Ocean in Motion 3: Gas and Water Do Mix!

A) OVERVIEW

1. Ocean in Motion -- Gas and water

In this program students will investigate the components of water and learn that it is a complex mixture of organic and inorganic compounds, including gases. We cannot “see” the air around us but it is also present in water. How can we test for it? What are the compounds dissolved in water and what variables affect their solubility? Students will learn ways in which some substances can be detected and measured.

2. Contents of Packet

- Overheads from broadcast
  - a) What's in air?
  - b) Sample graph/data table
- Worksheet for use with in-class demonstration—
  - a) Temperature and oxygen concentration worksheets
- Moving-on activities—
  - I. It's Soup
  - II. Air Cares (O_2 and CO_2, Part 1 and Part 2)
  - III. "Variable" graph

B.) PROGRAM PREPARATION

1. FOCUS POINTS

- Gases in air and seawater
  - a) Seawater is a complex mixture, consisting of particulate matter, dissolved solids, and gases.
  - b) The atmosphere contains a large number of gases, but 99% of the total consists of nitrogen and oxygen.
  - c) All of the gases found in the atmosphere can also be found in water, and the amount of a gas present in water is controlled by its “solubility.”
  - d) Factors which affect a gas’ solubility in water include: temperature, salinity, partial pressure.

2. ADDITIONAL

a) Pre-Program Demo

If you participated in Oceans in Motion II, the students have already seen this demonstration, yet you may wish to re-evaluate with your class in terms of gases dissolved in seawater.

Compare the density of saline and fresh water by coloring each with food dye before pouring them into a transparent container. Which water sinks to the bottom? Which rises to the top? What are the effects of stirring the mixture? Just as solids are dissolved in water, so too are gases.

2) Vocabulary

Solubility => having the quality of being dissolved in a given solvent

Saturation =>the condition of being unable to hold or contain anymore; filled to capacity

Partial pressure of gases =>the pressure that one component of a gas would exert if it were mixed with others in a container

Temperature => the degree of hotness or coldness of an environment measured on a standard scale

Salinity => the total grams of salt in 1 kg of water

3) Related Concepts

- •Variables (independent vs. dependent)
- •Constituents of air
- •Constituents of seawater
- •Water; structure (hydrophobic bonds) and properties—(density, freezing point, melting point, surface tension, latent heat of vaporization, latent heat of melting, heat capacity)
- •Equilibrium

C) SHOWTIME

1) Broadcast topics

This broadcast will link into discussions on gas solubility, relationships of gases found in both air and water, and how some of them arrived in each location.

a)What's in water?

Water is 96% of the ocean's water mass. Water exhibits many unique physical properties and can exist in 3 physical states within the temperature ranges found on earth. Its dipolar molecular structure and characteristic hydrogen bonds help make it an excellent solvent. Solids such as salts and minerals, gases, nutrient (inorganic) and carbon (organic) compounds are all dissolved in seawater; our drinking water contains essentially the same compounds, but has been treated to eliminate hazardous elements and minerals, pollutants and salts.

Associated Activity: It's Soup

b) What's in air?

There are a number of gases in the atmosphere including nitrogen (N_2), oxygen (O_2), carbon dioxide (CO_2), argon (Ar), water vapor, neon, helium, krypton, xenon, hydrogen (H_2), methane (CH_4), and nitrous oxide (N_2O); however nitrogen and oxygen make up approximately 99% of the total. The upper layers of the earth's oceans can take in or release gases (act as a "sink" or a "source") to reach equilibrium concentrations with the atmosphere. Carbon dioxide is one very important gas for which the ocean is generally a sink. It plays a major role in biological activity, carbon cycling and is a major greenhouse gas, predominantly because of human contributions to atmospheric CO_2. [In Ocean in Motion IV, we will examine the ocean's role in carbon cycling and the greenhouse effect.]

Overhead reproduction: What's in air?
Associated activity: Air cares

c) How much of a gas can be dissolved in water and what factors affect solubility?

There are several variables which affect the ocean's (or water's) ability to dissolve gases. A demonstration will be performed during the broadcast to illustrate that with continuous addition, solids will no longer dissolve in water; this is true as well for gases. Factors which can increase or decrease solubility of gases in water include temperature, salinity, and partial pressure. Solubility will increase with increasing temperature and pressure, and decreasing salinity.

