CARBON DIOXIDE IN ICE CORE SAMPLES

Lesson Concepts: Students will understand that the chemical composition of the Earth's ancient atmosphere is recorded in layers of ice. They will learn how paleo-climatology developed from studying ice core samples from polar regions. This information is crucial to understand the changes that may be occurring with today's climate. Students will have an opportunity to gather data from ice with varying amounts of CO_2 and will read about scientific collection of data from ice core samples. Students will observe, measure, and analyze the changes of balloon contents from solid to liquid/gaseous states.

Learning Objectives — Students will be able to:

- **Make scientically based observations and quantify data.**
- **Experience hands-on data collection involving ice with varying levels of CO_2.**
- **Chart data onto a graph.**
- **Analyze data from a graph.**

Link to *Air -The Search for One Clean Breath* from Executive Producer Barbara L. Page

In the film we visited the British Antarctic Survey Core Programme in Cambridge, England. As you can see, our photographer and sound man dressed warmly to film the arctic ice core samples. In this lesson, students will also experience ice cores, this time in their own classrooms.

Materials

Frozen Balloon Exploration

- 4 balloons per lab group (round, medium-sized)
- Carbonated water; unflavored soda water is perfect
- Measuring tapes
- Triple beam or balance scales
- One shallow bowl for each group (one for exposed carbonated water balloon to melt in)
- Tray to contain liquid as balloon melts
- Immersion thermometers
- Hand lens and Flashlights

Analyzing Evidence from Ice Cores

- *Stories in the Ice* article by Peter Tyson
- Data on Atmospheric Greenhouse Gases
- Pencil, ruler, and graph paper
- Note: Students can plot the data by hand or use appropriate computer program

Time and Student grouping

Two 50-60 minute class periods; Lab groups of 3-4 students

Grade Levels: 7-12

California Science Standards

Grade 7, 4.a. Students know Earth processes today are similar to those that occurred in the past and slow geologic processes have large cumulative effects over long periods of time.
Grade 7, 4.b. Students know the history of life on Earth has been disrupted by major catastrophic events, such as major volcanic eruptions or the impacts of asteroids.
Grade 7, 4.c. Students know that evidence from geologic layers and radioactive dating indicates Earth is approximately 4.6 billion years old and that life on this planet has existed for more than 3 billion years.
Grade 7, 4.d. Students know fossils provide evidence of how life and environmental conditions have changed.
HS Earth Science 7.b. Students know the global carbon cycle: the different physical and chemical forms of carbon in the atmosphere, oceans, biomass, fossil fuels, and the movement of carbon among these reservoirs.

National Science Standards

Grades 5-8 Physical Science Content Standard B.
Grades 9-12 Science in Personal and Social Perspectives Content Standard F.

Education and the Environment Initiative Educational Principles and Concepts

Principle IV: The exchange of matter between natural systems and human societies affects the long-term functioning of both. As a basis for understanding this principle:
Concept a. Students need to know that the effects of human activities on natural systems are directly related to the quantities of resources consumed and to the quantity and characteristics of the resulting byproducts.
Concept b. Students need to know that the byproducts of human activity are not readily prevented from entering natural systems and may be beneficial, neutral, or detrimental in their effect.

Teacher Tips

Prepare one set of CO_2 balloons all the same color. This will be the set that students open to examine the ice within.

Teacher Background

Climatology, the study of how the Earth's climate system works, operates under a distinct handicap in comparison to other phenomenological sciences. Other fields of study permit the formation of hypotheses and subsequent testing of these hypotheses by direct experimentation in the laboratory. This is not feasible in climatology, for we live in the only laboratory possible. It is called the Earth.

Because we would be ill-advised to experiment on our only laboratory, we are left to construct computer models of how we believe the climate system of our planet works. If we understand the climate system correctly and have constructed our model appropriately, then the behavior of our model climate system should mimic the behavior of the Earth's climate system. One of the best ways to test our model is to see if it can reproduce the changes in climate which have happened throughout the long history of the Earth. Thus, acquiring detailed climate records extending back many hundreds of thousands of years has become a research priority in the study of global change.

The study of ice cores is an indispensible part of this process. Over the past decade, research on the climate record frozen in ice cores from the polar regions has changed our basic understanding of how the climate system works. Changes in temperature and precipitation which we previously believed would require many thousands of years to happen, happened in fewer than 20 years as was revealed through the study of ice cores. These discoveries have challenged our beliefs about how the climate system works. We have been required to search for new, faster mechanisms for climate change and we have begun to consider the interaction between industrial man and climate in light of these newly revealed mechanisms.

Ice cores contain an abundance of climate information — more so than any other natural recorder of climate, such as tree rings or sediment layers. Although their record is short (in geologic terms), it can be highly detailed. An ice core from the right site can contain an uninterrupted, detailed climate record extending back hundreds to almost a million years. This record can include temperature, precipitation, chemistry and gas composition of the lower atmosphere, volcanic eruptions, solar variability, sea-surface productivity and a variety of other climate indicators. It is the simultaneity of these properties recorded in the ice that makes ice cores such a powerful tool in paleoclimatic research.

