UNIT 5 THE WATER PLANET

CHAPTER 15 *The World of Water*

CHAPTER 16 *Geology of the Ocean*

CHAPTER 17 *Climate and the Ocean*

Most people who look at a globe or world map will see it as land separated by oceans. Yet, people who spend their lives at sea will see oceans separated by land. Which perception is correct? Actually, both perceptions are valid — they just depend on one's point of view. However, the oceans do cover over 70 percent of the planet's surface, so it is accurate to call Earth a water planet.

Scientists who study the ocean know water has special properties that affect the organisms living in it. Water is the very basis of life. In the first chapter of this unit, you will learn about the chemistry of water and why it is so important for the support of life on Earth.

In the chapter on geology of the ocean, you will learn about the origin of the oceans and continents, and how they have changed over time. The ocean influences temperature, precipitation, and the formation of storms. The last chapter in this unit discusses the ocean's effect on climate.

15 The World of Water

When you have completed this chapter, you should be able to:

DISCUSS Earth's water cycle and water budget.

EXPLAIN the basic chemistry of water as a solvent.

DESCRIBE the importance of pH to water chemistry.

DISCUSS the sources of, and variations in, the ocean's salinity.

15.1
The Water Planet

15.2
The Water Budget

15.3
Water as a Solvent

15.4
The Salty Sea

All day and all night—every day and every night—the ocean keeps up a steady rhythm as it advances and then retreats from the shore, propelled by tidal forces. Moving in, the ocean waves break along the sloping shore; and just as quickly, the waves recede.

In some places, shallow tidal pools are left behind as the waves move away from the shore. Scientists think that several billion years ago, life on Earth began in the ocean—perhaps in a tiny pool of water left behind by the unending movement of the waves. Most likely, life probably began in the sea because ocean water contains important substances needed for life processes.

The chemical composition of ocean water is the main topic of this chapter. Knowledge about water and the substances it contains will provide you with a better understanding of how life exists in the sea.

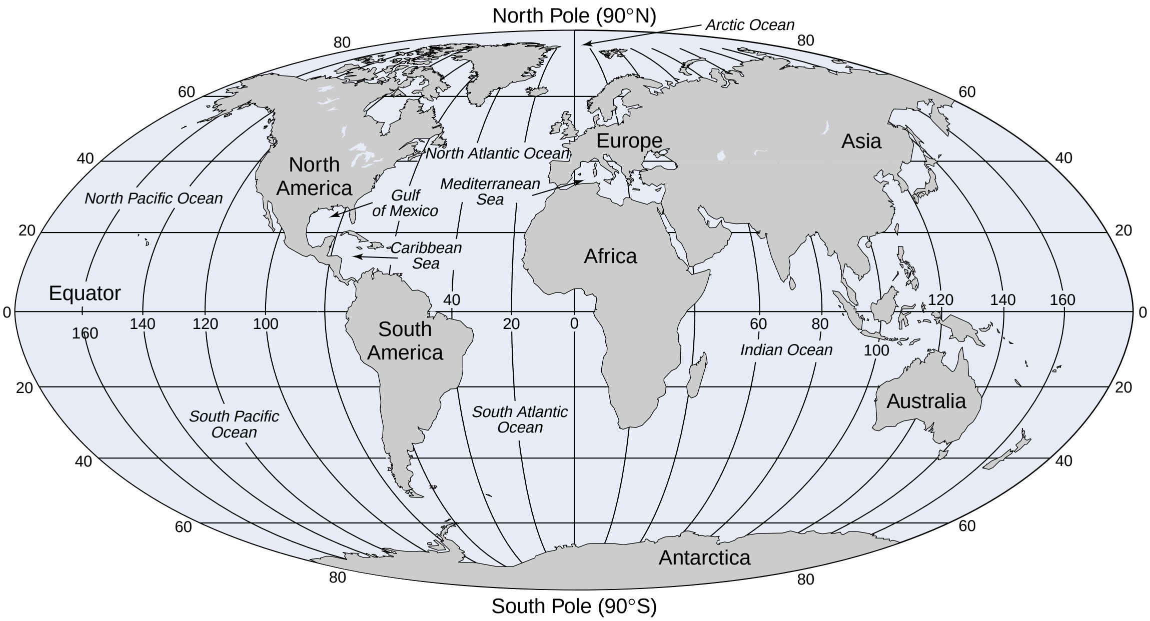
15.1 THE WATER PLANET

Since so much of Earth is covered by water, it is sometimes called the "water planet." If you look at a world map in an atlas, you will see that there is more water than land. In fact, more than 70 percent of Earth's surface is water, with most of that water in the ocean. The ocean surrounds landmasses known as continents, which are the remaining 29 percent of Earth's surface. The continents divide the ocean into four major parts: the Atlantic Ocean, Pacific Ocean, Indian Ocean, and Arctic Ocean. Often, where two continents lie close together, a smaller part of an ocean called a **sea** is formed. Locate the Caribbean Sea in Figure 15-1. Notice that it connects to the Atlantic Ocean. In fact, all of Earth's oceans and seas flow into one another, forming one continuous body of water.

Latitude and Longitude

To locate geographical areas with precision, people draw a grid, or series of lines, over maps and globes. The equator is one of the most important lines on this grid; it divides the world in half. The

Figure 15-1 The oceans and seas of the world.



northern hemisphere is the part of Earth located north of the equator; and the southern hemisphere is the part of Earth located south of the equator. The southern hemisphere has 20 percent more ocean than the northern hemisphere. Lines that run parallel to the equator are called lines of **latitude**. Distances north or south of the equator are measured in degrees. The latitude of the equator is 0 degrees. The latitude of the North Pole is 90 degrees north, and the latitude of the South Pole is 90 degrees south. All other latitudes fall between 0 and 90 degrees north or south of the equator.

