2019

AP CollegeBoard

AP® Environmental Science

Sample Student Responses and Scoring Commentary

Inside:

Free Response Question 3

- ☑ **Scoring Guideline**
- ☑ **Student Samples**
- ☑ **Scoring Commentary**

AP® ENVIRONMENTAL SCIENCE
2019 SCORING GUIDELINES

Question 3

The graph shows measurements of atmospheric levels of carbon dioxide (CO_2) at Mauna Loa Observatory, Hawaii, and the measurements of pH levels in the ocean nearby at Station ALOHA. Measurements of pH began in 1992.

(a) Use the graph above to answer the following questions.

(i) **Determine** the concentration of CO_2 (in ppm) recorded at Mauna Loa in 2005.

(1 point for identifying from the graph the correct value of concentration of CO_2 recorded at Mauna Loa in 2005)

380 ppm (+/-5 ppm)

(ii) **Determine** the pH recorded at Station ALOHA in 2005.

(1 point for identifying from the graph the correct value of pH recorded at Station ALOHA in 2005)

8.08 (+/- 0.02)

(b) Changes in atmospheric carbon dioxide affect Earth's oceans.

(i) **Predict** the effect of increased concentration of atmospheric CO_2 on the concentration of CO_2 in the ocean.

(1 point for correctly predicting the effect of an increase in concentration of CO_2 in the ocean)

- Oceanic CO_2 will increase.
- Dissolved oceanic CO_2 will increase.

(ii) Based on the data, **identify** the relationship in the concentration of atmospheric CO_2 and the pH of the ocean water.

(1 point for correctly identifying the relationship between the concentration of atmospheric CO_2 and the pH of ocean water based on data)

- As atmospheric CO_2 increases, pH decreases.
- As more CO_2 dissolves in the water, it becomes more acidic/less alkaline.
- As atmospheric CO_2 increases, H_3O^+ or H^+ ions increase.

(iii) **Provide** the complete chemical equation that represents the reaction between oceanic carbon dioxide (CO_2) and water (H_2O).

(1 point for the correct balanced chemical equation that represents the reaction between oceanic carbon dioxide and water)

- $CO_2 + H_2O \rightarrow H_2CO_3$ (carbon dioxide plus water produces carbonic acid)
- $CO_2 + H_2O \rightarrow H^+ + HCO_3^-$ (carbon dioxide plus water produces one hydrogen ion and one bicarbonate ion)
- $CO_2 + H_2O \rightarrow 2H^+ + CO_3^{2-}$ (carbon dioxide plus water produces two hydrogen ions and one carbonate ion)

Question 3 (continued)

(iv) **Identify** the specific environmental problem that directly results from the decrease in pH of Earth's oceans.

(1 point for correctly identifying the specific environmental problem that directly results from the decrease in pH of Earth's oceans)

Ocean Acidification

(c) Changes in pH in the world's oceans pose a risk to many marine organisms.

(i) **Explain** why certain organisms, in particular those with calcium carbonate shells or exoskeletons, are threatened by the decreasing pH levels measured in seawater.

(2 points; 1 point for correctly explaining the impact of a decrease in pH on shells or exoskeletons and 1 point for an impact on survival of organisms)

Chemical impact on shell/coral formation	**Impact on survival of organism**
A decrease in pH levels could • Cause shells/exoskeletons to dissolve • Prevent the growth of new coral/shells • Prevent renewal/maintenance of existing coral/shells	Organisms, such as mollusks and coral, would be threatened with • Reduced fitness/decreased number of offspring • Increased predation risk • Increased threat of disease

Question 3 (continued)

(ii) Other than threats posed by decreasing pH, **identify** an additional anthropogenic threat to the world's coral reef ecosystem and **describe** how the threat damages the coral reefs and coral reef ecosystems.

(2 points; 1 point for the correct identification of an additional anthropogenic threat to the world's coral reef ecosystem and 1 point for correctly linking a description of the identified threat to the damage to coral reefs and coral reef ecosystems)

Identify one additional anthropogenic threat to the world's coral reef ecosystems	**Describe how the threat damages coral reefs and coral reef ecosystems**
Increased ocean temperature	• Coral bleaching (loss of the algal symbiont) • Reduction of dissolved oxygen concentration
Recreational activities, such as watercraft, scuba, snorkeling, swimming, etc.	• Physical damage to/destruction of coral reefs
Fishing practices, such as bottom trawling, dynamite fishing, overfishing, etc.	• Physical damage to/destruction of coral reefs • Removal of key species disrupts the food web/causes a trophic cascade
Nutrient pollution (from agricultural runoff, wastewater treatment plants, etc.)	• Cultural eutrophication and eventual decrease in dissolved oxygen levels • Excessive algal growth reduces light penetration
Sediment pollution (from logging operations, mining, etc.)	• Increased turbidity/reduction in light penetration • Deposited sediments cover/smother coral reefs
Chemical pollution, such as oil spills, pesticide runoff, sunscreen, etc.	• Disruption of reproduction and growth cycles • Disruption of metabolic processes • Endocrine disruption/DNA damage • Reduction in light penetration
Plastic/solid waste pollution	• Physical damage to/destruction of members of the coral reef ecosystem • Reduction of light penetration
Introduction of invasive species (lionfish/turkey fish, Philippine mantis shrimp, etc.)	• Invasive species can outcompete native species

