

**AP[®] ENVIRONMENTAL SCIENCE
2011 SCORING GUIDELINES**

Question 2

(a) Explain how an increase in the amount of dissolved CO₂ in ocean water results in a decrease in the pH of ocean water.

(1 point for the following)

- When carbon dioxide dissolves in the ocean, it forms an acid (carbonic acid or H₂CO₃).

(b) Explain why the movement of carbon into the ocean has been increasing since 1850.

(2 points; 1 point for each of the following)

- The concentration of carbon or carbon dioxide in the atmosphere has increased.
- The source of the increase in carbon or carbon dioxide concentration in the atmosphere is the burning of fossil fuels.

(c) In order to model the effects of ocean acidification on coral reefs, some simplifying assumptions can be made. Use the assumptions in the table below to perform the calculations that follow.

Assume that the total global area of corals growing in reefs is $2.5 \times 10^{11} \text{ m}^2$.
Assume that corals grow only vertically and that the average vertical growth rate of corals is 3 mm/year.
Assume that the average density of CaCO₃ in corals is $2 \times 10^3 \text{ kg/m}^3$.

(i) Calculate the current annual global increase in volume, in m³, of CaCO₃ in coral reefs.

Show all steps in your calculation.

(2 points; 1 point for a correct setup and 1 point for the correct answer)

Units are not required in the answer; however, students must show the calculation in order to receive credit for the correct solution.

$$2.5 \times 10^{11} \text{ m}^2 \times \frac{3 \text{ mm}}{\text{year}} \times \frac{1 \text{ m}}{1 \times 10^3 \text{ mm}} = 7.5 \times 10^8 \text{ m}^3/\text{year}$$

Or

$$2.5 \times 10^{11} \text{ m}^2 \times \frac{3 \times 10^{-3} \text{ m}}{\text{year}} = 7.5 \times 10^8 \text{ m}^3/\text{year}$$

Notes

- Students who write the answer as a word problem may earn points.
- Solutions to the question that use alternative setups that produce a correct answer also earn points.
- Equivalent correct answers (e.g., 750,000,000 m³) are acceptable.

**AP[®] ENVIRONMENTAL SCIENCE
2011 SCORING GUIDELINES**

Question 2 (continued)

- (ii) Calculate the current annual global increase in mass, in kg, of CaCO₃ in coral reefs. Show all steps in your calculation.**

(2 points; 1 point for a correct setup and 1 point for the correct answer)

Units are not required in the answer; however, students must show the calculation in order to receive credit for the correct solution.

$$\frac{7.5 \times 10^8 \text{ m}^3}{\text{year}} \times \frac{2 \times 10^3 \text{ kg}}{1 \text{ m}^3} = 1.5 \times 10^{12} \text{ kg/year}$$

Notes

- Students who write the answer as a word problem may earn points.
- Solutions to the question that use alternative setups that produce a correct answer also earn points.
- Equivalent correct answers (e.g., 1,500,000,000,000 kg or 1.5×10^{12} kg) are acceptable.
- Incorrect answers transferred from (c)(i) can still earn full credit if used correctly.

- (iii) Because of ocean acidification, it is expected that in 2050 the mass of CaCO₃ deposited annually in coral reefs will be 20 percent less than is deposited currently. Calculate how much less CaCO₃, in kg, is expected to be deposited in 2050 than would be deposited if ocean water pH were to remain at its current value.**

(2 points; 1 point for a correct setup and 1 point for the correct answer)

Units are not required in the answer; however, students must show the calculation in order to receive credit for the correct solution.

$$0.2 \times 1.5 \times 10^{12} \text{ kg} = 3 \times 10^{11} \text{ kg}$$

Notes

- Students who write the answer as a word problem may earn points.
- Solutions to the question that use alternative setups that produce a correct answer also earn points.
- Equivalent correct answers (e.g., 300,000,000,000 kg or 0.3×10^{12} kg) are acceptable.
- Incorrect answers transferred from (c)(ii) can still earn full credit if used correctly.

**AP[®] ENVIRONMENTAL SCIENCE
2011 SCORING GUIDELINES**

Question 2 (continued)

- (d) Identify and describe one likely negative environmental impact of the loss of coral reefs.**
(2 points; 1 point for correctly identifying a negative impact and 1 point for a correct description of that impact. Only the first answer is scored.)

