

MWH'S WATER TREATMENT PRINCIPLES AND DESIGN

3rd Edition

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HOMEWORK SOLUTION MANUAL

FOR

Chapter 2

Physical and Chemical Quality of Water

Note: If any errors are noted in this solution manual or in the textbook, please notify Kerry Howe at howe@unm.edu
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PROBLEM 2-1

Problem Statement - Given the following test results, determine the mole fraction of calcium (Ca^{2+}).

Cation	Concentration, mg/L	Anion	Concentration, mg/L
Ca^{2+}	40.0	HCO_3^-	91.5
Mg^{2+}	12.2	SO_4^{2-}	72
Na^+	15.1	Cl^-	22.9
K^+	5.1	NO_3^-	5.0

Solution

- By definition, using Eq. 2-2, the mole fraction of Ca^{2+} is as follows.

$$X_{\text{Ca}^{2+}} = \frac{n_{\text{Ca}^{2+}}}{n_{\text{Ca}^{2+}} + n_{\text{Mg}^{2+}} + n_{\text{Na}^+} + n_{\text{K}^+} + n_{\text{HCO}_3^-} + n_{\text{SO}_4^{2-}} + n_{\text{Cl}^-} + n_{\text{NO}_3^-}}$$

- Substituting in the MW for each of the constituents yields the following:

$$\begin{aligned} X_{\text{Ca}^{2+}} &= \frac{40.08}{40.08 + 24.31 + 22.99 + 39.1 + 61 + 96 + 35.45 + 62} \\ &= \frac{40.08}{380.93} = 0.11 \end{aligned}$$

PROBLEM 2-2

Problem Statement - Determine the mole fraction of magnesium (Mg^{2+}) for the water given in Problem 2-1.

Solution

- By definition, using Eq. 2-2, the mole fraction of Mg^{2+} is as follows.

$$X_{\text{Mg}^{2+}} = \frac{n_{\text{Mg}^{2+}}}{n_{\text{Ca}^{2+}} + n_{\text{Mg}^{2+}} + n_{\text{Na}^+} + n_{\text{K}^+} + n_{\text{HCO}_3^-} + n_{\text{SO}_4^{2-}} + n_{\text{Cl}^-} + n_{\text{NO}_3^-}}$$

- Substituting in the MW for each of the constituents yields the following:

$$\begin{aligned}
 x_{\text{Mg}^{2+}} &= \frac{24.31}{40.08 + 24.31 + 22.99 + 39.1 + 61 + 96 + 35.45 + 62} \\
 &= \frac{24.31}{380.93} = 0.06
 \end{aligned}$$

PROBLEM 2-3

Problem Statement - Determine the mole fraction of sulfate (SO_4^{2-}) for the water given in Problem 2-1.

Solution

- By definition, using Eq. 2-2, the mole fraction of SO_4^{2-} is as follows:

$$x_{\text{SO}_4^{2-}} = \frac{n_{\text{SO}_4^{2-}}}{n_{\text{Ca}^{2+}} + n_{\text{Mg}^{2+}} + n_{\text{Na}^+} + n_{\text{K}^+} + n_{\text{HCO}_3^-} + n_{\text{Cl}^-} + n_{\text{NO}_3^-}}$$

- Substituting in the MW for each of the constituents yields the following:

$$\begin{aligned}
 x_{\text{SO}_4^{2-}} &= \frac{96}{40.08 + 24.31 + 22.99 + 39.1 + 61 + 96 + 35.45 + 62} \\
 &= \frac{96}{280.93} = 0.25
 \end{aligned}$$

PROBLEM 2-4

Problem Statement - Commercial-grade sulfuric acid is about 95 percent H_2SO_4 by mass. If the specific gravity is 1.85, determine the molarity, mole fraction, and normality of the sulfuric acid. Use Eq. 2-4 to determine molarity.

$$M, \text{ mole/L} = \frac{\text{mass of solute, g}}{(\text{molecular weight of solute, g/mole})(\text{volume of solution, L})}$$

$$M, \text{ mole/L} = \frac{(0.95)(1.85)}{(98)(1)} = 0.0179 \text{ mole/L}$$

- Use Eq. 2-2 to determine the mole fraction.

