Does carbon dioxide affect the pH of seawater and the strength of shells?

Objective

In this practical, students are investigating the effect of carbon dioxide (CO_2) on the ocean. In the first experiment, they observe the effect of increasing the concentration of CO_2 on the acidity of seawater. In the second experiment, they are investigating the effect of acidity on the shells of sea creatures.

Introducing the experiment

Write the words ACID and ALKALI on the board and invite students to work in pairs to list as many facts and examples as they can related to acids and alkalis.

Introduce ocean acidification by showing students the video *What is Ocean Acidification?* from the University of Plymouth: https://youtu.be/L2bxwnm7JG4 (less than 2 minutes).

During the experiment

Discuss with the students the difference in ease and accuracy of using a pH meter compared with UI solution. You may also decide to try UI paper or even litmus paper to demonstrate the effectiveness of certain indicators. Students are unlikely to see any changes with litmus paper.

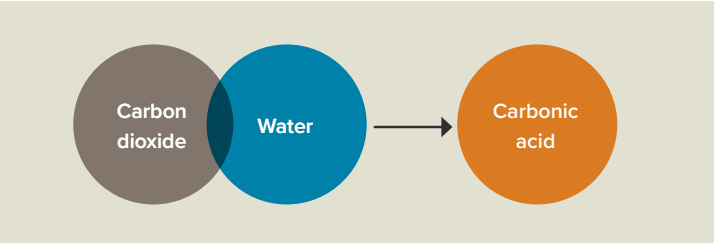
This is an activity that easily lends itself to having students design their own experiment if time allows.

Discussion points after the experiment

Ask students to prepare an 'elevator pitch' – give them one minute to explain what ocean acidification is and what the results of their experiment showed. Some students may want to prepare an elevator pitch on the limitations of the experiment.

The science behind this experiment

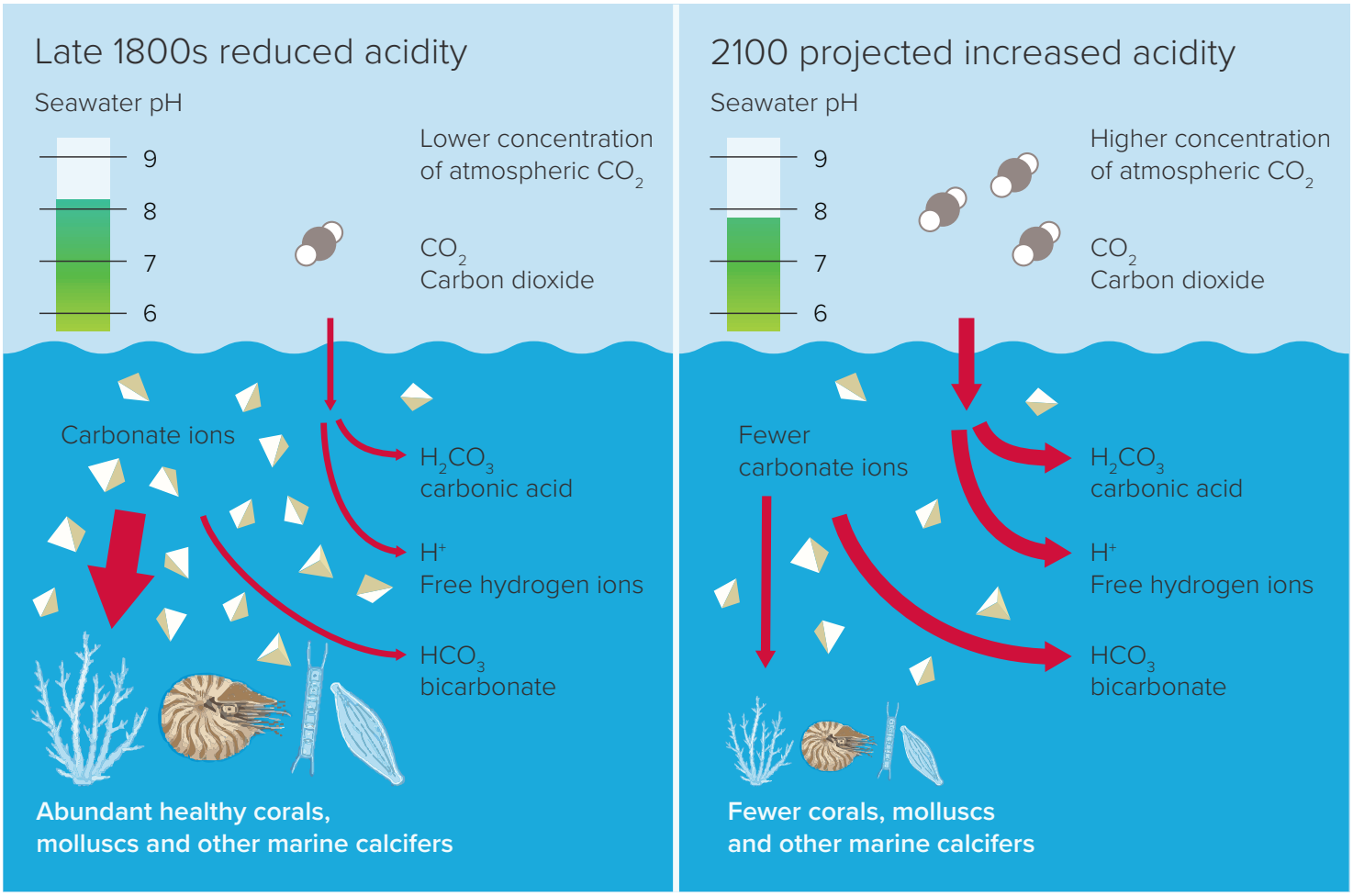
The ocean absorbs some of the CO_2 we emit as part of the carbon cycle. CO_2 dissolves in sea water to form carbonic acid, which lowers the pH of the water making it more acidic.