Try to locate the Galápagos Islands on the map in Figure 15-1. These islands are represented by a tiny spec right on the equator, at 0 degrees latitude, west of South America. If you follow east along the 0 degree line, you will see that many other land areas also lie on the equator. For example, Ecuador, Brazil, and several countries in Africa lie on the equator.

How are geographical areas located at the same latitude distinguished from one another? Another measurement, called **longitude**, when combined with latitude measurements can pinpoint geographical locations with great precision. On a globe, you can see that lines of longitude run from the North Pole to the South Pole, intersecting the lines of latitude. Longitude is measured in degrees east or west of the prime meridian. The prime meridian runs through Greenwich, England, and it is assigned the starting point of 0 degrees longitude. Earth is divided into 24 meridians; meridians are 15 degrees apart. The meridians cover a distance 180 degrees east and 180 degrees west of the prime meridian.

The precise location of a geographical area can be given by specifying the latitude and longitude lines that pass through the area. Look again at Figure 15-1 and find the exact location of the Galápagos Islands; they are located at about 85 degrees west longitude. In contrast, the mouth of the Amazon River in Brazil (not labeled on the map) is located at 50 degrees west longitude. However, both places are located at 0 degrees latitude; that is, both are at the equator.

15.1 Section Review

1. Why is Earth often called the "water planet"?
2. How are geographical places on Earth located with accuracy?
3. What is the precise difference between an ocean and a sea?

ENVIRONMENT

A Beacon on a Vanishing Beach

For centuries, sailors have used measurements of latitude and longitude to help them find their way. In addition, seafarers have relied on specific landmarks to guide their ships safely into port. Lighthouses are among the most important of these landmarks, helping sailors steer their way around offshore hazards.

The famous lighthouse in Cape Hatteras, North Carolina, built on a barrier island in 1870, is one such landmark that has been given a second life. At risk of toppling into the surf only 50 meters away, this historic structure was hoisted up by special lifts, placed onto platforms, and moved on rollers 400 meters inland. Now it stands 60 meters high, a beacon in the night to the countless ships that sail in these turbulent coastal waters—an area often referred to as the "graveyard of the Atlantic." But how long will it remain standing on this vanishing barrier beach? Scientists estimate that, if beach erosion continues at its present rate, by the year 2090 the lighthouse will have to be moved inland again or it will collapse into the sea.

Building on a barrier beach is like trying to build a castle in the sand. Sand is a very unstable substrate. Both wind and water can easily shift and move the sand about. Climatic conditions—in the form of coastal storms, heavy winds, tidal surges, and wave action—constantly change and erode the landscape of these barrier beaches, which run parallel to the main coastline.

But people like to live near the sea. Barrier islands along the Atlantic and Gulf coasts continue to attract developers, in spite of the hazards of beach erosion. Local governments have built a variety of barriers—including sea walls parallel to the beach and rock walls perpendicular to the beach—to keep the sand from washing away. Yet these efforts have been largely unsuccessful, since nature continues to reshape the barrier islands through erosion and deposition.

Dredging sand from the seafloor offshore and dumping it onto the beach is the latest attempt by coastal communities to keep erosion at bay. But the people of Cape Hatteras did not choose this method to save their lighthouse. After all, it would only be a short period of time before erosion would claim more land. Instead, they retreated inland with their lighthouse, which continues to send out signals in the night, but perhaps with a more symbolic warning for developers—don't build on a vanishing beach.

QUESTIONS

1. Why was the Cape Hatteras lighthouse moved 400 meters inland?
2. Describe the climate conditions that can contribute to beach erosion.
3. Compare the pros and cons of building on a barrier beach with building inland.

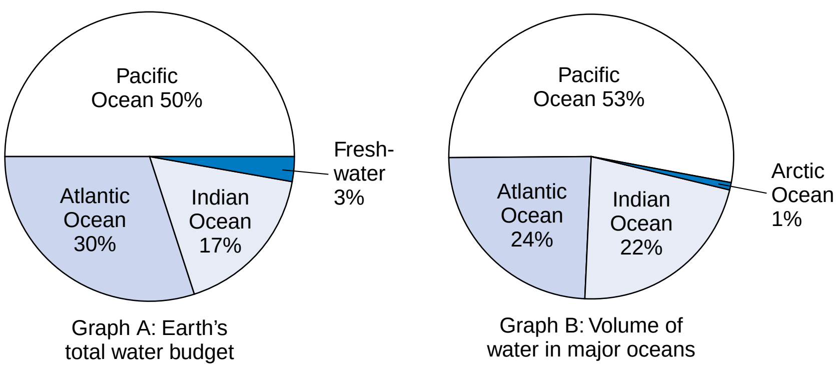
15.2 THE WATER BUDGET

Most people have to plan carefully how they spend their money. Very few people have unlimited amounts of money to spend. The amount of money needed for expenses over a given period is called a budget.

Earth also has a budget, a **water budget**. Earth's water budget is the total amount of water contained in and on the planet. As you can see in pie graph A in Figure 15-2, the oceans contain about 97 percent of all the water on Earth. Which ocean has the largest volume of water? The Pacific is the largest ocean, followed by the Atlantic, Indian, and Arctic oceans. (See pie graph B in Figure 15-2.) Only 3 percent of all the water on Earth is freshwater. Most of that 3 percent is frozen in glaciers and in ice found near the polar regions. Only about one-third of all freshwater on Earth is found as liquid in rivers and lakes, and in underground sources. Compared to the amount of salt water, the amount of freshwater on Earth is very small indeed.

The amount of water in the ocean determines sea level. The **sea level** is the point at which the ocean surface touches the shoreline. Over Earth's long history, the sea level has changed. About 12,000 years ago, during the last great ice age, the sea level was lower than it is today, perhaps as much as 100 meters lower. At that time, the edge of the sea was at the continental shelf. Why was the sea level so much lower then than it is today? During that period, Earth's climate was colder, snowfall increased, and as a result, much of the world's water was frozen—locked up in the form of glaciers and polar ice caps. When water freezes, less is available for the oceans,

Figure 15–2 Pie graphs: (A) Earth's total water budget and (B) the volume of water in Earth's oceans.



and the sea level drops. Since the Ice Age, the climate of Earth has warmed, causing much of the ice to melt. This melting ice added water to the ocean (through rainfall and runoff), and the sea level has risen.

