Esercitazione numerica n.4 – Estrazione liquido – liquido

1) A waste water from a process is loaded with acetone, which should be extracted with chlorobenzene. The equilibrium data for the ternary system water/acetone/ chlorobenzene are given.

composition of the coexisting phases in equilibrium in wt%					
water phase			organic phase		
water	acetone	chlorobenzene	water	acetone	chlorobenzene
99,89	0,00	0,11	0,18	0,00	99,82
89,79	10,00	0,21	0,49	10,79	88,72
79,69	20,00	0,31	0,79	22,23	76,98
69,42	30,00	0,58	1,72	37,48	60,80
58,64	40,00	1,36	3,05	49,44	47,51
46,28	50,00	3,72	7,24	59,19	33,57
27,41	60,00	12,59	22,85	61,07	15,08
25,66	60,58	13,76	25,66	60,58	13,76

You have to determine:
a) the triangle diagram including the phase equilibrium line and connodes.
b) The water and chlorobenzene content of the aqueous phase (raffinate) with an acetone concentration of 45 % and of the coexisting phase.
c) Which amount of acetone has to be added to a existing mixture of 90 g water and 110 g chlorobenzene for obtaining a single phase? What is the composition of the mixing point?
d) What is the water free composition of this mixing point?

2) 140 kg.hr^{-1} of a 40% acetone-in-water mixture are to be separated using trichloroethane as solvent.
   a) Draw a flow diagram that illustrates the cross-current streams, having only 2 cross-current stages.
   b) Draw a general flow diagram that illustrates the counter-current system, with two stages on one end, and two stages on the other end, and a general "Nth" stage in the middle.
   c) If 80 kg hr^{-1} of pure solvent is fed into the first cross-current stage and 60 kg hr^{-1} into the second cross-current stage, what will be the acetone purity leaving in the raffinate from stage 1 and stage 2?
   d) What is the overall acetone recovery from such a 2-stage cross-current system?

Now use a clean copy of the drawing and start the construction for the counter-current system. The objective is to achieve the same (or better) raffinate concentration in terms of acetone as the cross-current system, but using 40 kg.hr−1 of pure solvent. With a few basic lines on the drawing you should be able to find the values for these cross-current system:
   e) the expected raffinate flow rate;
   f) the expected extract flow rate;
   g) the expected extract composition.

Now locate the operating point, P , and use this to calculate the number of stages required. Submit your ternary diagram showing these calculations.

h) Assume that the last stage is at the point you selected in part 5 of this problem (i.e. that it was at that desired 11% level for acetone). Calculate the recovery of acetone for the counter-current system.

Now compare and contrast the following parameters for the two configurations:

i) the extract concentration (for the cross-current system this is the blended concentrations of E1 and E2);
j) the extract flow rate;
k) the recovery;
l) the solvent use.

3) Una miscela di cloroformio e acido acetico a 18 °C e 101.3 kPa è estratta con acqua per recuperare l'acido. 45 kg di miscela (35% w/w cloroformio, 65% w/w acido) vengono trattati con 22.75 kg di acqua pura. Determinare l'ammontare e la composizione delle due fasi di equilibrio. Il raffinato di cui sopra è nuovamente trattato con metà del suo peso di acqua: determinare le nuovi fasi all'equilibrio. Se da questo raffinato venisse rimossa tutta l'acqua, quale sarebbe la sua composizione? Risolvere graficamente l'esercizio costruendo il diagramma preferito a partire dai dati allegati.

LIQUID–LIQUID EQUILIBRIUM DATA FOR $CHCl_3$–H_2O–CH_3COOH AT 18°C AND 1 ATM

Heavy Phase (wt%)			Light Phase (wt%)		
$CHCl_3$	H_2O	CH_3COOH	$CHCl_3$	H_2O	CH_3COOH
99.01	0.99	0.00	0.84	99.16	0.00
91.85	1.38	6.77	1.21	73.69	25.10
80.00	2.28	17.72	7.30	48.58	44.12
70.13	4.12	25.75	15.11	34.71	50.18
67.15	5.20	27.65	18.33	31.11	50.56
59.99	7.93	32.08	25.20	25.39	49.41
55.81	9.58	34.61	28.85	23.28	47.87

a) Uno stadio batch;
b) Due stadi in cross flow, con eguale alimentazione di solvente;
c) Due stadi in controcorrente;
d) Infiniti stadi in controcorrente.

4) In a continuous countercurrent train of mixer-settlers, 100 kg/h of a 40:60 acetone-water solution is to be reduced to 10 percent acetone by extraction with pure 1,1,2-trichloroethane al 25°C. Find the minimum solvent rate. At 1.8 times the minimum (solvent rate)/(feed rate), find the number of stages required. For the above conditions find the mass ftow rates of all streams. Data are given in the following tables.