PAGE FOR ANSWERING QUESTION 3

ai) Mauna Loa station recorded approximately 377 ppm CO_2 in 2004.

aii) ~~Mauna Loa station recorded~~ Station Aloha recored an 8.08 ocean pH in 2004.

bi) Increased concentrations of atmospheric CO_2 will most likely lead to increased ~~levels~~ concentrations of of Ocean CO_2.

bii) The greater the concentration of atmospheric CO_2, the lower the pH of ocean water. This is an inverse relationship

biii) $H_2O + CO_2 \rightarrow H_2CO_3$

biv) Ocean Acidification results from the decrease in pH of Earth's Oceans.

ci) Organisms with calcium carbonate shells or exoskeletons are at risk due to lowering pH levels because the acidic water will dissolve these shells and exoskeletons, leading to an organism that is very vulnerable to predators.

cii) Global warming poses a threat to Earth's coral reef ecosystems, because rising water temperatures can cause photosynthetic algae in coral to leave the coral, causing coral bleaching and die offs.

GO ON TO THE NEXT PAGE.

PAGE FOR ANSWERING QUESTION 3

a. i) 375 ppm of CO_2

ii) 8.08

b. i) an increased concentration of CO_2 in the atmosphere leads to an increased concentration of CO_2 in the ocean.

ii) as the concentration of atmospheric CO_2 increases, the pH of ocean water decreases, so the two are inversely proportional.

iii) $CO_2 + H_2O \rightarrow CHO_3 + H$

iv) ocean acidification

c. i) a decrease in ocean water pH causes an increase in ocean acidity. This weakens the organisms with calcium carbonate shells/exoskeletons by making them softer, and therefore more vulnerable to their predators.

ii) the use of large fishing nets that scrape up the ocean floor tear apart the coral in the coral reefs and spread debris across the ocean floor. This not only damages the coral itself but also any organism in the ecosystem that depends on the coral.

GO ON TO THE NEXT PAGE.

PAGE FOR ANSWERING QUESTION 3

a) i. The concentration of CO_2 recorded at Mauna Loa in 2005 was about 375 ppm.

ii. The pH recorded at Station ALOHA in 2005 was about 8.08.

b) The increased concentration of atmospheric CO_2 results in a higher concentration of CO_2 in the ocean.

ii. As the concentration of CO_2 in the atmosphere increases, the pH of ocean water decreases.

iv. The decrease in pH of Earth's oceans directly impacts organisms that are suited to live under specific pH levels. A decrease in pH will affect the survival and reproduction of various marine organisms.

c) Since a decreasing pH level indicates more acidic waters, organisms with calcium carbonate shells and exoskeletons are affected; calcium carbonate shells and exoskeletons dissolve under acidic conditions.

ii. Anthropogenic activities increase the emissions of greenhouse gases which further the impact of global warming. Due to the ocean's low albedo, global warming results in warming

GO ON TO THE NEXT PAGE.

ADDITIONAL PAGE FOR ANSWERING QUESTION 3

waters. Coral reef and coral reef ecosystems thrive under certain temperatures. With warming ocean waters, the survival of coral reef organisms decreases, which in turn reduces the survival of coral reefs that depend on those organisms.

AP® ENVIRONMENTAL SCIENCE
2019 SCORING COMMENTARY

Question 3

Note: Student samples are quoted verbatim and may contain spelling and grammatical errors.

Overview

The intent of this question was for students to evaluate a graph showing the atmospheric carbon dioxide concentration at Mauna Loa and the oceanic pH at Station ALOHA, Hawaii. Students were asked to evaluate the effect of the changes in atmospheric carbon dioxide concentrations on Earth's oceans and to evaluate the affect that changes in the pH in the world's oceans pose to marine organisms. Additionally, students were asked to identify and describe an anthropogenic threat to coral reef ecosystems that was not posed by a change in pH.

In the first part of the question, the stimulus provided a line graph with two sets of data, the atmospheric concentration of carbon dioxide and the oceanic pH from 1960 to 2015. Students were asked to determine the concentration of CO_2 (in ppm) and the pH in 2005. Students were then asked to predict the effect of increased concentration of atmospheric CO_2 on the concentration of CO_2 in the ocean and to identify the relationship between the concentration of atmospheric CO_2 and the pH of ocean water. Students were asked to provide the complete chemical equation that represents the reaction between oceanic carbon dioxide and water and then to identify the specific environmental problem that directly results from the decrease in pH of Earth's oceans. These concepts were drawn from the following section of the topic outline: II. The Living World, E. Natural Biogeochemical Cycles and VII. Global Change, B. Global Warming.

