U.S. Department of Commerce
National Oceanic & Atmospheric Administration
National Marine Fisheries Service

Lesson 6: Ocean Layers I

Overview

Lesson 6 presents the importance of ocean chemistry with an activity about salinity, a measure of salt content in ocean water. Both salinity and temperature vary throughout the ocean. Because both salinity and temperature affect the density of water, this variance results in layers of water within the ocean. These layers in part determine the formation of ocean currents, which will be discussed in future lessons.

Lesson Objectives

Students will:

1. Define salinity and its common units
2. Predict the relationship between salinity and temperature and density of ocean water
3. Describe how differing salinity and temperature throughout the ocean results in layering

Lesson Contents

1. Teaching Lesson 6
    a. Introduction
    b. Lecture Notes
    c. Additional Resources
2. Teacher's Edition: Layers in the Ocean
3. Student Activity: Layers in the Ocean
4. Student Handout
5. Mock Bowl Quiz

Standards Addressed

National Science Education Standards, Grades 9-12

Unifying concepts and processes
Science as inquiry
Physical science
Science in personal and social perspectives

Ocean Literacy Principles

The Earth has one big ocean with many features

DCPS, High School

Chemistry
C.2.1. Investigate and classify properties of matter, including density, melting point, boiling point, and solubility

Environmental Science
E.2.1. Understand and explain that human beings are part of Earth's ecosystems, and that human activities can, deliberately or inadvertently, alter ecosystems
E.1.6. Plan and conduct scientific investigations to explore new phenomena, to check on previous results, to verify or falsify the prediction of a theory, and to use a crucial experiment to discriminate between competing theories

Lesson Outline[1]

I. Introduction

Use the demonstration below to introduce the lesson:

1. Fill a clear water bottle or beaker halfway with cool tap water. Add salt until it no longer dissolves. Fill another bottle or beaker with a smaller amount of tap water and a small amount of salt. Put a few drops of food coloring into this solution.

2. Gently pour the colored solution into the clear solution so that it forms a less dense layer over the clear, saltier, denser solution.

3. Tell the students that the clear layer has much more salt than the colored layer. Ask the students why they think the layers don't mix together. Introduce the concept that the denser layer is at the bottom and the top layer is less dense.

4. Tell them that salinity is a measure of the total concentration of dissolved (inorganic) solids (e.g., salts) in water, and they will do a lab activity to determine how salinity and temperature affect density of water layers.

II. Lecture Notes

Use the PowerPoint for Lesson 6 (File: Lesson 6 – Ocean Layers I.ppt) to present the following information. Distribute the Student Handout before you begin for students to take notes on key information.

Seawater is a mixture of pure water and chemical compounds (slides 4-6)

1. Seawater can be thought of as a solution. The dissolving agent or **solvent** is liquid water (H_2O) and the materials dissolved in water, such as salt, are the **solutes.**

2. The majority of seawater is pure water (H_2O), typically over 90%.

3. The major seawater constituents are seven dissolved salts that account for over 90% of all dissolved substances in seawater.

4. In a typical seawater sample of 1000 grams (1 kilogram), the seven primary salts that would be present, in order from largest amount to smallest amount would be:
    i. Chloride (Cl^-): 18.98g (54% of solution weight)
    ii. Sodium (Na^+): 10.56g (30% of solution weight)
    iii. Sulfate (SO_4^{2-}): 2.65g (8% of solution by weight)
    iv. Magnesium (Mg^{2+}): 1.28g (4% of solution by weight)
    v. Calcium (Ca^{2+}): 0.40g (1% of solution by weight)
    vi. Potassium (K^+): 0.38g (1% of solution by weight)

[1] Unless otherwise indicated, all websites provided or referenced in this guide were last accessed in November 2010.

vii. Bicarbonate (HCO^-): 0.14g (< 1% by weight

How do scientists figure out how much salt is in the water? (slides 7 and 8)

1. Salinity is a measure of the total concentration of dissolved (inorganic) solids (e.g., salts) in water.

2. The major constituents or salts of seawater display an interesting feature. These salts are always present in any of the world's ocean basins and in the same proportions to each other even if totally salinity varies. This is the Principle of Constant Proportions and helps scientists measure salinity. This principle states that the ratio of any two major constituents dissolved in seawater is constant. If a scientist can measure one of the major constituents in seawater, he/she can calculate the amounts of all other major constituents and the salinity of the sample.

