

CHEMISTRY

Chemical Reactions in the Marine Environment

Introduction

Stoichiometry is a core topic in introductory chemistry courses. It is often taught without practical applications. However, marine science offers many concrete examples of chemical reactions that can be used to write and balance equations. These reactions can be developed and easily explained to students. This approach provides students with an understanding of ocean processes and a framework for learning about chemical reactions.

This section contains background information for teacher lectures and student activities. The exercises and information are designed to be used as is or in parts. They vary in complexity. The list of elements can be used as individual examples when discussing chemical symbols, element names and the periodic table.

The first student activity involves naming elements and writing chemical symbols. The questions in this activity are good for review or test questions. The second activity offers equations to balance and an explanation of how the reactions these equations represent are important to the marine environment. These reactions would be good as a review worksheet or as test questions. The remainder of the exercises are lab activities.

Teacher Background Information

Below are elements and compounds important to the marine environment (Table 1).

Elements

Alkali metals—are major ions in seawater. They lack chemical reactivity in solution and exist mainly as cations. Sodium and potassium ions have long residence times. Residence time is the length of time a particle or substance spends in the ocean.

Calcium—is a major ion in seawater. It is concentrated in deep waters because of the abundance of calcium carbonate shells on the ocean floor. Clams have calcium carbonate shells. But below 4,000 meters calcium carbonate dissolves because its solubility increases in cold water. Thus calcium carbonate is commonly found topping seamounts, like snow on a mountain, and forms a "snow line" called the CCD line (carbonate compensation depth).

Strontium—is also a major ion in seawater. Its concentration is affected by absorption into living organisms.

Aluminum family—have short residence times in seawater. Aluminum is the most abundant, but the others in this family are low in abundance. Coastal waters have higher concentrations of thallium than ocean waters. Scientists cannot explain this trend, but they have observed it in numerous areas.

Germanium—has been found in high concentrations around hydrothermal vents. Hydrothermal vents are hot water springs on the sea floor. They are located near rifts, or breaks, in the ocean floor and cause a change in the temperature and chemistry of nearby seawater.

Nitrogen and phosphorus—are micronutrients. In seawater, nitrogen occurs in nitrates or ammonia, and phosphorus is found in phosphates.

Arsenic—has some chemical similarities to phosphorus. It may play a similar role to phosphates in metabolic processes. It is also known to interfere with conventional phosphate analysis through the formation of a molybdenum blue color.

Polonium—is concentrated by marine organisms. Because polonium's isotopes are radioactive, it is a good natural tracer of feeding pathways for marine animals.

Selenium—is quickly removed from seawater. Although toxic to organisms at high concentrations, at lesser concentrations it can be beneficial.

Chlorine—is abundant in the ocean. Historically, the amount of chloride ion in seawater has been used to determine salinity levels. Now, it is added to water as a disinfecting agent. However, the large input of chlorine by industry and water treatment plants may alter marine food chains, affecting larval organisms and small fish. Chlorine is also very reactive with organic compounds forming potentially dangerous chlorinated hydrocarbons.

Cadmium—a heavy metal, is a pollutant in the ocean. It is taken up by shellfish and in excess may cause a debilitating disease in humans.

Copper—is a metal found in the blood of crabs that is analogous to the iron in hemoglobin. It is used as an anti-fouling agent in marine paints for boats. When

found in high concentrations, it is toxic to marine animals.

Vanadium—is a trace element found in the blood of creatures such as sea squirts and sea cucumbers. The concentration of vanadium in these animals is 106 times greater than in seawater. Research shows that it probably acts as an anti-predator agent.

Cobalt—is a trace metal found in lobsters and mussels.

Nickel—is a metal found in mollusks such as clams.

Iodine—is found concentrated in seaweeds.

Magnesium—is the eighth most abundant element in the earth's crust and the third most abundant element in seawater.

Manganese—forms metal nodules on the ocean floor. They grow slowly (10 to 200 millimeters per one million years) around a nucleus such as a shark's tooth.

Mercury and lead—are enzyme poisons. In high concentrations, they can contaminate and kill fish and shellfish. These metals affect the neurological system of humans.

Compounds

Magnesium sulfate—is important acoustically. Its concentration in seawater affects the transmission of sound.

Carbonic acid and boric acid—act as buffers in the marine environment.

Silicon dioxide—is used by many organisms to make skeletal structures.

Calcium carbonate—is absorbed by many organisms and secreted as a protective shell or skeleton. Organisms that use calcium carbonate include shellfish, corals and some tropical algae.

Table 1. 44 Trace Elements Found in Seawater and Their Concentrations

Element	Concentration (PPB)*	Element	Concentration (PPB)
Carbon	200-3000	Cobalt	0.2-0.7
Lithium	170	Mercury	0.15-0.27
Rubidium	120	Silver	0.145
Barium	10-63	Chromium	0.13-0.25
Molybdenum	4.0-12.0	Tungsten	0.12
Selenium	4.0-6.0	Cadmium	0.11
Arsenic	3.0	Manganese	0.1-8.0
Uranium	3.0	Neon	0.1
Vanadium	2.0	Xenon	0.1
Nickel	2.0	Germanium	0.07
Iron	1.7-150	Thorium	0.05
Zinc	1.5-10	Scandium	0.04
Aluminum	1.0-10	Bismuth	0.02
Lead	0.6-1.5	Titanium	0.02
Copper	0.5-3.5	Gold	0.015-0.4
Antimony	0.5	Niobium	0.01-0.02
Cesium	0.5	Gallium	0.007-0.03
Cerium	0.4	Helium	0.005
Krypton	0.3	Beryllium	0.0005
Yttrium	0.3	Protactinium	2×10^{-6}
Tin	0.3	Radium	1×10^{-7}
Lanthanum	0.3	Radon	0.6×10^{-12}

*Note all values in parts per billion.

ACTIVITY 1

Elements and Compounds in the Ocean

Purpose

To review chemical symbols and teach elements and compounds found in the marine environment.

Procedure

For each marine example, you will need to write the chemical symbol or name for the element(s) listed.

