Balancing the Ocean

Georgia Standards of Excellence:

- SC3. Obtain, evaluate, and communicate information about how the Law of Conservation of Matter is used to determine chemical composition in compounds and chemical reactions.

  a. Use mathematics and computational thinking to balance chemical reactions (i.e., synthesis, decomposition, single replacement, double replacement, and combustion) and construct an explanation for the outcome of a simple chemical reaction based on the outermost electron states of atoms, trends in the periodic table, and knowledge of the patterns of chemical properties.

Next Generation Science Standards:

- HS-PS1-7 Use mathematical representations to support the claim that atoms, and therefore mass, are conserved during a chemical reaction

Learning Objective:

- Students will use stoichiometry to create a balanced equation.

Essential Question:

- How do some organisms use chemistry to sustain life in the ocean?

Key Vocabulary:

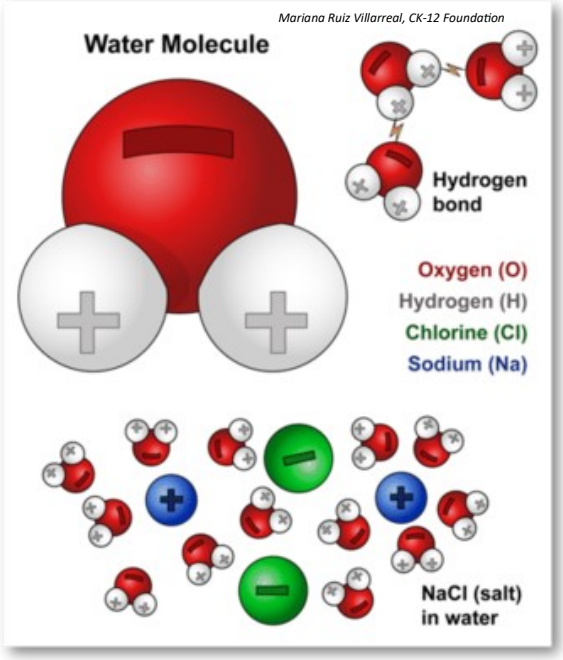
- Compound
- Ions
- Ionic Bond
- Covalent Bond
- Carbonic Acid
- Calcium Carbonate
- Phosphate

Materials:

- Balancing the Ocean Worksheet
- Pencil

Balancing the Ocean

Background Information (page one):

