AP® ENVIRONMENTAL SCIENCE
2007 SCORING GUIDELINES

Question 3

In the mid 1970s, Sherwood Rowland and Mario Molina predicted a thinning of the stratospheric ozone layer over Antarctica. The thinning was confirmed in the late twentieth century and has continued into the twenty-first century.

(a) Identify the class of chemical compounds that is primarily responsible for the thinning of the stratospheric ozone layer and describe TWO major uses for which these chemicals were manufactured. (3 points)

*1 point for identifying a **class** of compounds—CFCs, halocarbons*
1 point each for describing two major uses
If students do not correctly identify a class of chemical, they cannot earn points for describing use.

Chlorofluorocarbons (CFCs)
- Coolant/refrigerant/air conditioners/refrigerators
- Aerosol or propellant
- Foam-blowing plastics/insulation (Styrofoam)
- Solvents/cleaners (e.g., methyl chloroform, carbon tetrachloride)

Halocarbons/Halons
- Fire retardant (fire extinguishers)
- Soil fumigant/pesticide (e.g., methyl bromide)
- Solvents
- Foam-blowing insulation

(b) Describe how the chemical compounds that you identified in part (a) destroy stratospheric ozone molecules. You may include chemical equations as part of your answer. (3 points)

Answer must link to chemical compounds identified in part (a)
- Description of how CFCs are broken down by UV radiation resulting in the release of halogen atoms—chlorine/bromine/fluorine
- Description of the process by which the halogen atoms prevent the formation of O_3 by sequestering atomic O to form halogen oxides, which is necessary for the formation of O_3
- Description of how the halogen breaks down O_3 into $O + O_2$, thereby reducing O_3 levels
- Description of how halogen is released to catalyze further reactions

Students can also earn points for demonstrating understanding of ozone depleting chemicals
- Description of how the stability of CFCs and/or halocarbons allow them to reach the stratosphere/no reservoir for CFCs in nature/chemicals are persistent
- Stratospheric clouds and/or ice crystals tend to enhance the reactions that break down O_3 / polar vortex which concentrates clouds and ice over the Antarctic

Reactions:

$CCl_3F + UV \rightarrow Cl + CCl_2F$
$Cl + O_3 \rightarrow ClO + O_2$
$ClO + O \rightarrow Cl + O_2$

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Question 3 (continued)

(c) Identify the major environmental consequence of the depletion of stratospheric ozone and describe TWO effects on ecosystems and/or human health that can result. (3 points)

1 point for identifying the major environmental consequence of depletion as an increase in UV (specifically UVB) reaching the earth's surface
1 point <u>each</u> for describing <u>two</u> effects of the identified consequence [increased UV] on ecosystems and/or human health (consequence [increased UV] must be identified to earn these points)

Human Health	Ecosystems
• Sunburn (if not linked to skin cancer) • Skin cancer in humans • Eye damage (cataracts) • Damage/reduction in efficiency of human immune system • Possible synergistic effects with various other air pollutants	• Reduction of primary productivity in oceans • Disruption of food chains • Direct damage to fish/amphibians/mammals • Widespread effects on major food crops (beans, wheat, rice, corn) • Decreased plant productivity

Students do not earn points for simply reiterating that increased UV causes damage to ecosystems and/or human health as stated in the question.

(d) Ozone formed at ground level is a harmful pollutant. Describe TWO effects that ground-level ozone can have on ecosystems and/or human health. (2 points)

1 point for <u>each</u> description of an effect that tropospheric ozone can have on ecosystems and/or human health

Human Health	Ecosystems
• Respiratory irritant (lung problem/irritation) • Coughing • Throat irritation • Pain, burning, or discomfort in the chest • Shortness of breath/tightness in chest • Eye irritant • Mucous membrane irritant • Aggravation of asthma/emphysema/chronic bronchitis • Increased susceptibility to lung infections (pneumonia and bronchitis) • Suppression of the immune system • Lung scarring/fibrosis • Impaired development of lungs in young children	• Chlorosis, bleaching, stippling, and spotting of leaves • Crop damage resulting in decreased yields • Kills leaf tissue at high concentrations • Stresses plants, possibly making them more susceptible to other diseases • Decreased photosynthesis due to reduced effective solar radiation to plants • As a greenhouse gas, ozone leads to global warming; this, in turn, results in environmental damage (e.g., disruptions of food chains, increased extinction resulting from climatic changes that may exceed an organism's range of tolerance, etc.)

