Lab Session 4

Submitted By: Priyanshu Maurya

Roll No.: 220827

TA: Praful Mane

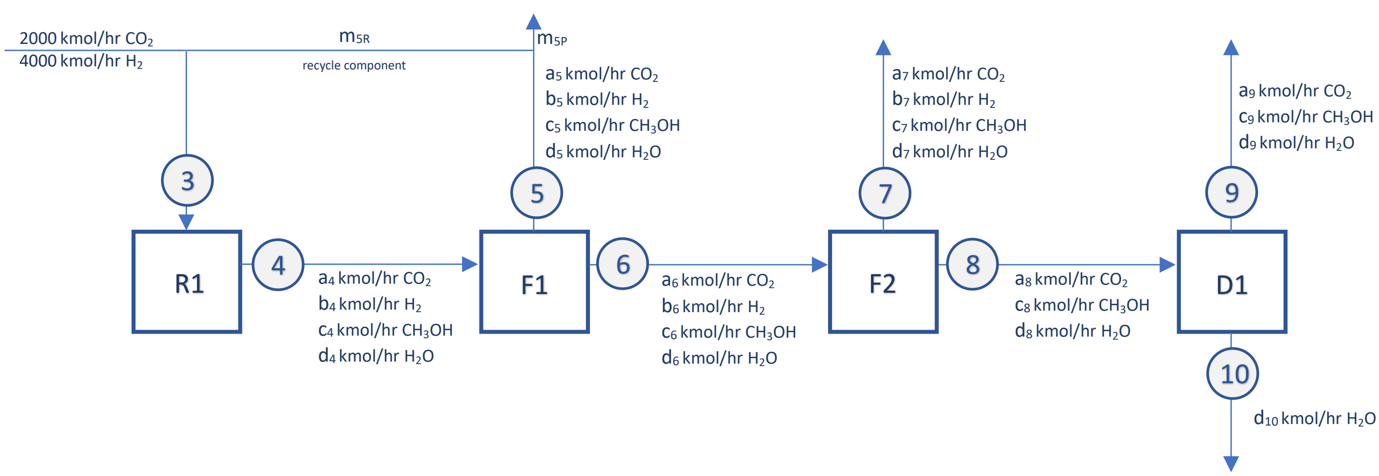
AIM

The goal of the laboratory session is to determine the total molar flow rates of all the streams and make a contour plot illustrating the variation of difference in methanol production cost with and without recycling as a function of CO_2 and H_2 prices.

METHOD

Approach 1: We first assign variables to different molar rates at each process as shown below,

a_2 = 2000 kmol/hr
b_2 = 4000 kmol/hr
a_6 = 145.34 kmol/hr
b_6 = 0.789 kmol/hr
c_6 = 1265.53 kmol/hr
d_6 = 1269.99 kmol/hr



Approach 2: Using appropriate mass and energy balances, we can form equations as follows:

Equations at reactor flask:

$0.3644*a_2 = 0.05*a_5 + a_6$
$b_4 = b_3 - 3*(a_4-a_3)$
$a_3 = 2000+0.95*a_5$
$b_3 = 4000+0.95*b_5$
$c_3 = 0.95*c_5$
$d_3 = 0.95*d_5$

Equations at flash drum 1:

$a_6 = a_4 - a_5$

$b_6 = b_4 – b_5$
$c_6 = c_4 – c_5$
$d_6 = d_4 – d_5$

Equations at flash drum 2:

$a_7 = 57.74* a_8$
$b_7 = b_6$
$c_7 = 0.0212*c_8$
$d_7 = 0.0043*d_8$
$a_6 = a_7 + a_8$
$c_6 = c_7 + c_8$
$d_6 = d_7 + d_8$

Equations at distillation column:

$a_9 = a_8$
$c_9 = c_8$
$d_9 = 0.0091*d_8$
$d_{10} = 0.9909*d_8$

Approach 3: Using MATLAB function `equationsToMatrix`, we will solve for variables.