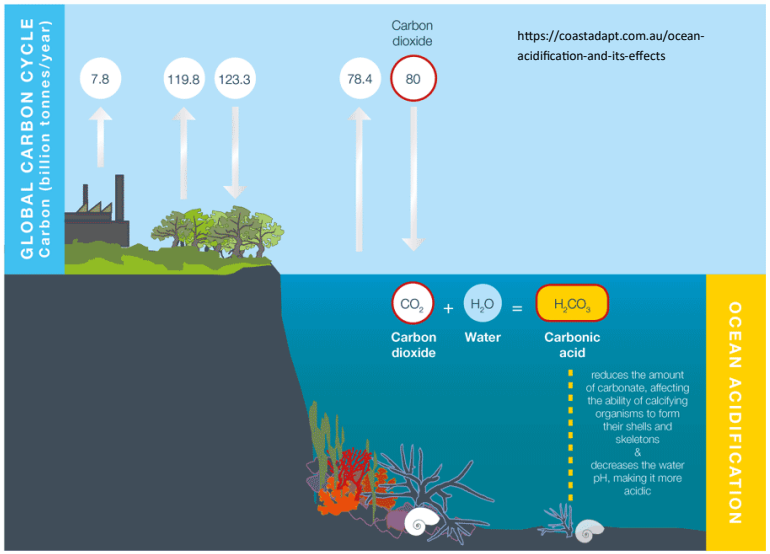


Water is one of the most versatile solvents, being able to dissolve a wide array of chemicals. It is water's chemical composition and physical attributes that make it such an excellent solvent. Water molecules have a polar arrangement of oxygen (negatively charged), and hydrogen (positively charged) atoms. Water can become so heavily attracted to a different compound, like salt (NaCl), that it can disrupt the attractive forces that hold the sodium and chloride in the salt compound together and, thus, dissolve it. The bonds in salt compounds are ionic, the positive and negative are attracted the chloride ion (negatively charged) and the sodium ion (positively charged). Likewise, a water molecule is ionic in nature, but the bond is called covalent, with two hydrogen atoms both orienting themselves with their positive charge on one side of the oxygen atom, which has a negative charge. When salt is mixed with water, the salt dissolves because the covalent bonds of water are stronger than the ionic bonds in the salt molecules. Water molecules pull the sodium and chloride ions apart, breaking the ionic bond that held them together. After the salt compounds are pulled apart, the sodium and chloride atoms are surrounded by water molecules, as this diagram shows. Once this happens, the salt is dissolved, resulting in a homogeneous solution (USGS). Salinity levels vary in different types of bodies of water, with the ocean average salinity level at 34.4 g/L. For comparison river water salinity levels average 120 mg/L. Hydron, oxygen, sodium and chlorine are vital elements in creation of the ocean. The ocean is made up of many other elements and ions, but a few important ones are Chlorine (Cl), Sulphate (SO_4), bicarbonate (HCO_3), bromine (Br), borate (H_2BO_3), fluoride (F), sodium (Na), magnesium (Mg_2) calcium (Ca_2), potassium (K), strontium (Sr_2), silicon (Si) and finally, the most important and abundant inorganic ions are nitrate (NO_3) and phosphate (PO_4). The ocean also absorbs much of the gases, particularly carbon dioxide, from the atmosphere to facilitate essential organic processes.

Balancing the Ocean

Background Information (page two):

Many marine organisms perform chemical processes on a regular basis and as a necessary part for living. The ocean has plants and phytoplankton performing photosynthesis to remove carbon dioxide and results in sugar and oxygen. Many animals will create shells or skeletons based on calcium. Since the industrial revolution, humans have proceed an exceeding and expanding rate of carbon dioxide. The sudden (on a geological timescale), and continuing, two-century injection of carbon dioxide into this chemical system has upset the balance. This imbalance is having an impact on calcium structure based marine life such as coral and shell builders. Calcium ions will bond with the dissolved bicarbonate to form calcium carbonate ($CaCO_3$). Calcium carbonate is the compound used by coral and shelled animals to create their structures. The net result of adding more carbon dioxide shifts the equilibrium concentrations to an increase in hydrogen ions, which creates a more acidic ocean, and a decreased availability of calcium carbonate and bicarbonate. If there becomes too great an excess of hydrogen ions it can also begin to dissolve existing calcium structures utilizing calcium carbonate.

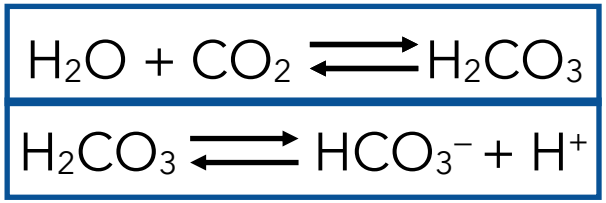


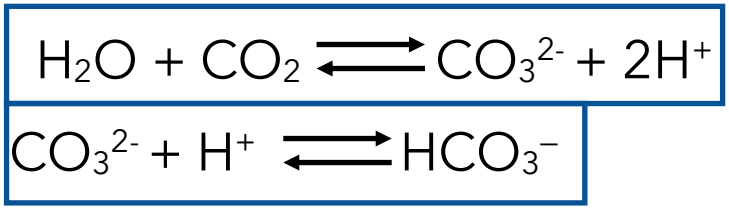
Corals and shelled animals aren't the only organisms performing chemical processes in the ocean. As mentioned, phytoplankton convert carbon dioxide into oxygen and sugars. The phytoplankton require nutrients, particularly nitrogen and phosphorus, just like plants on land. Jellies can help provide these nutrients by excreting ammonium (NH_4^-) and phosphate (PO_4^{3-}). As the waters are heating, jellies mature faster and appear to be creating "jellyfish blooms" more frequently. These blooms increase the ammonium and phosphate levels in the water as well as organic carbon. Jellies then indirectly increase the nutrients for phytoplankton. Once these massive blooms have died off they have the potential to lower the pH level creating a temporary higher acidity and lower dissolved oxygen leading to hypoxic conditions (Qu, Song and Li).

