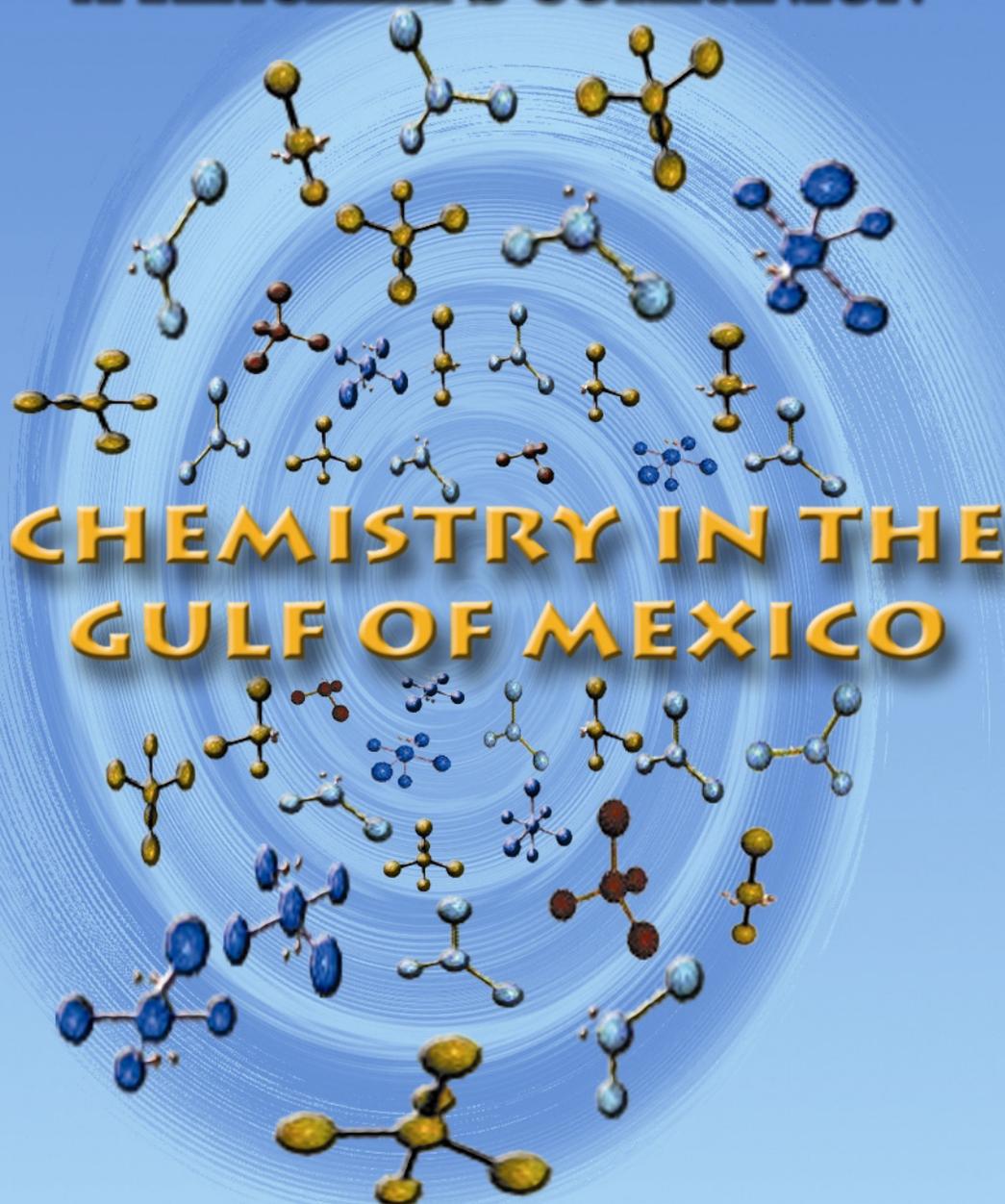


A TEACHER'S COMPANION



MMS

**U. S. Department of the Interior
Minerals Management Service
Gulf of Mexico OCS Region**

NOTE TO TEACHERS

Chemistry in the Gulf of Mexico is a teacher's instructional guide to accompany the poster of the same title. In this guide, you will find information that relates principles from a basic chemistry class to actual processes occurring in the ocean. This guide will focus on four of these processes. The information and activities are intended for use at the 11th to 12th grade levels. Additional topics and resources are included at the end of the guide.

