15 History of Earth's Atmosphere

INVESTIGATION

1 CLASS SESSION

ACTIVITY OVERVIEW

NGSS CONNECTIONS

In the "Atmosphere and Climate" activity, students learned about some of the characteristics of Earth's atmosphere. In this activity, they analyze and interpret data related to changes in Earth's atmosphere over time. They see that Earth's atmosphere has changed dramatically over geologic time. They also learn how human activity is causing small but significant changes to the level of carbon dioxide in the modern atmosphere.

NGSS CORRELATIONS

Performance Expectations

Working toward MS-ESS3-5: Ask questions to clarify evidence of the factors that have caused the rise in global temperatures over the past century.

Disciplinary Core Ideas

MS-ESS3.D Global Climate Change: Human activities, such as the release of greenhouse gases from burning fossil fuels, are major factors in the current rise in Earth's mean surface temperature (global warming). Reducing the level of climate change and reducing human vulnerability to whatever climate changes do occur depend on the understanding of climate science, engineering capabilities, and other kinds of knowledge, such as understanding of human behavior and on applying that knowledge wisely in decisions and activities.

Science and Engineering Practices

Planning and Carrying Out Investigations: Collect data to produce data to serve as the basis for evidence to answer scientific questions or test design solutions under a range of conditions.

Analyzing and Interpreting Data: Analyze and interpret data to provide evidence for phenomena.

Engaging in Argument from Evidence: Respectfully provide and receive critiques about one's explanations, procedures, models, and questions by citing relevant evidence and posing and responding to questions that elicit pertinent elaboration and detail.

Crosscutting Concepts

Scale, Proportion, and Quantity: Time, space, and energy phenomena can be observed at various scales using models to study systems that are too large or too small.

Stability and Change:

Explanations of stability and change in natural or designed systems can be constructed by examining the changes over time and forces at different scales, including the atomic scale.

Stability might be disturbed either by sudden events or gradual changes that accumulate over time.

Common Core State Standards—ELA/Literacy

SL.8.1: Engage effectively in a range of collaborative discussions with diverse partners on grade 8 topics, texts, and issues, building on others' ideas and expressing their own clearly.

INVESTIGATIVE PHENOMENA AND SENSEMAKING

Weather seems to be getting more extreme.

Students look at how the composition of the atmosphere has changed over time. This fills a potential gap in students' knowledge related to the history of atmospheric changes, especially regarding the levels of oxygen and carbon dioxide. The primary sensemaking opportunity occurs in the discussion of Analysis items 2 and 3, where students revisit the effect of living organisms on the atmosphere. This sets up future sensemaking, as it is a core consideration in the "Global Warming" activity.

WHAT STUDENTS DO

Students place in chronological order eight cards describing the history of Earth's atmosphere. With these cards, they examine the relative amounts of carbon dioxide and oxygen gases at different times in Earth's history, and the role of living organisms in determining the composition of the atmosphere.

MATERIALS AND ADVANCE PREPARATION

- *For the teacher*
  - 1 Visual Aid 15.1, "Composition of Earth's Atmosphere"
- *For each pair of students*
  - 1 set of 8 Atmosphere Cards

TEACHING SUMMARY

GET STARTED

1. Discuss whether Earth's atmosphere is stable or changes over time.
    a. Ask students, "Do you think that the composition of Earth's atmosphere has always been the same in Earth's past as it is today?"
    b. Have students read the introduction and guiding question.

DO THE ACTIVITY

2. Students arrange a set of Atmosphere Cards in chronological order.
    a. Distribute one set of Atmosphere Cards to each pair of students.
    b. Allow time for each pair to arrange the cards in order before instructing them to discuss their arrangement with another pair of students.

BUILD UNDERSTANDING

3. The class discusses the changes in Earth's atmosphere over geologic time.
    a. Review students' work on the "Earth's Atmosphere Through Time" table.
    b. Discuss the composition of the modern atmosphere.

TEACHING STEPS

GET STARTED

1. Discuss whether Earth's atmosphere is stable or changes over time.
    a. Ask students, "Do you think that the composition of Earth's atmosphere has always been the same in Earth's past as it is today?"