Will the warming trend continue? Will the level of the sea continue to rise? The past offers some clues. Several ice ages have occurred during Earth's history. And each ice age was followed by a warming trend. If the past provides hints about the future, there will most certainly be another period of global cooling, perhaps followed by another ice age. Some scientists are almost certain of this; it is only the timing of these events that remains uncertain. For now, the sea level still appears to be rising, very slightly, each year.

The Water Cycle

Water falls to the ground as rain, snow, sleet, and hail. These forms of moisture that fall to the earth are called **precipitation**, and they become the streams and rivers that eventually flow into the oceans. The land area through which water passes on its way to the ocean is called a **watershed**. Rain even falls directly over the ocean. You may wonder, then, why the sea level doesn't keep rising indefinitely. If you look at Figure 15-3, you will see that water also moves from the ocean to the atmosphere and back again to the land. This continuous movement of water is called the **water cycle**. The water cycle is responsible for the reuse, or recycling, of this most important of natural resources.

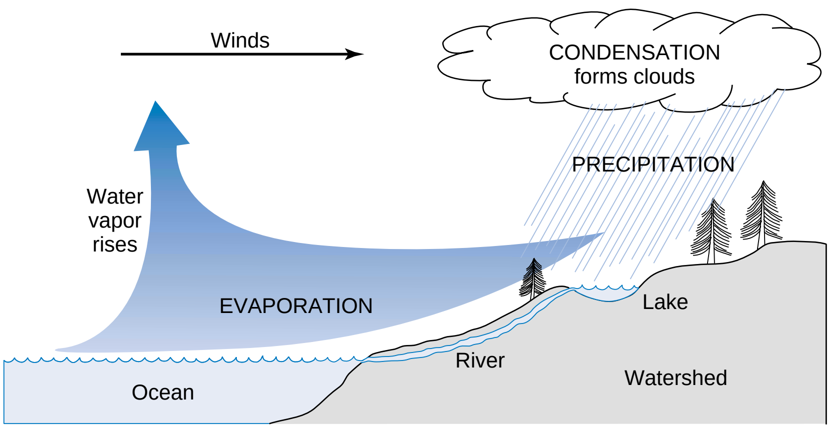


Figure 15-3 Earth's water cycle occurs through the processes of evaporation, condensation, and precipitation.

Follow the pathway of water. One of the stages in the water cycle is **evaporation**. Evaporation is the process by which liquid water changes to a gas. During evaporation, water molecules at the water's surface move into the air as water vapor, a gas. You cannot observe water molecules moving from a liquid to a gas. The water molecules are too small and too far apart to be seen. But if weather conditions are just right, you can observe water vapor in the air. If the temperature is cold enough, water vapor forms a cloud. Fog is a cloud of water vapor that forms close to the ground.

The process of cloud formation is called **condensation**. Condensation occurs when molecules of water vapor come close enough together to form a cloud. Condensation is another stage in the water cycle. Clouds are moist because they contain tiny droplets of water. If the droplets are heavy enough, they fall to the earth as rain or another form of precipitation. Thus, precipitation is an important part of the water cycle. As a result of the water cycle, freshwater is returned to the land to be used by plants and animals. Eventually, this water returns to the ocean.

15.2 Section Review

1. Why was the sea level lower during the last ice age? Why is the sea level higher today?
2. What is Earth's water budget? How much of it is freshwater?
3. Why doesn't the sea level rise continuously as water from rivers and rainfall enters the ocean?

15.3 WATER AS A SOLVENT

The next time it rains, observe some puddles of water. Note that, after they dry up, a residue of substances is left behind. Even tap water can leave a stain when it evaporates from a drinking glass or tabletop. The stain, or residue, includes chemical substances that were dissolved in the water. A liquid, such as water, that contains dissolved substances is called a **solvent.** Water is a good solvent because it can dissolve many different substances, including salt. In fact, water is so good at dissolving substances that it is often called the universal solvent. Ocean water contains many dissolved substances. The study of the chemical substances that are found in ocean water is a branch of marine science called *chemical oceanography.*

Substances in Sea Water

Ocean water is made up of about 96.5 percent water molecules. The remaining 3.5 percent is mostly salt, which is dissolved in the water. Any substance that water holds in a dissolved state is called a **solute**. In ocean water, salt is a solute because it is dissolved in water, the solvent. Salt mixed with water forms salt water, a **solution**. The relationship among solute, solvent, and solution can be seen in the following equation.

Salt	+	Water	⟶	Salt water
(solute)		*(solvent)*		*(solution)*

Many solutions, like ocean water, are also mixtures. A **mixture** contains two or more substances that can be separated by ordinary physical means. For example, seawater contains salts and water. You can separate the salt from the water by putting some ocean water in a beaker. After a short time, the water will evaporate, leaving a residue of salt behind. You can hasten this process by heating the beaker, causing the water to evaporate more quickly.

The salts dissolved in ocean water are called *sea salts*. A sea salt is a type of compound. A **compound** is a substance that contains two or more kinds of atoms that are chemically joined, or bonded, together. The compound sodium chloride is the most common of the sea salts. You already know it by its common name, table salt. Sodium chloride is made up of the elements sodium (Na) and chlorine (Cl). (See Table 15-1, which lists the sea salts, on page 368.)

Ocean water can be prepared by dissolving sea salts in tap water. When a salt is added to water, the elements joined in the compound break apart, or ionize, to form ions. An *ion* is an atom that is not electrically neutral and thus has a charge. Ordinary table salt (NaCl), when added to water, ionizes into the positively charged sodium ion (Na^+) and the negatively charged chloride ion (Cl^-).

