Student Workbook

California Education and the Environment Initiative

E

Earth Science Standard E.8.c.

Living Under One Roof

California Education and the Environment Initiative

Approved by the California State Board of Education, 2010

The Education and the Environment Curriculum is a cooperative endeavor of the following entities:

California Environmental Protection Agency
California Natural Resources Agency
Office of the Secretary of Education
California State Board of Education
California Department of Education
California Integrated Waste Management Board

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Key Partners:

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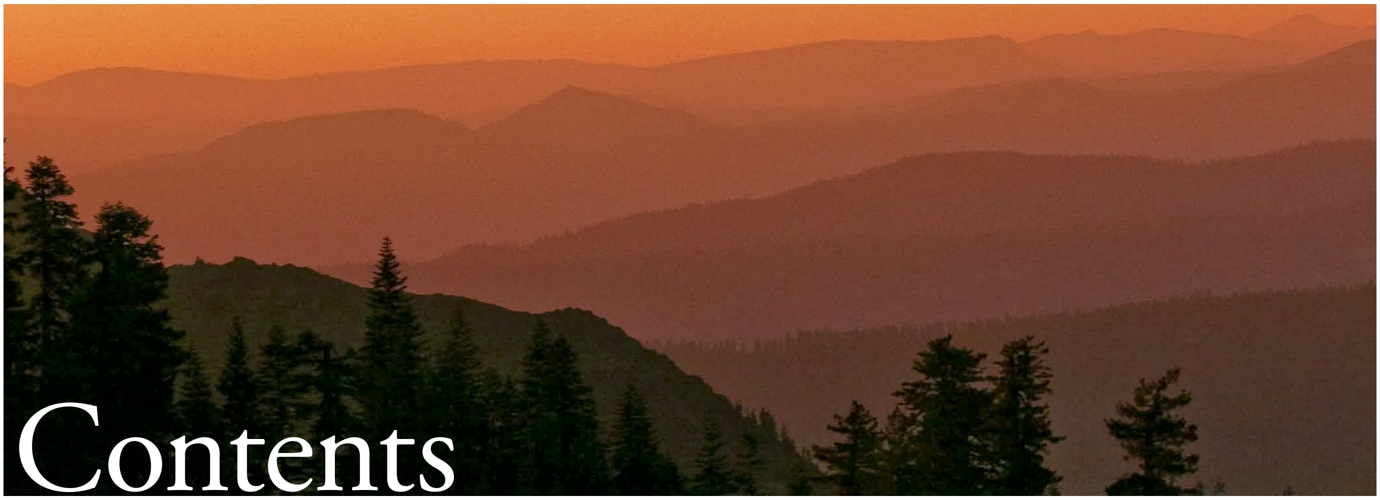


Contents

Adaptation: A change in the body or behavior of a species in response to a new environmental condition. Adaptation occurs over several generations.

Aerosol: A suspension of fine solid or liquid particles in a gas.

Antarctic ozone "hole:" An area of the ozone layer over the South Pole that is often seasonally depleted of ozone.

Bromine: A chemical element that occurs naturally in sea water as a gas and in salts.

Catalyst: A substance that facilitates or increases the rate of a chemical reaction.

Chlorine: A chemical element that is found commonly in gaseous, liquid, and solid forms.

Chlorofluorocarbon (CFC): A compound made of chlorine, fluorine, and carbon once used in aerosol sprays and as a coolant, propellant, and cleaning solvent.

Compliance: Following regulations, rules, policies, or laws.

Critical use: A regulatory exemption to use an ozone-depleting substance for a specific application when there is no economically feasible alternative available.

Dobson Spectrometer: An instrument used to compare two different wavelengths of ultraviolet radiation to determine the amount of ozone in the atmosphere.

Dobson Unit (DU): A unit of measurement of ozone found in the stratosphere.

Ecosystem: A specific area, such as a kelp forest, that contains a characteristic set of interdependent species that interact with each other and the abiotic components found there.

Emissions: The release of matter or energy into the environment including gases, particulates, noise, vibrations, light, heat, radiation, and odors.

Food web: A group of food chains interacting in an ecosystem.

