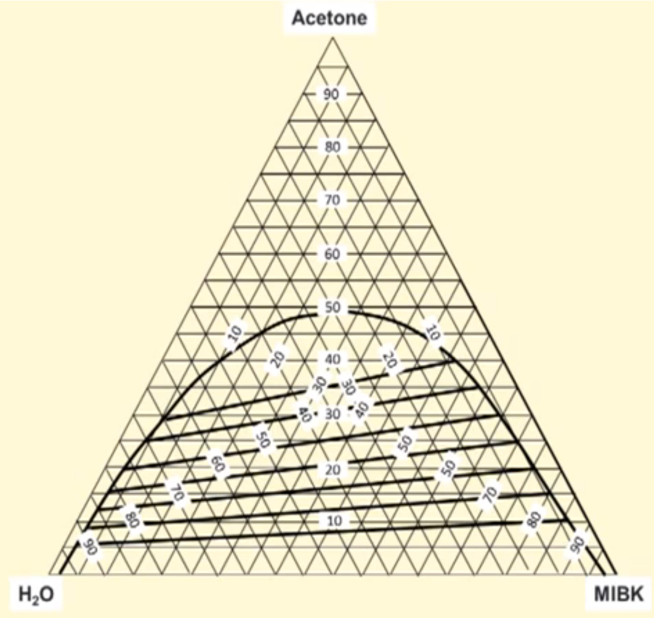
Triangular phase diagrams: from laboratory studies

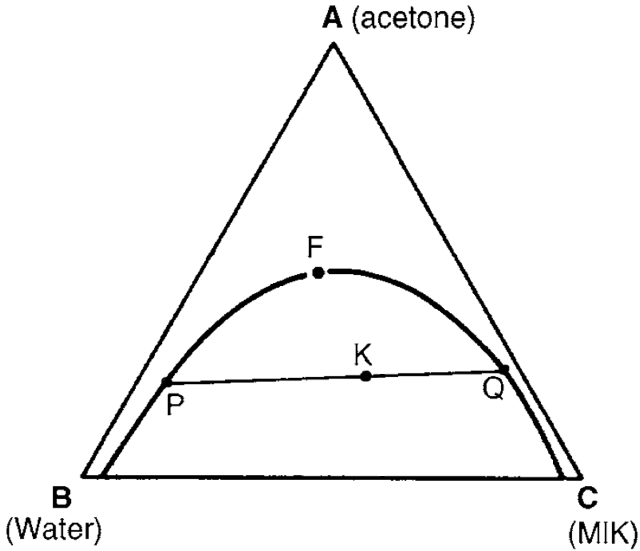
[Flickr# 3453475667]

Using a triangular phase diagrams



[http://www.youtube.com/watch?v=gGYHXhcKM5s]

Lever rule



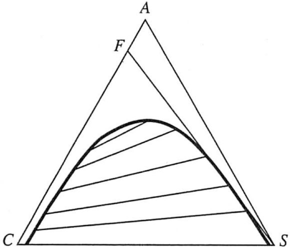
Mix P and Q

- mixture = K
- $\frac{PK}{KQ} = \frac{\text{amount Q}}{\text{amount P}}$
- The converse applies also: when separating a settled mixture
- Applies anywhere: even in the miscible region

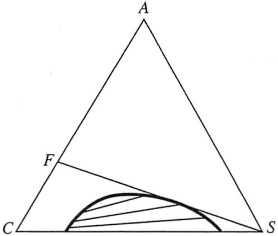
Q1: Using the lever rule

Which is a more *flexible* system?

