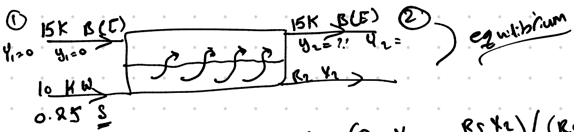
problem 1 :- ⟹ Seader chapter 5

Benzene → E - phase (fresh solvent)

water → R - phase.

Solution :-

1) Single stage equilibrium:-



% extraction of solute :- $(R_S X_1 - R_S X_2) / (R_S X_1) * 100\%$

eff.

$$= \frac{R_S (X_1 - X_2)}{R_S (X_1)} * 100\%$$

we need to know X_1, X_2 ← molar ratio.

$$X_1 = \frac{(0.25 * 10k)}{0.75 * 10k} = \frac{0.25}{0.75} = \frac{1}{3}$$

X_2 = (from material + eq. Balance)

A) mass Balance

$$R_S X_1 + E_S Y_1 \text{(zero)} = R_S (X_2) + E_S (Y_2)$$

Solve given KD

$$(10K * \tfrac{1}{3}) = 10K (X_2) + 15K (Y_2)$$

$$Y_2 = KD \, X_2$$

$$\hookrightarrow X_2 = \frac{X_1 + \frac{E_S}{R_S} Y_1}{1 + E}$$

(ext %)

$$\boxed{E = \frac{E_S}{R_S} \cdot KD}$$

↳ $E = 2.4$

$$X_2 = \frac{\frac{1}{3} + 0}{1 + 2.4} = \frac{1/3}{3.4} = 0.0980.$$

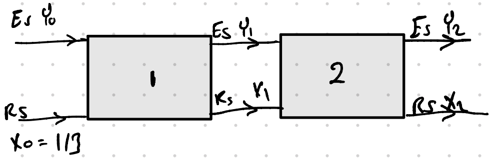
$$eff\,\% = \frac{1/3 - 0.0980}{1/3} * 100\%$$

eff = 70.6%

$$Y_2 = KD \, X_2$$

$\hookrightarrow Y_2 = 0.1172$

2) Co-current arrangement (2 stages)



لو ما كانوا عند eq $\Rightarrow$ X_1, Y_1

بنطبق علاقات أو ربطها

بال material Balance

From previous calculations:

$$\frac{R_S}{E_S} = 2$$

$$E = \frac{E_S}{R_S} \cdot K_D = 2.4$$

Same for both stages.

$$Y_1 = 0.1176$$

$$X_1 = 0.0980$$

⊛ **For stage no. 2:**

$$X_2 = \frac{X_1 + \frac{R_S}{E_S} Y_1}{1 + E}$$

Same as ①

$$X_2 = \frac{0.0980 + (2 * 0.1176)}{(1 + 2.4)} = 0.0980 \text{ Same as } X_1$$

(No separation)

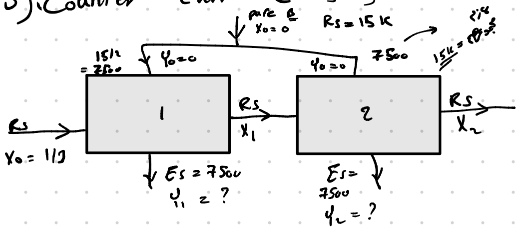
ما استفدنا لا نفس النتيجة.

"No extraction"

لأنه وصلوا عند equilibrium

فهيك ما في مجال للانتقال.

3) Counter current (2 Stage)



Para-dioxade

it's more soluble in benzene

% extraction => $\frac{Rs\,X_0 - Rs\,X_1}{Rs\,X_0} * 100\%$

$$eff = \frac{X_0 - X_1}{X_0} * 100\%$$

for each stage:

10k $\frac{Es/2}{Rs} = \frac{7500}{7500} = 1$

$E = \frac{Es/N}{Rs} KD = 1 * 1.2 = 1.2$

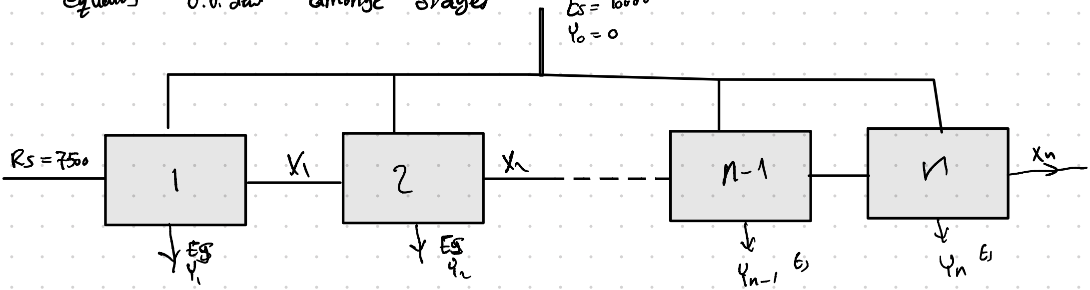
$$X_1 = \frac{X_0 + (\frac{Es}{Rs} Y_0)}{1+E} = \frac{(1/3)}{2.2} = 0.1515$$

$$X_2 = \frac{X_1 + [\frac{Es}{Rs} Y_0]}{1+E} = \frac{0.1515}{1.2} = 0.0689$$

→ Y_1, Y_2 => KD

$$\% eff = \frac{0.333 - 0.0689}{0.333} * 100\% = 79.34\%$$

in general for n stages crosscurrent with total solvent equally divided among stages



for each stage $\bar{E_s} = E_s = \frac{E_s}{n} \Rightarrow$

$$E = \frac{E_s/N}{R_s} K_D \Rightarrow \frac{E}{N}$$

→ extraction factor overall effective

$$\%\,recovery = \frac{X_0 - X_n}{X_0} * 100\%$$

$$X_1 = \frac{X_0 + [(E_s/N)/R_s \cdot Y_0]}{1 + (\frac{E}{N})}$$

[illegible] →

$$X_1 = \frac{X_1 + (E_s/n)\,R_s \cdot Y_0)}{[1 + \frac{E}{N}]}$$

[illegible]

$$X_n = \frac{X_0}{[1 + (\frac{E}{N})]^{N}}$$ ← per stage

$$\%\,recovery = \frac{X_0 - X_0(1 + \frac{E}{N})^{n}}{X_0}$$

E ↑ separation better.

$$\%\,recovery = \frac{(1 + \frac{E}{N})^{n} - 1}{(1 + \frac{E}{N})^{n}}$$

* if we have $n = \infty$ stages

$$\lim_{n\to\infty} \frac{X_0}{E * P(E)} = X_\infty = \frac{X_0}{e^{E}}$$

في [cross flow] طريقة التلامس أفضل

لأنه بعد كل stage بنرد نحط fresh solvent

هاد شي بزيد من driving force موجود co-current

لهذا في تحسن

↳ if $n = 5$

$$\% \text{ recovery} = \frac{1 + (2.4/5)^5 - 1}{(1 + (2.5/5)^5)} = 85.9\%$$

↳ if $n = 100$

$$\% \text{ recovery} = \frac{((1 + (2.4/100)^{100}) - 1}{(1 + (2.4/100)^{100}} = 90.67\%$$

$$X_{100} = \frac{0.333}{(1 + (2.4/100)^{100})} = 0.0311$$

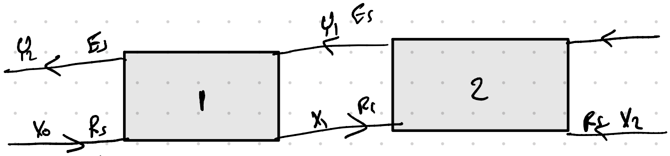
if we used $X_\infty \Rightarrow$

$$X_\infty = \frac{0.333}{e^{2.4}} = 0.0304$$

!! كلما زاد عدد stages كلما قربنا لل ∞ !!

$$\% \text{ recovery}_\infty = 90.93\%$$

d) counter current (2 stages)



$E_s = 10k$
$Y_0 = 0$

$X_0 = \frac{1}{8}$

$E = \frac{E_s}{R_s} \cdot KD$ for each stage

لو كانت ثابتة فيصبح
كأنك نفسه لان
ال effect

Stage ①:-

$R_s X_0 + E_s Y_2 = R_s X_1 + E_s Y_1$

$Y_1 = KD\ X_1$

$X_1 = \frac{X_0 + (Y_2 \cdot \frac{E}{R_s})}{1+E} \Rightarrow (*)$

Stage ②:-

$R_s X_1 + E_s X_2 = R_s X_2 + E_s Y_0$

$Y_2 = KD\ X_2$

$\hookrightarrow X_2 = \frac{X_1 + (Y_0\ E_s/R_1)}{1+E}$ (*) (zero)