From National Ice Core Laboratory, Why Study Ice Cores?

Vocabulary

Phase Change or States of Matter: A condition in which matter can exist, depending upon temperature and pressure, e.g., the solid, liquid, gaseous, and plasmatic states.

Paleoclimatology: The prefix ‘paleo’ refers to that which is ancient, prehistoric, primitive, or early; climatology is the study of climate.

Fossil Evidence: Utilization of the remains of an animal or plant preserved from an earlier era inside a rock or other geologic deposit, often as an impression or in a petrified state to serve as research data.

Parts Per Million (ppm) & Parts Per Million by Volume (ppmv): A unit of concentration often used when measuring levels of pollutants in air, water, body fluids (4 drops of ink in a 55 gallon barrel would produce an ink concentration of 1 ppm).

Advanced Preparation:

At least 48 hours in advance of the lesson, teacher will prepare five frozen balloons for each group of students. Balloons must contain approximately equal volumes of liquid as measured by a measuring cup.

- 1 Balloon with 1 cup regular water
- 1 Balloon with ½ cup regular water, ½ cup unflavored carbonated water. Soda water is perfect. Mix tap and carbonated water in measuring cup prior to pouring in balloon. Do not vigorously stir carbonated water to retain as much CO_2 as possible.
- 2 Balloons: 1 cup unflavored carbonated water.

Advanced Preparation continued

Note: Balloons must be equal in size. Use one color balloon for regular water, another color balloon for carbonated water, and a third color balloon for the 50/50 mixture. This will help you keep track that each student group has a sampling of all concentrations.

Preparation of balloons: Preparing the balloons can be accomplished by students in the class. Measurement, air pressure, and gravity are all necessary to discuss while balloons are filling.

<u>Filling balloons to equal amounts</u>: Fit the balloon to a piece of tubing (¼" PVC approximately two inches long) and pour the liquid from a cup until tube is full. The force of air pressure on the sides of the balloon will restrict the amount of liquid allowed into each balloon so that each balloon will have an equal amount of liquid. Slide the balloon off the end of tube, twist and tie a knot. This method will assure volume is approximately equal in all three balloons. **Note:** Do not fill balloons directly from the tap. Water pressure from the tap will exert extra pressure resulting in a disparity of liquid from balloons. Use the same method of pouring water into a tube fastened to the balloon for each water sample to achieve consistency. The balloons with the carbonated water will look bigger due to gas expanding.

When frozen, the balloons will all condense to approximately the same diameter. Students will notice that one of the balloons, the one filled with carbonated water, will grow to a larger diameter as it melts. **Note:** Because the balloons do not fill completely, they will not take much space in an ordinary kitchen freezer. Placing balloons on a flat surface gives them a uniform appearance making comparisons easier.

Procedure:

After viewing **Air-The Search for One Clean Breath** (41 minutes), lead students into a discussion of methods the scientists use to understand the atmosphere. Ask students to consider why it would be important to understand the events that took place in the distant, pre-human past. Lead students to the concept that by looking at various clues, fossil evidence of marine organisms that are known to exist within specific temperature ranges, concentrations of various gases accumulated in glaciers and ice shelves, a composite can be derived to present a picture of the past.

Day 1: Students engage in an exploration of frozen balloons with different concentrations of CO_2.

1. Teacher presents a sampling of frozen balloons to the class. Inform students of the different concentration of contents of the balloons, that each balloon has an equal amount of liquid, but don't tell them which balloon has which mixture.
2. Instruct students to predict which balloon is all CO_2 water, which is half and half and which is only H_2O as soon as the balloons are brought out. Let students know they can change their predictions as new observations are made.
3. Ask students to make a chart and record observations and changes of their predications every 5 minutes based on changes observed as balloons melt. Students will measure and record circumference of each balloon, record the temperature of each balloon by holding a thermometer to the side of the balloon, and weigh and record the weight of each balloon.
4. Lead students to making predictions concerning which balloons will look like when the states of the matter in the balloons change.
5. While the observation of the balloons is ongoing, instruct students to peel the latex from one of the two frozen balloons containing only carbonated water. (For each identification, use one color balloon for all CO_2 balloons).

Procedure continued

6. Students will use a hand lens and flashlight to observe CO_2 ice block. If possible, darken room for flashlight exploration of ice balloon**.** Carbon dioxide bubbles should be clearly evident. Direct students to record what they observe in writing and drawings.
7. Instruct students to allow CO_2 balloon to melt in a cup or some sort of dish. They should notice gas bubbling up in bowls as CO_2 balloon melts.
8. Ask students if it is possible to measure the amount of CO_2 in the balloon. **Note:** Balloon with all CO_2 water will be from 2 – 2.5 cm larger in diameter than the other two.
9. List responses.

Day 2: Students graph data collected from Antarctic ice cores.

