Investigating Ocean Acidification

BIOLOGICAL SCIENCES — CHEMICAL SCIENCES — EARTH SCIENCES

QGC | FUTUREMAKERS | QUEENSLAND MUSEUM NETWORK Queensland Government

Introduction

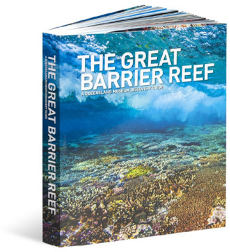
Coral reefs are iconic Queensland ecosystems, extending along nearly the entire coastline and out into the Coral Sea. The Great Barrier Reef is the largest coral reef ecosystem in the world and the largest structure ever built by living organisms. It is considered to be one of the most biodiverse marine habitats in the world. Estimates suggest that over 1500 fish species, 360 reef-building corals, 10,000 molluscs, 1500 sponge species, and numerous other marine species call the Great Barrier Reef home.

Queensland Museum has been an authority on the investigation, documentation and conservation of Queensland's biodiversity for over 150 years. This includes the study of our marine environment. Queensland Museum scientists have played a role in discovering more than 4000 new species since 1862! Queensland Museum's Biodiversity Collection grows as we increase our inventory and understanding of Queensland's natural resources. This research continues today, and we still have a great deal more to learn.

Resources

This resource can be used individually, or following the Queensland Museum resource *Introduction to Ocean Acidification.*

Other relevant resources include: The Queensland Museum Network *Field Guide to Queensland Fauna app* and *The Great Barrier Reef: A Queensland Museum Discovery Guide.*
The apps are free to download, while the book can be purchased from the Queensland Museum shop in-store or online.



The marine environment is on display in the *Wild State exhibition* at Queensland Museum, South Brisbane, and in *Colour - Secret Language of the Reef* at the Museum of Tropical Queensland, Townsville.

To learn what it is like to work on the Great Barrier Reef at the cutting edge of marine science, you can watch a short video of Dr Paul Muir as he explains what he loves about his job as a marine biologist with Queensland Museum.

Future Makers is an innovative partnership between Queensland Museum Network and Shell's QGC project aiming to increase awareness and understanding of the value of science, technology, engineering and maths (STEM) education and skills in Queensland.

This partnership aims to engage and inspire people with the wonder of science, and increase the participation and performance of students in STEM-related subjects and careers — creating a highly capable workforce for the future.

Activity Overview
Introduction to Ocean Acidification

Many marine organisms have shells or exoskeletons made of calcium carbonate ($CaCO_3$), including oysters, clams, sea snails and coral. In this activity you will investigate how ocean acidification may affect these organisms. Using the materials provided, you will develop and conduct an experiment to test the effect of carbonated water (water with high levels of dissolved carbon dioxide (CO_2)) on calcium carbonate. You will then analyse the results in a scientific report.

TEACHER TIPS

- Arrange students in groups of 3 – 4 to promote collaborative learning and communication.
- Use guiding questions when necessary, and include peer learning and feedback (for example, class discussions).
- It would be beneficial to discuss similarities and differences between this experiment and the natural process of ocean acidification.
- This investigation may be scaffolded to better fit with the year 10 curriculum by modifying the research question to investigate rates of reaction at different temperatures or pH. Students could also explore the effect of surface area by using different sized calcium carbonate chips.

Australian Curriculum Links

YEAR 9

Science Understanding

Ecosystems consist of communities of interdependent organisms and abiotic components of the environment; matter and energy flow through these systems *(ACSSU176)*

Chemical reactions involve rearranging atoms to form new substances; during a chemical reaction mass is not created or destroyed *(ACSSU178)*

Chemical reactions, including combustion and the reactions of acids, are important in both non-living and living systems and involve energy transfer *(ACSSU179)*

Science Inquiry Skills

Formulate questions or hypotheses that can be investigated scientifically *(ACSIS164)*

Plan, select and use appropriate investigation types, including field work and laboratory experimentation, to collect reliable data; assess risk and address ethical issues associated with these methods *(ACSIS165)*

Select and use appropriate equipment, including digital technologies, to collect and record data systematically and accurately *(ACSIS166)*

Analyse patterns and trends in data, including describing relationships between variables and identifying inconsistencies *(ACSIS169)*

Use knowledge of scientific concepts to draw conclusions that are consistent with evidence *(ACSIS170)*

Evaluate conclusions, including identifying sources of uncertainty and possible alternative explanations, and describe specific ways to improve the quality of the data *(ACSIS171)*

