1. **Liquid-liquid extraction: Counter current operation, construction of stages and calculation of concentration of solute in extract and raffinate.**

EXAMPLE 8.4 (*Multistage countercurrent extraction*) It is planned to extract diphenyl hexane (DPH) from a solution in docosane (*A*) using 'pure' furfural (*B*) as the solvent. The feed enters the extractor cascade at a rate of 2000 kg/h with 45% DPH (*C*) that has to be reduced to 4% in the final raffinate. The solvent rate is 2500 kg/h. Determine the number of theoretical stages required. Extraction is to be carried out at 45°C. Several compositions on the extract and the raffinate arms and the tie-line data in mass% of the components at 45°C are given below.

Equilibrium data

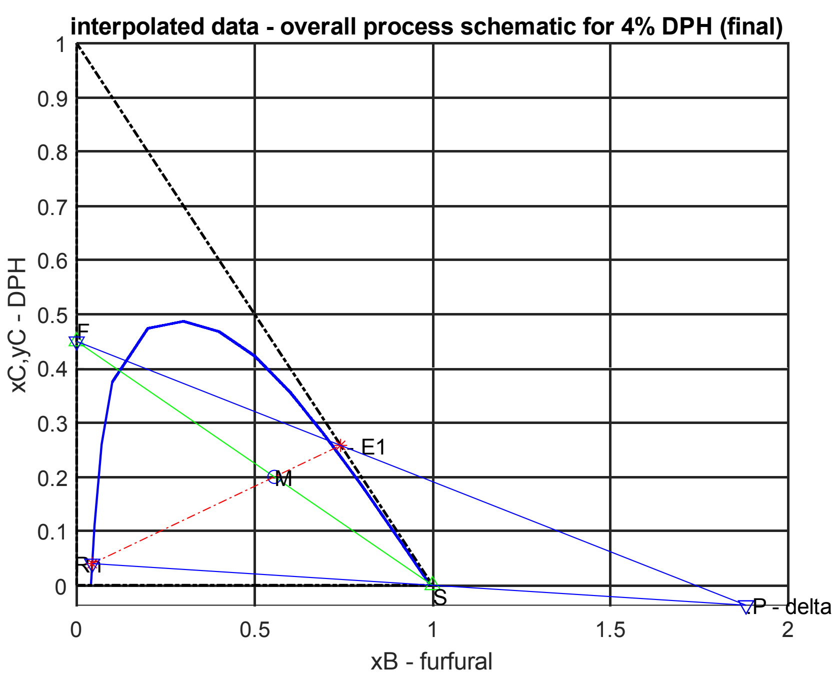
A:	96.0	84.0	67.0	52.5	32.6	21.3	13.2	7.7	4.4	2.6	1.5	1.0	0.7
B:	4.0	5.0	7.0	10.0	20.0	30.0	40.0	50.0	60.0	70.0	80.0	90.0	99.3
C:	0	11.0	26.0	37.5	47.4	48.7	46.8	42.3	35.6	27.4	18.5	9.0	0.0

Tie-line data

Raffinate (Docosane) phase, mass%			Extract (Furfural) phase, mass%		
A	*B*	*C*	*A*	*B*	*C*
85.2	4.8	10.0	1.1	89.1	9.8
69.0	6.5	24.5	2.2	73.6	24.2
43.9	13.3	42.6	6.8	52.3	40.9

Stage 1: Draw the ternary phase diagram in right angles triangle coordinate (blue points). Mention the feed and the solvent on the diagram (green). Draw FE1 and RS to construct **Delta point**: [previous class, fit a polynomial of degree 5 through the LLE curve**]**

1.



Today's class:

i=1

A. Show the tie lines (red).
B. If R(i)<Rn, join R(i) and delta point to get E(i+1)
C. Find the Equation of the line R(i) and delta
D. Find the intersection of the line R(i)-delta and the polynomial representing the LLE curve to get E(i+1) ---- using vpasolve function
E. Draw a tie line from E(i+1) to get R(i+1).
F. Find the tie_slope to find the intersection of tie line and polynomial for LLe curve. --- to get R(i+1)---using vpasolve function
G. Calculate the composition of E(i+1) and R(i+1) ---vpasolve function.
H. Calculate the flow rate E(i+1) and R(i+1)

i=i+1

1. Calculate the number of stages for achieving 4% DPH in the raffinate with **countercurrent operation**. Calculate the number of stages if 8% DPH and 1.5 % can stay in the raffinate (for 2500 kg/hr solvent rate) **[30]**
2. Plot the concentration of DPH in the raffinate vs number of stages for the three cases. Also plot the concentration of solute in the extract vs number of stages (When you perform a **countercurrent operation**). [**10]**
3. Plot the curve for percentage removal of DPH vs number of stages for 1.5%, and 4%, 8% DPH in raffinate. [**10]**

```
B = [0.04 0.05 0.07 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 0.993 1];
C = [0 0.11 0.26 0.375 0.474 0.487 0.468 0.423 0.356 0.274 0.185 0.09 0.001 0];
tiexc = [0.1 0.245 0.426];
tiexb = [0.048 0.065 0.133];
tieyc = [0.098 0.242 0.409];
tieyb = [0.891 0.736 0.523];
```

```
Locating tie line:

% initialization of Ex

Ri = 1;

count = 1;

Ex(1) = E1x;

Ey(1) = E1y;

while((Ri - Rendy) > 0.05)

if ((0 < Ey(count)) && (Ey(count) <= 0.098));

slope = …………………………

elsif

elseif((Ey(count) > 0.409));

slope = …………………..

end
```