Limiting solubility curve		
$C_2H_3Cl_3$, wt %	Water, wt o/o	Acetone, wt %
94.73	0.26	5.01
79.58	0.76	19.66
67.52	1.44	31.04
54.88	2.98	42.14
38.31	6.84	54.85
24.04	15.37	60.59
15.39	26.28	58.33
6.77	41.35	51.88
1.72	61.11	37.17
0.92	74.54	24.54
0.65	87.63	11.72
0.44	99.56	0.00

Tie lines					
Weight % in water layer			Weiglt % in trichloroethane layer		
C2H3Cl3	Water	Acetone	C2H3Cl3	Water	Acetone
0.52	93.52	5.96	90.93	0.32	8.75
0.73	82.23	17.04	73.76	1.10	25.14
1.02	72.06	26.92	59.21	2.27	38.52
1.17	67.95	30.88	53.92	3.11	42.97
1.60	62.67	35.73	47.53	4.26	48.21
2.10	57.00	40.90	40.00	6.05	53.95
3.75	50.20	46.05	33.70	8.90	57.40
6.52	41.70	51.78	26.26	13.40	60.34

5) The ether contained in a feed (45 wt% isopropyl alcohol, 50 wt% diisopropyl ether, and 5 wt% water) is to be recovered by liquid–liquid extraction with water, the solvent, entering the top and the feed entering the bottom, so as to produce an ether containing less than 2.5 wt% alcohol and an extracted alcohol of at least 20 wt%. The unit will operate at 25 °C and 1 atm. Find the stages required. Is it possible to obtain an extracted alcohol composition of 25 wt%?

PHASE-EQUILIBRIUM (TIE-LINE) DATA AT 25°C, 1 ATM

Ether phase			Water phase		
Wt% Alcohol	Wt% Ether	Wt% Water	Wt% Alcohol	Wt% Ether	Wt% Water
2.4	96.7	0.9	8.1	1.8	90.1
3.2	95.7	1.1	8.6	1.8	89.6
5.0	93.6	1.4	10.2	1.5	88.3
9.3	88.6	2.1	11.7	1.6	86.7
24.9	69.4	5.7	17.5	1.9	80.6
38.0	50.2	11.8	21.7	2.3	76.0
45.2	33.6	21.2	26.8	3.4	69.8

ADDITIONAL POINTS ON PHASE BOUNDARY

Wt% Alcohol	Wt% Ether	Wt% Water
45.37	29.70	24.93
44.55	22.45	33.00
39.57	13.42	47.01
36.23	9.66	54.11
24.74	2.74	72.52
21.33	2.06	76.61
0	0.6	99.4
0	99.5	0.5

6) Bisogna estrarre acido acetico (2000 lb/h, soluzione acquosa al 40% in moli) mediante controcorrente (3000 lb/h, etere isopropilico). L'acido nel raffinato deve essere il 4%. Quanti stadi di equilibrio sono richiesti? Qual è la portata minima di solvente?

7) Acetone is to be removed from a 30% mass aqueous solution by mixing with methyl isobutyl ketone (MIBK) and allowing the two phases that result to separate. How much MIBK must be added per hundred kg of the acetone/water solution to obtain a water-rich phase containing 15.0% mass acetone? Suppose only one-half of the MIBK previously determined is used and the two phases are allowed to separate. If the other half of the MIBK is mixed with the resulted water-rich phase, what would be the mass % of acetone in the water-rich phase?

8) Un sistema in controcorrente rimuove il 99% dell'acetone contenuto in una soluzione acquosa al 40% estraendolo con eguale portata di metil-isobutilchetone. Calcolare il numero di stadi ideali richiesti e la composizione dell'estratto che si ottiene.

9) L'acetone deve essere rimosso da una soluzione al 30% in etil-acetato usando acqua pura. Il raffinato finale deve contenere il 5% di acetone su base acqua priva. Determinare il minimo ed il massimo rapporto solvente/alimentazione, il numero di stadi di equilibrio richiesti per due valori intermedi del rapporto a vostra scelta e la massima percentuale in peso di acetone consentita in ingresso.