The Minerals Management Service (MMS) has funded numerous scientific studies to understand better the oceanographic processes in the Gulf of Mexico. This Teacher's Companion contains information that was gathered during these studies. The MMS is the Federal agency that regulates oil and gas activities on the U.S. Outer Continental Shelf. To learn more about the MMS, please visit our website at www.mms.gov.

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WHERE TO GET THE POSTER AND TEACHER'S COMPANION

Copies of the poster and Teacher's Companion may be obtained from the Public Information Office (MS 5034) at the following address:

U.S. Department of the Interior
Minerals Management Service
Gulf of Mexico OCS Region
Public Information Office (MS 5034)
1201 Elmwood Park Boulevard
New Orleans, Louisiana 70123-2394

Telephone Number: (504) 736-2519 or
1-800-200-GULF

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ABOUT THIS LESSON

This lesson is intended to address interesting chemical processes occurring in the Gulf of Mexico. The information and activities are related to chemical principles learned in an introductory chemistry class for grades 11-12. It is beyond the scope of this lesson to cover every topic in detail. Therefore, selected references and Internet sites are listed at the end for further investigation and understanding. You can also access this Teacher's Resource on line at <http://www.gomr.mms.gov/homepg/lagniapp/lagniapp.html>.

WHERE IT FITS INTO THE CURRICULUM

Topics: This lesson could be used to extend basic chemistry units to the marine environment. It can also be used as part of an oceanography or earth sciences curriculum. Some material is also applicable to environmental science and understanding the consequences of pollution.

Standards: The material meets the content standards for grades 9-12 as defined by National Science Education Content Standards of the National Science Teachers Association. The following content standards apply:

Science as Inquiry

- Abilities Necessary to do Scientific Inquiry
 - Identify questions and concepts that guide scientific investigation
- Understandings about Scientific Inquiry
 - Scientists usually inquire about how physical, living, or designed systems function.
 - Scientists conduct investigations for a wide variety of reasons.

Physical Science

- Structure and Properties of Matter
 - A compound is formed when two or more kinds of atoms bind together chemically.
- Chemical Reactions
 - Chemical reactions occur all around us.
 - Light can initiate many chemical reactions such as photosynthesis.

Life Science

- The Interdependence of Organisms
 - The atoms and molecules on earth cycle among the living and nonliving components of the biosphere.

Earth and Space Sciences

- Geochemical Cycles
 - The earth is a system containing essentially a fixed amount of each stable chemical atom or element. Each element can exist in several different chemical reservoirs, and moves among the reservoirs in the solid earth, ocean, atmosphere, and organisms as part of geochemical cycles.

Science in Personal and Social Perspectives

- Environmental Quality
 - Natural ecosystems provide an array of basic processes that affect humans. Those processes include maintenance of the quality of the atmosphere, generation of soils, control of the hydrologic cycle, disposal of wastes, and recycling of nutrients. Humans are changing many of these basic processes, and the changes may be detrimental to humans.

OBJECTIVES FOR STUDENTS

- 1) To understand chemical processes that are occurring in the marine environment.
- 2) To apply basic chemical principles in the marine environment.
- 3) To learn how human activity can impact the marine environment.
- 4) To propose hypotheses and design experiments.

MATERIALS FOR STUDENTS

Some of the pages can be photocopied and distributed to the students as an evaluation. The second activity involves chemicals and can either be done as a demonstration or in work groups. The Internet activity requires access by the students to the Internet. Sites containing all the necessary information are given.

WHAT IS CHEMICAL OCEANOGRAPHY?

