NeuLog CO$_2$ logger sensor
NUL-220

The CO$_2$ Sensor can be used for any science experiment where CO$_2$ levels are required. Some fields of study include Chemistry, Physiology, Exercise Science, Biochemistry, Biology, Earth Science, Environmental Science, etc.

The sensor comes pre-calibrated so you can start experimentation right out of the box using this guide.

This sensor is practical for testing CO$_2$ levels both in laboratories and in the field. An electromechanical cell in the sensor reacts with carbon dioxide to produce a voltage which is directly interpreted to give a CO$_2$ concentration reading.

Among hundreds of possible experiments that can be performed with the NUL-202 sensor are: Monitoring ecological systems, combustion reactions, CO$_2$ consumption rates, studying photosynthesis, testing chemical solutions, hydrogen peroxide decomposition, and many more.

The NeuLog CO$_2$ sensor's measurement unit is:
Parts per million (ppm): The total number of carbon dioxide molecules per million molecules sampled.

Sensor offset:

Prior to each use, the CO$_2$ sensor needs to warm up for roughly half an hour. For best results, plug the CO$_2$ sensor into a USB or battery module and allow it to sit for half an hour before to collecting data.

Open air mode:

Although the NeuLog CO$_2$ sensor does not need to be calibrated, it is recommended to offset its probe.

The sensor offsets to the standard atmospheric CO$_2$ concentration of 380 ppm in open air (assuming stable levels in the Earth's atmosphere at sea level).

Materials Needed:

- NUL-220 CO$_2$ sensor
- One of the following (depending on experiment type):
    - USB-200 Module (For On-line experiments)
    - BAT-200 Battery Module (For Off-line experiments)
    - VIEW-101 Graphic Display Module and BAT-200 Battery Module (Optional, for use with NeuLog Viewer)

Procedure:

1. It is recommended to offset the sensor outside (you can get it out through a window if it is connected to a USB module).
2. The CO$_2$ sensor needs a power supply to properly offset. Connect the CO$_2$ sensor to:
    - USB-200 module for On-line experiments
    - BAT-200 battery module for Off-line experiments
    - VIEW-101 graphic display module and BAT-200 battery module for use with the NeuLog Viewer.
3. After the sensor has been connected to a power supply for at least 30 minutes, check that the values are relatively stable.
4. The sensor now needs to be offset -
    hold the probe vertically with the opening facing the ground.
5. Press and hold the blue "Start/Stop" button on the faceplate of the sensor for 3 seconds.
6. The CO$_2$ Sensor is now offset for use.

Quick start procedure:

PC or Mac Computer

Materials needed:

- NUL-220 CO$_2$ Sensor
- USB-200 USB Module
- A USB to mini USB cable (included with the USB-200 module)

Prior to initial use the NeuLog CO$_2$ sensor needs to be offset. Please review the "Sensor offset" section in this document for detailed instructions.

Your CO_2 sensor needs to be connected to a USB-200 module. The USB-200 module then connects to a computer via a USB to mini-USB cable. Please note that you cannot plug the CO_2 sensor directly into the computer.

The browser based application can be downloaded for free at www.NeuLog.com as well as a full application user guide.
Choose "Downloads" on the main menu and then choose "Software and Application".

Procedure:

1. Follow the 'Sensor Offset" guide in this document.
2. Install the NeuLog application.
3. Connect the USB-200 module to the PC or Mac.
4. Connect the CO_2 sensor to the USB-200 module (they directly plug together). Please note that no calibration is required for this sensor.
5. Open the NeuLog application by clicking on the shortcut on the screen.
6. Once a CO_2 sensor module box appears on the left side of the screen the probe has been automatically identified and you can begin experimentation.
7. If the CO_2 sensor is not automatically identified, click the "Search for sensors" icon to find the sensor.
8. Select the "On-line experiment" icon; this will open a graph below.
9. Click on the "Module setup" button located in the CO_2 sensor module box to change the sensor's settings if need be.
10. Click on the "Experiment setup" icon to change the experiment settings if need be (experiment duration for example).
11. The CO_2 sensor will give a live reading in its module box while plugged in.
12. To run an experiment and collect data click the "Run experiment" icon.
13. To end data collection early, click the "Stop experiment" icon.

Tablet, smart phone device

Materials needed:

- NUL-220 CO_2 Sensor
- WIFI-201 WiFi Module
- BAT-200 Battery Module

Prior to initial use, the NeuLog CO_2 sensor needs to be offset. Please review the "Sensor offset" section in this document for detailed instructions.

