Multiphase flows

Daniel Fuster
fuster@dalembert.upmc.fr
Institute Jean Le Rond D'Alembert, Université Pierre et Marie Curie

MIXTURES

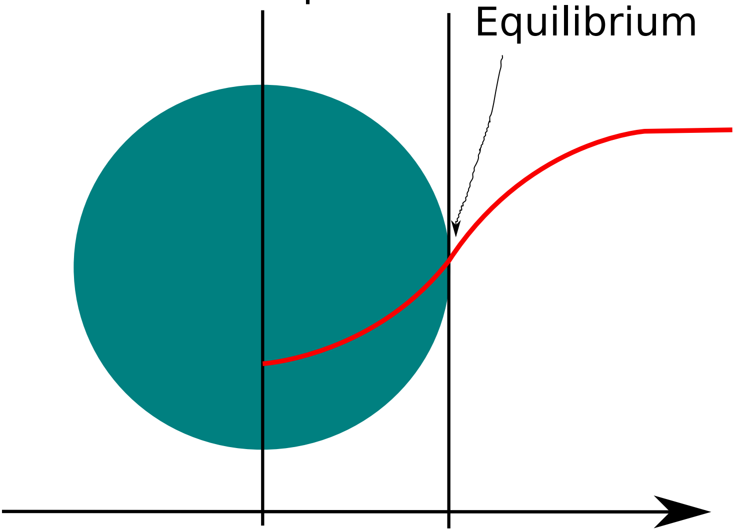
Some references:

- Kister H.Z. Distillation Design McGraw-Hill
- McCabe WL and JC Smith. Unit Operations of Chemical Engineering McGraw-Hill, 1976
- Treybal RE Mass-Transfer Operations McGraw-Hill

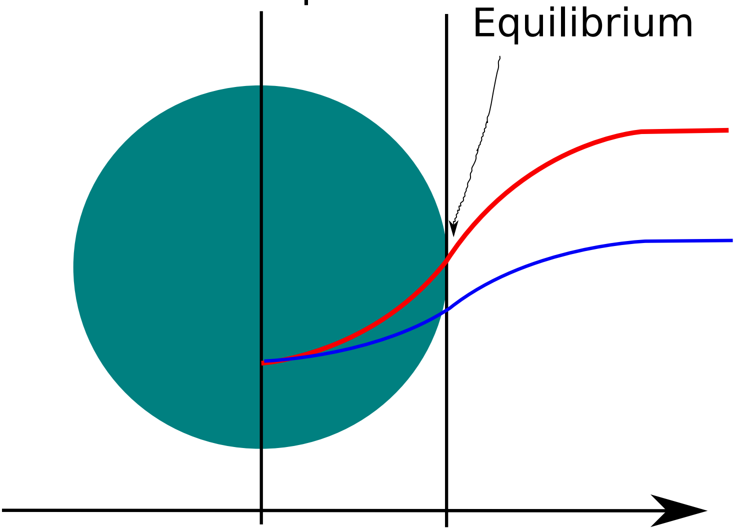
Phase change:

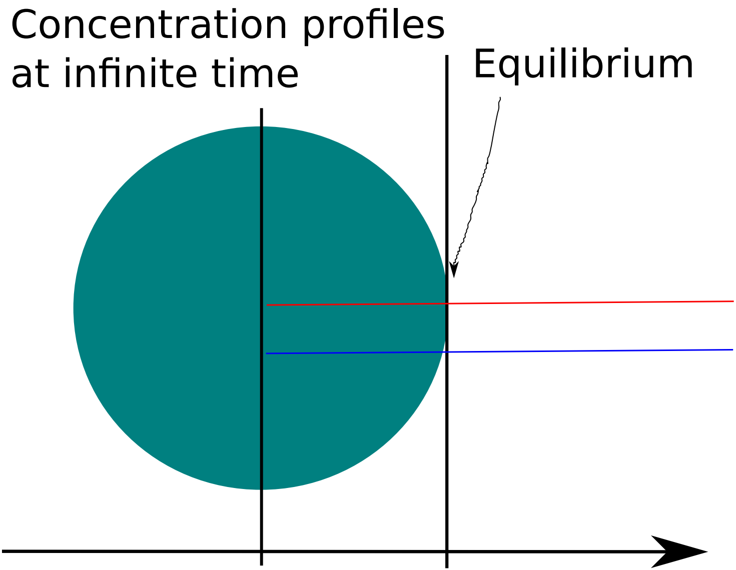
- In single fluids with a large enough amount of impurities (to avoid the increase of temperature induced by the process of nucleation that we saw in the 4th course) the phase change is produced at constant temperature (e.g., for water, 100C at 1 atm)
- In this lesson, we consider a mixture of two volatile fluids (e.g. water/ethanol)

