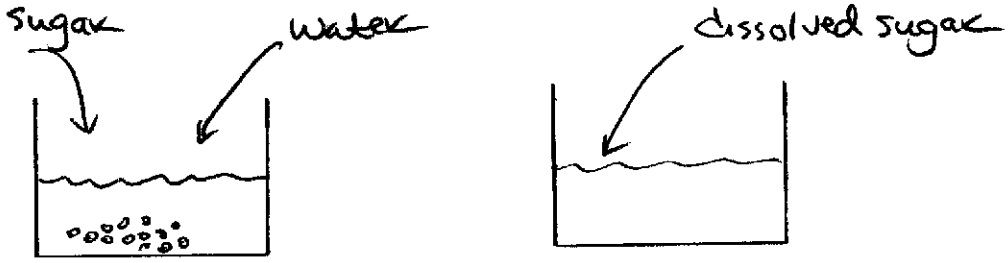
Separation Process Principles
CHEN 3660

1.2 Mechanism of Separation

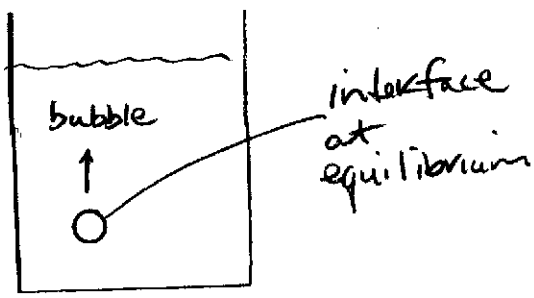
Mixing is a spontaneous process accompanied by an increase in entropy (randomness). The rate may be affected by adding energy but not the "outcome"



Given sufficient time, the system will attain equilibrium.

Systems at equilibrium are well understood (thermodynamics). Systems not at equilibrium are not as well understood or as easy to describe.

Even when a system is not at equilibrium, portions may be at or near equilibrium (local equibkium).

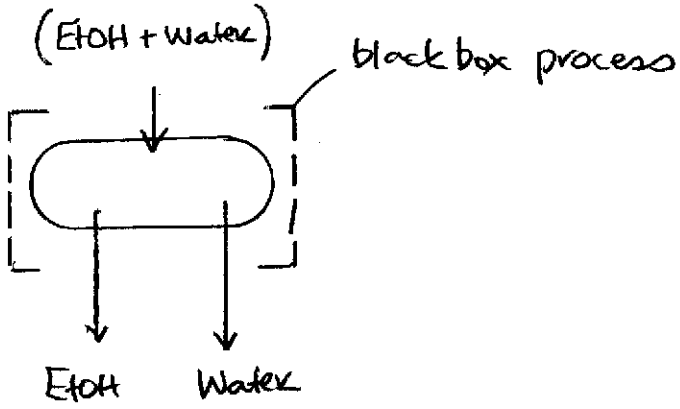


1-2

Separation is the inverse of mixing and is not a spontaneous process. Material to be separated often (usually) consists of a single homogeneous phase of two or more components.

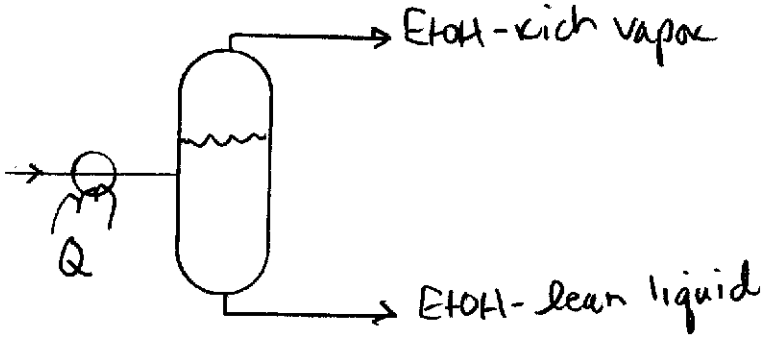
Industrially, separation is extraordinarily important. Few chemical reactions produce the high purity materials directly.

One key concept is that separation requires multiple phases to be present.

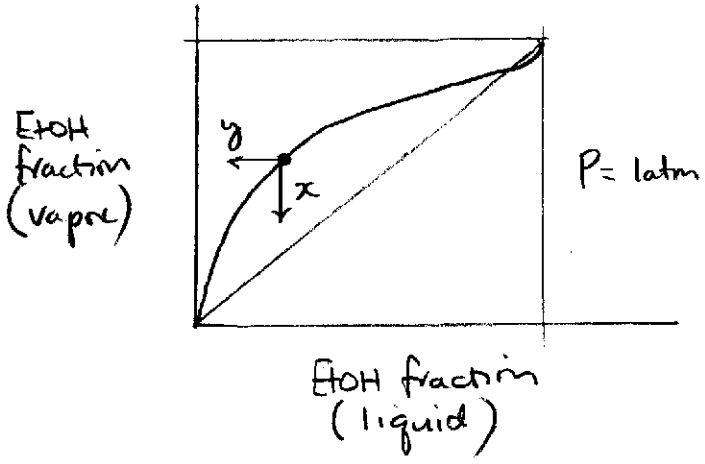


To affect separation we need enrichment in one location & depletion in another hence