Ground-level ozone: Ozone that forms in the troposphere when emissions from automobiles and industry react in the presence of heat and sunlight. Ground-level ozone is a major component of smog.

Halogen: The group of elements that includes chlorine, bromine, fluorine, iodine, and astatine.

Halon: A chemical compound made with the element bromine.

Hydrochlorofluorocarbon (HCFC): A compound made of hydrogen, chlorine, fluorine, and carbon that is less destructive to the atmosphere than chlorofluorocarbons.

Melanoma: A form of skin cancer that originates in the cells that produce the skin pigment melanin.

Methyl bromide: An agricultural pesticide and fumigant used to prevent soil diseases and to kill weeds, insects, and worms.

Model: A simulation of a process, event, concept, or the operation of a system, often with aid of a computer.

Montreal Protocol: The 1987 international treaty established to protect the ozone layer by phasing out the production and use of ozone-depleting substances.

Ozone: A strong-smelling, reactive gas consisting of three oxygen atoms that occurs naturally in the stratosphere. It is often considered a pollutant at Earth's surface, or troposphere, when in excess of normal trace amounts.

Ozone-depleting substance (ODS): Chemicals that react with ozone and ultraviolet radiation to destroy the ozone layer.

Ozone layer: A stratospheric layer of ozone that absorbs a portion of the Sun's radiation, preventing it from reaching Earth's surface.

Phase out: To stop using something over time.

Projection: An estimate or prediction of what might happen in the future based on present data or known trends.

Spectrum: The distribution of energy emitted by a radiant source, arranged in order of wavelengths.

Stratospheric polar clouds: Clouds made of ice crystals that form 80,000 feet above Earth's poles.

Sun Protection Factor (SPF): A number used to indicate the effectiveness of a sunscreen for a specific time period.

Treaty: A legally binding agreement between two or more nations that creates or restricts rights and responsibilities.

UV Index: A scale used to estimate the risk of sunburn from ultraviolet radiation. It ranges from 0 to 10 (no risk to maximum risk), based on midday sunlight at a given location, time of year, and set of atmospheric conditions.

UV radiation: Radiation in the part of the electromagnetic spectrum where wavelengths are shorter than visible light, but longer than x-rays.

Name: ______________________________

Mount Whitney—The Highest Mountain in the Lower 48 States
Location: South-Central, California near Death Valley
Elevation of Mount Whitney: 14,505 ft.
Elevation of Death Valley: -282 ft. (below sea level)
Mount Whitney Trail: 22 miles round-trip

UV Index and Weather Forecast

Date	High Temperature	Low Temperature	Skies	UV Index
August 26	95	60	Sunny	8
August 27	92	57	Mostly sunny	8
August 28	93	58	Sunny	8
August 29	94	60	Sunny	8

Assignment: You are a member of your school's High Adventure Hiking Club. For your big outing this year, your club will be climbing Mount Whitney, the tallest mountain in the lower United States. The hike will be 22 miles round-trip. Your group has decided to be on the mountain for four days. The trip is planned for August 26–29. The weather will be hot and sunny, but not as hot as it is in July. On Days 1 and 4, you will have some shade from trees along the trail. On Days 2 and 3, there are no trees along the trail, and the Sun will be strong. You are responsible for bringing what you need to protect yourself from the Sun.

Instructions: Write an essay answering the question: "What will you need in order to protect your skin from UV radiation damage during the trip?" Include the following points in your answer.

- Your "burn frequency," that is, "minutes to burn;" your skin type; and, how much Sun protection you will need
- Two or three things that you will do to protect yourself from damaging rays for the four days of the trip, based on the UV Index and the weather forecast
- Ways the group can plan the hike to avoid most harmful UV radiation
- How the role of the ozone layer relates to the need for different types of protection from UV radiation

Use the **Hiking Mount Whitney Scoring Tool** on page 4 to guide your writing.

Name: ____________________________

Extra Credit (1 point):

- If your group decides to include nearby Death Valley as an extra hike, how might your Sun protection needs and your hiking plans be different from the four days on Mount Whitney?
- You may refer back to **The UV Index and You** (Student Edition, pages 6–7) for information to help support your answer.