$$x_{\text{H}_2\text{SO}_4} = \frac{n_{\text{H}_2\text{SO}_4}}{n_{\text{H}_2\text{O}} + n_{\text{H}_2\text{SO}_4}}$$

$$= \frac{98}{18 + 98} = 0.84$$

2. Use Eq. 2-6 to determine the normality.

$$N, \text{ eq/L} = \frac{\text{mass of solute, g}}{(\text{equivalent weight of solute, g/eq})(\text{volume of solution, L})}$$

$$N, \text{ eq/L} = \frac{(0.95)(1.85)}{(49)(1)} = 0.036 \text{ eq/L}$$

PROBLEM 2-5

Problem Statement - If the UV intensity measured at the surface of a water sample is 180 mW/cm^2 , estimate the average intensity in a petri dish with an average depth of 15 mm (used to study the inactivation of microorganisms after exposure to UV light, as discussed in Chap. 13). Assume the absorptivity of the water, $k_A(\lambda)$ at $\lambda = 254 \text{ nm}$, is 0.10 cm^{-1} and that the following form of the Beer–Lambert law applies:

$$\ln \left(\frac{I}{I_0} \right) = -2.303 k_A(\lambda) x$$

Solution

1. The variables for the Beer-Lambert law are the following:

I = unknown

$I_0 = 180 \text{ mJ/cm}^2$

$k_A(\lambda) = 0.10/\text{cm}$

$x = 1.5 \text{ cm}$

2. Rearrange the Beer-Lambert law given in the problem statement to solve for I as follows:

$$I = I_0 e^{-2.303 k_A(\lambda) x}$$

$$I = 180 e^{-2.303(0.10)(1.5)}$$

$$I = 174 \text{ mJ/cm}^2$$

PROBLEM 2-6

Problem Statement - If the average UV intensity in a Petri dish containing water at a depth of 10 mm is 120 mW/cm^2 , what is the UV intensity at the surface of the water sample? Assume the absorptivity of the water, $k_A(\lambda)$ at $\lambda = 254 \text{ nm}$, is 0.125 cm^{-1} and that the equation given in Problem 2-5 applies.

Solution

1. The variables for the Beer-Lambert law are the following:

$$I = 120 \text{ mJ/cm}^2$$

$$I_0 = \text{unknown}$$

$$k_A(\lambda) = 0.125/\text{cm}$$

$$x = 1.0 \text{ cm}$$

2. Rearrange the Beer-Lambert law given in the problem statement to solve for I_0 as follows:

$$I_0 = \frac{I}{e^{-2.303k_A(x)}}$$

$$I_0 = \frac{120}{e^{-2.303(0.125)(1.0)}} = 160 \text{ mJ/cm}^2$$

PROBLEM 2-7

Problem Statement - If the transmittance is 92 percent and a photo cell with a 12-mm path length was used, what is the absorptivity?

Solution

1. Set up Eq. 2-12 to solve for T in terms of the variables which are given in the problem statement; $-k_A(\lambda)$, and x .

- a. From Eq. 2-10, $-A(\lambda)$

- b. $T, \% = 10^{-k_A(\lambda)x} \times 100$

- c. Variables for this equation are the following:

$$T, \% = 92$$

$$-k_A(\lambda) = \text{unknown}$$

$$x = 1.2 \text{ cm}$$

2. Rearrange Eq. 2-12 to solve for absorptivity, $k_A(\lambda)$, as follows:

$$\begin{aligned} -k_A(\lambda) \left(\frac{1}{x} \right) &= \frac{\log\left(\frac{T}{100}\right)}{x} \\ &= \frac{\log\left(\frac{92}{100}\right)}{1.2} = -0.030 \\ k_A(\lambda) &= 0.030 \text{ cm}^{-1} \end{aligned}$$

PROBLEM 2-8

Problem Statement - Given the following data obtained on two water supply sources, determine the constants in Eq. 2-16 and estimate the number of particles in the size range between 2.1 and 5. Also, comment on the nature of the particle size distributions.

