

I. TEACHER NOTES & GUIDELINES

Title of Lab: Carbon Dioxide Measurement

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OVERVIEW OF LAB

DESCRIPTION:

Since carbon dioxide measurement cannot be done directly, we have devised a mechanism for quantification of carbon dioxide output from a human under different conditions. The students will be directed to use laptops and probes to determine the rate of carbon dioxide exhalation while the student is at rest. Subsequently, the students will be asked to consider conditions that will change the CO₂ measurements. They will state a problem, a hypothesis, design an experiment, carry out the experiment, and analyze their results.

CURRICULUM CONSIDERATIONS:

This lab can be used to reinforce the concepts of cellular respiration and breathing, which is covered in unit 2 of the Regents Biology Syllabus.

REAL WORLD APPLICATIONS

- pH in a swimming pool
- acid rain
- carbonic acid equilibrium
- exercise uses energy
- carbonation in liquids

SAFETY CONSIDERATIONS:

The pH probe bottle needs a cap for "storage" so it does not sit open on the lab table. Place several layers of paper towels under the beaker to absorb splashing when students are bubbling.

BACKGROUND INFORMATION

A. SCIENTIFIC VIEWPOINT

Carbon dioxide exhaled through a straw into a beaker of water will combine with the water to form carbonic acid. Carbonic acid is a weak acid and will cause the water solution to become acidic. This increase in acidity can be measured by use of a pH probe and the results recorded on the computer. The students can relate the rate of carbon dioxide release by the rate of the change of pH. Comparing the rates of carbon dioxide exhaled under different conditions will result in identification of increases or decreases in respiration. As an enrichment activity, the pH of the solution can now be used in a series of chemical mathematics to figure out the volume of carbon dioxide that was exhaled.

B. COMMON MISCONCEPTIONS

1. Exhaled air contains only carbon dioxide.

Air contains nitrogen that is inert and therefore will be exhaled.

2. Breathing and respiration are the same process.

Breathing is a physical process, respiration is a chemical one.

3. Inhaled oxygen is converted into carbon dioxide.

Carbon dioxide results from the metabolism of glucose or some other organic nutrient during cellular respiration.

4. The difference between a pH of 3 and 5 is two single units of measure

Each pH unit is 10 times greater or lesser than the one next to it.

OBJECTIVES

1. To understand the importance of pH
2. To compare the rates of carbon dioxide production during different activities
3. To appreciate the use of technology in the field of science
4. To learn science through inquiry

EQUIPMENT/MATERIALS

PROVIDED BY SOTM

Laptop computers	interfaces and cables	surge protectors
pH probes	wash bottles	
Buffer solutions, pH 4 and 7	Kimwipes	

PROVIDED LOCALLY

beakers: 4- 50ml, 1-600ml, 1-250ml, 1-1000ml
straws
stopwatch (clock with second hand)
graduated cylinder - 500ml
distilled water - several gallons
paper towels
ring stands and clamps

ADVANCE PREPARATION

Familiarize yourself with the computer program and probes.
Soak the pH probes in distilled water for several hours or overnight
Familiarize yourself with the safety precautions.
Gather the necessary equipment and supplies.
Copy student edition of lab (pages 4 & 5)
Copy pre-lab exercise (page 3)

II. PRE-LAB

PRE-LAB EXERCISE TO ELICIT STUDENTS' PRIOR KNOWLEDGE AND MISCONCEPTIONS

Pre-lab Exercise

1. What is the chemical difference between pH 3 and pH 5?
2. What is meant by pH?
3. Explain respiration.
4. Explain breathing.
5. Briefly explain the chemical process between the time an individual breathes in and breathes out.
6. What gas(es) go in and what come out?
7. What processes occur in the cells?
8. What organelles produce the exhaled gases?
9. What happens to the exhaled air when you bubble it through the water?
10. From what chemical process does the exhaled air originate?
11. Neutrality on the pH scale is represented by what number?
12. Draw and label acidic, neutral, and alkaline on the pH scale indicating hydronium and hydroxyl ions.
13. Can you tell the pH of a solution by its color and explain.

Concept mapping terms

respiration
oxygen
base
OH⁻

breathing
carbonic acid
log
scale

carbon dioxide
acid
hydrogen ion
7

Neutral
Inhale
cellular respiration
organelle

buffer
excretion
aerobic
mitochondrion

exhale
volume
anaerobic

DISCUSSION OF PRECONCEPTIONS

See Appendix A (page 11)

III. EXPLORATION OF SCIENTIFIC PRINCIPLE & INTRODUCTION OF EXPERIMENTAL PROTOCOL

PROBLEM

To determine the rate of carbon dioxide exhalation while at rest.

