A Pinch of Salt

Key Concepts

1. The major components of sea salt are sodium and chlorine, or table salt.

2. The weathering of rock continually adds sodium (and some other materials) to earth's rivers, and hence to the ocean.

3. Chlorine appears to have been added to the seas during the original outgassing process that formed earth's oceans.

4. When seawater evaporates, the dissolved salts remain behind.

5. The saltiness of the seas is held in a "steady state", because sodium (and the other materials added by river water) is constantly removed from sea water by the formation of new rock on the sea's floor.

Background

Sea water contains many dissolved materials. In the world oceans, about 3.5% of the weight of seawater is due to dissolved salt. In a typical 1000g of seawater, 35g is dissolved salt which can be obtained as sea salt by evaporating sea water. The amount of salt in sea water is called the salinity. While the major components of sea salt are sodium and chlorine, or table salt, there are other constituents of sea salt.

The original sources of the salts in the ocean are both the crust and the interior of the earth. Chemical weathering of crustal rock provides positively-charged ions (i.e. sodium) in river runoff. Many types of rock, such as granite, contain sodium. Rain water falling on earth's rock slowly dissolves the rock, so that river water contains a trace of sodium. The hydrologic cycle continually adds sodium to earth's rivers, and hence to the ocean.

Rocks do not contain much chlorine, and river water does not add chlorine to the ocean. Chlorine appears to have been added to the seas during the original outgassing process that formed earth's oceans. Negatively charged ions (such as chloride) are still present in the earth's interior. Volcanic eruptions release the negative ions into the atmosphere, where they are dissolved in rainwater and carried to the sea. Deep sea vents release the negative ions directly into the sea.

So, is the sea becoming more salty? Not particularly. This is somewhat surprising, since rivers are constantly adding sodium to the sea. For the concentration of salts in the ocean to remain constant, the processes of salt removal must equal the inflow of salts from rivers and other sources.

Salt is removed in a number of ways to hold the salinity ("saltiness") of the seas in this "steady state", or balance. Sodium is constantly removed from sea water by the formation of new rock on the sea floor. In this process, fine sodium-rich particles are trapped in sediments and are no longer available to the seawater until geologic processes "recycle" them. Salt is also removed as sea spray deposits a salt film along the shore. This salt is later returned to the sea by runoff from the land. Biological activity in the ocean concentrates some salts in the bodies of organisms. These salts are removed if the organisms are harvested. In some arid locations, shallow arms of the sea are isolated and evaporated over time. In these cases, the salts remain behind as land deposits.

Materials

Activity 1 - Salty Dog

For each group of 3 or 4 students

- sea salt
- plastic bag
- beaker (150 or 250 ml)
- thermometer
- sea water
- beaker tongs
- tray - heat resistant
- balance and weights
- graduated cylinder
- hot plate
- stopwatch or timer
- safety goggles

Activity 2 - Rain Water, River Water, Sea Water

For each student:

- a glass slide
- 4" strip of masking tape

- scissors
- pencil

For the class:

- glass of rain water (about 1 cup) with an eye dropper
- glass of river water (about 1 cup) with an eye dropper
- glass of sea water (about 1 cup) with an eye dropper
- a warm place to set the slides, like near a lamp.

Activity 3 - How Salty Can the Sea Get?

For each pair of students:

- a piece of oil based clay about 1/2 the size of a golf ball
- a soda straw
- permanent marker (or a pencil and a strip of masking tape)
- a 2 liter pop bottle with the top cut off
- a cup filled with salt
- a teaspoon
- a ruler for stirring

Activity 4: "The Seas are Salted"

For each student:

- "scrambled comic strip frames" activity sheets (a continuation of "How the Earth Got Its Layers" comic strip)
- scissors
- glue stick
- 8 1/2" x 11" paper to mount the comic strip
- colored pencils, water colors, or crayons (optional, or assigned as homework)

Teaching Hints

"A Pinch of Salt" concludes the introductory exploration of current theories of the origin of the earth and its ocean with a series of four activities. The first activity, "Salty Dog", is a quantitative look at sea water in which students determine just how much salt is in a given sample of sea water. In the second activity, "Rain Water, River Water, Sea Water", students evaporate three different water sources and examine the materials left behind. In "How Salty Can the Sea Get?" students model the steady state system which maintains a constant salinity in the seas. The final activity, "The Seas are Salted", is the culmination of "How the Earth Got Its Layers" comic strip from the preceding activities.

