Mass transfer 2 **Feb 9-2024**

Please read the instructions carefully: **Total marks =85**

1. If you are found to have discussion with other students, the exam will be cancelled.
2. If the code/answer re found to be identical for two students, full marks will be deducted from both students.
3. The phone needs to be switched off and kept in bag.
4. If email or WhatsApp is used in your laptop screen, the exam will be cancelled.

Problem 1: Liquid-liquid extraction, calculate solute level in E and R from solvent level in E and R: 100 kg of solution containing 35% of the solute C is to be extracted using a solvent B. The composition of raffinate and extracts (xb and xc , **LLE data from experiments**) as well as tie-line information is given below:

```
B = [0 0.004 0.006 0.01 0.02 0.03 0.036 0.07 0.13 0.16 0.19 0.23 0.26 0.5 0.63 0.71 0.78 0.84 0.9 0.95 1];
C = [0 0.05 0.1 0.15 0.2 0.25 0.3 0.35 0.4 0.4025 0.405 0.402 0.4 0.35 0.3 0.25 0.2 0.15 0.1 0.05 0];
figure(1)
plot(B,C,'bo-');grid on;
tiexb =[ 0.0032    0.0053    0.0084    0.0229    0.1229]

tieyb = [ 0.9659    0.9329    0.9109    0.8471    0.6065]
```

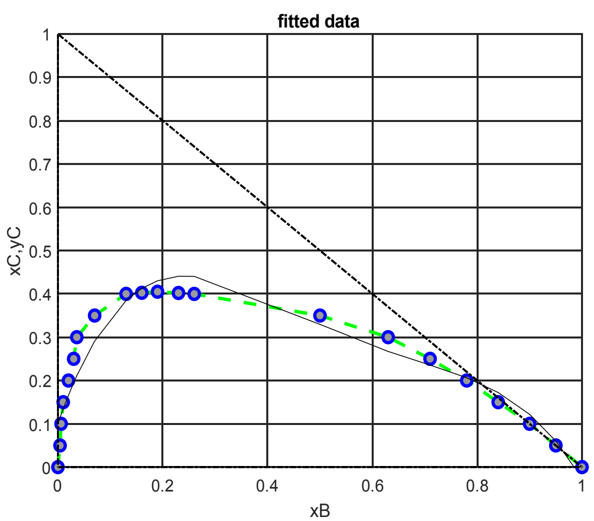


Figure 1: Draw the ternary phase diagram in right angled triangle co-ordinates as shown in the paper. Fit a polynomial of degree 4, to the entire LLE data for trimethyl amine as mentioned above. Use **one single polynomial** to for both raffinate and extract phase. Show the co-efficient of the polynomial (polyfit function). Using this equation of polynomial, plot the simulated curve (generate the concentration xc/ yc as a function xb /yb with 0.02 step size) along with experimental points. [**experimental points=blue points, simulation output from polynomial=black like**]. [15]

Figure 2: Use only the Tie-line information [tiexb, tieyb] **for drawing five tie lines** [Do not use join the points from LLE data for water rich phase and benzene rich phase composition for drawing the tie line] on the ternary phase diagram. From the given information on tie-line, **calculate the solute level in extract** and raffinate using the LLE curve equation [4th degree polynomial that is fitted to both raffinate and extract phase). Plot the five tie lines in LLE diagram. From this information, **calculate the slope of the tie lines**. Print the slopes for five tie lines. [20]

Problem 2: Multistage cross-current extraction with <u>different solvent compositions</u> at various stages

```
B = [0 0.0011 0.0021 0.0031 0.0058 0.0136 0.0372 0.11 0.1259 0.1376 0.1508 0.16 0.3357 0.4751 0.608
0.7698 0.8872 0.9982 1];
C = [0 0 0.1 0.2 0.3 0.4 0.5 0.5821 0.6 0.6058 0.6107 0.6093 0.5819 0.4944 0.3748 0.2223 0.1079 0 0];
figure(1)
plot(B,C,'bo-');grid on;
```

EXAMPLE 8.2 (*Single-stage extraction*) One thousand kilograms of an aqueous solution containing 50% acetone is contacted with 800 kg of chlorobenzene containing 0.5 mass% acetone in a mixer-settler unit, followed by separation of the extract and the raffinate phases. (a) Determine the composition of the extract and the raffinate phases and the fraction of acetone extracted. (b) Also calculate the amount of solvent required if 90% of the acetone is to be removed. Equilibrium and tie line data are given below.