Your CO_2 sensor needs to be connected to a WIFI-201 module. The WIFI-201 module will create a closed NeuLog Wi-Fi network which will stream the NeuLog data to a device of your choosing. Once your device is wirelessly connected to the NeuLog network, you can run experiments and collect data through a browser of your choosing.

Procedure:

1. Follow the 'Sensor Offset" guide in this document.
2. Connect the CO_2 sensor directly to the left side of a WIFI-201 module (no wires required).
3. Connect a BAT-200 module to the right side of the WIFI-201 module.
4. Although not required, we recommend plugging the BAT-200 to an outlet using a USB to mini USB charger (such as a typical cell phone charger). The WIFI-201 module will run for 60-90 minutes (depending on the sensor) without being plugged in.
5. The WIFI-201 can be powered directly using a mini to USB cord and plugging it into your computer or a wall charger. Please note this function is only available on WIFI-201 modules with the USB icon on the cover.
6. For further WIFI-201 instructions or the WIFI-201 quick start guide please visit: www.NeuLog.com; Choose "Products" on the main menu, then choose "WiFi Communication module".
7. The WIFI-201 indicator lights will flash; take no action until the LED to the far left turns blue; this can take up to one minute.
8. Take your tablet or smart phone, go to the WiFi settings and select the NeuLog network (NeuLog0184 for example) which matches the ID found on the back of the WIFI-201 module (0184 for example).
9. Give your device about 20 seconds to connect to the WIFI-201.
10. Once the device is connected, go to your browser and type the website **wifi201.com** into the URL bar, then wait for 30-60 seconds.
11. You will see a "Control mode" icon in the application, click on it.
12. The application will then load a new screen and begin to auto detect the sensor(s); this can take a minute. (You can stop the search when the sensor is found.)
13. If the application does not auto detect the sensor(s), select "Search for sensors".
14. Once the sensor is found you will see a module box on the left side of the screen for the CO_2 sensor. In this box, real time data will be displayed.
15. Click on the "Module setup" button located in the CO_2 sensor module box to change the CO_2 probe's settings if need be.
16. Click on the "Experiment setup" icon to change the experiment settings if need be (Experiment duration for example).
17. To run an experiment and collect data, click the "On-Line experiment" icon, then click the "Run experiment" icon.

18. If you have a newer generation WIFI-201 module (with the USB icon on the cover) this can be used as a USB-200, meaning you can tether the probes directly to the computer using the WIFI-201. To engage operation in this fashion, press 3 times on the panel button. Repeating this operation will return the module to WiFi mode.

Operation with NeuLog Graphic Display Module (viewer)

Materials needed:

- NUL-220 CO_2 Sensor
- VIEW-101 Graphic Display Module
- BAT-200 Battery Module

Procedure:

1. Follow the 'Sensor Offset" guide in this document.
2. Connect the CO_2 sensor to the left side of the viewer.
3. Connect the BAT-200 module to the right side of the viewer.
4. The VIEW-101 will auto detect the sensor and you will see it appear on the left side of the screen.
5. Once the sensor appears it will be monitoring data in real time.
6. To run an experiment and collect data press the run icon (little green person).

Off-line experiments

(Off-line experiments are when you do not have a sensor connected directly to a computer, tablet, smartphone, or NeuLog viewer).

Materials needed:

- NUL-220 CO_2 Sensor
- BAT-200 Battery Module

Materials needed to configure your offline experiment:

- USB-200 Module, WIFI-201 module or VIEW-101 Module
- USB to mini USB cable (included with the USB-200 module)

Procedure:

1. Follow the 'Sensor Offset" guide in this document.
2. To determine the experiment settings, first connect to your chosen device (PC, Mac, tablet, smart device) and click on the "Off-line experiment" icon after the sensor search has ended. (For more information on how to change the experiment settings, view the quick start procedure section for your chosen device in this document.)
3. Connect the CO_2 sensor directly to the left side of a charged BAT-200 module.
4. When ready to collect data press the "Start/Stop" button on the CO_2 sensor, a red light will turn on for the duration of the experiment.
5. After the experiment has concluded (the "Start/Stop" button is pressed again or the data collection period ends) connect the sensor to your chosen device (you can find full instructions in each device's quick start procedure section).
6. Open the NeuLog application.
7. Click the "Off-line experiment" icon.
8. Click the "Load data from sensors" icon.
9. Select which experimental data to upload (5 experimental runs can be stored at one time on the NUL-220 CO_2 sensor).