As the amount of CO_2 in the atmosphere increases it is likely that more CO_2 will dissolve in sea water making it more acidic.

The point of the lesson is to think about the rise in CO_2 levels due to human effects – ie more fossil fuel use. More CO_2 in the environment leads to more CO_2 dissolving in the water, ultimately making the sea more acidic.

Many of the plants and animals living in the oceans have skeletons or shells made out of calcium carbonate. Some species are very sensitive to changes in acidity. As ocean acidity increases, their shells and skeletons may start to dissolve, affecting their ability to build and repair their shells. This could ultimately affect the survival of some species. Physiological processes within organisms, for example growth and reproduction, are also sensitive to changes in pH. Microscopic plankton at the bottom of the food chain, shellfish and molluscs, and plants that cement the coral reefs together may all be affected, with wider implications for the marine food web, habitats, and the food security of many human populations.



Note: it is important to understand that the sea is not becoming an acid but the pH is moving towards the acidic scale. The sea will still be slightly alkaline. During the pre-industrial era, the average pH of the world's oceans was thought to be around 8.2. This has declined in recent years and it is thought that the pH could drop below 8 by the end of the century. It is a very small shift in pH value but some sea creatures are hugely sensitive to minute changes in pH.

FURTHER LINKS

- What is ocean acidification and why does it matter?
- *Ocean Acidification Research; an overview by Dr Helen Findlay*
- *Ocean Acidification: Connecting science, industry, policy and public*

For more school experiments and to access the accompanying videos, visit **royalsociety.org/schoolexperiments**

THANKS

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Experiment 1: Investigating the effect of carbon dioxide on the pH of water

Your task is to investigate how carbon dioxide (CO_2) can affect the pH of seawater. This will give you an idea of whether increasing CO_2 emissions are likely to result in ocean acidification.

Method

1. The concentration of salt in seawater is approximately 3.5% (or 35,000 ppm), which equates to 35 grams per litre. Use tap water and the measuring jug to make 500 cm^3 (half a litre) of seawater. (Tip: 1 level tablespoon of salt is approximately 18 grams).

   I added _____ tablespoons of salt to _____ cm^3 of water.

   (Step 1 may already have been done by the science technician)
2. Fill the two beakers with seawater (leave 1 – 2 cm space between the water and the lid) and save the rest for experiment 2.
3. Use the pH meter or Universal Indicator solution to record the pH of the water in the first beaker. Write this value into the first column of Table one.
4. Choose one person from your group who will do the task. Their job is to blow gently through a straw (adding CO_2) into the water for two minutes. Measure the pH of the water every 30 seconds and record your findings in Table one. Don't worry, you are allowed to breathe! Take small breaths when needed.
5. Repeat the experiment but this time cover the cup with a lid and insert the straw into the opening. Record your findings in Table two.
6. Answer the questions overleaf and be prepared to share your findings with the rest of the group.