Write your essay in the space provided.

Name: ______________________________

Name: ______________________________

Hiking Mount Whitney Scoring Tool

Component	3 points	2 points	1 point
Identifies his or her skin type based on the NOAA "burn frequency" criteria and how it relates to Sun protection needs.	Identifies his or her skin type using language from the NOAA "burn frequency" criteria and describes how it relates to Sun protection needs.	Identifies his or her skin type using language from the NOAA "burn frequency" criteria: "always," "frequently," "never."	Identifies his or her skin type using language different from the NOAA "burn frequency" criteria.
Describes "protective action" for his or her skin type based on the UV Index and weather forecast.	Describes action strategies that align with all of the data provided: the index reading of "8," the weather forecast, and student's skin type/burn frequency assessment.	Describes action strategies that align with most but not all of the data provided: the index reading of "8," the weather forecast, and the student's skin type/ burn frequency assessment.	Identifies protective action strategies, but they do not align with UV Index and skin type and/or do not make sense.
Relates ways the group can plan their hike to avoid Sun exposure during the trip.	Clearly outlines a plan for avoiding Sun exposure between the hours of 10–4, especially on Days 2 and 3 of the hike.	Mentions staying out of the Sun, but not specifically about plans to avoid Sun exposure between the hours of 10–4 on Days 2 and 3 of the hike.	Mentions ways the group can avoid Sun exposure, but ideas are vague or not clearly defined.

Name: ______________________________

Component	3 points	2 points	1 point
Relates the role of the ozone layer to the need for different types of protective action.	Includes a clear definition of the ozone layer and draws a connection between the ozone layer and the amount of UV radiation reaching Earth.	Includes a full definition of ozone layer, but fails to draw a clear connection between the ozone layer and the need for protective action against UV radiation.	Mentions the "ozone layer" but fails to include a description of its function (filter/ block UV radiation).
(Extra Credit) Demonstrates an understanding that UV radiation is greater at high elevations compared to sea level.	n/a	n/a	Compares the elevation differences between Mount Whitney and Death Valley and identifies that there will likely be a change in the UV Index.

