Comparison of the Effects of Increased CO_2 in the Air to Seawater and Distilled Water

The majority of the earth's surface is covered with water (70%) and only 3% of this is freshwater, the rest is seawater. How do increasing CO_2 concentrations in the atmosphere affect seawater and freshwater bodies like lakes and streams? Does salinity affect the influence of increasing CO_2 on oceans or lakes? Total salinity is determined by the concentration of dissolved compounds and individual ions in the water. In this experiment you will use distilled water, which is pure water, meaning it does not contain any dissolved ions or compounds and seawater and see how these are affected by increasing CO_2 in the air.

Preparation time:	30 Minutes
Duration of activity:	30 minutes
Target age group:	11-14 years old / Grades 5-8
Application:	Chemistry lessons/ After school activity
Time for data analysis and discusion:	30 minutes
Previous knowledge required:	Concept of acids and bases
Cost:	25 € for aquarium, aquarium pump and aerators (if not available)

Materials:
Big transparent basin or a big aquarium
2 500 ml-beakers
2 pH Meters
Aquarium pump
Plastic tubings and 2 airstones with regulator valves
Seawater
Distilled water
5 candles
Box of matches
Stopwatch

Procedure:

1. Fill one beaker half-full with seawater and the other with distilled water. Aerate the water in the beakers with the airstones connected to the aquarium pump. Regulate the aeration with the valves so that both beakers are bubbled with air to the same degree.

2. Place one pH electrode in each beaker and connect these to the pH meters. Make an initial reading and record this in the table.

3. Light the candles and place these in front of the beakers. Place the entire set-up under the inverted aquarium (Fig. 1). It is necessary that the aquarium pump should also be inside the aquarium. If the aquarium is not big enough, the pH meters can be placed outside.

4. Record the pH of the water in the beakers for 10 minutes at 1-minute intervals. Take note when the candles are still burning and when they start to die out.

5. Create a graph of your results.

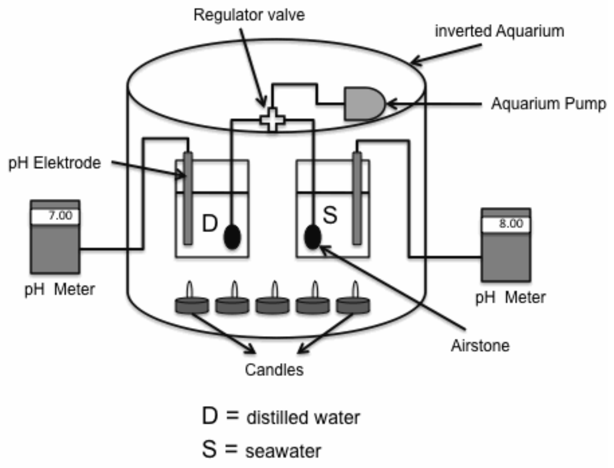


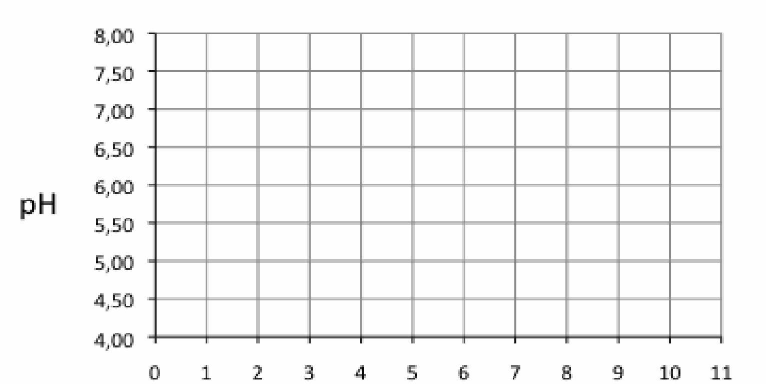
Fig. 1 *Set-up*

Results:

pH of the water in the beakers

	pH	
Time (min)	Seawater	Distilled water
0 (Initial)		
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		

Change in pH over time



Time (minutes)

1. In which beaker was there a greater change in pH? Did the water become more basic or acidic?

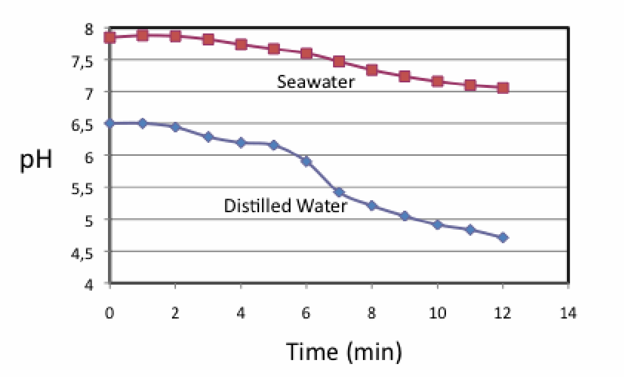
2. Many aquatic organisms cannot tolerate big pH changes in their environment. What do you think will be the effect of a high CO_2 environment to organisms in a lake and in the ocean?