Salty Dog

As a quantitative look at the amount of salt in a sample of sea water, "Salty Dog" provides your students with an opportunity for careful measurement. Balances and weights or scales capable of weighing 50 grams accurately are required.

If you are not close to a source of sea water, you can make your own for this experiment, dissolve 32 grams of table salt (sodium chloride) in one liter (1000 ml) of tap water. If you find that the solution is cloudy, you can let it stand and the cloudy precipitate will settle. The precipitate is usually aluminum silicate, a material that keeps the salt from caking. (While making us shiny inside?)

Note the "CAUTION" included in the student pages: Do not let the beakers boil dry on the hot plate. They will crack even though they are heat resistant pyrex glass. Have the students reduce the temperature as they near total evaporation. It is also helpful at this point to slightly tilt the beaker to reduce the spattering of salt.

Rain Water, River Water, Sea Water

In "Rain Water, River Water, Sea Water", students demonstrate through evaporation that "river water" has some trace of salt. The purpose of this activity is to make reasonable the idea that the hydrologic cycle can drive the salting of the sea.

Depending upon the background knowledge of your students, a discussion of terms such as salt, material, element, sodium, and chlorine may prove helpful.

While use of actual rain water, river water, and sea water is ideal, if you are not close to sources of these waters, you can make your own for this experiment. For rain water, use distilled water available at most grocery stores. For sea water, dissolve 32 grams of table salt (sodium chloride) in one liter (1000 ml) of tap water. For river water, tap water will usually be a reasonable substitute. (In many areas drinking water comes from reservoirs which store river water or from underground aquifers which store "underground river" water.) Caution: test local tap water because in some areas, tap water will not have dissolved materials. If such is the case, add a pinch of salt to a liter of water to make "river" water.

How Salty Can the Sea Get?

In "How Salty Can the Sea Get?" students are provided experience with a steady state to emphasize that the saltiness of the sea is constant because inflow of salt is balanced by outflow.

The processes in the ocean which determine the concentration of salts are complicated and not fully understood. This activity is designed to achieve a sense of the reasonableness of the steady state argument. In your discussions of this activity, it must be emphasized that, unlike the model created, the seas are not salted to saturation. The major outflow process in the ocean involves the adherence of sodium ions to sedimenting particles and becomes significant at a concentration well below the concentration where outflow due to crystallization from saturation becomes important.

The Seas are Salted

"The Seas are Salted" comic strip, is the culmination of "How the Earth Got Its Layers" comic strip from the preceding activities. The activity involves students in unscrambling and sequencing a series of comic strip frames. While supplying each student with a set of comic strip frames, have students continue to work in their groups of 3 or 4 students.

Key Words

dissolve - in this case, to make a solution of a solid material by mixing with water

evaporate - in this case, to remove the water from a solution of a solid material

salinity - concentration of dissolved salt in water, usually determined by measuring the concentration of chloride ions or the conductivity of the solution, both of which are proportional to the total dissolved salts

salt - a crystalline compound, sodium chloride (NaCl), a major constituent of sea water; also, any of a class of compounds composed of anions and cations which usually ionize in solution

steady state - a condition or system in which average inputs equal average outputs and hence are in dynamic equilibrium

Extensions

1. Have students research the importance and sources of the other major components of sea water (K, Ca, Mg, $SO_4{}^{--}$).

Answer Key

Salty Dog

1. Answers depend upon results.
2. Answers depend upon results. The samples should fall within the range.
3. Results will most likely differ. Differences may come from errors in weighing, errors in measuring, errors in recording, etc.
4. This question calls for an opinion. As such, accept any reasonable answer. Salt enters the sea from fresh water rivers. The salt is in very low concentration in the fresh water. Refer to Background sections for additional discussion.

