Interaction at the Air-Water Interface I

Introduction:
The world's oceans readily exchange carbon dioxide (CO_2) with the atmosphere. This occurs at the interface between air and the ocean surface. The extent of dissolution of CO_2 in seawater is determined by the partial pressure of CO_2 (P_{CO2}), chemical reactions of the dissolved carbon dioxide with other solutes and biological processes leading to CO_2 release or uptake.

Part 1.

Aim:
To demonstrate gas exchange and equilibration at the boundary layer between air and water.

Preparation time:	10 minutes
Activity time:	10 minutes (set-up), 1 week (observation)
Type of activity:	Hands-on experiment
This activity had been tested on students aged:	10-12 yrs., grades 5-7
Application:	Physics, Chemistry, After-school activity
Time for data analysis and discussion:	15 minutes
Prior knowledge required:	acid-base interaction, concept of "indicators"
Cost:	Indicator (12€/250 ml)
Degree of difficulty:	Easy

Materials:
2 bottles or flasks with covers (any size and material will do)
drinking straw
Pipette or medicine dropper
universal indicator (McCrumb)

Fig 1. Materials

Procedure:
1. Fill the bottles half-full with distilled water. Put several drops of indicator solution into the bottles with the pipette until the water in the 2 bottles has attained the same shade of green. Be sure to add the same amount of indicator in both bottles.
2. Blow air into the bottles until the color changes from green to yellow (basic to acidic). Blow air until no further color change can be obtained.
3. Cover one bottle tightly and leave the other one open.
4. Put the bottles in a place where they are not disturbed and not exposed to direct sunlight.

5. Observe the change in color of the water inside the bottles. This may take several days.

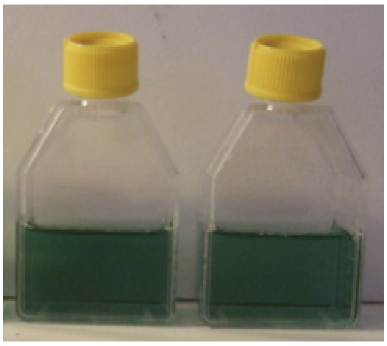


Fig 2a. Bottles with distilled water and the same amount of indicator.

Fig 2b. CO_2 was bubbled in the left bottle. Yellow color means acidic.

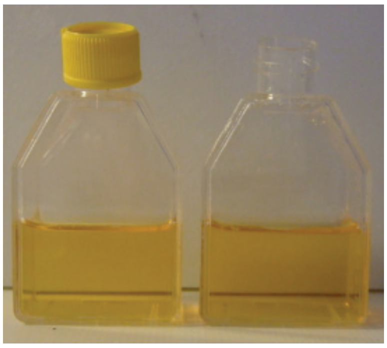


Fig 2c. CO_2 was bubbled in both bottle. Leave one bottle uncapped.

Results:

1. Was there a change in the color of the water in both bottles?
2. In which bottle was the color change faster? Why do you think did the color of the water change?

Notes:

1. The color of the water in the uncovered bottle will go back to its original green color faster because there is an exchange of gases occuring between the air inside and outside the bottle. The rate of color change will depend on the volume of the water, the size of the mouth of the bottle and the area of the water surface which has contact with the air above it.
2. The water in the covered bottle will eventually also revert back to its original color because the bottle may not be 100% air-tight. Try this with air-tight bottles, the color may not revert back at all. In the covered bottle, the air inside will also be containing more CO_2 immediately after the bubbling because the excess CO_2 in the water will escape into the air inside the bottle, maintaining a high CO_2 environment for some time.