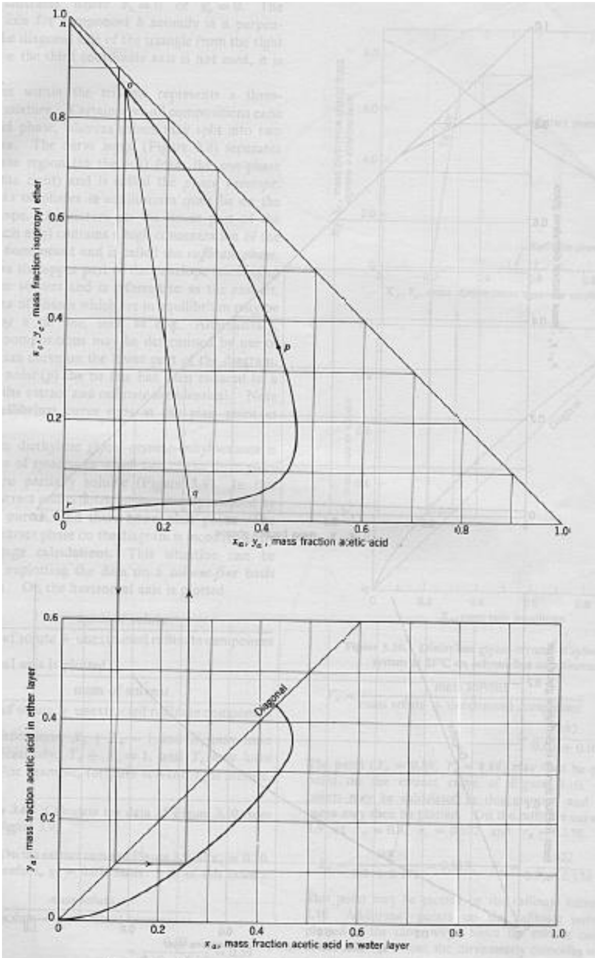
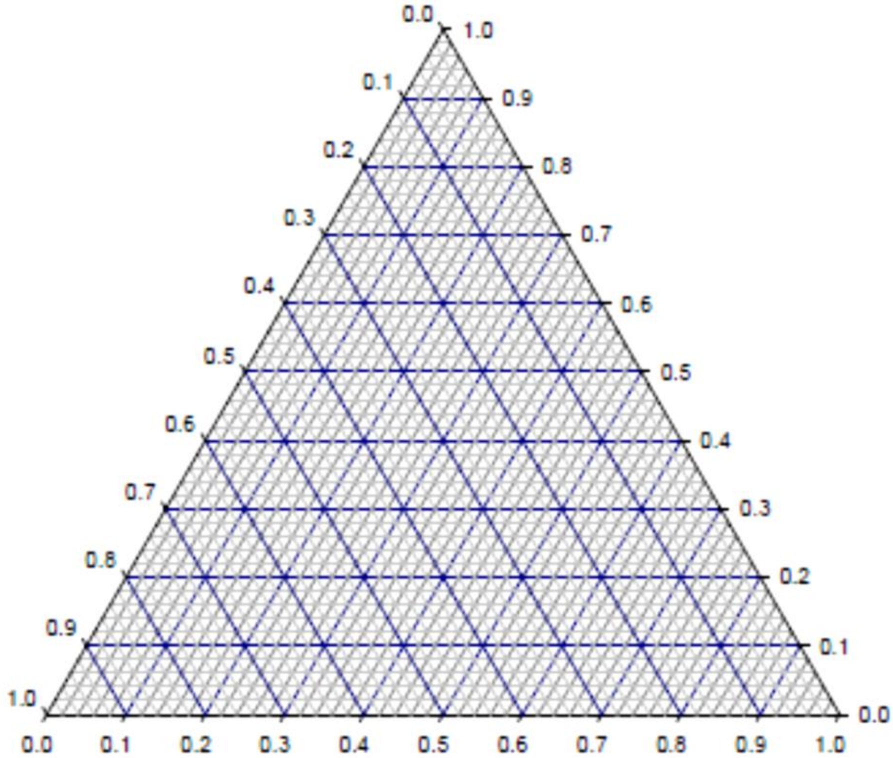
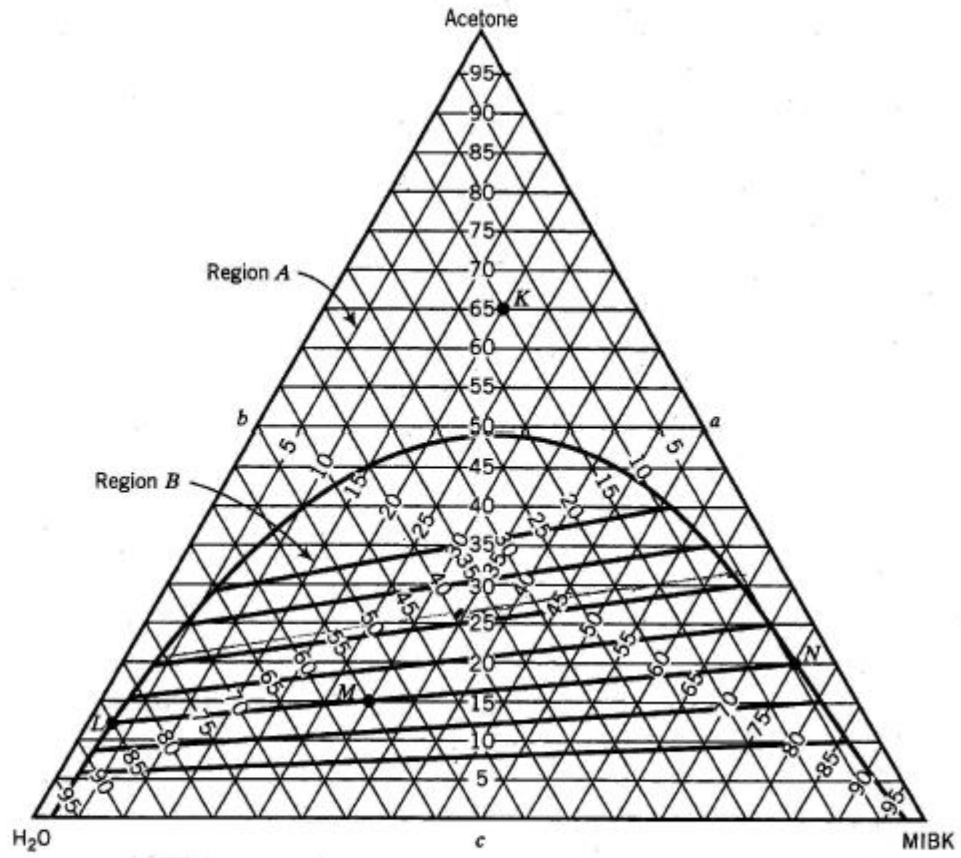
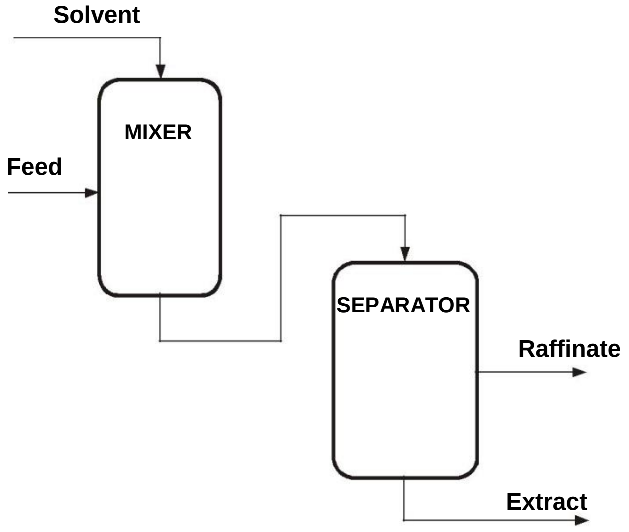