Rain Water, River Water, Sea Water

1. Answers will vary depending upon experimental results. In general, students will find lots of salt from “sea water” (salt water), a trace of salt from “river water” (tap water), and no salt from “rain water” (distilled water).
2. a. Answers will vary depending upon experimental results. In general, students will find dissolved materials in the “sea water” (salt water), and “river water” (tap water).

   b. Answers will vary depending upon experimental results. Usually, the “sea water” (salt water) sample will have the most dissolved materials.

   c. Answers will vary depending upon experimental results. The “rain water” (distilled water) sample would be expected to have the least dissolved materials.

   d. Answers will vary depending upon experimental results. In general, the amount of material dissolved in “river water” (tap water) will be much less than the amount dissolved in “sea water” (salt water).
3. Answers will vary depending upon experimental results but usually no material (or a very small amount) is dissolved in the drop of rain water.
4. This question calls for an opinion and sets the stage for a discussion of the weathering of rocks as a source of the river’s dissolved material.
5. a. Most rivers end in the ocean. This and the next three questions guide students to the conclusion that rivers are the major source of salts in the ocean.

   b. The dissolved material carried in river water ends up in the oceans.

c. Based on the observation that rivers have been flowing into the ocean day after day, year after year, for millions of years, one would expect the saltiness (salinity) of the sea to be increasing because river water carries with it small amounts of dissolved salt.

d. This question calls for students to infer that, if rivers are always adding salts and yet the salinity of the ocean remains the same, then salt must also be leaving the ocean at the same rate it is entering.

6. a. Chlorine is the major missing component of sea salt.

   b. While this question calls for an opinion, the hint points to outgassing as a source for the chlorine in sea water.

How Salty Can the Sea Get?

1. Answers depend upon experimental results. Generally, the soda straw with the clay ball floats higher with each addition of salt until it reaches a plateau.

2. Answers depend upon experimental results. Generally, the soda straw with the clay ball changes the same amount with the first several additions of salt, then the change decreases, and finally stops as the solution reaches saturation.

3. a. The model ocean is like the original ocean before the addition of salt commences.

   b. The model ocean increases in salinity during the time the straw rises.

   c. The model ocean is in a steady state condition once the addition of salt stops being reflected in a rise in the straw.

   d. Answers will vary. The model is an accurate representation in that it achieves a steady state. The mechanism of the steady state, however, is not an accurate representation of what happens in the ocean.

The Seas are Salted

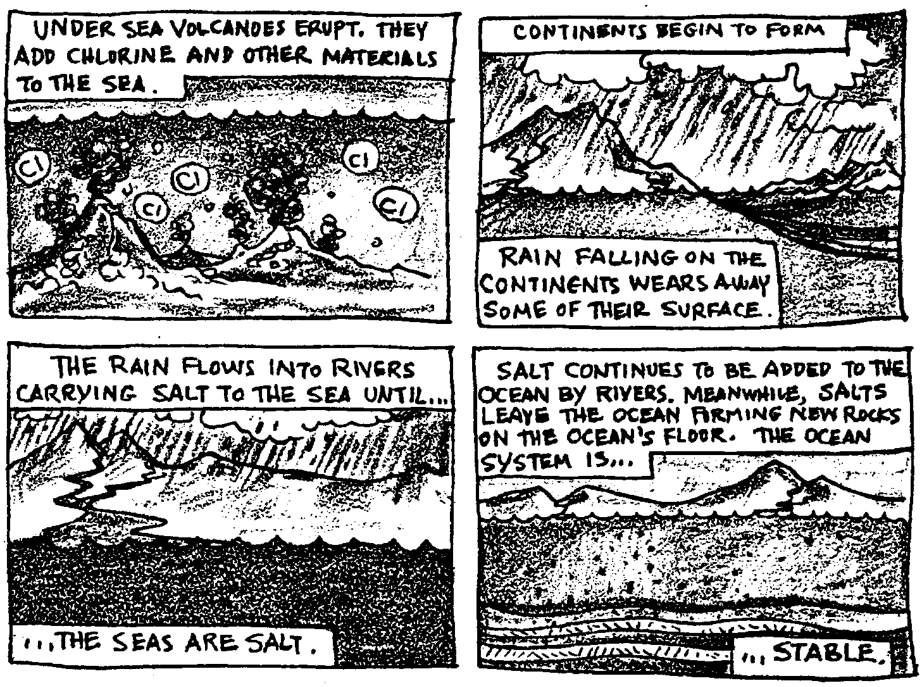
1. Undersea volcanoes were the source of chlorine in the ocean.