1. North Carolina has several large estuaries (Figure 1). Estuaries are partially enclosed bodies of water where seawater is diluted by fresh water that drains from the land. These estuaries act as filtering systems to remove some chemical elements and compounds from land runoff. But many elements are not removed. Some of these are: Ag, Sb, Cr, Co, Rb, Cs, Se and Mo. Name these elements.

Figure 1 North Carolina estuaries



2. Anoxic, or oxygenless, environments in the ocean have many causes. One is pollution. In anoxic environments, the precipitation of the following metal sulfides occurs. Write the formula for each compound.

Copper (II) sulfide _____

Zinc sulfide _____

Mercuric sulfide _____

Silver sulfide _____

Cadmium (II) sulfide _____

Bismuth (III) sulfide _____

Lead (II) sulfide _____

3. Phytoplankton are single-celled plants moved by ocean currents. They absorb and accumulate metals in concentrations 103 times greater than is present in seawater. These metals are listed below. Name them.

Al _____ Nb _____

Pb _____ Cd _____

As _____ P _____

Mn _____ Ce _____

Be _____ Pu _____

Ni _____ Cr _____

C _____ Sc _____

Co _____ I _____

Ag _____ Zr _____

Cu _____ Fe _____

Zn _____

4. Zooplankton are tiny animals moved by ocean currents. Copepods, small crustaceans, are common zooplankters. Food availability is greatest for zooplankton that live in surface waters because of light penetration. As a result they grow faster and molt more frequently than zooplankton at greater depths. This increase in frequency of molts decreases the time available for absorption of metals. Notice the variability in metal concentration in surface and deep water zooplankton (Table 2). Write the correct symbol for each metal.

Table 2.

Variations in the elemental composition of zooplankton from surface and deep (>99m) waters (Riley, 1975).

Element	Concentration (ug/g ash)*	
	Surface	Deep
Lead	117	183
Zinc	657	1,909
Iron	2,900	4,200
Cadmium	16	15
Cobalt	44	37
Copper	115	132
Nickel	100	150
Manganese	< 70	88
Strontium	890	1,140
Calcium	103,900	105,000
Magnesium	45,700	46,200

*Ash is the soft solid residue left after combustion with the zooplankton.

5. One of the most extraordinary examples of anomalies in elemental composition is found in the hot brines of the Red Sea. The hot brines are located in a section of the Red Sea that evaporated millions of years ago leaving salt deposits on the ocean floor. Hot solutions, like those at hydrothermal vents, have worked their way through the ocean crust and have dissolved the salt, forming dense brines that pool in depressions on the ocean floor. Write the name for each element or ion found in the hot brine.

- Cl _____ Na _____
- Mg _____ Zn _____
- Br _____ Ca _____
- Sr _____ Cu _____
- SO₄²⁻ _____ K _____
- Fe _____ Co _____
- Si _____ Ni _____
- Mn _____ Pb _____

6. From 1872 until 1876, an English expedition known as the Challenger Expedition gathered and analyzed the chemical composition of 77 samples of seawater taken at various depths of the ocean all over the world. In 1884, William Dittmar reported the expedition's results (Table 3). Dittmar's results were so precise that it took scientists almost 80 years to get more exact data. Write the name for each ion or compound measured.

Table 3.

Dittmar's values for the major constituents of seawater (values in grams per kilogram, ppt) (Sverdrup, 1946).

Ion/Compound	Original Values	
	ppt	%
Cl ¹⁻	18.971	55.29
Br ¹⁻	0.065	0.19
SO ₄ ²⁻	2.639	7.69
CO ₃ ²⁻	0.071	0.21
HCO ₃ ¹⁻**
F ⁻**
H ₃ BO ₃**
Mg ²⁺	1.278	3.72
Ca ²⁺	0.411	1.20
Sr ²⁺	0.411	1.20
K ¹⁺	0.379	1.10
Na ¹⁺	10.497	30.59
TOTAL	34.311	

* (.....) means that no measurement was made!

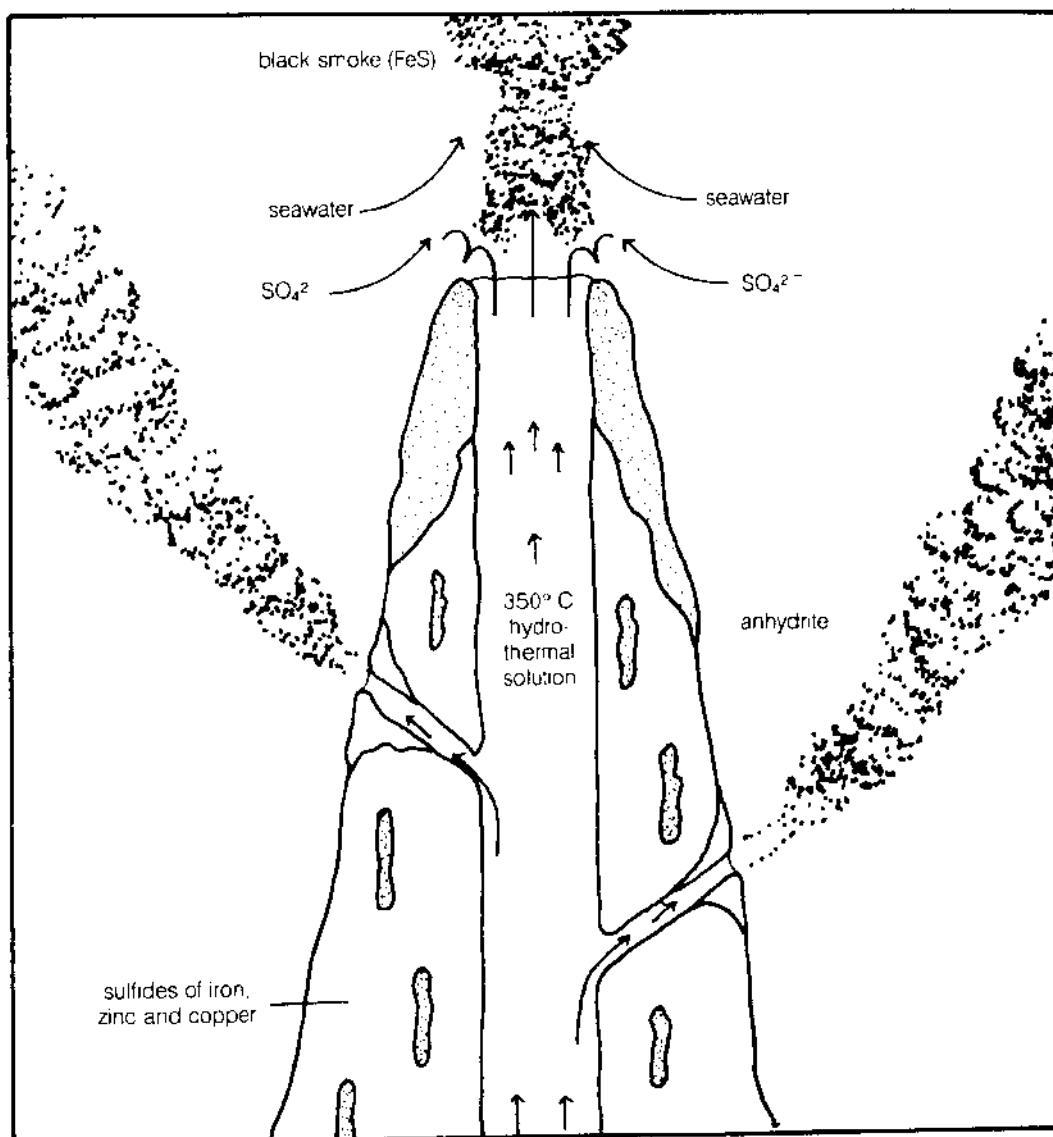
7. Manganese nodules have been found to be economically important sources of metals. Manganese nodules form slowly on the ocean floor. They contain large concentrations of manganese and iron, and smaller concentrations of nickel, copper and cobalt. Write the symbol for each of the metals found in the nodules.