- S = pure solvent used
- F = feed concentration point (more correctly it is x_F)



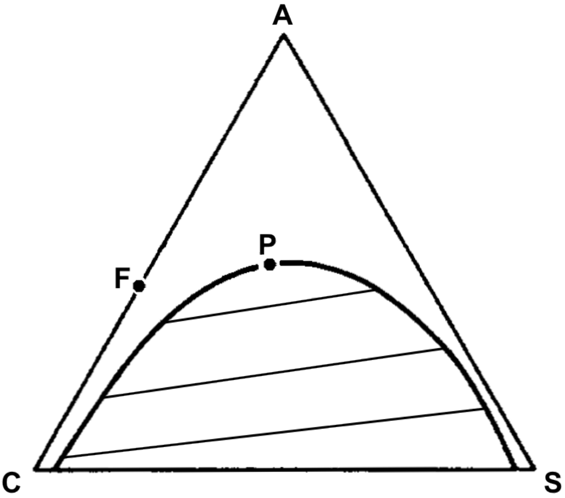
(a)



(b)

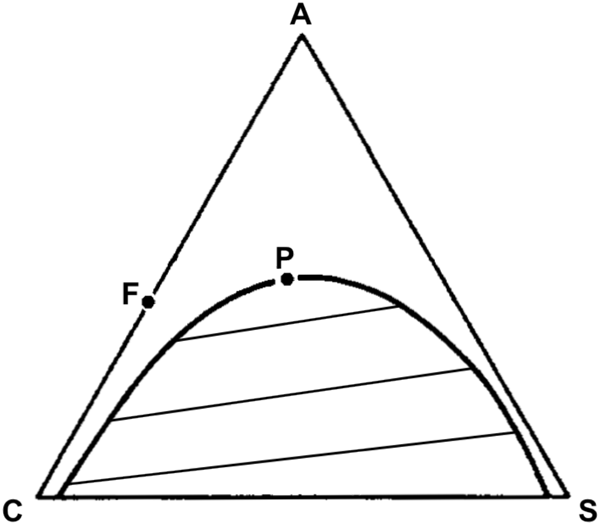
Answer:

Q2: Using the lever rule



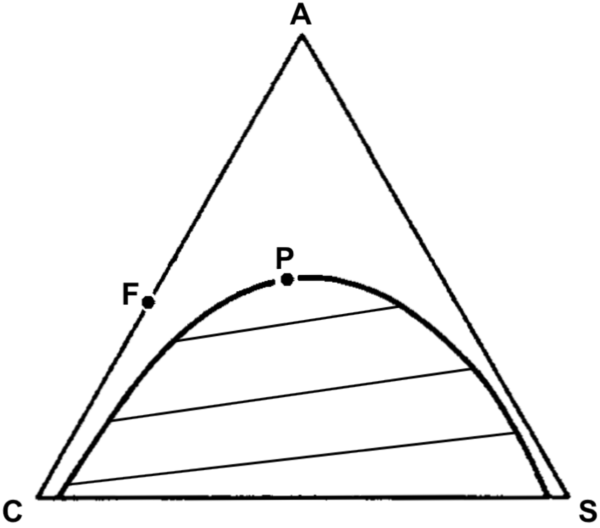
Mix a feed stream, F, containing C and A (i.e. x_F) with a pure solvent stream S (i.e. $y_S = 0$). Composition of the mixture?

Q3: Going to equilibrium



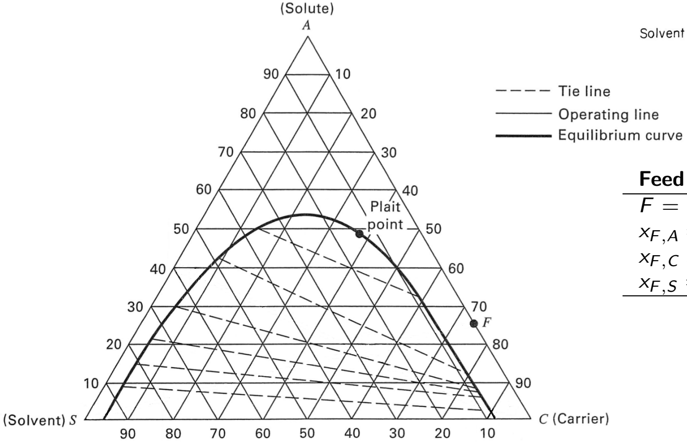
Let that mixture M achieve equilibrium. What is the composition of the raffinate and extract?