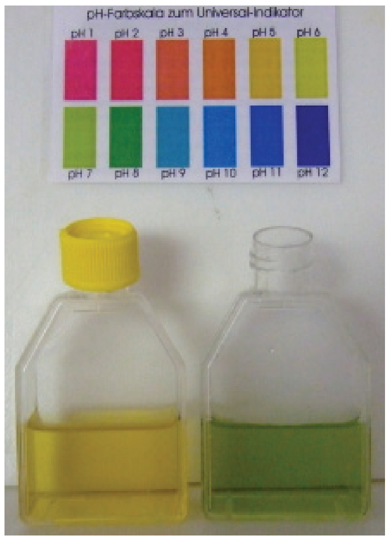
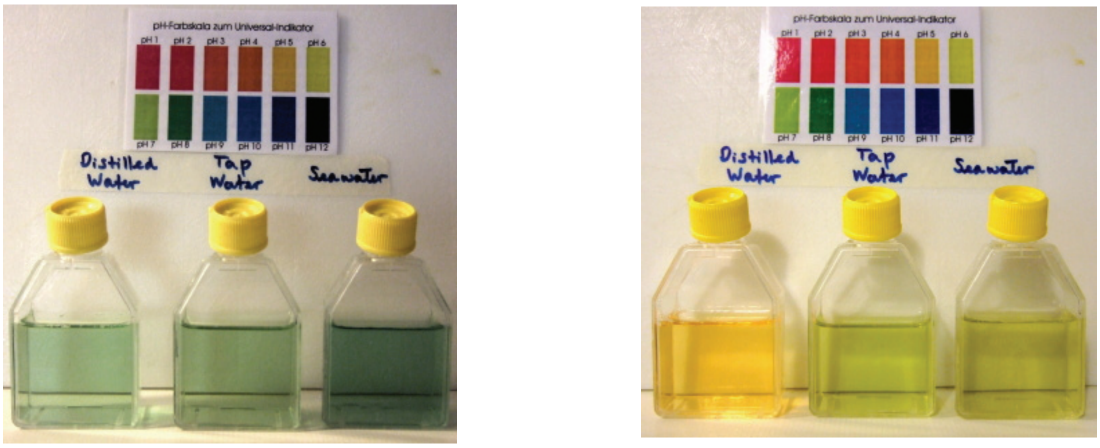


Fig 3. After a couple of days the water in the uncapped bottle turns green.

Additional experiments:

1. Compare the difference between distilled water, tap water and seawater. Distilled water will become more yellow than tap water and seawater which have calcium carbonate acting as buffer.



(A) **(B)**

Fig 4. Differences between distilled- , tap- and sea water with indicator solution before (A) and after (B) bubbling CO_2

2. To demonstrate the influence of surface area of contact between air and water on gas exchange, use two bottles or containers with different diameters. Use the same volume of water and bubble CO_2 in both. Leave both bottles uncovered and observe the speed of color change. The one with the larger diameter will exhibit a faster color change. After this experiment, you can point out to the students, that the ocean, covering 71% of the earth's surface, offers a large surface area for taking up CO_2.

Part 2.

Aim:

To demonstrate that temperature affects the escape of CO_2 back to the atmosphere. This part of the experiment will help the students visualise CO_2-degassing of the oceans at equatorial waters.

Preparation time:	10 minutes
Activity time:	10 minutes (set-up), 1 hour (observation)
Type of activity:	Hands-on experiment
This activity had been tested on students aged:	10-12 yrs., grades 5-7
Application:	Physics, Chemistry, After-school activity
Time for data analysis and discussion:	20 minutes
Prior knowledge required:	factors affecting gas solubility
Cost:	Indicator (12€/250 ml)
Degree of difficulty:	Easy

Materials:
3 bottles or flasks (any size and material will do)
3 beakers or drinking glasses
drinking straw
Pipette or medicine dropper
universal indicator (McCrumb)
hot water
ice cubes

Fig 5. Materials

Procedure:

1. Fill the bottles half-full with distilled water. Put several drops of indicator solution into the bottles with the pipette until the water in the bottles has attained the same shade of green. Be sure to add the same amount of indicator in both bottles, about 10 drops.

Fig 6. Bottles with distilled water with 10 drops Mc Crumb indicator solution

2. Using the drinking straw, blow air into the bottles until the color changes from green to yellow (basic to acidic) and no further color change can be obtained.

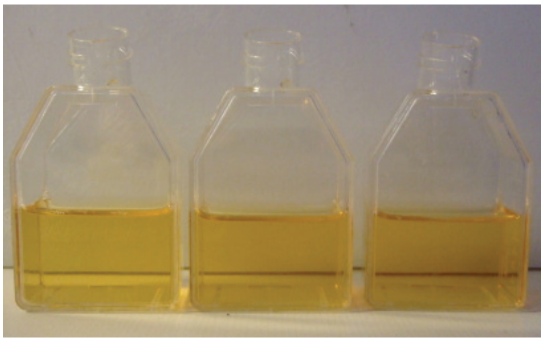


Fig. 7. CO_2 is blown into the bottles turning the water yellow (acidic).