8. Biological processes (photosynthesis, respiration, decomposition, etc.) involve the cycling of carbon, nitrogen and phosphorus. As these processes occur, carbon, nitrogen and phosphorus are usually found as CO₂, NO₃⁻, NH₃, NH₄⁺, PO₄³⁻ in the marine environment. Name these compounds and ions.

9. Studies have found active hydrothermal vents with water temperatures exceeding 350°C . These vents are called "black smokers" because the emissions contain sulfides that color them black (Figure 2). The sulfide mineralization occurs when very hot seawater circulates in the vents and leaches heavy metals and

sulfur from rocks below the sea floor. After coming in contact with cooler seawater, the metals and sulfur precipitate, producing deposits containing ferric sulfide, cuprous sulfide, zinc sulfide, silver sulfate and calcium sulfate. Write the formulas for these compounds.

Figure 2 Black smoker



ACTIVITY 2

Marine Chemical Reactions

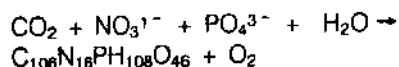
Purpose

To practice balancing chemical equations that describe marine reactions.

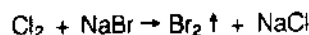
Procedure

Balance all equations in the problems below.

1. The formation of organic compounds in the ocean is an important process. This process uses carbon, nitrogen and phosphorus in a specific ratio called the Redfield ratio. Determine the ratio of atoms of C:N:P.



2. Scientists have determined ways to remove economically important metals from seawater. At Kure Beach, N.C., the first plant was built to extract bromine from seawater. (This plant is no longer in operation.) The reaction below occurs after the seawater is pumped into a plant. Chlorine is used to oxidize bromide into bromine gas.



3. The earliest recovery of bromine from seawater took place when the advent of leaded gasoline increased the demand for bromine. The following equation is another step in the process of extracting bromine from seawater. Bromine liberated in the reaction above diffuses into the surrounding air. The bromine-laden air passes into towers where it is absorbed by sodium carbonate. The products of this reaction are treated with sulfuric acid to liberate bromine.



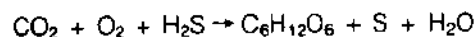
4. This is the equation for photosynthesis in plants.



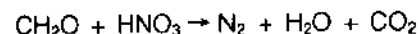
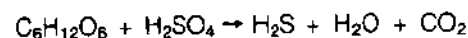
5. The equation below is blue-green algae photosynthesis in bacteria and cyanobacteria. This process uses hydrogen sulfide instead of water as the hydrogen source.



6. The following equation is for chemosynthesis in bacteria. This process is similar to photosynthesis but uses hydrogen sulfide as an energy source instead of light. The discovery of hydrothermal vents gave this process ecological importance.

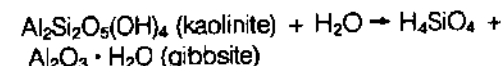
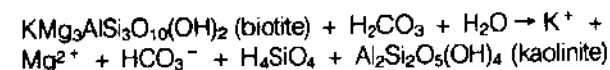
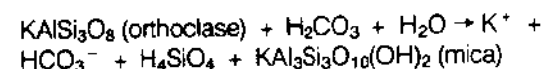
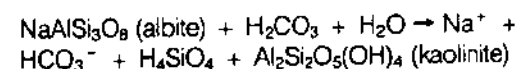
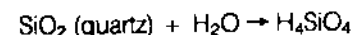


7. Bacteria are important to marine sediments. In sediment communities oxygen is used rapidly. Organisms living there are adapted to low oxygen levels, and they break down organic compounds without using oxygen. The next two equations show ways that bacteria break down organic compounds without using oxygen.

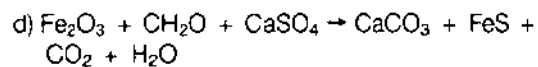
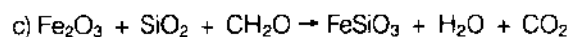
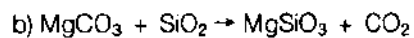
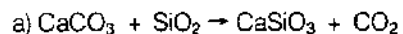


NOTE: CH_2O is the empirical formula for carbohydrates. It is the simplest form and makes balancing some equations easier.