Bin Size, mm	Particle Count	
	Water A	Water B
5.1–10	2500	110
10.1–15	850	80
15.1–20	500	55
20.1–30	250	36
30.1–40	80	25
40.1–50	60	20
50.1–75	28	15
75.1–100	10	10

Solution

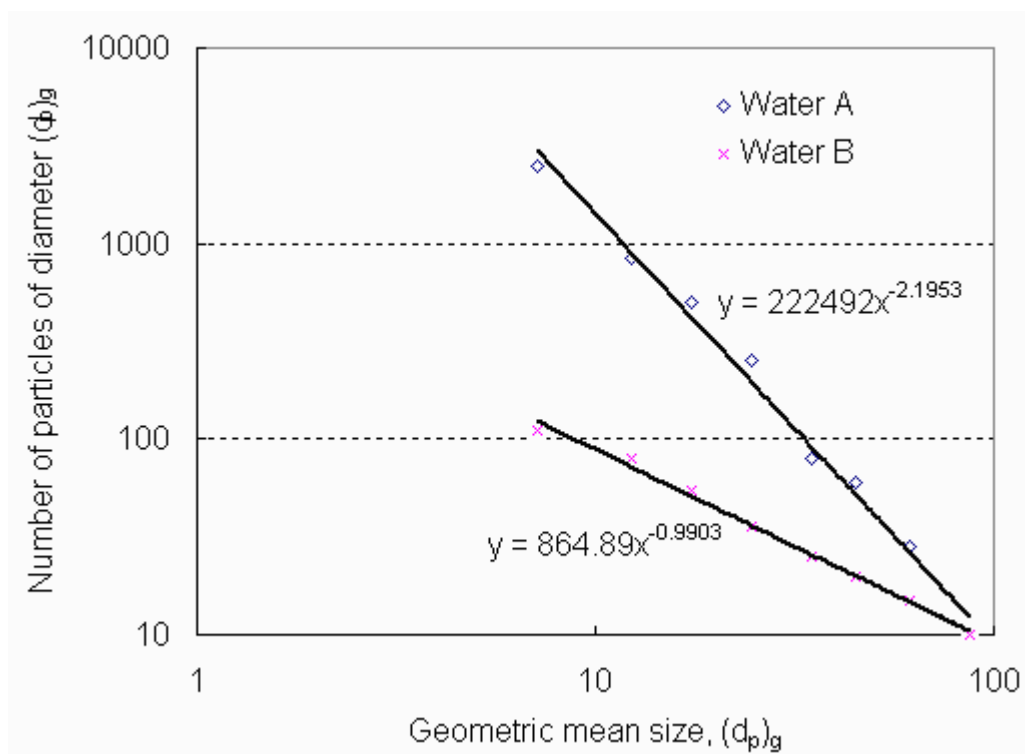
1. Calculate the information necessary to graphically represent the data. This information is shown in the following table.

Bin size, mm	Geometric mean diameter, $(d_p)_g$	Water A particle number	Water B particle number
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5.1 – 10	7.14 ^a	2500	110
10.1 -15	12.31	850	80
15.1 – 20	17.38	500	55
20.1 - 30	24.56	250	36
30.1 - 40	34.70	80	25
40.1 - 50	44.78	60	20
50.1 - 75	61.30	28	15
75.1 – 100	86.66	10	10

a $7.14 = \sqrt{5.1 \times 10}$

- Prepare a plot of the geometric mean diameter for the bin size, $(d_p)_g$, versus the number of particles in the corresponding bin size.



- Determine A and β using Eq. 9-4 and the data plot from step 2.

The value of A is determined when $d_p = 1 \mu\text{m}$ for the best-fit regression line through the data, along with β , which is the power law slope coefficient.

a. Water A

The equation for the data regression line is shown on the graph in step 2, and the values for A and β are:

$$A = 222492 \text{ and } \beta = 2.1953$$

b. Water B

The equation for the data regression line is shown on the graph in step 2, and the values for A and β are:

$$A = 864.89 \text{ and } \beta = 0.9903$$

4. Estimate the number of particles in the size range between 2.1 and 5.

a. Calculate the geometric mean size.

$$\sqrt{2.1 \times 5} = 3.24$$

b. Estimate the number of particles in water A using the equation for the data regression line determined in step 2.

$$n(3.24) = 222492 \times 3.24^{-2.1953} = 16,842$$

c. Estimate the number of particles in water B using the equation for the data regression line determined in step 2.

$$n(3.24) = 864.89 \times 3.24^{-0.9903} = 270$$

5. Comment on the nature of the particle size distributions.

Parameter A is much greater for water A than for water B. As the value of A increases, the total number of particles in each size classification increases, thus, the total number of particles in water A in each size classification is greater than in water B.

