UNIT OPS
CE 474/574 DA-5 Soln. Set Hardness Removal

GIVEN pH 7.3 Alk = 150 mg/L / 50 $\frac{\text{meq/L}}{\text{mg/L}}$ = 3.0 meq/L = $[HCO_3^-]$

(Near pH 7.3)

TH 165 mg/L
FINAL H - 75 mg/L
90 mg/L < 150 mg/L ∴ All hardness can be removed as CO_3 hardness (single stage)

Also TH 165 mg/L
CaH - 150 mg/L
MgH 15 mg/L ← Will not remove Mg-H

Find $[H_2CO_3]$ (CO_2) $\frac{[HCO_3^-][H^+]}{[H_2CO_3]} = 10^{-6.3}$

$$[H_2CO_3] = \frac{(3\times10^{-3})(10^{-7.3})}{10^{-6.3}} = \frac{(3\times10^{-3})(5\times10^{-8})}{(5\times10^{-2})}$$

$= 3\times10^{-4}$ M = 6×10^{-4} eq/L

H_2CO_3 is Diprotic, hence 1 mol = 2 eq.

$[H_2CO_3]$ = 0.6 meq/L

NOTE: I round off using exponential notation on the chem. calcs, so your exact numbers might be a little different

Hardness Removal ΔTH = 90 mg/L / 50 = 1.8 meq/L

LIME DOSE: $[H_2CO_3]$ + [ΔTH] + [Residual $CaCO_3$]
= 0.6 + 1.8 + 0.6 = **3.0 meq/L**

LIME DOSE BY MASS: $\left(\frac{3.0 \text{ meq/L}}{2 \text{ meq/mmol}}\right)\left(74 \frac{\text{mg } Ca(OH)_2}{\text{mmol}}\right)$ = **111 mg/L** LIME

TOTAL DAILY DOSE (111 mg/L)(0.106 MGD)(8.34) = **98 lb/d**

Final Water Composition:

$[Ca^{2+}] = 60\ mg/L / 50 = 1.2\ meq/L = 0.60\ mM$

$[Mg] = 15\ mg/L / 50 = 0.3\ meq/L = 0.15\ mM$

$[CO_3^{2-}] = 0.6\ meq/L = 0.3\ mM$

$[HCO_3^-] = Alk - \Delta TH - Res.CaCO_3 = (3.0 - 1.8 - 0.6)\ meq/L$
$= 0.6\ meq/L$

pH: Calc. from $[HCO_3^-]$ or $[CO_3^{2-}]$

$$\frac{[CO_3^-][H^+]}{[HCO_3^-]} = 10^{-10.3} \Rightarrow [H^+] = \frac{[HCO_3^-]}{[CO_3^{2-}]}\, 10^{-10.3}$$

$$(0.6/0.3)\, 10^{-10.3} = 10^{-10.0}$$

Must use $[CO_3^-]$ in mM NOT meq/L

$pH = \underline{10.0}$

BONUS 1 PT Recarbonate w/ Atmospheric CO_2

$$[H_2CO_3] = P_{CO_2} \cdot K_H = 10^{-3.5} \cdot 10^{-1.5} = 10^{-5.0}\ M$$

Final $[HCO_3^-] \approx$ Pre-CO_2 Alkalinity $= [HCO_3^-]^\circ + 2[CO_3^{2-}]^\circ$
$= (0.6 + 0.6)\ mM$
$= 1.2 \times 10^{-3}\ M$

And $\dfrac{[H^+][HCO_3^-]}{[H_2CO_3]} = 10^{-6.3}$ (actually 4.3×10^{-7} to be more precise $= 10^{-6.35}$ like the text)

$$[H^+] = \frac{[H_2CO_3]}{[HCO_3^-]}\, 10^{-6.3} = \frac{10^{-5.0}}{1.2 \times 10^{-3}} \cdot (4.3 \times 10^{-7}) = 3.5 \times 10^{-9}\ M$$

$pH = 8.4$ ← OK for release to system but might want higher CO_2 dose to bring it under 8