Aqueous phase (*Raffinate*)			Organic phase (*Extract*)		
Water	Chlorobenzene	Acetone	Water	Chlorobenzene	Acetone
x_A	x_B	x_C	y_A	y_B	y_C
0.9989	0.0011	0.0	0.0018	0.9982	0.0
0.8979	0.0021	0.1	0.0049	0.8872	0.1079
0.7969	0.0031	0.2	0.0079	0.7698	0.2223
0.6942	0.0058	0.3	0.0172	0.608	0.3748
0.5864	0.0136	0.4	0.0305	0.4751	0.4944
0.4628	0.0372	0.5	0.0724	0.3357	0.5919
0.2741	0.1259	0.6	0.2285	0.1508	0.6107
0.2566	0.1376	0.6058	0.2566	0.1376	0.6058

Use the **multistage cross current extraction code** (tutorial class) for simulation of three-stage extraction (that computes xci, yci, Ri, Ei etc. where i is the number of stages).

Figure 1: Instead of single stage operation with 800 kg, you want to use the three-stage crosscurrent extraction. The solvent flow for three stages is, 250, 300 and 350 kg, with 5%, 10% and 15 % acetone [ycs], respectively. Show the mixture point and tie line construction. [Use the existing interpolator for tie lines]. Calculate the **<u>fraction of c in raffinate</u>** every stage. [20]

Figure 2: If we use 250 kg solvent for every stage [ycs=0.005, for 0.5% acetone present in solvent for each stage, xF=0.5] , and perform multistage extraction of acetone, calculate the number stages required for 95 percent removal of acetone (approx.). [10]

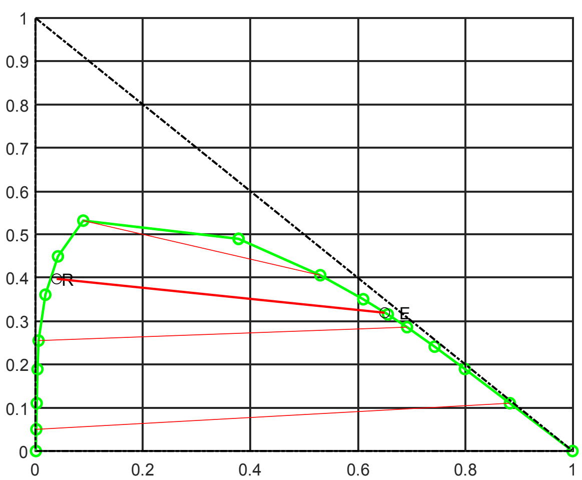
Problem 3: Liquid-liquid extraction: Tie line drawing [The data below are tie line data]