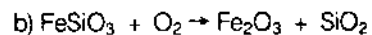
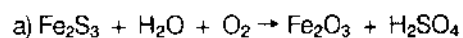
8. The next five equations describe the weathering (breakdown) of rocks containing silicon. This weathering process takes place primarily on land through the erosion of rocks by rainfall. Silicon becomes dissolved in the water and enters rivers, then estuaries, and finally the ocean. Knowledge of these five equations is the result of silicon studies performed in estuaries.



9. The chemical cycles of almost every major element found in the earth's crust involves carbon dioxide. The following equations are reactions that are part of the cycling of calcium, magnesium, iron and iron silicates through the marine environment.



10. The next two reactions are part of element cycling but involve oxygen in the reaction instead of carbon dioxide.



ACTIVITY 3

Identification of Halide Ions**Purpose**

To observe four chemical reactions between solutions of halide compounds and silver nitrate, and to use the results of those reactions to determine which halide ions are present in "unknown" solutions.

Background

The ocean is a practical example of elements existing as ions in water. Ions of elements in Group 1A, particularly sodium and potassium are found in seawater. All halogens, except for astatine, exist as ions in the ocean. The hot brines of the Red Sea contain chloride, bromide, sodium and potassium ions. Nitrogen is a micronutrient in the ocean and occurs in nitrate ions.

When salts dissolve in water they break into positive and negative ions. Negatively charged ions (other than polyatomic ions) have an "ide" ending on their names. Negative ions in the halogen group are collectively called halide ions. Chemical reactions can be used to determine the identity of ions in a solution.

Equipment/Materials

0.10 M sodium chloride
0.10 M sodium fluoride
0.10 M sodium iodide
0.10 M sodium bromide
0.10 M silver nitrate
notebook paper
glass plate
6 unknown halide ion solutions

CAUTION: Do not begin this lab until your teacher has given you safety instructions and cautions for each chemical. Wear eye and clothing protection. Silver nitrate temporarily stains human skin brown and decomposes when exposed to light.

Procedure**Section 1 / Reactions of Halide Compounds with Silver Nitrate**

Place a well-cleaned glass plate on a sheet of notebook paper. On the notebook paper beside each of the four corners of the glass plate, write one of the halide compound formulas.

Put two drops of the appropriate halide solution on each labeled corner of the glass plate. Then add two drops of silver nitrate solution to each of the four solutions already on the plate.

Write your observations of the four reactions in a data table. This will be Table 1. Be sure to give it a title.

Section 2 / Identifying Halide Ions in Unknown Solutions

Now you are ready to determine which halide ion is present in unknown solutions. Thoroughly clean your glass plate. Add two drops of silver nitrate to two drops of unknown solution #1 on the plate. Write your observations of this reaction in a new data table. This will be Table 2.

Use your observations from Table 1 to determine which halide ion is present in unknown solution #1. You have four possibilities: chloride, fluoride, iodide or bromide. There will be only one halide ion in each unknown solution.

Once you have determined the halide ion present in unknown #1, record the answer (by using the symbol of the ion and a negative charge) in Table 2 beside your observation. (NOTE: Halide ions are not diatomic. Do not use a subscript beside the ion symbol.)

Repeat the procedure above until you have identified the halide ions in all six unknown solutions. Record the observation and identification data for all unknowns in Table 2.

Questions

1. Write balanced equations for the chemical changes (reactions) that occurred in section 1.
2. Write the names and formulas for the three water-insoluble silver compounds (precipitates) produced in section 1.
3. Write the name and formula for the one water-soluble silver compound produced in section 1.
4. Is silver nitrate soluble in water?
5. Is sodium nitrate soluble in water?
6. Sodium fluoride, sodium iodide, sodium chloride and sodium bromide are all (soluble, insoluble) in water.

7. All compounds containing (silver, nitrate) are water soluble.
8. All compounds containing (sodium, silver) are water soluble.
9. All halide ions have a (negative, positive) charge.
10. What are the colors of the following compounds?
- (a) silver chloride
 - (b) silver bromide
 - (c) silver iodide
11. Mention two sources of error in this experiment and ways to correct them.
12. I have a bottle of acid that has no label. It is hydrochloric or hydrofluoric acid. These two acids are water solutions. I added a few drops of silver nitrate to a small portion of the acid in question. A white precipitate formed. Now I know the identity of the acid. Is the acid hydrofluoric or hydrochloric?
13. How did I know the identity of the acid in the questions above? HINT: Acids break into ions when they are in water solution just as salts do.
14. What is the most abundant halide ion found in the ocean?
15. What are the two most abundant ions in the ocean?

ACTIVITY 4

Magnesium and its Compounds**Purpose**

To produce and observe some compounds of magnesium.

Background

Magnesium (along with bromine, sodium chloride, natural gas, petroleum, sulfur and manganese nodules) is one of the substances that is currently being extracted from seawater. Magnesium is the third most abundant element in seawater and the eighth most abundant in the earth's crust. Zooplankton take up magnesium, particularly at greater depths. Magnesium is found in the hot brines of the Red Sea. The presence of magnesium sulfate affects the transmission of sound in the ocean.

Equipment/Materials

magnesium ribbon
 crucible tongs
 watch glass
 phenolphthalein
 test tube
 Bunsen burner
 hydrochloric acid (1.0 M)
 Bunsen burner lighter
 sodium hydroxide solution (1.0 M)
 test tube rack
 magnesium sulfate solution (sat'd)
 test tube holder

CAUTION: Do not begin this lab until your teacher has given you lab safety instructions and cautions for each chemical. Wear eye and clothing protection.

Procedure

Answer the questions and follow the instructions below.

1. Describe two physical properties of a piece of magnesium.

Hold a 3-cm strip of magnesium with crucible tongs and ignite it with a Bunsen burner. (CAUTION: Do not look directly at magnesium while it is burning because of the emission of ultraviolet light.) Hold the

magnesium above a clean watch glass. When the strip stops flaming, drop the burned piece on the watch glass. Keep this burned magnesium for later use.

2. Describe the state and color of the product of this reaction.

3. Write the balanced equation for the reaction above.

Moisten the magnesium oxide on the watch glass with a few drops of distilled water and add two drops of phenolphthalein.