The impact must be environmental — economic and societal impacts are not acceptable. The impact and the description must be correctly linked; however, students can earn a point for a description without earning a point for an impact.

Impact	Description
Loss of habitat	<ul style="list-style-type: none">• Elimination of a food source for marine life• Loss of breeding grounds for fish and bird species• Loss of shelter/hiding places
Loss of biodiversity or species diversity/richness/evenness	<ul style="list-style-type: none">• Extinction or decrease in populations of marine organisms
Decreased protection of coastal areas from waves/storm surges	<ul style="list-style-type: none">• Destruction of coastal habitats• Accelerated erosion of shoreline habitat
Loss of carbon sink	<ul style="list-style-type: none">• Less carbon storage in coral reefs

- (e) Identify one environmental problem (other than one due to ocean acidification or loss of coral reefs) that affects marine ecosystems on a global scale.**
(1 point; only the first answer is scored.)

Any of the following are correct responses:

- Overfishing
- Destructive fishing practices (e.g., bottom trawling, drift netting)
- Increased ocean temperatures
- Introduction of invasive species
- Nutrient pollution/Eutrophication
- Hypoxia/Dead zones
- Garbage/plastic debris (e.g., Great Pacific Garbage Patch)
- Oil spills/Off-shore oil drilling
- Mercury pollution

Note: Ocean acidification and loss of coral reefs are not acceptable answers.

ADDITIONAL PAGE FOR ANSWERING QUESTION 2

a. When CO_2 is dissolved in water, it forms carbonic acid which also results in the increase in free H^+ ions, thereby lowering the pH of the water.

b. Since the 1850s, the amount of combustion globally has increased dramatically (starting with the industrial revolution). This combustion of organic compounds has resulted in a drastic increase in atmospheric carbon. More carbon in the atmosphere ~~increases the likelihood that~~ decreases its vapor pressure above the sea, making it more likely to be dissolved into the water.

c. i. Annual increase in coral volume = $2.5 \times 10^{11} \text{ m}^2 \times 3 \times 10^{-3} \text{ m/year} = 7.5 \times 10^8 \text{ m}^3/\text{year}$

$$3 \text{ mm/yr} = 0.003 \text{ m/yr} = 3 \times 10^{-3} \text{ m/yr}$$

ii. Annual increase in coral mass = $7.5 \times 10^8 \text{ m}^3/\text{year} \times 2 \times 10^3 \text{ kg/m}^3 = 1.5 \times 10^{12} \text{ kg/year}$

iii. $1.5 \times 10^{12} \text{ kg} \times 20\% = 0.3 \times 10^{12} \text{ kg} = 3 \times 10^{11} \text{ kg}$

d. Loss of habitat for marine species, resulting in a decrease in marine biodiversity. Thousands of species rely on coral reefs for shelter from predators & ocean currents. The loss of the reefs means the loss of these species.

e. Global climate change and increasing mean temperatures also results in increasing sea temperatures. Not only does this threaten species with ~~off~~ specific habitable temperature ranges, it also decreases the amount of available dissolved O_2 , resulting in lowered carrying capacities in the seas.

GO ON TO THE NEXT PAGE.

ADDITIONAL PAGE FOR ANSWERING QUESTION 2

a) Increased amounts of CO_2 helps increase the temperature of the water. This results in the bleaching of many coral reefs and the decrease in pH levels in the ocean's water.

b) The amount of Carbon in the ocean has been increasing because of the amount of carbon in the atmosphere has been increasing. Since 1850, the industrial revolution happened and mass amounts of CO_2 from coal-burning power plants and automobile-vehicles have been ~~the~~ released into the atmosphere. Through diffusion, this carbon is consequently deposited into the ocean.

$$i) 2.5 \times 10^{11} \text{ m}^2 \times \frac{.003 \text{ m}}{\text{year}} = 1 \times 10^8 \frac{\text{m}^3}{\text{year}}$$

$$ii) 2 \times 10^3 \frac{\text{kg}}{\text{m}^3} \times 1 \times 10^8 \frac{\text{m}^3}{\text{year}} = 2 \times 10^{11} \frac{\text{kg}}{\text{year}}$$

$$iii) 2 \times 10^{11} \times .5 = 1 \times 10^{10} \text{ kg}$$

d) The loss of coral reefs would make ~~certain~~ ^{these} aquatic biomes more prone to destruction because of the drastic decrease in biodiversity. Thousands of species need coral reefs to survive, and without the coral, the ~~the~~ aquatic species will die.

e) The over-fishing of marine ecosystems decreases biodiversity and may even leave ~~the~~ certain species ~~extinct~~ extinct. One species, the blue fin tuna, is being over fished so much, that soon there will be none left. This is a terrible example of the tragedy of the commons.