2. The transport of minerals (from weathered rocks) in river water is the source of the sodium in the ocean.

3. The saltiness of the ocean remains constant in spite of salt being continually added from rivers because salts also leave the ocean, forming new rocks on the ocean's floor.

The Seas Are Salted - comic strip

The correct order of the comic strip frames is shown below:



1	2
3	4

A Pinch of Salt

Water vapor escaping from early earth's molten rock would have cooled as it rose skyward. It would have condensed to form clouds, and then fallen back as rain. That rain not only cooled the earth's crust. It eventually filled the oceans. But even though the oceans have been filled by rain, ocean water does not taste anything like rain water: Ocean water is downright salty.

But just how salty is sea water and what are some ways in which salt makes sea water different from fresh water? The following activities will help answer these questions.

Activity 1 - Salty Dog

In this activity, you will weigh and measure 50 ml of sea water. Then you will evaporate the water. Finally, you will calculate the per cent of salt as well as the salinity of the sample.

Materials

- sea salt
- plastic bag
- beaker (150 or 250 ml)
- thermometer
- sea water
- beaker tongs
- tray - heat resistant
- balance and weights
- graduated cylinder
- hot plate
- stopwatch or timer
- safety goggles

Procedure

1. Weigh the empty beaker using balance: _______ grams.

2. Measure 50 ml sea water using a graduated cylinder, then pour into the beaker.

3. Look at the 50 ml of sea water. Guess how much salt is dissolved in the water. Place that amount of salt in a plastic bag. Put your name on the bag.

4. Weigh the bag and salt: ________ grams. Set the bag aside.

5. Weigh beaker with the sea water in it: _______ grams.

6. To determine weight of water, subtract #1 from #5.

   Beaker with sea water (#5) ______ grams

   Subtract beaker empty (#1)_______ grams

   Weight of water (#6) = ______ grams

7. Place beaker on hot plate and evaporate all the water. As the water is being evaporated, record the temperature every 2 minutes.

NOTE: Record the time and temperature at which the sea water begins to boil. CAUTION: **Don't let the beaker boil completely dry as beaker will crack.** Be sure to wear safety goggles.

Starting Temp. ____________	10 min. ____________	20 min. ____________
2 min. ____________	12 min. ____________	22 min. ____________
4 min. ____________	14 min. ____________	24 min. ____________
6 min. ____________	16 min. ____________	
8 min. ____________	18 min. ____________	

Boiling Temperature: ___________degrees

Remove beaker from hot plate and place on tray.

8. Weigh beaker with dry salt residue left in it.

9. To find the weight of salt, subtract #1 from #8.

Beaker with dry salt (#8): __________ grams
Subtract empty beaker (#1): __________ grams

____

Weight of Salt (#9): __________ grams

10. The percent of salt is found by dividing the weight of residue by the weight of sea water used then multiplying by 100.

Weight of salt (#9) ____________ grams = ________ x 100 = _______ %
____
Weight of water (#6) ____________ grams

11. The salinity of ocean water is commonly expressed as so many parts of salt material per 1000 parts of water. We use the symbol ‰ to express parts per thousand. To determine parts per thousand multiply the per cent of salt by 10.

