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| **Lesson Name/appx. time** | **Driving Question** | **What Students Do, and Lesson Highlights**  | **What Students Figure Out** |
| **1 - *Introduce the Ocean Acidification Phenomenon*** One class period | Why are the oceans getting more acidic and what does that have to do with carbon dioxide? | Students are introduced to the ocean acidification phenomenon through observations and a reading. * Observe an indicator solution become acidic when carbon dioxide from different sources is added to it.
* Read an article about the pros and cons of carbon dioxide in the atmosphere.
* Share ideas and generate questions
 | Different science concepts need to be explored to understand the cause of ocean acidification and why it is a problem. * Carbon dioxide (CO2) gas dissolved in water causes water to become acidic.
* Burning a candle produces carbon dioxide gas.
* Sharing observations and questions generates curiosity and strengthens understanding.
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| **2 – *Atom Fundamentals***Three class periods | What do we need to know about atoms to begin to understand the process of ocean acidification? | Students learn about the parts of the atom and energy levels. * Do an experiment with static electricity as an introduction to protons and neutrons.
* Play card and online games about protons, neutrons, and electrons and energy levels as review and to strengthen understanding.
 | * Atoms are composed of protons, neutrons, and electrons.
* Protons have a positive charge, electrons have a negative charge, and neutrons have no charge.
* The basics of the periodic table including the meaning of atomic number, and atomic mass.
* Atoms have energy levels surrounding them where the electrons are.
* Only a certain number of electrons can be in a particular energy level.
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| **3 – *Covalent and Ionic Bonding***Two to three class periods | What are the two main substances in ocean water made of on the molecular level? | Students experiment to see the hydrogen and oxygen from water molecules. Students also observe and model the ions in sodium chloride. * Use pencils and a 9-volt battery to do electrolysis of water to generate oxygen and hydrogen gas.

 * View molecular animations to describe the ionic bonding in sodium chloride.
 | * The number of electrons on the outer energy level affects covalent bonding between atoms and how water molecules are formed.
* The number of electrons on the outer energy level affects how ions are formed and the ionic bonding of a salt crystal.
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| **4 – *The Water Molecule and Dissolving***About four class periods | What details about water do we need to know more about to understand why it’s such a good dissolver?  | Students investigate the characteristics of water on the molecular level and the effects of water being a polar molecule. * Experiments with water’s surface tension and comparing the evaporation of water and less-polar alcohol.
* Experiment with the solubility of salt and sugar in water and alcohol.
 | * Water is a polar molecule.
* The polarity of water molecules makes water a good dissolver of ionic and polar substances.
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| **5 – D*issolving Liquids and Gases***One to two class periods | How do liquids and gases like carbon dioxide dissolve in water? | Students investigate the ability of different liquids to dissolve in water. They also explore the solubility of carbon dioxide gas in water. * Observe the dissolving of isopropyl alcohol and mineral oil in water.
* Different substances and objects are placed in carbonated water and gas is observed collecting and bubbling out of the solution.
 | * Water can dissolve polar liquids but cannot dissolve non-polar liquids.
* Water can dissolve carbon dioxide gas.
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| **6 – *Temperature and Dissolving***Two class periods | Does the temperature of water affect how much of a substance can dissolve in it? | Students explore whether temperature affects the dissolving of a solid and a gas. * Help design an experiment to see if the temperature of water affects the dissolving of the coating of an M&M.
* Help design an experiment to see if the temperature of carbonated water affects the amount of carbon dioxide gas that stays dissolved in the water.
 | * The effect of increasing temperature has opposite effects on solids and gases.
* Increasing temperatures causes more dissolving of solids and less dissolving of gases.
* Increased carbon dioxide in the atmosphere increases global and ocean temperatures, which can affect the rate of dissolving of different substances.
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| **7 – *Chemical Reactions***Four to five class periods | What do we need to know about chemical reactions to understand the reaction between water and carbon dioxide that forms carbonic acid? | Students observe and analyze different chemical reactions to see evidence of chemical change and how the atoms in the reactants end up in the products. * Explore the combustion reaction of a burning candle.
* Investigate the reaction between vinegar and baking soda.
