These resources have been produced based on workshops developed and run by GeoBus in schools and are designed to support the teaching of Earth Science topics. You are free to use, modify and share materials for educational purposes but we ask that you please retain any image credits or references as appropriate.

If you are interested in sharing your experience of using these materials, we'd be grateful if you'd take the time to give us your thoughts via our resources survey (via the resources section of the website), or directly by email to geobus@st-andrews.ac.uk.

GeoBus has been supported by a range of industry and academic partners (as listed below) and we are grateful for their support in allowing us to develop and deliver materials. Information contained within this material, including any errors, remains the responsibility of the GeoBus team and does not reflect the specific interests or opinions of our supporters.

We are particularly grateful to Shell UK as their continued support has allowed us to adapt these resources in to a format suitable to be made freely available.

GeoBus supporters 2012 - 2018:

Climate Change

These workshop notes are designed for use along with the accompanying slides which contain explanatory images etc.

Year Group: S3 upwards (15+ years)

Length: ~50 minutes (activities can fairly easily be extended or shortened to fit available time)

Set-up Time: 10 minutes (+ freeze ice in advance, + make red-cabbage indicator if required)

Room requirements: A classroom space with desks for pupils, access to water nearby is useful.

Summary: Through a series of practical activities, pupils will learn about the impacts of CO_2 on planet Earth including changing ocean chemistry and circulation, and the effects of ice melting on sea level.

Equipment:

- Glass beakers (or clear plastic cups)
- Straws/tubing to blow through
- pH indicator
- Salt
- Red & blue food colouring
- Large shallow dish
- Hot and cold water
- Jugs
- Shelly limestone
- Vinegar/10% hydrochloric acid
- Balloons
- Lighter
- Tupperware/containers[1]
- Plasticine/gravel
- Ice cubes
- *Optional: Monopoly houses*

[1] For ice-melting experiment so transparent is best, takeaway container type size, 1 per group

Content:

Although most commonly discussed on a global scale, climate change has impacts at a regional and also local level. Adaptation Scotland, a programme funded by the Scottish Government, discuss some of the impacts on Scotland: https://www.adaptationscotland.org.uk/why-adapt/impacts-scotland.

What is the Greenhouse Effect?

Infrared radiation (from the sun) reaches Earth's surface and some is absorbed while some is radiated back to space. Greenhouse gases in the atmosphere (primarily CO_2 + H_2O) trap some of this radiated energy, acting like a layer of blankets to keep the planet warm – without them the average surface temperature would be -18°C (instead of +15°C). *[Geology In A Minute: What is the greenhouse effect?]*

There are three important considerations when it comes to the greenhouse effect and climate change.

1. CO_2 is an important gas for global warming
2. Humans have added CO_2 to the atmosphere
3. As a result, it's getting warmer

Humans have added massively to the levels of CO_2 through the burning of fossil fuels. This rapid increase is occurring too quickly for the climate system to adjust (about 10 times faster than any natural changes) and so the planet is getting warmer, faster. Consequently; ice is melting, sea level is rising, storms are increasing (air pressure changing as a reuslt of warming = more humidity = bigger storms), oceans are more acidic, ocean circulation is changing, weather is wierder.

Climate Change

ICE IS MELTING & SEA LEVEL IS RISING

All across the globe there is evidence of ice melting and glaciers retreating – for example the side by side comparison of Muir glacier in Alaska (1961 and 2004) shown in the powerpoint.

Set up the **Sea Level Rise** classroom activity using plasticine to build islands in tubs that will alternately contain land ice and sea ice to see which has a greater effect on sea level when it melts – detailed notes in *Impacts of Climate Change* resource included at the end of this lesson plan. Note that the experiment can be left while the ice melts so the following activities can be carried out with pupils encouraged to occasionally check on 'sea-level' in the tubs.

