



PART 1

Read the text below and answer questions 1–13.

THE CHEMISTRY OF A CHANGING OCEAN: UNDERSTANDING OCEAN ACIDIFICATION

A

For centuries, the ocean has acted as a vast buffer for the atmosphere by absorbing a large share of the carbon dioxide released by human activity. This buffering service slows the accumulation of CO_2 in the air and therefore moderates the pace of global warming. However, the benefit is not free. When CO_2 enters seawater, it triggers predictable chemical reactions that increase acidity (that is, lower pH) and reorganise the balance of dissolved carbon compounds. The term “ocean acidification” can be misleading to non-specialists because seawater remains alkaline overall, but on the pH logarithmic scale even a small downward shift represents a substantial rise in hydrogen-ion concentration. The concern, therefore, is not that the ocean becomes “acid” in everyday language, but that a persistent shift in carbonate chemistry alters the conditions under which many organisms grow, reproduce, and build the structures that support marine ecosystems.

B

The underlying chemistry is both simple and far-reaching. When carbon dioxide dissolves in seawater, it forms carbonic acid, which rapidly breaks apart and releases hydrogen ions. Those hydrogen ions do not merely remain in solution; they interact with other components of the carbonate system. A key step is that extra hydrogen ions bind with carbonate ions, converting them into bicarbonate. This matters because carbonate ions are the raw material for many forms of calcification. In other words, although the ocean contains more total dissolved inorganic carbon under higher CO_2 , the proportion present as carbonate declines. Scientists often describe this as a shift in “speciation”: more carbon exists as bicarbonate, less as carbonate, even if total carbon increases. Because carbonate chemistry helps regulate mineral formation and dissolution, the knock-on effects extend beyond pH itself, influencing how easily calcium carbonate minerals can be produced or maintained.

C

These chemical shifts have particular implications for calcifying organisms—species that construct shells or skeletons from calcium carbonate. The difficulty is not only “less building material”, but a change in the energetic cost of turning dissolved ions into solid structures. When carbonate becomes less available, some organisms must invest more energy in forming and maintaining protective shells, leaving less energy for growth, feeding, or reproduction. This can result in shells becoming thinner or more brittle, increasing



vulnerability to predation and physical damage. Researchers pay close attention to organisms such as pteropods (free-swimming snails) and coccolithophores (microscopic algae with calcium carbonate plates) because they sit at important points in food webs and biogeochemical cycles. Another scientific concept used to capture these risks is aragonite saturation, a measure of how favourable seawater is for forming aragonite—a common form of calcium carbonate used by many marine organisms. As saturation declines, calcification can become harder and dissolution more likely, especially in early life stages that are often the most sensitive.

D

Acidification is not uniform across the globe, and this geographical variability is central to understanding both risks and responses. Cold water absorbs more CO_2 than warm water, so high-latitude oceans can experience stronger chemical shifts for a given atmospheric concentration. In addition, upwelling regions can bring CO_2 -rich deep water to the surface, creating naturally lower pH conditions even without direct human influence. Coastal environments are more complex still: rivers can deliver nutrients and organic matter; pollution can alter biological activity; and intense photosynthesis or respiration can shift carbonate chemistry over short timescales. Consequently, local trends may diverge from global averages, and neighbouring sites can display different patterns depending on circulation, depth, and ecological dynamics. This variability complicates comparisons between monitoring locations, but it also provides natural “laboratories” where scientists can observe how organisms respond to low-pH conditions that resemble future scenarios.

E

Because the carbonate system is interconnected, scientists rarely rely on a single indicator. pH is widely used because it is intuitive and can be measured continuously, but it is only one part of the chemical story and can fluctuate daily or seasonally. Moreover, pH alone does not directly tell researchers how much carbonate remains available for calcification. For that reason, monitoring programmes often pair pH measurements with total alkalinity and dissolved inorganic carbon, using these values to calculate the full carbonate system more reliably. Total alkalinity captures the seawater’s capacity to neutralise acids and helps constrain the balance among carbonic acid, bicarbonate, and carbonate ions. With these parameters, researchers can estimate aragonite saturation states and other quantities that are more closely linked to biological impacts. Long-term observing networks are expanding, including moored sensors that record high-frequency variability and repeated ship surveys that map regional patterns. A key scientific aim is to separate short-term “noise” from long-term change so that trends can be attributed to rising atmospheric CO_2 rather than to local cycles alone.