Critically analyse the validity of information in primary and secondary sources and evaluate the approaches used to solve problems *(ACSIS172)*

Communicate scientific ideas and information for a particular purpose, including constructing evidence-based arguments and using appropriate scientific language, conventions and representations *(ACSIS174)*

YEAR 10

Science Understanding

Global systems, including the carbon cycle, rely on interactions involving the biosphere, lithosphere, hydrosphere and atmosphere *(ACSSU189)*

Different types of chemical reactions are used to produce a range of products and can occur at different rates *(ACSSU187)*

Science Inquiry Skills

Formulate questions or hypotheses that can be investigated scientifically *(ACSIS198)*

Plan, select and use appropriate investigation types, including field work and laboratory experimentation, to collect reliable data; assess risk and address ethical issues associated with these methods *(ACSIS199)*

Select and use appropriate equipment, including digital technologies, to collect and record data systematically and accurately *(ACSIS200)*

Analyse patterns and trends in data, including describing relationships between variables and identifying inconsistencies *(ACSIS203)*

Use knowledge of scientific concepts to draw conclusions that are consistent with evidence *(ACSIS204)*

Evaluate conclusions, including identifying sources of uncertainty and possible alternative explanations, and describe specific ways to improve the quality of the data *(ACSIS205)*

Critically analyse the validity of information in primary and secondary sources and evaluate the approaches used to solve problems *(ACSIS206)*

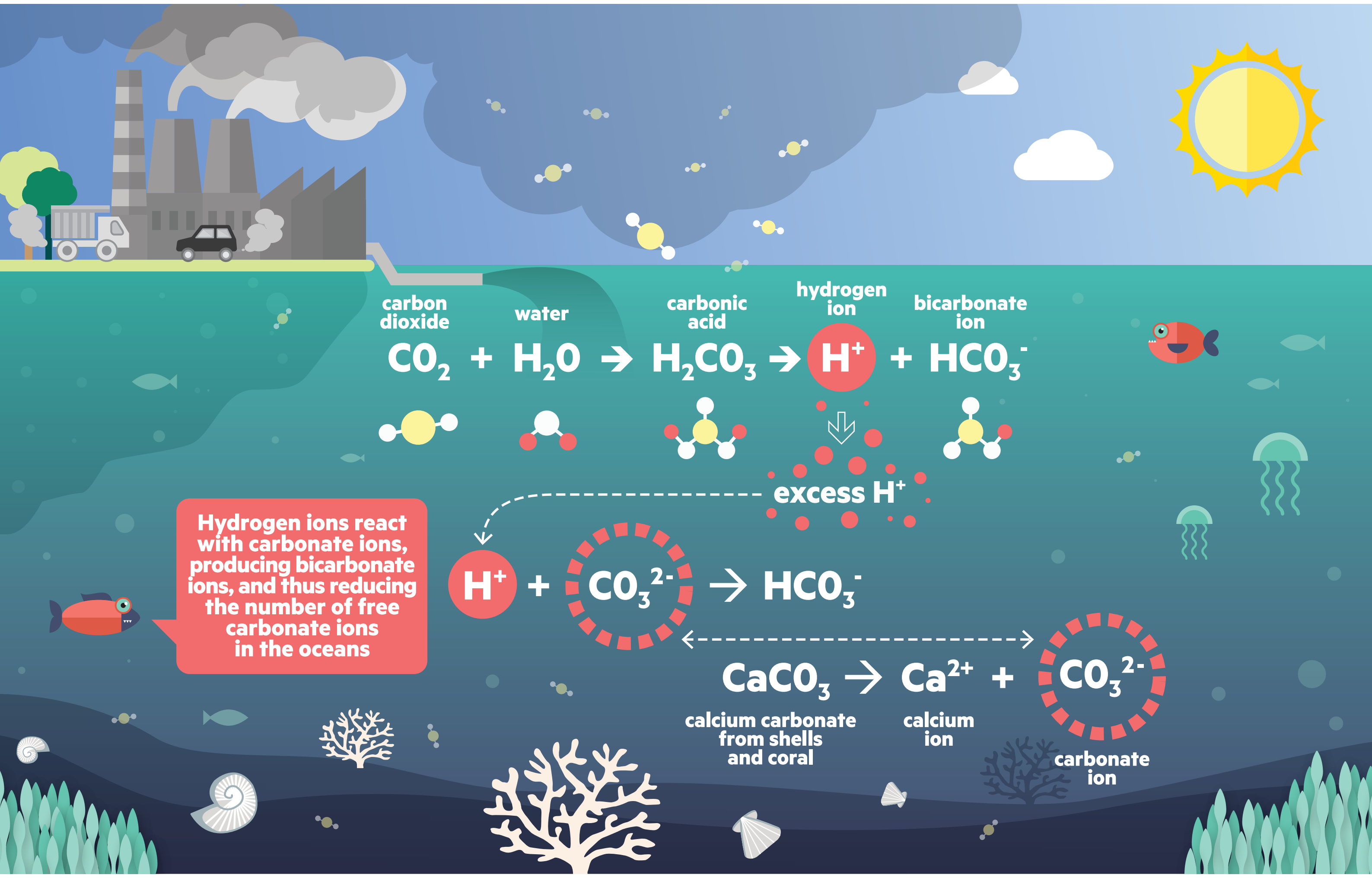
Communicate scientific ideas and information for a particular purpose, including constructing evidence-based arguments and using appropriate scientific language, conventions and representations *(ACSIS208)*