The slope β is a measure of the relative number of particles in each size range. Thus, if β is less than one, the particle size distribution is dominated by large particles, if β is equal to one all particle sizes are represented equally, and if β is greater than one the particle size distribution is dominated by small particles. The particle size distribution is dominated by small particles for water A because β (2.1953) is greater than one. All particle sizes are represented nearly equally for water B because β (0.9903) is close to one.

PROBLEM 2-9

Problem Statement - The following particle size data were data obtained for the influent and effluent from a granular medium filter. Determine the constants in Eq. 2-16 and assess the effect of the filter in removing particles.

Bin Size, mm	Particle Count	
	Influent	Effluent
2.51–5	20000	101
5.1–10	8000	32
10.1–20	2000	6
20.1–40	800	3.2
40.1–80	400	1.2
80.1–160	85	0.34
160.1–320	40	0.12

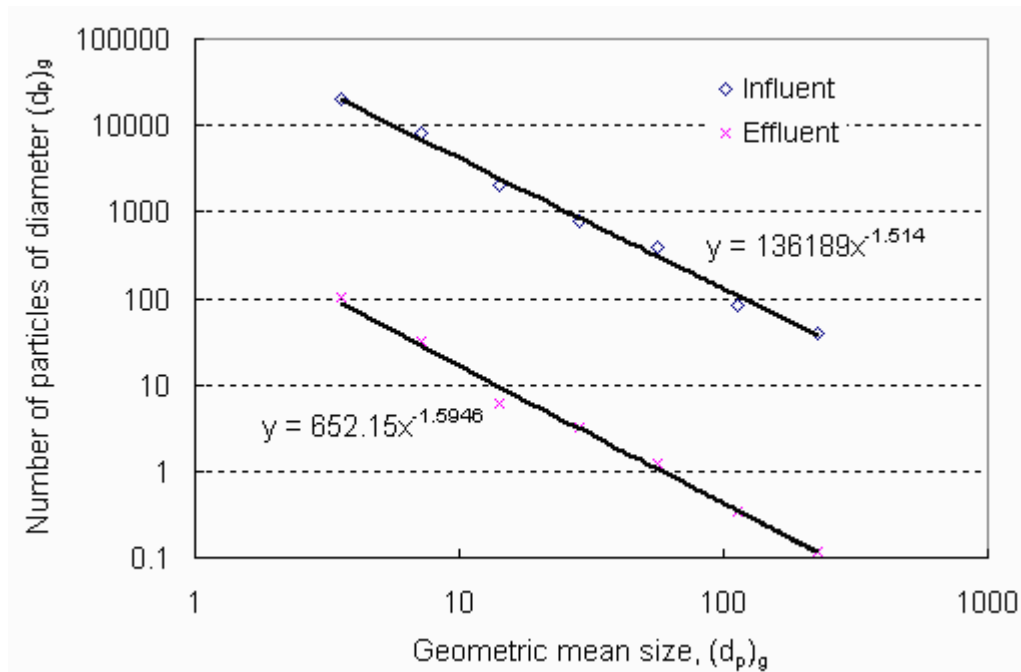
Solution

1. Calculate the information necessary to graphically represent the data. This information is shown in the following table.

Bin size, mm	Geometric mean diameter, $(d_p)_g$	Influent particle number	Effluent particle number
2.51 - 5	3.54 ^a	20000	101
5.1 – 10	7.14	8000	32
10.1 – 20	14.21	2000	6
20.1 - 40	28.35	800	3.2
40.1 – 80	56.64	400	1.2
80.1 - 160	113.21	85	0.34
160.1 - 320	226.34	40	0.12

^a $3.54 = \sqrt{2.51 \times 5}$

2. Prepare a plot of the geometric mean diameter for the bin size, $(d_p)_g$, versus the number of particles in the corresponding bin size.



