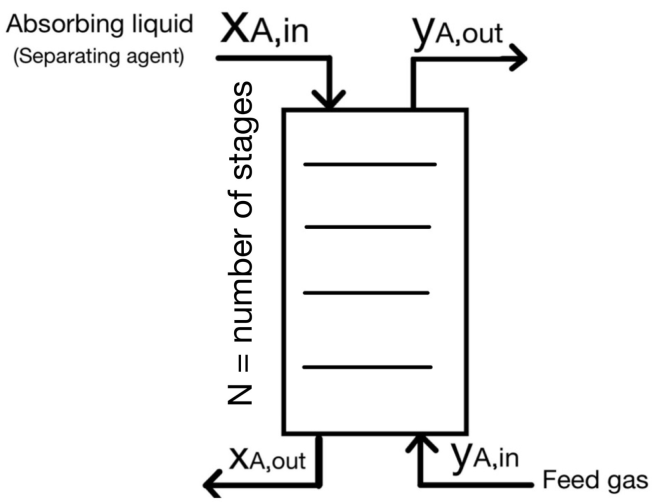
# ENCH 445: KSB Equations

When the operating and equilibrium lines are straight, there is an analytical solution for a staged contactor. One such equation is the Kremson, Saunders, Brown Equation

📕 See pages 485 - 493 of Wankat for the derivation

**Absorber**- use the absorber form of the KSB equation.




$K_A$ = equilibrium constant

$$K_A = \frac{y_A}{x_A}$$

👉 In textbook, this is represented by *m*

Drop the component subscript for simplicity:

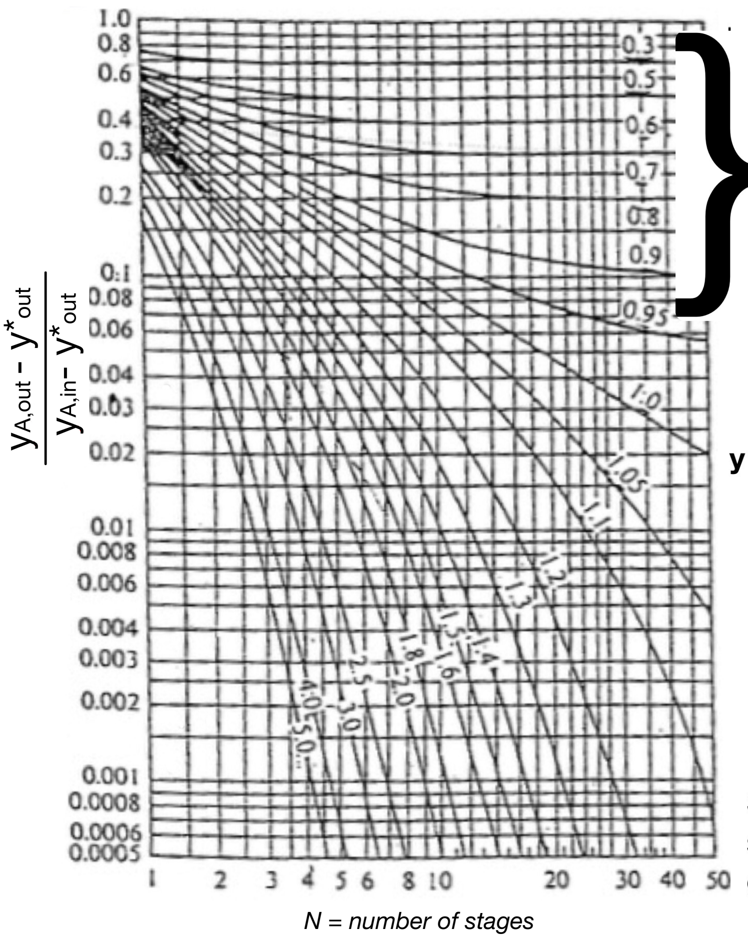
$$\frac{y_{out} - y^*_{out}}{y_{in} - y^*_{out}} = \frac{1 - \frac{L}{KV}}{1 - \left(\frac{L}{KV}\right)^{N+1}}$$

🔍 The $*$ notation denotes the value of $y_A$ which would be in equilibrium with $x_{A,in}$

In a typical design problem, $y_{in}$, $y_{out}$ , $x_{in}$ , K are specified ➡️ $y^*_{out} = x_{in}K$ ($y_{out}$ often = 0)