Chemical Oceanography is the study of chemical processes that occur in the ocean and at the seafloor. It includes the effects of the physical, geological, and biological processes on the chemistry of the ocean. Chemical oceanographers are also interested in the distribution of chemical compounds of major and trace chemical components. The major components include the dissolved atoms and molecules that make the sea salty, such as sodium, potassium, chloride, and sulfate. Minor components include nutrients such as phosphates and nitrates, trace organic compounds, and trace metals. Lead, copper, mercury, and iron are examples of trace metals found in the sea. Actually, almost all of the elements in the periodic table are present in seawater! The interactions between the sun's energy, atmospheric compounds, dissolved and suspended oceanic organic and inorganic material, sea life, and the seafloor are studied. The impact on oceanic chemistry of both natural substances (such as natural seafloor petroleum seeps) and manmade material (such as waste or pollution) is also investigated.

CHEMICAL OCEANOGRAPHY IN THE GULF OF MEXICO

The Gulf of Mexico is considered a marginal sea because it is located on the margin. Processes that occur in the Mississippi River, which drains 45 percent of the continental shelf, are a source of freshwater, nutrients, and pollutants for the Gulf. The Gulf is characterized by "rings" that form from the Loop Current. The Gulf is also known for its massive salt that underlies the seafloor and forms brine pools. A large area of hypoxia forms along the coast as a result of input from the Mississippi River. Gas hydrate areas of the Gulf, one of the few places in the world where barite deposits that form chimneys are also not found are in the deep Gulf and result in slicks observed from satellite. The poster and discussed in the following pages. The poster discusses the chemistry of the Gulf of Mexico to evaluate the effects on the natural system.

Gulf Facts:

Salinity?

Central Gulf: 35.6

Orca Basin brine: >250

Water Volume?

3.35 million cubic km

Average Surface Water Temperature?

Summer: 84°F/29°C

Winter: 70°F/22°C

Deepest Part?

Sigsbee Deep: 4,384 m

Total Area?

1.5 million square km

TEMPERATURE AND SALINITY PLOTS

Oceanographers plot the temperature and salinity values versus depth to gain an understanding of the ocean structure. An example is shown at the center of the poster. The plots are used to identify the thermocline and also can be used to understand the movement of water in the water column. Temperature and salinity affect the density of the water. Warm freshwater is less dense than cold saltwater. When freshwater from rivers, such as the Mississippi, enters the ocean, the freshwater forms a layer on the surface. In the case of the Mississippi, two-thirds of the water moves west along the Louisiana coast while one-third moves to the east. Eventually, wind and currents mix the freshwater with the saltwater.

THERMOCLINE

The thermocline is defined as the depth range over which the temperature decreases rapidly with depth. This zone generally occurs between 300 and 1,000 m, but it varies with latitude. The thermocline divides the ocean into a warm surface layer heated by the sun and a cold, deep layer that has a fairly constant global temperature of 4-4.5°C. The Gulf of Mexico is no different from the major oceans. The graph at the center of the poster is a representative plot of temperature vs. depth. The thermocline is identified as a layer, although the plot does not extend to the coldest and deepest water.

SUSPENDED SEDIMENTS

Along with water and nutrients, the Mississippi River also transports a tremendous amount of sediment from the erosion of the land, about one million cubic yards per day. The Mississippi drains approximately one-third of the contiguous United States. The sediment contributes to the formation of the delta and is also carried along shore to the east and the west. Most of the load is carried to the west and is a source of the “muddy” water observed by beach goers along the Louisiana and Texas coasts. Some of the sediment is also transported to the east. Other rivers flowing into the Gulf contribute sediment as well. The suspended load is measured as turbidity, which is determined by the attenuation of a light beam passed through a water sample.

