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)

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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

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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