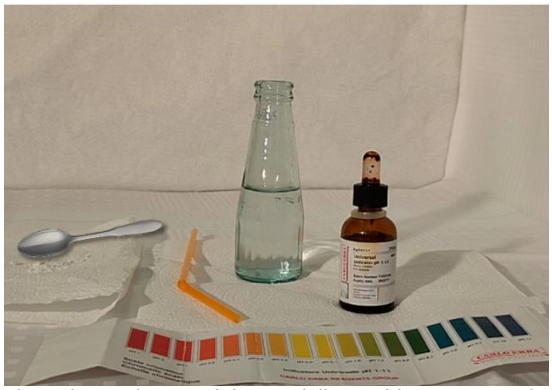
Ocean acidification – The other CO_2 problem

See how acidified water affects calcareous marine organisms

This activity can be used to demonstrate how increased CO_2 levels in the atmosphere affect calcifying marine organisms, namely organisms which have shells, skeletons and other body parts made of calcium carbonate (molluscs, corals, sea urchins, some algae, and other marine organisms).

- Have a small bottle or boiling tube 2/3 filled with distilled (or deionized) water (Fig.1).



Fig;1 The equipment (*photo: Giulia Realdon CC BY-SA*)

- Add some drops of universal pH indicator to the water until it becomes a medium-green colour and mix it by rotating the bottle.
- Ask students to observe the colour and compare it with the pH colour scale (*it is expected to correspond to a pH value of 7, meaning a neutral solution*).
- Ask students to predict what will happen if someone blows into the solution, Ask one student to use a straw and blow into the solution for at least 30 seconds.
- Ask students to describe what is happening (*the colour of the solution will change from green to yellow*) and to estimate the new pH value (*it ought to decrease at least by 1 pH unit. Fig 2a*).
- Ask one student to add one teaspoon of shell powder to the solution and stir it by rotating the bottle.
- Ask students to observe what is happening in the solution (*the solution will turn green and cloudy, due to the reaction between the acidified water and the calcium carbonate of the seashell powder. Fig 2b*).

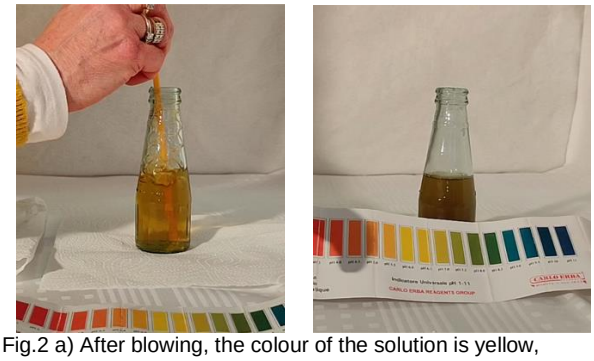


Fig.2 a) After blowing, the colour of the solution is yellow, b) turning into green after the addition of seashell powder (*photo: Giulia Realdon CC BY-SA*)

It can take a few minutes to observe a change: the finer the shell powder, the faster the reaction occurs.
Invite the students to link the observed phenomenon with the global phenomenon of ocean acidification, asking them to imagine the consequences of the phenomenon on calcifying organisms and on the ecosystems of which they are a part.
You can also extend the discussion to the carbon footprint of human activities in addition to fossil fuel burning (production of food, of clothes and other goods, …), and to students' life and consumption styles, to make them aware of the direct link between individual (and collective) choices and global environmental problems.

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The back up

Title: Ocean acidification – The other CO_2 problem

Subtitle: See how acidified water affects calcareous marine organisms

Topic: A demonstration, involving blowing into neutral water to produce a weak acid. Powdered seashells are added and react with the acid, as a quick-acting laboratory example of how acidifying ocean affects the life of many marine organisms.

Age range of pupils: 11-18 years

Time needed to complete activity: 15 minutes, plus discussion

Pupil learning outcomes: Pupils can:

- explain that the acidity, neutrality, or alkalinity of a solution can be measured by the pH scale;
- explain that a pH indicator is a compound (or a mixture) that changes colour depending on the pH of a solution;
- explain how a neutral solution (distilled water) can become slightly acidic with the CO_2 contained in exhaled air, as CO_2 reacts with water molecules, forming carbonic acid, which releases H^+ ions in the solution;
- explain that H^+ ions react with calcium carbonate ($CaCO_3$) contained in seashells;
- explain that the same reaction can happen in the ocean as it becomes more acidic, affecting organisms with body parts made of calcium carbonate.

