Section 3

Ocean Water Chemistry

Reading Preview

Key Concepts

- How salty is ocean water?
- How do the temperature and gas content of ocean water vary?
- How do conditions in the ocean change with depth?

Key Terms

- salinity
- submersible

Target Reading Skill

Asking Questions Before you read, preview the red headings. In a graphic organizer like the one below, ask a *how* or *what* question for each heading. As you read, answer your questions.

Ocean Water Chemistry

Question	Answer
How salty is the ocean?	One kilogram of ocean water has . . .

Lab zone Discover Activity

Will the Eggs Sink or Float?

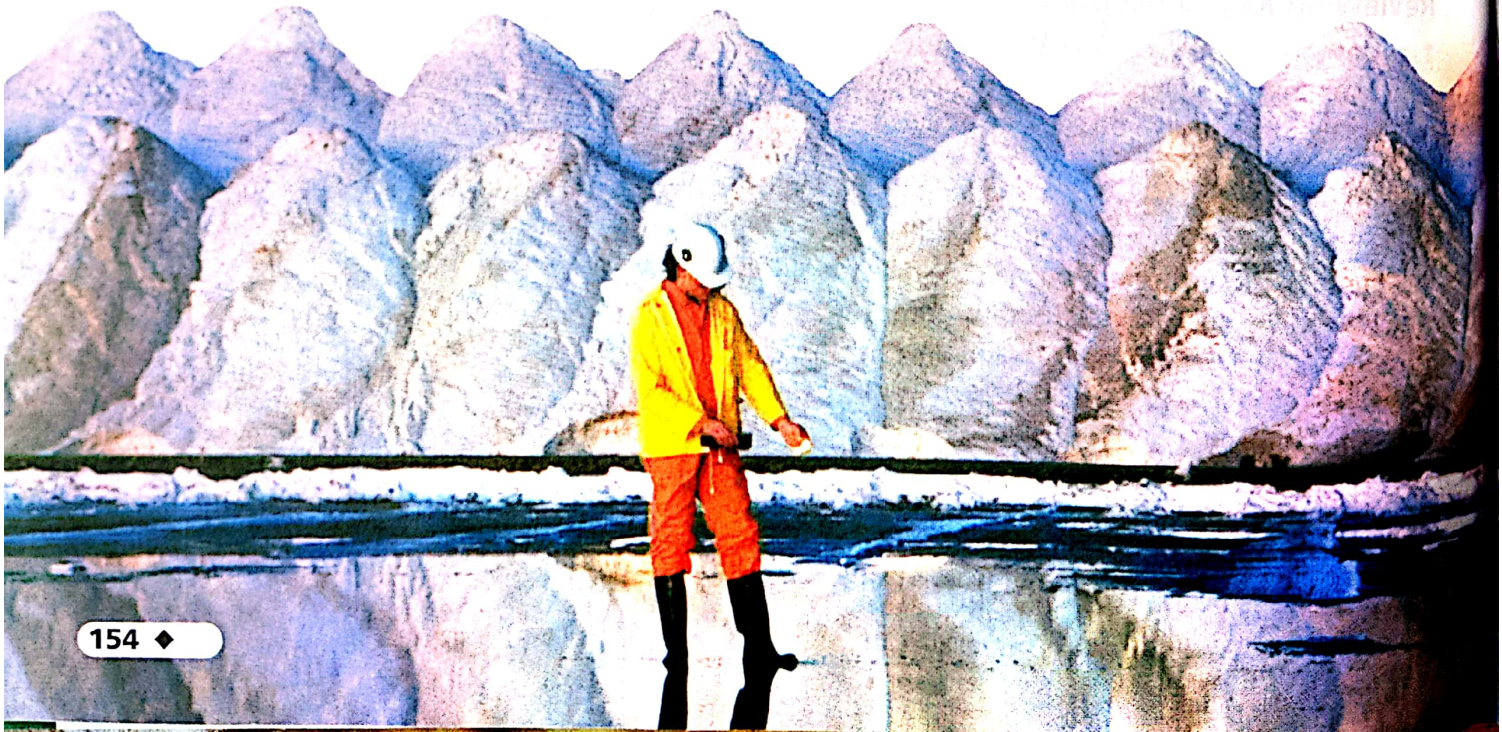
1. Fill two beakers or jars with tap water.
2. Add three teaspoons of salt to one beaker. Stir until it dissolves.
3. Place a whole, uncooked egg in each jar. Handle the eggs gently to avoid breakage. Observe what happens to each egg.
4. Wash your hands when you are finished with this activity.