Extension: discuss the fact that sea level is also rising because the oceans are warming up, and warm water takes up more space than cold water (for more information, see this NASA activity on thermal expansion: https://sealevel.jpl.nasa.gov/files/archive/activities/ts1pcac2.pdf).

OCEANS ARE MORE ACIDIC

Using beakers of fresh water and salt water with pH indicator, the effect of adding CO_2 on acidity can be investigated by blowing through a straw in to each beaker and timing the pH change – see detailed notes in the *Impacts of Climate Change* **Ocean Acidification** activity, at the end of this lesson plan.

To demonstrate the effects of increasing the acidity of seawater, the extension to this activity uses small pieces of shelly limestone and weak acid (10% hydrochloric acid, or vinegar will also show a similar but less pronounced effect) to show that shelly creatures will be particularly effected as the material they create their shells from – calcium carbonate – dissolves in acid.

OCEAN TEMPERATURE AND CIRCULATION IS CHANGING

Set up the **Heat Capacity** demonstration using balloons to show that water is able to absorb heat more easily than air (a balloon with a small amount of water in the bottom of it takes much longer to pop when a lighter is held underneath it - further notes in the *Impacts of Climate Change* resource included at the end of this lesson plan). It is estimated that Earth's oceans have currently absorbed around 80% of the human created temperature increase!

Place the large shallow dish (roughly 3/4 full of lukewarm water) on a table at the front of the room so that pupils can gather round (the demonstration is best viewed with the dish at eye level so pupils may wish to crouch down. Gently pour cold, blue-coloured, water in one end of the dish at the same time as pouring hot, red-coloured water in at the other end (useful to have a volunteer to help by pouring the cold water). Observe the cold blue water begin to sink towards the bottom of the glass dish, while the warm red water will (hopefully!) spread out in a layer across the top. Eventually, the red water will cool down and start to sink at the other side of the dish.

This interaction between two bodies of water at different temperatures demonstrates the effects of the Gulf Stream, which is responsible for Scotland's temperate climate (compared to other countries at a similar latitude – e.g. Canada).

Expand on the demonstration by encouraging pupils to consider what would happen if the temperature of the waters changed - for an interesting summary on the Gulf Stream and what changing ocean currents could mean for future climates, check out the BBC article (available as a pdf from the GeoBus website) https://www.bbc.co.uk/news/science-environment-44875508.

Climate Change: it's serious

Sea Level Rise

Overview

Activity Description	The influence of melting ice caps on sea-level will be explored and experimentally demonstrated.
Time	40-50 minutes (leave to melt and complete other activities)
Learning Outcomes	• Learn how climate change will impact sea-level • Understand the impact of melting land ice vs sea ice • Explore how different topographies may influence ice-melt
Student Organisation	Groups (discussion)
Materials Needed	Sea Level Rise student worksheet (one per group)
Other resources	Transparent containers (about 20cm x 15cm x 5cm), gravel or plasticine to build land surfaces, coloured white board markers, ice, water, rulers [Optional: monopoly houses, hairdryer, desk lamps] This material was adapted from an Andrill teaching resource, which can be found here: **http://cleanet.org/resources/42700.html**

Background information

The area covered by sea ice in the Arctic Ocean has been shrinking. For many decades, more sea ice has melted away during summers than has reformed during winters. Projections show that the ocean around the North Pole could be ice-free during summer months as early as the year 2030! The ice sheet on Greenland is also shrinking. Over the past 30 years, the total area of the Greenland ice sheet affected by summer melting has grown significantly and one big difference is that the melting ice sheet is land ice, not sea ice.

In the southern hemisphere, Antarctica has both ice sheets on land, with floating ice shelves, and sea ice surrounding it.

Talking Points

How might the melting of this sea ice (representing an area larger than the country of India) affect the rest of the world?

What effect might melting land ice have? For example, the melting of the Greenland ice sheet.