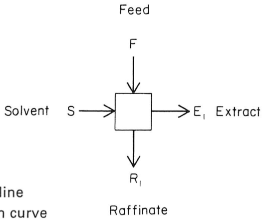
Q4: Altering flows



Same system, but now lower solvent flow rate (to try save money!). What happens to (a) extract concentration and (b) solute recovery?

Q5: Composition of the mixture, M?

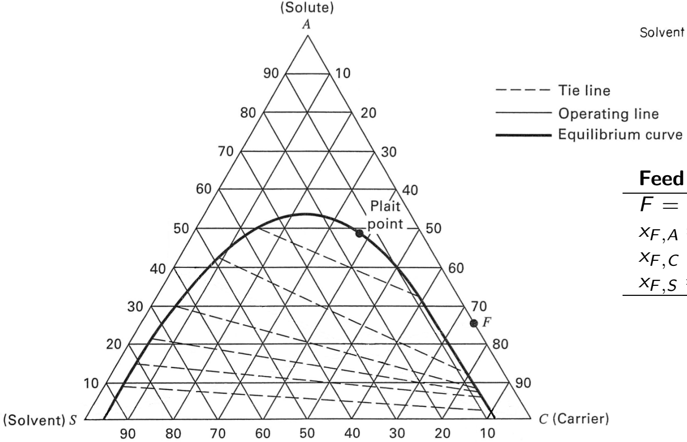


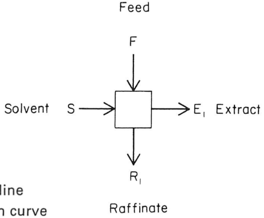


Feed	**Solvent**
$F = 250$ kg	$S = 100$ kg
$x_{F,A} = 0.24$	$x_{S,A} = 0.0$
$x_{F,C} = 0.76$	$x_{S,C} = 0.0$
$x_{F,S} = 0.00$	$x_{S,S} = 1.0$

Answer: $M =$ $x_{M,A} =$ $x_{M,C} =$ $x_{M,S} =$

Q6: Composition of the 2 phases leaving in equilibrium?





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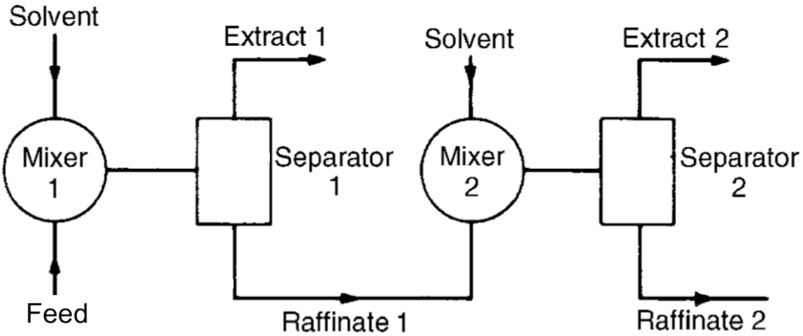
$x_{F,S} = 0.00$	$x_{S,S} = 1.0$

$R_1 =$ $\quad x_{R_1,A} =$ $\quad x_{R_1,C} =$ $\quad x_{R_1,S} =$

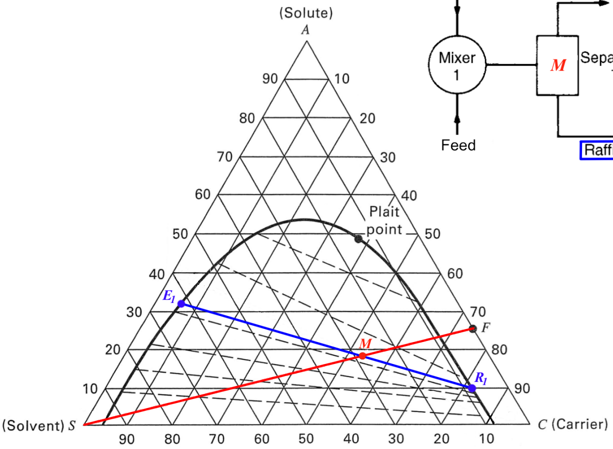
$E_1 =$ $\quad x_{E_1,A} =$ $\quad x_{E_1,C} =$ $\quad x_{E_1,S} =$