3. There are several tools available to measure ion concentration and to approximate salinity. One example is an instrument known as a CTD, short for conductivity, temperature and depth. The CTD measures how easily electric currents pass through a sample of seawater (conductivity). Because salt content directly affects a water sample's conductivity, the measurement of conductivity can be translated to a measurement of salinity. In addition, the NASA Aquarius satellite is a relatively new technology that will be used to measure salinity on a global scale from space.

Salinity is variable across the ocean (slides 10 and 11)

1. Salinity is not homogenous throughout the ocean.

2. Geographically, salinity varies as a function of evaporation, precipitation and freshwater input (e.g., river outflow, ice melt).

3. In general salinity increases with decreasing latitude from the poles to the tropics and then decreases from the tropics to the equator. At the mid-latitudes, high salinity levels can result from warm, dry conditions and increased evaporation. Near the equator, greater rainfall occurs resulting in lowered salinity. At high latitudes, melting ice contributes to lower salinity levels.

Why is salinity important? (slide 12)

1. Salinity is one variable that affects the density of water. When water has different densities, it forms layers as was demonstrated at the beginning of the lesson.

2. Layers in the ocean are part of the reason the ocean has currents, which we will learn about in future lessons.

III. Additional Web Resources

1. Background information: http://www.classzone.com/books/earth_science/terc/navigation/home.cfm

Layers in the Ocean

Overview
In this activity, students mix saltwater solutions to determine how temperature and salinity affect water density. Students observe how density differentials lead to layer formation in saltwater. This is an important foundation for students to understand currents and weather patterns, which are presented in subsequent lessons.

This lesson was adapted from the "Density: Sea Water Mixing & Sinking" activity from the NASA Aquarius project, on the web at: http://aquarius.nasa.gov/seawater_mix_sink.html.

Alternative lesson ideas can be found at the NOAA site below. For example, "A funny taste" and "Salt'n'Lighter" may be interesting to your students:
http://www.srh.noaa.gov/jetstream/ocean/seawater.htm.

Background
Students have learned that seawater is a solution made of water mixed with many different types of salt. The ocean is not a homogeneous solution where all of the water is the exact same temperature and exact same salinity. There are parts of the ocean that have cooler water and some parts with warmer water. Likewise, certain parts of the ocean have higher salinity than others. What effect do you think this might have on the ocean? In this activity, students conduct a test to see how temperature and salinity affect the density of ocean water.

Materials
- Triple–beam balances or electronic scales (If you don't have scales, you can make seawater without measuring by pouring salt into a sample of water just to the point at which salt no longer dissolves.)
- Food coloring or dye
- Clear Tupperware or other plastic containers large enough to hold 1L of liquid (two per group)
- Two 500mL beakers for mixing and pouring per group (Note: If you do not have beakers for measuring, use plastic cups and tell students to fill the cups halfway rather than measuring.)
- If available, ice can be used to make the cool solutions and hot plates to make the warm solutions

Procedure
1. Break your students into groups and distribute the Layers in the Ocean activity.

2. Assist your students with the activity, but let them mix the solutions if possible. If you are short on supplies, you may want to complete this activity as a class, using student volunteers to do the mixing.
3. As the activity progresses, ask students to describe the following concepts:

- Cool water is denser than warm water and will sink below the warmer water.
- Water that is more saline is denser than water with lower salinity and thus will sink below the water of lower salinity.
- Water temperature has more of an effect on water movement than salinity.

Stress to your students that the layering they observe in the lab occurs on a large scale in the oceans, and that these layers lead to ocean currents

Making the saltwater stock solution
The normal saltwater solution is made by dissolving 35g (about 3.5 tablespoons) of table salt (NaCl) into a liter of room-temperature water. This roughly approximates the salinity of seawater at 3.5%. If your plastic containers are too small to hold 1L of liquid, you can make your saltwater solutions by placing 3.5g (a little less than half a tablespoon) of salt into 100mL of water. If you don't have a scale, gently pour salt into water while stirring just until the salt stops dissolving.