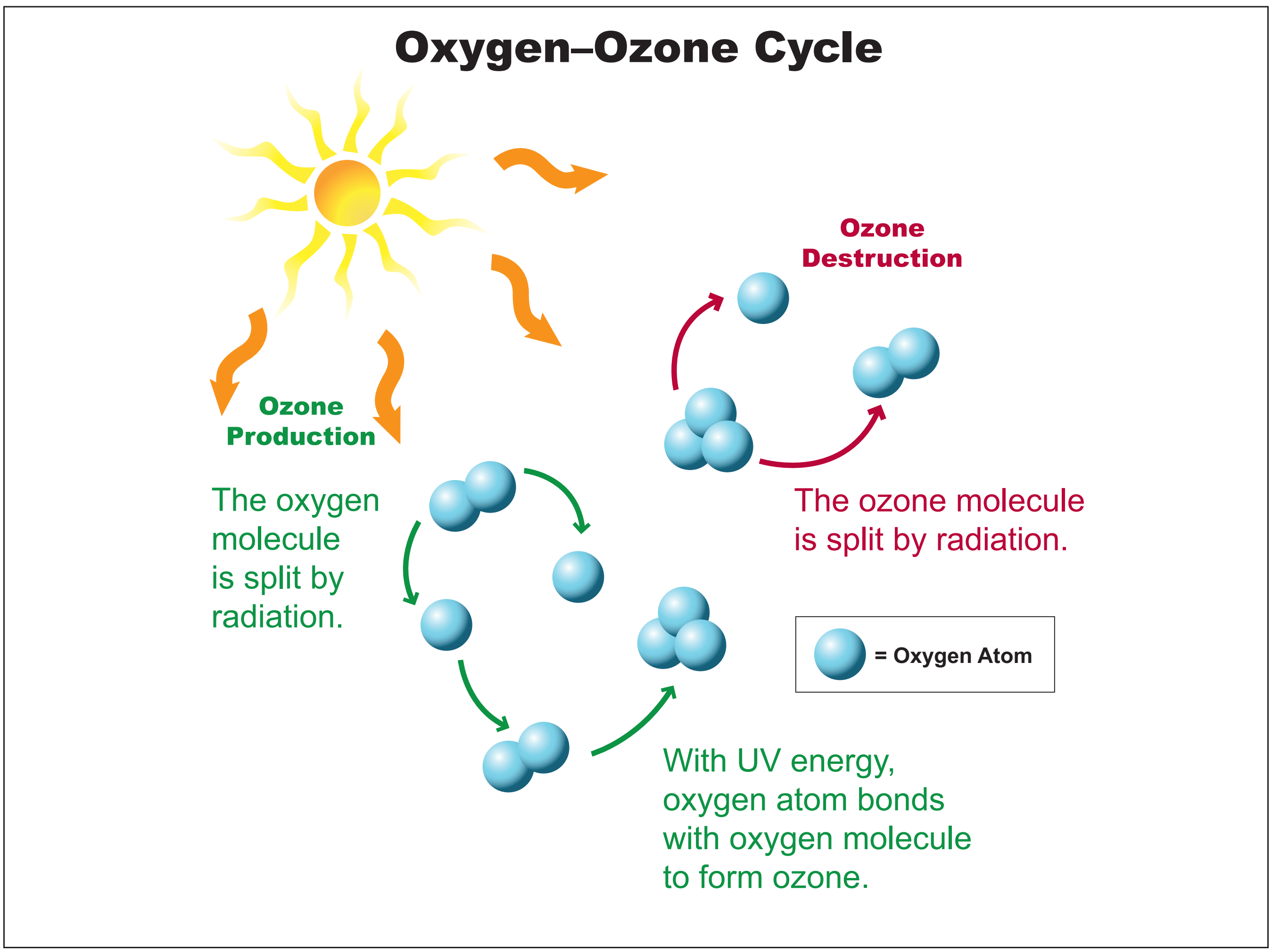
Name: ______________________________

How much ozone is in the ozone layer?

Although ozone exists from Earth's surface all the way to the upper stratosphere, it is most abundant in what scientists refer to as the "ozone layer," between 10 and 20 miles above Earth's surface. Yet even in the ozone layer, ozone is rare and spread out thinly. There is less than one ozone molecule in every 100,000 molecules of gas in the ozone layer.

How is ozone produced in the stratosphere?

Oxygen naturally exists as a gas containing two atoms of oxygen, O_2. UV radiation from the Sun splits the oxygen molecule into two single oxygen atoms. The free oxygen atoms (O) bond with other oxygen molecules (O_2) to form ozone, a molecule of three oxygen atoms (O_3). Ozone forms naturally in the stratosphere or by the reaction of pollutants at Earth's surface. The natural production of ozone is shown in the Oxygen-Ozone Cycle diagram below.



Name: ___________________________________

How does ozone naturally stay in balance in the stratosphere?

UV radiation is also able to split apart ozone into a separate oxygen atom and the molecule O_2. This oxygen-ozone cycle prevents the ozone layer from becoming a smothering blanket that would otherwise continually get thicker. The natural production-destruction process helps explain why ozone is rare.

How is ozone measured?

UV-radiation is a certain wavelength of energy that the Sun releases. The electromagnetic spectrum is the distribution of energy emitted by the Sun, arranged in order of wavelengths. People can see the light spectrum, which a prism shows as a rainbow of colors. UV-radiation is not a visible wavelength.

One way ozone can be measured is by using a Dobson Spectrometer, an instrument that compares wavelengths of UV radiation to figure out the amount of ozone in the stratosphere. G. M. B. Dobson, one of the first scientists to investigate atmospheric ozone in the 1930s, designed the Dobson Spectrometer to measure ozone in the stratosphere while standing on the surface of Earth. Because ozone absorbs UV radiation, Dobson used a spectrometer to measure the amount of UV radiation that reached Earth—the amount that was not absorbed by ozone in the ozone layer. Most UV radiation that reaches Earth is either UV-A or UV-B. The ozone layer does not block any UV-A rays, it filters some UV-B rays, and it completely blocks all UV-C rays—or should, if there is enough ozone in the ozone layer.