location = phases



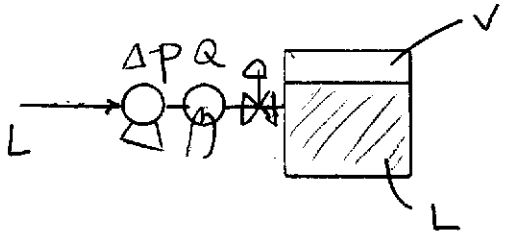
These multiple phase processes frequently occur at or near equilibrium, therefore thermodynamics is <u>key</u> to solving separation problems.



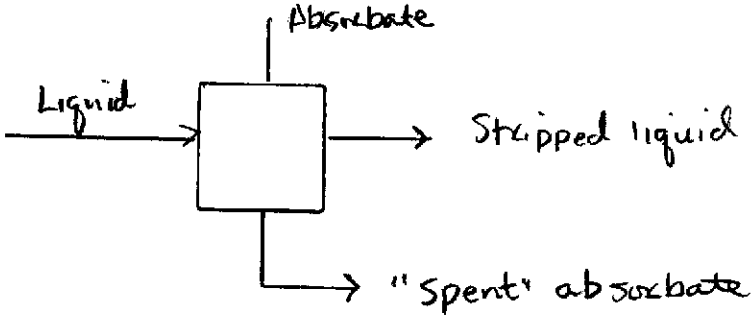
This phase "production" requires one of two agents be present.

MSA mass separating agent

ESA energy " " (work/heat)



"ESA"



"MSA"

1-4

Figure 1.7 (p6) shows 5 common separation techniques

(a) phase creation ESA
(b) phase addition MSA
(c) barrier ESA
(d) solid agent MSA
(e) fields and gradients ESA

Table 1.1 (p 8-10) summarize separation processes based on phase creation or addition

We will particularly focus on

(1) partial condensation/vaporization
(2) flash vaporization
(3) distillation
(11) liquid-liquid extraction

Some of these are covered in detail in your heat/mass transfer course

(6) absorption
(7) stripping
(13) drying
(14) evaporation
(15) crystallization

Each of these is discussed in considerable detail on pages 7-14. The student is responsible* for covering this information

* quiz item ?

especially (1), (2), (3) & (11).

In a similar fashion, Table 1.2 (p 15) displays barriers employing separation processes. Again, the student should read the supporting material.

Table 1.3 (p17) solid agent processes
1.4 (p18) external field / gradient

You will not be tested on these final two areas.

1.7 Component recoveries & product purities.

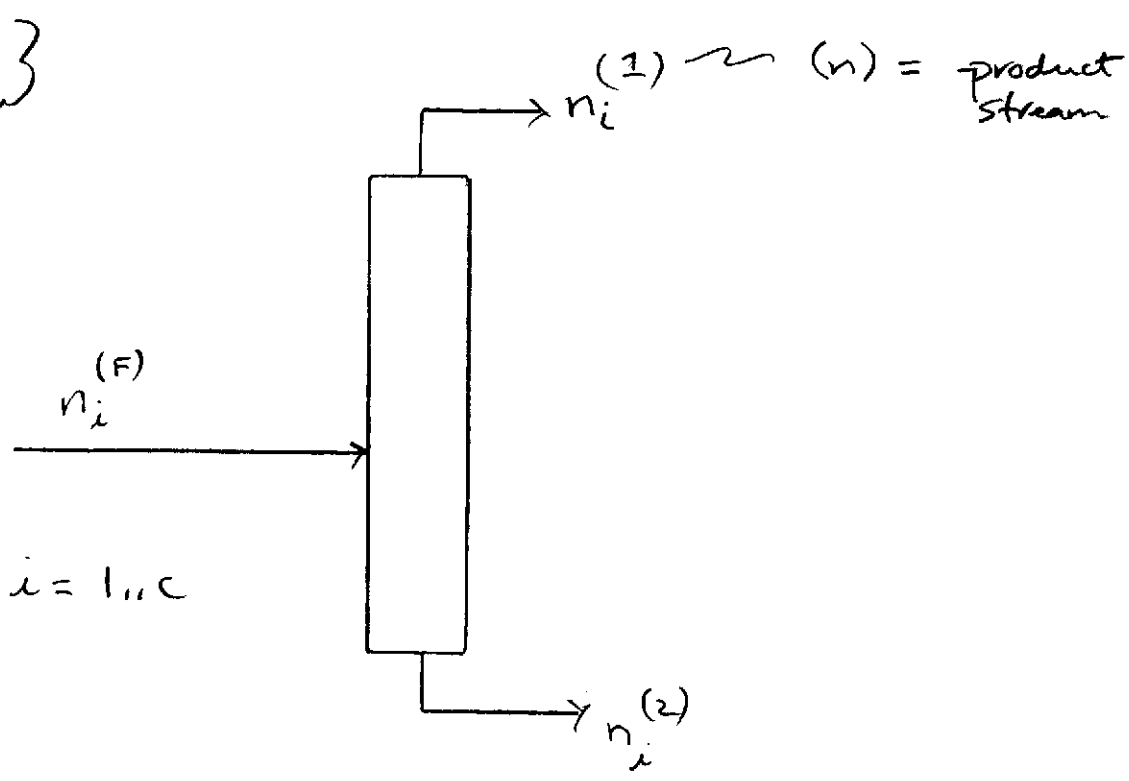
All chemical processes are subject to MB (material balances) & EB (energy balances)