Percent of salt _______ x 10 = ________ ‰

12. Record your salinity on the chalk board.

Analysis and Interpretation

1. Compare the weights of the salt in your bag and the salt from evaporation. How close was your guess?

2. The salinity of sea water in the open ocean usually ranges from 30 parts per thousand to 37 parts per thousand. Does your sample fall in that range?

3. Compare the salinity of sea water that you obtained with the results of other groups. Do they differ? If so, what might have caused the differences?

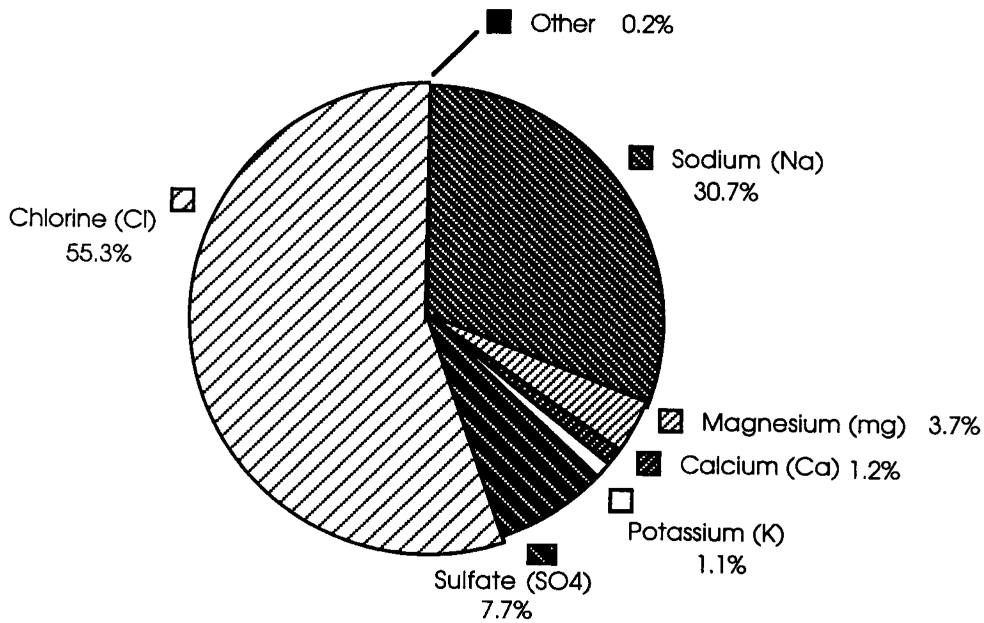
4. How do you think salt gets into the sea?

Activity 2: Rain Water, River Water, Sea Water

How did the oceans get salty? Maybe knowing a bit more about sea salt will help us find the answer. You've just evaporated sea water to find sea salt. But what is sea salt? Is it just like the table salt you buy at the grocery store? If you had a good chemistry laboratory, you could run tests on the salt and find out. You would find that table salt contains only two materials: sodium and chlorine. You would find that sea salt contains many materials. The major ones are listed in the pie chart below.

Major components of sea salt

% by mass



You can see from the chart that just two materials account for most of the salt in the sea. Sodium and chlorine (the same materials that make up table salt) make up about 86% of the salt. If we can discover how sodium and chlorine get into the sea, we'll be well on the way to understanding how the sea got its salt. In the following activities you will evaporate water samples, and dissolve salt crystals made of sodium and chlorine.

Materials

- glass slide
- 4" strip of masking tape
- scissors
- pencil
- rain water
- river water
- sea water

Procedure

1. Make sure your slide is clean and dry. Handle it by the edges so you won't smudge it with fingerprints.

2. Cut a thin strip of masking tape. Put the tape along one side of your slide, as shown in figure 2. Write labels on the masking tape: **rain**, **river** and **sea**, as shown below.