Figure 3.8. Isopropyl ether–acetic acid–water system at 20°C. (7)

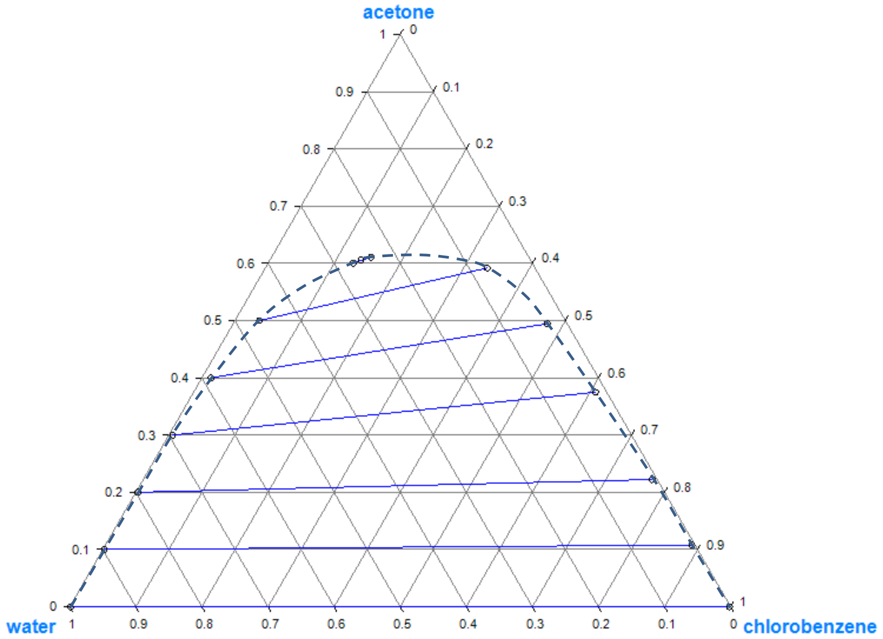

0.0
1.0
0.1
0.9
0.2
0.8
0.3
0.7
0.4
0.6
0.5
0.5
0.6
0.4
0.7
0.3
0.8
0.2
0.9
0.1
1.0
0.0
0.0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1.0


