POLAR TREC

TEACHERS AND RESEARCHERS EXPLORING AND COLLABORATING

How Does Polar Ice Coverage Effect the Carbon Dioxide Concentration of Polar Water Bodies?

Overview

When a bottle or can of carbonated beverage is opened the carbon dioxide is allowed gas to come out of solution. This is because there is a pressure differential between the carbon dioxide in the liquid and carbon dioxide in the air. The pressure in the liquid is higher than the pressure in the air so the carbon dioxide moves from high to low. This is the tiny bubbles seen in the carbonated drink as it fizzes. This will go on until there is an equilibrium reached where the pressure inside the liquid is equal to the pressure of the air. It is at this point that the beverage is "flat"– as in no bubbles. So the question is how does the carbon dioxide get into the liquid in the first place, That is, in chemistry speak, how does carbon dioxide go into solution?

There is an old adage in chemistry that "like dissolves like". This is a helpful way of predicting weather or not two chemicals will get together and form a solution. Polar molecules – those molecules with distinctly positive and negative ends – will dissolve other polar molecules. Non-polar molecules – molecules with an even distribution of positive and negative charge – will dissolve non-polar molecules. The problem with this is carbon dioxide (the solute) is non-polar and the water that it will dissolve in (the solvent) is polar. So why does carbon dioxide dissolve in water?

A good place to start is at the particle level. Carbon dioxide is a linear molecule: Since there are lots of electrons around the oxygen atoms of both the water and carbon dioxide molecules and the hydrogen atom side of the water molecule is low electron density (so slightly positive) it is reasonable to assume that there must be

Details

- Lesson
- ArcticAntarctic
- Less than a week
- Download, Share, and Remix
- High school and Up

Materials

Two Vernier (or other) CO2 Gas Sensors
Data collection computer to interface the above probes
A 12 oz can of soda water
Two 250 ml beakers
Two ring stands and clamps
Molecular models (ball and stick) or drawn models of the carbon dioxide molecule and the water molecule. This will be used to explore the intermolecular forces between the carbon dioxide and water molecules.

Standards

some low level of attraction between the ends of the carbon dioxide and the hydrogen side of the water molecule. It is those very weak bonds that initiate the dissolving of carbon dioxide in water.

Gas phase concentrations of carbon dioxide are usually measured with infrared spectral techniques. The carbon oxygen double bonds in the carbon dioxide molecule absorbs infrared radiation in a narrow band at 4260 nm. The concentration of CO2 follows Beer's Law with the absorbance increasing with the concentration. The solubility of carbon dioxide follows Henry's Law with the solubility of the gas increasing as the partial pressure of the gas increases.

Next Generation Science Standards (NGSS)

HS-PS1-2. Construct and revise an explanation for the outcome of a simple chemical reaction based on the outermost electron states of atoms, trends in the periodic table, and knowledge of the patterns of chemical properties.

HS-PS1-5. Apply scientific principles and evidence to provide an explanation about the effects of changing the temperature or concentration of the reacting particles on the rate at which a reaction occurs.

HS-PS1-6. Refine the design of a chemical system by specifying a change in conditions that would produce increased amounts of products at equilibrium.

Objectives

At the conclusion of this lesson students should be able to incorporate the following understandings into their thinking about gaseous solutions:
1) Carbon dioxide dissolves in water because of weak dipole-dipole attractive forces.
2) When a can or bottle of carbonated beverage is opened carbon dioxide bubbles form because the pressure of the carbon dioxide outside the container is less than the pressure of the carbon dioxide inside a container which effectively pushes the carbon dioxide out of solution.
3) A sheet of ice on a body of water can act as lid on a container effectively sealing it not allowing the carbon dioxide dissolved in the water to equilibrate with the atmospheric carbon dioxide.
4) An unsealed carbonated beverage will go "flat" over time because the carbon dioxide dissolved in the beverage equilibrates with the carbon dioxide in the air?
5) The water in the oceans of the Arctic and Antarctic can serve as potential carbon sinks where large quantities of carbon dioxide can dissolve as the ice covering the oceans decreases due to climate change.

Lesson Preparation

Gather materials for the experiment.

Procedure

- Set up the two ring stands so that the sensors are positioned pointing downward and clamped (not too tightly) in the clamps.
- Position the two 250 ml beakers under the sensors.
- Set up the computer so the sensor is interfaced according to manufacture directions and collecting data continuously. The experiment will run for at least 24 hours.

- Position the ring stand/sensor/beaker assemblies approximately 1 meter from one another.
- Position the sensors' tip even with the top edge of the beaker it is suspended and centered over.
- Fill one beaker ¾ full with room temperature tap water and the other beaker ¾ full with room temperature soda water.
- Begin collecting data with the computer.

