Demonstration of Relationship between CO2 and pH Instructions

Note - If you are interested in running the demonstration in class, follow the Leading the Demonstration in Class instructions below to run it stating after Session 9, Section B #3 "Project slide of Atmospheric CO_2 vs. ocean pH" going until Session 9, Section C #2 "Comparing Graphs."

Materials Needed

- Computer
- Projector
- Spark unit (w/ charger and Garmin Cable (USB-to-mini-USB-B))
- Electric kettle
- pH probe (w/ extra Storage Solution; make sure to equilibrate the sensor, refer to manufacturer's instructions on how to do this—usually takes ~60 minutes)
- CO_2 probe (PASPORT Carbon Dioxide Gas Sensors are available from PASCO for ~$260)
- 2 round 500 mL bottles
- 3 square 250 mL bottle
- 1 BioChamber (square 125mL bottle w/ holes; Vernier BioChambers are available from Ward's Science for ~$7)
- 2 funnels
- 1 timer
- 1 piece of rubber tubing connected to straight connectors to small, black stopper (#3) at one end and large, black stopper (#6) at other end
- 1 piece of rubber tubing connected with a straight connector to small, black stopper (#3)
- 6 sugar packets
- 2 yeast packets

Preparation of Materials

- Familiarize yourself with the sensors and Spark unit. Make sure the Spark unit is fully charged before class (they take about 12 hours to fully charge). It is not necessary to calibrate the equipment.
- Load the Spark Science Learning System Resource & Support Materials CD into your computer.

a. Select the Emulator folder.
b. Select the folder appropriate for the type of operating system that you are using (Macintosh or Windows).
c. Install the SPARKvue application onto your computer. This will enable your computer to project the Spark unit screen for the students to see the data as it is being collected.

- Set-up your computer and projector. Attach the Spark unit into a wall outlet with the charger. Do not turn the Spark unit on yet.
- Connect the Spark unit to the computer using the Garmin USB-to-mini-USB-B cable. The mini-USB-B part of the Garmin cable connects to the Spark unit between the two data ports and to the right of the USB port. The USB part of the Garmin cable connects to a USB port in your computer.
- Organize and set-up materials for the pH part of the demonstration:
    a. Fill the square 250 mL bottle with 100 mL of room temperature water.
    b. Place the open end of the rubber tubing into the square 250 mL bottle; make sure the tip is submerged in the water.
    c. To remove the pH probe from its storage container, hold the probe vertically, unscrew the lid from the container and then gently pull the sensor (with the lid attached) out of the container. Put the container in a safe location so that the storage solution does not spill out.
    d. Insert the pH probe into the square 250 mL bottle; make sure the probe is submerged in the water. The rest of the probe should remain dry (it is not waterproof).
    e. Connect the pH probe to the PASPort pH Sensor.
    f. Connect the PASPort Water Quality Sensor to the left port on the top of the Spark unit.
    g. Set out 1 round 500 mL bottle (without its cap), 3 sugar packets, 1 yeast packet, and 1 funnel next to the end of the rubber tubing that has the small, black stopper (#3) attached.


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- Organize and set-up materials for the CO_2 part of the demonstration:
    a. Remove to the cap to the BioChamber and place the CO_2 probe horizontally in the BioChamber. The BioChamber bottle should be on its side (Rutgers label facing down),

and the CO_2 probe will enter the bottle through the bottle top. The CO_2 probe cannot get wet.

b. Connect CO_2 probe to right port on the top of the Spark unit.

c. Place the rubber tubing end with the large, black stopper (#6) in the black-rimmed hole in the side of the BioChamber that is facing up. Make sure the seal is tight.

d. Set out 1 round 500 mL bottle, 3 sugar packets, 1 yeast packet, and 1 funnel next to the other end of the rubber tubing that has the small, black stopper (#3) attached.