The Dobson Spectrometer measures and compares the amount of UV-A and UV-C radiation that reaches Earth. We can know how much total radiation is reaching Earth on any day by measuring the UV-A waves, because the ozone layer does not block these rays. Then, by measuring the amount of UV-C rays that reach Earth, we can find out how much ozone is in the ozone layer. The ozone layer should be blocking all UV-C rays so, if some UV-C rays pass through the ozone layer, we know that there is less than the "normal" amount of ozone in the ozone layer.

The difference between the amount of UV-A and UV-C radiation is called a Dobson Unit or DU. The Dobson Unit is the standard unit of ozone measurement used in ozone research. A normal reading on a typical day on Earth is 300 to 500 Dobson Units; anything below 300 DU means that a lot of UV-C made it through to the Earth's surface because there was not enough ozone to block it. Low DU means ozone-layer depletion. When any area on Earth has a concentration below 220 DU, it is an indicator that an ozone hole exists.

Name: ___________________________________

Instructions: Answer the following questions based on the reading pages 1 and 2 and the **Key Unit Vocabulary,** pages 2–3 in this book. (5 points each)

1. How are ground-level ozone and stratospheric ozone the same? How are they different?

2. How is the amount of ozone in the ozone layer measured?

Name: ____________________________

3. What protection does the ozone layer provide to life on Earth? Is this important? Why, or why not?

4. What do you think would happen to life on Earth if the ozone layer were to become thinner than it is under normal conditions?

Notes on the Effects of UV Radiation

Lesson 3

Name: ______________________________

Instructions: Select a person to read the case study aloud to the group. Discuss the evidence and the effects of UV radiation described in the reading, and complete the chart below for your topic. For some of the questions, you will need to make inferences—logical conclusions about what you think would happen given the information in the text.

Component	Human Health	Oceanic Food Web	Crop Production
If UV radiation increases, how does this affect life, including plants, animals, bacteria, and humans?			
If UV radiation increases, how does this affect human economies? (Consider how jobs, costs of items, or spending might change.)			
If UV radiation increases, how does this affect human communities? (Consider how populations of people might change.)			

Name: ______________________________

Part 1: Notes on Ozone Destruction

Instructions: Use the information in your **News Reports** (Student Edition, pages 15–16) to complete the first two rows for your topic. Take notes during class discussion to complete the remainder of the chart. (1 point per cell)

News Reports	Solar Flares	Volcanoes	Polar Stratospheric Clouds
How does this affect the ozone layer?			
What catalyst contributes to ozone destruction?			
Is this likely to be involved in long-term ozone thinning?			