Temperature test

1. The first test involves having students create 500mL of hot and 500mL of cold seawater. The cold water can be made by chilling a beaker of the "seawater" in an ice bath for a few minutes.

2. The warm seawater can be made by warming the solution on a hot plate or using hot tap water to make the solution. Add food coloring to one of the solutions.

3. Ask the students to predict which sample will rise or sink when gently poured into the room-temperature solution and record their prediction in their lab notebook.

Caution: If the beakers are poured into the Tupperware too quickly the solutions will mix. Otherwise, your students should note that the hot solution floats on relatively cooler water and the cool solution sinks below relatively warmer water.

4. Once the students have finished observing the layering and made notations in their notebooks regarding their observations, have them discard the solutions in the drain and rinse their Tupperware for the next test.

Salinity test

1. For the next test, students will make a 500mL sample of regular seawater by adding 17g (a little less than two tablespoons) of salt to 500mL of room temperature tap water in their containers.

2. They will make another solution that is FOUR times as salty in a beaker by adding 60g of salt to 500mL of room temperature water.

3. Students should gently pour the saltier solution into the stock. Make sure to add dye to one of the solutions. They should see that the more saline solution sinks to the bottom.

Temperature vs. salinity

1. Finally the students should predict which is more important to the layering: temperature or salinity.

2. Ask the students to design an experiment to test their hypothesis. If you have time, you can even let them go ahead and try their experiment.

Answer key

1. Write your predictions for the hot and cold water test.
   Answers vary. Make sure students write the reasoning behind their predictions (e.g., the hot water will float BECAUSE it is less dense than cool water).

2. Did your prediction match the observed results of the test?
   Answers vary.

3. Describe your results in terms of the density of the solutions. Which solution was denser? How does temperature affect density?
   As temperature increases, density decreases.

4. Record your predictions for the salinity water test.
   Answers vary.

5. Did your prediction match the observed results of the test?
   Answers vary.

6. Describe your results in terms of the density of the solutions. Which solution was denser? How does salinity affect density?
   As salinity increases, density increases.

7. What is your hypothesis about which factor, salinity or temperature, affects density more? Write down how you would test this hypothesis.
   Answers vary.

8. If you ran your test, did the results of your final experiment support your hypothesis, or were they different from your hypothesis?
   Answers vary.

Layers in the Ocean

You know that the ocean is a solution made of water mixed with many different types of salt. Do you think that the ocean is one homogeneous solution where all of the water is the exact same temperature and exact same salinity?

As you might have guessed, there are parts of the ocean that have cooler water and some parts with warmer water. Likewise, certain parts of the ocean have higher salinity than others. What effect do you think this might have on the ocean? In this activity, we will conduct a test to see how temperature and salinity affect the density of ocean water.

Materials

- Scale
- Food coloring or dye
- Tupperware container
- Table Salt
- Two 500mL beakers
- Ice

Making your seawater (stock solution)

1. Dissolve 35g of table salt (NaCl) into a 1L of room-temperature water in one plastic container. This roughly approximates the salinity of seawater at 3.5%.

2. Using a 500mL beaker, transfer HALF of this solution (500mL) into your second plastic container. You will use these solutions for your temperature test.

Temperature test

For this test, we will create hot and cool seawater solutions and mix them with room temperature seawater. Do you think the hot water will mix evenly with the room temperature water? If not, do you think it will float on top of or sink beneath the room temperature water? Write down your hypothesis on the lab worksheet. Also write a similar hypothesis for your cold water test.

1. Place 500mL of tap water into a beaker. Add 17g of table salt. Place this solution on ice for a few minutes.

2. Add a few drops of colored dye to your cold seawater.

3. Gently pour the cold solution into one of your plastic containers of stock seawater. Record your observations.

4. Place 500mL of HOT tap water into another beaker with 17g of salt. Your teacher will tell you whether to use water from the hot tap or to use a hot plate.

