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Dissolved CO_2 Sensor

(Order Code CO2L-BTA)

The Vernier Dissolved CO_2 Sensor can be used to measure the concentration of dissolved carbon dioxide (CO_2) in aqueous samples. It requires a Vernier interface for connection to a computer.

The Dissolved CO_2 Sensor is a sensor that measures CO_2 concentration in solution. After conversion to CO_2 by pH adjustment with a citrate buffer, carbonate and bicarbonate ions can also be measured (see Figure 1). The probe uses a glass pH electrode and a reference electrode, mounted behind a gas permeable membrane. The membrane separates the sample from a thin film of internal solution pressed between the membrane and the surface of the glass electrode. The CO_2 in the sample diffuses through the membrane until the partial pressure of CO_2 in the sample and the film are equal. The CO_2 partial pressure is proportional to CO_2 concentration. Carbon dioxide reacts with water in the internal solution to form carbonic acid. The glass electrode measures the resulting pH change.

Standards and samples must be buffered to a pH value between 4.8 and 5.2, to ensure conversion of carbonate and bicarbonate to CO_2 (see Figure 1). Because CO_2 diffuses rapidly out of acidic solution, it is important to minimize surface area of the sample, avoid vigorous stirring, and make measurements as soon as possible after acidification. Samples should be aqueous, and not contain oils, which may coat the membrane and adversely affect response time.

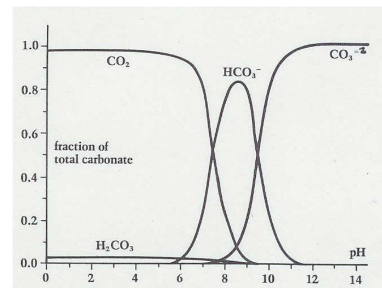

Figure 1: Carbonate, bicarbonate, and carbon dioxide as a function of pH

The Dissolved CO_2 Sensor can be used to perform a wide variety of tests or planned experiments, including the following:

- **Cellular Respiration of Aquatic Organisms:** You can monitor the dissolved CO_2 during cellular respiration of an organism (e.g., snails) in an aqueous environment.
- **Photosynthesis of Aquatic Plants:** Students can use the Dissolved CO_2 sensor to monitor decreases in CO_2 concentration during photosynthesis of aquatic plants (e.g., Elodea, Anacharis).
- **Human Respiration:** You can monitor the level of dissolved CO_2 in water samples as you exhale your breath through a straw into water.

Inventory of Items Included with the Dissolved CO_2 Sensor

- Dissolved CO_2 Ion-Selective Electrode
- Electrode Amplifier
- Three Dissolved CO_2 Membrane Caps
- Internal Filling Solution for a Dissolved CO_2 Sensor
- pH Buffer/ISA Solution

Preparing the Dissolved CO_2 Sensor for Use

1. Carefully remove the internal glass electrode from the box. Carefully remove the protective sleeve that covers the end of the internal glass tip. **Note:** The internal glass electrode is soaking in buffer pH 4 storage solution in the sleeve. While the electrode is in use, be sure to position the sleeve in an upright position in a container, so the solution does not spill.
2. Obtain one of the Membrane Caps that came with the sensor. Remove its blue protective boot.
3. Add 3.5 mL of the Internal Filling Solution to fill the Membrane Cap.
4. Rinse the internal glass electrode with distilled water, and carefully blot dry.
5. Attach the filled membrane body to the internal glass electrode. **It is very important to make sure that the top opening of the internal glass electrode cap fits into the slot at the top opening of the body.** Tighten the membrane cap (turn clockwise) until snug. Do not over-tighten.
6. Attach the electrode to the Electrode Amplifier, and soak the electrode in a pH 4 buffer.

The method for determining the concentration of dissolved CO_2 using the Dissolved CO_2 Sensor:

- The interface reads a voltage that is related to ion concentration.
- Using the voltage reading and the principle described in Figure 2, the natural log of concentration of the specific ion can be determined.
- The ion concentration can be determined from the natural log of concentration.