Another compound found in the ocean is calcium carbonate ($CaCO_3$). Calcium carbonate is also called *limestone*. It is the main component of seashells and of the limestone that makes up coral

TABLE 15-1 SEA SALTS FOUND IN OCEAN WATER (PERCENT)

Type of Sea Salt	Sea Salt Content
Sodium chloride	67.0
Magnesium chloride	14.6
Sodium sulfate	11.6
Calcium chloride	3.5
Potassium chloride	2.2
Other sea salts	1.1

reefs. Chalk, which was originally formed in the ocean, is made of calcium carbonate. The wearing down of seashells and coral reefs releases calcium carbonate into the seawater. Again, in this case, its ions are released: the positively charged ion Ca^{2+} and the negatively charged ion CO_3^{2-}. Note that each of these ions has a charge of 2.

The charge on each ion results from the presence or absence of the negatively charged particles called *electrons*. An excess of electrons produces an ion with a negative charge; a lack of electrons produces an ion with a positive charge.

Ions with opposite charges are attracted to each other by a force known as *electrostatic force*. The elements in both sodium chloride (NaCl) and calcium chloride ($CaCl_2$) are held together by electrostatic forces when these compounds exist as solids (not in solution). However, when they are in solution, these solids break into ions because the electrostatic forces in the water pull them apart.

The Water Molecule

How does salt dissolve in water? We have to focus on the structure of a molecule of water before we are able to answer this question. Look at Figure 15-4. The chemical, or molecular, formula for water is H_2O. A water molecule is formed from two atoms of hydrogen and one atom of oxygen. A *molecule* is defined as the smallest quantity of an element or a compound that can exist without losing the properties of that substance.

Notice in Figure 15-4 that the oxygen atom is larger than the hydrogen atom. An atom of oxygen contains more atomic particles than does a hydrogen atom. Each oxygen atom has eight protons and eight neutrons in its nucleus. Each of these atomic particles is assigned a weight of one, so an atom of oxygen has an atomic weight of 16. Each atom of oxygen also has eight electrons. The electrons are located in an area surrounding the atom's nucleus. However, the weight of an electron is so small that it does not contribute to the atomic weight. Hydrogen has one proton and no neutrons in its nucleus. It also has one electron. Because it contains only one proton, the hydrogen atom is assigned a weight of one.

Now let's focus on a single molecule of water. The oxygen atom has more electrons than do the two hydrogen atoms. Therefore the oxygen side of a water molecule is more negative than the hydrogen side. The hydrogen side of a water molecule is less negative, or more positive, than the oxygen side. The opposite charges on the two sides of all water molecules cause them to be attracted to each other, forming weak hydrogen bonds.

When you sprinkle table salt (NaCl) into tap water, the salt dissolves because the opposite charges on the water molecules attract ions from the salt. The oppositely charged water molecule, which is called a polar molecule, behaves like a magnet. When sodium chloride is added to water, the Na^+ is attracted to the negative end of the water molecule, and the Cl^- is attracted to the positive side. The sodium and chloride ions separate and become surrounded by water molecules. The result is that salt dissolves in water.

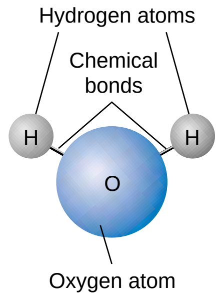


Figure 15-4 The water molecule; hydrogen and oxygen atoms are held together by chemical bonds.

pH

Not all water molecules exist as the polar molecule shown in Figure 15-4. A small number of water molecules separate into positive and negative ions, as shown in the following equation:

$$\underset{\textit{Water}}{H_2O} \longrightarrow \underset{\textit{Hydrogen ion}}{H^+} + \underset{\textit{Hydroxyl ion}}{OH^-}$$

The ion with the positive charge is called the *hydrogen ion,* and the ion with the negative charge is called the *hydroxyl ion.*

A solution that contains a larger number of hydrogen (rather than hydroxyl) ions is called an **acid**. A solution that has a larger number of hydroxyl (rather than hydrogen) ions (OH^-) is called a **base**, or alkaline solution. The degree of acidity or alkalinity of a solution is called its **pH**. The term *pH* refers to the concentration (power) of hydrogen ions in a solution. The pH of a solution is measured on a scale that runs from 0 to 14.0. An acid has a pH that lies between the numbers 0 and 6.9 on the pH scale. One characteristic of an acid is its sour taste. Imagine biting into a lemon or a lime. The sour taste of these two fruits is due to the presence of citric acid ($C_6H_8O_7$), a substance that in water produces a large number of hydrogen ions.

A basic solution has a pH that lies between 7.1 and 14.0 on the pH scale. Bases include sodium hydroxide (NaOH) and potassium hydroxide (KOH). Soaps and detergents are bases. Some common medicines that are used to neutralize stomach acid are bases. If a substance contains equal numbers of hydrogen ions and hydroxyl ions it is called **neutral**. A neutral solution has a pH of 7.0. Find the pH of ocean water on the pH scale shown in Figure 15-5. As you can see, the pH of ocean water is approximately 8.0. Is ocean water acidic or basic?

Sometimes bodies of water can become acidic due to acid rain, also called **acid precipitation**. Acid rain is formed when chemicals released by the burning of fossil fuels are absorbed by moisture in the air. Acid rain has changed the pH of hundreds of lakes and ponds. In extreme cases, the pH of these bodies of water may fall as low as 4 or 5. This high acidity has been responsible for a drop in fish populations in many freshwater environments.