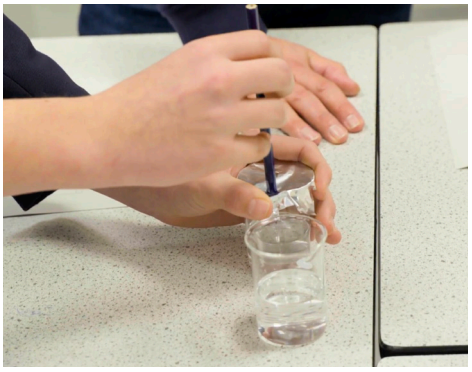
EQUIPMENT LIST

Materials for each group

- Salt
- Water
- 2 cups/beakers
- 1 lid
- 2 straws
- pH meter or Universal Indicator solution
- Measuring jug
- Tablespoon
- Stopwatch
- Where might we get a reliable and free source of CO_2?

SAFETY PRECAUTIONS

- Make sure to blow through the straw and to not suck the water up.
- Make sure to clean up any spills immediately and to keep the water well away from any electrical devices.
- If you break any glassware, make sure to tell your teacher immediately. Do not try to clean up broken glass yourself.



Results

Table one: results (without lid)					
Time(s)	0	30	60	90	120
pH					

Table two: results (with lid)					
Time(s)	0	30	60	90	120
pH					

Questions

1. **Your breath contains CO_2 gas in it. After blowing through the straw into the samples, describe what happened to the pH of the water.**

2. **Using your knowledge of ocean acidification, can you explain what happened here?**

3. **Was there any difference in the pH change of the two samples of water, one without a lid and one with? Why do you think this was?**

4. **What have you learnt about the process of ocean acidification from this experiment?**

5. **What do you think are the limitations of this experiment?**

6. **How could this experiment be improved?**

Experiment 2: Investigating the effect of acidity on the shells of sea creatures

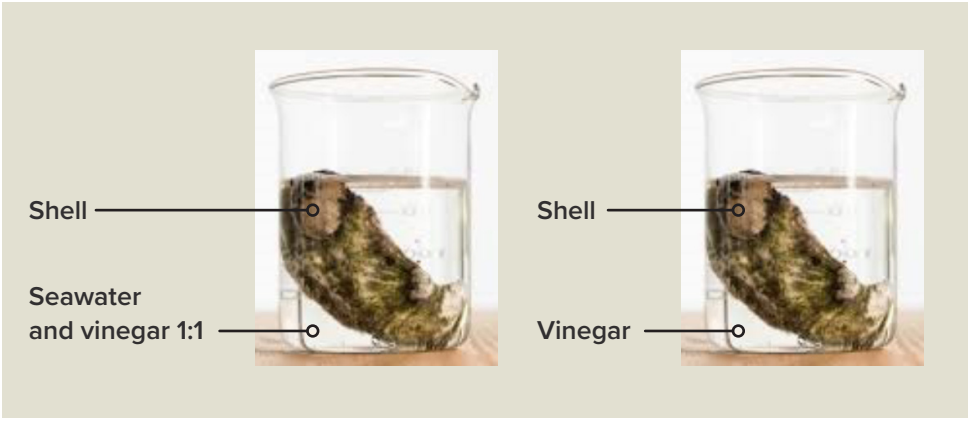
Your task is to investigate how increased acidity in seawater can affect the calcium carbonate shells of sea creatures. This will give you an idea of the possible implications of ocean acidification for marine organisms and ecosystems.

Instructions

There are two parts to this experiment, the first looks at what happens to a calcium carbonate shell when it is placed in an acidic liquid. The second compares the strength of two shells, one of which has been soaked in vinegar (a strong acid) for two days.

Part one – method

1. If you have seawater left over from the first experiment, you can use it or you can make some more following the instructions on page 1. Fill one of the beakers half-way with seawater (Hint: measure the approximate volume first so you know how much vinegar to add).
2. Now add the same quantity of vinegar to your beaker so that you have a ratio of 1:1 water and vinegar.
3. In the other beaker, pour a measure of vinegar on its own.
4. Place one unsoaked shell in each beaker and start the stopwatch. Observe what happens and record it in Table one (page 4).