Think It Over

Observing Compare what happens to the two eggs. What does this tell you about the difference between salt water and fresh water?

If you've ever swallowed some water while you were swimming in the ocean, you know that the ocean is salty. Why? According to an old Swedish legend, it's all because of a magic mill. This mill could grind out anything its owner wanted, such as herring, porridge, or even gold. A greedy sea captain once stole the mill and took it away on his ship, but without finding out how to use it. He asked the mill to grind some salt but then could not stop it. The mill ground more and more salt, until the captain's ship sank from its weight. According to the tale, the mill is still at the bottom of the sea, grinding out salt!

Salt storage area ▼



The Salty Ocean

Probably no one ever took this legend seriously, even when it was first told. The scientific explanation for the ocean's saltiness begins with the early stages of Earth's history, when the ocean covered much of the surface of the planet. Undersea volcanoes erupted, spewing chemicals into the water. Gradually, the lava from these volcanic eruptions built up areas of land. Rain fell on the bare land, washing more chemicals from the rocks into the ocean. Over time, these dissolved substances built up to the levels present in the ocean today.

Salinity Just how salty is the ocean? If you boiled a kilogram of ocean water in a pot until all the water was gone, there would be about 35 grams of salts left in the pot. **On average, one kilogram of ocean water contains about 35 grams of salts—that is, 35 parts per thousand.** The total amount of dissolved salts in a sample of water is the **salinity** of that sample.

The substance you know as table salt—sodium chloride—is the salt present in the greatest amount in ocean water. When sodium chloride dissolves in water, it separates into sodium and chloride particles called ions. Other salts, such as magnesium chloride, form ions in water in the same way. Together, chloride and sodium make up almost 86 percent of the ions dissolved in ocean water. Ocean water also contains smaller amounts of about a dozen other ions, including magnesium and calcium, and other substances that organisms need, such as nitrogen and phosphorus.

