1. **Liquid-liquid extraction: Single stage operation/multistage operation**

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

Multistage cross current operation: MATLAB/ Python solution

Use the ternary equilibrium curve on the right-angled triangular co-ordinate system from the previous class. Use all tie lines given for your tie line interpolation.

Using the hints given in the question paper, build a model that can generate the composition of extract and raffinate for multiple stages.

a. Compare the Plot the concentration of solute in extract and raffinate at each stage [for 3 stages cross current extraction] for the following cases of solvent scheme. [create two plots, one for extract, one for raffinate] [20]
   Case 1. S1= 800, S2= 800 and S3=800, and S1=800, S1=200, S1= 200]. Calculate the final amount of solute removed for both the multistage cross current extraction.
b. Show the tie line and extract and raffinate positions and composition on the graph generated by MATLAB/Python [$xc_{,R}$ and $yc_{,E}$] for all the stage. Calculate the amount of extract and raffinate for stage 1, 2 and 3. [20]
c. Calculate solute level in extract and the fraction of solute removed in each stage. Plot these two variables as a function of number of stages for the two solvent addition schemes. [10]

d. Calculate the overall percentage of solute separated from the as a function of solvent amount if all the three stages use same amount of solvent. [S varying from 400 to 1200] [10].

e. Calculate the number of stages required for 96% removal of the solute for the second solvent scheme, if possible. [Using the same code or some modification of the code]. If not possible, find the higher possible removal using the second solvent scheme. [30]

1. **Construct the LLE curve using right angled triangular co-ordinate (GREEN) and show the given tie lines using a different color (RED) [Tutorial one]**

```
%%  Data
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
```

2. **Show the feed composition and solvent composition as two points on your graphical system (BLACK). Draw the FS line. Suppose two tie lines are given with the following co-ordinates.**

```
   tiexc = [0.1 0.3      ];
tieyc = [0.1079 0.3748     ];
tiexb = [0.0021 0.0058      ];
tieyb = [0.8872 0.608      ];
%% Plotting the tie lines
for i = 1:length(tiexc)

   plot([tiexb(i) tieyb(i)], -------);
end
 %% Slopes of the tie lines
tie_slope = zeros(1,length(tiexc));
for i = 1:length(tiexc)
tie_slope(i) = ( ----- minus  -----)/(tieyb(i) - tiexb(i));
end
%% Draw the feed line (FS line)
F = [     ];
S = [     ];
plot(F,S,'g','linewidth',0.35)
text(-----'F')
text(-----'S')
```

3. Calculate the amount of extract and raffinate phase after 3 stage-extraction.

Step 1: Fit a polynomial for the raffinate and extract phases.

```
p1 = polyfit(B(1:10),C(1:10),5);
p2 = polyfit(B(10:19),C(10:19),3);
```

Plot the predicted points for xb values from 0- 0.17 with an increment of 0.001 (Raffinate phase) and plot the predicted points for xb values from 0.17- 1 with an increment of 0.001 (Extract phase).

Step 2: Initialize variables.

```
stages = 3;
S = [800     ];
F =   ;
xbf =  ;
xcf = ;
ybs = ;
ycs = ;
r = ones(1,stages);
e = ones(1,stages);
xbr = ones(1,stages);xcr = ones(1,stages);
ybe = ones(1,stages);yce = ones(1,stages);
M = ones(1,stages);
Mx = ones(1,stages);
My = ones(1,stages);
syms R E
syms x y
```

Loop start:

Step 3: Get the mixture point.

```
M(i) = F + S(i);
My(i) = (F*xcf + S(i)*ycs)/M(i); % y coordinate of the mixture point
Mx(i) = (F*xbf + S(i)*ybs)/M(i);  % x coordinate of the mixture point
```

Step 4: Estimate the slope of the line passing through the mixture point.[create the grid structure (0.1, 0.3, 0.5, 0.6, 0.61) for location of th tie line through Mi point]

```
if (… < My(i)) && (My(i) <= …)
slope = tie_slope(1) + ( My(i)-0.1) * (tie_slope(2) - tie_slope(1)) / (0.3 - 0.1 );
elseif (… < My(i)) && (My(i) <= …)
       Fill the conditions here
elseif (… < My(i)) && (My(i)<=…)
       Fill the conditions here
elseif (My(i)>0.6)
        slope = tie_slope(4) + (My(i) - 0.3) * (0.12) / (0.6107 - 0.5);
end
```

Step 5: Get the intersection points of the LLE curve and line passing through the mixture point

Step 5a: For the Raffinate Phase

```
[xbr(i),xcr(i)] = vpasolve([y == poly2sym(p1),y == My(i) + slope*(x -
Mx(i))],[x,y],[0 0.1508; 0 0.6107]);
```

Step 5b: For the Extract Phase

```
[,] = vpasolve( Fill in here    ],[],                    ]);
```

```
You will get the concentration of solute in extract and raffinate phase.

%% Plotting

plot([double(xbr(i)) double(ybe(i))],[double(xcr(i)) double(yce(i))],'o-
','Color',[0,0.25,1],'linewidth',0.35)
    plot(double(Mx(i)),double(My(i)),'bo')
    text(double(xbr(i)-0.05),double(xcr(i)),['R',num2str(i),' - '])
    text(double(ybe(i)),double(yce(i)),[' - ','E',num2str(i)])
    text(double(Mx(i)),double(My(i)+0.02),['M',num2str(i)])
```

Step 6: Solve the system of algebraic equations to get the amount of extract and raffinate.

```
[r(i),e(i)] = solve([R + E - M(i),((R*xcr(i)) + (E*yce(i)) -
(M(i)*My(i))),R>0,E>0],[R,E]);
F = r(i); % This is the feed in the subsequent stage
xcf = xcr(i); % Respective concentration
```