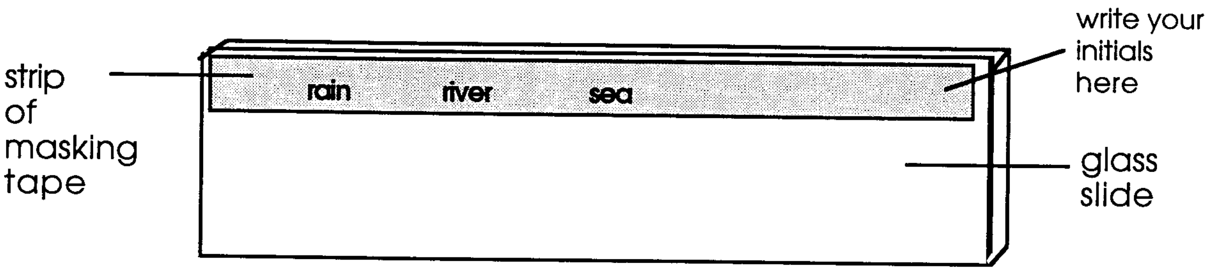


figure 2

3. Write your initials on one end of the masking tape strip.

4. Now put a drop of water below each label, as follows:

   Below **rain** put a drop of **rain water**.

   Below **river** put a drop of **river water**.

   Below **sea** put a drop of **sea water**.

   As you work, be careful not to tip your slide, or let your drops of water flow together.

5. Place your slide in a warm place (like on a sunny window sill, or near a lamp bulb) where it won't be disturbed. Leave it there for at least 1/2 hour.

6. Answer the following questions after the drops of water on your slide have evaporated.

Analysis and Interpretation

1. Now that the drops have evaporated, describe what you observe on your slide in each location:
   a. rain water:

   b. river water:

   c. sea water:

2. When water evaporates, any material that was dissolved in the water is left behind.
   a. Which water samples had dissolved materials?

   b. Which sample had the most dissolved materials?

   c. Which sample had the least dissolved materials?

   d. How does the amount of material dissolved in river water compare with the amount dissolved in sea water?

3. How much material was dissolved in your drop of rain water?

4. Most rain water has nothing dissolved in it. But most river water does have a trace of dissolved material in it. Since river water comes from rain water, where do you think the river's dissolved material comes from? (Hint: Think about where rain water falls and what it trickles across on its way to a river.)

5. a. Where do most rivers end?

   b. Where do you think the dissolved material carried in river water ends up?

   c. Rivers have been flowing into the ocean day after day, year after year, for millions of years. Would you expect the saltiness (salinity) of the sea to be increasing, decreasing, or staying the same? Why?

   d. The salinity (saltiness) of the ocean has been the same for over a billion years. (Scientists can tell this from studying rocks and other things.) If rivers are always adding salts, how can salinity remain the same?

6. On his travels, Jet Setter gathered a jar of water from each of the world's rivers. When he returned home, he mixed them together in his hot tub. He then took off for Alaska. Returning chilled from the cold, he jumped into the hot tub. Was he surprised! The heater had gone wild all the water had evaporated. All that was left was a small amount of dry material on the tub's floor. Being a curious sort, Jet tested the material in his chemistry laboratory. He found that it contained sodium, magnesium, potassium and bicarbonate.

   a. What major component of sea salt was missing?

   b. It turns out, the missing component doesn't come from river water. Where might it come from? (Hint: Where did the water in the ocean come from?)

Activity 3: How Salty Can the Sea Get?

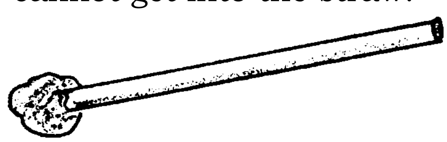
In the above activities, we've seen that rivers add salts to the sea. This raises a question. Just how salty can the sea get? In answering this salty question, you will make use of a fact you yourself may have discovered: You float better in salt water than in fresh water. And the saltier the water, the higher you float. If you've been swimming in The Great Salt Lake of Utah you'll know this first hand. The Great Salt Lake is saltier than the open ocean. In it, you float like a cork, even if you sink in a fresh water pool or lake. Below we will make use of this fact, by making a special "floater" to gauge saltiness.

