ADDITIONAL EXERCISES FOR CHAPTER 24

EXAMPLE 1

Based on the pie chart showing the distribution of various forms of water in Figure 24.2, what is the ratio of the amount of seawater to that of groundwater?

SOLUTION

$$\frac{\text{seawater\%}}{\text{groundwater\%}} = \frac{97.6\%}{(2.4\%)(0.206)} = 200$$

Of all water found on Earth, 2.4 percent is freshwater; however, only 20.6 percent (0.206) of freshwater is found in the ground.

EXAMPLE 2

The analytical test results of a water sample are shown with the concentration unit of mg/L in the following table. Calculate the salinity of the water sample in parts per thousand (ppt) by assuming a water density of 1.008 g/cm^3. What are the percentages of calcium and bicarbonate by weight in the salt residue if the water is evaporated to dryness?

Calcium	Magnesium	Sodium	Potassium	Bicarbonate	Sulfate	Chloride	Silica
40.7	7.2	1.4	1.2	114	36	1.1	3.7

SOLUTION

$$\text{salinity} = \frac{(40.7 + 7.2 + 1.4 + 1.2 + 114 + 36 + 1.1 + 3.7)\ \text{mg/L}}{(1.008\ \text{g/cm}^3)(1{,}000\ \text{cm}^3\text{/L})}$$

$$= 2.0 \times 10^{-1}\ \text{ppt}$$

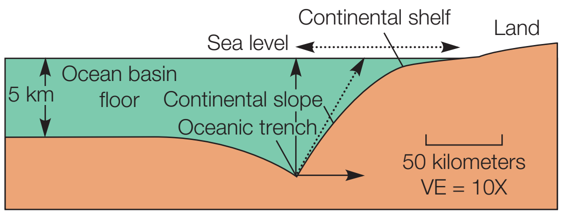
$$\%\ \text{calcium (w/w)} = \frac{40.7}{205.3} \cdot 100 = 19.8\%$$

$$\%\ \text{bicarbonate (w/w)} = \frac{114}{205.3} \cdot 100 = 55.5\%$$

EXAMPLE 3

What is the gradient of the steepest part of the continental slope (i.e., dotted line with a single arrowhead) shown in the figure below that is drawn with vertical exaggeration of 10X? What is the shortest horizontal distance (i.e., dotted line with double arrowheads) one must travel from the shoreline before passing directly over the deepest point of the oceanic trench?

ACTIVE CONTINENTAL MARGIN



SOLUTION

$$\text{gradient of steepest slope} = \frac{(\text{vertical arrow})_{\text{trench}}}{(\text{horizontal arrow})_{\text{trench}}(\text{VE})}$$

$$= \frac{17.5\ \text{mm}}{(10.0\ \text{mm})(10)} = 0.175$$

shortest distance between shoreline and trench

$$= (24.0\ \text{mm})\left(\frac{50\ \text{km}}{11.0\ \text{mm}}\right) = 110\ \text{km}$$

PARALLEL EXERCISES

Group A

1. Based on the pie chart showing the distribution of various forms of water in Figure 24.2, what is the percentage of freshwater existing as ice relative to ocean water?

2. Based on the test results of the following six water samples, identify the seawater and rainwater samples and calculate their salinity values. The units of the test results are mg/L, and the density of all samples can be approximated as 1.0 kg/L except sample 3 which has a density of 1.2 kg/L.

Table 1 Concentrations of dissolved ions in different water samples

	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Sample 6
Calcium	0.65	40.7	241	400	144	3.11
Magnesium	0.14	7.2	7,200	1,350	55	0.7
Sodium	0.56	1.4	83,600	10,500	27	3.03
Potassium	0.11	1.2	4,070	380	2	1.09
Bicarbonate		114	251	28	622	20
Sulfate	2.2	36	16,400	185	60	1
Chloride	0.57	1.1	140,000	19,000	53	0.5
Silica		3.7	48	3	22	16.4

3. Chloride (Cl^-) accounts for 55.05 percent by weight among all the salts that are found in a seawater sample that has a salinity of 3.50 percent. Estimate the mass of chloride that can be obtained from complete evaporation of 1.00 cubic meters of seawater with density of 1,030 kg/m^3.

