**Ocean Acidification Module - Lesson Flow**

**Materials (per group):**

* 3 large cups or beakers (containers)
* 1 small cup (measuring)
* (at least) 3 shells
* Scale
* Gloves
* Tap water
* Solutions: vinegar, soda, lemon juice, milk, tap water, limewater, baking soda, soapy water, seawater (can be made artificially)
* Citric powder
* pH paper
* Marker
* Stirrers

**Additional material:**

* “Precise” pH-paper, to be distributed before the CO2 dissolution experiment

**Preparation:**

* Set up the materials at each group’s table (logistics TBD)
* Prepare the baking soda, soapy water solutions, get seawater
* Prepare the solutions: pour in cups for each group (logistics TBD)

1. **Introduction (20 mins)**

* Split the students into groups, have them introduce themselves (Give your name, where you’re from, and a fun fact about yourself).
* Each group should be given paper and pencils. Students discuss and list three acidic things and three non-acidic things in their kitchen, as a group.
* Bring together answers (suggest some if needed)
  + Acidic: vinegar, lemon juice, pineapples
  + Non-acidic: water, baking soda
  + What about milk? carbonated water? the lesson will answer these!
* Give examples of why acidity matters (how does acidity in the atmosphere and ocean affect our lives).
  + Increased acidity in the atmosphere can cause acid rain (chemicals like sulfur dioxide (SO2) and nitrogen oxides (NO, NO2) are released when burning fossil fuels, react with water, oxygen, CO2, and sunlight in the atmosphere to form sulfuric and nitric acids).
    - This can damage forests, etc.
  + Ask the class: what do you think happens if the acidity of an ocean increases? Tell them to raise their hands and give some suggestions.
* Give big picture of the lesson: what will be covered, what will they learn:
  + What is acidity?
  + How do we measure it?
  + What is ocean acidification?
  + What is its effect on wildlife?
  + What can we do against it?

1. **Shell experiment set-up (15 mins)**

* Safety talk! Good laboratory practices:
* Wear gloves at all times when handling chemicals/solutions
* Use different containers for different solutions, never use a container twice without properly washing it (avoid cross-contamination)
* Safety goggles not needed here, but could be with other chemicals
* Identify what is in containers (a clear solution could be lots of things…)
* Write down everything! in 15min you’ll have forgotten what you’ve put in which beaker
* In groups, start the shell dissolution experiment: students follow steps 1-7 of “Shell experiment” on the worksheet.

1. **pH definition and measurement (30 mins)**

* Students make hypothesis as to which solutions are more acidic: step 1 of “pH measurement” on the worksheet.
* We need a good way of qualifying how acidic a solution is. Define pH and how to measure it (pH-meter vs pH paper):
* Quantitative (=number) measure of acidity/basicity
* If between 0 and 7, then solution is acid (closer to 0 is more acidic)
* If between 7 and 14, solution is basic (closer to 14 is more basic)
* If 7, solution is neutral
* Very well, but how do we get this value? Two traditional ways of measuring it:
* pH-meter (have one to show them?) is an electronic apparatus with a probe that is dipped into the sample, and an console that displays the value
* pH-paper: strip of paper that changes colour depending on the pH, provided with a colour scale to refer to
* Have students think about advantages/drawbacks of each method: when would you use one of the other? (if the students don’t speak up, use example cases: scientist in a research lab looking at slight changes during a chemical reaction, vs scientist in a remote location wanting to know the pH of an underground lake)
  + pH-paper is less precise but cheap and easy, pH-meter is more precise but bulkier and more expensive
* Measure a range of solutions: students follow steps 2-4 of “pH measurement” on the worksheet.
* Talk about their ranked solutions, show a wider range of pHs on a chart:
* Tested solutions cover a wide range of pH but don’t go all the way to the extremes
* However there exist solutions that have pH down to 0 or up to 14, such as battery acids or gastric acid (acidic) and drain cleaner (basic)
* Ask the class:
  + Where do most foods fall on this pH scale?
    - Most foods are acidic to varying degrees. This is why we might get an upset stomach sometimes when we eat too much foods.  We are essentially adding acids to our stomach fluid, which is already acidic.
  + What do we do to combat an upset stomach and why?
    - Typically we will take an antacid which is a base.  When we add a base to our acidic stomach fluid, we help raise the pH slightly, restoring it to its natural pH.
  + Do you recognize any solutions on here that are bad for you?
    - Solutions with very low (0-2) and very high (12-14) pH levels can be toxic.  Our bodies depend on a narrow range of pH values in order to function properly.  When we are exposed to strong acids or bases, it can change our pH and consequently affect our physiology such as gas exchange.
* *(For older students only) Introduce H+:*
* *pH is a number - where does it come from?*
* *Definition of an acid: molecule that can give an H+*
* *Give examples of acid/base couples, write equations*
  + *HF = H+ + F-*
  + *H2O = H+ + OH-*
  + *H2CO3 = H+ + HCO3-*
  + *HCO3- = H+ + CO3(2-)*
* *Introduce concentration: how much of something in a given volume*
* *Give formula: pH = - log(H+)*
* Students study the effect of dilution using lemon juice:
* Follow steps 5-6 of “pH measurement” on the worksheet.
* Teacher talks about scientific process: how many data points are needed to be confident in the trend that we observe?
* Repeat steps 5-6 of “pH measurement” on the worksheet.
* Do step 7 of “pH measurement” on the worksheet (students discuss in their group).
* Bring together discussions: have students share their conclusions.
  + pH goes up as the concentration of H+ decreases with dilution - it can go up to 7.
  + If they ask what happens with a basic solution (the effect is opposite: pH goes down towards 7, as the water neutralizes OH- ions) tell them that adding water “makes it more neutral” and therefore makes pH go to 7.