3. Determine A and β :

a. Influent

The equation for the data regression line is shown on the graph in step 2, and the values for A and β are:

$$A = 136189 \text{ and } \beta = 1.514$$

b. Effluent

The equation for the data regression line is shown on the graph in step 2, and the values for A and β are:

$$A = 652.15 \text{ and } \beta = 1.595$$

4. Assess the effect of the filter in removing particles.

a. Parameter A is much greater for the influent than it is for the effluent.

Therefore, the effluent contains fewer particles than the influent, meaning the filter successfully removed many particles.

b. Both the influent and the effluent are dominated by small particles because β (1.514 for influent and 1.595 for effluent) is greater than one. The filter is effective in removing all sizes of particles because β for the effluent is close to the value for the influent.

PROBLEM 2-10

Problem Statement - Determine the alkalinity and hardness in milligrams per liter as CaCO_3 for the water sample in Problem 2-1.

Solution

1. Determine alkalinity.

a. Use Eq. 2-26 and determine the alkalinity in milliequivalents per liter.

$$\text{Alk, meq/L} = (\text{HCO}_3^-) + (\text{CO}_3^{2-}) + (\text{OH}^-) - (\text{H}^+)$$

Alkalinity ions	Conc., mg/L	mg/meq ^a	meq/L
HCO_3^-	91.5	61.02	1.50

^a Molecular weight/Z (see Eq. 2-7)

b. Adding the conversion from meq/L to mg/L as CaCO_3 (see page xxx of the text) with Eq. 2-26 yields the following:

$$\begin{aligned} \text{Alkalinity as } \text{CaCO}_3 &= \text{meq/L of substance} \times \text{meq/L mass of } \text{CaCO}_3, 50 \text{ mg/meq} \\ \text{Alk} &= (1.50)(50) = 75 \text{ mg/L as } \text{CaCO}_3 \end{aligned}$$

2. Determine hardness.

a. Use Eq. 2-23 and determine the hardness in milliequivalents per liter.

$$\text{Hardness, meq/l} = (\text{Ca}^{+2}) + (\text{Mg}^{+2})$$

Hardness ions	Conc., mg/L	mg/meq ^a	meq/L
Ca^{2+}	40	20.04 ^b	2.00
Mg^{2+}	12.2	12.15	1.00
Σ hardness ions			3.00

^a Molecular weight/Z (see Eq. 2-8)

b. Adding the conversion from meq/L to mg/L as CaCO_3 (see page xxx of the text) with Eq. 2-23 yields the following:

$$\begin{aligned} \text{Hardness as } \text{CaCO}_3 &= \text{meq/L of substance} \times \text{meq/L mass of } \text{CaCO}_3, 50 \text{ mg/meq} \\ \text{Hardness} &= (3)(50) = 150 \text{ mg/L as } \text{CaCO}_3 \end{aligned}$$

PROBLEM 2-11

Problem Statement - Given the following incomplete water analysis, determine the unknown values if the alkalinity and noncarbonate hardness are 50 and 150 mg/L as CaCO_3 , respectively:

Ion	Concentration, mg/L
Ca^{2+}	42.0
Mg^{2+}	?
Na^+	?
K^+	29.5
HCO_3^-	?
SO_4^{2-}	96.0
Cl^-	35.5
NO_3^-	4.0

Solution

1. Determine the concentration of HCO_3^- using Eq. 2-26.

$$\text{Alk, meq/L} = (\text{HCO}_3^-) + (\text{CO}_3^{2-}) + (\text{OH}^-) - (\text{H}^+)$$

- a. Convert alkalinity from mg/L as CaCO_3 to meq/L.

mg/L alkalinity as CaCO_3 :

= meq/L of alkalinity ions x meq/L mass of CaCO_3 , 50 mg/meq

$$\text{meq/L of alkalinity ions} = \frac{\text{mg/L alkalinity as CaCO}_3}{\text{meq/L mass of CaCO}_3}$$

$$\text{meq/L of alkalinity ions} = \frac{50 \text{ mg/L}}{50 \text{ mg/meq}} = 1 \text{ meq/L}$$

- b. Use Eq. 2-26 to determine the alkalinity ions that are present in the water analysis. The only alkalinity ion listed in the water analysis is HCO_3^- , which is unknown.
- c. Convert the concentration of HCO_3^- in meq/L to mg/L as follows:

Alkalinity ions	Conc., mg/L	mg/meq ^a	meq/L
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HCO ₃ ⁻	61.02	61.02	1.00
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^a Molecular weight/Z (see Eq. 2-7)

2. Determine the value of Mg²⁺ using Eq. 2-23. (Non-carbonate hardness is the concentration of Ca²⁺ and Mg²⁺ associated with nonalkalinity anions such as Cl⁻ and SO₄²⁻. In this problem, 1.0 meq/L of Ca²⁺ are associated with HCO₃⁻ an alkalinity anion. The remaining concentration of Ca²⁺, 1.1 meq/L and all of the Mg²⁺ are associated with SO₄²⁻ and Cl⁻, both nonalkalinity anions.)