(Note: The Science Workshop program records and displays the pH of the solution. Since carbon dioxide combines with water to form carbonic acid, the pH will indicate the amount of carbon dioxide exhaled. The pH drops as the water contains more carbonic acid.)

EXPERIMENT AND TECHNICAL OPERATION OF EQUIPMENT

Part I - Computer Setup

1. Connect the Science Workshop interface to the computer, turn on the interface, and then turn on the computer. Refer to separate sheet, if necessary.
2. Connect the pH probe DIN plug into Analog Channel A on the interface.
3. Open the Science Workshop program on the computer:
 - a) Click the Zoom box or the Maximize button to change the experiment setup window to full size.
 - b) Click and drag the icon of the analog plug to Analog Channel A and release. This will cause a new screen to appear for the selection of the probe.
 - c) Scroll to the pH probe. Double click on the pH probe. This places the pH sensor on the original screen (Experimental Setup Window) in a square box.
 - d) Click onto and drag the graph icon from among the display options to the pH box. A choice box will appear. Click on pH, then click display and a graph will appear.
 - e) Click on graph display bar and drag the graph display to the bottom right of the screen.
 - f) Click onto and drag the digits icon from among the display options to the pH box.
 - g) In the choice box, click on pH, then click display and a digits box will appear.
 - h) Click on digits display bar and drag the digits display to an empty area on the screen.

Part II: Calibration of the pH sensor

Note: If the sensors have not been soaked, calibration may not be possible.

1. Gently blot the pH probe with Kim wipes.
2. Double click on pH and this brings up the pH Analog Sensor Calibration screen.
3. It is important to calibrate the pH probe. For calibration you will need distilled water and buffer solutions of pH 7 and 4. The probe must be kept moist at all times.
4. Immerse the end of the pH probe in the pH 7 buffer solution.
5. When the voltage displayed as the Cur Value: (current value) stabilizes, click on the READ button for the High Value: Then move the cursor to the High Value box and enter 7.0.

(Note: Check pH of tap water. If near 7, it may be substituted for distilled water)

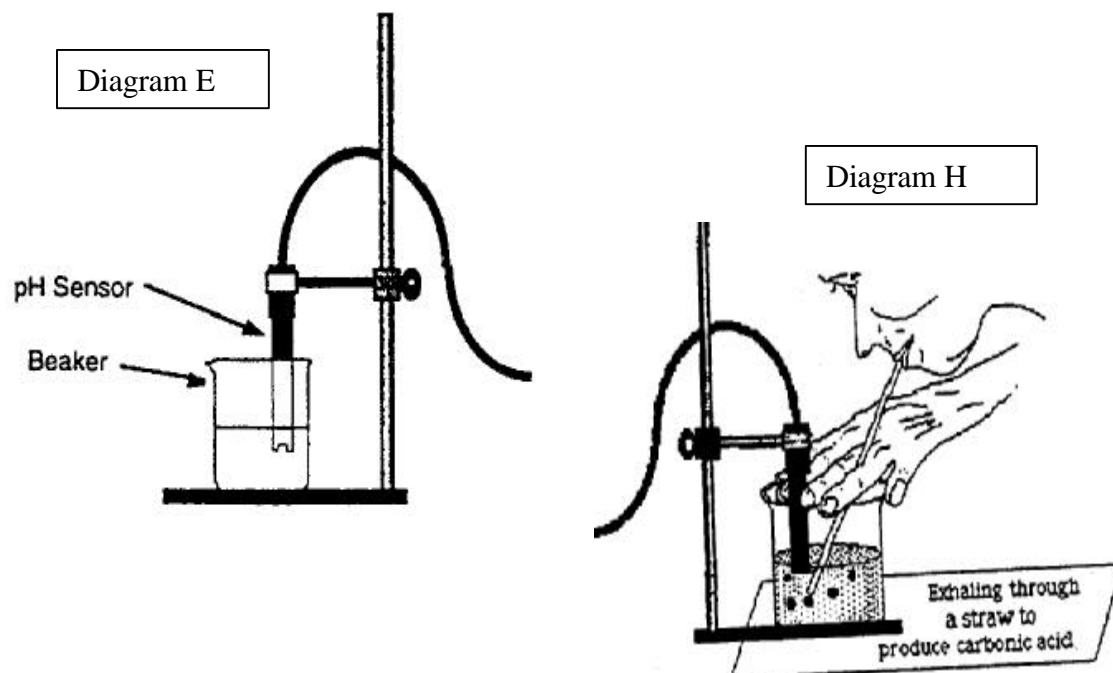
6. Thoroughly rinse the pH probe in distilled water, (using an empty beaker to catch the runoff), gently bot dry it with a Kim wipe and immerse the end of the probe in the pH 4 buffer solution.