Concentration profiles



Concentration profiles




Concentration profiles
at infinite time
Equilibrium

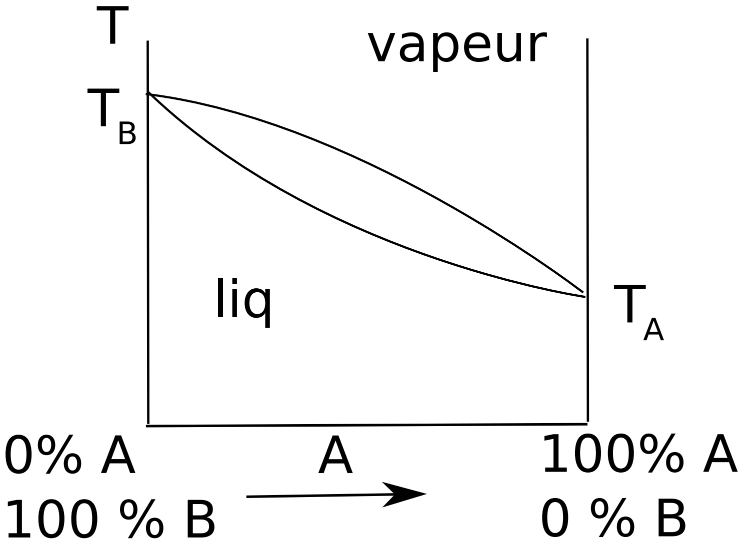
The dynamic (transient state) is given by the flux, therefore, we need to solve the Fick's law. However, at infinite time only counts the difference on the equilibrium conditions that ultimately depends on T,P.

Imagine two different liquids, A and B, with two different vapor pressures: $p_{A,vap}$ and $p_{B,vap}$. The important factor is the *relative volatility*

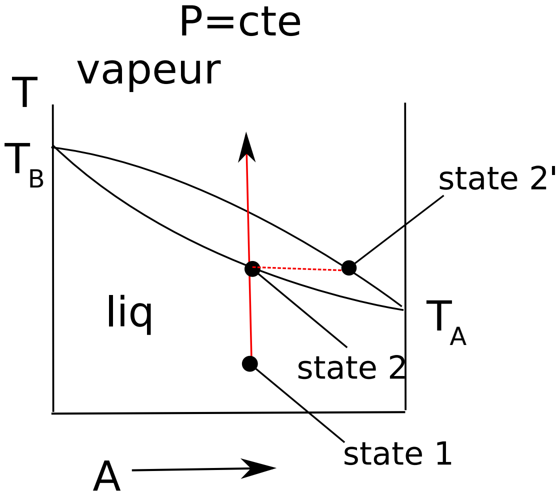
$$\alpha_{AB} = \frac{p_{A,vap}}{p_{B,vap}} \tag{1}$$

- If α_{AB} = 1, separation is difficult.
- If $\alpha_{AB} \ll 1$ or $\alpha_{AB} \gg 1$, separation is simple

P=cte

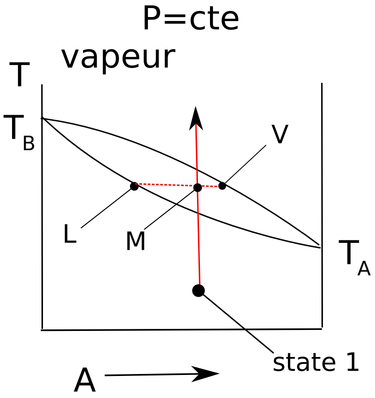


We increase the temperature



state 1: Initial mixture of known composition of A and B.
state 2: Evaporation starts. Saturated liquid.
state 2': Vapor in equlibrium with the saturated liquid

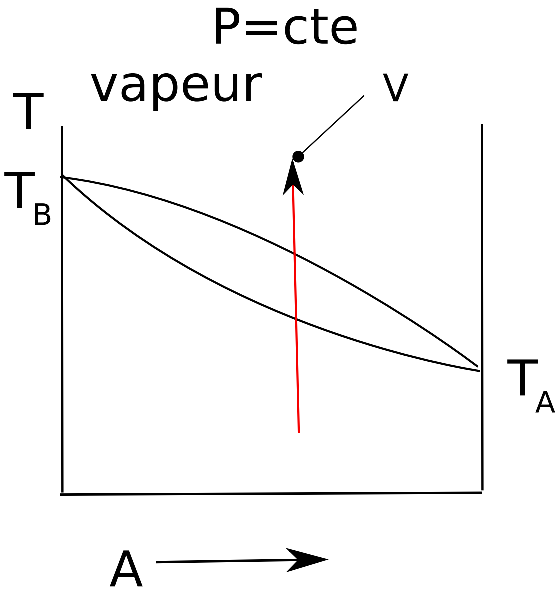
We increase the temperature



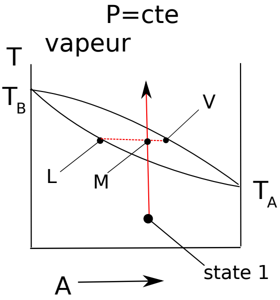
As we increase the temperature, the amount of liquid and vapor as well as their concentrations in equlibrium change.