4. What do you observe?

5. Is this solution acidic or basic?

6. Write the balanced equation for the reaction that has occurred. (Do not include phenolphthalein in your equation.)

Put 5 ml of dilute hydrochloric acid in a test tube and add a 3-cm length of magnesium ribbon. (Keep the test tube and contents for later use.)

7. Describe the reaction between magnesium and hydrochloric acid.

8. Write the balanced equation for the reaction in number 7.

Heat the test tube and contents (saved from above) gently with a very low flame. Move the test tube in and out of the flame slowly. Continue to heat gently until all the liquid evaporates.

9. Describe the residue left after the liquid evaporates.

10. Write the name and formula of the residue.

Place 3 cm of magnesium ribbon in a clean test tube with enough distilled water to cover the magnesium. Heat to boiling (use a test tube holder). Remove the test tube from the flame and observe the surface of the magnesium. CAUTION: Be careful not to burn yourself.

11. Was a gas formed in this reaction?

12. Add two drops of phenolphthalein to the test tube. What do you observe?

13. Is the solution acidic or basic?

14. Write a balanced equation for the reaction between magnesium and water. Do not include phenolphthalein in your equation.

In a test tube, combine 5 ml of magnesium sulfate and 5 ml of 1.0 M sodium hydroxide.

15. Describe what you observed after the two solutions were combined.

16. Write a balanced equation for this reaction. Be sure to show which product is insoluble in water (i.e. forms a precipitate).

ACTIVITY 5

Magnesium from the Sea**Purpose**

To separate a magnesium compound from seawater and write an appropriate balanced chemical equation for the reaction.

Background

Magnesium (along with bromine, sodium chloride, natural gas, petroleum, sulfur and manganese nodules) is one of the substances that is currently being extracted from seawater. Magnesium is the third most abundant element in seawater and the eighth most abundant in the earth's crust. Zooplankton take up magnesium, particularly at greater depths. Magnesium is found in the hot brines of the Red Sea. The presence of magnesium sulfate affects the transmission of sound in the ocean.

Equipment

250-ml beaker
100-ml graduated cylinder
1.0 M NaOH (41 g/l)
5.0 g MgSO₄
distilled water
stirring rod
balance
goggles
apron
centrifuge
centrifuge tubes

Caution: Do not begin this lab until your teacher has given you lab safety instructions and cautions for each chemical. Wear eye and clothing protection.

Procedure

Mass out 5.0 grams of magnesium sulfate, MgSO₄. Place 100 ml of distilled water in a 250-ml beaker. Dissolve the 5.0 grams of MgSO₄ in the water, stirring as needed. (Some of the MgSO₄ may not dissolve.) This solution will represent seawater. Answer question 1.

Add 30 ml of 1M sodium hydroxide, NaOH, to the beaker of seawater. CAUTION: Sodium hydroxide is corrosive. Avoid skin contact. Rinse spills with plenty of water. Answer question 2.

Carefully follow the instructions provided by your instructor for using a centrifuge. Should a centrifuge tube break, it can cause serious injury.

The centrifuge must be balanced when you are using it. Add 8 ml of the solution just mixed to a centrifuge tube. Label your tube for easy identification. Place it in the centrifuge across from another student's tube or another tube filled with 8 ml of water for balance.

Centrifuge the tube for at least two minutes. Allow the centrifuge to stop slowly. Do not stop the spinning head with your hand. Remove your tube and answer questions 3 to 6.

Questions

1. Describe the appearance of the seawater you prepared.
2. Describe the seawater after the addition of the sodium hydroxide.
3. What did you observe after the solution was in the centrifuge?
4. Write a balanced equation for the reaction of magnesium sulfate and sodium hydroxide.
5. The magnesium was concentrated from the seawater by a technique known as precipitation. What is the name of the precipitate?
6. How do you think the magnesium could be separated from the hydroxide to yield pure magnesium metal?

ACTIVITY 6

Biogeochemical Zonation**Purpose**

To illustrate the oxidizing agents at various depths in the ocean.

Background

Oxidation-reduction reactions involve the loss or gain of electrons from one atom, compound or ion to another. Better known as redox reactions, they include many naturally occurring reactions such as synthesis and decomposition that are important in maintaining life.

In photosynthesis, plants store chemical energy converted from solar energy. Other organisms eat plants to get this chemical energy. Chemically speaking, plants store energy in the bonds of the organic molecules they produce. This energy is released when the bonds are broken. This energy release, called cellular respiration, involves (among other reactions) the oxidation of carbon in organic molecules by an oxidizing agent.

In the mid-1970s, studies on respiration in marine sediments revealed distinct layers of microorganism communities. Each community uses a different oxidizing agent according to the efficiency with which it breaks bonds and its availability at different depths in the sediment.

This sequence of community layers is called biogeochemical zonation. "Bio" indicates the presence of living organisms that make the reaction go. The act of respiration involves chemical reactions; hence, the "chemical" part of the word. "Geo" refers to some mineral formation that occurs as a byproduct of these reactions.

In the top sediment layer, O_2 is the primary oxidizing agent. The use of different oxidizing agents at different depths results in different products being formed in each zone. This affects the chemistry of neighboring layers and the sediments as a whole.

On a global scale, oceans cover about 75 percent of the earth's surface, and sediments line a large percentage of the oceans' bottom. The chemistry of sediments has a large influence on the fate of important elements and related processes.

Materials

5 transparencies
1 large candy bar
1 small piece of candy
1 stick of chewing gum
1 small rock
tape

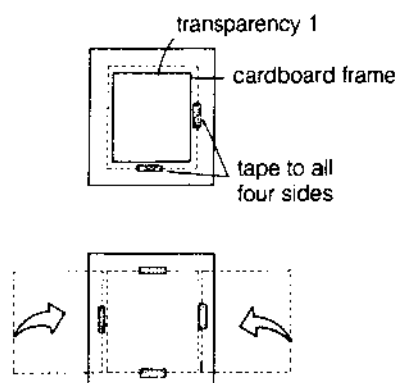
Procedure One

There are five sheets in this package that are intended to be xeroxed onto overhead transparency sheets. Transparency 1 is the base transparency. Tape it to a cardboard frame on all four sides.