4. The quarterly precipitation in a city is given as follows. Assuming that 13 inches of snow melts to give 1 inch of water, what is the annual precipitation?

	January–March	April–June	July–September	October–December
Rain (inches)	5	17	15	11
Snow (inches)	48	0	0	27

5. The salinity of a lake can vary significantly under drought conditions due to the evaporative loss of water. Calculate the salinity of a lake that has lost 7.20 percent of the lake water volume. Before the drought, the salinity was measured at 2.90 percent or 29.0 ppt with a density of 1.020 g/mL. After the drought, the density increased to 1.023 g/mL.

6. The salinity of water for a river was measured to be 0.82 percent at 5 miles upstream from the estuary, 1.65 percent at the estuary, and 3.35 percent at the sea where the river discharges into. What is the degree of seawater contribution to the estuary salinity? In the rainy season when the river flows more rapidly, would the salinity increase or decrease?

7. Use Figure 1 on the next page to estimate the average salinity range of Lostmans River over the five-year span as indicated by the solid line with double arrowheads. Calculate the average minimum salinity as a percentage of the average maximum salinity.

Group B

1. Based on the pie chart showing the distribution of various forms of water in Figure 24.2, what is the percentage of easily accessible freshwater in the forms of surface waters (i.e., rivers and lakes) and groundwater relative to ocean water?

2. Based on the data presented in Table 1, identify the groundwater sample that has been in contact with limestone, and calculate its salinity.

3. Chloride (Cl^-) accounts for 55.05 percent by weight of all the ionic components in a seawater sample that has a salinity of 3.50 percent and a density of 1,030 kg/m^3. What is the volume of seawater that must be evaporated to dryness in order to obtain 1.000 kg of chloride salt?

4. The quarterly precipitation in a Canadian city is given as follows. Assuming that 13 inches of snow melts to give 1 inch of water, what is the annual precipitation?

	January–March	April–June	July–September	October–December
Rain (inches)	7	14	11	15
Snow (inches)	56	19	0	44

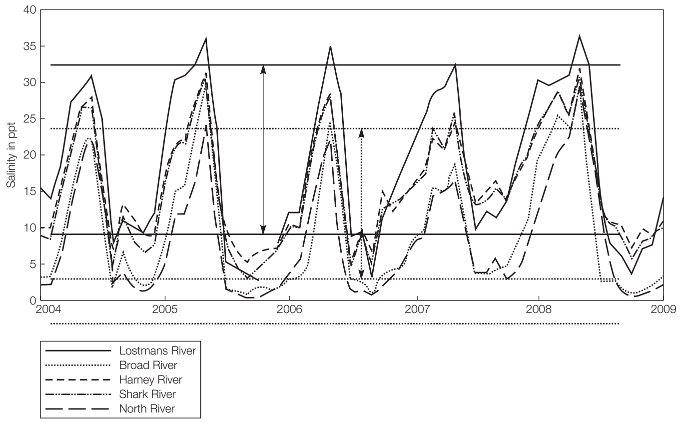
5. The salinity of a river can be reduced after a major rainstorm because rainwater has very few dissolved ions and hence dilutes the river salinity before the rain. Calculate the salinity of a river that had undergone a volume increase of 12.4 percent due to the rain. The river salinity before the rain was 1.46 percent or 14.6 ppt with a density of 1.014 g/mL. After the drought, the density increased to 1.011 g/mL.

6. The salinity of water for a river was measured to be 0.94 percent at 10 miles upstream from the estuary, 1.81 percent at the estuary, and 3.35 percent at the sea into which the river discharges. What is the degree of seawater contribution to the estuary salinity? In the rainy season when the river flows more rapidly, would the salinity increase or decrease?

7. Use Figure 1 to estimate the average salinity range of Broad River over the five-year span as indicated by the dotted line with double arrowheads. Calculate the average minimum salinity as a percentage of the average maximum salinity.