<u>Locating the point R (raffinate) for i the stage. [raffinate composition, amount of solute in raffinate</u>]

```
syms x y
  [x,y] = vpasolve([y ==…….,y == ……………..],[x,y],[0 0.3; 0 0.49]);

  plot([Ex(count) double(x)],[Ey(count) double(y)],'o-.','Color',[1,0,0],'linewidth',0.75)

  Rx(count) = double(x);

  Ry(count) = double(y);
```

Calculation of the extract composition for i+1 th stage.

```
text(double(x)-0.05,double(y),['R',num2str(count),' - '])

% calculation of the slope of the line joining R and delta point
   slope3 = ………….);
   syms x y
   [x,y] = vpasolve([y == ………… ,y == …………… ],[x,y],[0.3 1; 0 Ey(count)]);
   plot([…..   …..],[……  ………],':','Color',[0,0.75,0.75],'linewidth',1.5)
   Ex(count + 1) = ;
   Ey(count + 1) = ;
   text(double(x),double(y),[' - E',num2str(count+1)])

   Ri = Ry(count);
   count = ……..;

end
```

Calculation of the stage number and the final concentration of solute in raffinate…

For Plotting the raffimate and extract , saving stage number in intermediate.

```
Rx(………) = Rendx;
Ry(……..) = Rendy;
disp('total number of stages (final DPH conc = 4%):')
disp(…….)
stages = zeros(1,3); %---------------------- 3 cases 4%, 1.5%, 8%
stages(1) = length(Ex);

percent4Ex = Ex;
```

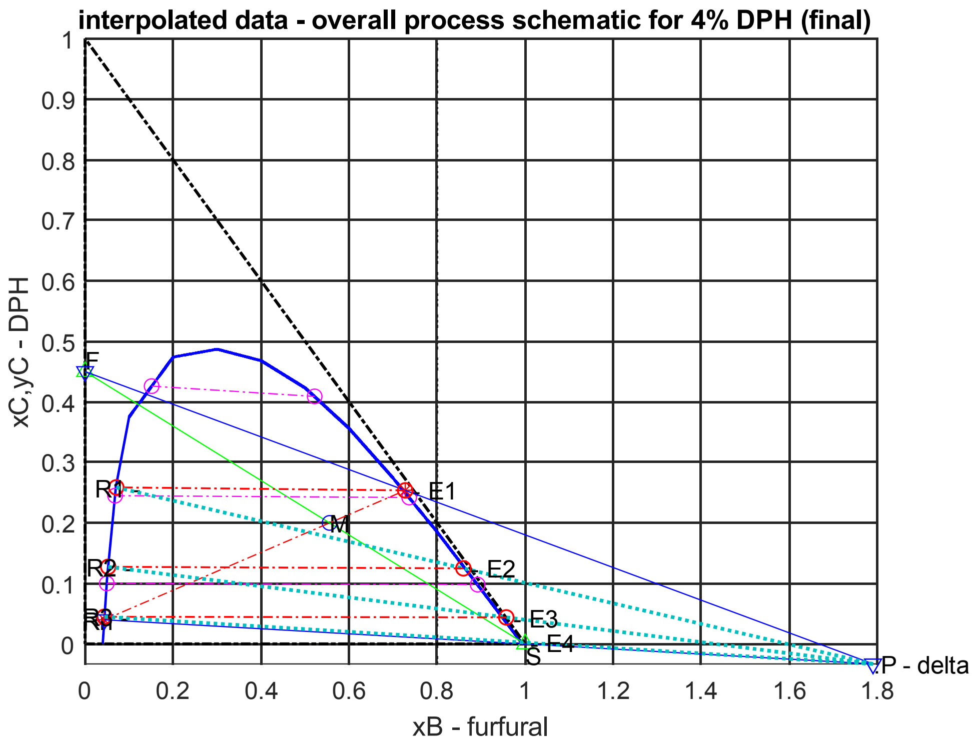
Calculation of amount of raffinate and extract in each stage:

This is required for calculation of percentage removal.

```
syms R E
[RN,E1] = solve([..........................................................................,R>0,E>0],[R,E]);

Rcase1 = zeros(1,length(Ex));
Ecase1 = zeros(1,length(Ex));
syms R E
for i = 1:length(Ex)-1;
   [r,e] = solve(...............................................................................................,R>0,E>0],[R,E]);
   Rcase1(i) =……. ;
   Ecase1(i + 1) = ……;
end
Rcase1(length(Ex)) = RN;
Ecase1(1) = E1;

for i = 1:length(Ex);
conc_removed1(i) =;
end
```

Plotting the solute level in extract and raffinate as a function of number of stages.

```
figure(4)
% plot(intermediate,percent4Ry,'bo-',intermediate,fliplr(percent4Ey),'mo-','linewidth',1.25)
plot(      ………………..,'bo-',…………………..,'mo-','linewidth',1.25)
title('intermediate stage vs Rxc,Eyc conc profile, 4%');grid on;
xlabel('intermediate stage')
ylabel('fraction of DPH')
legend('raffinate','extract')
set(gca,'XTick',1:length(percent4Ey))

%-------------------------------------------------figure 5

figure(5)
plot(………………..,'bo-','linewidth',1.25)
title('intermediate stage vs DPH removal, 4%');grid on;
xlabel('intermediate stage')
ylabel('percentage of DPH removed')
set(gca,'XTick',0:length(percent4Ey))
```



interpolated data - overall process schematic for 4% DPH (final)
xC,yC - DPH
xB - furfural
F
R1
E1
M
R2
E2
E3
E4
S
P - delta