Ocean water has a more stable pH and is affected less by acid rain than is a smaller body of water such as a lake or pond. When it rains into the ocean, the large volume of ocean water dilutes the acid rain. Also, chemicals in ocean water, called **buffers**, help main-

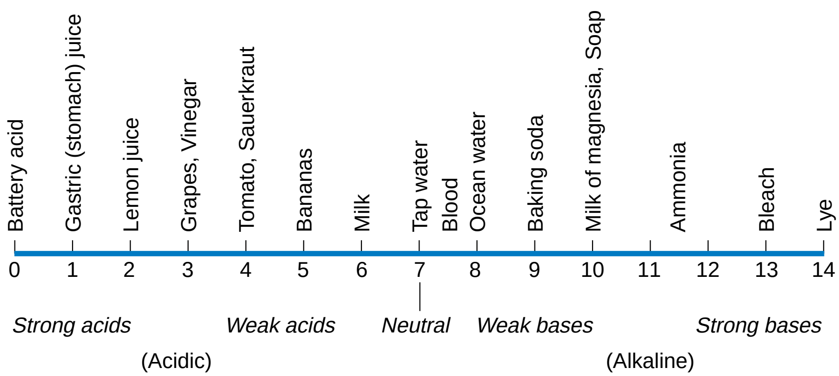


Figure 15-5 The pH scale; ocean water is slightly basic due to its carbonate buffer.

tain a stable pH. A buffer is a substance that lessens the tendency of a solution to become too acidic or too basic. One of the buffers present in ocean water is the carbonate buffer (CO_3^{2-}). The carbonate buffer can accept hydrogen ions, causing the water to become less acidic or more basic. The carbonate buffer can also release hydrogen ions, making the water more acidic and less basic. The actions of this buffer can be seen in the following reaction:

Carbon dioxide + Water ⟶ Carbonic acid ⟶ Bicarbonate ion + Hydrogen ⟶ Carbonate ion + Hydrogen ions

Acidity increases (an increase in hydrogen ions) ⟶

$$CO_2 + H_2O \longrightarrow H_2CO_3 \longrightarrow HCO_3^- + H^+ \longrightarrow CO_3^{2-} + 2H^+$$

⟵ Acidity decreases (hydrogen ions are removed)

In ocean water, the buffering action goes to the left, producing a slightly basic pH that lies between 8 and 9. However, the pH of ocean water varies slightly within this range over each 24-hour period, as shown in the graph in Figure 15-6. During the day, as marine algae carry out photosynthesis (the manufacture of simple carbohydrates), CO_2 is removed from the water. The removal of dissolved CO_2 forces the buffering reaction to move to the left, which removes hydrogen ions. As hydrogen ions are removed, the water becomes less acidic or more basic. The pH of ocean water rises. At night, photosynthesis does not occur—but respiration (the release of stored energy found in nutrients) does. Respiration adds CO_2 to the water. The CO_2 causes the buffering reaction to move to the right. The number of hydrogen ions is increased, and the pH of ocean

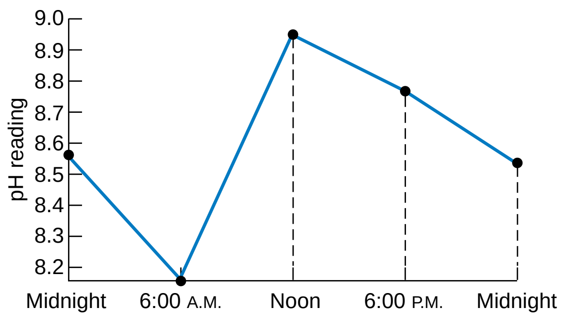


Figure 15–6 Change in ocean water pH over a 24-hour period.

water is lowered. The opposite effects of photosynthesis and respiration cause the slight changes in ocean water pH that occur over each 24-hour period.

Oxygen in the Water

If you try to hold your breath, your body's need for air will overcome your attempt not to inhale within a minute or two. You need air to survive—specifically, the oxygen in the air, which is the gas produced by plants during photosynthesis. It may surprise you to learn that a great deal of Earth's supply of oxygen is the result of photosynthesis carried out by algae and plants that live in water.

The oxygen produced in photosynthesis is in the form of molecular oxygen (O_2). After oxygen leaves the plant, some of it dissolves in the water. The rest is released into the atmosphere at the water's surface (some of which goes back into the sea). The oxygen you take in with every breath includes some that comes from marine plants and algae!

The oxygen that dissolves in ocean water is called **dissolved oxygen**, or **DO** for short. Some marine organisms take in oxygen through pores and moist cell membranes on their body surface; other organisms, such as fish, obtain their oxygen through membranes in special structures called gills.

However, oxygen is not very soluble in water. The quantity is fairly small, so scientists measure the DO in parts per million (ppm). Ocean water can hold from 1 to 12 ppm of dissolved oxygen (depending on the water's temperature). This amount is much less than the amount of oxygen in air, which is about 200 ppm.

How is oxygen distributed in ocean water? Figure 15-7 shows the distribution of oxygen from the surface of the ocean to the bottom. You can see in the graph that, as depth increases to about 1000 meters below the surface, the DO in the water decreases. Notice that the lowest amount of oxygen, called the **O_2 minimum zone**, is located at 1000 meters and not at the bottom of the ocean. The bottom contains a slightly higher level of DO than the O_2 minimum zone. This increase in DO on the bottom is a result of the temperature and pressure of the water at this depth. Cold, dense water contains a higher concentration of oxygen than does warm, less dense water.

Why is there more DO at the surface of the ocean than in the

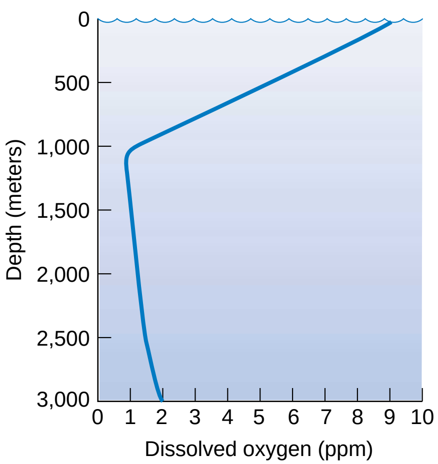


Figure 15-7 Dissolved oxygen levels at different ocean depths.

depths? Recall that much of the oxygen in ocean water is produced by marine plants and algae within the sunlit zone, which extends down to a depth of about 60 meters. Since photosynthesizing plants cannot live in the darkness below this depth, the level of dissolved oxygen found there is much less.