Ocean Acidification

Pure water is neither acidic nor alkaline, as it has a neutral pH of 7.0. However, as seawater contains many dissolved substances such as salts, it is slightly alkaline, with a pH of approximately 8.1[1].

Carbon dioxide occurs naturally in the atmosphere; however, since the industrial revolution the amount of carbon dioxide in the atmosphere has increased exponentially, predominately due to anthropogenic (human) sources. Today the carbon dioxide (CO_2) levels in the atmosphere are higher than they have been in at least the last 740,000 years, and possibly 20 million years[2]. The continuing increase of carbon dioxide in the atmosphere means that more carbon dioxide is being dissolved into the oceans. Already, the ocean surface pH is 0.1 units below pre-industrial values, and it is predicted that by the end of this century the pH will have dropped by another 0.3 - 0.4[3]. This translates to a 100-150% increase in hydrogen ion concentration [H^+], and thus a 100-150% increase in acidity[4].

Carbon dioxide (CO_2) combines with water (H_2O) in the oceans to produce carbonic acid (H_2CO_3). In water, carbonic acid (H_2CO_3) disassociates to form bicarbonate ions (HCO_3^-) and hydrogen ions (H^+). The presence of more hydrogen ions makes seawater more acidic. The additional hydrogen ions react with the free carbonate ions (CO_3^{2-}), resulting in an increase in bicarbonate ions, and a decrease in free carbonate ions. Carbonate ions occur naturally in sea water and are used by many marine organisms to build shells. The decrease in free carbonate ions reduces the ability of marine organisms to build calcium carbonate shells and skeletons[4].



Although scientists do not believe the pH of sea water will drop below 7.0, research suggests that even the decrease in pH of 0.3 – 0.4 may have a negative impact on marine organisms with calcium carbonate shells, such as bivalves (e.g. oysters, clams, mussels), and gastropod molluscs (e.g. sea snails), particularly in the larval stages[5]. Likewise, organisms with calcium carbonate skeletons (such as coral) may have difficulty reproducing, and may become more brittle and prone to damage[2].

Additionally, most researchers agree that slight increases in pH may have serious impacts on the marine producers and primary consumers that rely on calcium carbonate exoskeletons[3]. For example, slight increases in acidity predicted to occur within this century may be enough to cause the shells of pteropods to dissolve[4] (cover image). As many food webs depend on organisms like pteropods and calcifying phytoplankton, slight changes in ocean chemistry could potentially disrupt entire food webs.

With billions of people relying on the ocean for food, and many economies depending on the ocean, this could potentially have serious social and economic implications[2]. More research into the potential impacts of ocean acidification on the marine environment is required.

Figure 2: To learn what it is like to work on the Great Barrier Reef at the cutting edge of marine science, you can watch a short video of Dr Paul Muir as he explains the coral reef ecosystem and what he loves about his job as a marine biologist with the Queensland Museum.

Activity 1
Investigating the effect of ocean acidity on shelled marine organisms

Today you are a scientist working with the Queensland Museum. Your task is to investigate the effect of ocean acidity on shelled marine organisms by examining how carbonated water affects their calcium carbonate shells.

Objective

Design and conduct an experiment to investigate the effect of ocean acidity on calcium carbonate. Present the findings as a scientific report.