A specialized nomenclature exists for describing the "degree" of separation.

Consider Fig 1.9 (p.19) where a separation of a mixed hydrocarbon feed is to be separated in a 3 distillation column sequence.

Feed is C_2H_6 C_3H_8 i C_4H_8 n C_4H_{10}
i C_5H_{12} n C_5H_{12} and C_6^+ fraction

1-6



∴ MB provides (1-1)

$$n_i^{(F)} = \sum_{p=1}^{N} n_i^{(p)} \qquad \left(\text{no } \overset{w/}{\text{rxn}}\right)$$

Split Fraction, SF

$$SF_{i,k} = \frac{n_{ik}^{(1)}}{n_{ik}^{(F)}} \qquad (1\text{-}2)$$

Split fraction in "k^{th}" separator

Generally (1) is the outlet stream where the most volatile component "enriches" in.

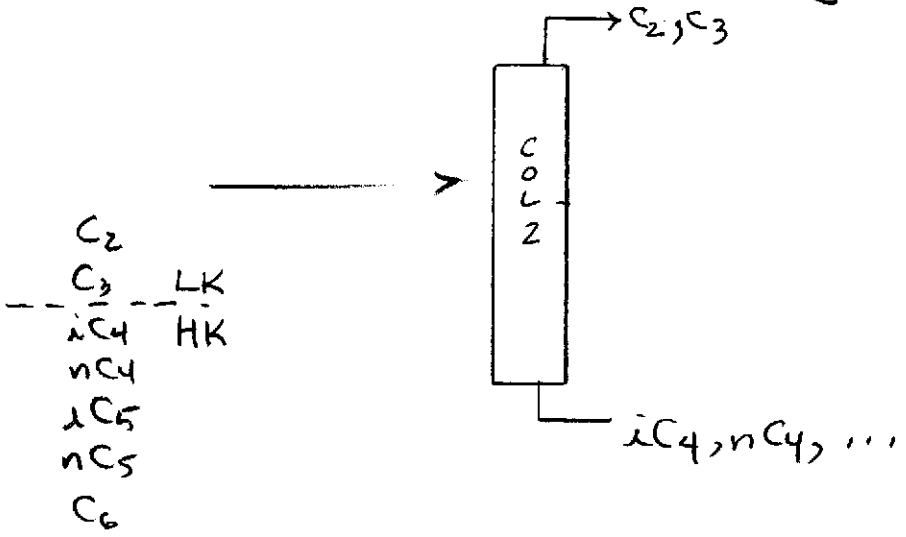
Split Ratio, SR

$$SR_{i,k} = \frac{n_{ik}^{(1)}}{n_{ik}^{(2)}} = \frac{SF_{ik}}{(1 - SF_{ik})} \qquad (1\text{-}3)$$

1-7

A <u>huristic</u> of separations is that generally a column (operation) splits adjacent "key components"

A "key" component is (by definition) the "important" ones in a given separation.



Two other measures of the extent of separation are

1. Percent Recovery
2. Product Purity

Note: Both have units of % so do not confuse them.

A final measure is "Separating Power", SP

$$SP_{i,j} = \frac{c_i^{(1)} / c_i^{(2)}}{c_j^{(1)} / c_j^{(2)}} \qquad (1\text{-}4)$$

where i & j are components

SP is basically the ratio of the improvement ratios for two components.

In (1-4) C can be mole or mass fraction or concentration in moles or mass / vol.

$$SP_{ij} = \frac{SR_i}{SR_j} \qquad (1\text{-}5)$$

$$SP_{ij} = \frac{SF_i / SF_j}{(1 - SF_i)/(1 - SF_j)} \qquad (1\text{-}6)$$

Tables 1.5, 1.6, 1.7, 1.8 show a detailed calculation for the 3 column separation in Figure 1.9

Note each column has a specific purpose which is evident from the split fraction info.

Generally $SF > 0.95$ LK

$SF < 0.05$ HK

For example, in column 2, the split is

LK	HK
0.9614	0.0035
C_3H_8	iC_4H_{10}

Column 1 is actually not effectively separating material since

LK = 0.9969 HK = 0.7025

This causes problems later in column 3.

1.9 Selection of feasible separation processes
(pp 23-27) LFS (Left for Student)