- When the voltage displayed as the Cur Value stabilizes, click on the READ button for the Low Value. Then move the cursor to the Low Value box and enter 4.0. Click on OK when finished. Now the calibration is complete.
WARNING: If you quit the program and begin again, a new calibration must be done.
- Thoroughly rinse the pH probe with distilled water and then place it back into the original beaker of distilled water.
- On the left side of the screen is a box labeled Sampling Options. Click on this box to choose the correct frequency for sampling. Set "Periodic Sampling" for 2 Seconds. Click on slow in the upper left corner and then set 2 S. Click OK at the bottom of the box.

Part III: The Experiment

The lab group consists of 2 - 4 students.

- Using the graduated cylinder, measure 500 ml. of distilled water and pour it into the 600 ml beaker
- Set up the ring stand and attach the probe to the ring stand with the end of the probe in the beaker. See (diagram E). Place the beaker on multiple layers of paper towels.
- One student double click on the REC button in the main window.
- Another student uses a straw to exhale into the water. Hold the straw between your fingers and keep your fingers around the probe. This will minimize splashing. See (diagram H). Continue this for two minutes. Your results will appear on the digits display and on the graph display.
- Click STOP at the end of two minutes.
- Run #1 will appear in the Data list in the experiment setup window. To observe results of this run, click on Run #1. You can then click on the Autoscale button to re-scale the graph to fit the data.
- If possible, save to a disc and print a copy of the graph.
- Using the graph, write out a data table of Time vs. pH (see sample)



IV. ELABORATION OF SCIENTIFIC PRINCIPLE: INQUIRY-BASED STUDENT INVESTIGATION

PROBLEM

After students have completed the “at rest” breathing rate experiment, have them discuss in their lab groups the following question, “What condition can result in a change in the amount of CO₂ produced in the basic experiment?”

Have groups make a list of factors that might result in a change. (Possible factors include: exercise, weight (size) of person, sex of person, holding one’s breath for a while, re-breathing air into a paper bag several times.

HYPOTHESIS OR PREDICTION

Have students select one factor that they would like to investigate and have them write a sentence that will show the relationship between the factor and the rate of CO₂ exhalation.

EXPERIMENTAL DESIGN

Questions to ask students:

1. What is the variable that you are studying?
2. How will you attempt to test the effects of this variable?
3. What equipment do you need?
4. What safety precautions must you be sure to follow in your experiment?

Student groups prepare written experimental design

CHECKPOINT (Teacher checks to see that students have answered questions appropriately.)

PLAN FOR DATA COLLECTION AND ANALYSIS

1. Questions to ask students:
2. What data do you plan to collect?
3. What icons will you need to open on your laptop screen?
4. Design an appropriate data table.
5. What information will you be graphing?
6. How do you plan to use the data collected to help you confirm or refute your hypothesis?

Student groups complete written plan for investigation.

CHECKPOINT (Teacher checks plans for feasibility.)

CONDUCTING THE EXPERIMENT

Groups carry out their experiments using the written procedures they have developed.

CHECKPOINT (Teacher monitors students’ investigations in progress.)

ANALYSIS OF DATA

- As the teacher circulates among the groups, the following questions might be asked:
- Were there any surprises in your data?
- If yes, does this pose any new problems?
- Why do your two graphs look similar or different?
- Why do your data tables look similar or different?

CHECKPOINT (Teacher checks students' data.)

DISCUSSION OF RESULTS

COMPARE:

Each group will present its findings to the entire class. They should be sure to include:

- The hypothesis
- An evaluation of the hypothesis
- Evidence to support the results of the investigation
- Comparison of preconceptions with the experimental conclusions

PERSUADE:

As each group presents, it is responsible for convincing the other groups of the validity of its findings.

RELATE:

The teacher may lead a discussion of how results relate to real world situations, as applicable. Some of these may include:

- pH in a swimming pool
- Acid rain
- Exercise uses energy
- Carbonation of liquids
- Carbonic acid equilibrium
- Use of technology in industry and research

V. EVALUATION

POST-LAB SURVEY OF STUDENTS' CONCEPTIONS

Have students retake the Pre-Lab Exercise. Compare pre-lab and post-lab responses.