You may wonder why there is any oxygen at all dissolved in the deepest parts of the ocean. Actually, the ocean is not a calm, unmoving body of water. Waves and currents circulate the water throughout the ocean, causing some oxygen from surface waters to reach the lowest depths.

15.3 Section Review

1. How does salt (sodium chloride) dissolve in water?
2. Why is the ocean more basic (alkaline) than a freshwater pond?
3. What is the relationship between DO and ocean depth?

15.4 THE SALTY SEA

Fill two beakers, one with clean ocean water and the other with tap water. Ask a classmate to distinguish between them. It won't be easy, because they both look alike; yet the beaker of ocean water contains 3.5 percent salt. How can you tell them apart? Of course, you (or your classmate) could taste a sample. However, this method of testing is not the best way to determine the chemical makeup of an unknown substance—and it should ***never*** be used to test any substances in a laboratory (or anywhere else)! A much safer way is to use an *indicator solution*. An indicator solution changes in the presence of a particular substance. For example, you can use an indicator called silver nitrate (AgNO3). When silver nitrate is added to salt water, a milky white substance forms. When silver nitrate is added to freshwater, no change in the solution is observed. The milky white substance is called a **precipitate**. A precipitate is a solid substance that may be produced when two liquids are mixed. In this case, the precipitate in the beaker of salt water is the compound silver chloride (AgCl). Silver nitrate will produce a precipitate only when it is added to a solution that contains chloride ions. This chemical reaction is summarized in the following equation:

$$\underset{\textit{sodium chloride}}{\mathrm{NaCl}} + \underset{\textit{silver nitrate}}{\mathrm{AgNO_3}} \longrightarrow \underset{\textit{silver chloride}}{\mathrm{AgCl}} + \underset{\textit{sodium nitrate}}{\mathrm{NaNO_3}}$$

The silver nitrate test for chloride ions is a qualitative test. A *qualitative test* is used to reveal the presence or absence of a substance. In this case, it tests whether there are chloride ions in solution. A test that measures the actual amount of a substance (numerically) is called a *quantitative test*. For example, the hydrometer described in Chapter 2 is used to measure the salinity of water in units of specific gravity. Thus, you can use a hydrometer to quantitatively test the salt content of your aquarium tank.

Salinity Variations

Does the salinity of ocean water vary around the world? Look at the salinity chart of surface waters shown in Figure 15-8. As you can see, the salinity, expressed in parts per trillion (ppt), does not vary greatly from place to place, but there are differences. For example, the middle of the Pacific shows a salinity of over 35 ppt, whereas the middle of the Atlantic shows a salinity of over 37 ppt. Readings from the Red Sea and the Mediterranean Sea can be even higher. How can the high salinity in these two seas be explained? Both seas

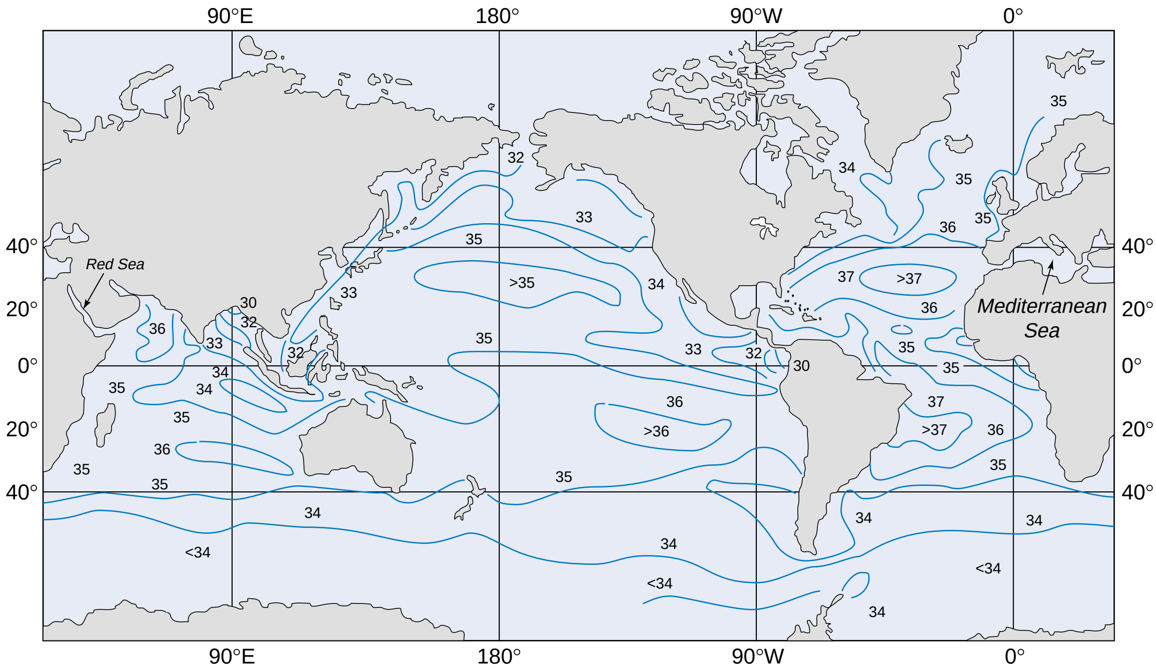


Figure 15-8 Salinity ranges of surface ocean waters.

are in hot areas with high levels of evaporation and less precipitation than open oceans at the same latitude. When water evaporates from the ocean, salt is left behind. Thus, evaporation increases the salinity of an ocean, especially if it is a small, enclosed sea such as the Mediterranean. (See Figure 15-9 on page 376.)