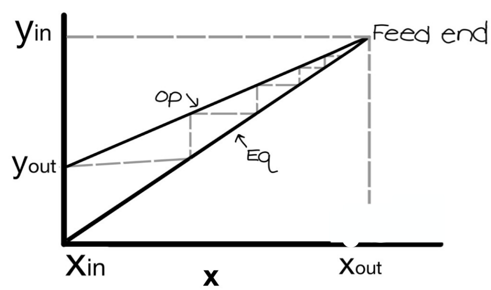
Then N and $x_{out}$ can be determined for a given value of $\frac{L}{V}$

For a typical <u>operating</u> problem, $y_{in}$, $x_{in}$, $K$ and N are specified ➡️ $y^*_{out} = Kx_{in}$ ➡️ This equation can be used to determine $y_{out}$.




$$\frac{L}{KV} < 1 \quad \text{i.e.} \quad \frac{L}{V} < K$$

and pinch exists at feed end as N becomes large. This makes it difficult to achieve large amounts of absorption even as N $\rightarrow \infty$



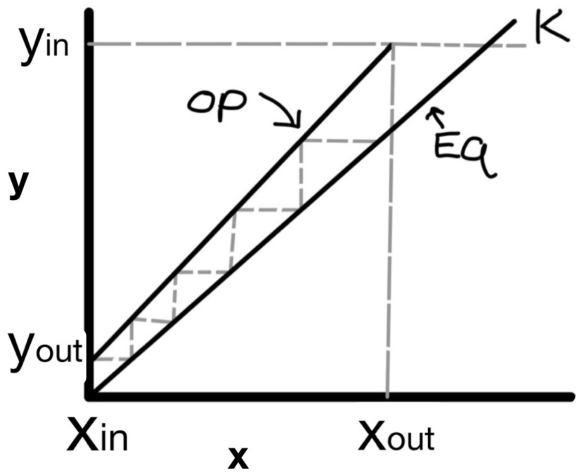

Since $y^*_{out} = 0$ in above diagram, a simple overall material balance gives

$$V = (y_{in} - y_{out}) = L\, x_{out}$$

But $x_{out} = y_{in}/K$ therefore:

$$\frac{y_{out}}{y_{in}} = 1 - \frac{L}{KV}$$

When $\frac{L}{KV} > 1$ : large amounts of absorption can be attained even with a moderate number of stages




As seen in the graph, as $\frac{L}{KV}$ becomes greater than ~ 3, there is not much benefit in a further increase of $\frac{L}{KV}$

**Basic Rule for selecting the flow rate for absorbing liquid:**

⭐ Pinch should be at product end of column and, more specifically, the optimal flow rate of the absorbing liquid is given by:

$$\frac{L}{KV} \sim 1.2$$

**Stripper**- the following form of the KSB equation is more convenient

$$\frac{x_{A,out} - x^*_{out}}{x_{in} - x^*_{out}} = \frac{1 - \frac{KV}{L}}{1 - \left(\frac{KV}{L}\right)^{N+1}}$$

Value of $x_{out}$ which would be in equilibrium with $y_{in}$, i.e. $x^*_{out} = y_{in}/K$

📌 For graph for the above equation, just replace y with x and KV/L withL/KV on the graph on previous page. i.e. the parameter on graph is KV/L

For the design of a stripper, the pinch should again be at product end, which now means that the optimal flow rate of stripping gas is given by:

$$\underbrace{\frac{KV}{L}}_{\text{Stripping factor}} \sim 1.2$$

## Design of a Staged Stripper

In the manufacturing of peanut oil, crushed peanuts are extracted with hexane to remove the peanut oil. In one particular plant, 10 tons/hr of this extract containing 15 wt-% peanut oil in hexane is to be processed to remove the hexane. The allowable residual hexane content is 0.01 wt-%. It is proposed to remove the hexane using the following two steps: (i) multieffect vaporization to reduce the hexane content to 1.0 wt-%, followed by (ii) steam stripping to reduce the hexane content from 1.0 wt-% to 0.01 wt-%. Propose a design for the steam stripper.

Additional Information:

The temperature of the peanut oil may not be allowed to exceed 80 C. The vapor pressure of hexane above the product oil at 80 C has been measured to be 0.6 mm Hg. Peanut oil is virtually nonvolatile. Cooling water is available at 30 C.

Vapor pressure of hexane:

| P (mm Hg) | 10 | 40 | 100 | 200 | 400 | 760 | 1100 |
|---|---|---|---|---|---|---|---|
| T (C) | -25 | -2.3 | 16 | 32 | 50 | 69 | 80 |

Vapor pressure of water:

| P (mm Hg) | 31.8 | 55.3 | 92.5 | 149 | 234 | 355 |
|---|---|---|---|---|---|---|
| T (C) | 30 | 40 | 50 | 60 | 70 | 80 |

Heat of vaporization of hexane: 36.1 cal/g

Heat capacity of liquid hexane: 0.527 cal/g C