RESULTS and ANALYSIS

After solving using linsolve in MATLAB we get:

Total molar flow rates for:

n3 = 20743.10 kmol/hr
n_4 = 18200 kmol/hr
n_5 = 15519.06 kmol/hr
n_{5R} = 14743.10 kmol/hr
n_6 = 2681.64 kmol/hr
n_7 = 175.36 kmol/hr
n_8 = 2506.28 kmol/hr
n_9 = 1253.23 kmol/hr
n_{10} = 1253.04 kmol/hr

For stream 3:

a_3 = 13085.78 kmol/hr CO_2
b_3 = 7524.32 kmol/hr H_2
c_3 = 107.73 kmol/hr CH_3OH
d_3 = 22.99 kmol/hr H_2O

For stream 4:

a_4 = 11814.54 kmol/hr CO_2
b_4 = 3713.00 kmol/hr H_2
c_4 = 176.2 kmol/hr CH_3OH
d_4 = 1294.2 kmol/hr H_2O

For stream 5:

a_5 = 11669 kmol/hr CO_2

b_5 = 3712.2 kmol/hr H_2
c_5 = 113.4 kmol/hr CH_3OH
d_5 = 24.2 kmol/hr H_2O

For stream 6:

a_6 = 145.34 kmol/hr CO_2
b_6 = 0.789 kmol/hr H_2
c_6 = 1265.5 kmol/hr CH_3OH
d_6 = 1270 kmol/hr H_2O

For stream 7:

a_7 = 142.86 kmol/hr CO_2
b_7 = 0.789 kmol/hr H_2
c_7 = 26.27 kmol/hr CH_3OH
d_7 = 5.437 kmol/hr H_2O

For stream 8:

a_8 = 2.47 kmol/hr CO_2
c_8 = 1239.3 kmol/hr CH_3OH
d_8 = 1264.6 kmol/hr H_2O

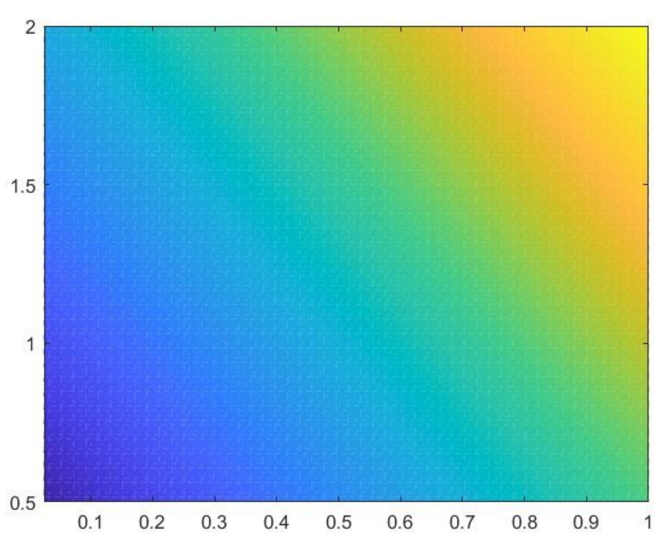
For stream 9:

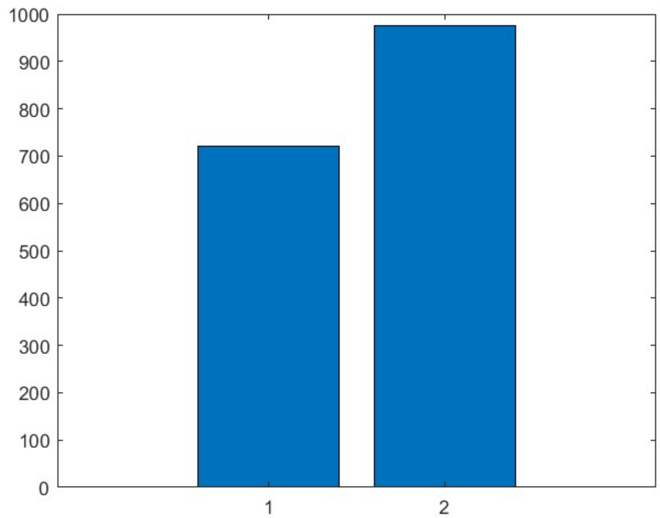
a_9 = 2.47 kmol/hr CO_2
c_9 = 1239.3 kmol/hr CH_3OH
d_9 = 11.6 kmol/hr H_2O

For stream 10:

d_5 = 1253.0 kmol/hr H_2O

The contour plot illustrating the variation of CH_3OH production cost as a function of CO_2 and H_2 prices is shown below:





CONCLUSION

We got the molar flow rate for all the processes. Then we calculated the variation of cost of production of CH_3OH by varying the prices of CO_2 and H_2 in the feed. Using this data, we plotted this on a contour graph.