Acetone
Region A
K
b
a
Region B
N
M
L
H2O
c
MIBK

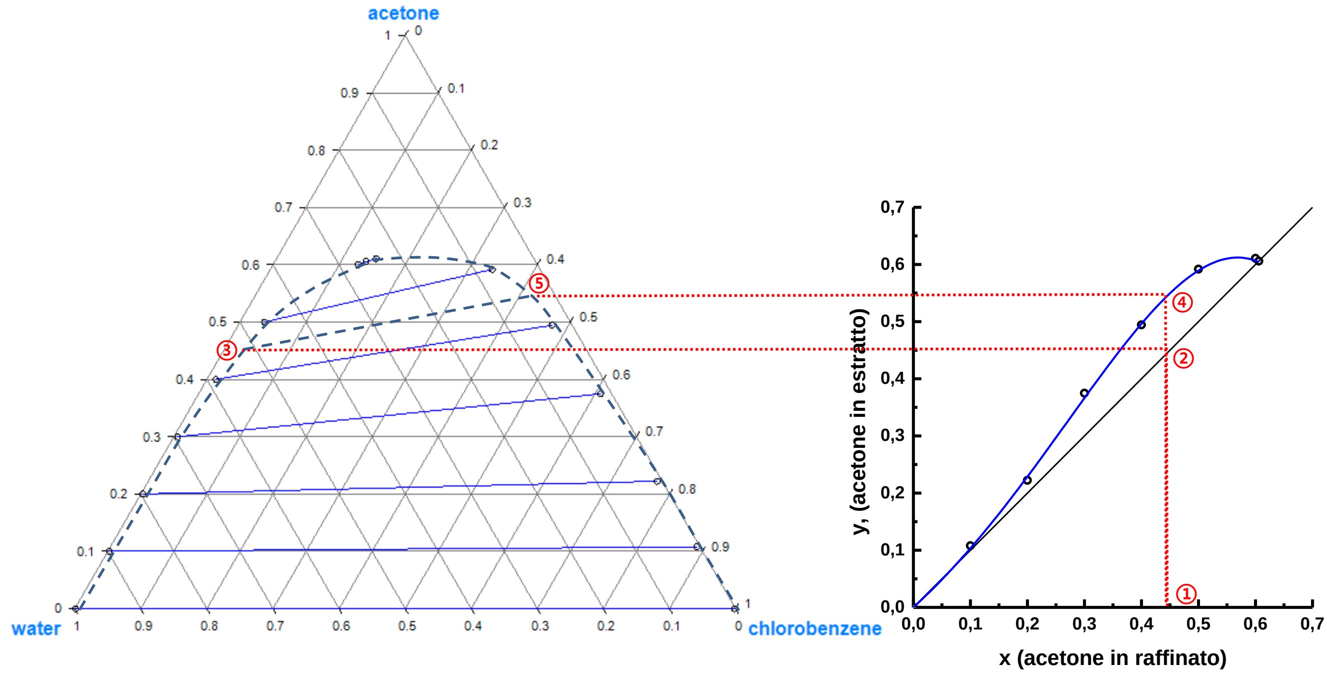
Svolgimento esercizio 1)

