Solutions Manual
to accompany

Water and Wastewater Technology
Seventh Edition

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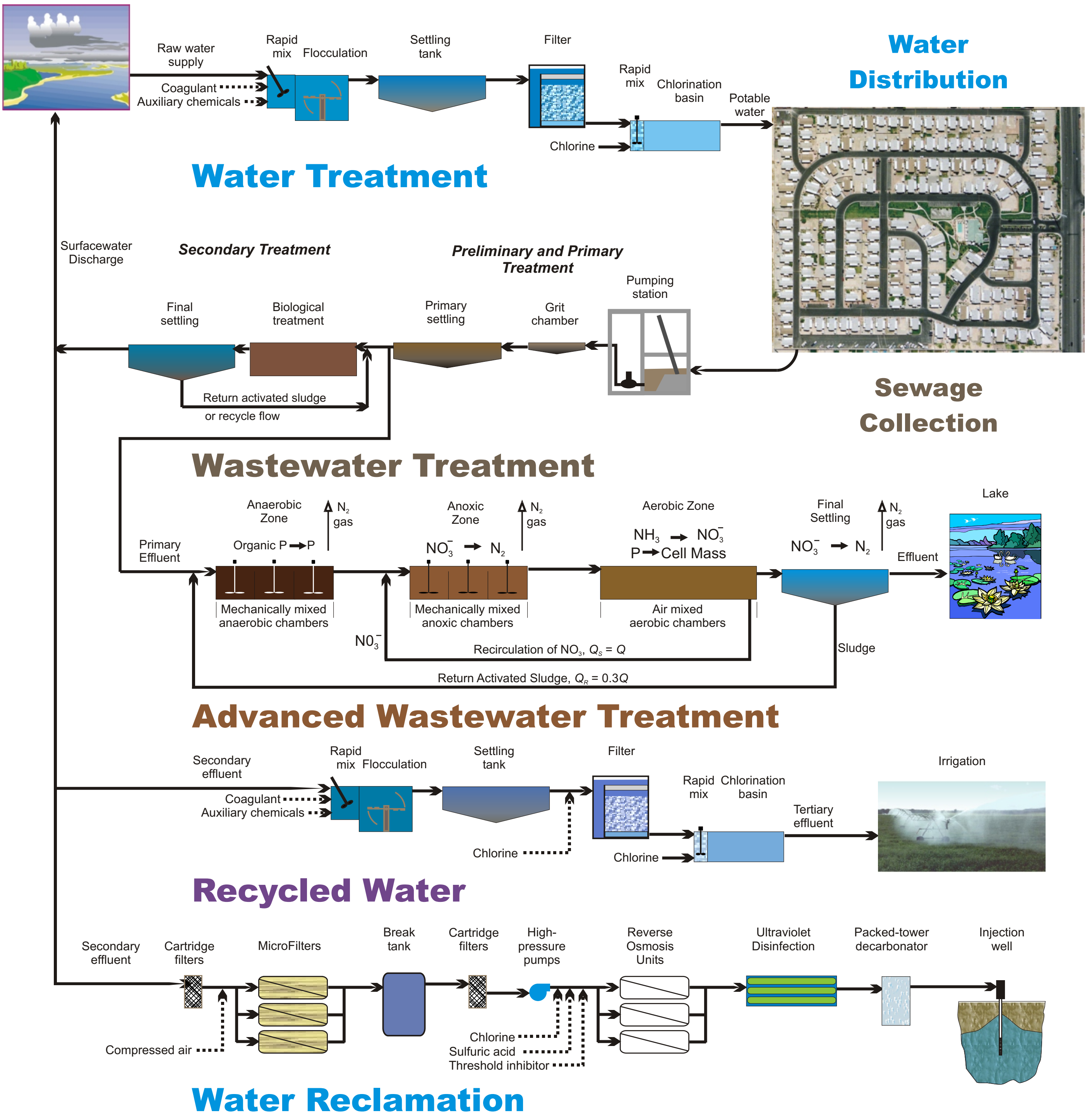

This solutions manual has been prepared by the authors for classroom use by instructors teaching from *Water and Wastewater Technology, Seventh Edition.* Textbook problems are an effective method of measuring student's understanding and performance; therefore, the safekeeping of solutions is important to all instructors. Under no circumstance should any solution in this manual be reproduced and distributed or otherwise released in any form for student use. Obviously, solutions must be presented in a classroom by writing calculations on the classroom board or by projecting calculations using a projector. Your cooperation in maintaining the integrity of the homework solutions is appreciated.

The inside book cover is intended as a reference and as a teaching aid to the overall treatment processes.

