Lesson Plans: Dissolved Gases in Water

Objective

The objective of this activity is to prove that ocean water can absorb greenhouse gases and to demonstrate that what appears to be clear water is actually a complex solution of dissolved gases.

Materials

Each student or group of students will need the following:

- Unopened bottle of soda or carbonated mineral water (clear, plastic, screw-top bottle)
- Two small glasses of equal size
- Tap water
- Distilled water
- Boiled water (cooled)
- Aerated water
- Magnifying glass

Important Points to Understand

Oceans take in CO_2 and other gases to maintain an equilibrium, or a balance of concentration, between gases in the sea and air. How do the oceans absorb CO_2? Once drawn into water, CO_2 molecules react with already-present carbonate ions to form bicarbonate ions (H_2CO_3). This transformation removes $C0_2$ proper from the water. Furthermore, bicarbonate ions are used by marine animals and plants in forming the calcium carbonate ($CaCO_3$) with which their shells are made. When these marine organisms die, their shells settle to the sea floor and are often buried in sediments there. Some fraction of the calcium carbonate dissolves back into the ocean waters, but a large portion is trapped as solid sediment, effectively locking away the atmospheric CO_2 used to make it. Through these processes, the ocean ultimately has a major role in determining the atmosphere's CO_2 content. At one time, it was thought that the ocean could continue to absorb carbon dioxide indefinitely. Although the extent to which earth's oceans can take up greenhouse gases is still not fully known, some scientists now believe that oceans absorb about half of the CO_2 produced by human activities. This might change if ocean temperatures rise due to global climate change, however, because gases in warm water become less soluble. If more readily released into the air, additional CO_2 Would intensify an already-problematic greenhouse effect.

Preparation

Demonstrate that water contains invisible gases. Collect and cover samples of several different types of water: tap, boiled, distilled, and aerated (shaken vigorously to force up the oxygen level). Study these by eye and using a hand lens. Are there any visible differences? Divide each sample into two equally sized small glasses. Cover one, leave the other uncovered, and place both in a sunny and/or warm spot for 24 hours. Are any differences visible now? What happens when these various waters are frozen? Which water would you use to create the clearest possible ice cube?

Procedure

1. Open the bottle of soda or carbonated water and listen for the characteristic "whoosh" sound of gas escaping from the bottle. Also observe bubbles forming in solution and rising upward.
2. Re-cap the bottle, then immediately remove the cap for a second time. Was a whoosh heard this time? Again, re-cap it and set it aside for several hours or until the next day.
3. Open the bottle and listen for the whoosh. Re-cap and set aside. Repeat this process until you no longer hear the whoosh upon opening the bottle after a long rest. Count the number of times you repeat the process.

Questions

1. What causes the whoosh when the bottle is first opened?
2. Why does not the bottle whoosh when it is re-capped and then immediately re-opened (in step (2) above)?
3. Why does the bottle stop burping after many repetitions?
4. How does this demonstration involving C02 dissolved in water relate to the real world and the subject of global climate change?

Some Hints for the Questions

The solution is supersaturated with carbon dioxide. This means that the conditions of room temperature and pressure, there is more CO_2 dissolved in the solution than it can accomiodate. The pressure of $C0_2$ inside the bottle is greater than the pressure of CO_2 in the air outside the bottle. When the bottle is opened, some of the CO_2 gas rushes out to equalise the pressure.

Notice that the bottle is not completely filled with liquid; there is a small pocket of air at the top. In the unopened bottle, some of the carbon dioxide has escaped from the solution and entered the air pocket. The pressure of CO_2 in solution and the pressure Of CO_2 in the air above the solution are equivalent. But this equalisation process is not instantaneous. When you open the cap and re-open the bottle rapidly, there is not enough time for the air pocket in the bottle to re-pressurise with CO_2.

Each time the bottle is opened and re-capped, a new state of equilibrium is reached. That is, the pressure Of CO_2 in the liquid and in the air pocket equalise. And each time you open the bottle, the pressure Of CO_2 in the air pocket and in the air outside the bottle equalise. With each repetition, some of the excess CO_2 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.

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 a limit to the amount of gas that can be stored in reservoirs through natural-process.