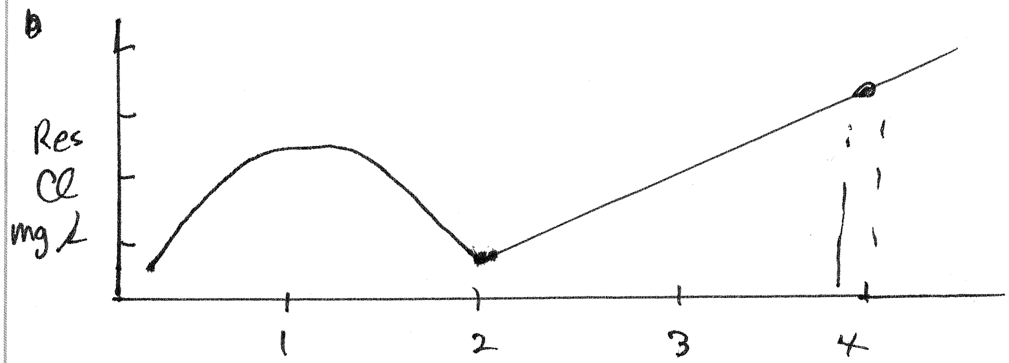

↑ Breakpoint Dose

(1.) ~ **2.0 mg/L** ANS.

(2.) Achieve residual of 2.2 mg/L with about **3.8 - 4.0 mg/L** ANS

(3.) Liquid Cl_2:

Popl'n = 1,011 × $\frac{105\ g}{d \cdot capita}$ = 106,000 gpd = 0.106 Mgd

For 4.0 mg/L dose:

$$[4.0\ mg/L][0.106\ mgd]\left[8.34\ \frac{lb/MG}{mg/L}\right] \cong \boxed{3.5\ \frac{lb}{d}}\ Cl_2$$ ANS

↑ (or any equivalent units conversion)

(4) HTH

$Ca(OCl)_2$ that is "70% active" as Cl_2

$$\left[3.5\ \frac{lb\text{-}Cl_2}{d}\right]\left[\frac{1\ lb\text{-}HTH}{0.70\ lb\text{-}Cl_2}\right] \cong \boxed{5.1\ lb\text{-}HTH/d}$$ ANS.

(5) pK METHOD: From Eq. 16.9 @ 12°C = 285 K

find $pK_a = 7.67$ ($K_a = 10^{-7.67}$)

$$K_a = \frac{[H^+][OCl^-]}{[HOCl]} = 10^{-7.67} \Rightarrow \frac{[OCl^-]}{[HOCl]} = \frac{10^{-7.67}}{10^{-6.0}} = 10^{-1.67}$$

$\frac{OCl^-}{HOCl}$ Ratio is 0.02 (2%) or, about 46-50x more HOCl (98%) than OCl⁻

TABLE 16.1 METHOD: Interpolate for 12°C between 0°C & 20° @ pH 6.0

Find ~ 98% HOCl (similar result as above, ~2% OCl⁻)

(6) Soda Ash needed to keep @ pH 6.0

Cl_2 added: $(4.0 \text{ mg/L})\left(\frac{1 \text{ mmole}}{71 \text{ mg}}\right) = 0.056 \text{ mM } Cl_2$

If you need 1 mole Na_2CO_3 per mole Cl_2 reacted

OVERALL REACTION $[\, Cl_2 + H_2O + Na_2CO_3 = HOCl + HCO_3^- + 2Na^+ \,]$

(Cl_2 : Na_2CO_3 — 1:1 ratio)

∴ Need 0.056 mM or 5.6×10^{-5} mol/L Na_2CO_3

FW: Na_2CO_3 = 2Na (2×23) = 46
C 12 = 12
3×16 = 48
———
106 g/mol

$(5.6 \times 10^{-5} \text{ mol/L})(106 \text{ g/mol}) = 6.0 \times 10^{-3} \text{ g/L} = 6.0 \text{ mg/L}$

Total Usage: $(0.106 \text{ MGD})(6.0 \text{ mg/L})\left(8.34 \frac{\text{lb/MG}}{\text{mg/L}}\right)\left(\frac{1}{0.95}\right) = $ **5.6 lb SODA ASH / day** (ANS)

(0.95 ↑ PURITY)