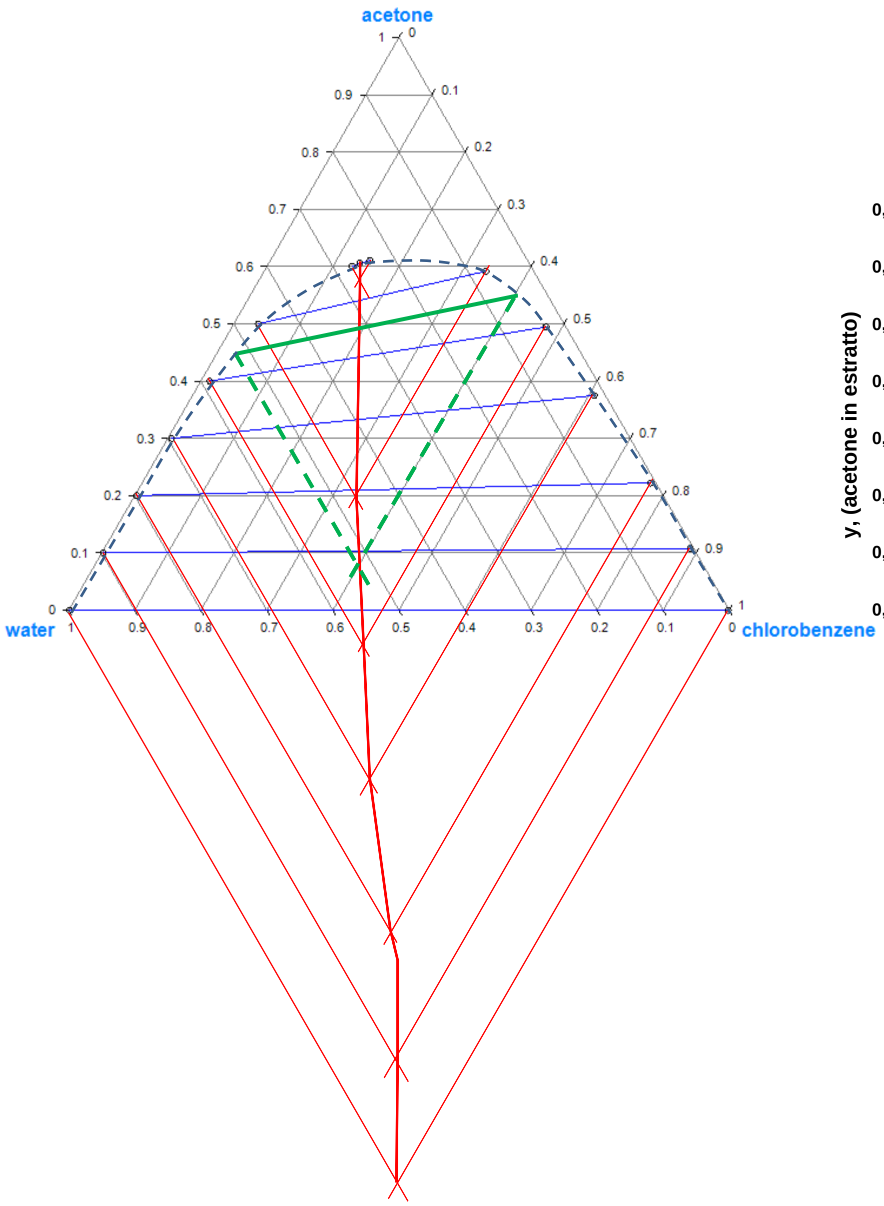


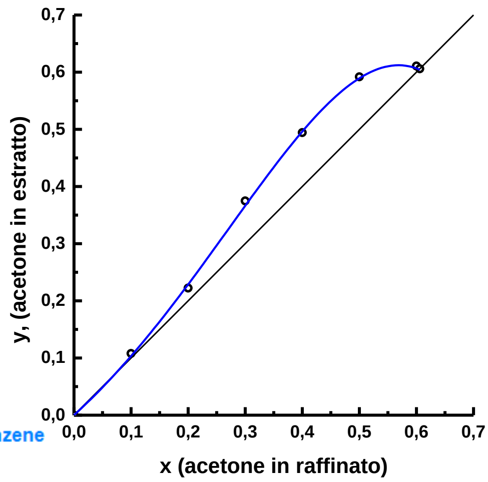
a) the triangle diagram including the phase equilibrium line and connodes.



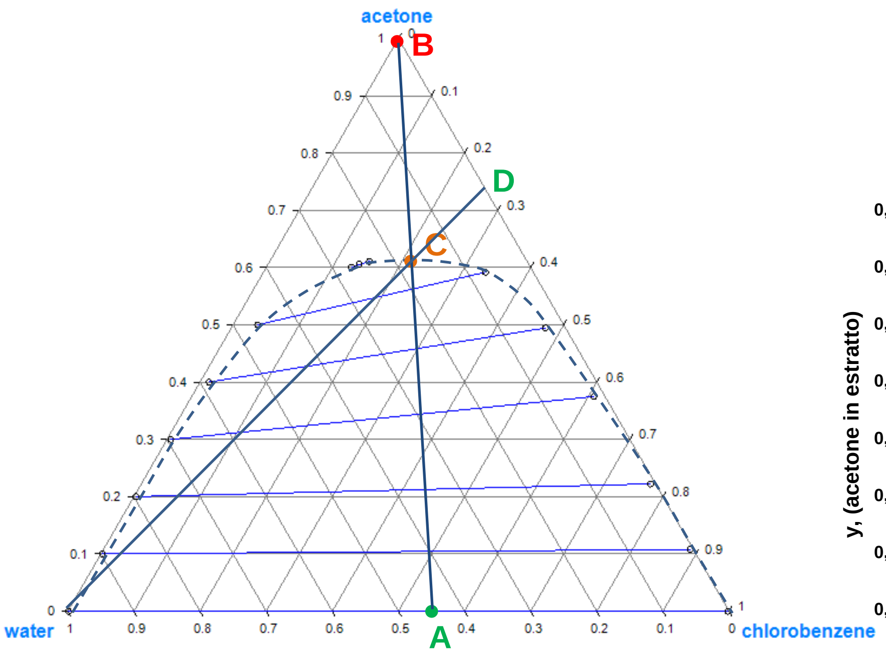
b) The water and chlorobenzene content of the aqueous phase (raffinate) with an acetone concentration of 45 % and of the coexisting phase.

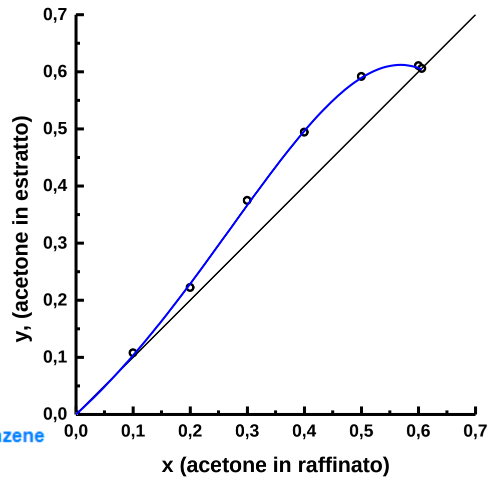



acetone
water
chlorobenzene
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0


y, (acetone in estratto)
x (acetone in raffinato)
0,0
0,1
0,2
0,3
0,4
0,5
0,6
0,7

c) Which amount of acetone has to be added to an existing mixture of 90 g water and 110 g chlorobenzene for obtaining a single phase? What is the composition of the mixing point?





X(clorobenz) = 110/(110+90) = 0.55 **(A)**

Aggiunta di acetone puro **(B)**

Miscela

Composizione **(C)**

<u>Regola della leva</u>

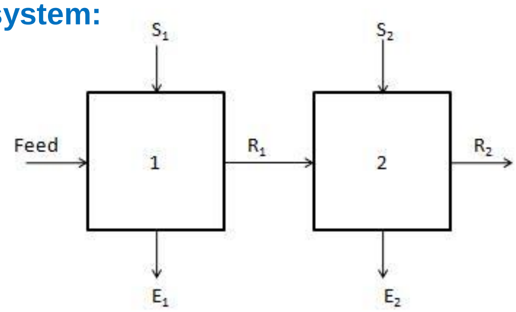
Segmento BC ∝ 200; Segmento AC ∝ Acetone da aggiungere

d) What is the water free composition of this mixing point?