    Accept all responses but ask students to explain the reasoning behind their responses. Follow up by asking how scientists might learn about the composition of the air thousands, millions, or billions of years ago.

    b. Have students read the introduction and guiding question.

    Explain that atmospheric scientists and climatologists use evidence from Earth's ice and rock layers to measure past levels of atmospheric gases and to determine when certain major events on Earth occurred. Point out that air bubbles trapped in ice and rock layers provide a record of the composition of Earth's atmosphere at different times in the past. Since deeper layers were formed before upper layers, samples from deep layers are likely to contain older air than samples from upper layers.

DO THE ACTIVITY

2. Students arrange a set of Atmosphere Cards in chronological order.

   a. Distribute one set of Atmosphere Cards to each pair of students.

   Explain that students will examine cards that describe the composition of the atmosphere at various points in time. They will first work in pairs to arrange the cards in order, from oldest to most recent, by looking for patterns in the data presented on the cards. Point out that some cards have dates on them, and others do not. Students will have to carefully read the information on each card to figure out where the cards without dates fit into the order. If necessary, clarify any information on the cards.

   b. Allow time for each pair to arrange the cards in order before instructing them to discuss their arrangement with another pair of students.

   After both student pairs in each group have completed their work, have them compare their two arrangements. Remind students to respectfully provide and receive critiques about the arrangements, citing relevant evidence and posing and responding to questions that elicit pertinent elaboration and detail. In doing so, student groups work together to agree on the order of a single set of cards. Each student creates a table like the one shown below, "Earth's Atmosphere Through Time." The table shows the correct order for the cards and sample student responses.

Card	Gases present in the atmosphere (and percentage, if listed)	Important date and event
B	*Hydrogen, helium*	*Earth forms more than 4.5 billion years ago.*
E	*Water vapor, carbon dioxide, nitrogen, sulfur dioxide*	*Volcanoes erupt.*
C	*70% carbon dioxide, 30% nitrogen*	*Water vapor condenses into liquid water on Earth's surface.*
H	*20% carbon dioxide*	*3.5 billion years ago, the oceans absorb carbon dioxide.*
G	*15% carbon dioxide, less than 1% oxygen*	*2–3 billion years ago, living organisms produce oxygen.*
D	*21% oxygen*	*400–500 million years ago, land plants produce oxygen.*
A	*78% nitrogen, 21% oxygen, less than 1% carbon dioxide*	*The modern atmosphere forms.*
F	*Higher than 0.04% carbon dioxide*	*Between 1959 and 2015, carbon dioxide in the atmosphere increases by 27%.*

BUILD UNDERSTANDING

3. The class discusses the changes in Earth's atmosphere over geologic time.

    a. Review students' work on the "Earth's Atmosphere Through Time" table.

    Make sure they have recorded the cards in the correct order. If necessary, give students an opportunity to correct their work based on the class discussion. Ask this question again: "Has Earth's atmosphere always been the same as it is today?" Students should be able to conclude that Earth's atmosphere has changed significantly over its 4.5 billion-year history.

    b. Discuss the composition of the modern atmosphere.

    Use Visual Aid 15.1, "Composition of Earth's Atmosphere," to review the composition of the modern atmosphere. Draw students' attention to the increasing levels of carbon dioxide as indicated on Atmosphere Card F. Use Analysis items 2 and 3 to stimulate students' thinking about possible reasons for the increasing levels of carbon dioxide in the atmosphere. Tell students that they will learn more about this phenomenon in the "Global Warming" activity.

STRATEGIES FOR TEACHING DIVERSE LEARNERS

Below are suggestions for differentiating instruction and assessment in this activity for diverse learners in your classroom:

- Students with learning disabilities: Review the information on each card, and model how to transcribe the information from the cards to the table.
- English learners: Review the information on each card, and have students discuss the Procedure steps together in small groups before starting the activity.
- Academically gifted students: Challenge students to research how scientists estimate the composition of the atmosphere that existed thousands, millions, and billions of years ago.

SAMPLE RESPONSES TO ANALYSIS

1. Look carefully at your completed table.

    a. How has the amount of carbon dioxide gas in the atmosphere changed over Earth's history?