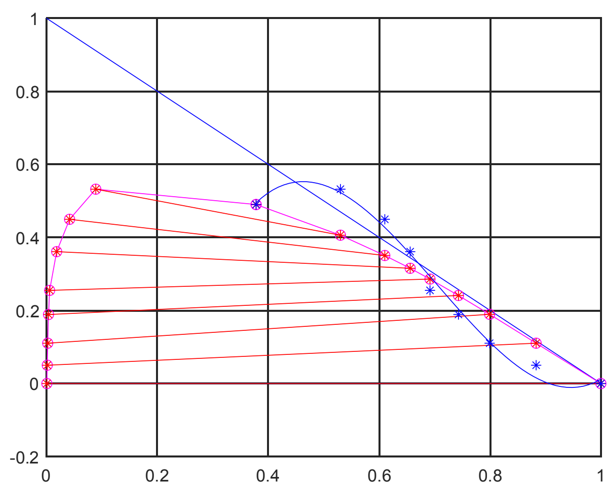
Pyridine	Chlorobenzene	Water	Pyridine	Chlorobenzene	Water
0	99.95	0.05	0	0.08	99.92
11.05	88.28	0.67	5.02	0.16	94.82
18.95	79.90	1.15	11.05	0.24	88.71
24.10	74.28	1.62	18.90	0.38	80.72
28.60	69.15	2.25	25.50	0.58	73.92
31.55	65.58	2.87	36.10	1.85	62.05
35.05	61.00	3.95	44.95	4.18	50.87
40.60	53.00	6.40	53.20	8.90	37.90
49.0	37.8	13.2	49.0	37.8	13.2

```
B =
[0.0008,0.0016,0.0024,0.0038,0.0058,0.0185,0.0418,0.089,0.378,0.378,0.53,0.61,0.6558,0.6915,0.7428,0.799,0.8828,0.9995];
C =
[0,0.0502,0.1105,0.189,.255,0.361,0.4495,0.5320,0.49,0.49,0.4060,0.3505,0.3155,0.2860,0.2410,0.1895,0.1105,0];
figure(1)
plot(B,C,'bo-');grid on;
```

[1-9 , raffinate phase, 10-18, extract phase]

Figure 1: Create a code using (if/else loop structure) to find a tie line through any point in the graph using 3 tie lines [red lines]. Show the three line on the graph that are used for interpolation. Set the intervals of the grid according to the LLE data provided. Create the tie line interpolator based on the given liquid-liquid equilibrium data. Using that draw the tie line through Mc =0.4, Mb=0.02, ,. **(20)**





Extra credit, Figure 2: Construct the conjugate line based on given 7 tie lines. **(15)**

<u>Hints:</u>

<u>Problem 2: Interpolation of tie-line slope [Problem 2, Figure 1 and 2]</u>

<u>Can be used as a hint for problem 3, Figure 1</u>

```
%% Example tie lines
tiexc = [0.1 0.3 0.5 0.6 ];
tieyc = [0.1079 0.3748 0.5919 0.6107];
tiexb = [0.0021 0.0058 0.0372 0.1259];
tieyb = [0.8872 0.608 0.3357 0.1508];


if (0.1 < My(i)) && (My(i) <= 0.3)
      slope = tie_slope(1) + ( My(i)-0.1) * (tie_slope(2) - tie_slope(1)) / (0.3 - 0.1 );
   elseif (0.3 < My(i)) && (My(i) <= 0.5)
      slope = tie_slope(2) + (My(i) - 0.3) * (tie_slope(3) - tie_slope(2)) / (0.5 - 0.3);
   elseif (0.5 < My(i)) && (My(i)<=0.6)
      slope = tie_slope(3) + (My(i) - 0.3) * (tie_slope(4) - tie_slope(3)) / (0.5 - 0.3);
   elseif (My(i)>0.6)
      slope = tie_slope(4) + (My(i) - 0.3) * (tie_slope(4) + 0.05) / (0.6107 - 0.5);
   end
```

Hint: Problem 3, Figure 2.

```
xctie=…;
yctie=….;

xbtie=…;
ybtie=….;

for i=1:length()

   sol=solve(……..,……..==0,x,y);
   ……..=double(sol.x);
   ……..=double(sol.y);
end
l=length();
qfit1=polyfit(……….,3);
conjxnew=xb(l):0.01:1;
conjynew=polyval(qfit1,conjxnew);

a=[0 1 0];
b=[1 0 0];

figure(1)
plot(a,b,'b');
hold on
plot(B,C,'mo-');
hold on
%  plot(bq,Cnew,'g*');
% hold on
```

```
for i=1:length(xb);
    plot([xbtie(i) ybtie(i)],[xctie(i) yctie(i)],'-*r');
    hold on
end
% plot([0 1],[0.3 0],'-*k');
% hold on
plot(conjx,conjy,'*b');
hold on
plot(conjxnew,conjynew,'-b');
hold on
```