- a. Convert hardness from mg/L as CaCO₃ to meq/L.

$$\begin{array}{l} \text{mg/L hardness} \\ \text{as CaCO}_3 \end{array} = \text{meq/L of hardness ions} \times \text{meq/L mass of CaCO}_3, 50 \text{ mg/meq}$$

$$\text{meq/L of hardness ions} = \frac{\text{mg/L hardness as CaCO}_3}{\text{meq/L mass of CaCO}_3}$$

$$\text{meq/L of hardness ions} = \frac{150 \text{ mg/L}}{50 \text{ mg/meq}} = 3 \text{ meq/L}$$

- b. Use Eq. 2-23 and determine the hardness ions that are present in the water analysis.

$$\text{Hardness, meq/l} = (\text{Ca}^{2+}) + (\text{Mg}^{2+})$$

The ions listed in the water analysis are Ca²⁺ and Mg²⁺; the concentration of Mg²⁺ unknown.

- c. Determine the concentration of Mg²⁺ and convert the concentration of Mg²⁺ in meq/L to mg/L as follows:

Hardness ions	Conc., mg/L	mg/meq ^a	meq/L
Ca ²⁺	42.0	20.04 ^b	2.1
Mg ²⁺	10.94	12.15	0.9
Σ hardness ions			3.0

^a Molecular weight/Z (see Eq. 2-8)

3. Determine the concentration of Na⁺ from an anion, cation balance.

- a. Prepare a cation-anion balance.

Cation	Conc., mg/L	mg/meq ^a	meq/L	Anion	Conc., mg/L	mg/meq ^a	meq/L
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Ca ²⁺	42.0	20.04 ^b	2.1	HCO ₃ ⁻	61.02	61.02	1.00
Mg ²⁺	10.94	12.15	0.9	SO ₄ ²⁻	96.0	48.03	2.00
Na ⁺		23		Cl ⁻	35.5	35.45	1.00
K ⁺	29.5	39.1	0.75	NO ₃ ⁻	4.0	62.01	0.06
Σ cations			3.75	Σ anions			4.06

^a Molecular weight/Z (see Eq. 2-7)

^b For calcium, equivalent weight = 40.08/2 = 20.04 g/eq or 20.04 mg/meq

- b. Calculate the concentration of Na⁺ from the difference between the sum of the cations and the sum of the anions.

$$\text{Na}^+ \text{ meq/L} = \sum \text{anions} - \sum \text{cations}$$

$$\text{Na}^+ \text{ meq/L} = 4.06 - 3.75 = 0.31$$

$$\text{Na}^+ \text{ mg/L} = \text{Na}^+ \text{ mg/meq} \times \text{Na}^+ \text{ meq/L}$$

$$\text{Na}^+ \text{ mg/L} = (23)(0.31) = 7.13 \text{ mg/L}$$

PROBLEM 2-12

Instructors Note: See Chap. 19 for a more thorough discussion of hardness, where total, carbonate, and non-carbonate hardness are explained.

Problem Statement - Given the following incomplete water analysis measured at 25°C, determine the unknown values if the alkalinity and noncarbonate hardness are 40 and 180 mg/L as CaCO₃:

Ion	Concentration, mg/L
Ca ²⁺	55.0
Mg ²⁺	?
Na ⁺	23.0
K ⁺	?
HCO ₃ ⁻	?
SO ₄ ²⁻	48.0
Cl ⁻	?
CO ₂	4.0

Solution

1. Determine the concentration of HCO_3^- using Eq. 2-26.

- a. Convert alkalinity from mg/L as CaCO_3 to meq/L.