Materials

- 3 g x calcium carbonate ($CaCO_3$)
- Digital scales
- Carbonated water
- Stopwatch
- 50 mL Measuring cylinder
- Spatula
- Test tubes
- Test tube rack
- Deionised water
- Universal indicator or pH probe

SAFETY FIRST
WEAR SAFETY GOGGLES
AND COVERED SHOES

Questions

1. **Design an experiment to answer the research question 'How does a carbonic acid solution affect calcium carbonate?'**
2. **Write a scientific report.**
   Use the scaffold on page 9 for guidance. The report should be written in third person, past tense.

Structure of a Scientific Report

1. **Aim:** To investigate the effect of a carbonic acid solution on calcium carbonate.
2. **Introduction:** Give background information on the topic being investigated, and explain the purpose of the experiment and how it will be conducted.
3. **Hypothesis:** Write an educated prediction as to the outcome of the experiment. This must incorporate the independent variable and the dependent variable. Remember to justify the hypothesis by giving reasons for why the particular prediction was made.
4. **Variables:** Include an independent variable (variable that is purposely changed), a dependent variable (variable that is measured), and at least five control variables (variables that are kept the same for a fair experiment).
5. **Materials:** List all equipment used in the experiment, include number and amounts. E.g. 4 x 250 ml beakers.
6. **Method/ Procedure:** List the steps taken to conduct the experiment. Remember, there should be enough detail for someone else to pick up the method and conduct the exact same experiment, and the method should be written in past tense.
7. **Risk Assessment:** What safety considerations must be made before, during and after this experiment? Include AT LEAST five hazards and how to minimise them.
8. **Results:** Include both qualitative observations and quantitative data. Record the results in a table. Use Microsoft Excel to graph the results, and briefly summarise the observations in a paragraph.
9. **Discussion:** Analysis of results and experimental design.
   - ☐ Describe what the results found. Include data in the analysis.
   - ☐ Explain if the results support or do not support (refute) the hypothesis.
   - ☐ How do the results compare with the information in the introduction?
   - ☐ Give possible reasons for why the results occurred. Include background knowledge, and an explanation for any inconsistent or unexpected results.
   - ☐ What problems were encountered and how could these be overcome in future investigations?
   - ☐ **Evaluate** the experiment and results:
     - — Were the results **fair?** (Were all the control variables kept the same throughout the experiment?)
     - — Were the results **reliable?** (Has the experiment been repeated many times with similar results?)
     - — Were the results **accurate?** (Were the measurements precise?)
   - ☐ Suggest how the experiment could be **improved** in the future.
   - ☐ Explain future experiments that would be useful for collecting further information, and answering unknown questions.
   - ☐ Where is this experiment useful or important to real life?
10. **Conclusion:** Summarise the experiment and the results. Was the hypothesis supported or refuted?
11. **References:** List all sources in a consistent format and include in-text referencing in the introduction and discussion.

References

[1] National Oceanic and Atmospheric Adminstration (NOAA). (2017). *Ocean Acidification: Surface pH.* Retrieved from: https://sos.noaa.gov/datasets/ocean-acidification-surface-ph/

[2] Hoegh-Guldberg, O., Mumby, P., Hooten, A., Steneck, R., Greenfield, P., Gomez, E., ... Hatziolos, M. (2007). Coral Reefs Under Rapid Climate Change and Ocean Acidification. *Science,* 318(5857), 1737-1742. http://dx.doi.org/10.1126/science.1152509

[3] Manno, C., Bednaršek, N., Tarling, G., Peck, V., Comeau, S., Adhikari, D., ... Ziveri, P. (2017). Shelled pteropods in peril: Assessing vulnerability in a high CO_2 ocean. *Earth-Science Reviews*, 169, 132-145. http://dx.doi.org/10.1016/j.earscirev.2017.04.005

[4] Orr, J., Fabry, V., Aumont, O., Bopp, L., Doney, S., Feely, R., ... Yool, A. (2005). Anthropogenic ocean acidification over the twenty-first century and its impact on calcifying organisms. *Nature*, 437(7059), 681-686. http://dx.doi.org/10.1038/nature04095

[5] Gazeau, F., Parker, L., Comeau, S., Gattuso, J., O'Connor, W., Martin, S., ... Ross, P. (2013). Impacts of ocean acidification on marine shelled molluscs. *Marine Biology*, 160(8), 2207-2245. http://dx.doi.org/10.1007/s00227-013-2219-3