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How does Temperature Affect the Solubility of CO_2 in Water?

Increasing CO_2 concentrations in the atmosphere leads to increasing air temperatures and consequently, warming of the oceans. Does this increase of water temperature have a positive or negative feedback to CO_2 concentrations in the atmosphere? Will this effect be seen on a global or regional basis?

Preparation time:	10 Minutes
Duration of activity:	15-20 minutes
Target age group:	11-14 years old / Grades 5-8
Application:	Chemistry and Physics lessons/ Geography/ After school activity
Time for data analysis and discusion:	20 minutes
Previous knowledge required:	None
Cost:	0.50 € for the effervescent tablets

Materials

- 500 ml graduated cylinder
- Funnel
- Petri dish cover
- Transparent basin or an aquarium
- Stand and Clamp
- Ice cubes/ cold water
- Water heater/Warm water
- Effervescent (Fizz) tablets

Procedure

1. Fill the basin half-full with cold water. Place the stand beside the basin.

2. Fill the graduated cylinder to the brim with cold water and place it carefully upside down in the basin. Be sure that no water spills out of the cylinder so that no air bubble is formed. To do this, cover the mouth of the full cylinder with a Petri dish. Invert the cylinder and immerse this in the basin. Remove the Petri dish after the mouth of the cylinder is already underwater. (Younger pupils may need assistance here).

3. Secure the graduated cylinder with the clamp to the stand and place the funnel in the mouth of the cylinder making sure that there is minimal space between the funnel and the opening of the cylinder. (See Figure 1).

4. Place an effervescent tablet carefully under the funnel and observe how an air space develops on top of the upside down cylinder. Record the volume of the air space formed in the table below. Make several trials.

5. Repeat the same procedure with warm water and record your results in the table. What happens with the air space when warm water is used?

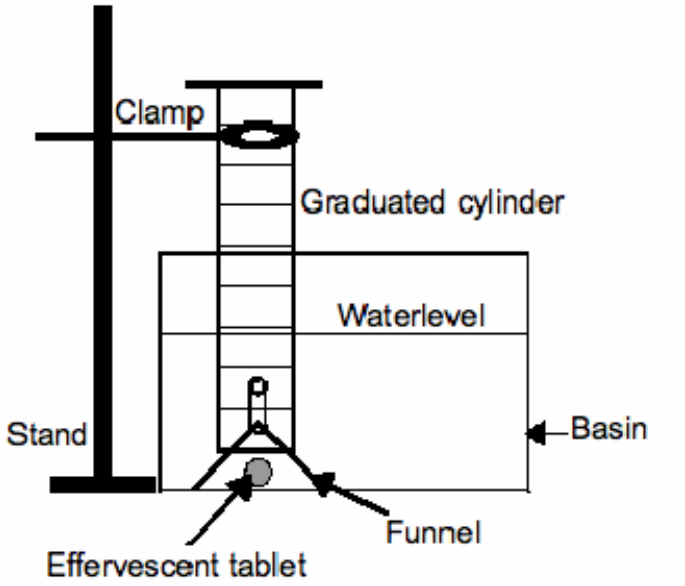

Fig 1. *Experimental Set-up*

Volume of the air space formed inside the graduated cylinder

Number of effervescent tablets	Volume of air space formed (ml)	
Trial number	cold water	warm water
1		
2		
3		

Results:

1. Which produces a larger volume of air space inside the graduated cylinder, cold water or warm water?

2. What will be the consequence of a “warming ocean”? How will this affect the role of the oceans as a CO_2 sink?

3. Where in the world's oceans would you expect more CO_2 uptake? Where will it be less?

Notes:

1. The bubbles set free by the effervescent tablets when dissolved in water is carbon dioxide. The volume of the air space formed in the graduated cylinder is equal to the volume of CO_2 (or gas) which can not be dissolved in water anymore. The initial gas freed during the dissolution of the tablet will first be dissolved in the water and when the water is already saturated with gas, the gas will escape into the air displacing water inside the cylinder forming the air space.
2. The solubility of gases decreases with increasing temperature, so the air space inside the cylinder when cold water was used will be less compared to warm water. The cold water will take up more CO_2 and less will escape to the air.
3. In the world's oceans, the northern Atlantic and the southern Oceans act as major sinks of CO_2 because they are colder. In addition to this, cold water is denser than warm water, causing it to sink. The carbon dioxide taken up at the surface can be effectively transported to the deeper waters by convection; hence the CO_2 is stored in the bottom layers of the ocean.
4. On the other hand, warm equatorial waters tend to release CO_2 into the atmosphere. In these regions upwelling of CO_2-rich deep waters occurs. When the water reaches the surface, it is warmed, thus decreasing gas solubility and leading to the degassing of CO_2.
5. For discussion purposes, I suggest that the teacher shows a world map to the students and discusses on the basis of geographical location which part of the worlds oceans are effective CO_2 sinks.

Further experiments:

1. Try the experiment with different salinities. The effect of salinity is, however, not as great as temperature. Therefore, use greatly differing salinities e.g., compare distilled water with full strength seawater (35 psu).

2. Try using 2 Tablets, one after the other, but with the same temperature of water. The students will assume that a tablet will always produce the same volume of air inside the cylinder. The second tablet will of course, produce a larger volume of air because the water is already saturated. This will demonstrate that water has a limited capacity to take up gases.

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