Group A (Continued)

Figure 1: Comparison of mean monthly salinity at five major rivers along the southwest coast of Everglades National Park.



8. To investigate if other unaccounted ions exist for a water sample with the following analytical results for the commonly measured ions, calculate the ratio of cationic charges to anionic charges for the water sample, and comment on the significance of the ratio.

Sample A	Calcium	Magnesium	Sodium	Potassium	Bicarbonate	Sulfate	Chloride
mg/L	241	7,200	83,600	4,070	251	16,400	140,000

9. How far out from a beach horizontally can we expect the incoming waves with an average wavelength of 3.5 meters to increase in wave height if the gradient of the beach slope has a ratio of 1:20? Note that the 1:20 slope ratio means an increase in water depth of 1 meter for every 20 meters in distance traversed by the waves toward the beach.

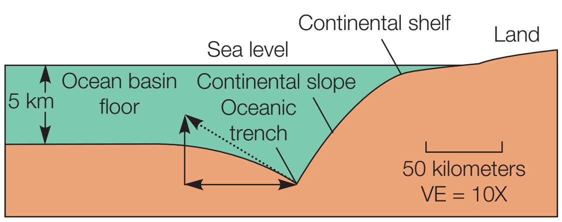
10. If the breaker waves were observed at 20 meters away from the shoreline of a beach with the 1:20 slope, what was the wave height for the breaker waves?

11. If the base of Mt. Everest (29,029 ft) were to be situated at the deepest point of the deepest ocean trench, Mariana Trench of 11,033 m, would the summit protrude above or still be submerged below the ocean? What is the difference in trench depth and mountain height in meters?

12. Sea level rise due to glacial melting and thermal expansion of seawater due to global warming threatens to submerge the Maldive Islands which have an average ground level of 1.5 meters. Using the highest estimate of sea level rise at 8.80 mm per year, when can one expect the Maldive Islands to become completely submerged?

13. Based on the figure below that is drawn with vertical exaggeration of 10X, what is the gradient of the steepest part of the ocean basin floor (i.e., dotted line with a single arrowhead) encountered by a remotely operated undersea vehicle traveling from the relatively flat ocean floor to the trench? What is the horizontal distance with varying degrees of slope as indicated by the solid line with double arrowheads?

ACTIVE CONTINENTAL MARGIN



Group B (Continued)

8. To investigate if other unaccounted ions exist for a water sample with the following analytical results for the commonly measured ions, calculate the ratio of cationic charges to anionic charges for the water sample, and comment on the significance of the ratio.

Sample B	Calcium	Magnesium	Sodium	Potassium	Bicarbonate	Sulfate	Chloride
mg/L	144	55	27	2	622	60	53

9. How far out from a beach horizontally can we expect the incoming waves with an average wavelength of 2.80 meters to increase in wave height if the gradient of the beach slope has a ratio of 1:15? Note that the 1:15 slope ratio means an increase in water depth of 1 meter for every 15 meters in distance traversed by the waves toward the beach.

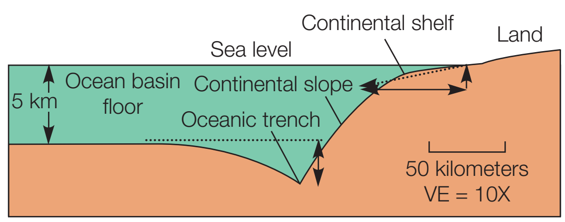
10. If the breaker waves were observed at 25 meters away from the shoreline of a beach with the 1:15 slope, what was the wave height for the breaker waves?

11. If the base of Mt. Everest (29,029 ft) were to be situated at the deepest point of the Puerto Rico Trench of 8,605 m, would the summit protrude above or still be submerged below the ocean? What is the difference in trench depth and mountain height in meters?

12. The rise of sea level may cause the submersion of the Maldive Islands which have an average ground level of 1.5 meters. Using the average estimate of sea level rise of 4.80 mm per year, when can one expect the Maldive Islands to become completely submerged?