3. Why should the water in the beakers be aerated? Why should the pump also be placed inside the inverted aquarium?

4. What do the burning candles do to the air inside the aquarium? Where does the oxygen go? What gas do the burning candles produce?

Notes:

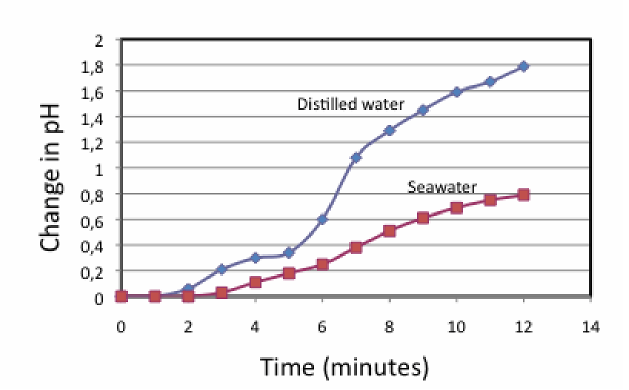
1. The decrease in pH of the distilled water was faster and greater than that of the seawater.



pH of the water in the beakers over time

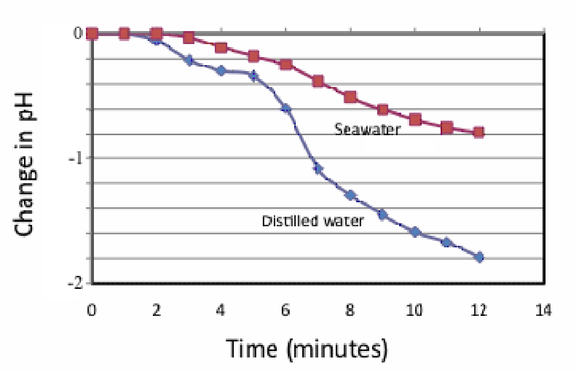
In our example the change of pH in distilled water was from 6.5 to 4.6 in ten minutes whereas in seawater the pH decreased from 7.8 to 7. So the change in pH can be calculated as pH at the start of the experiment (pH_{t0}) minus the pH at a given time (pH_{tn}). Ask the students to create a graph and plot the change in pH over time.

pH change in the beakers



Another way of showing the change in pH is by multiplying the values for the graph above with -1. Plotting the results will give:

pH change in the beakers



How the results will be shown will depend on the preferences of the teacher.

2. The water should be aerated to for 2 reasons: 1) By placing the pump under the inverted aquarium together with the candles, you will be pumping air from inside the aquarium into the water, and 2) aerating the water increases the contact between the air inside the aquarium and the water dissolving more gas into the water.
3. The buffering capacity of water (alkalinity) is dependent on the carbonate chemistry of the water along with the common anions. Alkalinity is a measure of the ability of water to resist pH changes.
4. Some lakes have “hard water” containing high magnesium and calcium and these exhibit high alkalinities. On the other hand, some have “soft water” with low salinity, specifically low in calcium and magnesium, thus also having low alkalinities. Seawater has a high salinity (35 psu) and has a high buffering capacity.
5. Lakes can either be sinks or sources of CO_2. However, most lakes are acidic, receiving acidic water from run-off of terrestrial origin as well as from acidic “wet” and “dry” precipitation. This is further exacerbated by the small volume and shallowness of lakes compared to oceans, where dilution and convection can mitigate the effects of high CO_2 inputs both from the atmosphere and land.

Further experiments:

1. If time allows, continue to record the pH until no further changes can be measured. Take note how long it takes and what the final pH of the water in the two beakers is. After sometime, the pH in both beakers will stabilise corresponding to the point when the amount of CO_2 in the air and in the water is in equilibrium.
2. Try to compare the buffering capacity of water from different lakes. If you can find “hard water” and “soft water” lakes.
3. Compare buffering capacity of water with different salinities by dissolving different amounts of sea salt in water.

Additional reading:

Lakes: Chemical Processes. In www.waterencyclopedia.com/Hy-La/Lakes-Chemical-Processes.html

Cole, J.J. et al. 1994. Carbon dioxide supersaturation in the surface waters of lakes. Science Vol. 265 . No. 5178. Pp. 1568-1570.

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