After a 24 hour (or more) data collection period, students should process the data with the following questions being used as a guide:
1) What were the independent, dependent, and control variables in this experiment?
2) Did the concentration of the airspace over the water beaker change over time? If so describe the change.
3) Did the concentration of the airspace over the soda water beaker change over time? If so describe the change.
4) Based on your observation of the carbon dioxide concentration over the water beaker, what could be inferred about the concentration of the carbon dioxide dissolved in the water?
5) Based on your observation of the carbon dioxide concentration over the soda water beaker, what could be inferred about the concentration of the carbon dioxide dissolved in the soda water?
6) Gently swirl both of the beakers. Do any bubbles form in either of the beakers?
7) Based on your observation in item #6 would you conclude that the concentration of carbon dioxide is the same or different in the two beakers?
8) Refer back to the data at the first hour of the experiment, what can be concluded about the concentration of dissolved carbon dioxide in the two beakers?
9) What can be inferred about the relationship between the concentration of carbon dioxide in the air above a body of water and the concentration of dissolved carbon dioxide in the water.
10) Carbon dioxide is a linear nonpolar molecule, and water is a bent polar molecule. Provide a particle level sketch (model) of the possible intermolecular interactions (bonds??) that might cause carbon dioxide to be soluble in water.
11) Based on your understanding of inter-molecular and intra-molecular bonding, would conclude that the water/carbon dioxide bonding be very strong, strong, weak, or very weak. Defend your response!
12) If the concentration of carbon dioxide in the air above an open body of water (the Beaufort Sea say) were to increase, could you predict what might change in the concentration of carbon dioxide? If so what might the change be?
13) If the same body of water were covered with ice and there were the same increase in atmospheric carbon dioxide how would you predict the concentration of carbon dioxide in the water to change?

Extension

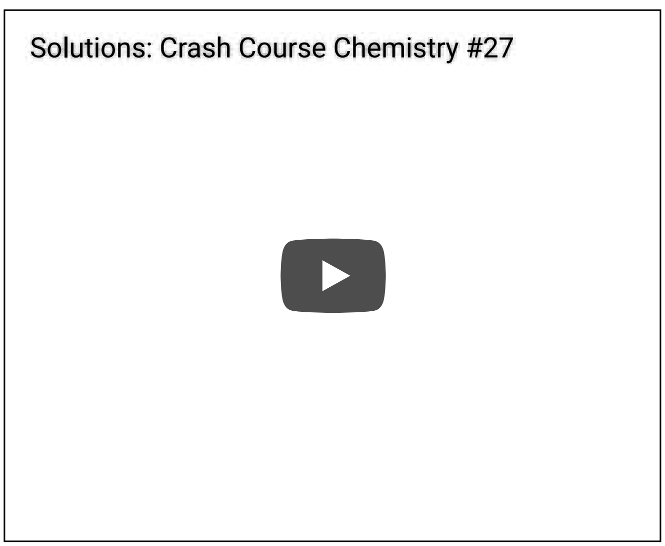
1) How does temperature affect the solubility of carbon dioxide in water?
The same experiment can be run but with the two beakers filled ¾ full of soda water. The two beakers are the subjected to the following treatments:

a. one of the beakers is kept at a temperature of between 35 and 40 C, and
b. the other is kept at a temperature of 5-10 C.

Resources

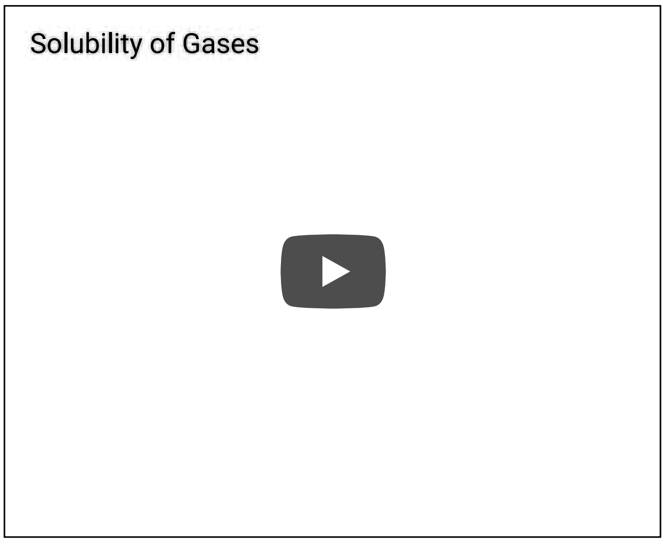
1) Vernier CO2 Gas Sensor available at https://www.vernier.com/products/sensors/co2-sensors/
2) PASCO CO2 Gas Sensor available at https://www.pasco.com/prodCatalog/PS/PS-2110_pasport-carbon-dioxide-gas-...
3) Instructional videos:
a. Water solutions:
i.

ii.



b. Gas solubility:
i.

ii.



Assessment

The following questions can be used to assess student learning:

1) Carbon dioxide will dissolve in water because:
a. Carbon dioxide is a polar, water is a polar molecule and like dissolve like.
b. Both carbon dioxide and water have intra-molecular covalent bonds.
c. Carbon dioxide forms an ionic bond with the water.
d. Weak dipole attractive forces form between carbon dioxide and water molecules.

2) If the concentration of carbon dioxide is increased in the atmosphere above a body of water the concentration of carbon dioxide in the water will:
a. Increase
b. Decrease
c. Stay the same
d. There is no way to predict.

3) If a can of soda water is opened and allowed to stand:
a. The concentration of carbon dioxide in the surrounding air will decrease and the concentration of dissolved carbon dioxide will increase.

b. The concentration of carbon dioxide in the surrounding air will increase and the concentration of dissolved carbon dioxide will decrease.
c. The concentration of carbon dioxide in the surrounding air and the concentration of dissolved carbon dioxide will not change.
d. There is no way to predict what will occur.

4) Loss of Polar sea ice due to climate change could cause
a. An increase in dissolved carbon dioxide
b. A decrease in dissolved carbon dioxide
c. No change in dissolved carbon dioxide

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