



## The pH scale and the chemistry of ocean acidification – teacher notes

### **Education in Chemistry**

Sustainability in chemistry 2021

Goal 14: conserve and sustainably use the oceans, seas and marine resources

[rsc.li/3lkmoW3](https://rsc.li/3lkmoW3)

### **Ocean acidification provides a useful and engaging context to explore the pH scale and other chemistry topics.**

Use the questions in the worksheet to check or aid understanding during the lesson, or as a homework task to consolidate knowledge.

Question 4 gives learners an opportunity to apply their knowledge and practise a longer-answer question. A structure strip to support this question is provided on page 4. Structure strips give scaffolded prompts and help overcome 'fear of the blank page'. Learners stick the strip into the margin of their exercise book, or a sheet of A4 paper, and write alongside it. Read more at [rsc.li/2P0JDIW](https://rsc.li/2P0JDIW).

The extension questions provide further challenge for learners within the topic. Question 7c asks learners to consider equilibrium and they may need a prompt to think about Le Chatelier's principle if attempting this question.

Question 9 asks learners to undertake further research and present their findings as a poster or infographic, you could suggest alternative formats for this. You could also give learners more of a scaffold, eg:

- Choose a sea creature that will be affected by ocean acidification.
- State why that creature is affected.
- Identify what might happen to other creatures, either who eat this organism or who are eaten by it.
- Use the information on carbonic acid in this worksheet to help you include the chemistry.

The references below contain a wealth of information, in an accessible form for learners and you may wish to give these, either as a starting point or for sole use in this piece of work.

- [National Institute of Water and Atmospheric Research, New Zealand](#)
- [Smithsonian Museum, USA](#)
- [Compound Chemistry: ocean acidification infographic](#)

### **Answers**

1. We talk about 'ocean acidification' because the pH of the oceans is decreasing, but seawater is actually an alkaline solution.

Match each pH change of a solution with the correct description of the change.

*1d, 2b, 3a, 4c*

2. The pH of a solution is measured on a logarithmic scale, so each change in a unit of pH means the acidity or alkalinity has changed by a magnitude of 10.

For example, a solution with a *pH of 1* is 10 times as acidic as a solution with a *pH of 2*. A solution with a *pH of 8* is 10 times less alkaline than a solution with a *pH of 9*.

Match the sentence stems and endings to create a correct description of the relationship between pH values.

*1b, 2c, 3a, 4d*

3. A solution with a pH of 9 is 100 times more alkaline than a solution with a pH of 7. A solution with a pH of 2 will be 100 times more acidic than a solution with a pH of 4.

a. How much more acidic would a solution with a pH of 3 be than a solution with a pH of 5?

*100 times more acidic*

b. How much more acidic would a solution with a pH of 2 be than a solution with a pH of 5?

*1000 times more acidic*

4. Ocean pH has dropped from 8.2 to 8.1 since the industrial revolution. If we continue to add carbon dioxide at current rates, seawater pH may drop to 7.8 or 7.7 by the end of this century, creating an ocean more acidic than any seen for the past 20 million years or more.

Many people think the oceans are acidic, because we talk about 'ocean acidification', and they may also believe that a change from pH 8.2 to pH 7.7 is only a small change.

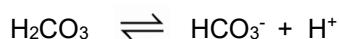
Help them to understand more about the oceans, and correct some of their incorrect ideas, using ideas about acidity and pH.

*Answers will vary, key points for each section of the structure strip are given below.*

Explain whether the oceans are acidic or alkaline and describe how this relates to their pH value.	<i>Seawater is alkaline  pH &gt; 7</i>
Is a solution with pH 8.2 acidic or alkaline?	<i>Alkaline</i>
How would you describe a change from pH 8.2 to 8.1? Is it becoming more, or less, acidic?	<i>More acidic</i>
Outline the connection between carbon dioxide and ocean pH.	<i>Carbon dioxide dissolves in seawater and reacts to form carbonic acid. This lowers the pH.</i>
State the link between ocean pH, carbon dioxide and human activity.	<i>Human activity increases the amount of carbon dioxide released into the atmosphere. This dissolves into the oceans and lowers the pH. This has increased significantly since the industrial revolution.</i>
Suggest why ocean pH might drop more by the end of this century than it has in the past 20 million years.	<i>The industrial revolution led to an increase in the amount of carbon dioxide produced via human activity, which has a knock-on effect on ocean pH.</i>
How does the acidity change with each decrease in a unit of pH?	<i>Acidity increases by a factor of 10 for each decrease in unit of pH.</i>
Outline how the magnitude of the acidity changes when the pH decreases from 8 to 7.	<i>Acidity increases by a factor of 10.</i>

## Green chemistry extension questions

5. Carbonic acid is a weak acid. It dissociates into a hydrocarbonate ion and a hydrogen ion. Use your knowledge of acids and the equation shown below, to explain why carbonic acid is weak.