1. **Ocean acidification (30 mins)**

* Introduce the concept of ocean acidification: we just measured in the previous section that seawater is acidic, while pure water is neutral. How come?
* The ocean is a large ecosystem where lots of animals live. Their habitats (places where they live) and their food chains rely on their environment being stable. However, over the past few decades, the pH in the ocean has been declining--the water is becoming more and more acidic. Why could this be?
* There is CO2 in the atmosphere:
* CO2 in atmosphere
* Talk about how the amount of carbon dioxide in the atmosphere has been steadily rising over the years. Ask the class if they know why this is so. Take a couple of suggestions.
* Write the term “greenhouse gases” on the board. Ask the class if they know what greenhouse gases are. Write down any correct examples they give. Then, go through the following chart:
* CO2 in oceans:
* How does the CO2 in the atmosphere influence the ocean pH? Do the CO2 dissolution experiment:
* Distribute to each group some more precise pH-paper
* Follow steps 1-2 of “CO2 dissolution” on the worksheet
* Ask the class what gases humans exhale: take answers, then give true answers (78% nitrogen - not used by human body, 16% oxygen - used by human body to work, 4% CO2 - created by human body)
* Demonstrate how to blow bubbles into the water using a straw
* Follow steps 3-4 of “CO2 dissolution” on the worksheet
* Write down on the board the final pH value obtained by each group. Talk about variations, estimating sources of errors:
  + Each group blew air for a different amount of time (probably a small source of error)
  + pH-paper precision (probably a large source of error)
* Talk about the carbon cycle:
* What is actually happening to make the water more acidic? The carbon dioxide is reacting with the water to create carbonic acid.
* *(For older students only?) Write the chemical formula for water (explaining that one water molecule is composed of two hydrogen atoms and one oxygen atom) and the chemical formula for carbon dioxide (explaining that one carbon dioxide molecule is composed of one carbon atom and two oxygen atoms) and then that these two compounds can react to form a new compound: carbonic acid.*
* *(For older students only?) Write the chemical formula of carbonic acid on the board, and show how it makes sense that everything in the first two reactants is accounted for in the product (two hydrogen atoms, one carbon atom, and two oxygen atoms).*
* *(For older students only) The presence of carbonic acid, which dissolves into hydrogen and bicarbonate ions, lowers the pH of the water (increased H+ concentration).*

1. **Effects of ocean acidification: interpret shell experiment (30 mins)**

* Have each group make a hypothesis for what the pH values of each of the solutions that they made at the beginning will be. Say that they will now be able to test their hypotheses, and that there’s nothing wrong with having your hypothesis turn out to be incorrect.
* Follow steps 1-5 of “Shell experiment” on the worksheet:
* Ask the class why they think the shells partially dissolved. Explain that shells are made of calcium carbonate. Write the chemical formula on the board (CaCO3), whose carbonate ions react with hydrogen ions to form bicarbonate ions.
* Ask the class what they think this means for animals who live in these shells in the ocean. Ask what it will mean if the oceans continue to get more and more acidic. Show the above image of the dissolving shell.
* Scientific method question: Why did we use a solution with plain water? Because we need a control solution.

1. **Remedies to acidification (20 mins)**

* We have now established that ocean acidification is bad for the environment. How can we do something against it?
* Ask the students to think of a way to curb ocean acidification (discuss in groups for a few minutes). Share some with the class: burn fewer fossil fuels, use more renewable energy sources, plant more forests to act as carbon sinks
* Limewater experiment:
* Follow steps 1-4 of “Limewater experiment” on the worksheet
* Write down on the board the final value obtained by each group
* The students should realize that adding the limewater raised the pH of their solution. Ask the class why they think this happened.
* (For younger students) Explain that limewater is basic and cancels out the acidity of vinegar.
* (For older students) Explain that limewater contains dissolved limestone, which is primarily composed of calcium carbonate, the same compund that makes up the shells. The added calcium carbonate reacts with the hydrogen ions in the solution to form bicarbonate ions, so the overall concentration of hydrogen ions in the solution goes down.
* Talk about how this has been done to reduce acidity in some lakes, to make the water more livable for fish and other animals
* But it isn’t a scalable solution for the ocean (an enormous amount, equal to 25 times the annual production of limestone, would be required)
* Reducing CO2 emission is the only solution to slow down ocean acidification

1. **Clean up (5 mins)**