5. Add a few drops of dye to the hot seawater.

6. Gently pour your hot solution into your second plastic container of room temperature stock seawater. Record your observations.

Salinity test
For this test, we will make a solution that has high salinity (much more salty) compared to our stock salinity. Which layer do you think will be on top – the high or low salinity water? Record your hypothesis on the lab worksheet.

1. Rinse out your plastic containers and beakers from the previous test.

2. Make a new stock solution in one plastic container by mixing 17g of salt into 500mL of room temperature water.

3. In one of your beakers, mix 500mL of room temperature water with 60g of salt. This solution is four times as salty as the regular stock seawater.

4. Add a colored dye to the salty solution.

5. Gently pour your salty solution into your plastic container of stock seawater. Record your observations.

Salinity vs. temperature
What do you think has the greater effect on density: temperature or salinity? How would you test your hypothesis? Write out the steps for your experiment. If you have time, your teacher may let you run your test!

Lab Worksheet

1. Write your predictions for the hot and cold water test.

2. Did your prediction match the observed results of the test?

3. Describe your results in terms of the density of the solutions. Which solution was denser? How does temperature affect density?

4. Record your predictions for the salinity water test.

5. Did your prediction match the observed results of the test?

6. Describe your results in terms of the density of the solutions. Which solution was denser? How does salinity affect density?

7. What is your hypothesis about which factor, salinity or temperature, affects density more? Write down how you would test this hypothesis.

8. If you ran your test, did the results of your final experiment support your hypothesis, or were they different from your hypothesis?

Tips for the Bowl - Salinity

Definitions and facts
Write definitions and key concepts for these terms during your teacher's presentation. You may see them again!

Salinity:

Typical unit of salinity:

Rule of Constant Proportions:

Facts:

- The equator and high latitudes (near the poles) have low salinity and the mid-latitudes have high salinity
- The Red Sea and Mediterranean Sea have the highest salinities on Earth.

Make the connections!
The relationships between variables and concepts are very important for success at the Bowl. Make sure you understand the following relationships from this section.

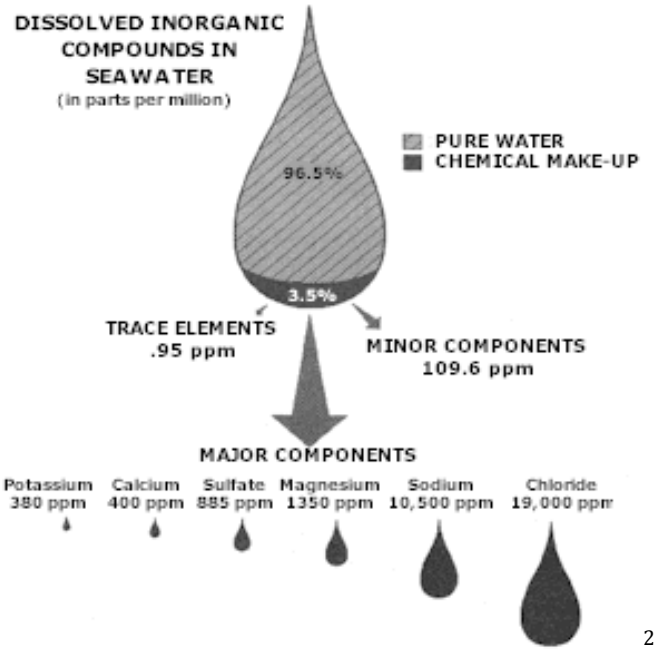
1. We know the proportion of elements in seawater (see second page). Therefore if we measure one component of a sample of seawater, we can calculate all the other elements using the Rule of Constant Proportions.
2. As temperature *increases*, the density of water *decreases*, so colder layers of water sink below warmer layers.
3. As salinity *increases*, the density of water *increases* so saltier water layers sink below less salty layers.
4. Water temperature is the more important of the two factors in determining ocean layers.

Why does it matter?
The concepts you learn are almost always related to human interaction with the oceans. Here are just a few of the human-ocean interactions from this lesson. Can you think of others?

- Different water densities form currents in the oceans, which impacts our climate and weather. We will learn more about this in other lessons.
- Human activities that impact water temperature and salinity have the capacity to impact water density and currents. Can you think of any human activities that might make the water warmer?