Balancing the Ocean

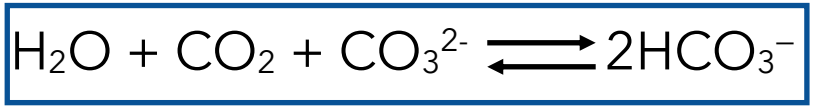
Activity Instructions:

1. Cover the first page background information with students.
2. Ensure they have a grasp on ionic and covalent bonds as well as the effects of dissolution in water.
3. Explain to the students, writing the formulas on the board, that the ocean absorbs carbon dioxide dissolved in water to form carbonic acid or carbonate ions. The carbonic acid can then dissolve further into bicarbonate and hydrogen ions. Additionally, carbonate ions are attracted to the hydrogen ions creating bicarbonate ions.





4. All those processes can be simplified into one oceanic inorganic synthetic compound formula. Ensure students understand why all the above equations are considered balanced.



5. Inform the students they will have their own chance at writing and balancing a chemical equation.
6. Go over second page of background information and hand out worksheet of chemical equations to be balanced.

Balancing the Ocean

Evaluate:

Review student answers and as a class go over the correct answers with thorough explanations.

References and Extensions:

The second page of the background section covered animals using calcium carbonate to create shells and structures. Utilize the Woods Hole Oceanographic Institute's website for an interactive demonstration of these chemical processes.

"Ocean Chemistry." *American Chemical Society,"* accessed 8/10/2020. https://www.acs.org/content/acs/en/climatescience/oceansicerocks/oceanchemistry.html

Flos, Jordi. "The Carbon Carbonate System," in "Oceanography: A Key to Better Understanding our World." Universitat de Barcelona & Fundació Navegació Oceànica Barcelona, Coursera.org 2018. Online Class. https://www.coursera.org/learn/oceanography/home/welcome

Balancing the Ocean

Name: _____

Directions: Using the background information complete and balance the chemical equations.

Phytoplankton performs photosynthesis.

$$\_\_CO_2 + \_\_H_2O \longrightarrow \_\_ C_6H_{12}O_6 + \_\_O_2$$

Coral utilizes ions in the water to form it's skeleton. Fill in the missing ion and balance the equation.

$$\_\_Ca^{2+} + \_\_\_\_\_ \longrightarrow \_\_\_ CaCO_3 + H^+$$

Increased levels of carbon dioxide are acidifying the ocean. Fill in carbon dioxide and balance the equation.

$$\_\_H_2O + \_\_\_\_\_ + \_\_CaCO_3 \longrightarrow \_\_H_2CO_3 + 3CaCO_3$$

Jellies are frequently excreting two ions, fill in the missing ions.

$$3\_\_\_\_ + \_\_\_\_\_ \rightleftharpoons (\_\_\_\_)_3\_\_\_\_$$

Redfield's Ratio states that there is a the consistent atomic ratio of carbon, nitrogen and phosphorus found in marine phytoplankton and throughout the deep oceans. Balance the respiration equation:

$$(CH_2O)_{106}(NH_3)_{16}H_3PO_4 + 138O_2 \longrightarrow 106CO_2 + 122H_2O + \_\_\_HNO_3 + \_\_\_H_3PO_4$$

Balancing the Ocean

KEY

EDUCATION
GEORGIA AQUARIUM

Directions: Using the background information complete and balance the chemical equations.

Phytoplankton performs photosynthesis.

$6\ CO_2 + 6\ H_2O \longrightarrow 1\ C_6H_{12}O_6 + 6\ O_2$

Coral utilizes ions in the water to form it's skeleton. Fill in the missing ion and balance the equation.

$1\ Ca^{2+} + HCO_3^- \longrightarrow 1\ CaCO_3 + H^+$

Increased levels of carbon dioxide are acidifying the ocean. Fill in carbon dioxide and balance the equation.

$1\ H_2O + CO_2 + 3\ CaCO_3 \longrightarrow 1\ H_2CO_3 + 3CaCO_3$

Jellies are frequently excreting two ions, fill in the missing ions.

$3\ NH_4^+ + PO_4^{-3} \rightleftharpoons (NH_4)_3PO_4$

Redfield's Ratio states that there is a the consistent atomic ratio of carbon, nitrogen and phosphorus found in marine phytoplankton and throughout the deep oceans. Balance the respiration equation:

$(CH_2O)_{106}(NH_3)_{16}H_3PO_4 + 138O_2 \longrightarrow 106CO_2 + 122H_2O + 16\ HNO_3 + 1\ H_3PO_4$