 = \frac{F_4}{3} = 99.38$$

$$F_4 = 298.148$$

$$700 \times y_{1P} = 501.234 \times 0.3$$

$$\Rightarrow y_{1P} = 0.2148$$

$$y_{1C} = 0.38 - y_{1P} = 0.1652$$

$$\begin{cases} F_2 = 99.38 & y_{1P} = 0.2148 & y_{3C} = 0.2306 \\ F_3 = 501.234 & y_{4m} = 0.6066 & \\ F_4 = 298.148 & y_{4N} = 0.2633 & \\ y_{1C} = 0.1652 & y_{3e} = 0.369 & \end{cases}$$

The flow rate of ethene in stream A is $(501.234 \times 0.369) \times 28 = 5183.111$ g/hr

when $F_1 = 500$

$$\begin{cases} 165 = F_3 \times 0.1 + F_4 y_{4m} \\ 145 = F_3 \times y_{3e} + F_4 \times 0.06 \\ 500 \times y_{1P} = F_3 \times 0.3 \\ 500 \times y_{1C} = F_3 \times y_{3C} \\ F_2 \times 0.79 = F_4 \times y_{4N} \\ F_2 \times 0.21 = F_4 \times 0.07 \\ y_{1P} + y_{1C} = 38\% \\ y_{3e} + y_{3C} = 60\% \\ y_{4m} + y_{4N} = 87\% \end{cases}$$

$$\begin{array}{l} 500 \times y_{1C} = F_3 (0.6 - y_{3e}) \\ +\ 500 \times y_{1P} = F_3 (0.3) \\ \hline 500 \times 0.38 = F_3 (0.9 - y_{3e}) \end{array} \Rightarrow y_{3C} = 0.2306$$

$$\Rightarrow y_{3e} = 0.9 - \frac{190}{F_3} \Rightarrow 0.369$$

$$F_2 \times 0.79 = F_4 (0.87 - y_{4m})$$

$$\Rightarrow \frac{1}{3} F_4 \times 0.79 = F_4 (0.87 - y_{4m})$$

$$\Rightarrow y_{4m} = 0.6066$$

$$y_{4N} = 0.2633$$

$$\begin{cases} 335 = 0.9 F_3 + 0.06 F_4 \\ 165 = 0.1 F_3 + 0.6066 F_4 \end{cases}$$

$$\Rightarrow F_3 = 358.02 \Rightarrow F_2 = \frac{F_4}{3} = 70.98$$

$$F_4 = 212.96$$

$$500 \times y_{1P} = 358.02 \times 0.3$$

$$\Rightarrow y_{1P} = 0.2148$$

$$y_{1C} = 0.38 - y_{1P} = 0.1652$$

$$\begin{cases} F_2 = 70.98 & y_{1P} = 0.2148 & y_{3C} = 0.2306 \\ F_3 = 358.02 & y_{4m} = 0.6066 \\ F_4 = 212.96 & y_{4N} = 0.2633 \\ y_{1C} = 0.1652 & y_{3e} = 0.369 \end{cases}$$

The flow rate of ethene in stream A

is $(358.02 \cdot 0.369) \times 28 = 3702.222\ g/hr$ ✗✗

(c) by linear solver

此問題為非線性，無法用線性求解

(c) by non-linear solver

程式碼於 homework 2.ipynb 檔內

```python
#Question 3(F1=700)
from scipy.optimize import fsolve

variable_names = ["F2","F3","F4","y1p","y1c","y3e","y3c","y4m","y4n"]

def equations(V):
    F2, F3, F4, y1p, y1c, y3e, y3c, y4m, y4n = V
    F1=700
    return(F1*0.33-F3*0.1-F4*y4m,
           F1*0.29-F3*y3e-F4*0.06,
           F1*y1p-F3*0.3,
           F2*0.79-F4*y4n,
           F2*0.21-F4*0.07,
           F1*y1c-F3*y3c,
           y1p+y1c-0.38,
           y3e+y3c-0.6,
           y4m+y4n-0.87)

sol = fsolve(equations, [100,100,100,0.01,0.01,0.01,0.01,0.1,0.1] )
ethene = (sol[1]*sol[5])*28
print("When F1=700")
for i in variable_names:
    print("solved",i, "= ", sol[variable_names.index(i)])

print("\nThe flow rate (by weight) of ethene in stream A is ",ethene,"g/hr")
```

```
When F1=700
solved F2 =  99.38271605019571
solved F3 =  501.23456790319506
solved F4 =  298.1481481505871
solved y1p =  0.21481481481565504
solved y1c =  0.16518518518434497
solved y3e =  0.36931034482715064
solved y3c =  0.2306896551728493
solved y4m =  0.6066666666887259
solved y4n =  0.26333333331127406

The flow rate (by weight) of ethene in stream A is  5183.111111125271 g/hr
```

```python
#Question 3 (F1=500)
from scipy.optimize import fsolve

variable_names = ["F2","F3","F4","y1p","y1c","y3e","y3c","y4m","y4n"]

def equations(V):
    F2, F3, F4, y1p, y1c, y3e, y3c, y4m, y4n = V
    F1=500
    return(F1*0.33-F3*0.1-F4*y4m,
           F1*0.29-F3*y3e-F4*0.06,
           F1*y1p-F3*0.3,
           F2*0.79-F4*y4n,
           F2*0.21-F4*0.07,
           F1*y1c-F3*y3c,
           y1p+y1c-0.38,
           y3e+y3c-0.6,
           y4m+y4n-0.87)

sol = fsolve(equations, [100,100,100,0.01,0.01,0.01,0.01,0.1,0.1] )
ethene = (sol[1]*sol[5])*28
print("When F1=500")
for i in variable_names:
    print("solved",i, "= ", sol[variable_names.index(i)])

print("\nThe flow rate (by weight) of ethene in stream A is ",ethene,"g/hr")
```

```
When F1=500
solved F2 =  70.9876543220026
solved F3 =  358.0246913581955
solved F4 =  212.96296296600775
solved y1p =  0.21481481481491732
solved y1c =  0.16518518518508268
solved y3e =  0.36931034482179237
solved y3c =  0.2306896551782076
solved y4m =  0.6066666666848854
solved y4n =  0.2633333333151146

The flow rate (by weight) of ethene in stream A is  3702.222222165907 g/hr
```