EQUIPMENT LIST

Materials for each group

- Salt
- Water
- Vinegar
- 2 cups/beakers
- Measuring jug
- Tablespoon
- 1 soaked shell
- 3 unsoaked shells
- Stopwatch
- 1 kg masses plus cardboard guide

SAFETY PRECAUTIONS

- Make sure to clean up any spills immediately and to keep the water well away from any electrical devices.
- Make sure the masses are well away from the edge of the table.
- If you break any glassware, make sure to tell your teacher immediately. Do not try to clean up broken glass yourself.

Part one – results

Table one	
Shell one: seawater/vinegar solution	
Time	Observation
Shell two: pure vinegar	
Time	Observation

Part two – method

Take two shells, one that has been soaked in vinegar solution for two days and one that has not. Compare the difference between the two shells visually and write your observations in Table two below.

1. Place the shells in the cardboard guide tube and carefully place 1kg masses on the top of each shell, one at a time and wait 10 seconds before placing the next. Record what happens in Table two.
2. Answer the questions on this part of the experiment and be prepared to share your findings with the rest of the group.

WARNING: Make sure you are not set up by the edge of the table and be careful of trapping fingers.

Cardboard guide

Shell

1kg mass

Part two – results

Table two	
Shell one: seawater/vinegar solution	
Time	Observation
Shell two: pure vinegar	
Time	Observation

Questions

1. **What happened when you placed the shells in vinegar/ vinegar solution?**

2. **Why do you think you were asked to do both?**

3. **You may have seen some bubbles generated around the shells. What do you think these bubbles were composed of?**

4. **What happened to the shell that had been soaked in vinegar for two days?**

5. **What have you learnt from this experiment about the effect of ocean acidification on sea creatures?**

6. **What do you think are the limitations of this experiment?**

7. **How could this experiment be improved?**

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Background

Many of the plants and animals living in the oceans have skeletons or shells made out of calcium carbonate. Some species are very sensitive to changes in acidity. As ocean acidity increases, their shells and skeletons may start to dissolve, affecting their ability to build and repair their shells. This could ultimately affect the survival of some species. Physiological processes within organisms, for example growth and reproduction, are also sensitive to changes in pH. Microscopic plankton at the bottom of the food chain, shellfish and molluscs, and plants that cement the coral reefs together may all be affected, with wider implications for the marine food web, habitats, and the food security of many human populations.

Preparation notes

If you are unable to collect seawater for the experiments, a similar concentration can be mixed using tap water and salt. The concentration of salt in seawater is approximately 3.5% or 35,000 ppm, which equates to 35g per litre. One level tablespoon of salt is approximately 18g. You can either mix the water in advance or have the students to do it as part of the experiment.

Something that will need to be done in advance is the soaking of sea shells in vinegar solution for the second part of experiment 2 to investigate the effect of water acidity on the shells of sea creatures. This can either be done by the teacher/technician or by the students in a previous lesson. Shells can be soaked in pure white vinegar, a 50:50 mix of vinegar and water, or a mixture which recreates the possible pH of seawater affected by ocean acidification (between pH 7.0 and 7.5).

Ideally, thin sea shells such as slipper limpets or mussels would be used, as these have the potential to show the greatest effect. Alternatively, egg shells can be used. They should be soaked for between 24 and 48 hours.

EQUIPMENT LIST

Materials for each group

- Sea water or water and salt (enough to fill two cups/beakers for experiment 1, and half a cup/beaker for experiment 2).
- Universal Indicator solution or pH meter.
- 3 Sea shells or egg shells.
- 1 Sea shell or egg shell that has been soaked in vinegar solution for 48 hours.
- 2 cups or beakers.
- 1 lid for the cup/beaker with a hole for the straw.
- 2 straws.
- White vinegar (enough to fill one and a half cups/beakers).
- Stopwatch.
- Measuring jug.
- Tablespoon.
- 100g masses or heavy books.
- Pieces of cardboard for experiment 2b.

SAFETY PRECAUTIONS

- CLEAPSS recommends eye protection for all but the most dilute acids; household vinegar has a concentration of about 0.8M ethanoic acid and may still cause harm in the eyes or in a cut, so safety glasses should be worn.
- There should be plenty of paper towels for students to clean up any spills and a glassware disposal kit should be available in the classroom if glass equipment is being used.
- Students should take care with the masses to ensure they don't fall onto their feet.

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