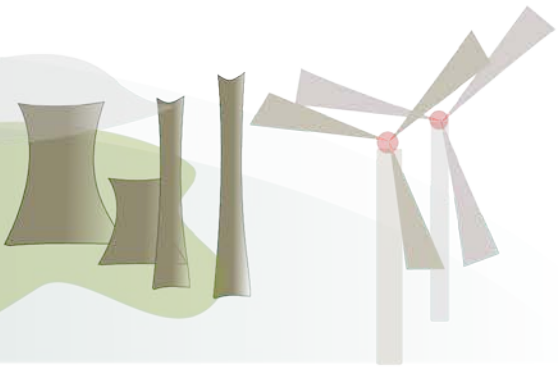
Use this sea level rise video about Greenland (1 min long) to motivate discussion.

https://www.youtube.com/watch?time_continue=106&v=yLm7PSsvW8g

To summarise, use this video, which further explores the impacts of melting ice sheets (6 mins long).

https://www.youtube.com/watch?v=b6CPsGanO_U

Sea Level Rise



Classroom Activity

In this activity, you will make two ice sheet models that are identical except for one factor – one will have ice on "land" and the other will have ice in the "sea".

Compare how melting ice influences the sea level in each model.

What you need:

Transparent containers (about 20cm x 15cm x 5cm – plastic takeaway containers are a good size)

Approximately 2 cups of gravel per container, or a largish ball of plasticine

White board markers (ideally 2 per group)

Ice (roughly a handful per container)

Lukewarm water (cold also works, it just takes longer for the ice to melt!)

Rulers

[Optional: monopoly houses, hairdryer/table lamp to simulate warming conditions]

Method:

1. Label the containers 'land ice' or 'sea ice' – depending on numbers, each person/group can do an example of both (two containers per group), or half of the groups can do 'land ice' and half 'sea ice' (one container per group)
2. Set up the land in each container so that it comes half way up the side of the tub and there is land at both ends with a gap in the middle – either pour in the gravel and make a pile at each end, or warm up the plasticine and use it to build land forms at either end of the container

   [Note: the land surface should be approximately the same height in all containers]
3. In the 'land ice' containers: place ice cubes on to one of the land surfaces

   In the 'sea ice' containers: place the same amount of ice in the middle of the container
4. If you are using houses, place them on a land surface (not one covered by ice!)
5. Pour water in to each container so that it just comes up to the level of the land but doesn't flood over it, and draw a line on the outside of the container to mark the starting water level
6. Measure the water level, making sure it is approximately the same between the land ice and sea ice containers
7. Every 3-5 minutes, record the change in water level and estimate the percentage of ice that has melted

   [Note: to speed up the experiment, simulate rises in global temperature by adding a lamp over the container, or using a hairdryer]
8. After 30 minutes, record the final measurements and mark the new water level using a different coloured marker

Sea Level Rise

Talking Points

When ice that is floating in the ocean melts, sea level does not change. This applies to all floating ice, including sea ice and ice shelves: the floating ice is displacing its own volume already. This is also why melting ice cubes in drinks don't make the drinks spill when they melt.

When ice that is on land melts and runs into the sea, additional water is being added to the ocean, so sea level rises. This means that the melting of land ice will have a much bigger impact on rising global sea levels. It is estimated that if the whole of the Greenland ice sheet melted, sea level would rise by approximately 7m, flooding coastlines around the world.

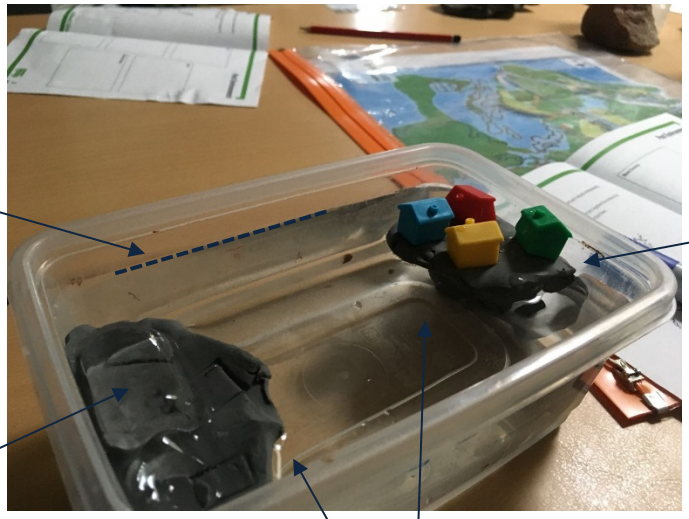
You can explore recent changes in ice cover in Greenland and Antarctica using interactive images at:

http://climate.nasa.gov/interactives/global-ice-viewer/#/

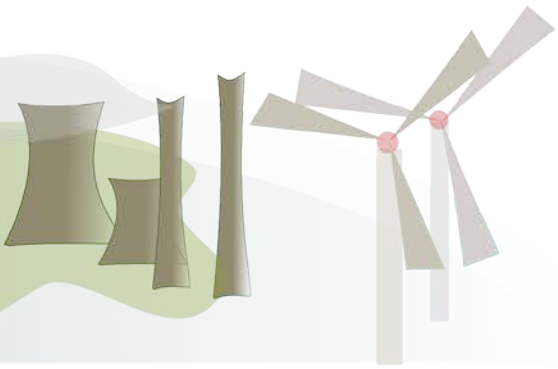
You can also see the projected influence of different amounts of sea level rise on countries around the world using this map viewer.

http://geology.com/sea-level-rise/

Example of land ice experiment set-up:



Sea Level Rise
Student Worksheet



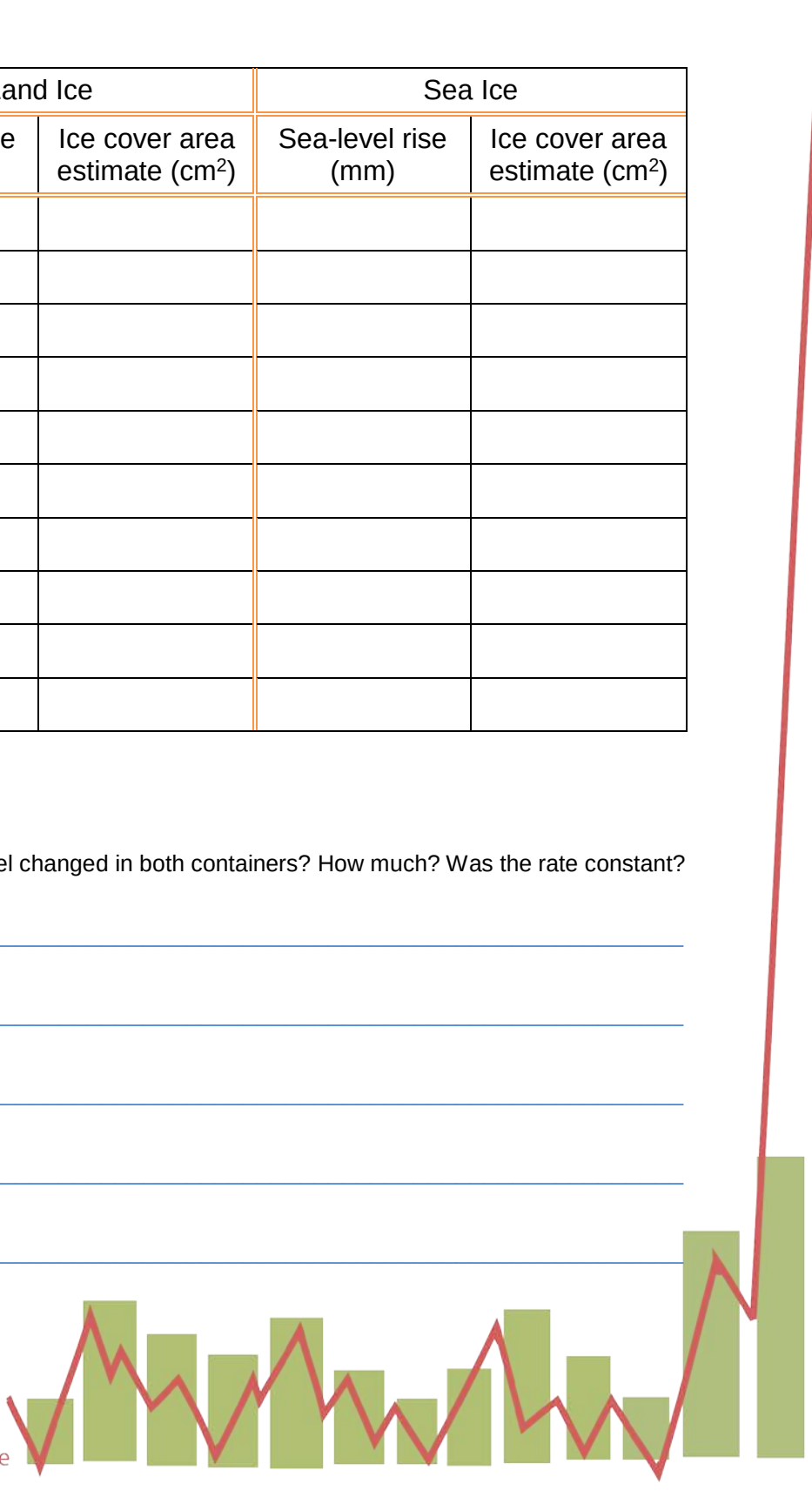
Land Ice vs Sea Ice

Results table

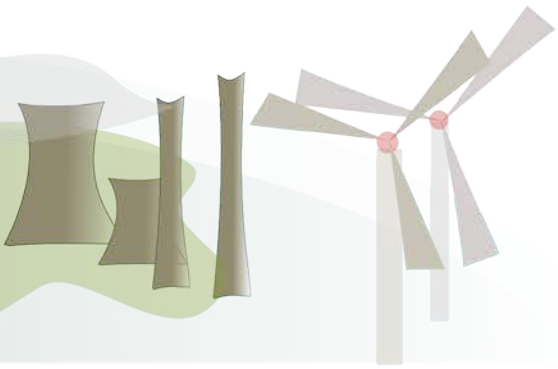
	Land Ice		Sea Ice	
Time (minutes)	Sea-level rise (mm)	Ice cover area estimate (cm^2)	Sea-level rise (mm)	Ice cover area estimate (cm^2)

Conclusion

Describe your results: has sea level changed in both containers? How much? Was the rate constant?



Sea Level Rise
Student Worksheet



Results Graph

Chose an appropriate scale, and plot the recorded data for land ice. Add the data for sea ice in a different colour (if your group only did one, share data with another group).

Title: _____

Sea-level rise (mm)

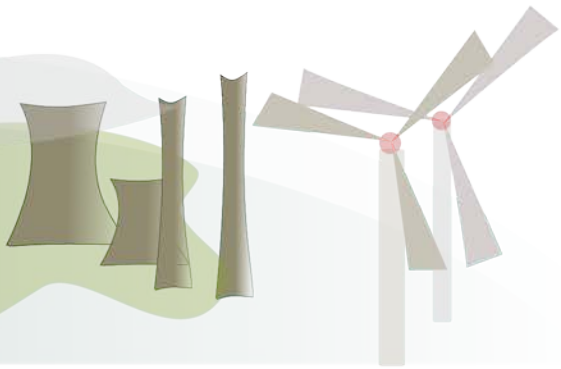
Time (mins)