$$\frac{molesL}{molesV} = \frac{\overline{MV}}{\overline{ML}}$$

We increase the temperature



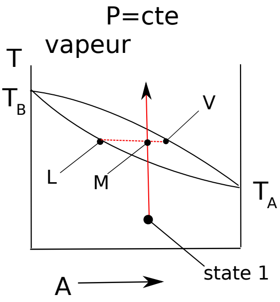
Above a certain temperature all the mixture is evaporated (obviously the vapor



$$\frac{molesL}{molesV} = \frac{\overline{MV}}{\overline{ML}}$$

There is a range of temperatures for which we can get separation

- In the example, low temperature is good to separate the vapors but the amount produced is very small
- As we increase the temperature, the amount of vapor generated is larger but the separation is worse



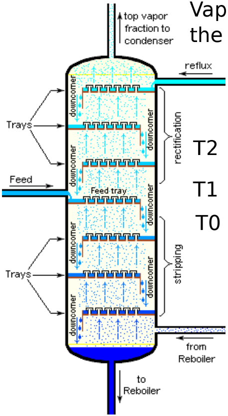
Typically we know the total mass (M) and the initial concentration $X_{A,0}$. The mass balance:

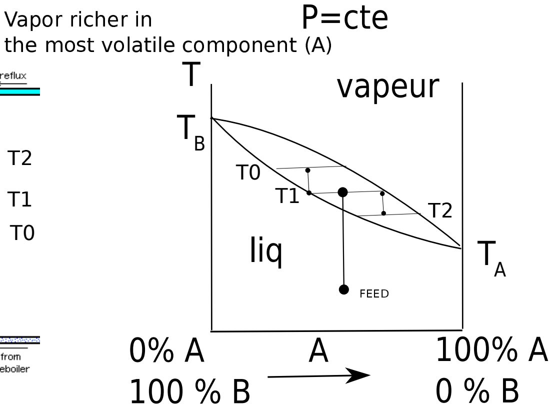
$$M = M_V + M_L \quad (2)$$

$$M X_{A,0} = M_V X_{A,V} + M_L X_{A,L} \quad (3)$$

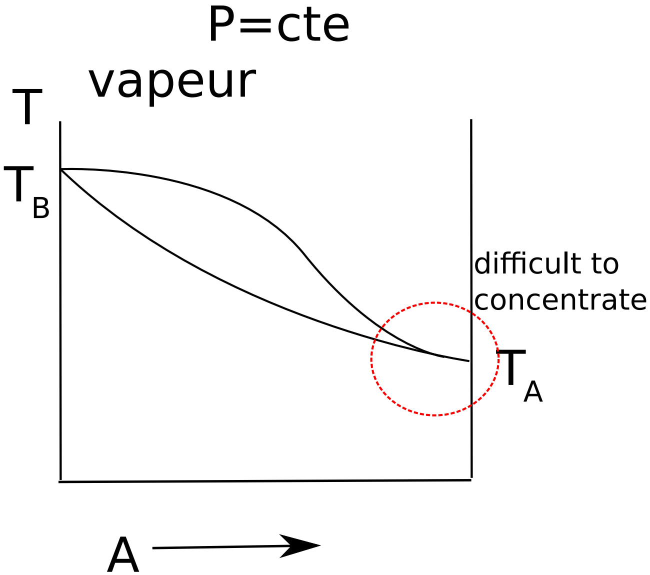
2 eqs and 2 unknowns $\rightarrow$ OK

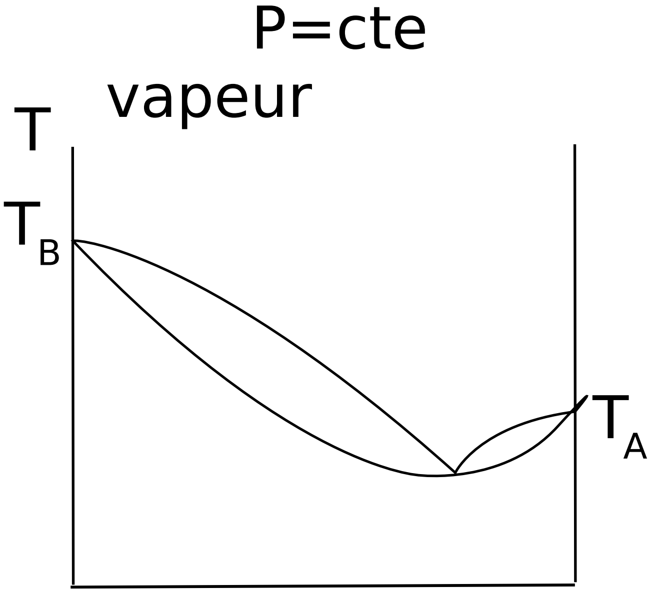
Applications: Separation:

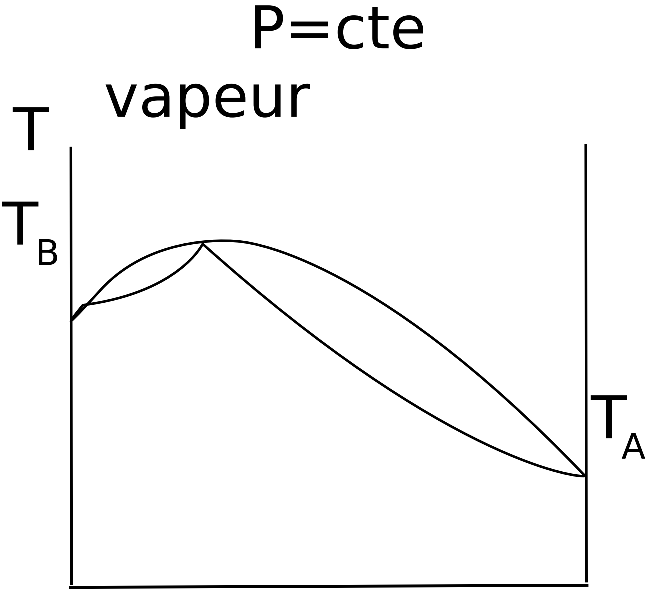




Real mixtures: Sometimes mixtures show "anomalous" behaviors



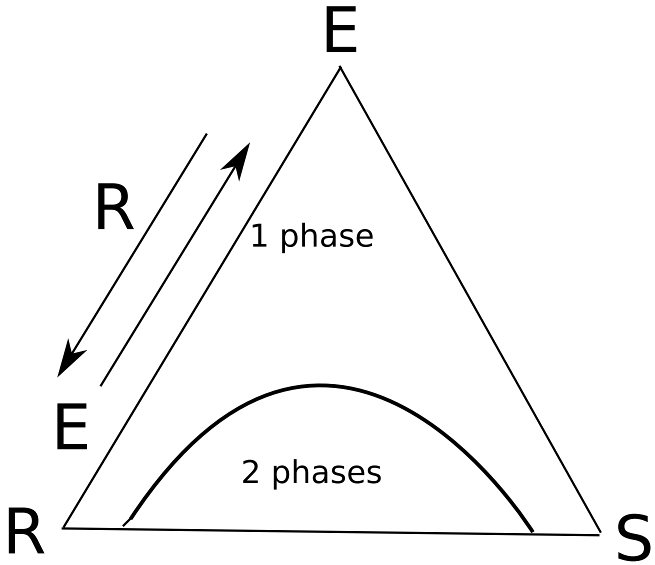

P=cte
vapeur
T
T_B
T_A


P=cte
vapeur
T
T
B
T
A

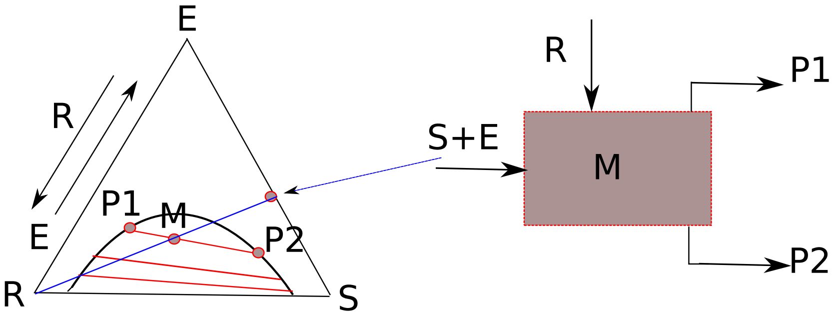
Liquid/liquid/solute systems.

- How the contaminant concentration changes
- How to concentrate one substance

We can add one liquid to change the concentration


E
R
1 phase
E
2 phases
R
S

- If we want to concentrate a solution of E+S, we add a component R easy to separate from E+S
- Depending on the amount of R and R+S, we move along the blue line in the diagram
- The goal is to obtain a mixture (M) that falls into the two phases region
- In the two phase region we can obtain two phases with two different concentrations (P1 and P2)



When we change the amount of R we move along the blue line again. When R is completely removed we obtain a solution in R+S that is richer in E