Using a Hydrolab, the second demonstration will compare several components of water including pH, salinity, oxygen concentration and temperature. Follow-up activity will allow students to plot data obtained using the Hydrolab

Classroom worksheet: temperature, salinity, and oxygen concentration
Overhead reproduction: Sample graph
Associated activity: "Variable" graph

D. ACTIVITIES

I. It's Soup—

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Key concepts:

a. temperature
b. salinity
c. pressure
d. CO_2 solubility
e. equilibrium
f. variables

Materials:

- 3 plastic containers of club soda or carbonated mineral water (16 oz.)
- pour-spout salt

Objective: Solubility of dissolved gases is affected by temperature and salinity. Demonstrations will examine their relative influences.

Methods: Label bottles with numbers 1-3.

1)Bottle 1 is the control for all experiments. As quickly as possible, pour liberal amount of salt into bottle two and recap tightly. Allow solids to dissolve. Place bottle number 3 in the refrigerator or in a bucket of ice. Allow to sit until chilled. Bottles 1 and 2 should sit at room temperature out of direct heat or sunlight. (You may begin the experiment and leave all bottles overnight in their locations.) Have the students discuss their predictions of the results.

2) Open bottle one, and listen for the "whoosh" of gas escaping. Observe the sounds and look for bubbles in the solution rising upwards. Replace the cap and immediately remove a second time. What differences do you observe compared to the first opening? Repeat for bottle 2 and then number 3, recording the same observations. Place bottles back in their original places. Leave until the next day. Again, open the bottles and record the sounds and appearances. How many openings does it take until you can no longer hear the "whoosh?"

Classroom Discussion:

a) What causes the "whoosh" sound?

b) Why doesn't the bottle whoosh when is recapped and immediately re-opened?

c) Why does the bottle stop burping after many repetitions?

d) What effects did you find that temperature and salinity have on the solubility of gases?

e) How is this important in terms of the carbon cycle and global climate change?

Teacher's Guide for Discussion Questions:

a) Soda water is a supersaturated solution of carbon dioxide in water. Under conditions of room temperature and pressure, there is more carbon dioxide (CO_2) dissolved in the solution than it can accommodate. The pressure of CO_2 inside the bottle is greater than air pressure outside the bottle. When the bottle is opened, some of the CO_2 gas rushes out to equalize the pressure.

b) Notice that the bottle is not completely filled with liquid; there is a small gas pocket at the top. In the unopened bottle, some of the carbon dioxide has come out of solution and entered the gas pocket. The pressure of CO_2 in solution and the pressure of CO_2 in the gas pocket above the solution are equivalent; however, this equalization process is not instantaneous. When you open, cap and reopen the bottle rapidly, there is not enough time for the gas pocket in the bottle to repressurize.

c) Each time the bottle is re-capped, a new state of equilibrium is reached. That is, the pressure of CO_2 in the gas pocket and in solution equalize, given sufficient time. With each re-opening, more of the excess gas in the soda escapes from the bottle. Eventually, the pressure of CO_2 in all three zones—liquid, air pocket, air outside bottle—is the same, so there is no imbalance to cause the burp. (it is now in equilibrium).

d) Colder temperature allow more gas dissolution; increasing salinity decreases the solubility.

e) The burning of fossil fuels (coal, oil, gas) is causing levels of CO_2 and other heat-trapping gases to build up in the atmosphere. This increase might cause global temperatures to rise, changing conditions in various areas in ways that might be inconvenient or harmful. Some of the excess CO_2 that we are releasing is absorbed by the oceans and continents. So it is important to understand how much CO_2 can be held. Just as there was a limit to the quantity of CO_2 dissolved in the soda, there is also a limit to the amount of gas that can be stored in reservoirs, like the ocean, through natural processes.

II. Air Cares—

Key concepts:

a. gases in air

b. solubility (gases in water)

c. pH (acid-base)

Part 1: Testing for CO2

Materials:

- distilled water
- artificial seawater (you will need to add 2 tablespoons of sodium bicarbonate- baking soda)
- litmus paper for pH testing with range of at least 6.0 to 8.0
- drinking straws

Objective: CO_2 is present in the air in very small amounts, but is a very important gas. Students will examine to see if dissolved CO_2 is present in water and to explore the relationship of salinity to CO_2 solubility.