13. Based on the figure below that is drawn with vertical exaggeration of 10X, what is the initial slope of the continental shelf indicated by the dotted line with a single arrowhead? What is the difference in the depths of the ocean floor and the lowest point of the oceanic trench as indicated by the solid line with double arrowheads?

ACTIVE CONTINENTAL MARGIN



SOLUTIONS TO ADDITIONAL GROUP A & B PARALLEL EXERCISES FOR CHAPTER 24

Group A

1. $\frac{\text{freshwater (ice)\%}}{\text{seawater \%}} = \frac{(2.4\%)(0.785)}{97.6\%}(100\%) = \boxed{1.9\%}$

2. The calculated values of salinity for the samples, after summing the dissolved ion concentrations of each sample and adjusting for the density, are as follows. It is clear that S4 or sample 4 is the seawater since its salinity is closest to 3.5 percent or 35 parts per thousand (ppt). Although it is tempting to pick sample 3 as seawater because of the high values of the salt concentrations, its salinity value of 209.8 is more suggestive of brine, and it is indeed the Great Salt Lake sample from Utah. The rainwater sample has to be the S1 or sample 1 with the lowest level of dissolved solutes. Rainwater is formed by evaporation of water from different surface waters (i.e., lakes, rivers, sea) and subsequent condensation from the rain clouds; these two processes do not provide minimal sources of dissolved salts.

salinity of sample 3

$$= \left(\frac{400 + 1{,}350 + 10{,}500 + 380 + 28 + 185 + 19{,}000 + 3}{1{,}000}\right) \text{ppt}$$

$$= \boxed{209.8 \text{ ppt}}$$

	S1	S2	S3	S4	S5	S6
Salinity (ppt)	0.004	0.205	209.8	31.8	0.985	0.046

3. Cl^- mass

$$= 1.00 \text{ m}^3 \left(\frac{1.030 \times 10^6 \text{ g seawater}}{1.00 \text{ m}^3}\right)\left(\frac{3.50 \text{ g salt}}{100 \text{ g seawater}}\right)\left(\frac{55.05 \text{ g Cl}^-}{100 \text{ g salt}}\right)$$

$$= \boxed{1.98 \times 10^4 \text{ gCl}^-}$$

4.

	January–March	April–June	July–September	October–December
Rain (inches)	5	17	15	11
Snow (inches)	48	0	0	27

$$\text{precipitation} = (5 + 7 + 15 + 11) \text{ in} + \frac{(48 + 27)}{13} \text{ in} = \boxed{54 \text{ in}}$$

5. salt concentration before drought

$$= \frac{29.0 \text{ g salt}}{1{,}000 \text{ g lake water}} \cdot \frac{1.02 \text{ g lake water}}{\text{mL}} = \frac{29.6 \text{ g salt}}{1{,}000 \text{ mL}}$$

$$\text{salinity after drought} = \left[\frac{29.6 \text{ g salt}}{(1{,}000 - 72) \text{ mL}}\right]\left[\frac{1 \text{ mL}}{1.023 \text{ g}}\right]$$

$$= \boxed{3.11\% \text{ or } 31.1 \text{ ppt}}$$

6. If we let Y be the fractional volume of seawater contribution, then we can formulate and solve the following equation for calculating the *weighted average* of the estuary salinity.

$$3.35Y + 0.82(1 - Y) = 1.65$$
$$3.35Y - 0.82Y = 1.65 - 0.82$$
$$2.53Y = 0.83$$

Therefore, $\boxed{Y = 0.328}$ which is equivalent to 32.8 percent volumetric contribution of seawater to the estuary water mixing. The estuary salinity should decrease during the rainy season.