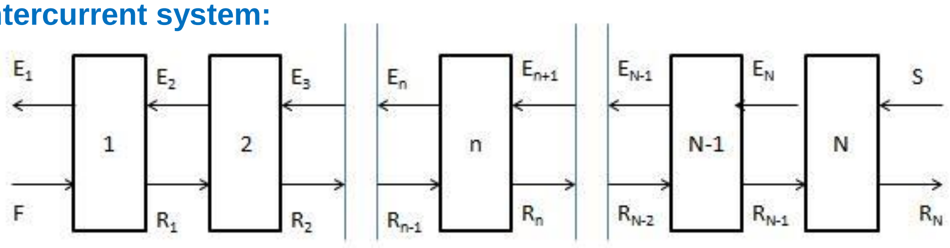
Composizione acqua-priva (water-free) **(D)**

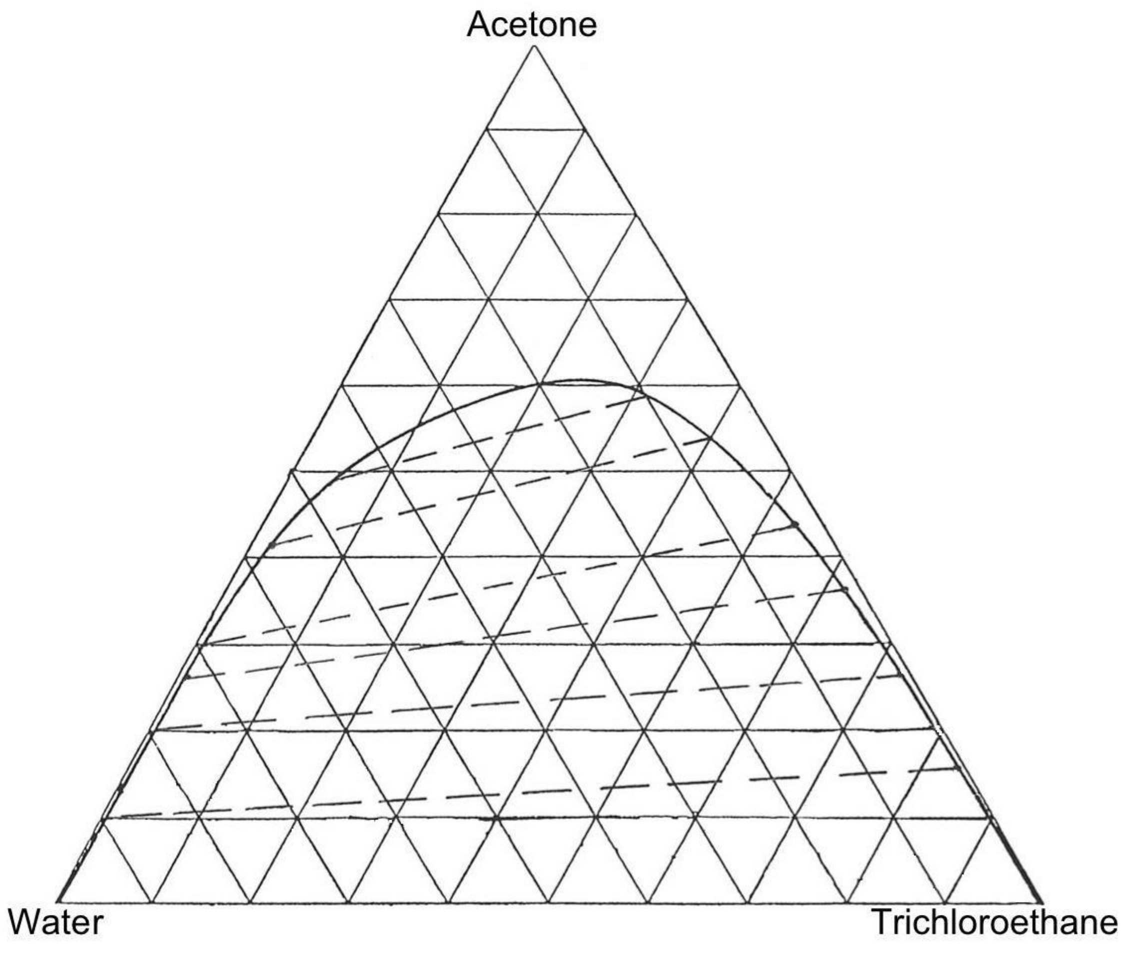
Svolgimento esercizio 2)