Salinity also varies with latitude. Look again at Figure 15-8. Notice that at 20 degrees north latitude and 20 degrees south latitude, salinity is approximately 36 ppt, higher than at the equator. The salinity is lower at the equator because it rains more there. Rain dilutes the ocean, making it less salty. At the 20 degrees north and south latitudes, there is less precipitation and more evaporation. The lower rainfall and greater evaporation cause the ocean water in this area to be slightly saltier than the water at the equator.

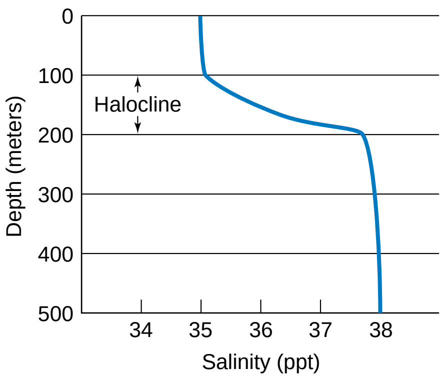
You may live near the coast where a river or stream enters the ocean. Freshwater from these sources lowers the salinity of the nearby ocean. Rainwater runoff from the land also lowers the salinity of ocean water near the coast.

Salinity also varies with the depth of the ocean. Look at the graph in Figure 15-10, on page 376. The salinity at the bottom of

Figure 15-9 The Mediterranean, which is a small, enclosed sea, has a higher salinity than that of the Atlantic Ocean.

the ocean is greater than at the surface. However, the change in salinity that occurs with increasing depth does not occur at a uniform rate. There is a layer of water, located at a depth between 100 and 200 meters, called the **halocline**. The halocline layer shows a rapid change (increase) in salinity. Why does salinity increase with depth? It has to do with the temperature of the water. Water is much colder at great depths than at the surface. You may recall that

Figure 15-10 Salinity levels at different ocean depths; note the halocline.



cold water contains molecules that are closer together. Cold water also causes salt ions to move closer together, thus increasing the salinity. In warmer surface water, the ions are farther apart, making the water less salty.

Why the Sea Is Salty

The salty taste of ocean water is mainly due to the presence of sodium chloride, one of various salts found in ocean water. The ocean gets its salts from several different sources. Rivers and streams that flow into the ocean are not just an important source of freshwater. Salts eroded from streambeds and riverbeds, and from adjoining land areas, also flow toward the sea. These salts are important to life in the ocean in various ways. Some marine organisms use salts directly. For example, to make their shells of calcium carbonate (a type of salt), mollusks remove calcium from ocean water. Silica is absorbed by diatoms (unicellular organisms) and used to make up their glassy cell walls. The sodium and chloride ions in NaCl are not removed in large amounts from the water, so these ions accumulate in the sea.

Another source of salt is the ocean floor itself. In ancient times, the Norse people believed that a giant "salt mill" ground salt from rocks on the ocean floor. Actually, this folktale was not too far from the scientific truth. Recently, oceanographers have discovered hot water spewing from hydrothermal vents on the seafloor. This hot water contains minerals dissolved from deposits found beneath the ocean floor. These minerals include sodium and chloride, the main components of sea salts.

15.4 Section Review

1. How does the salinity of ocean water vary with depth?
2. How does the salinity of the ocean vary with latitude?
3. Describe some sources for the salt found in the sea.

Laboratory Investigation 15

Determining Seawater Salinity

PROBLEM: How much salt is dissolved in ocean water?

SKILLS: Using a graduated cylinder and a triple-beam balance; calculating percentages.

MATERIALS: Triple-beam balance, 100-mL beakers, graduated cylinder, salt water, Bunsen burner or hot plate, beaker cover, tongs, cooling pad.

PROCEDURE

1. Balance your scale at the zero point. Determine the mass of an empty 100-mL beaker. In your notebook, record the amount in a copy of Table 15-2.

2. Measure out 20 mL of salt water into a graduated cylinder. Pour the 20 mL into the 100-mL beaker. Use the balance to find the mass of the beaker containing the water. Record the amount in the table.

3. Place the beaker of water over the burner or hot plate and heat it until all the water is boiled off. Place a cover on the beaker when most of the water is boiled off to prevent the salt from splattering out. (See Figure 15-11.)

4. Use the tongs to remove the beaker from the hot plate. Place the beaker on a cooling pad for a few minutes; then place it on the balance to find its mass. Record the mass of the beaker plus salt in your copy of Table 15-2.

5. Calculate the mass of the salt and the mass of the water (subtract the mass of the empty beaker from that amount plus salt and that amount plus water, respectively) and write the amounts in the table. To calculate percent salt, divide the results for #3 into the results for #5 and multiply by 100.

TABLE 15-2 SALINITY DETERMINATION

1. Mass of empty beaker	________ grams
2. Mass of beaker plus water	________ grams
3. Mass of water (subtract #1 from #2)	________ grams
4. Mass of beaker plus salt	________ grams
5. Mass of salt (subtract #1 from #4)	________ grams

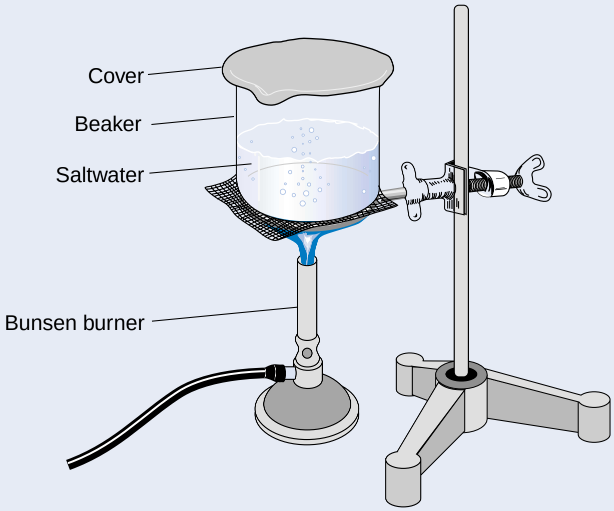


Figure 15-11 Heating a beaker of salt water to determine the salinity.