Major components of ocean water

Hydrogen and oxygen are the most abundant elements in seawater, followed by the major components listed below. You should remember that **trace elements** are those elements that occur at less than 0.95parts per million (ppm).



[2]

[2] Photo courtesy of the Chesapeake Bay Program. .2006. EPA 903-R-06-003, CBP/TRS 281/06, Chesapeake Bay: Introduction to an Ecosystem (p 11).

Salinity

1. The "Rule of Constant Proportions"
    w. **Allows scientists to determine salinity from the concentration of a single ion in seawater**
    x. Means that salinity is constant throughout the oceans
    y. Means that salinity and temperature have the same effects on seawater density
    z. Means that density of seawater is constant

2. Seawater is
    w. **A mixture**
    x. An ion
    y. A compound
    z. An element

3. Reminder question: When carbon dioxide combines with ocean water, what is produced?
    w. Calcium carbonate
    x. **Bicarbonate**
    y. Carbonic acid
    z. Carbonate

4. Which of the following has the highest average salinity?
    w. **Mediterranean Sea**
    x. Atlantic Ocean
    y. Arctic Ocean
    z. Gulf of Mexico

5. Traditionally, salinity has been expressed as...?
    w. grams per cubic centimeter
    x. parts per million
    y. grams
    z. **parts per thousand**

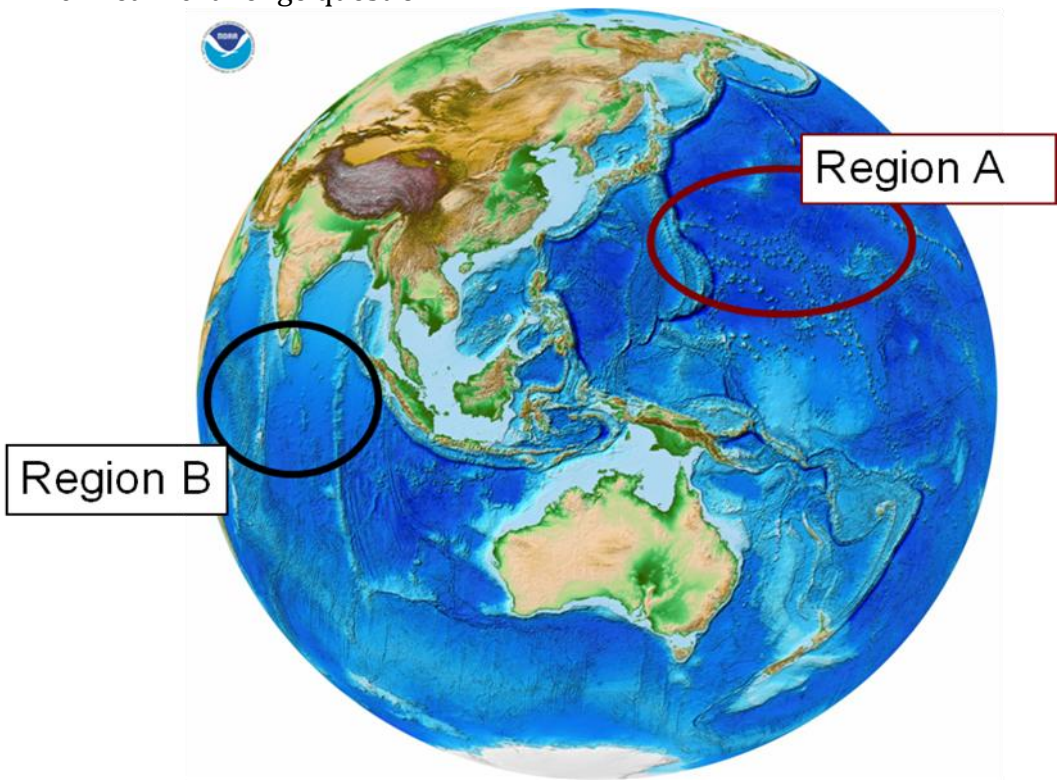
6. Which of the following is the most abundant ion in sea water?
    w. **Chloride**
    x. Calcium
    y. Potassium
    z. Sulfate