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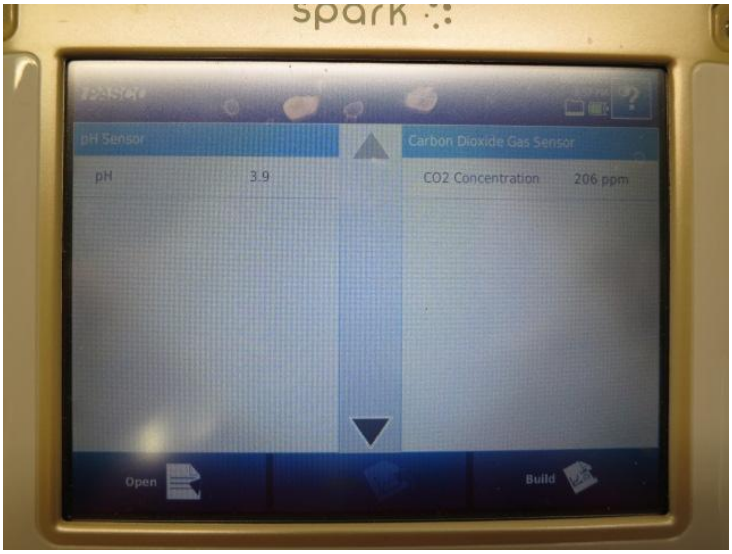
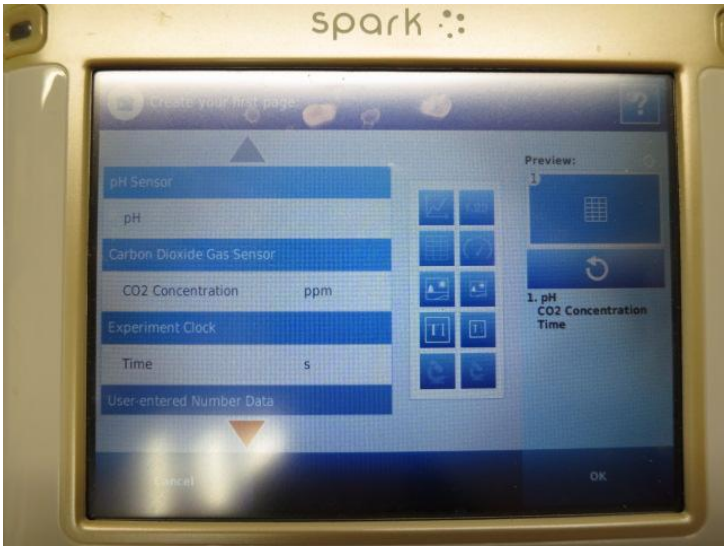
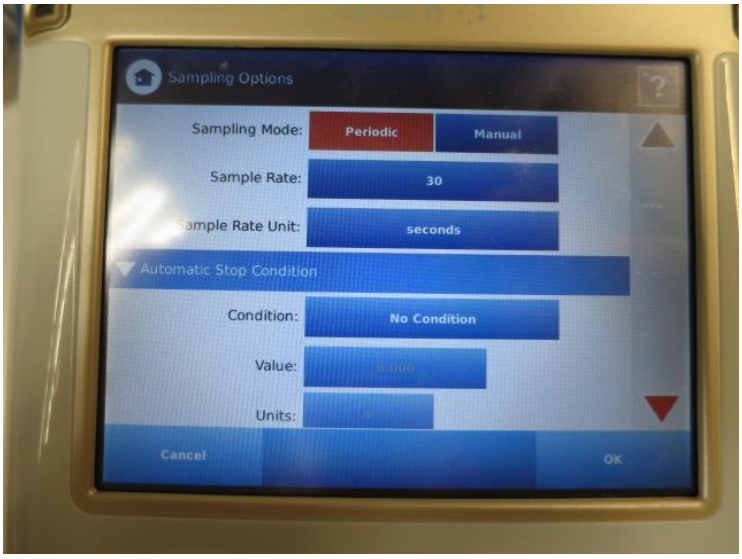
- Prepare hot water (about 100ºF) just before the start of class in the remaining 2 square 250mL bottles. This will be used to activate the yeast, so make sure it is not too hot.
- Turn on the Spark unit on by pressing the blue on button on the bottom on the Spark unit.
- After the unit has started up, there should be two large boxes taking up the majority of the screen.
    a. On the right should be “Carbon Dioxide Gas Sensor” with CO_2 Concentration ### in the field.
    b. On the left should be “pH Sensor” with multiple variables listed in the field, including pH ###



- Equilibrate the sensors:
    a. Let the CO_2 sensor equilibrate by just being where it is. The sensor should give a CO2 concentration somewhere between 300-600 ppm (higher if the ventilation in your classroom is poor). Allow a few minutes for the sensor to produce a stable value, by watching the Spark unit Carbon Dioxide Gas Sensor/CO_2 Concentration values.
    b. Then, gently swirl the pH probe in the water for 3 minutes; during this time the pH should rise. After 3 minutes, stop swirling. Watch the pH Sensor/pH values on the Spark unit and wait for the pH reading to settle. The pH reading should be stable for at least 1 minute before beginning the demonstration. It is very important that the sensor equilibrate, so be patient. The sensor should give a pH of approximately 6-8. The pH of pure water is 7, but tap water often contains harmless, dissolved minerals that can affect its pH.
- Along the bottom of the screen should be two options in white: Open on the left and Build on the right. Select Build.
- Using the up and down arrows select these variables from the left-hand column of variables: pH Sensor/pH, Carbon Dioxide Gas Sensor/CO_2 Concentration ppm, and demonstration Clock/Time s.