Solutions	Preparation Method using High Quality Distilled Water
1000 mg/L CO_2 Standard	(1.0 g CO_2/1 L)*(84 g $NaHCO_3$/44 g CO_2) = 1.909 g $NaHCO_3$ (sodium bicarbonate) per 1 L solution
pH Buffer/ISA solution	13.66 g $H_3C_6H_5O_7$ (citric acid) and 10.30 g $Na_3C_6H_5O_7$ (sodium citrate) per 100 mL solution, adjust the pH to 4.5
	Or, alternatively, 21.00 g of $H_3C_6H_5O_7$ (citric acid) and 5.00 g of NaOH per 100 mL solution, adjust the pH to 4.5
Internal Filling Solution	1.18 g NaCl and 0.42 g $NaHCO_3$ (sodium bicarbonate) per 1 L solution

How can I have my Dissolved CO_2 Sensor read mV output instead of mg/L?

The amplification equation is: $V = 0.00727*mV + 1.223$
Therefore, the reverse amplification equation, solving for mV, would be:
$mV = 137.55*V - 168.2$

Warranty

Vernier warrants this product to be free from defects in materials and workmanship for a period of five years from the date of shipment to the customer. The membrane cap is warranted to be free from defects for a period of 12 months from the date of shipment to the customer. This warranty does not cover damage to the product caused by abuse or improper use. This warranty covers educational institutions only.

More Information About Your Dissolved CO_2 Sensor

The Vernier Dissolved CO_2 Sensor is a membrane-based gas-sensing electrode that measure a specific specie (e.g., CO_2) in an aqueous solution. The voltage developed between the sensing and reference electrodes is a measure of the concentration of the reactive ion being measured. As the concentration of the specie reacting at the sensing electrode varies, so does the voltage measured between the two electrodes.

As described in the Nernst equation, ISE response is a linear equation:

$$E = E_o + m(\ln a)$$

where *E* is the measured voltage, *Eo* is the standard potential for the combination of the two half cells, *m* is the slope, *ln* is natural log, and *a* is the activity of the measured specie.

Assuming the ionic strength is fairly constant, the Nernst equation may be rewritten to describe the electrode response to the concentration, *C*, of the measured specie:

$$E = E_o + m(\ln C)$$

A graph of the natural log of concentration, *lnC*, *vs.* potential, *V*, can be plotted:

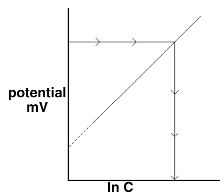

Figure 2

Preparing Standards

7. Prepare a 1000 mg/L CO_2 Standard.

8. Prepare a High Standard (200 mg/L CO_2) and a Low Standard (10 mg/L CO_2), using the 1000 mg/L CO_2 Standard made in Step 7. Combine the volumes of the 1000 mg/L CO_2 Standard and distilled water shown in Table 1 to prepare these two standards.

Table 1 **CO_2 Standards**	1000 mg/L CO_2 (mL)	Distilled H_2O (mL)	Concentration (mg/L CO_2)
High Standard	20	80	200.0
Low Standard*	10	990	10.0

*Alternatively, you can use two serial dilutions to prepare the Low Standard:

a. Combine 100 mL of the 1000 mg/L CO_2 Standard with 900 mL of distilled water. Mix well. The resulting solution is 100 mg/L CO_2.
b. Then combine 100 mL of the solution made in step (a) with 900 mL of distilled water. Mix well. The resulting solution is 10 mg/L CO_2.

Adjusting pH of Standards and Samples

9. Measure 50 mL of the High Standard (200 mg/L) into a 100 mL beaker. Add pH Buffer/ISA Solution dropwise, with stirring, until the pH level is between 4.8 and 5.2. **Note:** It may require ~40 drops, or ~2 mL of pH Buffer/ISA.

10. Measure 50 mL of the Low Standard (10 mg/L) into a second 100 mL beaker. Add pH Buffer/ISA Solution dropwise, with stirring, until the pH level is between 4.8 and 5.2. **Note:** Will require less than the High Standard, ~10 drops, or ~0.5 mL.