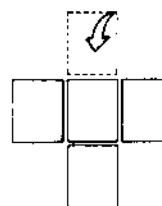
Tape each of the remaining transparencies, 2 through 5, to a different side of the frame. Put them in a clockwise order.

Use only one overlay at a time. After the base transparency is introduced, transparency 2 may be folded onto it. When finished with 2, return it to its original position and fold over 3. Continue this procedure.

Transparencies on cardboard frame



Tape remaining transparencies to frame in clockwise order.



Fold one transparency at a time over base transparency.

Transparency 1

This transparency provides a sectional view of the earth's surface that shows three major regions: atmosphere, water and sediment. These three regions have different properties (i.e. density, chemical composition, opacity). Think about how these differences will affect the movement of different sized objects, living and nonliving. How are animals adapted to move through each region? How would the properties of each region affect a steel ball's vertical movement? How would dissolved oxygen differ in each region?

Transparency 2

This transparency represents a schematic grouping of the major actors in photosynthesis and decomposition.

Microorganisms are very small (several microns in length) organisms that may be found on land or in water. There are many kinds. Some make their own food; others decompose dead things.

Phytoplankton is derived from "phyto" meaning plant. Plankton means wanderer. They are microscopic plants that float or are suspended in the water. Phytoplankton are found near the water's surface because they need sunlight for photosynthesis. They make their own food.

Zooplankton is derived from "zoo" meaning animal. They are microscopic animals that float or are suspended in the water. Zooplankton can exist in deeper water because they do not photosynthesize. They live where they can find food—other zooplankton and sometimes dead organisms. They also eat phytoplankton.

Larger organisms, such as fish, eat phytoplankton, zooplankton or each other. Fish inhabit a greater range because they can move to find food.

Transparency 3

This transparency illustrates a very simple ocean food chain. Zooplankton may consume phytoplankton, microorganisms or other zooplankton. Fish may consume phytoplankton, zooplankton or other fish. Marine microorganisms may consume one another, other dead organisms or small dissolved molecules. Microorganisms are a vital part of the decay process. They reduce organic matter back to nitrates and phosphates.

Transparency 4

Waste products and dead organisms drift through the water to the sediment. As they sink or collect in

the sediment, they are consumed by other organisms or decomposed by microorganisms. The matter that is not eaten is buried in the sediments.

Transparency 5

This transparency illustrates various redox reactions taking place in the water column and sediments. These reactions represent forms of respiration taking place. The equations show generic reactants and products. Many intermediate reactions are not shown. It is not unusual for reactions to stop at some midpoint rather than produce the completion products shown. This could be due to slow reaction, presence of inhibitors or competing reactions for same reactants.

If oxygen is unavailable and NO_3^- is available in the nitrate reduction and oxidation zones, animals, plants and organisms that use NO_3^- will dominate respiration. If NO_3^- and SO_4^{2-} are both present, NO_3^- will still dominate because it is thermodynamically more efficient. The transport of elements, ions and compounds is important in making reactions happen in different zones.

Notice that the reactions shown are not balanced and the number of organic molecules decreases with depth. The organic molecule quantities tend to decrease with depth because of continuous decomposition.

Procedure Two

The following is a simple student activity. It will illustrate how organisms use the oxidizing agents available to them at the level of the ocean in which they live.

Give the first student in a row in the classroom a tray on which you have placed a large candy bar, a smaller piece of candy, a stick of chewing gum and a small rock.

Tell the first student to take any item on the tray. Usually he or she will take the large candy bar.

The next student in the row is told to take any of the three items left on the tray. This student will likely take the smaller piece of candy. The third student will take the stick of gum, leaving the rock for the fourth student.

Students clearly see that organisms use (take) what is available to them. If several choices are available, organisms take the most desirable. Thus if several oxidizing agents are available in a sediment region, the most thermodynamically desirable one will be used.

Questions

Transparency 1

1. Name at least three forces that transport objects in each of three regions:

- (a) atmosphere
- (b) water
- (c) sediments

2. What force works in all three regions: atmosphere, water and sediments?

3. If the element silicon comes primarily from rocks found on land, how does it end up dissolved in the ocean?

4. Trace the pathway of a silicon atom as it starts in the sands of the Sahara Desert and ends up dissolved in the eastern Atlantic Ocean.

Transparency 2

The ocean, on average, is 3,800 meters deep; the photosynthetic zone is 100 to 200 meters deep.

1. Why do you think phytoplankton live in the photosynthetic layer of the ocean?
2. Why do you think zooplankton live in the photosynthetic layer of the ocean?

Transparency 3

Living organisms affect the fate of certain elements and compounds. Phytoplankton get their carbon from CO_2 and convert it to food (organic molecules) through photosynthesis.

1. Where do zooplankton get their carbon? How do fish satisfy their carbon needs?
2. When a fish eats zooplankton, what happens to the elements and compounds of the zooplankton?

Transparency 4

Elements and compounds are distributed throughout the ocean by living organisms that eat or filter materials containing compounds and elements. Upon death and decay of the organism, these chemicals are redistributed.

1. In what form does carbon exist in living organisms?
2. How does a carbon atom go from a CO_2 gas molecule in the atmosphere to:
 - (a) be dissolved in the surface layer of the ocean?
 - (b) a solid state at the surface layer of the ocean?
 - (c) a solid at the bottom of the ocean?

Transparency 5

The redox reactions represent respiration modes of decomposition.

1. In photosynthesis, organic molecules are made. Notice that deeper in the ocean there is less organic matter. How could you explain such a decrease?
2. Just because O_2 is used as an oxidizing agent at some depth, doesn't mean that other oxidizing agents are not present. They may even be used, but their use is not significant. What might take place if all the O_2 in an area were used up?
3. What would happen to dead matter if all the oxidizing agents were removed or used up? (This takes place when lots of organic matter is drained into a lake or pond. Organisms eat the organic matter, using up all the oxygen. Fish die because they need oxygen, resulting in more organic matter to eat and more consumption of oxidizing agents.)