GO ON TO THE NEXT PAGE.

2C1

ADDITIONAL PAGE FOR ANSWERING QUESTION 2

The increased increase of dissolved CO_2 in ocean water results in a decrease of pH because dissolved CO_2 is acidic, and therefore reduces the total pH of ocean water, which is naturally more basic.

The movement of carbon into the ocean has increased since 1880 due to several factors. Atmospheric CO_2 levels have increased, leading to higher carbon levels. ~~Commercial~~^{Also,} Commercial agriculture has sharply increased, leading to larger runoff of carbon compounds.

i) $\frac{2.5 \times 10^{11} \text{ m}^2 \times 3 \text{ mm}}{\text{year}} \times \frac{1 \text{ m}}{1000 \text{ mm}} = 7.5 \times 10^8 \text{ m}^3$ (annual global increase of CaCO_3)
per year

ii) $\frac{2 \times 10^3 \text{ kg}}{\text{m}^3 \text{ per year}} \times 7.5 \times 10^8 \text{ m}^3 = 15 \times 10^{11} \text{ kg per year}$

iii) normal $\rightarrow \frac{15 \times 10^{11} \text{ kg}}{\text{year}} \times 39 \text{ years} = 585 \times 10^{11} \text{ kg}$

20% less $\rightarrow \frac{7.5 \times 10^{11} \text{ kg}}{\text{year}} \times 39 \text{ years} = 292.5 \times 10^{11} \text{ kg}$

$292.5 \times 10^{11} \text{ kg per year less}$

One negative impact of loss of coral reefs would be the loss of habitat for countless marine animals. Coral reefs are a huge part of coastal marine ecosystems. Another environmental problem that affects globally affects marine ecosystems is the dumping of waste into the ocean. This waste can

GO ON TO THE NEXT PAGE.

AP[®] ENVIRONMENTAL SCIENCE

2011 SCORING COMMENTARY

Question 2

Overview

The intent of this question was to assess students' knowledge about ocean acidification and its effects on coral reefs. Students were also asked to perform a series of calculations about the dimensions of coral reefs and to identify another problem affecting marine ecosystems.

Sample: 2A

Score: 10

One point was earned in part (a) for stating that carbonic acid is formed. One point was earned in part (b) for relating the greater amount of carbon in the oceans to an "increase in atmospheric carbon." No point was earned for the mention of "combustion of organic compounds," because it does not specify the increase in fossil fuel combustion that accounts for the overall increase in combustion of organic compounds since 1850. Two points were earned in part (c)(i) for a correct setup and the correct answer. Two points were earned in part (c)(ii) for a correct setup and the correct answer. One point was earned in part (c)(iii) for the correct answer. Two points were earned in part (d): 1 for identifying "[l]oss of habitat" as an impact, and 1 for including "shelter from predators" in the description of habitat loss. One point was earned in part (e) for identifying "increasing sea temperatures" as an environmental problem that affects marine ecosystems on a global scale.

Sample: 2B

Score: 8

No points were earned in part (a). Two points were earned in part (b): 1 for stating that the amount of carbon in the atmosphere is increasing and 1 for identifying coal burning as a source of carbon dioxide. One point was earned in part (c)(i) for a correct setup. Two points were earned in part (c)(ii) for the setup and an answer consistent with the incorrect answer in part (c)(i). No point was earned in part (c)(iii). One point was earned in part (d) for identifying a "decrease in biodiversity" as a negative effect of the loss of coral reefs, and 1 point was earned for describing that impact by stating that "species will die." One point was earned in part (e) for identifying overfishing as an environmental problem that affects marine ecosystems on a global scale.

Sample: 2C

Score: 6

No points were earned in part (a). One point was earned in part (b) for stating that atmospheric carbon dioxide levels have increased. Two points were earned in part (c)(i) for a correct setup and the correct answer. Two points were earned in part (c)(ii) for a correct setup and the correct answer. No point was earned in part (c)(iii). One point was earned in part (d) for identifying "the loss of habitat" as a negative consequence of the loss of coral reefs. No points were earned in part (e); "dumping of waste" does not identify a specific environmental problem.