☐ Land Ice

☐ Sea Ice

Climate Change: it's serious

The role of the Ocean



Overview

Activity Description	A series of experiments and demonstrations looking at role the role of the oceans in global climate systems, and their response to climate change. Demonstrations and experiments can be combined or used independently to suit.
Time	20 minutes (10 mins Heat Capacity, 10 mins Ocean Acidification)
Learning Outcomes	• Learn how increased levels of CO_2 impact the oceans • Explore the impacts of climate change on ocean circulation • Investigate the relationship between different water masses
Student Organisation	Small groups/pairs (discussion)
Materials Needed	Instruction sheets, worksheets, [depending on experiments being carried out, you will also need; balloons, funnels, water, timers, lighter or candle + matches, spoons, plastic cups or beakers, marker pens, pH indicator, salt, straws]

Background information

In climate change discussions, the importance of Earth's oceans can often be overlooked. In fact, the oceans play a hugely significant role; not least acting as a large store of both heat and carbon.

As levels of CO2 increase, oceans are being subjected to a series of rapid changes resulting in; seasonal shifts, ocean acidification, coral bleaching, sea level rise, coastal erosion, new diseases, loss of marine life, changes in precipitation, fishery declines.

Understanding the role of the oceans in climate change has allowed scientists to more accurately model past conditions and consider future responses to increasing global temperatures.

Classroom Activities

The classroom activities for this resource are described as distinct experiments under two headings – these can be used separately, or combined to make a longer lesson investigating the role of the oceans in global climate, and climate change.

1. Heat Capacity (water vs. air – oceans as a heat buffer)
2. Ocean Acidification (fresh water vs. salty water – oceans as a CO_2 buffer)

Heat Capacity

Classroom Activity 1: Heat Capacity

In this demonstration you will use two balloons to demonstrate the heat capacity of water, and consider the impact this has on the distribution of heat across the surface of planet Earth.

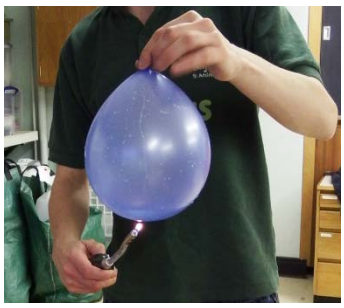
This can either be done as a whole class demonstration (get pupils to hold the balloon!) or in groups, depending on age/class size.

What you need:

- Two balloons
- A funnel
- 150ml cold water
- A timer
- A lighter or candle + matches
- A tray/tub to place under the balloons and catch the water

Method:

1. Blow up one of the balloons, tying it securely
2. Using a funnel, pour 150ml of water into the second balloon
3. Blow up the second balloon and tie the end securely
4. Make a prediction about what you think will happen when a flame is held underneath each balloon. Will both balloons pop? Will one last longer than the other? Estimate how many seconds you think it will take for each balloon to burst.
5. First, hold the balloon containing only air above the tray, and hold either the lighter flame or the candle directly underneath it – time how long it takes to burst
6. Repeat step 5. with the balloon containing some water (make sure you hold the flame directly underneath, so that the heat is being applied to the area with water in it)
7. Discuss the result – which balloon took longer to pop?

Left to right: equipment needed, filling the second balloon with water, experiment in progress!

Heat Capacity

Talking Points

Water has a high thermal (heat) capacity, which means it can store more heat per unit volume than air can. When the flame is held under the balloon containing only air, the rubber of the balloon quickly heats up and becomes weak, so the balloon pops. In the second balloon, the water absorbs the heat from the flame so the balloon rubber takes longer to heat up enough to become weak.

The oceans acts in a similar way for the earth, absorbing the extra thermal radiation that is being trapped in the atmosphere because of increased CO_2 levels.

Earth's oceans are therefore playing an important role in keeping the planet cooler than we might except from the measured rise in greenhouse gases (particularly CO_2). However, just like the second balloon did eventually pop, the oceans are slowly warming and will reach a point where they can't absorb all of the excess heat.

What influence do you think an increase in ocean temperature might have on these things?