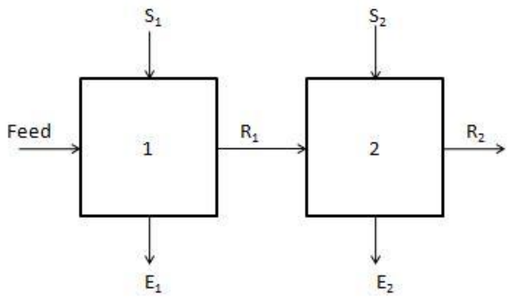
a) Cross-current system:



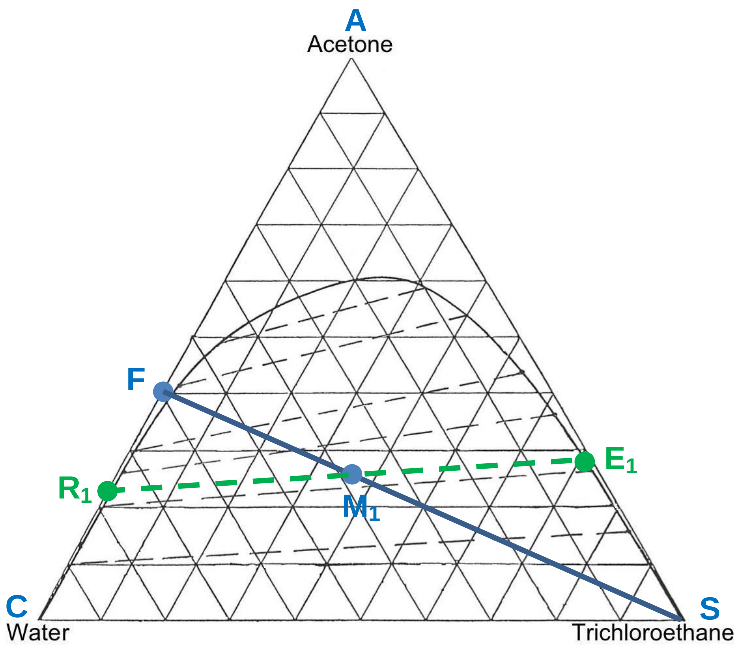
b) Countercurrent system:







$F = 140$ kg/h, $x_{F,A} = 40\%$, $x_{F,C} = 60\%$
$S_1 = 80$ kg/h, $S_2 = 60$ kg/h



Stage 1

Overall balance:
$F + S_1 = 140 + 80 = 220$ kg/h $= M_1$

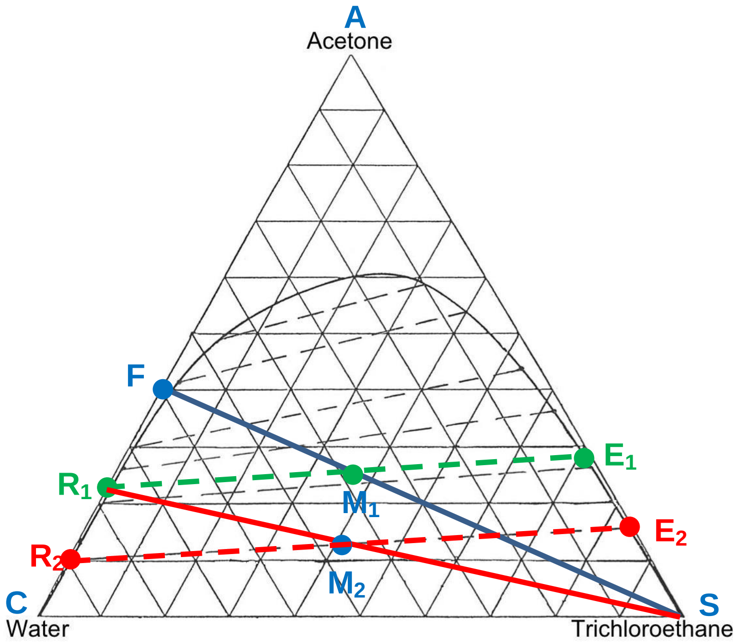
Balance on acetone:
$F\, x_{F,A} + S_1\, x_{S,A} = x_{M1,A} M_1$
$(140)(0.4) + 0 = x_{M,A}\,(220)$
$x_{M1,A} = 0.255$

Balance on solvent:
$F\, x_{F,S} + S_1\, x_{S,S} = x_{M,S} M$
$0 + (80)(1) = x_{M,S}\,(220)$
$x_{M1,S} = 0.363$
$x_{M1,C} = 1 - x_{M1,A} - x_{M1,S} = 0.382$

Reading off the ternary diagram:
$x_{R1,A} = 0.23$ $\quad x_{E1,A} = 0.27$
$x_{R1,C} = 0.75$ $\quad x_{E1,C} = 0.01$
$x_{R1,S} = 0.02$ $\quad x_{E1,S} = 0.72$

$x_{M,A} M_1 = x_{R1,A} R_1 + x_{E1,A} E_1$
$R_1 = 220 - E_1$
$E_1 = 135$ kg/h; $R_1 = 85$ kg/h

Therefore, the acetone purity in the raffinate from the first stage is 23%.


A
Acetone
F
E1
R1
M1
E2
R2
M2
C
Water
S
Trichloroethane