Materials

- piece of oil based clay about 1/2 the size of a golf ball
- soda straw
- permanent marker (or a pencil and a strip of masking tape)
- 2 liter pop bottle with the top cut off
- cup filled with salt
- teaspoon
- ruler for stirring

Procedure

1. Press a small ball of plasticine clay into one end of a straw. The clay should act as a plug so water cannot get into the straw.



2. The pop bottle will be your model ocean. Add fresh water to your pop bottle until the water is about 1" from the top.

3. Put the straw with the ball of clay "floater" in the fresh water. Remove or add clay until the "floater" just rests on the bottom of the container.

4. Mark the water level on the straw with a permanent marker and label it zero (meaning no salt added).

5. Rivers flowing into the ocean carry salt. Add 2 teaspoons of salt to the water in your model ocean. Dissolve all the salt in the water. Put the "floater" into the water. NOTE: If this is not enough salt to raise the "floater" from the bottom, add more salt, 2 tablespoons at a time. Keep track of how many teaspoons you add.

6. When the "floater" just floats, use the marking pen to mark the water line. Label the line with the number of teaspoons of salt that you added.

7. Add two more teaspoons of salt to the water. Dissolve all the salt in the water. Mark the water line. Label the line with the total number of teaspoons of salt that you added.

8. Repeat step 7 until no you note no further change in the way the "floater" floats.

Analysis and Interpretation

1. What happened to the soda "floater" as you added more and more salt?

2. Did the soda "floater" change the same amount with each addition of salt?

3. The salt you added to your model ocean was like the salt added by rivers flowing into the real ocean.

   a. Scientists think the ocean was originally filled by rainwater. During which part of the activity was your model ocean like the original ocean?

   b. Scientists think the ocean gradually became more salty. Much of the salt came from the addition of salts by rivers. During which part of the activity was your model ocean increasing in salinity?

   c. The ocean appears to have been the salinity we find today for millions of years. Scientists call this condition a "steady state." During which part of the activity was your model in a steady state?

   d. Your model reached a steady state because no more salt could dissolve in the "ocean" water. The saltiness of the seas is held in a "steady state" in a different way. In the seas, sodium (and the other materials added by river water) is constantly removed from sea water by the formation of new rock on the sea floor.

   With this in mind, in what ways is your model ocean an accurate representation of what happens in the real world? In what ways is the model not an accurate representation?

Activity 4: "The Seas are Salted"

The above experiments have provided more pieces to the puzzle of earth's ocean. Use this information to add a new chapter to the comic strip you began in "How the Earth Got Its Layers".

Materials

for each student:

- "scrambled comic strip frames" activity sheets (a continuation of "How the Earth Got Its Layers" comic strip)
- scissors
- glue stick
- 8 1/2" x 11" paper to mount the comic strip
- colored pencils, water colors, or crayons (optional, or assigned as homework)

Procedure

1. Cut out each frame for the comic strip. (Hint: Your final product might look best if you cut just outside the black line surrounding each frame.)

2. As you cut out each frame, study the pictures and text.

3. Put the frames in the order you think makes the best sense. DON'T GLUE THEM DOWN, YET!

4. Wait for the other people in your group to decide on the order for their frames. While you wait, you might begin to add color to your drawings.

5. Your teacher will hold an election where everyone can vote on the order they consider best. Be prepared to defend you order!

6. After considering how other people have ordered the frames, make your final decisions. Next, glue your frames on the backing sheets in the order you think is best.

