Name Key

Name

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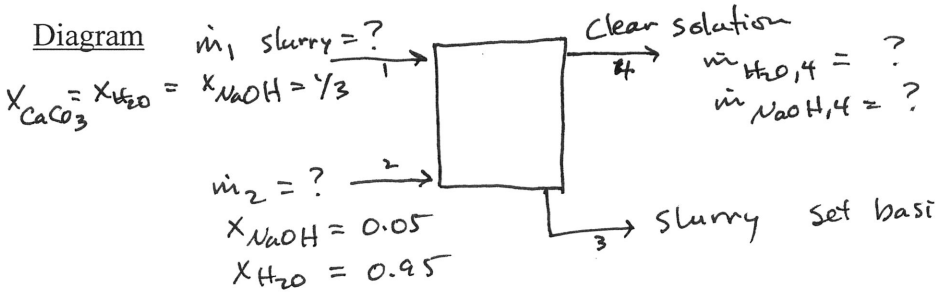
Chemical Engineering 273
Class 7 In-Class Assignment

A slurry of $CaCO_3$ (s) in NaOH and H_2O is washed with an equal mass of dilute 5 wt% NaOH in water. The washed and settled slurry contains 2 lb_m of solution per lb_m of solid $CaCO_3$. A clear solution with no solids is withdrawn from the unit. The mass fraction of NaOH in the liquid solution portion of the final slurry may be considered to be the same as the mass fraction of NaOH in the clear liquid solution withdrawn from the unit. If the feed slurry contained equal mass fraction of all components, calculate the mass fraction of NaOH in the clear solution. Don't forget to do the DOF analysis.
Note: The term "solution" here means some mixture of H_2O and NaOH. "Slurry" contains solid $CaCO_3$ and solution.
Hints: Use a basis of 1 lb_m/min of $CaCO_3$ in the exit slurry, which corresponds to 2 lb_m/min of solution in the exit slurry. Also, your diagram should have 2 inlet streams and 2 outlet streams.

Diagram



set basis: 1 lb_m/min of $CaCO_3 = \dot{m}_{CaCO_3,3}$

$\dot{m}_{soln} = 2\ lb_m/min$

$X_{NaOH,3} = ?$

DOF

unknowns = 5 ($\dot{m}_1, \dot{m}_2, \dot{m}_{H_2O,4}, \dot{m}_{NaOH,4}, X_{NaOH,3}$)

balance eqns = 3

extra relations = 2 → $\begin{cases} X'_{NaOH,3} = X_{NaOH,4} \\ \dot{m}_1 = \dot{m}_2 \end{cases}$

DOF = 0

where x' means composition of only the liquid

$CaCO_3$ balance

$\dot{m}_{CaCO_3,1} = \frac{1}{3}\dot{m}_1 = 1\ lb_m/min \Rightarrow \dot{m}_1 = \boxed{3\ lb_m/min}$

($\dot{m}_{CaCO_3,3}$)

extra relation $\dot{m}_2 = \dot{m}_1 = \boxed{3\ lb_m/min}$

Total Mass Balance

$\dot{m}_2 + \dot{m}_1 = \dot{m}_3 + \dot{m}_4$

$3 + 3 = 3 + \dot{m}_4 \Rightarrow \boxed{\dot{m}_4 = 3\ lb_m/min}$

NaOH Balance

$X_{NaOH,1}\dot{m}_1 + X_{NaOH,2}\dot{m}_2 = X'_{NaOH,3}\dot{m}_{3,soln} + X_{NaOH,4}\dot{m}_4$ (equal)

$1\ \frac{lb_m}{min} + .05\left(3\ \frac{lb_m}{min}\right) = X\,(2\ lb_m/min) + X\,(3\ lb_m/min)$

(2 not 3)

$X'_{NaOH,3} = X_{NaOH,4} = \frac{1.15}{5} = 0.23\ \frac{g\ NaOH}{g\ soln}$ (X'_3)

or $\frac{g\ NaOH}{g\ slurry}$ (X_4)