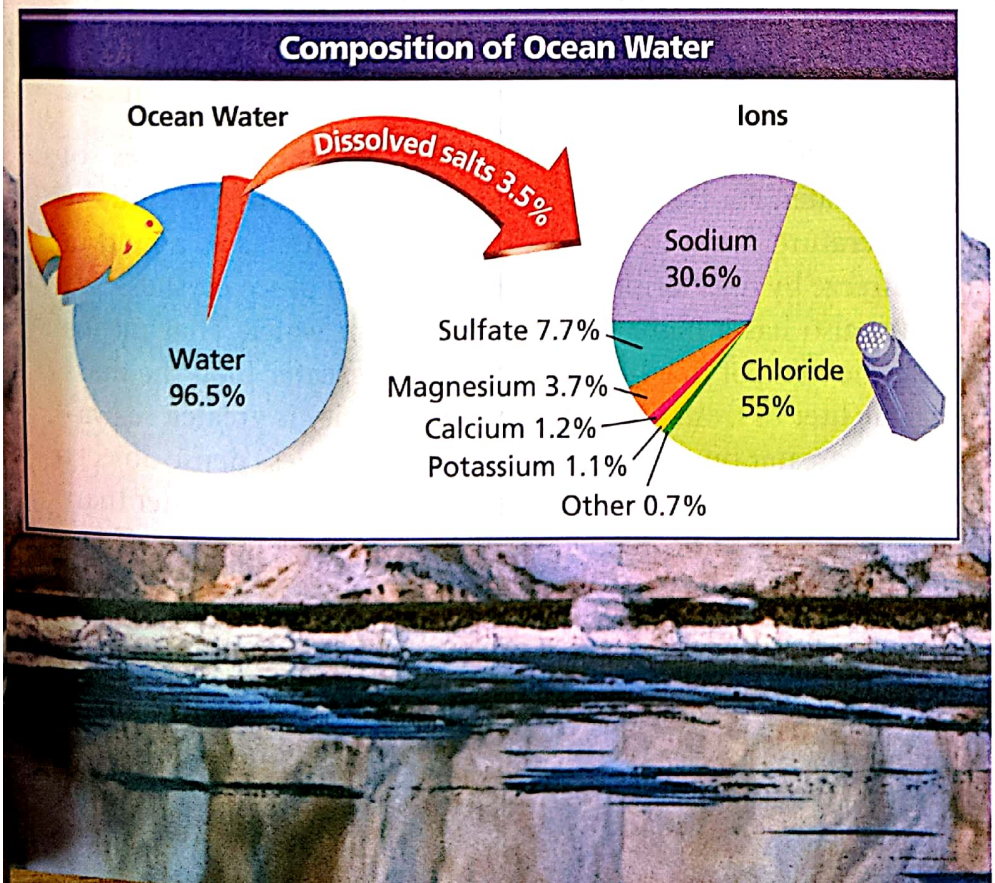


FIGURE 13
Composition of Ocean Water Ocean water contains many different dissolved salts. When salts dissolve, they separate into particles called ions.
Reading Graphs *Which ion is most common in ocean water?*

FIGURE 14
Salinity and Density These people are relaxing with the paper while floating in the water! The Dead Sea between Israel and Jordan is so salty that people float easily on its surface.
Relating Cause and Effect *How is the area's hot, dry climate related to the Dead Sea's high salinity?*

Variations in Salinity In most parts of the ocean, the salinity is between 34 and 37 parts per thousand. But near the ocean's surface, rain, snow, and melting ice add fresh water, lowering the salinity. Salinity is also lower near the mouths of large rivers such as the Amazon or Mississippi. These rivers empty great amounts of fresh water into the ocean. Evaporation, on the other hand, increases salinity, since the salt is left behind as the water evaporates. For example, in the Red Sea, where the climate is hot and dry, the salinity can be as high as 41 parts per thousand. Salinity can also be higher near the poles. As the surface water freezes into ice, the salt is left behind in the remaining water.

Effects of Salinity Salinity affects several properties of ocean water. For instance, ocean water does not freeze until the temperature drops to about –1.9°C. The salt acts as a kind of antifreeze by interfering with the formation of ice crystals. Salt water also has a higher density than fresh water. That means that the mass of one liter of salt water is greater than the mass of one liter of fresh water. Because its density is greater, seawater has greater buoyancy. It lifts, or buoys up, less dense objects floating in it. This is why an egg floats higher in salt water than in fresh water, and why the people in Figure 14 float so effortlessly in the Dead Sea.

Reading Checkpoint **Why does salt water have greater buoyancy than fresh water?**

Math Skills

Calculating Density

To calculate the density of a substance, divide the mass of the substance by its volume.

$$\text{Density} = \frac{\text{Mass}}{\text{Volume}}$$

For example, 1 liter (L) of ocean water has a mass of 1.03 kilograms (kg). Therefore,

$$\text{Density} = \frac{1.03\ \text{kg}}{1.00\ \text{L}}$$

$$\text{Density} = 1.03\ \text{kg/L}$$

Practice Problems A 5-liter sample of one type of crude oil has a mass of 4.10 kg. What is its density? If this oil spilled on the ocean's surface, would it sink or float? Explain your answer in terms of density.

Other Ocean Properties

In New England, the news reports on New Year's Day often feature the shivering members of a "Polar Bear Club" taking a dip in the icy Atlantic Ocean. Yet on the same day, people enjoy the warm waters of a Puerto Rico beach. **Like temperatures on land, temperatures at the surface of the ocean vary with location and the seasons. Gases in ocean water vary as well.**

Temperature of Ocean Water Why do surface temperatures of the ocean vary from place to place? The broad surface of the ocean absorbs energy from the sun. Near the equator, surface ocean temperatures often reach 25°C, about room temperature. The temperature drops as you travel away from the equator.