3. Fill one beaker half-full with water at room temperature. Fill the second beaker half-full with hot water and the last beaker with ice water.
4. Put the **uncapped** bottles, one in each beaker and observe the change in color of the water inside the bottles. Depending on the temperature of your water bath, this may take about an hour.

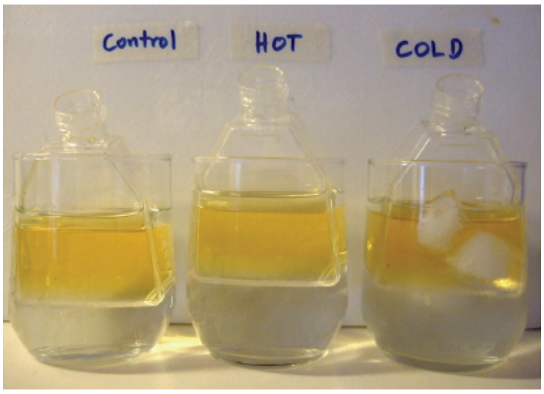


Fig 8. The uncapped bottles are placed in waterbaths with different temperatures

Results:

1. Was there a change in the color of the water in the bottles?
2. What does the color change in the bottle mean?

Notes:

1. The water in the bottle placed in the hot water bath changed gradually from yellow to green. This means that the dissolved CO_2 escaped back to the air making the water more basic. This demonstrates partly why CO_2 in low latitude waters is degassed out of the water. In this region, cold newly upwelled CO_2-richwater is warmed thus releasing CO_2 into the atmosphere.

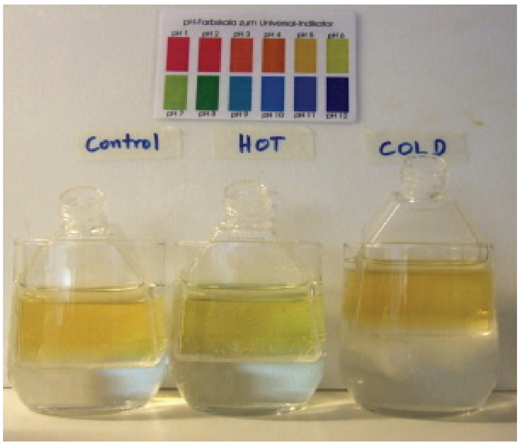


Fig 9a. Change in color after 30 minutes

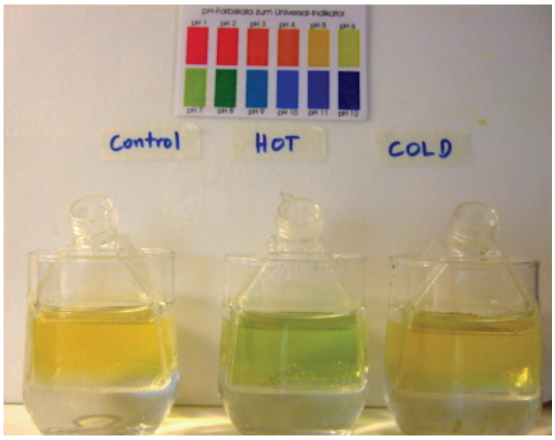


Fig. 9b. Change in color after 1 hour

2. High temperature decreases the solubility of gases in water and consequently encourages the release of dissolved gases to the atmosphere.

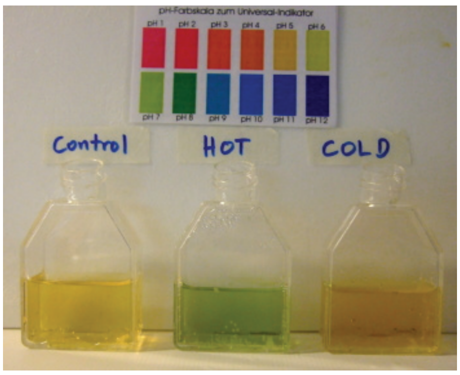


Fig 10. In the hot water bath, CO_2 escaped back into the atmosphere after several minutes.

3. Seawater as well as tap water can also be used in this experiment.

References:

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