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2-1 CHEMISTRY

2-1

(a) $Al_2(SO_4)_3 \cdot 14.3\ H_2O = 2Al + 3S + 12O + 14.3\ (2H + O)$

$MW = 2 \cdot 27.0 + 3 \cdot 32.1 + 12 \cdot 16.0 + 14.3\ (2 \cdot 1.0 + 16.0) = 600$

$EW = 600/6 = 100$

(b) lime = CaO

$MW = 40.1 + 16.0 = 56.1$

$EW = 56.1/2 = 28.0$

(c) $FeSO_4 \cdot 7H_2O = Fe + S + 11O + 14H$

$MW = 55.8 + 32.1 + 11 \cdot 16.0 + 14 \cdot 1.0 = 278$

$EW = 278/2 = 139$

(d) flousilicic acid = $H_2SiF_6 = 2H + Si + 6F$

$MW = 2 \cdot 1.0 + 28.1 + 6 \cdot 19.0 = 144$

EW is not applicable since F^- is released in solution.

(e) soda ash = $Na_2CO_3 = 2Na + C + 3O$

$MW = 2 \cdot 23.0 + 12.0 + 3 \cdot 16.0 = 106$

$EW = 106/2 = 53$

2-2. (a) $NaNO_3 = Na^+ + NO_3^-$

(b) $H_2SO_4 = 2H^+ + SO_4^=$

(c) $Ca(OCl)_2 = Ca^{++} + 2OCl^-$

(d) $Na_2CO_3 = 2Na^+ + CO_3^=$ (below pH 8.3, HCO_3^-, Equation 2-7)

2-3. $$\text{F concentration} = 1.0\frac{(6 \cdot 19.0)}{144} = 0.79 \quad \text{mg/l}$$

2-4. $$\text{Hardness} = 29.0\frac{50}{20} + 16.4\frac{50}{12.2} = 140\ \text{mg/l}$$

2-5. $$Ca^{++} = 20\frac{175}{50} = 70\ \text{mg/l}$$

$$Mg^{++} = 12.2\frac{40}{50} = 9.8\ \text{mg/l}$$

2-6. $$\text{Alkalinity} = 12\frac{50}{30.0} + 100\frac{50}{61.0} = 102 \quad \text{mg/l}$$

2-7. $$\text{Alkalinity} = 20\frac{50}{30} + 34\frac{50}{61} = 61.2\ \text{mg/l}$$

2-8. Calcium = 94/20.0 = 4.70 meq/l

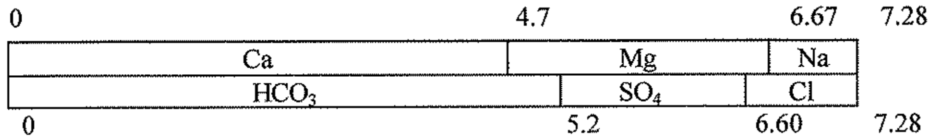
Magnesium = 24/12.2 = 1.97

Sodium = 14/23.0 = 0.61

Bicarbonate = 317/61.0 = 5.20

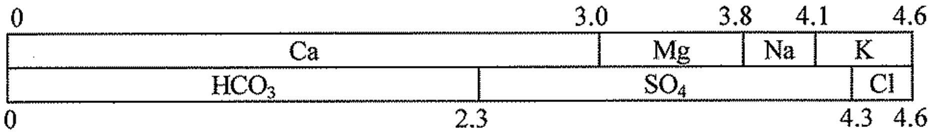
Sulfate = 67/48.0 = 1.40

Chloride = 24/35.5 = 0.68

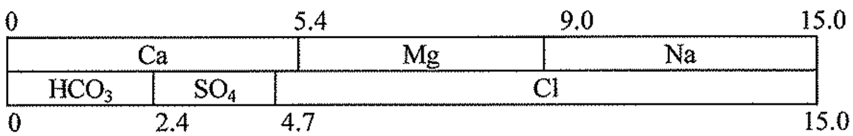


2-9.

Component	mg/l	EW	meq/l
Ca	60	20.0	3.0
Mg	10	12.2	0.8
Na	7	23.0	0.3
K	20	39.1	0.5
HCO_3(Alk)	115	50.0	2.3
SO_4	96	48.0	2.0
Cl	11	35.5	0.3



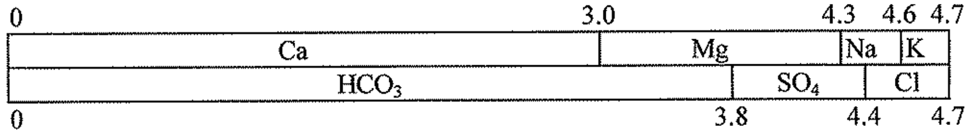
2-10. Calcium = 108/20.0 = 5.40 meq/l
Magnesium = 44/12.2 = 3.61
Sodium = 138/23.0 = 6.00
Bicarbonate = 146/61.0 = 2.39
Sulfate = 110/48.0 = 2.29
Chloride = 366/35.5 = 10.31



Carbonate hardness = 2.4 • 50 = 120 mg/l
Noncarbonate hardness = (5.4 - 2.4)50 = 150 mg/l
Total hardness = 9.0 • 50 = 450 mg/l
Alkalinity = 2.4 • 50 = 120 mg/l

2-11.