3. In the mid 1970s, Sherwood Rowland and Mario Molina predicted a thinning of the stratospheric ozone layer over Antarctica. The thinning was confirmed in the late twentieth century and has continued into the twenty-first century.

   (a) Identify the class of chemical compounds that is primarily responsible for the thinning of the stratospheric ozone layer and describe TWO major uses for which these chemicals were manufactured.

   (b) Describe how the chemical compounds that you identified in part (a) destroy stratospheric ozone molecules. You may include chemical equations as part of your answer.

   (c) Identify the major environmental consequence of the depletion of stratospheric ozone and describe TWO effects on ecosystems and/or human health that can result.

   (d) Ozone formed at ground level is a harmful pollutant. Describe TWO effects that ground-level ozone can have on ecosystems and/or human health.

a) Chlorofluorocarbons, or CFC's, are primarily responsible for the thinning of stratospheric ozone. CFC's were manufactured primarily for use as aerosols in cans of hairspray, spray paint, and other items, as well as refrigeration coolant. When these products are disposed of incorrectly, CFC's escape into the atmosphere.

b) When CFC's come into Ultraviolet light exposure, they split and a Chlorine atom escapes. Chlorine is highly reactive on its own, and thus goes and bonds with an oxygen atom stolen from an Ozone molecule.

$$Cl + O_3 \rightarrow ClO + O_2$$

c) The main consequence of stratospheric ozone depletion is increased Ultraviolet radiation since ozone reflects UV back into space. The increased UV radiation is linked to increased cases of skin cancer and melanoma in humans. It also leads to cataracts and glaucoma in humans.

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Since ozone reflects back UV light, and more UV light enters as ozone is depleted, ozone is an example of a positive feedback loop since more UV triggers more CFC decomposition reactions which increase ozone depletion which increases UV exposure.

d) Tropospheric ozone poses another health threat to humans. It triggers/causes respiratory diseases, especially asthma, and can also cause severe eye irritation and other allergy symptoms.

3B,

3. In the mid 1970s, Sherwood Rowland and Mario Molina predicted a thinning of the stratospheric ozone layer over Antarctica. The thinning was confirmed in the late twentieth century and has continued into the twenty-first century.

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(b) Describe how the chemical compounds that you identified in part (a) destroy stratospheric ozone molecules. You may include chemical equations as part of your answer.

(c) Identify the major environmental consequence of the depletion of stratospheric ozone and describe TWO effects on ecosystems and/or human health that can result.

(d) Ozone formed at ground level is a harmful pollutant. Describe TWO effects that ground-level ozone can have on ecosystems and/or human health.

a. CFCs (chlorofleurocarbons) are the chemical compounds that thin stratosphere ozone. These compounds are typically manufactured ~~for use in~~ for aerosol can products (hairspray, cleaning products) or ~~for~~ for factories.

b. The CFCs break down the ozone layer when they come in contact with it. They are able to move through the troposphere to reach the stratospheric ozone molecules, which are then, in a sense, strangled by the overpowering CFCs.

C. Depletion of ozone allows for the infiltration of UV rays, which can be harmful to human skin (sunburn) and eyesight. as it exaggerates the effects of the sun. Many plants and trees will be unable

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to adapt to the change in ozone and UV levels and many forested ~~regions~~ areas could be wiped out, as a result.

D. Ozone can serve as a powerful respiratory irritant, particularly to those already suffering from an ailment such as ~~copper~~ asthma. When ozone is inhaled it can narrow breathing passages making it difficult for the victim to breathe. It also causes eye irritation (itchy, watery eyes) due to high concentrations of ~~more~~ elements humans are not intended to come in contact with

3. In the mid 1970s, Sherwood Rowland and Mario Molina predicted a thinning of the stratospheric ozone layer over Antarctica. The thinning was confirmed in the late twentieth century and has continued into the twenty-first century.

   (a) Identify the class of chemical compounds that is primarily responsible for the thinning of the stratospheric ozone layer and describe TWO major uses for which these chemicals were manufactured.

   (b) Describe how the chemical compounds that you identified in part (a) destroy stratospheric ozone molecules. You may include chemical equations as part of your answer.