APPENDIX

The MATLAB code to solve the problem is as follows:

```
% a for ch3oh,b for co2, c for h2, d for h2o;
% for stream 6:
a6=1265.53;
b6=145.34;
c6=0.789;
d6=1269.99;
m6=a6+b6+c6+d6;
% for stream 7:
a7=0.0212*a6/(1+0.0212);
b7=57.74*b6/(1+57.74);
c7=c6;
d7=0.0043*d6/(1+0.0043);
m7=a7+b7+c7+d7;
% for stream 8:
a8=a6/(1.0212);
b8=b6/58.74;
c8=0;
d8=d6/1.0043;
m8=a8+b8+c8+d8;
% for stream 3,4,5:
b5=(2000*(1-0.6356)-b6)/0.05;
b3=2000+0.95*b5;
b4=b3-0.6356*2000;
a5=(b3-b4-a6)/0.05;
a3=0.95*a5;
a4=a3+0.6356*a3;
d5=(b3-b4-d6)/0.05;
% for stream 10:
d10=0.9909*d8;
```

```
m10=d10;
% forstream 9:
a9=a8;
b9=b8;
d9=(1-0.9909)*d8;
m9=a9+b9+d9;

d3=0.95*d5;
d4=d3+0.6356*2000;
c5=(4000-3*(-b4+b3)-c6)/0.05;
c3=4000+0.95*c5;
c4=c3-3*2000*0.6356;
m3=a3+b3+c3+d3;
m4=a4+b5+c5+d5;
m5=a5+b5+c5+d5;

 % part 2:

 mm3=44*b3+2*c3+18*d3+32*a3;
 f3=2000*44+4000*2;
 %molar flow rates of streams 4, 6, and 8, respectively, obtained in lab session 3
 n4=6000;
 n6=2689.2;
 n8=2639.1;
 % methanol produced:
 M1=641.3*100;
 M2=a8*100;

p1 =[14694200 9.7 0 12];
p2 =[29418000 21.5 0 20.9];
R1 =[1.53*107*f3/54000 0.65 0 0.28 0];
C1=[ 269600 0 0 22.6];
F1= [171300 0 0 0];
F2=[ 168100 0 0 0];
H1 =[63000 0 0.8 0];
D1=[ 1507900 0 15.7 15.4];


c_cap1=(p1(1)+p2(1)+R1(1)+C1(1)+F1(1)+F2(1)+H1(1)+D1(1));
c_cap2=(p1(1)+p2(1)+1434700+(1.53*10^7*(mm3/54000)^0.65)+(269600*(m4/n4)^0.6) ...
        + (171300*(m4/n4)^0.6) +(168100*(m6/n6)^0.6)+(63000*(m8/n8)^0.6) ...
        +(1507900*(m8/n8)^0.6));
CM=zeros(100,100);

% graph work:
cco2=linspace(0.025,1,100);
ch2=linspace(0.5,2,100);
for i=1:100
    x=cco2(1,i);
    for j=1:100
         y=ch2(1,j);

c_op1=((9.7+21.5)*0.072*1000)+((0.28+0.8+15.7)*2.5*0.001)+((12+20.9+22.6+15.4)*2.12*0.0001)+x+y;

c_op2=((9.7+21.5+0.97)*0.072*1000+(19.76+1.76+30.22)*2.5*0.001+(12+20.9+65.7+29.6)*2.12*0.0001)+x+
y;
        CM(i,j)=(0.1*c_cap1+c_op1)/M1 -(0.1*c_cap2+c_op2)/M2 ;
    end

end
figure
```

```
 contour(cco2,ch2,CM,1000);

% part 3:
% c_capi=annual capital cost,c_ei= electricity,c_si= heating,c_ci= cooling, and c_r= raw material
costs
c_e1=(9.7+21.5)*0.072*1000; c_s1=((0.28+0.8+15.7)*2.5*0.001);
c_c1=((12+20.9+22.6+15.4)*2.12*0.0001);c_r1=200/44+2000;
c_e2=(9.7+21.5+0.97)*0.072*1000;c_s2=(19.76+1.76+30.22)*2.5*0.001;c_c2=(12+20.9+65.7+29.6)*2.12*0.
0001;c_r2=200/44+2000;
CMM=[c_cap1/M1 c_e1/M1 c_s1/M1 c_c1/M1 c_r1/M1 ; c_cap2/M2 c_e2/M2 c_s2/M2 c_c2/M2 c_r2/M2];
figure
bar(CMM ,"stacked");
```