Method: Pour distilled water and seawater into glasses; test the pH with litmus paper. One glass of each water sample will act as a control. Place straws in the other two glasses (1 seawater and 1 distilled water). Students take turns blowing through the air stone for a total for 5-10 minutes. Repeat the pH test with a new piece of litmus paper and record your results.

Classroom Discussion Questions:

a) Is there a difference in pH between the two water samples at the start? Is there a difference before and after blowing through the straws? Which water sample exhibits the greatest difference? Why?

Teacher's Guide for Discussion Questions:

For DI water: Water is neither a base nor an acid. It is neutral. Thus, its pH should be relatively close to 7.0 on a scale of 1 (acidic) to 14 (basic). As CO_2 from student's breath is blown through the water, it reacts with the water to form carbonic acid which increases the acidity of the water. The litmus test should reveal a slight change toward a more acidic pH, which causes the visible difference in the color of the litmus paper. If no CO_2 were present in the air, no carbonic acid would form, and no change would be detected.

($CO_2 + H_2O \rightleftharpoons H_2CO_3$)

For Seawater: Seawater is a complex mixture of components. It's pH is fairly constant at about 8.0, on the basic side. This is due to the presence of carbonate ions which have the capacity to neutralize increased concentrations of carbonic acid formed upon additions of CO_2, therefore changes in pH are extremely small, and there should be no change observed.

Part 2: Testing for oxygen

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Key Concepts:

a. oxygen consumption

b. density

c. CO_2 production

Materials:

- two short candles
- medium-sized pickle or some other jars
- matches
- one 10x15 cm index card

Objective: Demonstrate that oxygen is a gas present in the atmosphere and that burning consumes oxygen. Fuel-driven "machines," like power plants and cars, need oxygen to produce energy, and it is also required for humans to burn their own "fuel," food. In turn humans produce CO2- just like the man-made machines.

Method: Light the candles and place the glass jar over one of them. Let the candle continue to burn inside the glass jar until it goes out. Slide the index card under the jar, sealing it as you pick it up and turn it over. The mouth of the jar now faces upwards. (This step must be performed quickly because the gases in the jar are now heavier than air. They will escape from the jar if its mouth is pointed down.) Remove the index card and immediately "pour" the air in the jar over the second burning candle. It should go out.

Classroom Discussion Questions:

a) Why did the candle go out when burned inside the jar?

b) Why did the second candle go out when the air in the jar was poured over it?

Teacher's Guide for Classroom Discussion:

a) Candles require O_2 to burn. O_2 is one of the gases present in air. Therefore, a candle will burn as long as O_2 is available. When the jar was place over the candle, O_2 was present in the air inside the jar. However, as the candle burned, it consumed the O_2 inside the jar and produced CO_2 and other gases. Eventually the candle exhausted all the O_2 in the jar, and the flame went out.

b) The air left in the jar after the candle burned out had no O_2 in it. It was also heavier than the air in the room because CO_2, a dense gas, had been added to it by the burning candle. Thus, when this "heavy," O_2-poor air was poured over the candle, it displaced the O_2-rich air in the room and extinguished the flame.

III. Temperature vs. [O_2] graph

Key concepts

a. dependent and independent variables
b. plotting and interpreting data

Materials:

- Hydrolab data
- graph sheets

Method: Temperature and oxygen concentration data sets have been provided for 4 different water samples. On the graphs, plot temperature and O_2 concentration for each water sample. The dependent variable is O_2. (A sample graph is included)

Classroom Discussion:

a) How does oxygen concentration in water vary with temperature?
b) How does oxygen concentration vary between salty water and freshwater?
c) What will happen as the cold sample comes to room temperature?
d) Draw a line connecting all freshwater data points. What is the temperature dependence of oxygen concentration?

Teacher's Guide for Classroom Discussion:

a) As temperature increases, solubility of gases in water decreases; less O_2 is dissolved and therefore the concentration
decreases.
b) Increasing salinity decreases solubility of gas in water, therefore dissolved O2 concentration decreases.
c) As the water warms, O_2 will be released, and the concentration in the water sample will decrease.
d) The temperature dependence will be the slope of the line between data points.

HYDROLAB DATA

	fresh #1	fresh #2	fresh #3	saline
Temperature (deg. C)	12.8	22.5	31.9	22.9
Oxygen Concentration (mg/L)	9.3	7.6	6.6	6.7