7. Reminder question: This term refers to the capture and storage of carbon:
    Answer: Carbon sequestration

8. What percentage of average seawater is pure water?
   w. 3.5
   x. 50
   y. 75.5
   z. **96.5**

9. Short answer: As salinity increases, what happens to water density?
   Answer: It increases

10. Team challenge question



1. In the image above, which region do you expect to have higher salinity, Region A or Region B? Why? (3pt)

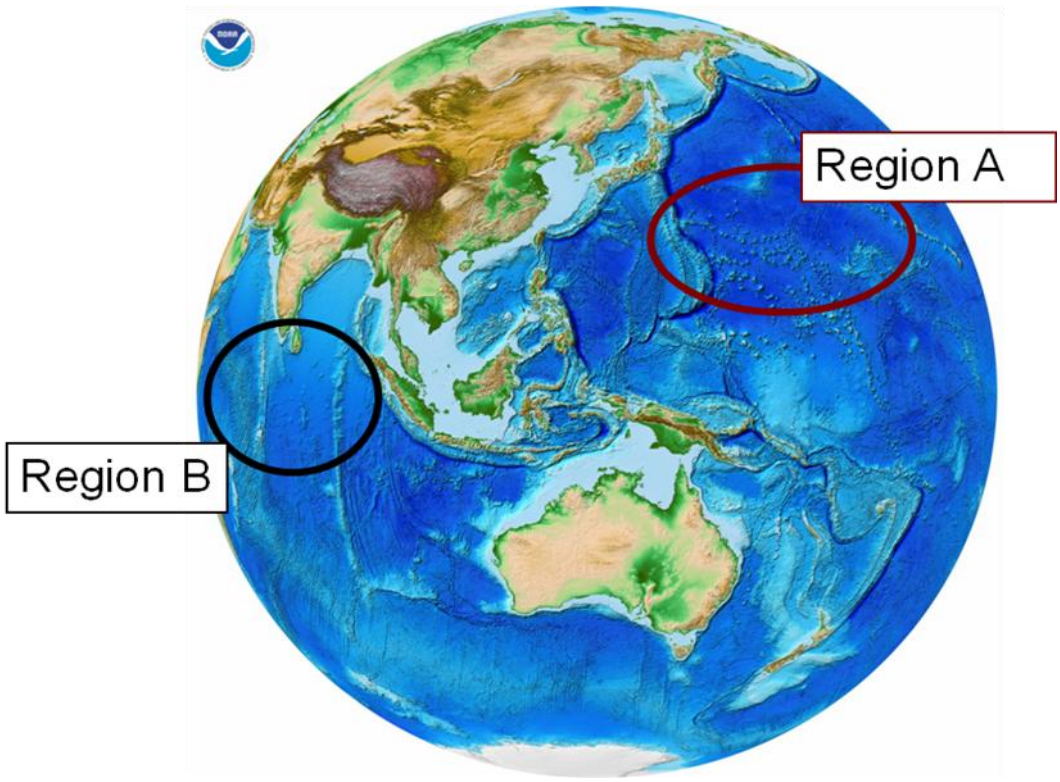
2. In what two general parts of the globe is salinity typically lowest? (2pt)

3. Name one piece of technology used to measure salinity. (1pt)

4. What property of water is determined by salinity and temperature? (1pt)

[3]Photo: NOAA, http://www.ngdc.noaa.gov/mgg/global/global.html

ANSWER



1. In the image above, which region do you expect to have higher salinity, Region A or Region B? Why? (3pt)
   Region A (1pt). Region A is mid-latitude with higher evaporation (2pt).

2. In what two general parts of the globe is salinity typically lowest? (2pt)
   At (1) the equator and (2) high latitudes (1pt each).

3. Name one piece of technology used to measure salinity.(1pt)
   Satellite, CTD, salinometer are all acceptable responses.

4. What property of water is determined by salinity and temperature? (1pt)
   Density

[4]Photo: NOAA, http://www.ngdc.noaa.gov/mgg/global/global.html