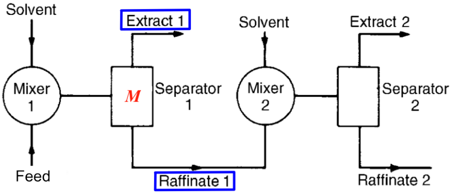
Link units in *series*



[Richardson and Harker, p 723]

Q7: send raffinate from Q6 to second mixer-settler

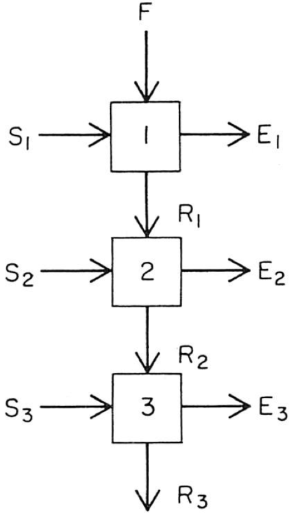




Question: how much solvent should we use in the second stage?

Series of co-current units

$N = 3$ in this illustration



[Schweitzer, p 1-263]

- Recovery = fraction of solute recovered

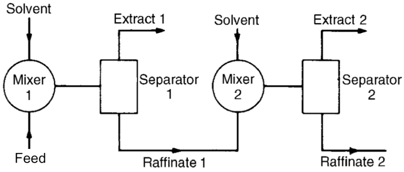
$$1 - \frac{(x_{R_N})(R_N)}{(x_F)(F)}$$

- Concentration of overall extract = solute leaving in each extract stream, divided by total extract flow rate

$$\frac{\sum_n^N (y_{E_n})(E_n)}{\sum_n^N E_n}$$

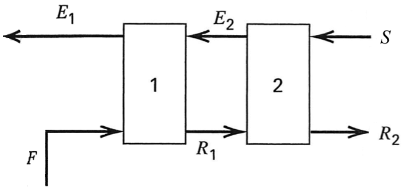
Co-current *vs* counter-current

Co-current ($N = 2$ stages)



- We combine multiple extract streams
- (Only 2 in illustration)
- In general: $y_{E_1} > y_{E_2} > \dots$
- Fresh solvent added at each stage

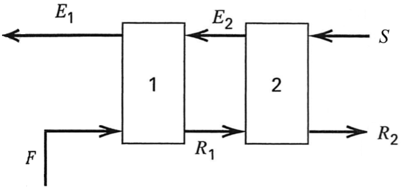
Counter-current ($N = 2$ stages)



- "Re-use" the solvent, so
- Far lower solvent flows
- Recovery $= 1 - \dfrac{(x_{R_N})(R_N)}{(x_F)(F)}$
- Concentration $= y_{E_1}$

You will have an assignment question to compare and contrast these two configurations

Some theory: Two *counter-current* units



Just **consider $N = 2$ stages** for now. Steady state mass balance:

$$F + E_2 = E_1 + R_1 \qquad\qquad E_2 + R_2 = S + R_1$$

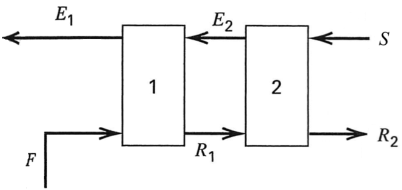
Rearrange:

$$F - E_1 = R_1 - E_2 \qquad\qquad R_1 - E_2 = R_2 - S$$

$$(F - E_1) = (R_1 - E_2) = (R_2 - S) = P$$

Note: each difference is equal to P (look on the flow sheet where those *differences* are).