7. range $= 32.4 \text{ ppt} - 9.6 \text{ ppt} = \boxed{22.8 \text{ ppt}}$

% salinity $= (9.6 \text{ ppt}/32.4 \text{ ppt})(100\%) = \boxed{29.6\%}$

Group B

1. $\frac{\text{freshwater (ice)\%}}{\text{seawater\%}} = \frac{(2.4\%)(0.206 + 0.008)}{97.6\%}(100\%) = \boxed{0.53\%}$

2. Sample 5 or S5 has unusually high levels of bicarbonate ion, which is a telltale sign of the groundwater having been in contact with limestone formation. Its salinity is calculated as follows and is characteristic of most groundwater samples.

salinity of groundwater (S5)

$$= \left(\frac{144 + 55 + 27 + 2 + 622 + 60 + 53 + 22}{1{,}000}\right) \text{ppt} = \boxed{0.985 \text{ ppt}}$$

3. Volume of seawater

$$= 1{,}000 \text{ g Cl}^- \left(\frac{100 \text{ g salt}}{55.05 \text{ g Cl}^-}\right)\left(\frac{100 \text{ g seawater}}{3.50 \text{ g salt}}\right)\left(\frac{1.00 \text{ m}^3}{1.030 \times 10^6 \text{ g seawater}}\right)$$

$$= \boxed{5.04 \times 10^{-2} \text{ m}^3}$$

4. $\text{precipitation} = (7 + 14 + 11 + 15) \text{ in} + \frac{(56 + 19 + 44)}{13} \text{ in}$

$$= \boxed{56 \text{ in}}$$

5. salt concentration before rain

$$= \frac{14.6 \text{ g salt}}{1{,}000 \text{ g lake water}} \cdot \frac{1.014 \text{ g lake water}}{\text{mL}} = \frac{14.8 \text{ g salt}}{1{,}000 \text{ ml}}$$

$$\text{salinity after rain} = \left[\frac{14.8 \text{ g salt}}{(1{,}000 + 72) \text{ mL}}\right]\left[\frac{1 \text{ mL}}{1.011 \text{ g}}\right]$$

$$= \boxed{1.30\% \text{ or } 13.0 \text{ ppt}}$$

6. If we let Y be the fractional volume of the seawater contribution, then we can formulate and solve the following equation for calculating the *weighted average* of the estuary salinity.

$$3.35Y + 0.94(1 - Y) = 1.81$$
$$3.35Y - 0.94Y = 1.81 - 0.94$$
$$2.41Y = 0.87$$

Therefore, $\boxed{Y = 0.361}$ which is equivalent to 36.1 percent volumetric contribution of seawater to the estuary water mixing. The estuary salinity should decrease during the rainy season.

7. range $= 23.8 \text{ ppt} - 3.2 \text{ ppt} = \boxed{20.6 \text{ ppt}}$

% salinity $= (3.2 \text{ ppt}/23.8 \text{ ppt})(100\%) = \boxed{13.4\%}$

Group A—Continued

8. cationic charge on $Ca^{2+} = \left(\frac{241\text{ mg}}{\text{L}}\right)\left(\frac{\text{mmole}}{40.1\text{ mg}}\right)\left(\frac{2\text{ meq}}{1\text{ mmole}}\right) = \boxed{12.0\text{ meq/L}}$

anionic charge on $HCO_3^- = \left(\frac{251\text{ mg}}{\text{L}}\right)\left(\frac{\text{mmole}}{61\text{ mg}}\right)\left(\frac{1\text{ meq}}{1\text{ mmole}}\right) = \boxed{4.1\text{ meq/L}}$

When the charges for all the cations and anions are calculated and added as given in the table below, the total cationic charge is 4,343 and the total anionic charge is 4,289. The overall ratio is (4,343/4,289), or $\boxed{1.013}$. Since the ratio is almost equal to exactly 1, the slight excess of cations at 1.3 percent greater charge relative to anions can be due to measurement error.