- In the center white column select the data table icon.
- Along the right-hand side of the screen under Preview it should have the data table image with "1. CO_2 Concentration, pH, Time" listed below. Select OK.
- A table view should show up in the screen. At the bottom center of the screen it should say "Periodic: 1 Hz" with a clock icon to the right. Select the clock icon.
    a. Select the Sample Rate Unit by tapping on the blue box with Hz. Select "seconds."
    b. Select the Sample Rate by tapping on the blue box with a 1. Select "30."
    c. Select OK in the bottom right corner.



Leading the Demonstration in Class (after Session 9, Section B #3 "Project slide of Atmospheric CO_2 vs. ocean pH")

1. **Prepare the materials**. Explain to the participants that they will be testing the relationship between atmospheric CO_2 and ocean pH using yeast, as well as pH and CO_2 sensors. Prepare all of the materials for the demonstration in a central location so that participants can see.

2. **Explain the background of the demonstration.** Inform the participants that you will activate yeast by adding warm water and sugar, causing the yeast to respire CO_2 gas as you did in a previous session (Session 6). In one set-up you will direct the CO_2 gas into a chamber that contains air, and will measure the change in gaseous CO_2 concentration in this chamber over time, to see how much CO2 is produced through respiration by the yeast. In the other set-up you will direct the CO_2 gas into a chamber that contains tap water, and will measure the resulting change in pH of the water over time.

3. **Address the use of two yeast set-ups (optional).** Participants may ask why you are not directing the CO_2 gas from a single bottle of activated yeast into both the CO_2 chamber and the water sample chamber for pH. Explain to them that one bottle of yeast does not produce enough pressure to travel through both tubes, so it is necessary for the pH and the CO_2 trials to be done using separate bottles of yeast.

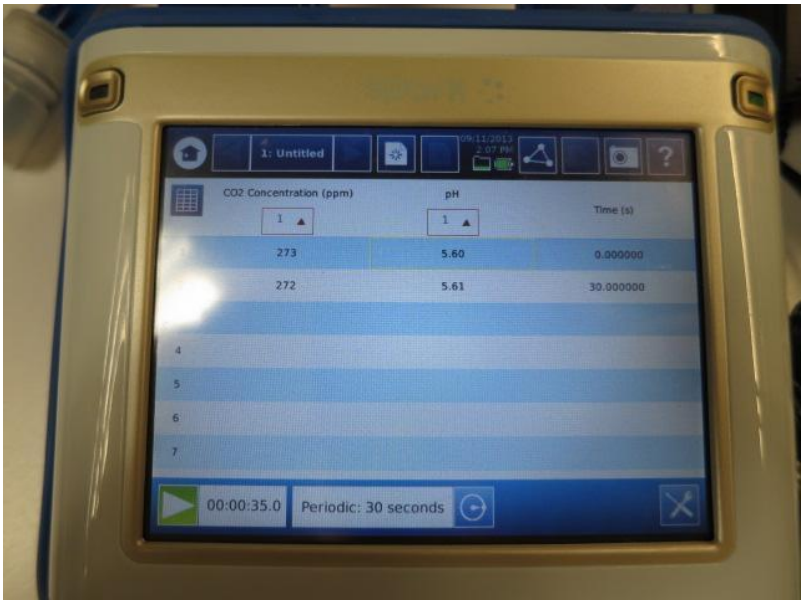
4. **Make predictions.** Before you begin the demonstration, have participants discuss their predictions with a partner. What will happen to the CO_2 concentration in chamber 1 and the pH in

chamber 2? Do you think that the CO_2 will change throughout the demonstration? If so, will it change at a constant rate? Remind participants that they need to state what prior knowledge they are using when making their predictions, as predictions are not random guesses but rather based upon prior knowledge and understanding of the system. [Participants will likely draw evidence from the previous yeast demonstration done in Session 6. In that demonstration, they used BTB as a chemical indicator and determined that yeast fed sugar created CO_2. They may also remember that BTB actually indicates the presence of an acid because when CO_2 when added to water makes carbonic acid, therefore the change in color of BTB is a proxy for change in CO2 concentrations.]