Because warm water is less dense than cold water, warm water forms only a thin layer on the ocean surface. Generally, the deeper you descend into the ocean, the colder and denser the water becomes. When water temperature is lower, the water molecules stay closer together than at higher temperatures. So, a sample of cold water has more water molecules than a sample of warm water of the same volume. The sample of cold water is denser.

Gases in Ocean Water Just as land organisms use gases found in air, ocean organisms use gases found in ocean water. Two gases that ocean organisms use are carbon dioxide and oxygen.

Carbon dioxide is about 60 times as plentiful in the oceans as in the air. Algae need carbon dioxide for photosynthesis. Animals such as corals also use carbon dioxide, which provides the carbon to build their hard skeletons.

Unlike carbon dioxide, oxygen is scarcer in seawater than in air. Oxygen is most plentiful in seawater near the surface. Oxygen in seawater comes from the air and from algae in the ocean, as a product of photosynthesis. The amount of oxygen in seawater is affected by the water temperature. The cold waters in the polar regions contain more oxygen than warm, tropical waters. But there is still enough oxygen in tropical seas to support a variety of organisms.

Reading Checkpoint **What are two sources of oxygen in ocean water?**

FIGURE 15
Organisms and Ocean Temperatures
From the warmest tropical waters to the coldest Antarctic sea, you can find organisms that are adapted to extreme ocean temperatures.

▲ This longfin anthias fish swimming near Hawaii lives in one of the warmest parts of the Pacific Ocean.

▲ This rockcod is swimming through a hole in an iceberg in near-freezing ocean water.

FIGURE 16

The Water Column

Conditions change as you descend to the ocean floor. **Interpreting Diagrams** *What two factors affect the density of ocean water?*

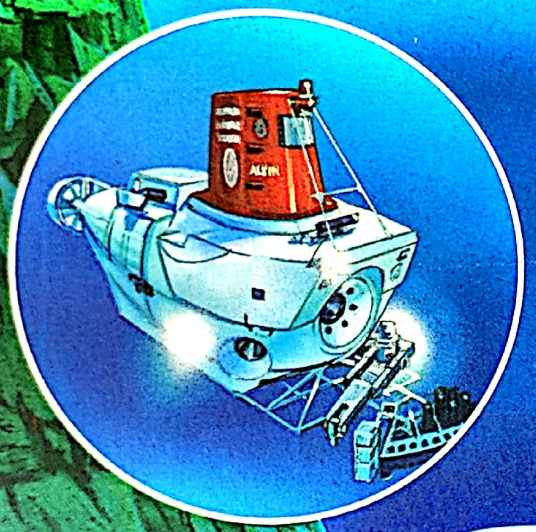
A scuba diver can descend to about 40 meters.

Surface Zone
Extends from the surface to about 200 meters. Average temperature worldwide is 17.5°C.

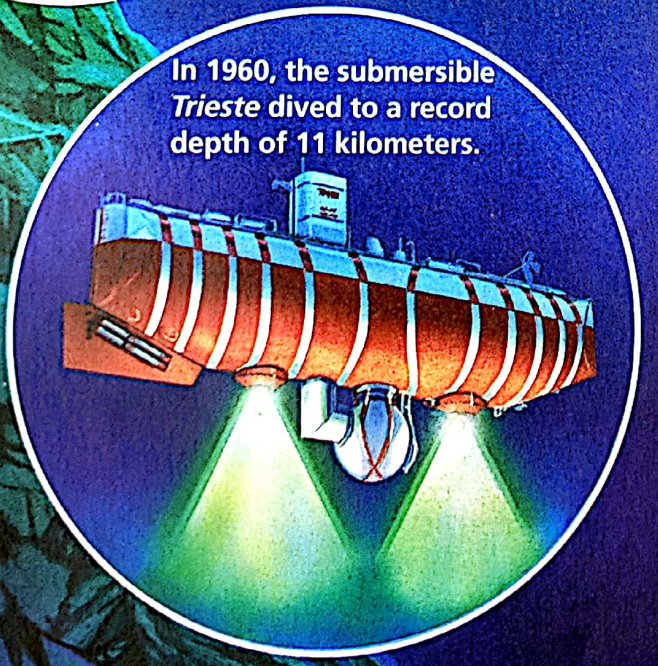
Transition Zone
Extends from bottom of the surface zone to about 1 kilometer. Temperature rapidly drops to 4°C.

