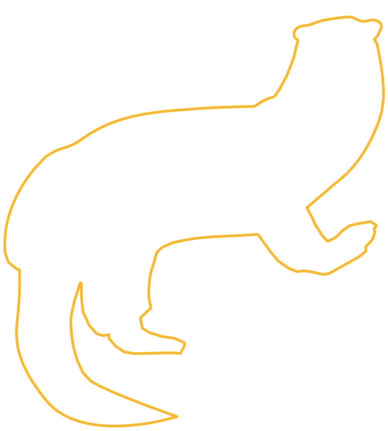
Family Fun

The Chemistry of Ocean Acidification

Enduring Understanding: The chemistry of our oceans is changing on a molecular level, and it is important to understand the process.

Materials

• "The Chemistry of Ocean Acidification" worksheet
• Paper to display
• Writing materials



Setup:

1. Print "The Chemistry of Ocean Acidification" worksheet.
2. Write Le Chatelier's principle on a paper you can display somewhere (see Glossary).
3. Prepare writing materials.

Program outline:

What is ocean acidification?

- Ocean acidification is the term given to the changing chemistry of our oceans. Human carbon emissions have increased the concentration of CO_2 in the atmosphere. Post Le Chatelier's principle somewhere in the room and ask your student to describe what they believe occurs as the atmospheric CO_2 concentration increases.
  - Because the concentration of CO_2 in the atmosphere is higher than it is in the oceans, this extra CO_2 is absorbed by seawater. As a result, the oceans are becoming more acidic and less alkaline.

Chemical equations of ocean acidification

- Introduce the chemistry behind ocean acidification by having your students write out and balance the equation below, as well as predict the products when only given the reagents, or vice versa. Verbally explain the process and then give them the equation with missing elements so that they can fill in the blanks and describe the equation in their own words. To simplify the process, you may want to break down each of the equations rather than giving it as a whole.

Program outline continued:

- Ocean acidification chemical equations

$$CO_{2\,(aq)} + H_2O <=> H_2CO_3 <=> HCO_3^- + H+ <=> CO_3 2^- + 2\,H^+$$

- Step by step explanation
  - Carbon dioxide (CO_2) from the atmosphere reacts with water (H_2O) to form carbonic acid (H_2CO_3), which then dissociates to form bicarbonate (HCO_3^-) and hydrogen ions (H^+).
  - Seawater is naturally saturated with carbonate ions (CO_3^{2-}), a base that acts like an antacid to neutralize the H^+, forming more bicarbonate.
- Example problems

$$CO_{2\,(aq)} + \_\_\_\_\_\_ <=> H_2CO_3 <=> HCO_3^- + \_\_\_\_\_\_ <=> CO_3^{2-} + \_\_\_\_\_\_ H^+$$

$$CO_{2\,(aq)} + \_\_\_\_\_\_ <=> H_2CO_3$$

$$H_2CO_3 <=> HCO_3^- + \_\_\_\_\_\_$$

$$HCO_3^- + H^+ <=> CO_3^{2-} + \_\_\_\_\_\_ H^+$$

$$HCO_3^- + H^+ <=> \_\_\_\_\_\_ + 2\,H^+$$

Understanding the steps

$$CO_{2\,(aq)} + H_2O <=> H_2CO_3$$

- When CO_2 is added to seawater, the carbonic acid is an intermediate step and is present only in small amounts. Therefore, we can represent this first part of the equation as

$$CO_{2\,(aq)} + H_2O <=> HCO_3^- + H^+$$

- What happens when we increase the concentration of CO_2 in this reaction (such as when the atmospheric CO_2 increases)?
  - The forward reaction is favored in order to maintain equilibrium. Seawater is weakly buffered with respect to changes in hydrogen ions, and there will be a much larger proportional change in the concentration of H^+ than HCO_3^-.
  - The excess H^+ is used up in another reaction:

$$CO_3^{2-} + H^+ <=> HCO_3^-$$

- What is the net effect when CO_2 is added to seawater?
  - The concentration of H^+ and HCO_3^- increases, while the concentration of CO_3^{2-} decreases.

Program outline continued:

- This net reaction for all the equations above can be represented by the following equation.

$$CO_{2\,(aq)} + H_2O + CO_3^{2-} <=> 2HCO_3^-$$

- It's important to remember that the H^+ increases proportionally to the ratio between the concentrations of HCO_3^- and CO_3^{2-}. The increase in H^+ concentration is what causes ocean acidification, where the decrease in concentration of naturally occurring CO_3^{2-} is the main threat to calcifying marine organisms.

Background information:

Chemistry of Ocean Acidification

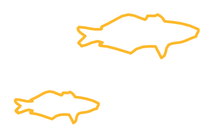
Atmospheric CO_2 is absorbed by ocean water. It reacts with H_2O to form carbonic acid, a corrosive chemical that can degrade the shells of marine organisms. The more immediate concern with ocean acidification is the availability of carbonate. Numerous marine species rely on naturally occurring carbonate to build their calcareous structures. Ocean acidification decreases the availability of carbonate, making it harder for these organisms to produce a calcareous structure. Their shells and skeletons become thinner and weaker, making them more vulnerable to predation, competition, and harsh elements. They use more metabolic energy to try and build shells, so they have less energy available for basic survival needs, such as finding food and shelter. Many scientists fear that ocean acidification could eventually decrease marine biodiversity on a large scale.