5. **Record predictions on the board.** After a minute or so, pull the class back together and have participants report out their predictions. Write them on the board. Be accepting of all predictions/hypotheses, but remember to probe for their reasoning.

6. **Explain plan for recording data.** Inform participants that the demonstration will run for the next 24 minutes, and you will record the data every three minutes on the board on the class data table. Ask for volunteers to take the pH and CO_2 readings for the first 3 minutes and record the data on the board. If possible, have multiple participants take the readings, as this will help them to make sense of the data. While the participants complete the active reading below, continue to record the data for them every three minutes for 24 minutes (Continue with the next step while the next 21 minutes of data is being recorded)

7. **Begin the demonstration.** After participants have shared their predictions, begin the demonstration (you will need a helper as both bottles need to be started at the same time):
    a. Start the demonstration for both the pH and the CO_2 portions of the demonstration at the same time (i.e., ask for a volunteer to assist with this part of the demonstration).
    b. Fill each round 500mL bottle with 250mL of hot water (to the touch).
    c. Use the funnel to add 3 packets of sugar to each of the round 500mL bottles and then 1 yeast packet. Stir by swirling the round 500mL bottles for 5 seconds. Note – this is the only time you need to stir the solution. Do not overmix!
    d. Then quickly insert the small, black stopper (#3) into the top of each round 500mL bottle. Make sure the seal is tight.
    e. Start collecting data on the Spark unit by selecting the green play arrow in the bottom left corner of the screen. Initial recordings for pH and CO_2 will appear in the data table, and then recordings every 30 seconds after that.



a. The yeast solution should begin to foam. In a few minutes, the gas being produced by the yeast should travel through the rubber tubing, producing bubbles in the water where pH is being measured.
b. When the foam reaches the top portion of the round 500mL bottle as it starts to narrow (or after 24 minutes – whichever comes first), stop the demonstration by: selecting the red play button in the bottom left corner of the screen to stop recording data, removing the small, black stoppers (#3) from the round 500mL bottles, and unplugging the probes from the Spark Unit.
c. Use the mouse to scroll up and down in the data table for the students to see the data to complete the data-graphing portion of the activity.
d. Note- when you are done recording the data, turn off the Spark unit with the power button on the bottom of the unit and detach from your computer and the wall.

8. **Use the active reading protocol to discuss Cause and Effect.** While you are recording data from the yeast demonstration (approximately 21 minutes), engage participants in the active reading protocol around the Crosscutting Concept of Cause and Effect.

a. Hand out pages 86-89 of *A Framework for K-12 Science Education.* Remind participants to underline interesting and important points, to circle things they have questions about, and to write their questions in the margins.
b. Tell them to partner up when they have finished reading and to discuss what they found interesting, surprising, or confusing.
c. When about 6 minutes remain for this part of the session, ask participants to share out anything they found relevant or questions they still have with the class.

d. Tell participants to keep the crosscutting concept of cause and effect in mind as they move through today's session.

C. Transferring Data from Tables into Visualizations to Interpret

1. **Completing the Yeast handout.** Return to the yeast demonstration and distribute the "Yeast Investigation Handout." Ask participants to complete the handout by creating graphs of the pH and CO_2 concentration over time. Before the participants make their graphs have them refer back to their Data Visualization Key from Session 4 and ask them (using the "Transferring Data from Tables into Visualizations to Interpret" slides):
    - What kind of data do we have? [*Continuous data*]
    - What do they want to show with the data? [*Comparison over many time periods*]
    - Therefore, what kind of graph should they use to display the pH and CO_2 data? [*Line chart*]

    While the students are graphing the data, begin to clean up the demonstration:
    - Rinse and dry the round 500mL bottles that had the yeast in it.
    - Rinse and dry the funnel.
    - Rinse and dry the square 250mL bottles.
    - Do not rinse the pH probe. To store the pH probe, insert the probe into the container of storage solution and screw the top back on. The tip of the sensor should be immerses in the storage solution, but should not touch the bottom of the container.
    - Do not rinse the CO_2 sensor, just return it to its zip lock bag.
    - Do not rinse the BioChamber, just put the cap back on and return it to its zip lock bag.