CO_2 Gas and Human Respiration

Background

The process of breathing accomplishes two important tasks for the body. During inhalation, oxygen-rich air is brought into your lungs. During exhalation, air depleted in oxygen and rich in carbon dioxide is forced out. Oxygen is then transported to the cells where it is used in the process of cellular respiration, yielding carbon dioxide as a product. The equation for cellular respiration is as follows:

$$C_6H_{12}O_6 + 6\,O_2 \rightarrow 6\,H_2O + 6\,CO_2 + \text{energy}$$

Gas exchange takes place in the lungs at the membrane between special air sacs (called alveoli) and the tiny blood vessels within the lungs that surround the air sacs (pulmonary capillaries). It is here that oxygen diffuses into the bloodstream – to be delivered to cells – and carbon dioxide diffuses out of the blood. Under normal circumstances, oxygen and carbon dioxide levels in the blood are maintained at specific levels for the proper functioning of cells. Several mechanisms are involved in maintaining this balance. One such mechanism involves special receptors that are part of the nervous system. These specialized receptors respond to changes in carbon dioxide and oxygen concentrations and influence the body's breathing patterns and rate to maintain the proper balance of blood gases.

In this experiment, you will determine what factors affect how long you can hold your breath. You will be tested under two different conditions. The first condition is normal breathing. The second condition is immediately following hyperventilation. Hyperventilation is when your breathing rate is greater than what is necessary for proper exchange of oxygen and carbon dioxide. This will be achieved by a period of rapid breathing prior to holding your breath.

Objective(s)

- ✓ to use a CO_2 gas sensor to determine carbon dioxide levels in exhaled air
- ✓ to observe the relationship between internal CO_2 concentration and breathing pattern and rate

Materials

- LabQuest 2
- CO_2 sensor
- ring stand
- ring stand clamp
- plastic bag
- masking tape
- timer

Pre-Lab Questions

Answer the following questions on your lab paper. For actual questions, you must either write out the questions, or include the questions in your responses. Be sure to use complete sentences and show your work for math problems.

1. How long do you think you can hold your breath?
2. When you hold your breath, what do you think happens to the carbon dioxide concentration in your lungs? Explain.
3. When you hold your breath, what do you think happens to the oxygen concentration in your lungs? Explain.
4. On average, people can hold their breath for a minute. What do you think prevents people from holding their breath for 2 or 3 minutes?
5. What does the unit of measure "ppm" mean?

✓ Use a ruler to recreate the Data Table(s) below neatly on your lab paper, and be sure it is drawn approximately the same size

Safety

★ *As part of this activity, a test subject will be asked to hold his/her breath. The test subject should remain seated during the procedure and should not hold his/her breath if they feel light-headed, dizzy, or unsafe in any way. Immediately inform the teacher if this occurs!*

Procedure

1. Secure the CO_2 Gas Sensor using a test tube clamp and ring stand as instructed. Make a small hole in the center of the bottom of the plastic bag. Insert the sensor into that hole, make sure not to cover any of the openings on the sensor. Use masking tape to seal the plastic bag to the sensor.
2. Set the switch on the CO_2 Gas Sensor to the 0 – 100,000 ppm range then connect to the LabQuest 2.
3. Turn on the LabQuest 2. When it is fully booted up, the CO_2 sensor requires about 90 seconds to warm-up. Do not proceed until 90 seconds have passed. After it has, make the following settings:
   - ✓ Sample Rate: 4 s/sample
   - ✓ Length: 480 s
4. When you begin collecting data, it is important that data collection begins at the same point the subject begins to hold his breath.
   a. Have the subject take a deep breath and hold it. Immediately start data collection by pressing the Collect button or icon. The subject should hold his/her breath as long as possible.
   b. When the subject can no longer hold his/her breath, he/she should blow his breath into the produce bag and twist the open end shut. This should result in the plastic bag filling with the air the subject was holding in his/her lungs. Allow data collection to proceed for the full 480 seconds or until the graph has reached a steady value.
   c. When data collection has finished, open the plastic bag and pull it back from the sensor exposing the sensor to room air. Leave the bag in that position until you are ready to collect data again.
   d. Tap on the graph screen to obtain data to answer these questions:
      i. How long did the subject hold his breath? Record the time in the **Data Table**.
      ii. Determine the maximum and minimum CO_2 concentrations and record them in the **Data Table**.
      iii. Click on the file cabinet icon to save Run 1.

   ★ *NOTE*: Before proceeding, the CO_2 sensor takes time to recover and return to its original value. It may take 5 – 7 minutes before the readings drop to the initial readings you observed in step 4.
5. You will move to Run 2 and are now ready to collect a second run.
6. Collect data following mild hyperventilation.
   a. Pull the plastic bag back down off the sensor in preparation for data collection.
   b. Have the subject take 10 quick deep breaths, forcefully blowing out all air after each breath. The subject should then take an 11th breath and hold it. Immediately click to begin data collection. The subject should hold his/her breath as long as possible.
   c. When the subject can no longer hold his/her breath, he/she should blow his breath into the produce bag and twist the open end shut. This results in the plastic bag filling with the air the subject was holding in his lungs. Allow data collection to proceed for the full 480 seconds.
   d. When data collection has finished, open the plastic bag and pull it back from the sensor exposing the sensor to room air.
   e. Tap on the graph screen to obtain data to answer these questions:
      i. How long did the subject hold his breath? Record the time in the **Data Table**.
      ii. Determine the maximum and minimum CO_2 concentrations and record them in the **Data Table**.
7. To see both runs on the same graph, tap the "Run 2" space and choose "All Runs."

Data Table

Condition	Breath Held (sec)	Max. CO_2 Concentration (ppm)	Min. CO_2 Concentration (ppm)	Change in CO_2 (ppm)
Normal				
Hyperventilation				

Clean Up

- ✓ trash: plastic bag, masking tape
- ✓ exit the app by clicking "File" → "Quit" – do not save the data
- ✓ everything returned to its original location

Results & Analysis

Answer the following questions on your lab paper. For actual questions, you must either write out the questions, or include the questions in your responses. Be sure to use complete sentences and show your work for math problems.

1. Did the CO_2 concentration change as you expected? If not, explain how it was different.
2. Did the amount of time you held your breath change after hyperventilation (taking the 10 quick breaths)? If so, did the time increase or decrease? Explain.
3. After hyperventilation, was the resulting concentration of CO_2 in your exhaled breath higher or lower than in the first attempt? How much did it change? What do you contribute this to?
4. On the first trial, what do you believe forced you to start breathing again?
5. On the second trial, what do you believe forced you to start breathing again?
6. Based on your answers to questions 4 and 5, does the concentration of oxygen or carbon dioxide have a greater influence on how long one can hold his breath?