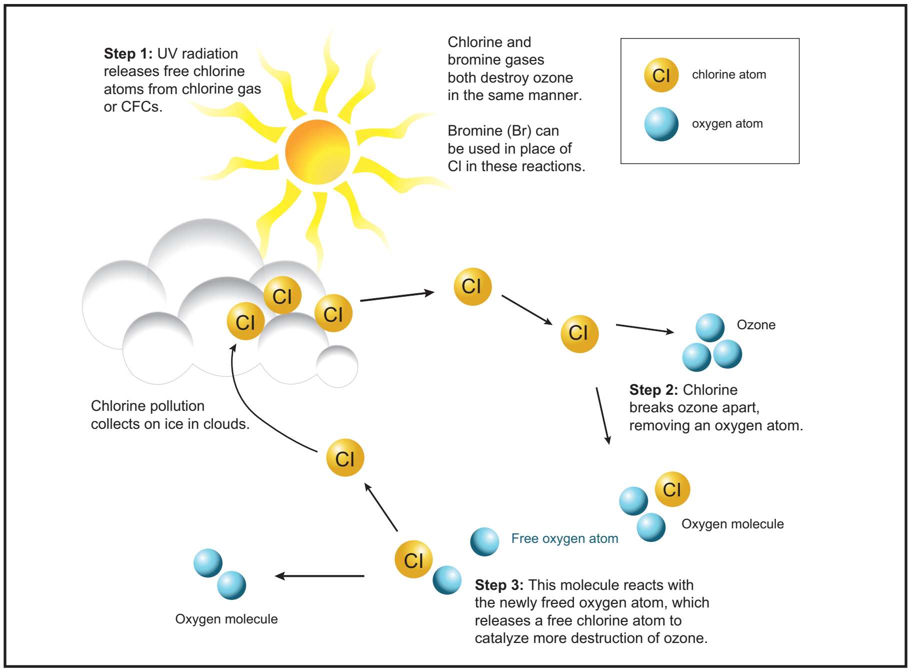
Name: ______________________________

Part 2: Drawing Ozone Destruction

Instructions: Draw a picture showing how polar stratospheric clouds contribute to the process of ozone destruction. Include labels in your drawing to explain what happens. (5 points)

Background on Miracle Products

In 1928, Thomas Midgley invented a group of safe and stable gases called chlorofluorocarbons (CFCs). CFCs are man-made compounds made with chlorine, fluorine, and carbon atoms. CFC gases are cold and so are used as a coolant in refrigerators and air conditioning. CFCs are also used in aerosol spray cans. An aerosol is a suspension of fine liquid or solid particles in a gas. The gas pushes the mixture out of a can as a thin mist, such as in spray paint. Compared to other aerosol gases, only a little bit of CFC gas is needed to push a liquid out of a can. This means that a large amount of the product, such as paint, can be put into the can.



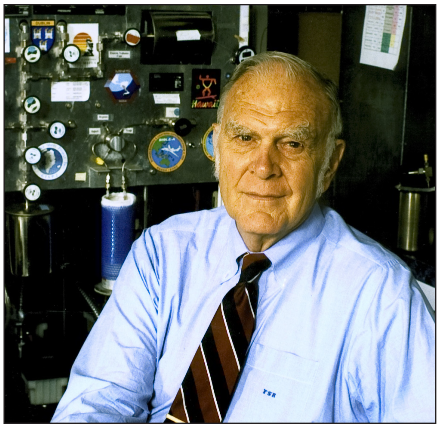
Ozone destruction process

CFCs and HCFCs

CFCs are stable and nonreactive in the lower atmosphere: they do not react with other substances or break down. In fact, these compounds only break down into other chemicals under the powerful UV radiation found in the upper stratosphere. When scientists found that CFCs could destroy the ozone layer, they developed hydrochlorofluorocarbon (HCFC) by adding the element hydrogen to CFCs. By adding hydrogen, the compound is less destructive to the ozone layer because there is less chlorine in it. HCFCs *do* harm the ozone layer, but much less than CFCs. Therefore, HCFCs are being used in the United States and many other countries as a short-term replacement for CFCs.

CFCs and HCFCs are made from chlorine and fluorine, which are both elements from the halogen family of elements. Bromine is also a halogen element. Bromine is used in fire extinguishers, pesticides, and other products. When industry refers to the bromine used in fire extinguishers, they simply call this compound "halon." Because all of these chemicals are stable and nonreactive in the lower atmosphere, they remain in the air as air pollution and slowly drift up into the stratosphere.

When these gases reach the stratosphere, they are hit by powerful UV radiation. This breaks the bonds between the elements in the compounds, leaving the chlorine or



F. Sherwood Rowland

bromine atoms as separate atoms that are very reactive (see illustration).

These reactive free atoms act as catalysts in the destruction of ozone. They react with ozone molecules (O_3), pulling off an oxygen atom (O) and leaving a molecule of oxygen (O_2) behind. When the new, unstable molecule of chlorine (or bromine) and oxygen encounter a free oxygen atom, another molecule of oxygen is made, releasing the free halogen atom to catalyze yet another reaction.

These reactions rapidly break apart ozone, always leaving the free halogen atom available to catalyze more and more reactions of ozone destruction. According to scientists, a single chlorine or bromine atom can destroy 100,000 ozone molecules! For this reason, all of these man-made compounds are called "ozone-depleting substances" or ODSs.

The illustration shows how ozone is being destroyed by chlorine from CFCs, but stratospheric chlorine or bromine from any of the substances described as "Miracle Products" or from natural sources, such as volcanic eruptions, can destroy ozone in the same way.

