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

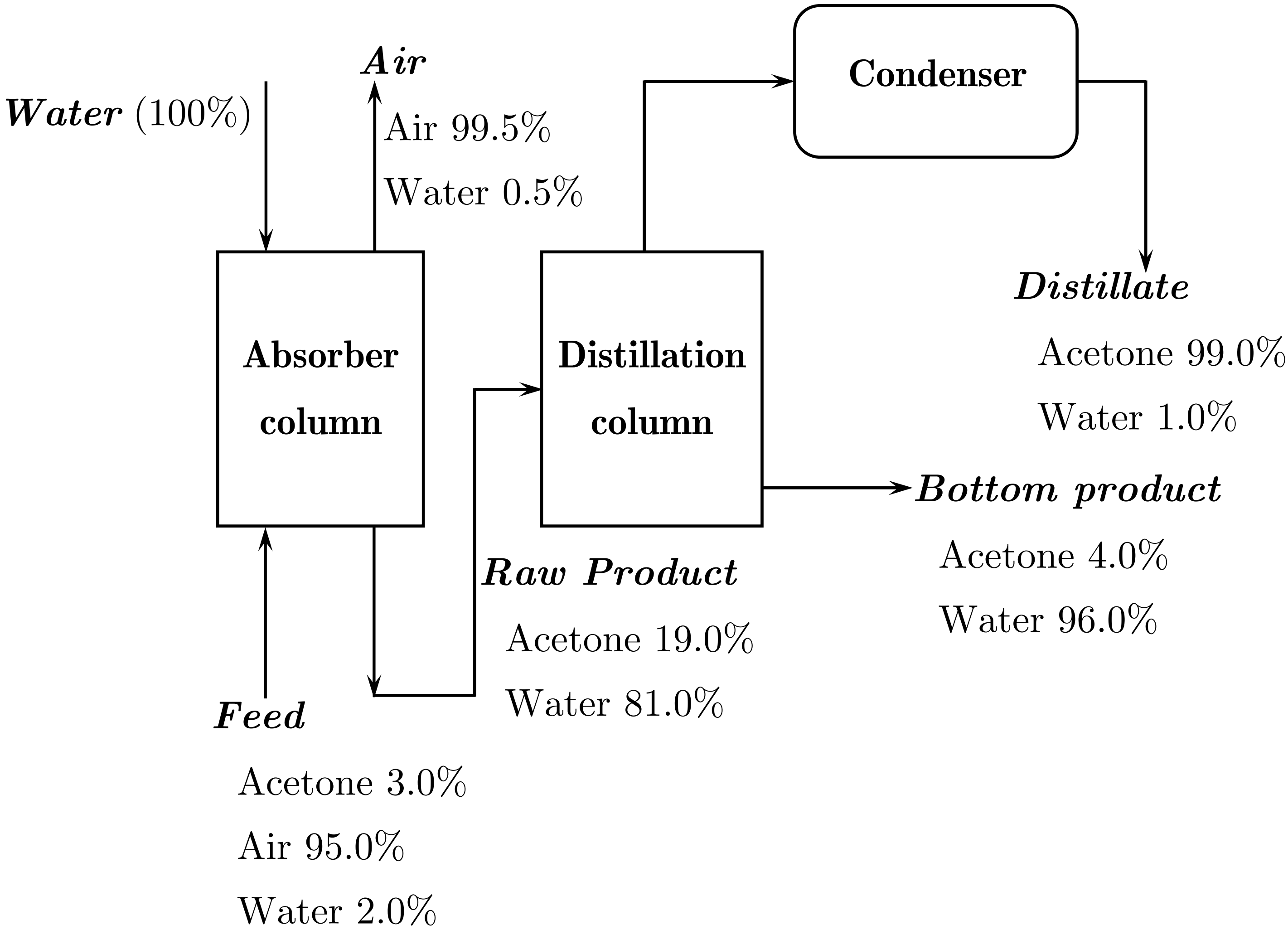

Figure 1.1: The acetone recovery process

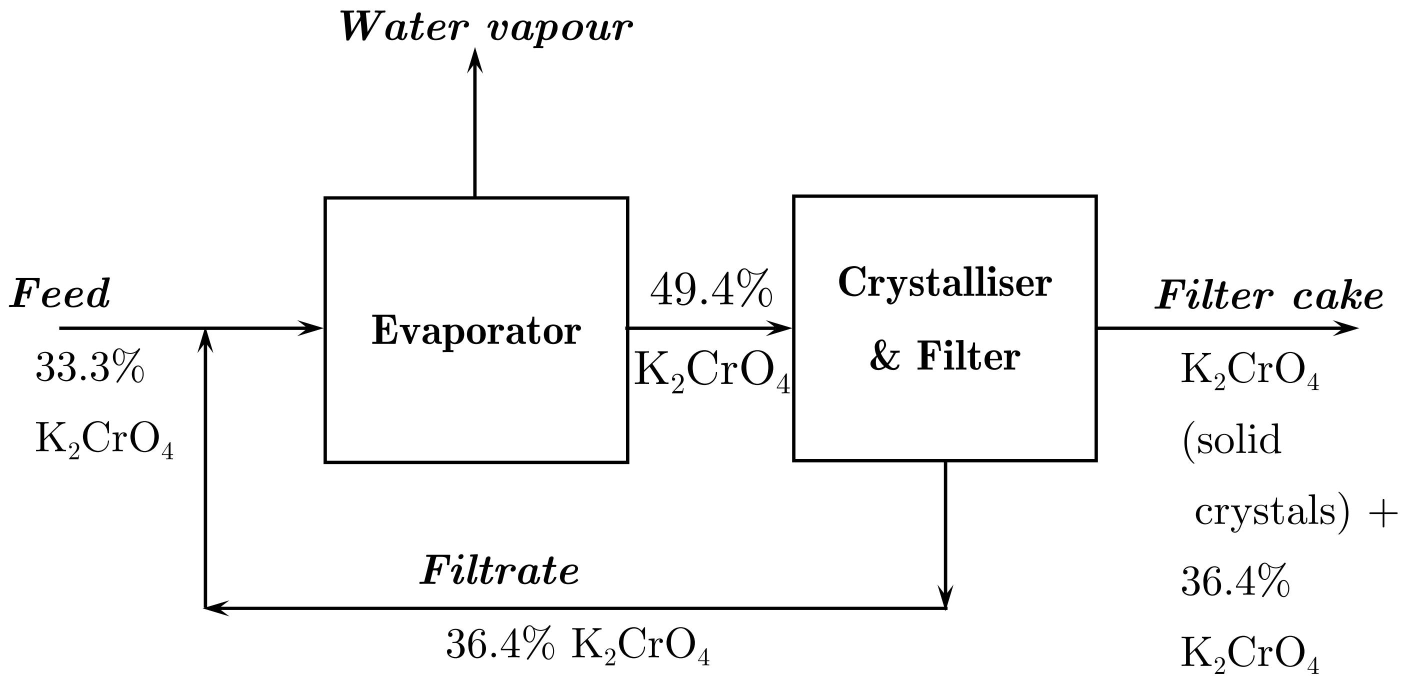

Figure 1.2: The production of K_2CrO_4 crystals

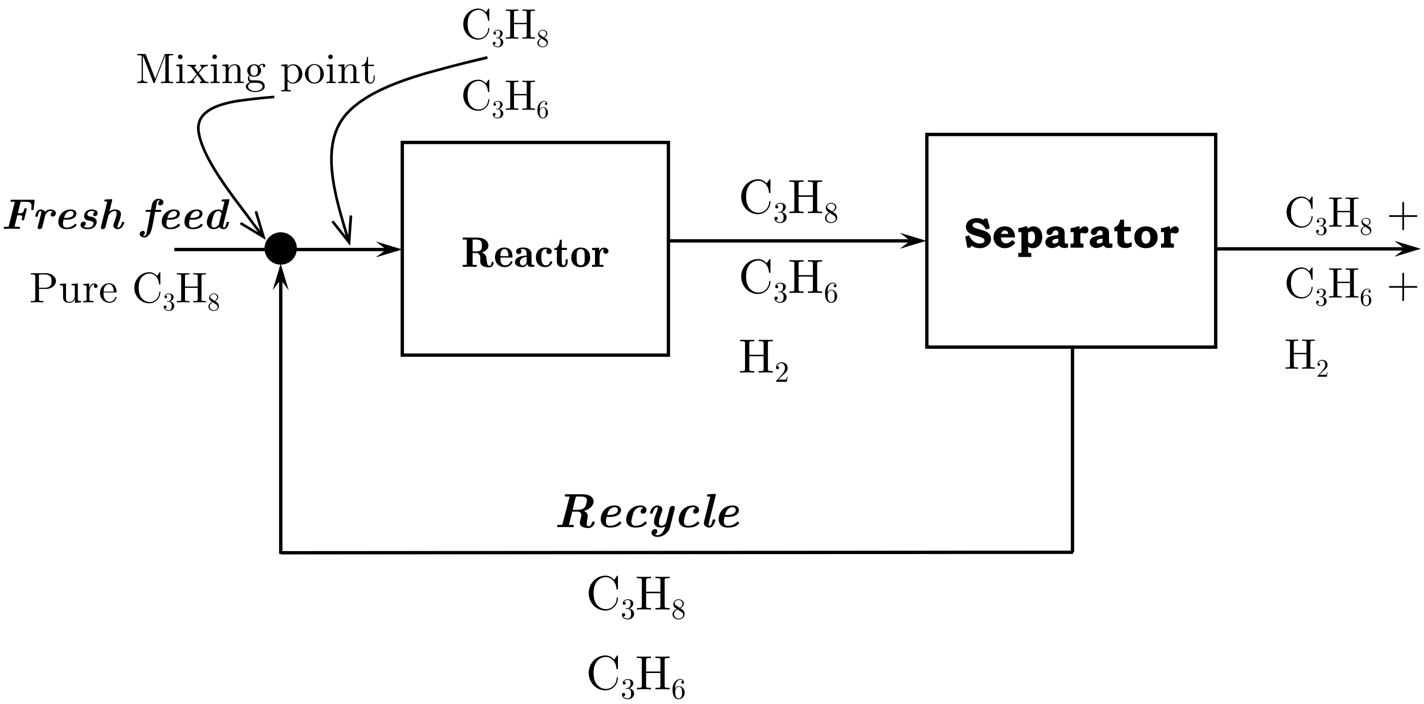

Figure 1.3: The production of poly-propylene (PP)

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"?)

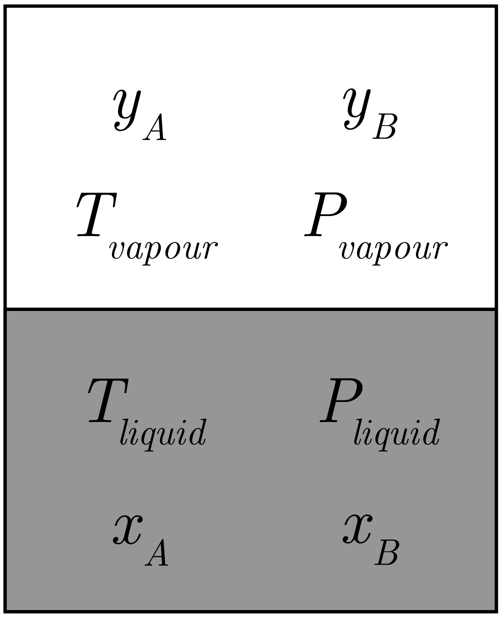

Figure 1.4: Vapour-liquid equilibrium (VLE) of a binary mixture

We have learned that, at equilibrium,

- $T_{vapour} = T_{liquid}$
- $P_{vapour} = P_{liquid}$
- $\mu_i^{vapour} = \mu_i^{liquid}$

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:

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

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 = mass transfer coefficient in gas phase

K_x = mass transfer coefficient in liquid phase

a = contacting area

x_i or y_i = concentration of species i at any instant of time

x_i^* or y_i^* = concentration of species i 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:

- Wankat, P.C., **Separation Process Engineering**, 2nd ed., Prentice Hall, 2007

1.4b Recommended additional textbooks

- Geankoplis, C.J., **Transport Processes & Separation Processes**, 4th ed., Prentice Hall, 2003
- King, C.J., **Separation Processes**, 2nd ed., McGraw-Hill, 1980
- McCabe, W.L., Smith, J.C., and Harriott, P., **Unit Operations of Chemical Engineering**, 7th ed., 2005
- Seader, J.D., and Henley, E.J., **Separation Process Principles**, 2nd ed., Wiley, 2006