   (c) Identify the major environmental consequence of the depletion of stratospheric ozone and describe TWO effects on ecosystems and/or human health that can result.

   (d) Ozone formed at ground level is a harmful pollutant. Describe TWO effects that ground-level ozone can have on ecosystems and/or human health.

a) The class of chemical compounds that is primarily responsible for the thinning of the stratospheric ozone layer are CFC's. Two major uses for which these chemicals were manufactured were for use in aerosol cans and in other canned substances.

b) CFC's are directly responsible for the destruction of stratospheric ozone molecules, or ozone (O_3). Ozone is very important to our survival because it traps heat in our atmosphere. Without ozone, the Earth would be much colder than it is today. CFC's effectively destroy ozone molecules, and do not allow them to blanket the Earth.

c) The major environmental consequence of the depletion of stratospheric ozone is increased UV radiation exposure. The depletion of stratospheric ozone can have effects on ecosystems and human health. The thinning of the stratospheric ozone layer over Antarctica is responsible for the loss of habitat in that region. Also, humans are at risk when they are exposed to UV radiation. Being exposed to UV radiation is

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linked to medical conditions like skin cancer, and cataracts.

d) Two effects that ground-level ozone can have on ecosystems and human health include susceptibility to skin cancer and increased temperature. Exposure to UV radiation is a known cause of skin cancer, and not blocking out these UV rays can increase an ecosystem's average temperature.

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Question 3

Overview

This question was designed to gauge students' understanding of stratospheric ozone depletion, the class of chemical compounds primarily responsible for the thinning, the mechanism by which ozone molecules are broken down in the stratosphere, and the major environmental consequence of ozone depletion. It also required students to make a clear distinction between the problem of stratospheric ozone depletion and the presence of ground-level ozone, with the intent of assessing their ability to separate these two issues and the respective environmental consequences. The question also evaluated the ability of students to separate the problem of stratospheric ozone depletion and its consequences from two other major problems: global warming and acid deposition.

Sample: 3A
Score: 10

Part (a): Three points were earned: 1 point for identifying Chlorofluorocarbons (CFCs) as the primary class of chemicals "responsible for the thinning of stratospheric ozone," and 1 point each for correctly describing "aerosols in cans" and "refrigerator coolants" as major uses of these compounds.

Part (b): Two points were earned: 1 point for describing how CFCs are broken down by UV radiation to release a Cl atom, and 1 point for indicating how the Cl atom functions in the breakdown of ozone.

Part (c): Three points were earned. One point was earned for identifying an increase in UV radiation reaching Earth's surface as the major environmental consequence of ozone depletion. No deduction was made for the misconception that ozone reflects UV. One point each was earned for correctly describing an increase in skin cancer (melanomas) and cataracts in humans as major effects of increased UV radiation.

Part (d): Two points were earned: 1 point each for describing "respiratory diseases" such as asthma and "severe eye irritation" as effects of ground-level ozone.

Sample: 3B
Score: 7

Part (a): Two points were earned: 1 point for identifying CFCs as the major class of chemicals responsible for the thinning of the stratospheric ozone layer, and 1 point for correctly describing the use of CFCs in "aerosol can products."

Part (b): No points were earned, since intact CFCs do not break down ozone.

Part (c): Three points were earned: 1 point for indicating that increased UV radiation reaching Earth's surface is the major consequence of stratospheric ozone depletion, and 1 point each for correctly describing sunburn and eye damage as human health effects of increased UV radiation.

Part (d): Two points were earned: 1 point for describing ground-level ozone as a "respiratory irritant," and 1 point for stating that "[i]t also causes eye irritation."

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Question 3 (continued)

Sample: 3C
Score: 4

Part (a): Two points were earned: 1 point for identifying CFCs as the primary class of chemical compounds responsible for ozone depletion in the stratosphere, and 1 point for describing "aerosol cans" as a major use of CFCs.

Part (b): No points were earned, since CFC molecules do not break down ozone.

Part (c): Two points were earned: 1 point for identifying the major environmental consequence of ozone thinning as an increase in UV radiation reaching Earth's surface, and 1 point for describing "skin cancer" as an effect of the increased UV. The point for cataracts was not earned, since the student indicates earlier (incorrectly) that increased UV radiation was responsible for habitat loss in the Antarctic.

Part (d): No points were earned. Ground-level ozone does not cause skin cancer.