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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. |
| **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. |
| **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. |
| **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. |
| **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. |
| **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. |
| **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. |
| **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. |
| **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. |
| **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. |
| **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. |
| **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. |