Chapter 1:
Introduction to Separation Process Engineering

Why are we—as chemical engineers—required to study “separation processes”?

- **Separations** are crucial in chemical engineering (e.g., chemical plants, petroleum refineries)
- Chemical plants commonly have from 40% to 70% of both capital and operating costs in separations
Examples of the Importance of Separations

**Figure 1.1: The acetone recovery process**

- **Water** (100%)
- **Air**
  - Air 99.5%
  - Water 0.5%

- **Absorber column**
  - Feed
    - Acetone 3.0%
    - Air 95.0%
    - Water 2.0%
  - Raw Product
    - Acetone 19.0%
    - Water 81.0%

- **Distillation column**
  - Condenser
    - Distillate
      - Acetone 99.0%
      - Water 1.0%
    - Bottom product
      - Acetone 4.0%
      - Water 96.0%
Figure 1.2: The production of $\text{K}_2\text{CrO}_4$ crystals
Figure 1.3: The production of poly-propylene (PP)
In this course, we shall focus on the separation processes in which *two separated phases* are in contact and *in equilibrium* with each other.

Such processes include:

- distillation
- absorption & stripping
- extraction

Note also that this course is also used the concept of “*unit operations*”: 

“although the specific design may vary depending on what chemicals are being separated, the basic design principles for a given separation method (as listed above) are always the same”
1.1 Equilibrium

- What is “equilibrium”?
- What is(are) the difference(s) between “equilibrium” and “steady state”?

Let’s consider the vapour-liquid system of a binary mixture (what is a “binary mixture”?)

![Vapour-Liquid Equilibrium Diagram]

Figure 1.4: Vapour-liquid equilibrium (VLE) of a binary mixture
We have learned that, at equilibrium,

- \( T_{\text{vapour}} = T_{\text{liquid}} \)
- \( P_{\text{vapour}} = P_{\text{liquid}} \)
- \( \mu_i^{\text{vapour}} = \mu_i^{\text{liquid}} \)

This means that, at equilibrium, all properties of the system are identical in all phases, and, on the macroscopic scale, there are no further changes in those properties.

It should be noted, however, that, the change may still take place in microscopic or molecular scale; for example, at equilibrium, condensation and evaporation of each species still occur, but the rate at which each species condenses is equal to the rate at which it evaporates.
When referring to the term “equilibrium”, it means there are no changes in any properties with time and there are no differences, also in any properties, within the system.

However, when referring to the term “steady state”, it means there are no changes in any properties with time only, implying that there may be differences in any properties within the system.
1.2 Mass Transfer Basics

A basic mass transfer equation can be formulated as follows:

\[
\text{Mass transfer rate} = (\text{Area}) \times (\text{Mass transfer coefficient}) \times (\text{Driving force})
\] (1.1)

Eq. 1.1 can be written in equation form as follows

\[
\text{Rate} = K_y a \left( y_i^* - y_i \right) \quad (1.2)
\]
or
\[
\text{Rate} = K_x a \left( x_i - x_i^* \right) \quad (1.3)
\]
where

\[ K_y = \text{mass transfer coefficient in gas phase} \]

\[ K_x = \text{mass transfer coefficient in liquid phase} \]

\[ a = \text{contacting area} \]

\[ x_i \text{ or } y_i = \text{concentration of species } i \text{ at any instant of time} \]

\[ x_i^* \text{ or } y_i^* = \text{concentration of species } i \text{ at equilibrium} \]
1.3 Pre-requisite Materials for Studying this Course (AE 335 Separation Processes)

- Reading skills (both Thai and English)
- Mathematics
  - Algebra (including Matrix)
  - Graphical analysis (linear, exponential, logarithmic)
- Material & energy balances
- Phase equilibria (from ChE Thermodynamics II)
- Problem solving skills
1.4a Main textbook:


1.4b Recommended additional textbooks