ANOTHER APPROACH: Use mole ratio on Cl_2 & MW ratio (easier if you see it)

(EASIER) → $\left[3.5 \frac{\text{lb } Cl_2}{d}\right]\left[\frac{106 \text{ lb-}Na_2CO_3}{71 \text{ lb-}Cl_2}\right]\left[\frac{1}{0.95}\right] = $ **5.5 lb SODA ASH / d**

Cl_2 DOSAGE; ↑ Mol. wt. ratio; (same to round-off error)

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(7) Added HTH ($Ca(OCl)_2$) to achieve same [HOCl + OCl⁻] as if you had added 4 mg/L Cl_2. At pH 6 ~all Cl as HOCl (Ans (5))

1 mole Cl_2 → 1 mole HOCl

$\frac{4 \text{ mg/L } Cl_2}{71 \text{ mg-}Cl_2\text{/mmol}} = 0.056 \text{ mmol/L} = [HOCl]$ (if from Cl_2)

∴ w/ HTH you added $[OCl^-] = 0.056$ M but rxn occurs:

$OCl^- + H^+ = HOCl$ (~complete at pH 6)
(0.056 M) (0.056 M)

↳ NEED $[H^+] = [HCl] = 0.056 \frac{\text{mol}}{L}$

(cont'd)

$HCl_{TOT} = 0.056\ mmol/L$ FW HCl = 36.5

"Muriatic Acid" dose = $(0.056\ mmol/L)(36.5\ \frac{mg}{mmol})(\frac{1}{0.37}) = \boxed{5.6\ \frac{mg}{L}}$

PURITY

DAILY DOSE USE: $(5.6\ \frac{mg\ Mur\text{-}acid}{L})(0.106\ MGD)(8.34\ \frac{lbs/MG}{mg/L}) = 4.9\ \frac{lbs}{d}$ (~5 lbs/d)

OR Mole ratio method: $(3.5\ \frac{lb\text{-}Cl_2}{d})(\frac{36.5\ lb\ HCl}{71\ lb\ Cl_2})(\frac{1}{0.37}) = $ → ~SAME

MUR. ACID USE (by WEIGHT)

To convert to gal/d

need density of water = 8.34 lb/gal

sp. grav. of acid = 1.18 lb-acid/lb H_2O

ANS (7) → $(4.9\ \frac{lb\text{-}acid}{d})(\frac{1\ lb\ H_2O}{1.18\ lb\text{-}acid})(\frac{1\ gal}{8.34\ lb\text{-}H_2O}) = \boxed{0.50\ \frac{gal}{d}}$

MURIATIC ACID USE gallons

ANS

(8.) Interpolate 87 & 58 C·t

Find $\boxed{C\cdot t = 76\ @\ 12°C}$

$C = 2.0\ mg/L \quad \therefore\ t_d = \frac{76}{2} = \boxed{38\ min}$

Assume PLUG FLOW $t_d = t = 38\ min$

$V = Qt = (106{,}000\ \frac{gal}{d})(38\ min)(\frac{1\ d}{1440\ min})$

$V = (\boxed{2{,}800\ gal})(\frac{1\ ft^3}{7.48\ gal})$

$\boxed{V = 374\ ft^3}$ ANS (Can give answer as either gallons or in ft^3.)

(9) Yes because C·t for 4-log reduction for viruses is only 5.2, so we way exceed.

Cont'd

(10) Chemical Costs

YOU CAN ROUND OFF ⇩ COSTS

Cl_2: $(3.5\ lb/d)(\$150/tank)\left(\frac{1\ tank}{100\ lb}\right) = \$5.25/d$

HTH: $(5.1\ lb/d)(\$170/drum)\left(\frac{1\ drum}{50\ lb}\right) = \$17.30/d$

Na_2CO_3: $(5.5\ lb/d)(\$11/sack)(1\ sack/50\ lb) = \$1.20/d$

HCl (Mur. Acid): $(0.50\ gal/d)(\$58/drum)\left(\frac{1\ drum}{55\ gal}\right) = \$0.50/d$

SO TOTALS: $Cl_2 + Na_2CO_3 \cong \$6.45/d$

$HTH + HCl \cong \$17.80/d$

Obviously Cl_2 + soda ash is much cheaper but even HTH is quite cheap for a small city like Drain, so safety & convenience would dictate using HTH