	Impact of increased ocean temperature
Coral reefs	
Sea level	
Tropical storms	
Ice melting	

Check out this article for some more information:

https://www.nationalgeographic.com/environment/oceans/critical-issues-sea-temperature-rise/

Classroom Activity 2: Ocean Acidification

This experiment considers the effect of dissolved CO_2 on both fresh and salt water – considering the impact of rising levels on oceans and sea-life.

What you need:

- 2 spoons
- 2 clear plastic cups or beakers
- Marker pen/paper for labels
- pH indicator (liquid or paper)
- Cold water
- Salt
- Straws
- Timer
- Worksheet

Method:

1. Fill both cups/beakers approximately half full with water (if you live near the coast, you can use real seawater in one cup and miss out the 'adding salt' stage!)
2. Mark one as 'fresh water' and one as 'sea water', and dissolve 3 - 4 heaped teaspoons of salt in to the 'sea water' cup
3. Add 6 drops of pH indicator to each cup, swirling to mix
4. Note the starting pH of the 'fresh water' cup (describe the colour or use the chart)
5. Using a straw, blow in to the 'fresh water' cup for 10 seconds, then record the new pH
6. Continue blowing, recording the change every 10 seconds until 40 seconds has passed
7. Repeat steps 12 – 14 for the 'sea water' cup

	Initial pH (before CO_2)	pH after CO_2 **10 s**	pH after CO_2 **20 s**	pH after CO_2 **30 s**	pH after CO_2 **40 s**
Fresh water					
Seawater					

Ocean Acidification

Talking Points

During the experiment the water becomes more acidic, because CO_2 – one of the gases that humans breathe out – is dissolving and forming carbonic acid (H_2CO_3) which can release H^+ ions, causing a drop in pH*. There is a difference in the reaction time between fresh water and seawater because the dissolved salt in the seawater acts as a buffer, neutralising some of the acidity – if you use real sea water instead of adding just salt, this effect is even stronger because real sea water has more dissolved salts (not just NaCl – table salt).

Seawater is therefore currently acting as a buffer, absorbing some of the CO_2 from the atmosphere and meaning Earth is not warming up as much as it would be without the oceans. However, the seawater cup/beaker also eventually changed colour, and similarly the oceans are becoming more acidic; over the last 300 million years ocean pH has been ~8.2, but over the last 200 years this has decreased to ~8.1. Because the pH scale is logarithmic, this represents a 25% increase in acidity!

* Higher concentration of H^+ ions in a solution = lower pH, since $pH = -\log_{10}[H^+]$

Extension

This experiment illustrates the effect of ocean acidification on shell creatures, using limestone which is primarily made of calcium carbonate ($CaCO_3$) – the same material as many shells are made from.

What you need:

- Pieces of limestone
- Vinegar (or other weak acid – follow appropriate safety precautions as appropriate)
- Eye wear & protective gloves
- Shallow container/tray

Method:

Experiment 1: Simply place a couple of drops of vinegar (or acid) on to a piece of limestone and observe what happens – you should see bubbles start to form as the acid reacts with the carbonate and starts to dissolve it.

Experiment 2: Place a small piece of limestone in a container and pour in enough vinegar to just cover it. Leave it undisturbed for around 1 week, and you should see small white crystals growing on top of the rock.

The vinegar is dissolving calcium carbonate from the rock, forming calcium acetate (also an acid). As the liquid starts to evaporate, the concentration of calcium acetate increases and the solution becomes saturated – at which point it starts to crystallise.

Note: take care when using acids, making sure to avoid contact with eyes and to wash hands thoroughly before handling food – it is recommended that eye protection and gloves are worn

Talking Points

Ocean acidification is bad news for sealife! Shells made of calcium carbonate start to dissolve or are weakened and this has a significant effect on the ocean food-chain. Fish, coral and other creatures are also effected by the changing pH – for example more acidic waters is causing a reduction in numbers of cod in the North Atlantic.