*The  $\text{H}_2\text{CO}_3$  does not dissociate or ionise very much and therefore there is only a low concentration of  $\text{H}^+$ .*

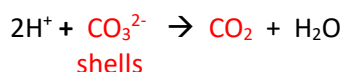
6. a. Carbon dioxide reacts with seawater to form carbonic acid. Write a word and symbol equation to show this.

*Carbon dioxide + water  $\rightarrow$  carbonic acid*



b. Shells of sea creatures, including corals, are often made from calcium carbonate ( $\text{CaCO}_3$ ), which contains carbonate ions. The hydrogen ions ( $\text{H}^+$ ) released in the reaction in question 5 will react with carbonate ions ( $\text{CO}_3^{2-}$ ) dissolving the shells of these organisms releasing more carbon dioxide.

Complete the equation below to show how shells could dissolve as the ocean becomes more acidic. Indicate which ion represents the shells.



c. Using the equation from question 5 ( $\text{H}_2\text{CO}_3 \rightleftharpoons \text{HCO}_3^- + \text{H}^+$ ), state and explain what happens to the equilibrium position when the  $\text{H}^+$  ions react with shells and are 'removed' from the equilibrium system.

*The equilibrium will shift toward the right (or in the forward direction) in order to increase the concentration of  $\text{H}^+$ .*

7. Fish without shells are also affected by carbonic acid in seawater. It changes the pH of their blood, and they use energy to excrete the excess acid. This makes it more difficult to do other things, such as escaping predators, catching food or reproducing. You have already learnt about the effect on organisms that use calcium carbonate.

Produce an infographic or poster explaining some of the consequences of ocean acidification on marine organisms. Make your poster concise, focussing on the key points and the chemistry behind each point.

*A variety of resources could be found. A selection of what learners might write about:*

- dissolving of coral reefs*
- dissolving a variety of plankton relying on  $\text{CaCO}_3$  as an integral part of their structure*
- dissolving of sea organisms shells*
- the change in hydrocarbonate blood buffering systems of various organisms and the subsequent extra energy needed to react to the change*
- the effects on animal chemical signalling*
- the knock on effect on the food chain (especially if plankton species are being removed)*

Ocean acidification Structure strip	Ocean acidification Structure strip	Ocean acidification Structure strip	Ocean acidification Structure strip	Ocean acidification Structure strip
Explain whether the oceans are acidic or alkaline and describe how this relates to their pH value.	Explain whether the oceans are acidic or alkaline and describe how this relates to their pH value.	Explain whether the oceans are acidic or alkaline and describe how this relates to their pH value.	Explain whether the oceans are acidic or alkaline and describe how this relates to their pH value.	Explain whether the oceans are acidic or alkaline and describe how this relates to their pH value.
Is a solution with pH 8.2 acidic or alkaline?	Is a solution with pH 8.2 acidic or alkaline?	Is a solution with pH 8.2 acidic or alkaline?	Is a solution with pH 8.2 acidic or alkaline?	Is a solution with pH 8.2 acidic or alkaline?
How would you describe a change from pH 8.2 to 8.1? Is it becoming more, or less, acidic?	How would you describe a change from pH 8.2 to 8.1? Is it becoming more, or less, acidic?	How would you describe a change from pH 8.2 to 8.1? Is it becoming more, or less, acidic?	How would you describe a change from pH 8.2 to 8.1? Is it becoming more, or less, acidic?	How would you describe a change from pH 8.2 to 8.1? Is it becoming more, or less, acidic?
Outline the connection between carbon dioxide and ocean pH.	Outline the connection between carbon dioxide and ocean pH.	Outline the connection between carbon dioxide and ocean pH.	Outline the connection between carbon dioxide and ocean pH.	Outline the connection between carbon dioxide and ocean pH.
State the link between ocean pH, carbon dioxide and human activity.	State the link between ocean pH, carbon dioxide and human activity.	State the link between ocean pH, carbon dioxide and human activity.	State the link between ocean pH, carbon dioxide and human activity.	State the link between ocean pH, carbon dioxide and human activity.
Suggest why ocean pH might drop more by the end of this century than it has in the past 20 million years.	Suggest why ocean pH might drop more by the end of this century than it has in the past 20 million years.	Suggest why ocean pH might drop more by the end of this century than it has in the past 20 million years.	Suggest why ocean pH might drop more by the end of this century than it has in the past 20 million years.	Suggest why ocean pH might drop more by the end of this century than it has in the past 20 million years.
How does the acidity change with each decrease in a unit of pH?	How does the acidity change with each decrease in a unit of pH?	How does the acidity change with each decrease in a unit of pH?	How does the acidity change with each decrease in a unit of pH?	How does the acidity change with each decrease in a unit of pH?
Outline how the magnitude of the acidity changes when the pH decreases from 8 to 7.	Outline how the magnitude of the acidity changes when the pH decreases from 8 to 7.	Outline how the magnitude of the acidity changes when the pH decreases from 8 to 7.	Outline how the magnitude of the acidity changes when the pH decreases from 8 to 7.	Outline how the magnitude of the acidity changes when the pH decreases from 8 to 7.