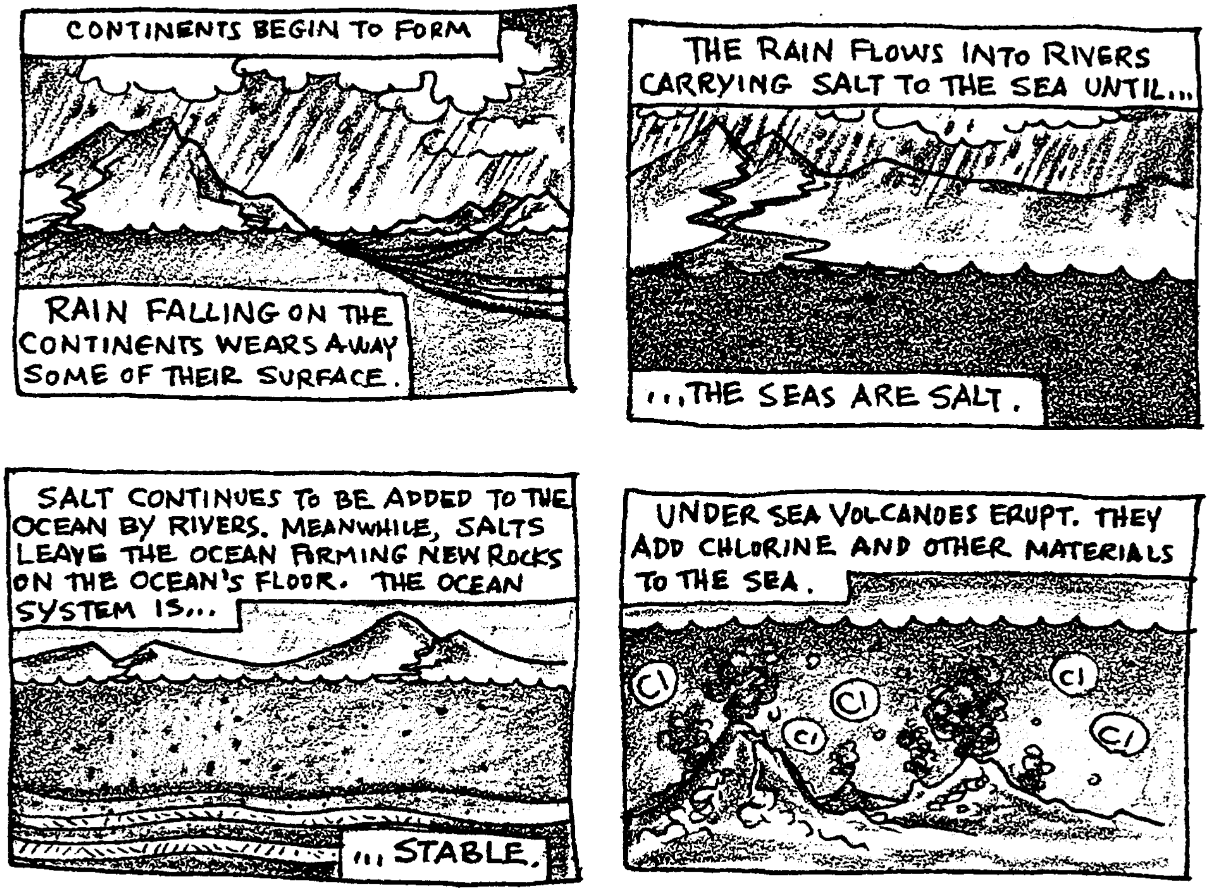
7. After the glue is dry, you can finish adding color. Always clean up!

Analysis and Interpretation

1. What was the source of the chlorine in the ocean?

2. What is the source of the sodium in the ocean?

3. How does the saltiness of the ocean remain constant in spite of salt being continually added from rivers?


CONTINENTS BEGIN TO FORM
RAIN FALLING ON THE CONTINENTS WEARS AWAY SOME OF THEIR SURFACE.
THE RAIN FLOWS INTO RIVERS CARRYING SALT TO THE SEA UNTIL...
...THE SEAS ARE SALT.
SALT CONTINUES TO BE ADDED TO THE OCEAN BY RIVERS. MEANWHILE, SALTS LEAVE THE OCEAN FIRMING NEW ROCKS ON THE OCEAN'S FLOOR. THE OCEAN SYSTEM IS...
...STABLE.
UNDER SEA VOLCANOES ERUPT. THEY ADD CHLORINE AND OTHER MATERIALS TO THE SEA.
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