$$\begin{array}{l} \text{mg/L alkalinity} \\ \text{as } \text{CaCO}_3 \end{array} = \text{meq/L of alkalinity ions} \times \text{meq/L mass of } \text{CaCO}_3, 50 \text{ mg/meq}$$

$$\text{meq/L of alkalinity ions} = \frac{\text{mg/L alkalinity as } \text{CaCO}_3}{\text{meq/L mass of } \text{CaCO}_3}$$

$$\text{meq/L of alkalinity ions} = \frac{40 \text{ mg/L}}{50 \text{ mg/meq}} = 0.8 \text{ meq/L}$$

- b. Use Eq. 2-26 and determine the alkalinity ions that are present in the water analysis.

$$\text{Alk, meq/L} = (\text{HCO}_3^-) + (\text{CO}_3^{2-}) + (\text{OH}^-) - (\text{H}^+)$$

The only alkalinity ion listed in the water analysis is HCO_3^- , which is unknown.

- c. Convert the concentration of HCO_3^- in meq/L to mg/L as follows:

Alkalinity ions	Conc., mg/L	mg/meq ^a	meq/L
HCO_3^-	48.82	61.02	0.80

^a Molecular weight/Z (see Eq. 2-8)

2. Determine the value of Mg^{2+} using Eq. 2-23, which is for non-carbonate hardness.

- a. Convert hardness from mg/L as CaCO_3 to meq/L.

$$\begin{array}{l} \text{mg/L hardness} \\ \text{as } \text{CaCO}_3 \end{array} = \text{meq/L of hardness ions} \times \text{meq/L mass of } \text{CaCO}_3, 50 \text{ mg/meq}$$

$$\text{meq/L of hardness ions} = \frac{\text{mg/L hardness as } \text{CaCO}_3}{\text{meq/L mass of } \text{CaCO}_3}$$

$$\text{meq/L of hardness ions} = \frac{180 \text{ mg/L}}{50 \text{ mg/meq}} = 3.6 \text{ meq/L}$$

- b. Use Eq. 2-23 and determine the hardness ions that are present in the water analysis.

$$\text{Hardness, meq/l} = (\text{Ca}^{2+}) + (\text{Mg}^{2+})$$

The hardness ions listed in the water analysis are Ca^{2+} and Mg^{2+} , and the concentration of Mg^{2+} is unknown.

- c. Determine the concentration of Mg^{2+} and convert the concentration of Mg^{2+} in meq/L to mg/L as follows:

Hardness ions	Conc., mg/L	mg/meq ^a	meq/L
Ca^{2+}	55.0	20.04 ^b	2.74
Mg^{2+}	10.45	12.15	0.86
Σ hardness ions			3.6

^a Molecular weight/Z (see Eq. 2-7)

PROBLEM 2-13

Problem Statement - Review the current literature and cite three articles in which the SUVA (specific UV absorbance) measurements were made. Prepare a summary table of the reported values. Can any conclusions be drawn from the data in the summary table you have prepared?

Solution

Answers will vary depending on the articles reviewed. References for several potential articles related to measurement of SUVA are provided below:

- Karanfil, T., Schlautman, M. A. and Erdogan, I. (2002) Survey of DOC and UV Measurement Practices with Implications for SUVA Determination, *J. AWWA*, **94**, 12, 68-80.
- Weishaar, J. L., Aiken, G. R., Bergamaschi, B. A., Fram, M. S., Fujii, R. and Mopper, K. (2003) Evaluation of Specific Ultraviolet Absorbance as an Indicator of the Chemical Composition and Reactivity of Dissolved Organic Carbon, *Environ. Sci. Technol.*, **37**, 20, 4702-4708.
- Weiss, W. J., Bouwer, E. J., Ball, W. P., O'Melia, C. R., Aboytes, R. and Speth, T. F. (2004) Riverbank Filtration: Effect of Ground Passage on NOM Character, *J. Water Supply Res. and Technol.-Aqua*, **53**, 2, 61-83.
- Westerhoff, P., Chao, P. and Mash, H. (2004) Reactivity of Natural Organic Matter with Aqueous Chlorine and Bromine, *Water Res.*, **38**, 6, 1502-1513.