Deep Zone
Extends from about 1 kilometer to ocean floor. Average temperature is 3.5°C.

The submersible *Alvin* can descend to about 4 kilometers.



In 1960, the submersible *Trieste* dived to a record depth of 11 kilometers.



Depth

0.5 km

1.0 km

1.5 km

2.0 km

2.5 km

3.0 km

3.5 km

4.0 km

PRESSURE INCREASES

3.8 km
Average ocean depth

Color and Light
Sunlight penetrates the surface of the ocean. It appears first yellowish, then blue-green, as the water absorbs the red light. No light reaches below about 200 meters.

Temperature
Near the surface, temperature is affected by the weather above. In the transition zone, the temperature drops rapidly. In the deep zone, the water is always extremely cold.

Salinity
Rainfall decreases salinity near the surface, while evaporation increases salinity in warm, dry areas. Below the surface zone, salinity remains fairly constant throughout the water column.

Density
The density of seawater depends on temperature and salinity. The ocean is generally least dense in the surface zone, where it is warmest. However, higher salinity also increases density. The most dense water is found in the cold deep zone.

Pressure
Pressure increases at the rate of 10 times the air pressure at sea level per 100 meters of depth.

Changes With Depth

If you could descend from the ocean's surface to the ocean floor, you would pass through a vertical section of the ocean referred to as the water column. Figure 16 on the previous page shows some of the dramatic changes you would observe.

Decreasing Temperature **As you descend through the ocean, the water temperature decreases.** There are three temperature zones in the water column. The surface zone is the warmest. It typically extends from the surface to between 100 and 500 meters. The transition zone extends from the bottom of the surface zone to about 1 kilometer. Temperatures drop very quickly as you descend through the transition zone, to about 4°C. Below the transition zone is the deep zone. Average temperatures there are 3.5°C in most of the ocean.

Increasing Pressure Water pressure is the force exerted by the weight of water. **Pressure increases continuously with depth in the ocean.** Because of the high pressure in the deep ocean, divers can descend safely only to about 40 meters. To observe the deep ocean, scientists must use a **submersible,** an underwater vehicle built of materials that resist pressure.

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Reading Checkpoint What is a submersible?

Section 3 Assessment

Target Reading Skill **Asking Questions** Use the questions you wrote about the headings to help you answer the questions below.

Reviewing Key Concepts

1. a. **Defining** What is salinity? What is the average salinity of ocean water?
   b. **Describing** Describe one factor that increases the salinity of seawater and one factor that decreases its salinity.
   c. **Inferring** Would you expect the seawater just below the floating ice in the Arctic Ocean to be higher or lower in salinity than the water in the deepest part of the ocean? Explain.
2. a. **Identifying** Where would you find the warmest ocean temperatures on Earth?
   b. **Comparing and Contrasting** How do carbon dioxide and oxygen levels in the oceans compare to those in the air?
   c. **Relating Cause and Effect** How does the temperature of ocean water affect oxygen levels in the water?
3. a. **Reviewing** How do temperature and pressure change as you descend in the ocean?
   b. **Predicting** Where in the water column would you expect to find the following conditions: the highest pressure readings; the densest waters; the warmest temperatures?

Math Practice

4. **Calculating Density** Calculate the density of the following 1-L samples of ocean water. Sample A has a mass of 1.01 kg; Sample B has a mass of 1.06 kg. Which sample would likely have the higher salinity? Explain.