Restoring sensor's factory default settings:

Procedure:

1. Connect the USB-200 to a PC, Mac, tablet, or smart device.
2. Connect the CO_2 sensor to a USB-200 module (they directly plug together).
3. Open the NeuLog application.
4. Click the "Tools" icon.
5. Click the "Restore sensor's factory defaults" on the menu.

Included with the sensor:

- NeuLog CO_2 sensor probe attached to the sensor's body by a durable rubber-coated wire
- NeuLog NUL-220 CO_2 Sensor Guide (This Document)
- Glass bottle

Sensor specifications:

Sensor specifications:	
Range and operation modes	350-10,000 ppm
ADC resolution	14 bit
Resolution	1 ppm
Max sample rate (S/sec)	100

Experiment Duration: 1 seconds to 31 days.

Sensor's features:

- Fully digital data
- Rugged plastic ergonomic case
- Push button switch for Start/Stop experiments in off line mode
- LED indicator of experiment status (blinks while collecting data)
- Attached probe cased in durable plastic

    Note: NeuLog products are intended for educational use.

Videos and experiment examples:

- Videos, literature and other probes can be found at www.NeuLog.com.
- In order to access the CO_2 sensor's page, choose "Products" on the main menu and then "CO_2 logger sensor".
- In order to find the science experiments, choose "Experiments" on the main menu of the NeuLog website, then choose "Physics", "Chemistry", "Biology" or "Environmental Science".
- Biology Experiments:
    - Photosynthesis (B-10)
    - Respiration of Germinating Seeds (B-11)

Technical background:

The philosophy behind NeuLog's plug and play technology is based on each sensor's ability to store its own data due to an internal flash memory chip and micro-controller in each plastic NeuLog body. This technology allows the sensor to collect and then store the digital data in the correct scientific units (^oC, ^oF, Lux, %, ppm, for example).
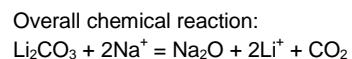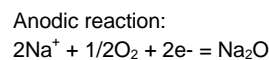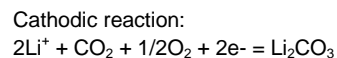
The sensor is pre-calibrated at the factory. The built-in software in the logger can be upgraded for free at any time using the provided firmware update.

In spite of that, the probe needs to be offset prior to its initial use. Please review the "Sensor offset" guide at the beginning of this document for detailed instructions.

The CO_2 sensing element consists of a cation (Na^+) solid electrolyte formed between two electrodes together with a printed heater (RuO_2) substrate.

The cathode (sensing element) consists of lithium carbonate and gold, while the anode (counter electrode) is made of gold.

When the sensor is exposed to CO_2 gas, the following electrochemical reaction occurs:

Cathodic reaction:
$2Li^+ + CO_2 + 1/2O_2 + 2e- = Li_2CO_3$

Anodic reaction:
$2Na^+ + 1/2O_2 + 2e- = Na_2O$

Overall chemical reaction:
$Li_2CO_3 + 2Na^+ = Na_2O + 2Li^+ + CO_2$

As a result of the electrochemical reaction, an electro-motive force (EMF) is generated according to Nernst's equation:

$$EMF = Ec - (R \times T) / (2F) \ln (P(CO_2))$$

where
$P(CO_2)$: Partial pressure of CO_2,
Ec : Constant value R : Gas constant
T : Temperature (K) F : Faraday constant

By monitoring the electromotive force (EMF) generated between the two electrodes, it is possible to measure CO_2.

Maintenance and storage:

- Never submerge the NeuLog sensor's plastic body and probe in any liquid.
- Do not allow liquid into the NeuLog sensor's plastic body and probe.
- After use, wipe off all excess material, liquid or residue from the CO_2 probe's body.
- Store in a box at room temperature out of direct sunlight.

Warranty:

We promise to deliver our sensor free of defects in materials and workmanship. The warranty is for a period of 3 years from the date of purchase and does not cover damage of the product caused by improper use, abuse, or incorrect storage. Sensors with a shelf life such as ion selective probes have a warranty of 1 year. Should you need to act upon the warranty, please contact your distributor. Your sensor will be repaired or replaced.

Thank you for using NeuLog!

Flexible, simple, fast, forward thinking.
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V11042014