Ocean acidification equation:

$$CO_{2\,(aq)} + H_2O \Leftrightarrow H_2CO_3 \Leftrightarrow HCO_3^- + H^+ \Leftrightarrow CO_3^{2-} + 2\,H^+$$

Carbon dioxide (CO_2) reacts with water (H_2O) to form carbonic acid (H_2CO_3), which then dissociates to form bicarbonate (HCO_3^-) and hydrogen ions (H^+). Seawater is naturally saturated with carbonate ions (CO_3^{2-}) a base that acts like an antacid to neutralize the H^+, forming more bicarbonate.

The net reaction for this equation:

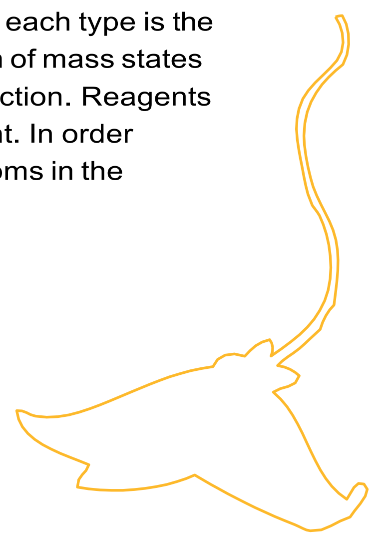


$$CO_{2\,(aq)} + H_2O + CO_3^{2-} \Leftrightarrow 2HCO_3^-$$

where H^+ increases proportionally to the ratio between the concentrations of HCO_3^- and of CO_3^{2-}. The increase in H^+ concentration is what causes ocean acidification, where the decrease in concentration of naturally occurring CO_3^{2-} is the main threat to calcifying marine organisms.

Balancing Chemical Equations

A chemical equation is balanced when the number of atoms of each type is the same on each side of the equation. The law of the conservation of mass states that you cannot make or destroy atoms during a chemical reaction. Reagents are on the left side of an equation and products are on the right. In order to balance an equation, you must have the same number of atoms in the products as in the reagents.



glossary:

Calcareous: Adjective meaning mostly or partly composed of calcium carbonate

Calcification: Process by which marine organisms sequester carbonate and calcium to form calcium carbonate shells and skeletons

Chemical Equation: Written representation of a chemical reaction in which the symbols and amounts of the reactants are separated from those of the products by an equal sign, arrow, or a set of opposing arrows

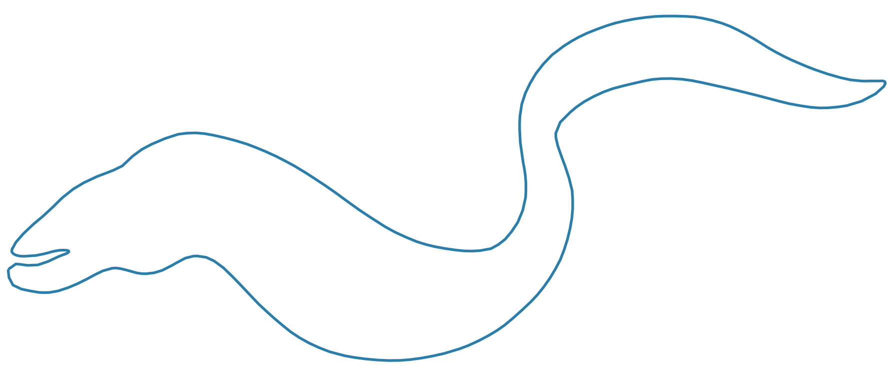
Le Chatelier's Principle: When a system at equilibrium is subjected to change in concentration, temperature, volume, or pressure, then the equilibrium readjusts itself to counteract the effect of the applied change and a new equilibrium is established; also known as "The Equilibrium Law."

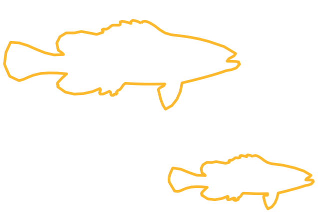
Ocean Acidification: Reduction in pH of seawater caused by the absorption of carbon dioxide (CO_2) from the atmosphere

Products: Substance that is formed as the result of a chemical reaction

Reactants: Substance that takes part in and undergoes change during a chemical reaction

Sequester: The act of forming a chelate or other stable compound with an ion, atom, or molecule so that it is no longer available for reactions





Name:______________________

Date: ______________________

The chemistry of ocean acidification

According to what you read above, what does ocean acidification mean? Why is it occurring?

Determine the missing reactants and products and balance the following equations:

$$CO_{2\,(aq)} + \_\_\_\_\_\_ \Leftrightarrow H_2CO_3\,H$$

$$CO_2 \;{}_3 \Leftrightarrow HCO_3^- + \_\_\_\_\_\_$$

$$HCO_3^- + H^+ \Leftrightarrow CO_3^{2-} + \_\_\_\_\_\_ H^+$$

$$HCO_3^- + H^+ \Leftrightarrow \_\_\_\_\_\_ + 2\,H^+$$

Using proper nomenclature, describe the chemical equations above.

Breaking down the steps:

$$CO_{2\,(aq)} + H_2O \Leftrightarrow HCO_3^- + H^+$$

Using Le Chatelier's principle, describe what happens when we increase the concentration of CO_2 in the reaction above.

Where does the excess H^+ end up?

What is the net reaction for ocean acidification?