1. Class reads article *Stories in the Ice* by Peter Tyson.
2. Review data on *Atmospheric Greenhouse Gases Affected by Human Activities* raw data chart with students. Discuss how data was collected relating this to the previous activity. Discuss what types of graphs might be used to project data, what a trend is, and how to project a trend.
3. Divide class into pairs to transfer a data set onto a line graph.
4. Model setting up of axis' of graph for students.
5. Plot X axis as time. Demonstrate clearly labeling the line with date – final two digits – to avoid future confusion.
6. Ask students to determine range – high and low of data – and label their Y axis with low end of range as opposed to zero.
7. Demonstrate locating intersect of year and data point marking that intersection with a dot.
8. Move around the room to monitor that groups are correctly entering data.
9. Model how to connect data points recorded on graphs.
10. Select groups to present their graph.

Closure:
Ask students to discuss the data they gathered and observations they made with the samples they used in the previous lessons. Engage class in discussion of what trends the plots show. Ask students to consider meaning of trends. How does using math help scientists understand nature? What is the importance of looking at fossil evidence to understanding present day conditions?

Assessment: Students write a compare and contrast paper detailing observations they made with their pre-prepared balloons and how those observations related to the long cylinders of ice cores that scientists use. The prompt instructs students to write about how they used math to describe and measure their ice balloons compared to the math the scientists used to determine the age of the ice samples they were observing.

Extension: Students will read, or see video, about collection and analysis of ice cores.

Homework: None

Resources:
Nova website which presents a graph providing a variety of information on data found in ice cores. http://www.pbs.org/wgbh/nova/warnings/stories/icecore.html.

Related Web Sites:
Ice Cores That Tell About the Past, http://www.gisp2.sr.unh.edu/MoreInfo/Ice_Cores_Past.html.

Stories in the Ice

Nature's Time Machine

How would you like to have a time machine that could take you back anywhere over the past 300,000 years? You could see what the world was like when ice sheets a thousand feet thick blanketed Canada and northern Europe, or when the Indonesian volcano Toba blew its top in the largest volcanic eruption of the last half million years.

Well, scientists have such a time machine. It's called an ice core. Scientists collect ice cores by driving a hollow tube deep into the miles-thick ice sheets of Antarctica and Greenland (and in glaciers elsewhere). The long cylinders of ancient ice that they retrieve provide a dazzlingly detailed record of what was happening in the world over the past several ice ages. That's because each layer of ice in a core corresponds to a single year—or sometimes even a single season—and most everything that fell in the snow that year remains behind, including wind-blown dust, ash, atmospheric gases, even radioactivity.

Indeed, fallout from the Chernobyl nuclear accident has turned up in ice cores, as has dust from violent desert storms countless millennia ago. Collectively, these frozen archives give scientists unprecedented views of global climate over the eons. More important, the records allow researchers to predict the impact of significant events—from volcanic eruptions to global warming—that could strike us today.

Source: Peter Tyson, Online Producer, NOVA
http://www.pbs.org/wgbh/nova/warnings/stories/

Atmospheric Greenhouse Gases Affected by Human Activities

ppmv = Parts per million by volume

CO_2 Concentration

Year	ppmv
1958	314.80
1959	316.10
1960	317.00
1961	317.70
1962	318.60
1963	319.10
1964	319.40
1965	320.40
1966	321.10
1967	322.00
1968	322.80
1969	324.20
1970	325.50
1971	326.50
1972	327.60
1973	329.80
1974	330.40
1975	331.00
1976	332.10
1977	333.60
1978	335.20
1979	336.50
1980	338.40
1981	339.50
1982	340.80
1983	342.80
1984	344.30
1985	345.70
1986	346.90
1987	348.60
1988	351.20
1989	352.90
1990	354.20
1991	355.60
1992	356.40
1993	357.00
1994	358.90
1995	360.90
1996	362.60
1997	363.80
1998	366.60
1999	368.30

Methane Concentration

Year	ppmv
1850	0.90
1879	0.93
1880	0.90
1892	0.88
1908	1.00
1917	1.00
1918	1.02
1927	1.03
1929	1.13
1940	1.12
1949	1.18
1950	1.20
1955	1.26
1956	1.30
1957	1.34
1958	1.35
1975	1.45
1976	1.47
1977	1.50
1978	1.52
1979	1.55
1980	1.56
1981	1.58
1982	1.60
1983	1.60
1984	1.61
1985	1.62
1986	1.63
1987	1.65
1988	1.67
1989	1.69
1990	1.72

CO_2 Concentration

continued . . .

Year	ppmv
2000	369.50
2001	371.00
2002	373.10
→ 2003	375.60
2004	377.40

CFC Production

Year	Amount
1955	100.00
1957	120.00
1959	140.00
1961	150.00
1963	150.00
1965	200.00
1967	225.00
1969	290.00
1971	320.00
1973	375.00
1975	350.00
1977	360.00
1979	330.00
1981	325.00
1983	320.00
1985	340.00
1987	300.00
1989	305.00
1991	310.00

Nitrous Oxide

Year	ppmv
1750	283.00
1760	283.50
1770	284.00
1780	284.00
1790	285.00
1800	285.50
1810	286.00
1820	286.50
1830	287.00
1840	287.50
1850	288.00
1860	288.50
1870	289.00
1880	289.50
1890	290.00
1900	291.00
1910	292.00
1920	292.50
1930	293.00
1940	294.00
1950	295.00
1960	297.00
1970	299.00
1980	305.00
1990	310.00