Component	Mg/l	EW	meq/l
Ca hardness	150	50.0	3.0
Mg hardness	65	50.0	1.3
Na	8	23.0	0.3
K	4	39.1	0.1
Alkalinity	190	50.0	3.8
SO_4	29	48.0	0.6
Cl	10	35.5	0.3



Hypothetical combinations: 3.0 $Ca(HCO_3)_2$; 0.8 $Mg(HCO_3)_2$; 0.5 $MgSO_4$; 0.1 Na_2SO_4; 0.2 NaCl; 0.1 KCl

2-12. $H_2SO_4 + 2CaCO_3 = Ca(HCO_3)_2 + CaSO_4$

$$\frac{X}{98.1} = \frac{20\ \text{mg/l}}{2 \times 100} \qquad X = 9.8\ \text{mg/l of } H_2SO_4$$

2-13. 2-13. $$\frac{\text{Wt. of acid / l}}{\text{MW} \cdot 1000} = \frac{10\ \text{mg / l}}{98{,}100\ \text{mg / mole}} = 0.000{,}101{,}9\ \text{mole / l } H^+$$

$$\text{pH} = \log\left[\frac{1}{0.000{,}101{,}9}\right] = 4.0$$

2-14. (a) $$\frac{\text{Wt. of acid/l}}{\text{MW} \cdot 1000} = \frac{3.0\text{mg/l}}{98{,}100\text{mg/mole}} = 0.000{,}030{,}6\text{mole/l } H^+$$

$$\text{pH} = \log\left[\frac{1}{0.000{,}030{,}6}\right] = 4.5$$

(b) $\frac{1.0}{98{,}100} = 0.000{,}010{,}2$ mole/l H^+, pH = 5.0

2-15. $CO_2 + Ca(OH)_2 = CaCO_3 + H_2O$ [Eq. 7-19]

$$\frac{X}{44.0} = \frac{35}{74.1} = \frac{Y}{100} \qquad X = 20.8\ \text{mg/l},\ Y = 47.2\ \text{mg/l}$$

2-16. $CaCO_3 + CO_2 + H_2O = Ca(HCO_3)_2$ [Eq. 7-23]

$$\frac{47.2}{100} = \frac{X}{44.0}$$

X = 20.8 mg/l

2-17. $Ca(OH)_2 + Ca(HCO_3)_2 = 2CaCO_3\downarrow + 2H_2O$

Since one equivalent of lime (CaO) reacts with one equivalent of calcium hardness, the calculation for this problem is easily performed using equivalent weights.

$$\frac{CaO}{CaCO_3} = \frac{28.0}{50} = \frac{X}{100} \qquad X = 56 \text{ mg/l}$$

2-18. $3Mn_2^{+} + 2Mn_7 + O_4^{-} = 5Mn_4 + O_2\downarrow$

$2MnO_4^{-}$ is in solution from dissolution of $KMnO_4$

$3Mn^{2+}$ gains $3 \bullet 2e = 6e$

$2Mn^{7+}$ loses $2 \bullet 3e = 6e$

$$\frac{3Mn}{2KMnO_2} = \frac{3\bullet 54.9}{2\bullet 15.8} = \frac{X}{1.0} \qquad X = 0.52 \text{ mg/l as Mn}$$

2-19. $CaO + 2CO_2 + H_2O = Ca(HCO_3)_2$

$$\frac{A}{56.1} = \frac{B}{88.0} = \frac{45 \text{ mg/l}}{40.1} \qquad A = 63 \text{ mg/l CaO} \qquad B = 99 \text{ mg/}CO_2$$

2-20. (a) The rate of a zero-order reaction depends only on time since it is independent of the concentration of any reactant or product.
(b) The rate of a first-order reaction proceeds at a rate directly proportional to the remaining concentration of one reactant.

2-21. The value of θ in Equation 2-26 is 1.072 if the rate of a reaction doubles for a 10°C temperature increase, therefore, the increase from a 5°C increase is:

$$k_2/k_1 = (1.072)^5 = 1.42$$

2-22 Using Table 2-5,
DO saturation at 15°C at sea level = 10.1 mg/l
At an elevation of 2000 ft, DO saturation = 9.5, more accurately 9.3 mg/l

2-23 DO saturation at 22°C at sea level = 8.7 mg/l
At an elevation of 4000 ft, 7.5