* Use baking soda and calcium chloride solutions to form a precipitate.
* Use vinegar and baking soda, and calcium chloride and baking soda solution to produce an endothermic and exothermic reaction.
 | * Chemical reactions create one or more new substances with new properties.
* In a chemical reaction, the atoms of the reactants unbond, rearrange, and rebond to form the products.
* Increasing the amount of reactants increases the amount of products.
* A clue that a chemical reaction has taken place is production of gas, forming a precipitate, or a change in temperature.
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| **8 – *Temperature and the Rate of a Chemical Reaction***One class period | Since the temperature of the oceans are rising, how does temperature affect the rate of a chemical reaction? | Students help design an experiment to explore how temperature affects the rate of a chemical reaction. * Heat and cool baking soda solution and calcium chloride solution and combine the cold solutions and warm solutions and observe reactions.
 | * Reactants must be moving fast enough and hit each other hard enough for a chemical reaction to take place.
* Increasing the temperature increases the average speed of the reactant molecules.
* As more molecules move faster, the number of molecules moving fast enough to react increases, which results in faster formation of products.
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| **9 – *pH and Color Change***One class period | What is an acid and a base and how do we measure how acidic or basic a solution is? | Students add increasing concentrations of an acid and a base to a pH indicator solution and approximate the pH based on color.* Add increasing concentrations of citric acid and sodium carbonate solutions to samples of universal indicator solutions and observe the resulting color.
* Compare color to universal indicator pH color chart to approximate the pH.
 | * Whether a solution is acidic or basic can be measured on the pH scale.
* When universal indicator is added to a solution, the color change can indicate the approximate pH of the solution.
* Acids cause universal indicator solution to change from green toward red.
* Bases cause universal indicator to change from green toward purple.
* Water molecules (H2O) can interact with one another to form H3O+ ions and OH*−* ions.
* At a pH of 7, there are equal numbers of H3O+ ions and OH−ions in water, and this is called a neutral solution.
* Acidic solutions have a pH below 7 on the pH scale.
* Basic solutions have a pH above 7 on the pH scale.
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| **10 – *The Effect of Increasing Acidity on Ocean Organisms***One class period | How does increasing ocean acidity affect sea creatures that make shells? | Students see a chemical equation and a video showing how more acidic ocean water affects shell-making organisms. * Analyze an equation showing the effect of an acid on carbonate ion.
* Analyze scenes in video showing process of ocean acidification.
* Begin research on ways to reduce carbon dioxide emissions into the atmosphere.
 | * Shell-making organisms need to combine calcium ions with carbonate ions to produce calcium carbonate shells.
* The proton from the carbonic acid combines with carbonate ion to form bicarbonate ion which the shell-making organisms cannot use.
* There are many ways to reduce the burning of fossil fuels so that less carbon dioxide is produced, and the rate of ocean acidification can be slowed.
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| **11 – *Neutralizing an Acid***One class period | Is it possible to add a substance to a solution to make it less acidic, and could this be used to reverse the process of ocean acidification? | Students explore using a base to neutralize an acid and consider whether this might be a practical solution for the problem of ocean acidification. * Use sodium carbonate solution to neutralize a citric acid solution.
* Investigate how the concentration of citric acid affects the amount of sodium carbonate solution required to neutralize it.
 | * A base can neutralize an acid.
* The more acidic a solution is, the more base is required to neutralize it.
* Even though a base can neutralize an acid, adding base to the ocean is probably not a practical way of solving the problem of ocean acidification.
* The most practical way of dealing with ocean acidification is to reduce the amount of carbon dioxide entering the atmosphere by reducing the burning of fossil fuels.
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| **12 – *Ocean Acidification Public Education Project***One class period | How can we take everything we now know and make a clear and organized presentation to the public about the problem of ocean acidification? | Students **use data and observations** to **explain** and **communicate** how the Lava Lamp works with an **annotated model**.* Summarize evidence
* Model entire explanation
* Celebrate success
 | Answering the question, “How does a Lava Lamp work?”, is complex endeavor tying together concepts of energy, structure and function of a system and cause and effect which result in predictable patterns. |