TRADITIONAL

Submit lab report for evaluation

ALTERNATIVE

See following rubric and rubric criteria sheets.

Carbon Dioxide Measurements

Examples of value points for each skill. Other suggestions may be better and may depend on your own style. You **may** also use a non-graded scale.

Physically connects the components

1. connects no parts
2. connects computer and power pack
3. can connect computer, power and interface
4. connects all parts but can't trouble shoot
5. connects all parts and is able to trouble shoot problems

Operates the computer for setup

1. can't turn the computer on
2. opens program and is then clueless
3. follows directions for setup of software
4. aware of what he/she is doing with software
5. is able to troubleshoot software problems

Manipulation of sensor -software

1. sits and looks at the screen
2. able to start recording of data
3. can start and stop recording
4. knows how to use windows to show data
5. can do a run and restart for next run

Usage of multiple programs

1. no usage
2. can only use Science Workshop
3. can use Science Workshop and other program

Can print out important data

1. cannot turn the Printer on
2. turns printer on but can't operate-it
3. can only print one part of lab
4. can print lab data in one form (graph)
5. can print all lab data and WP lab report

Is able to evaluate the data

1. looks at the data and grins
2. can explain what happens in one trial
3. can explain data in multiple trials
4. can explain connections between two trials
5. can use data to explain human processes

Can explain the purpose of the lab

1. thinks the lab has to do with breathing
2. thinks the lab is to learn how to use a computer
3. thinks the lab is about exercise and rest
4. thinks the lab is about comparing rates
5. thinks the lab is about human variability

Can explain the sequences

1. does not know what a sequence is
2. cannot go beyond hooking up the hardware
3. can only explain software sequencing
4. can combine software and hardware
5. can go beyond components to lab exercise

Understands the limitations of the lab

1. there are no limitations
2. understands software limitations
3. understands variations in lab

Can enumerate sources of error

1. can not find any source of error
2. finds only superfluous sources of error
3. sophisticated experimental errors

Collaborates with partners for success

1. does not participate in lab
2. only wants to watch others
3. will only record data - not participate
4. will participate in the whole lab
5. takes leadership role in the group

Extrapolates the principle to real world

1. does not know what extrapolation means
2. provides erroneous extrapolation
3. can only provide extrapolation
4. can provide extrapolation & explanation
5. can provide evidence of multiple extrapolations

Carbon Dioxide Measurement

Name:

Period:

Date:

A. Physically connects the components	1	2	3	4	5
B. Operates the computer for setup	1	2	3	4	5
C. Manipulation of sensor software	1	2	3	4	5
D. Usage of multiple programs	1	2	3	4	5
E. Can Print out important data	1	2	3	4	5
F. Is able to evaluate the data	1	2	3	4	5
G. Can explain the purpose of the lab	1	2	3	4	5
H. Can explain the sequences	1	2	3	4	5
I. Understands the limitations of the lab	1	2	3	4	5
J. Can enumerate sources of error	1	2	3	4	5
K. Collaborates with partners for success	1	2	3	4	5
L. Extrapolates the principle to real world	1	2	3	4	5

Appendix A

Questions the teacher may wish to ask the student to think about.

Why doesn't the pH drop below 4.3

Because carbonic acid and CO_2 and water reach equilibrium at pH of 4.3

Explain why it does drop below 4.3 momentarily

Because the reaction is pushed past equilibrium momentarily.

Why is time important in this lab.

Because time is used to measure the rate (speed) at which CO_2 is produced.

Why is it necessary to start each trial with fresh water

Because the previous water is no longer water. It contains carbonic acid and could be tested with an indicator to prove it.

Why was calibration necessary?

In order to equate the pH of the water with the sensing equipment.

What questions would you ask about this lab?

The student may ask a variety of questions of a particular nature.

Common Misconceptions and Solutions

Exhaled air contains only CO_2

Air contains nitrogen that is inert, therefore will be exhaled as well

Breathing and respiration confusion

Breathing is a physical process, respiration a chemical one

CO_2 combines with H_2O to form carbonic acid not just bubbled out

Can see the drop in pH on the graph

Colorless water or carbonic acid looks the same

Radioactive labeled oxygen doesn't show up in CO_2 , but in water excreted

Observation - they both look clear

Can use indicators to show difference

Oxygen is converted to carbon dioxide

Explain the Electron transport system and Krebs cycle

Concerning pH

Use pH probe, graph, indicators show pH scale,

*This material is based upon work supported by the National Science Foundation under Grant No. ES1 9618936. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.