Context:
This activity is a simplified model of a world-wide phenomenon; ocean acidification due to the high level of atmospheric CO_2. Ocean acidification is a less perceived consequence of increasing atmospheric CO_2 in comparison to global warming, but its effects on marine organisms are becoming more and more relevant.

Following up the activity:
This activity gives the opportunity to discuss with the students the "other CO_2 problem" linked to the burning of fossil fuels and other human activities which produce CO_2.
Other possible discussion topics include:

- the pH scale and other logarithmic scales used in Earth sciences;
- the solubility of gases in water and the major effect of ocean acidification in cold seas.

Underlying principles:
It is estimated that, from 1750 to 2021, 474 Pg of carbon (1 Pg = 10^{15} g = billion tonnes) were emitted as CO_2 from the use of fossil fuels*. About half of the CO_2 emitted remains in the atmosphere, now exceeding 400 parts per million**, the rest is partially dissolved in the ocean. (Fig 3).

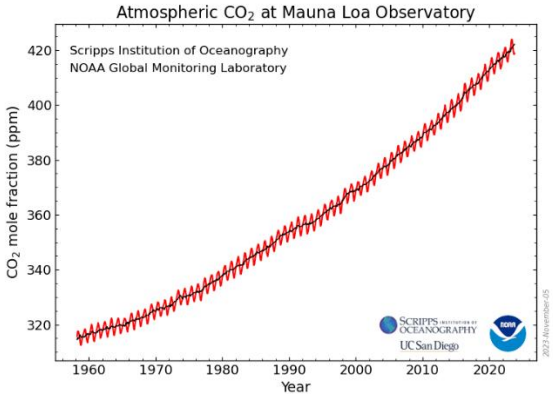

Fig 3. Atmospheric CO_2 at Mauna Loa Observatory (*Image: NOAA, permitted non-commercial use*)

The consequence is that, since the Industrial Revolution, the pH of the ocean's surface waters has decreased from 8.21 to 8.10: a drop of 0.11 pH unit, indicating about a 30% increase in acidity, a faster change than any known change in ocean chemistry in the last 50 million years (Fig 4).

Fig 4. Changes in acidity related to the pH Scale (*Image: NOAA, permitted non-commercial use*)

This means that as the ocean acidifies, the concentration of CO_3^{2-} carbonate ions decreases. Calcifying organisms, such as molluscs, corals, and various plankton species, need carbonate ions to build their shells or skeletons so, with less carbonate ions available, the more 'costly' calcification becomes, especially in polar seas, where the solubility of CO_2 is higher due to lower water temperatures.

Thinking skill development: through this simplified model, students will be able to perceive a phenomenon far from personal experience and public understanding.
The colour change due to the chemical reaction of weakly acidic water with seashell powder could be unexpected and cause a cognitive conflict. The link with the global ocean acidification implies bridging capacity.

Resource list:

- a small glass bottle or beaker (approx. 100-150 ml)
- a drinking straw
- "distilled" (demineralised) water for ironing
- universal liquid pH indicator
- indicator colour scale
- a few shells (or eggshell) reduced to powder
- a teaspoon

Useful links:

- Earthlearningidea activity Weathering limestone – with my own breath! https://www.earthlearningidea.com/PDF/214_Weathering_limestone.pdf
- https://www.noaa.gov/education/resource-collections/ocean-coasts/ocean-acidification
- https://www.pmel.noaa.gov/co2/story/A+primer+on+pH

Source: Giulia Realdon, University of Camerino, UNICAMearth group, Italy.
* Data source: Global Carbon Budget (2022)
**Monthly average for October 2023 at Mauna Loa Observatory = 418.82 ppm

Disclaimer: this simplified model using distilled water does not consider the buffering power of seawater resulting from dissolved ions like HCO_3^- and CO_3^{2-}.