Transparency 1

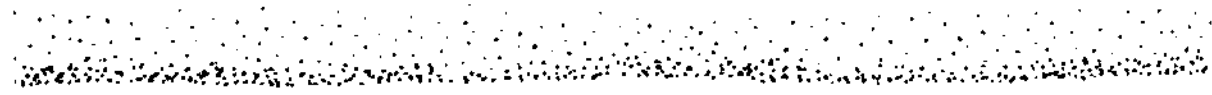
Somewhere in the ocean...

ATMOSPHERE



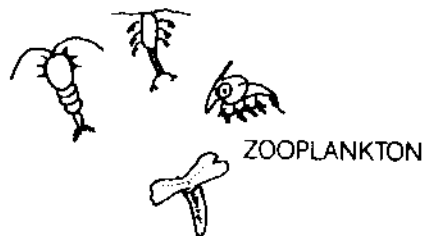
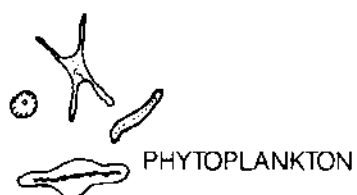
WATER

SEDIMENT

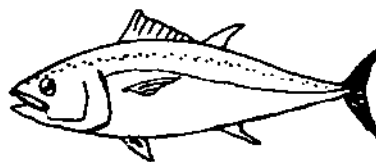


Transparency 2

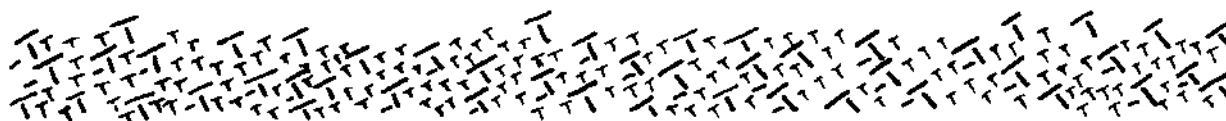
...live all kinds of organisms...