A Nobel Discovery

In 1974, University of California, Irvine, chemistry professor, F. Sherwood Rowland, and research assistant, Mario Molina, discovered that chlorine emissions from CFCs were directly linked with the thinning ozone layer. They quickly presented their findings to other scientists, industry that was using CFCs, and government leaders. They were awarded the Nobel Prize for Chemistry in 1995.

Ozone-depleting Potential

Some types of chlorine or bromine emissions are better at destroying ozone than others. How "bad" chemicals are for the ozone layer is called their "ozone-depleting potential" or ODP. A chemical with a small ODP number is less destructive to ozone while a chemical with a large ODP number is more destructive. The ODP of a compound is affected by the kind of halogen it contains (bromine is a more effective ozone-destruction catalyst than chlorine), how many chlorine or bromine atoms are in a molecule, and how long a molecule will stay in the atmosphere. The ODP scale ranges from 0.1 to about 16. Most CFCs fall into the 1.0 range, while some bromine compounds are very destructive and can be ranked as high as 16.0.

Mario Molina

Name: ______________________________

Word Bank:

A. Aerosol	E. Chlorine	I. HCFC
B. Bromine	F. Emissions	J. Hydrogen chloride
C. Catalyst	G. Halogen	K. Ozone-depleting potential or ODP
D. CFC	H. Halon	

Part 1: Ozone Destruction Vocabulary

Instructions: Using the word bank provided, match each term to the definition. Write the corresponding letter of the term in the blank next to the definition. (1 point each)

1. _______ A compound made of hydrogen, chlorine, fluorine, and carbon that is replacing CFCs because it is less destructive to the atmosphere.
2. _______ A gaseous element in the halogen family that occurs naturally in sea water and salt deposits and is used in pesticides, fire extinguishers, and as a fire retardant.
3. _______ A gaseous element in the halogen family that is used as a bleaching agent and disinfectant, and is implicated in the thinning of the ozone layer.
4. _______ The release of substances, such as gases or particulates, that contribute to air pollution.
5. _______ A scale that helps people understand how "bad" a compound is for the ozone layer.
6. _______ A suspension of fine solid or liquid particles in a gas.
7. _______ A substance that speeds up the rate of a reaction but is itself unchanged at the end of the process.
8. _______ A family of elements on the periodic table that includes chlorine, bromine, fluorine, iodine, astatine, and ununseptium.
9. _____ A gas produced from a reaction of evaporated sea spray or released from a volcanic eruption.

Name: ______________________________

10. _______ A chemical compound made with the element bromine.

11. _______ A compound made of carbon, chlorine, and fluorine that was formerly used in aerosol sprays and as a coolant and cleaning solvent.

Part 2: Sources That Destroy Ozone

Instructions: Complete the following tasks in the spaces provided.

12. Provide three (3) examples of man-made sources that can destroy ozone. (3 points)

13. What is the predominant source of halogen gases in the stratosphere: natural or man-made sources? (1 point)

Name: ______________________________

Governments use scientific knowledge to guide their policymaking. Starting in 1985, governments throughout the world began to work together to address the thinning of the ozone layer. How did scientific knowledge influence policymaking?

Instructions: Complete the following sentence starters to answer the question. (1 point for each completed sentence)

1. In the 1980s, atmospheric scientists discovered that the ozone layer was ____________.
2. They also discovered that the leading cause of this problem was ____________ ____________.
3. Scientific and political leaders gathered to discuss the problem. Their first decision was to ____________
4. When they gathered again, they developed the Montreal Protocol, in which participating countries agreed to ____________
5. When scientists discovered new information about the rate of ozone recovery or that some ozone-depleting substances were worse than others, governments ____________ ____________
6. In addition to regulating ozone-depleting substances, the Montreal Protocol also requires members to ____________, so that scientists will know whether the ozone layer is improving and how the amount of ozone-depleting substances in the atmosphere is changing.

Name: ______________________________

Instructions: Answer the following question in the space provided.

7. What are three factors that limit scientists' knowledge about how the ozone layer is changing and how subsequent changes in UV radiation might affect the environment? (3 points)

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