Finally, students were asked to explain why certain organisms, in particular those with calcium carbonate shells or exoskeletons, are threatened by the decreasing pH levels measured in seawater. Students were asked to identify an additional anthropogenic threat to the world's coral reef ecosystem and to describe how that threat damages the coral reefs. These concepts were drawn from the following sections of the topic outline: II. The Living World, A. Ecosystem Structure; III. Population, B. Human Population, 3. Impacts of Population Growth; IV. Land and Water Use, F. Fishing; and VI. Pollution, A. Pollution Types, B. Impacts on the Environment and Human Health.

Sample: 3A
Score: 10

The response earned 2 points in part (a): 1 point in (a)(i) for determining from the data in the graph that the concentration of CO_2 was "377 ppm," which is within the accepted range at Mauna Loa in 2005, and 1 point was earned in part (a)(ii) for determining that the pH recorded at Station ALOHA in 2005 was "8.08" based on the data in the graph. The response earned 4 points in part (b): 1 point in (b)(i) for predicting that increased concentration of atmospheric CO_2 would "lead to increased concentrations … of ocean CO_2"; 1 point in (b)(ii) for using the graph to identify that "the greater the concentration of atmospheric CO_2, the lower the pH of ocean water"; 1 point in (b)(iii) for providing "$H_2O + CO_2 \rightarrow H_2CO_3$" as the complete chemical equation that represents the reaction between oceanic carbon dioxide and water; and 1 point in part (b)(iv) for identifying that "[o]cean acidification" is the specific environmental problem caused by the decrease in pH of Earth's oceans. The response earned 4 points in part (c). The response earned 2 points in part (c)(i): 1 point for explaining "the acidic water will dissolve there shells" and 1 point for explaining how the organisms are threatened in "leading to an organism that is very vulnerable to predators." The response earned 2 points in part (c)(ii): 1 point for identifying "rising water temperatures" and 1 point for linking the description of "cause photosynthic algae in coral to leave the coral, causing coral bleaching" to rising ocean temperatures.

Question 3 (continued)

Sample: 3B
Score: 8

The response earned 2 points in part (a): 1 point in (a)(i) for determining the concentration of CO_2 is "375 ppm," which is within the accepted range at Mauna Loa in 2005 based on the data in the graph and 1 point in (a)(ii) for determining the pH was "8.08" at Station ALOHA in 2005 based on the data in the graph. The response earned 3 points in part (b): 1 point in (b)(i) for predicting that increased atmospheric CO_2 will lead to "increased concentration of CO_2 in the ocean"; 1 point in part (b)(ii) for identifying that as "atmospheric CO_2 increases, the pH of ocean water decreases." No points were earned in part (b)(iii) because the response does not correctly provide the formulas for bicarbonate ion or hydrogen ion. The response earned 1 point in part (b)(iv) for identifying "ocean acidification." The response earned 3 points in part (c): 1 point in (c)(i) for explaining that organisms would become "more vulnerable to their predators," but the student did not earn the point for the impact on shell formation because the explanation does not describe the chemical changes to the shells. The response earned 2 points in part (c)(ii): 1 point for identifying "use of large fishing nets" and 1 point for the linking the description of "scrape up the ocean floor tear apart the coral in the coral reefs" to the use of fishing nets.

Sample: 3C
Score: 6

The response earned 2 points in part (a): 1 point in (a)(i) for determining that the concentration of CO_2 is "375 ppm," which is within the accepted range at Mauna Loa in 2005 based on the data in the graph and 1 point in (a)(ii) for determining that the pH is "8.08" at Station ALOHA in 2005 based on the data in the graph. The response earned 2 points in part (b): 1 point in (b)(i) for predicting that increased atmospheric CO_2 "results in a higher concentration of CO_2 in the ocean" and 1 point in part (b)(ii) for identifying that as the "concentration of CO_2 in the atmosphere increases, the pH of ocean water decreases." No points were earned in part (b)(iv) because the student does not correctly identify ocean acidification as the specific environmental problem that directly results from the decrease in pH of Earth's oceans. The response earned 2 points in part (c): 1 point in (c)(i) was earned for explaining that "calcium carbonate shells and exoskeletons dissolve under acidic conditions." The second point in part (c)(ii) was not earned because the student does not explain the impact that the chemical threat would have on the organism. The response earned 1 point in part (c)(ii) for identifying that "global warming results in warming waters." The response did not earn the description point in part (c)(ii) because the response does not include a description of how increased ocean temperatures impact coral reefs and coral reef ecosystems.