    After Earth formed, the amount of carbon dioxide gas increased significantly, from none to 70%. It then began to decrease, dropping to about 15% 2–3 billion years ago. Today, the atmosphere is less than 1% carbon dioxide.

b. How has the amount of oxygen gas in the atmosphere changed over Earth's history?

There was no oxygen gas in the atmosphere until about 2–3 billion years ago, when photosynthetic organisms began to produce oxygen. The amount of oxygen continued to increase until it reached the 21% it is today.

2. **Revisit the issue:** What effect have living organisms (including people) had on the composition of Earth's atmosphere? Support your answer with examples from this activity.

Living organisms have caused an increase in both the amount of oxygen and the amount of carbon dioxide in Earth's atmosphere. Beginning about 2–3 billion years ago, the presence of photosynthesizing organisms began to increase the amount of atmospheric oxygen until it reached present-day levels. Today, the amount of carbon dioxide gas in the atmosphere is increasing.

3. **Revisit the issue:** Do you think that the atmosphere will have different amounts of oxygen and carbon dioxide in the future? Explain your reasoning.

Students' responses will likely vary, but some students may predict that Earth is likely to continue to undergo changes in the amount of carbon dioxide gas due to a growing human population. A sample response is shown here:

I think that oxygen in the atmosphere will decrease over time, as the human population increases and uses more oxygen while simultaneously reducing the land area of photosynthesizing plants. I think carbon dioxide will continue to increase as the human population increases.

REVISIT THE GUIDING QUESTION

Has Earth's atmosphere always been the same as it is today?

Earth's atmosphere has changed dramatically over geologic time. The early atmosphere consisted primarily of hydrogen and helium gas, but over time, most of these gases escaped into space. Volcanic activity introduced gases such as water vapor, carbon dioxide, nitrogen, and sulfur dioxide. As Earth cooled, the water vapor condensed into liquid water, and the atmosphere consisted mainly of carbon dioxide and nitrogen. Over billions of years, living organisms used the carbon dioxide and water with Sunlight through the process of photosynthesis. This slowly decreased the carbon dioxide levels while increasing the level of oxygen in the atmosphere. Land plants accelerated this process, and the level of oxygen rose to around 21% while the level of carbon dioxide fell to much less than 1%. Recently, the level of carbon dioxide has been increasing.

KEY VOCABULARY

atmospheric scientist

climatologist

BACKGROUND INFORMATION

EARTH'S ATMOSPHERE

Documenting Earth's atmosphere over its geological history is an area of active research. When Earth was formed, its atmosphere (the primordial atmosphere) consisted primarily of hydrogen and helium gas. Because of Earth's size and proximity to the Sun, these gases could not be retained in Earth's atmosphere, so they escaped into space. Scientists have determined this by comparing the ratio of nitrogen gas to an isotope of neon gas with cosmic ratios. These values indicate that much of the nitrogen in Earth's atmosphere was not originally present, and its appearance marked the development of what scientists refer to as Earth's "secondary" atmosphere.

The secondary atmosphere began to develop as a result of volcanic activity, when such gases as water vapor and carbon dioxide were predominant. There was no free oxygen. The free oxygen that makes up the modern atmosphere is probably a result of two processes: (1) Solar ultraviolet radiation broke water vapor into hydrogen and free oxygen, and (2) photosynthesis by organisms such as cyanobacteria produced free oxygen. It likely took at least 1 billion years for there to be enough oxygen in the atmosphere to cause oxidation of iron sandstones, and more than 2 billion years for high levels of free oxygen to collect in the atmosphere. Earth's present atmosphere continues to depend heavily on the biological processes that replenish free oxygen.

VISUAL AID 15.1

COMPOSITION OF EARTH'S ATMOSPHERE

Gases in Earth's Atmosphere	Percent (by Volume)
Nitrogen	78.1
Oxygen	20.9
Water vapor*	0–4.0
Argon	0.9
Carbon dioxide	0.04
Neon	0.002
Helium	0.0005
Methane*	0.0002
Krypton	0.0001
Hydrogen	0.00005
Nitrous oxide*	0.00003
Xenon	0.000009
Ozone*	0.000004

* The percentage varies with location and time.