PROTOCOL 9. MEASURING DISSOLVED CARBON DIOXIDE

Objective

To measure carbon dioxide concentrations in water.

Background

Through the process of respiration, plants, animals, and microorganisms break down organic compounds to obtain the energy needed to sustain life. Carbon dioxide (CO_2) is produced as a waste product.

Respiration:

organic matter + oxygen → carbon dioxide + water + energy

In aquatic systems, the dissolved CO_2 concentration can be used as an indicator of the rate of respiration vs. photosynthesis. Plants produce CO_2 as a waste product of respiration, but they also use CO_2 to build food through the process of photosynthesis. While respiration occurs 24 hours per day, photosynthesis occurs only in the light. Ponds that are rich in plant life therefore have swings in CO_2 concentration over the course of the day and night.

Bacteria and fungi produce CO_2 when they break down organic wastes. In water containing a lot of organic matter, microbes grow and reproduce rapidly. As a result, they use up a lot of oxygen and produce high CO_2 concentrations. Fish tend to avoid water with CO_2 concentrations of 1–6 mg/L, and higher concentrations can kill them.

This protocol measures CO_2 concentrations in water, based on the same chemical reactions used in packaged test kits (such as LaMotte #7297-DR or Hach #143601). If the sample contains CO_2, it is acidic. As you add drops of NaOH, this base neutralizes the acid according to the following chemical reaction:

CO_2	+	NaOH	→	$NaHCO_3$
carbon dioxide		*sodium hydroxide*		*sodium bicarbonate*

You stop adding NaOH when the solution turns pink, which occurs at a pH of 8.3.

Materials (per student group)

- 50 mL buret or "Poor Man's Buret" (e.g., Flinn #AP8752)
- Ring stand with buret clamp
- 100 mL flask or beaker
- 50 mL water sample
- 2 drops phenolphthalein indicator solution (1%)
- 50 mL 0.02 N NaOH solution
- Goggles
- Gloves

NOTE: Samples should be analyzed promptly after collection because the concentration of dissolved CO_2 is likely to change over time. If you will be collecting samples in the field for analysis in the lab, fill the sample bottles completely (leaving no room for air), keep them on ice, and perform the lab analyses as soon as possible after sampling.

Procedure

1. Wearing goggles and gloves, attach the buret to the ring stand so that it is suspended over the beaker or flask. Fill the buret with 50 mL NaOH solution.
2. Gently pour 50 mL of your sample into the beaker or flask, being careful not to shake the sample or to create bubbles.
3. If your lab table is a dark color, place a piece of white paper under the beaker so that you will be able to see color change in the solution.
4. Add two drops phenolphthalein indicator solution. If a pink or red color develops, there is no dissolved carbon dioxide. If no color develops, go on to the next step.
5. One drop at a time, add NaOH solution and gently swirl the sample. Continue until a light pink color develops and does not disappear when swirled.
6. Read on the buret how many mL of NaOH solution have been used.

Analysis

Use the following equation to calculate the CO_2 concentration in your solution:

CO_2 concentration = _____ mL NaOH x 17.6 = _____ mg CO_2/L

(17.6 converts from mL NaOH to mg CO_2/L. In case you're interested in the math, here's how it is derived):

$$\frac{\text{mL NaOH}}{\text{50 mL sample}} \times \frac{\text{0.02 mol NaOH}}{\text{L}} \times \frac{\text{1 mol } CO_2}{\text{mol NaOH}} \times \frac{\text{44 g } CO_2}{\text{mol}} \times \frac{\text{1000 mg}}{\text{g}} = \text{mg } CO_2/\text{L}$$

The final step is to interpret these results. Your interpretations will depend on your particular experiment. How do your data compare with the predictions you made at the beginning of your experiment?

If you tested water from a lake or stream, keep in mind that fish and other aquatic organisms tend to avoid water with CO_2 concentrations of 1–6 mg/L, and higher concentrations can kill them. In waters with high CO_2 concentrations, the dissolved oxygen concentrations tend to be low. How would you explain this correlation?