Counter-current graphical solution: 2 units



Rearranging again:

$$F + P = E_1$$

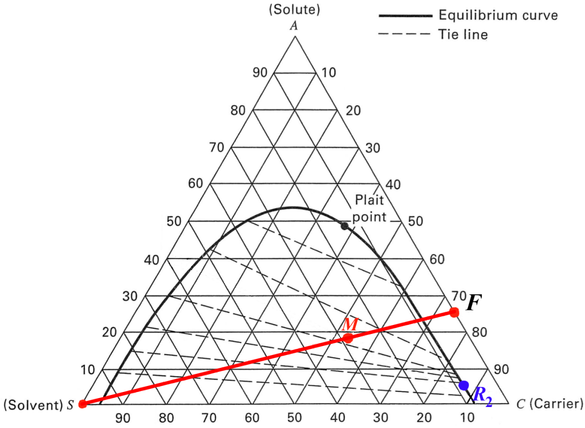
$$R_1 + P = E_2$$

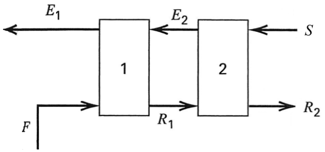
$$R_2 + P = S$$

Interpretation: P **is a fictitious operating point on the ternary diagram** (from lever rule)

- P connects F and E_1
- P connects R_1 and E_2
- P connects R_2 and S

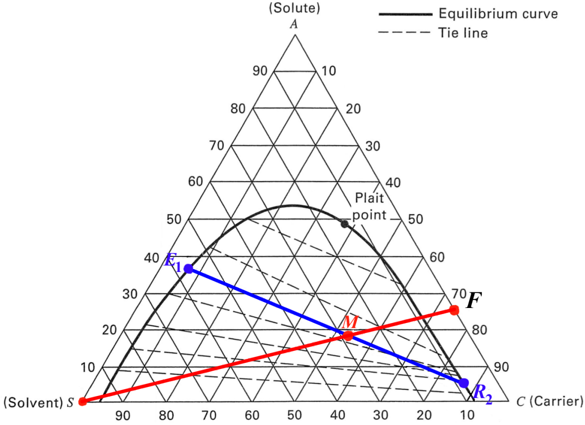
Counter-current graphical solution: 2 units

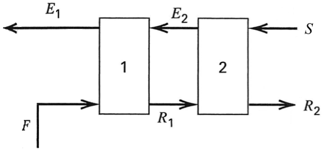




For example, let's require $x_{R_2,A} = 0.05$ (solute concentration in raffinate).
What is $y_{E_1,A}$ then (concentration of solute in the extract)?

Counter-current graphical solution: 2 units

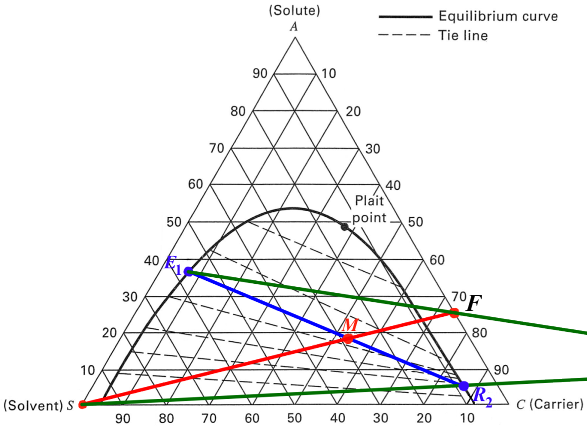


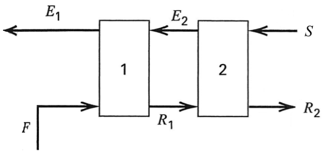


Note: the line connecting E_1 **to** R_2 **is not a tie line**. We use the lever rule and an overall mass balance ($F + S = E_1 + R_2$) to solve for all flows and compositions of F, S, E_1, and R_2.

$y_{E_1,A} \approx 0.38$ is found from an overall mass balance, through M.

Counter-current graphical solution: 2 units





Recall:

$$F + P = E_1$$

$$R_2 + P = S$$

Extrapolate through these lines until intersection at point P.

Minimal achievable E_1 concentration? *mentally move point M towards S.*
What happens to P? Alternative (simpler?) explanation on next slide.