$\Rightarrow X_2 = \frac{[X_0 + Y_2(E_s/R_s)]/1+E}{(1+E)}$

$X_2 = \frac{X_0 + Y_2(E_s/R_s)}{(1+E)^2}$

$Y_2 = KD\ X_2$

$(1+E)^2 \cdot X_2 = \frac{X_0 + [(\frac{E_s}{R_s} \cdot KD)\ X_2]}{(1+E)^2} \cdot (1+E)^2$ (with $\frac{E_s}{R_s} \cdot KD = E$)

$(1+2E+E^2) \cdot X_2 = X_0 + E X_2$

$(1+E+E^2)\ X_2 = X_0$

$X_2 = \frac{X_0}{1+E+E^2}$

$X_0 = 0.33$

$X_2 = 0.036$

% recovery = 89.05%

for n stages

$$x_n = \frac{X_0}{\sum_{0}^{n} E^i}$$

for $n = 5$

$$x_5 = \frac{X_0}{E^0 + E^1 + E^4 + E^5} = \frac{X_0}{1 + E + E^2 + E^3 + E^5}$$

(X_0 ← 0.333; E → 2.4)

$x_5 = 0.0025$

$$\% r = \frac{X_0 - x_5}{X_0} \times 100\% = 99.26\%$$

!! of cross flow in line i

@ $n = \infty$
X_0 = zero ⇒ 100% extraction

$x_\infty = 0$ $1 \leq E \leq \infty$ % recovery = 100%

$x_\infty = (1-E) X_0$
$E \leq 1$ % recovery = E

Summary

number of stages	1 eq. stage	co-current	crossflow	counter current
1	70.6%	—	—	—
2	70.6%	70.6%	79.34	89.08%.
5	70.6%	70.6%	85.02%	99.26%
∞	70.6%	70.6%	90.93	$100 \leq E \leq \infty$ $E \leq 1$

Notes:-

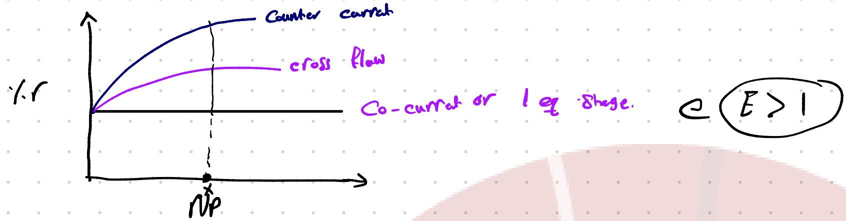
- for very small values of E (0.1 for example)

cross flow $X_\infty = \frac{X_0}{e^E}$ $= 0.301$ counter flow $X_\infty = (1-E)\, X_0$ $= 0.2997$

% recovery = 9.52%   % recovery = 10 %

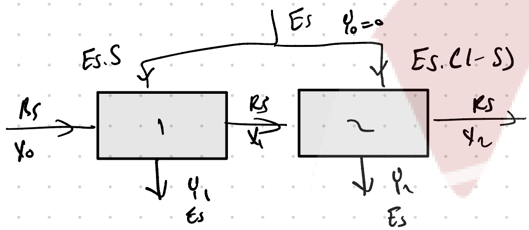
- if the difference small, counter current is preferred. Since it is desirable to operate with $E > 1$.

- now, if we plot Np vs % recovery:



in cross flow There is a Split factor ⇒ يعني رح أقسم ال flow الرئيسي عل كل stage

مثلاً stage 1 عل 10% و stage 2 عل 90%



Split	X_1	Y_1	X_2	Y_2	% recovery
0	0.333	3.946	0.098	0.1176	70.59%
0.1	0.263	0.3228	0.085	0.102	74.48%
0.5	0.1514	0.1117	0.069	0.0828	79.39
0.9	0.105	0.126	0.098	0.102	74.48
1	0.098	0.1176	0.098	0.1176	70.59

وحدة stage