LARGER ORGANISMS

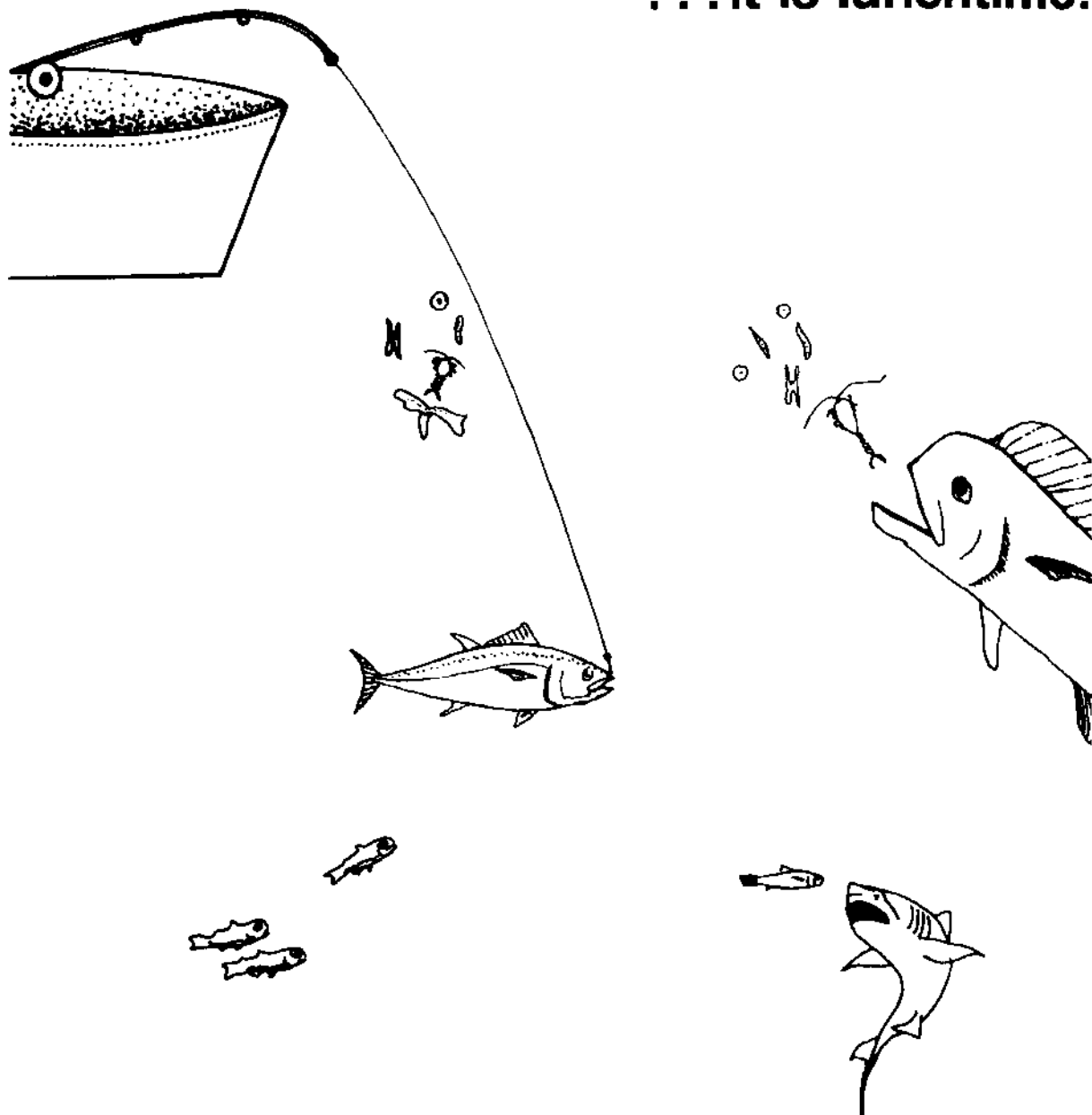


MICROORGANISMS



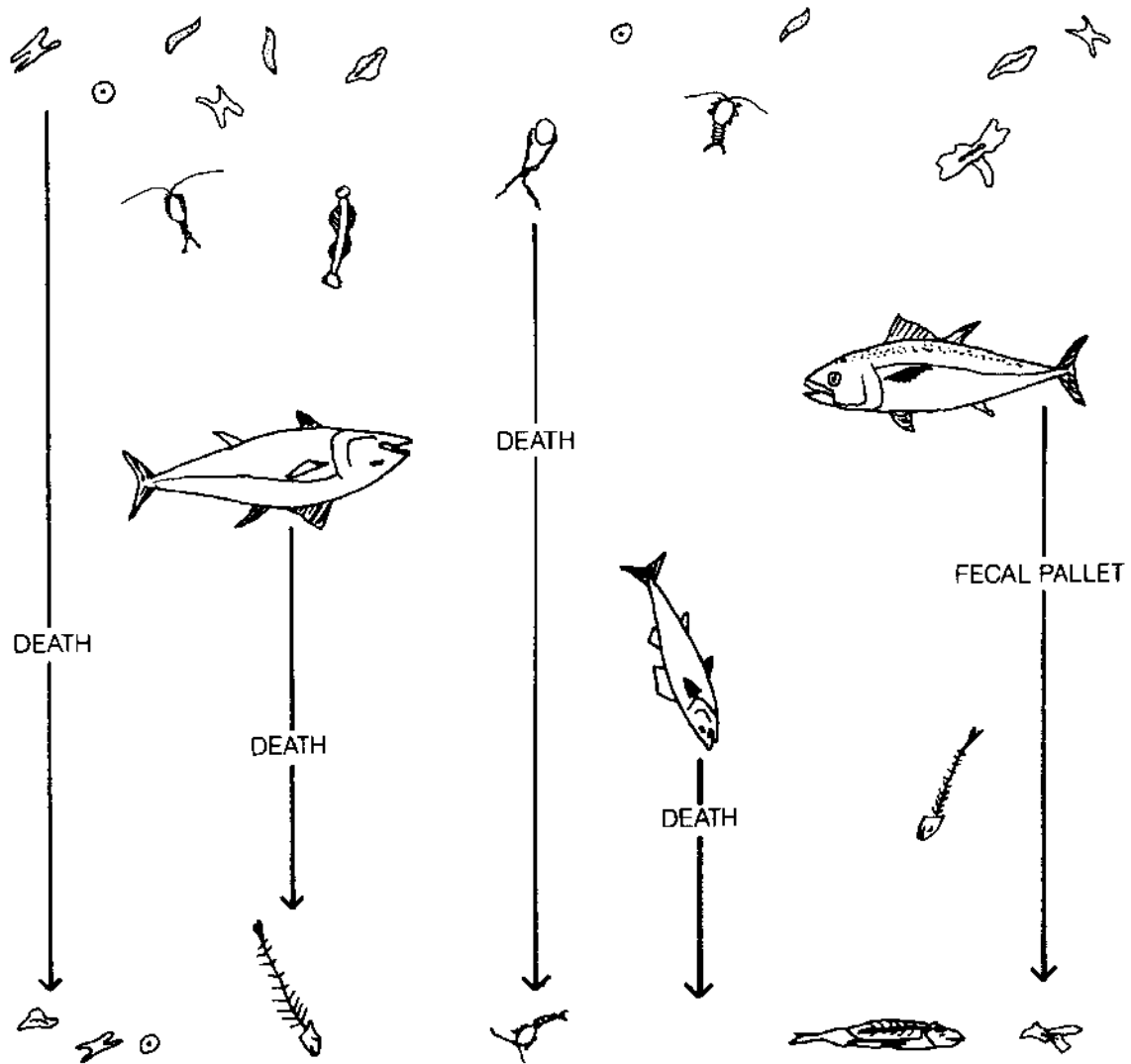
Transparency 3

...it is lunchtime!



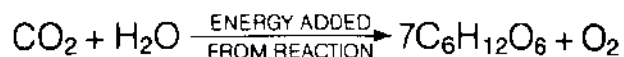
Transparency 4

there's death and decay...



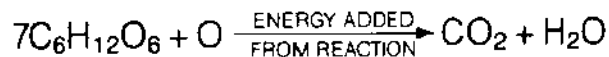
chemistry happens.

PHOTOSYNTHESIS

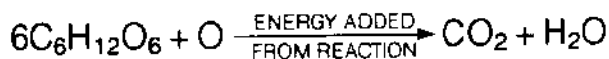


RESPIRATION

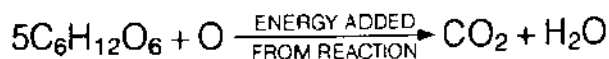
OXIDATION



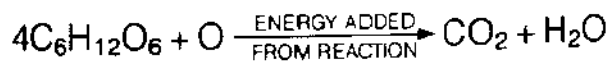
OXIDATION



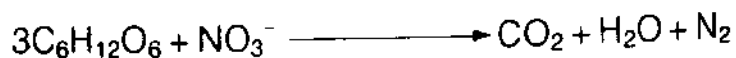
OXIDATION



OXIDATION



NITRATE-REDUCTION



IRON REDUCTION



SULFATE REDUCTION



Competency Factors/References

Competency Levels

Chemistry-Academic—

5.1 know how to write and use chemical formulas and equations;

6.1 know the concept of oxidation-reduction.

Chemistry-Applied/Technical—(see above).

Physical Science-Academic—

3.4 know that chemical reactions occur when two or more elements interact and form one or more new substances; and

3.5 know the processes of oxidation and reduction.

Competency Measures

Chemistry-Academic—

5.1.1 relate chemical names and formulas;

5.1.2 write the reactants and products of a chemical reaction in the form of an equation;

5.1.3 balance a chemical equation by inspection;

6.1.1 write the oxidation numbers for each element in a compound; and

6.1.2 identify and write the oxidation-reduction half reactions in a redox equation.

Chemistry-Applied/Technical—

5.1.1 relate chemical names and formulas;

5.1.2 write simple chemical reactions;

5.1.3 balance a simple chemical equation by inspection;

6.1.1 write the oxidation numbers for each element in a compound; and

6.1.2 identify oxidation-reduction equations.

Physical Science-Academic—

3.4.1 write chemical equations from word equations;

3.4.2 demonstrate knowledge of the law of conservation of mass by writing balanced equations; and

3.5.2 define chemical oxidation and reduction and illustrate the process using simple equations.

Physical Science-Applied/Technical—

3.4.4 write simple chemical equations.

References

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