11. Measure 50 mL of the sample to be measured into a third 100 mL beaker. Add pH Buffer/ISA Solution dropwise, with stirring, until the pH level is 4.8 to 5.2.

Using the Dissolved CO_2 Sensor with a Computer

12. Connect the Dissolved CO_2 Sensor to a Vernier computer interface.

13. Start Logger *Pro*, which will automatically identify the Dissolved CO_2 Sensor.

Calibrating the Dissolved CO_2 Sensor

14. Choose Calibrate from the Experiment menu and then click Calibrate Now.

15. **Low Standard Calibration Point:** Rinse the Dissolved CO_2 Sensor with distilled water, blot dry, and place it into the beaker with low standard. Make sure no air bubbles are trapped below the electrode. Hold the electrode still and wait for the voltage reading to stabilize. Enter the concentration value of the Low Standard (**10** for 10 mg/L) in the edit box.

16. When the displayed voltage reading for Reading 1 stabilizes (~ 1 minute), then click the Keep button.

17. **High Standard Calibration Point:** Remove the electrode from the Low Standard, rinse well with distilled water from a wash bottle, and gently blot dry with a paper towel or lab wipe. Place the electrode into the High Standard.
18. Hold the electrode still and wait for the voltage reading displayed on the computer to stabilize. Enter the concentration value of the High Standard (**200** for 200 mg/L). When the displayed voltage reading for Reading 2 stabilizes, click the Keep button, then click the Done button.
19. After calibrating, rinse off the end of the electrode, and then blot it dry with a paper towel or lab wipe.
20. Insert the tip of the electrode into the sample to be tested. **Important:** Make sure no air bubbles are trapped below the electrode. **Note:** Do not completely submerge the sensor. The handle is not waterproof.
21. Hold the electrode still and wait for the reading displayed on the computer to stabilize. Record the reading, in units of mg/L as CO_2.

Storing Your Dissolved CO_2 Sensor

Proper care and storage of your Dissolved CO_2 Sensor is an important consideration for optimal longevity.

- **Long-Term Storage of the Dissolved CO_2 Sensor (longer than 1 week)** When you finish using the Dissolved CO_2 Sensor, remove the membrane cap from the main electrode body. Do this by rotating the sensor body counter-clockwise until it comes loose from the main body. Discard the internal filling solution. **Important:** Handle the glass electrode with care so it does not break. Rinse the internal glass electrode and membrane cap with distilled water. Carefully cover the tip of the internal glass electrode with the original sleeve (replenish the storage solution, if necessary[1]). Replace the blue protective boot over the membrane cap. Store all parts securely in the original box.
- **Short-term, wet storage (less than 1 week)** Between measurements, or for overnight storage, keep the electrode tip immersed in pH 4.00 buffer.

Specifications

- Range: 4.4 to 440 mg/L or ppm (1.0×10^{-4} M to 1.0×10^{-2} M)
- Resolution (12-bit): 0.7% of reading (e.g., 10.0 ±0.07 mg/L near the low end of the sensor's range, or 440 ±3 mg/L at the high end)
- pH range: samples and standards must be adjusted to a pH between 4.8 and 5.2
- Interfering ions: only volatile weak acids
- Electrode slope (log voltage *vs.* concentration): +56-62 mV/decade
- Approximate calibration Volts (amplified): High (200 mg/L) 1.4 V Low (10 mg/L) 1.0 V
- Electrode resistance: <1000 MΩ
- Reproducibility: ± 5% of reading (with calibration)
- Temperature range (can be placed in): 0 to 50°C (no temperature compensation)
- Minimum sample: 10 mL in a 100 mL beaker
- Electrode length: 155 mm
- Body diameter: 12 mm
- Cap diameter: 16 mm
- Cable length: 100 cm

[1] You can prepare additional storage solution by adding 10 g of solid potassium chloride (KCl) to 100 mL of pH 4 buffer solution. Add mold inhibitor if available.