F

To judge whether current changes are exceptional, scientists draw on historical archives, although such evidence comes with uncertainty. Ice cores reveal past atmospheric CO₂ concentrations, while marine sediments preserve chemical signals that can be interpreted as clues to earlier ocean conditions. These records suggest that Earth has experienced different carbon states in the distant past, but the present rate of change is unusually rapid. For marine life, speed is critical. Adaptation through evolution and adjustment through migration may be possible, yet both operate within biological limits and require time. In reality, acidification also acts alongside other stressors—warming, deoxygenation, pollution, and overfishing—which can erode resilience and reduce the capacity of populations to cope. This is why researchers increasingly investigate multiple drivers together: a species that tolerates lower pH in a laboratory may struggle when higher temperature or reduced oxygen is added, or when food availability changes in a real ecosystem.

G

Economic and policy consequences follow ecological ones, and they are unevenly distributed. Shellfish aquaculture, for instance, can be vulnerable if early life stages fail in water that is already close to chemical thresholds, while coral reef tourism and fisheries may be affected if habitat-forming species weaken. The most direct long-term solution is reducing CO₂ emissions, because the ultimate driver is the concentration of carbon dioxide in the atmosphere. At the same time, some regions explore local measures that may moderate conditions temporarily or in specific habitats. Restoring seagrass meadows can increase local uptake of CO₂ during active growth and potentially raise pH in nearby waters under certain conditions; however, such approaches are not substitutes for emission cuts and their effectiveness depends on location, season, and ecosystem dynamics. Understanding ocean acidification, then, is both a chemistry lesson and a policy challenge: the reactions are well known, but outcomes depend on biology, geography, monitoring capacity, and choices about mitigation and adaptation.

Questions 1–4

Choose the correct heading for each paragraph.

List of Headings

- i Biological vulnerability when mineral building becomes energetically costly
- ii Why place and ocean circulation make trends uneven
- iii A global service that creates an overlooked chemical trade-off



iv What long-term archives imply about speed and resilience

v How dissolved carbon reorganises into different chemical forms

vi Why solutions include both emission cuts and limited local buffering

vii Why multiple measurements are needed to describe the carbonate system

1 Paragraph **A**

2 Paragraph **B**

3 Paragraph **C**

4 Paragraph **D**

Questions 5–8

Choose **TRUE** if the statement agrees with the information given in the text, choose **FALSE** if the statement contradicts the information, or choose **NOT GIVEN** if there is no information on this.

5 The passage suggests that the ocean can become more acidic even though seawater remains alkaline.

6 The passage suggests that reduced carbonate availability can force some organisms to spend more energy building or maintaining hard structures.

7 The passage suggests that pH fluctuations make it useless for monitoring long-term change.

8 The passage states that seagrass restoration has already been made compulsory in all coastal regions.

Questions 9–13

Complete the notes below. Choose **NO MORE THAN TWO WORDS** from the text for each answer.

The process and impact of acidification

- When carbon dioxide enters the ocean, it dissolves to form **9**, a compound that releases hydrogen ions.
- These ions then bind with **10**, which reduces the raw material available for calcification.



- As a result, organisms that build hard structures may have to spend more energy, and in some species shells can become thinner or more **11**
- To track these changes reliably, scientists combine pH measurements with data on **12**
- In some local mitigation efforts, restoring seagrass **13** may help increase CO₂ uptake.

Answer Key

1. iii
2. v
3. i
4. ii
5. TRUE
6. TRUE
7. FALSE
8. NOT GIVEN
9. carbonic acid
10. carbonate ions
11. brittle
12. total alkalinity
13. meadows