PROBLEM 2-14

Problem Statement - Review the current literature and prepare a brief synopsis of two articles in which the DOM (dissolved organic matter) was measured. What if any conclusions can be drawn from these articles about the utility of DOM measurements.

Solution

Answers will vary depending on the articles reviewed. References for several potential articles related to the measurement and utility of DOM are provided below:

- Afcharian, A., Levi, Y., Kiene, L. and Scribe, P. (1997) Fractionation of Dissolved Organic Matter from Surface Waters using Macroporous Resins, *Water Res.*, **31**, 12, 2989-2996.
- Amy, G. L., Sierka, R. A., Bedessem, J., Price, D. and Tan, L. (1992) Molecular-Size Distributions of Dissolved Organic-Matter, *J. AWWA*, **84**, 6, 67-75.
- Li, F. S., Yuasa, A., Ebie, K., Azuma, Y., Hagishita, T. and Matsui, Y. (2002). Factors Affecting the Adsorption Capacity of Dissolved Organic Matter onto Activated Carbon: Modified Isotherm Analysis, *Water Res.*, **36**, 18, 4592-4604.
- Schneider, O. D. and Tobiason, J. E. (2000) Preozonation Effects on Coagulation, *J. AWWA*, **92**, 10, 74-87.

PROBLEM 2-15

Problem Statement - Determine the concentration in $\mu\text{g}/\text{m}^3$ of 10 ppm_v (by volume) of trichloroethylene (TCE) (C_2HCl_3) at standard conditions (0°C and 1 atm).

Solution

Use Eq. 2-29 to solve for concentration of TCE (C_2HCl_3).

1. Determine the variables for Eq. 2-29

$$\text{ppm}_v = 10$$

$$\text{mw} = 2(12.01) + 1 + 3(35.45) = 131.37$$

concentration, $\mu\text{g}/\text{m}^3$ = unknown

2. Solve for concentration using Eq. 2-29.

$$\mu\text{g}/\text{m}^3 = \frac{(\text{concentration, ppm}_v)(\text{mw, g/mole of gas})(10^6 \mu\text{g/g})}{(22.141 \times 10^{-3} \text{ m}^3/\text{mole of gas})}$$

$$\text{concentration, } \mu\text{g}/\text{m}^3 = \frac{\left(\frac{10 \text{ m}^3}{10^6 \text{ m}^3}\right)(131.37 \text{ g/mole})(10^6 \mu\text{g/g})}{22.141 \times 10^{-3} \text{ m}^3/\text{mole gas}}$$

$$\text{concentration, } \mu\text{g}/\text{m}^3 = 5.93 \times 10^3$$

PROBLEM 2-16

Problem Statement - If the concentration of TCE at standard conditions (0°C and 1 atm) is $15 \mu\text{g}/\text{m}^3$, what is the corresponding concentration in ppm_v (by volume)?

Solution

Use Eq. 2-29 to solve for concentration of TCE (C_2HCl_3).

1. Determine the variables for Eq. 2-40

ppm_v = unknown

$$\text{mw} = 2(12.01) + 1 + 3(35.45) = 131.37$$

$$\text{concentration, } \mu\text{g}/\text{m}^3 = 15 \mu\text{g}/\text{m}^3$$

2. Rearrange Eq. 2-29 and solve for ppm_v as

$$\text{conc. } \mu\text{g}/\text{m}^3 = \frac{(\text{conc. ppm}_v)(\text{mw, g/mole of gas})(10^6 \mu\text{g/g})}{22.141 \times 10^{-3} \text{ m}^3/\text{mole of gas}}$$

$$\text{follows: } \text{conc. ppm}_v = \frac{(\text{conc. } \mu\text{g}/\text{m}^3)(22.141 \times 10^{-3} \text{ m}^3/\text{mole of gas})(1 \text{ m}^3/10^6 \text{ m}^3)}{(\text{mw, g/mole of gas})(10^6 \mu\text{g/g})}$$

$$\text{conc. ppm}_v = \frac{(15 \mu\text{g}/\text{m}^3)(22.141 \times 10^{-3} \text{ m}^3/\text{mole of gas})(1 \text{ m}^3/10^6 \text{ m}^3)}{(131.37 \text{ g/mole of gas})(10^6 \mu\text{g/g})}$$

$$\text{conc. ppm}_v = 1.685 \times 10^{-4}$$