Sample A	Calcium	Magnesium	Sodium	Potassium	Bicarbonate	Sulfate	Chloride
mg/L	241	7,200	83,600	4,070	251	16,400	14,0000
g/mole	40.1	24.3	23	39.1	61	96.1	35.5
charge	2	2	1	1	−1	−2	−1
meq/L	12.02	592.59	3,634.78	104.09	−4.11	−341.31	−3,943.66
Total			Cationic charge	4,343		Anionic charge	−4,289

9. The waves begin to increase in wave height at a depth of 1.75 meters that corresponds to one-half of the wavelength at 3.5 meters. Therefore, this occurs at a distance of

$\left(1.75\text{ m} \cdot \frac{20\text{ m}}{1\text{ m}}\right) = \boxed{35\text{ m}}$

10. The water depth when breaker waves occurred was 1 meter, which would be equivalent to 1⅓ the wave height.

Therefore, wave height = (3/4) × 1 m = $\boxed{0.75\text{ m}}$

11. Depth of Mt. Everest = (29,029 ft) (1 m/3.28 ft) = 8,850 m

Mt. Everest would remain submerged. The difference between the trench depth and the mountain height is 11,033 m − 8,850 m = $\boxed{2,183\text{ m}}$.

12. Maldive Islands become submerged after

$\frac{1.5 \times 10^3\text{ mm}}{8.80\text{ mm/year}} = \boxed{170\text{ years}}$

13. gradient of steepest slope $= \frac{(\text{vertical arrow})_{\text{trench}}}{(\text{horizontal arrow})_{\text{trench}}(\text{VE})} = \frac{8.0\text{ mm}}{(15.5\text{ mm})(10)} = \boxed{0.052}$

Horizontal distance with varying degree of slope = (15.5 mm) (50 km/11.0 mm) = $\boxed{70\text{ km}}$

Group B—Continued

8. cationic charge on $Ca^{2+} = \left(\frac{144\text{ mg}}{\text{L}}\right)\left(\frac{\text{mmole}}{40.1\text{ mg}}\right)\left(\frac{2\text{ meq}}{1\text{ mmole}}\right) = \boxed{7.18\text{ meq/L}}$

anionic charge on $HCO_3^- = \left(\frac{622\text{ mg}}{\text{L}}\right)\left(\frac{\text{mmole}}{61\text{ mg}}\right)\left(\frac{1\text{ meq}}{1\text{ mmole}}\right) = \boxed{10.2\text{ meq/L}}$

When the charges for all the cations and anions are calculated and added as given in the table below, the total cationic charge is 12.93 and the total anionic charge is 12.94. The overall ratio is (12.93/12.94), or $\boxed{1.000}$. Since the ratio is equal to exactly 1, the magnitudes of the positive and negative charges are equal to one another.

Sample B	Calcium	Magnesium	Sodium	Potassium	Bicarbonate	Sulfate	Chloride
mg/L	144	55	27	2	622	60	53
g/mole	40.1	24.3	23	39.1	61	96.1	35.5
charge	2	2	1	1	−1	−2	−1
meq/L	7.18	4.53	1.17	0.05	−10.20	−1.25	−1.49
Total			Cationic charge	12.93		Anionic charge	−12.94

9. The waves begin to increase in wave height at a depth of 1.40 meters that corresponds to one-half of the wavelength at 2.80 meters. Therefore, this occurs at a distance of

$\left(1.40\text{ m} \cdot \frac{15\text{ m}}{1\text{ m}}\right) = \boxed{21\text{ m}}$

10. The water depth when breaker waves occurred was 5/3 meters, or 1.67 meters, which would be equivalent to 1⅓ the wave height.

Therefore, wave height = (3/4) × (5/3) m = $\boxed{1.25\text{ m}}$

11. Depth of Mt. Everest = (29,029 ft) (1 m/3.28 ft) = 8,850 m

Mt. Everest would protrude above the sea level. The difference between the trench depth and the mountain height is 8,850 m − 8,605 m = $\boxed{245\text{ m}}$.

12. Maldive Islands become submerged after

$\frac{1.5 \times 10^3\text{ mm}}{4.80\text{ mm/year}} = \boxed{310\text{ years}}$

13. gradient of the initial slope $= \frac{(\text{vertical arrow})_{\text{trench}}}{(\text{horizontal arrow})_{\text{trench}}(\text{VE})} = \frac{1.5\text{ mm}}{(13.0\text{ mm})(10)} = \boxed{0.012}$

difference in depths of ocean floor and trench = (6.0 mm) (50 km/11.0 mm) = $\boxed{27\text{ km}}$