OBSERVATIONS AND ANALYSES

1. What is meant by salinity? What is the salinity of your water sample?
2. Give two reasons why students using the same water samples may determine different salinities.
3. Which location would have a higher salinity, an estuary or the open ocean? Explain your answer.

Chapter 15 Review

Answer the following questions on a separate sheet of paper.

Vocabulary

The following list contains all the boldface terms in this chapter.

acid, acid precipitation, base, buffers, compound, condensation, dissolved oxygen (DO), evaporation, halocline, latitude, longitude, mixture, neutral, O_2 minimum zone, pH, precipitate, precipitation, sea, sea level, solute, solution, solvent, water budget, water cycle, watershed

Fill In

Use one of the vocabulary terms listed above to complete each sentence.

1. The acidity or alkalinity of a substance is called its ________.
2. Forms of moisture that fall to the earth are called ________.
3. Liquid water changes to a gas in the process of ________.
4. Molecules of water vapor form a cloud when ________ occurs.
5. The total amount of water on Earth makes up its ________.

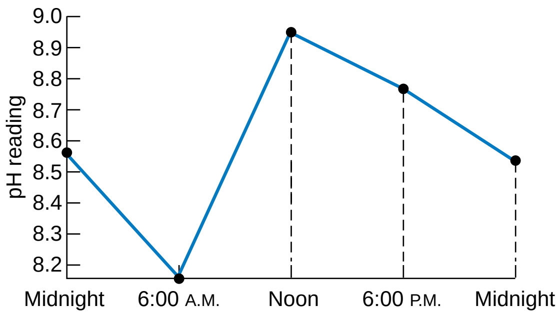
Think and Write

Use the information in this chapter to respond to these items.

6. Why does water at the ocean bottom have more dissolved oxygen than seawater at a depth of about 1000 meters?
7. Explain why a small sea may have a higher salinity than the open ocean at the same latitude.
8. How do the processes of evaporation and condensation contribute to the water cycle?

Inquiry

Base your answers to questions 9 through 11 on the graph below, which shows fluctuations in the pH of ocean water over a 24-hour period, and on your knowledge of marine science.



9. At what time of the day is ocean water the least alkaline?
   a. noon *b.* 6:00 A.M. *c.* midnight *d.* 6:00 P.M.

10. Which statement is accurate, based on data in the graph?
    a. The pH varies from very acidic to very basic over 24 hours.
    b. From midnight to 6:00 A.M., there is a decrease in pH.
    c. From 6:00 A.M. to noon, there is a decrease in pH.
    d. From noon to 6:00 P.M., there is an increase in pH.

11. What conclusion can be drawn from the information in the graph? *a.* The pH of ocean water varies during a 24-hour period. *b.* The time of day has no impact on the pH of ocean water. *c.* The average pH of ocean water is about 8.9. *d.* The pH of ocean water falls within an acidic range.

Multiple Choice

Choose the response that best completes the sentence or answers the question.

12. The continuous movement of water between the ocean, atmosphere, and land is called the *a.* water budget *b.* water cycle *c.* water level *d.* watershed.

13. The layer of ocean water in which the salinity increases is called the *a.* mixture *b.* watershed *c.* halocline *d.* solvent.

Base your answers to questions 14 and 15 on the graph on page 373.

14. As the depth of the ocean increases, the amount of dissolved oxygen *a.* increases only *b.* decreases only *c.* increases and then decreases *d.* decreases and then increases slightly.

15. At about what depth does the O_2 minimum zone appear? *a.* 100 meters *b.* 500 meters *c.* 700 meters *d.* 1000 meters

16. A likely reason for any decrease in dissolved oxygen below 60 meters would be *a.* the respiration of marine animals *b.* a decrease in pH *c.* a decrease in photosynthesis *d.* an increase in salinity.

17. The pH of ocean water is about *a.* 1 *b.* 3 *c.* 5 *d.* 8.

18. Water is an excellent solvent mainly because *a.* it is a liquid *b.* it can dissolve other substances *c.* water molecules are uncharged *d.* objects can float in it.

19. Of the following items, which one is probably *not* a source of O_2 in seawater? *a.* algae and plants *b.* waves *c.* the atmosphere *d.* water molecules

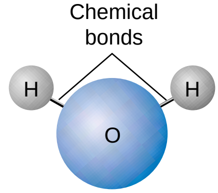
20. If a sample of ocean water is tested and found to have a pH of 6, it means that *a.* OH ions outnumber H ions *b.* H ions outnumber OH ions *c.* H and OH ions are equal in number *d.* the water is slightly alkaline.

21. The correct sequence of stages in the water cycle is *a.* precipitation, condensation, evaporation *b.* evaporation, precipitation, condensation *c.* condensation, evaporation, precipitation *d.* evaporation, condensation, precipitation.

Base your answer to question 22 on the graph on page 376.

22. The graph illustrates that *a.* as depth increases, salinity tends to decrease *b.* as depth increases, salinity tends to increase *c.* as depth increases, pressure decreases *d.* salinity does not change with depth.

23. The diagram at right represents a molecule of *a.* water *b.* sodium chloride *c.* carbon dioxide *d.* hydrogen peroxide.



24. The following equation, $H_2O \longrightarrow A + OH^-$, shows the dissociation of water into two substances. What missing substance does the letter *A* represent? *a.* H^- *b.* OH *c.* H_2 *d.* H^+

Research/Activity

Does ocean ice that melts cause the sea level to rise? Find out for yourself. Add a few ice cubes to a glass of water; be sure to fill the glass to the top (without overflowing). Place the glass on a dry paper towel. Let the water sit at room temperature until the ice cubes have melted. Did the water overflow? Report your results. What is the relationship between melting ice and sea level? Does it make a difference if the ice is located on land or in the sea? Explain.