NUTRIENTS

Nutrients are supplied to the ocean from rivers, land runoff, atmospheric deposition, and recycling of living material already in the ocean. The primary nutrients in ocean waters are nitrate, nitrite, phosphate, silicate, ammonia, and iron. The Mississippi River is the primary source of nutrients to the Gulf of Mexico. Within ocean waters, plants and animals living at the surface die and sink to the bottom as detrital rain. While they sink, bacteria in the ocean break down the organic matter into basic chemical components, which form nutrients. The deepwater becomes enriched in these nutrients. The nutrient-rich deepwater can be returned to the surface by upwelling.

PHYTOPLANKTON

Tiny, single-celled plants or phytoplankton are at the base of the food chain in the ocean. Like all plants, they need light and, therefore, are found very near the surface. They also need nutrients such as nitrates (NO_3^-) and phosphates (PO_4^{3-}) to grow. When large amounts of nutrients enter the ocean in a short period of time, the phytoplankton respond with rapid growth and multiplication, called a “bloom.” The plankton continue to bloom until all the nutrients are gone. The phytoplankton then die and sink to the bottom as a part of the detrital rain.

DETRITAL RAIN

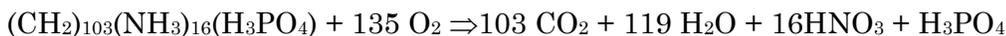
Along with the phytoplankton, tiny animals or zooplankton live in the water column of the ocean. When these plants and animals die, their body parts sink to the bottom. This sinking material is known as detrital rain. As the detritus sinks, it is eaten by bacteria and degraded into nitrates, phosphates, and other nutrients, as well as organic molecules. As the degradation occurs, oxygen is consumed. Often the detrital rain settles in the region of the thermocline, where the density of the water increases with the decreasing temperature. As a result, the thermocline is a region where there is low oxygen.

Off the coast of Louisiana, nutrients from the Mississippi feed the phytoplankton and cause tremendous growth. When all these tiny plants die, the detrital rain increases, bringing large volumes of organic matter to the seafloor. The result is a depletion in oxygen and hypoxic (low oxygen) conditions.

HYPOXIA

The rivers bring nutrients and sediments to the ocean from the erosion of land, land-derived organic matter, and runoff from farmland and cities. The rivers also bring pollutants from the developed areas of their drainage basins. The increased nutrients are a great source of food for plants (phytoplankton) that live in the surface of the ocean. Once the food supply is used up, these plants die and sink to the bottom. Degradation of this plant material results in the depletion of oxygen and the creation of a situation known as hypoxia. Hypoxia occurs when the dissolved oxygen concentration of water decreases to below 2 milligrams/liter. Normally, the oxygen concentration in the water is between 5 and 8 milligrams/liter. Hypoxia is of interest because shrimp, crabs, and fish that live in the ocean need oxygen to survive just as we need to breathe the air. The shrimp, crabs, and fish are a major source of commercial fisheries and must leave the area of hypoxia. Unfortunately, some animals cannot leave the area and die. These animals are also a food source for some species of commercial fish, thus affecting this resource.

In the Gulf of Mexico, the hypoxia has extended all the way to Freeport, Texas, although in most years it extends to the Texas-Louisiana border. This process occurs during the summer, when a layer of warm freshwater floats on top of a layer of cold water and prevents the water from mixing and bringing oxygen from the surface to depth. During the winter, the cold air cools the surface water and allows the entire water column to be mixed.



This equation demonstrates how the breakdown of algae to nutrients consumes oxygen.

CURRENTS, EDDIES, AND UPWELLING—THE EDDY GRAVEYARD

The currents, or movement of water, affect the distribution of chemicals, especially nutrients, in the Gulf of Mexico. Along the coast, the circulation patterns distribute sediments and pollutants, as well as nutrients. The primary current is the Loop Current, which enters the Gulf through the Yucatan Channel between the Yucatan Peninsula and Cuba and exits through the Straits of Florida, where it feeds the Gulf Stream. While the current is in the Gulf, eddies split off from the Loop Current and form spinning rings that move into the western Gulf. Eventually, these rings slow down and can no longer be distinguished from the surrounding water. The region where the rings “disappear” is known as the eddy graveyard. These circulating rings are believed to cause exchange of water from the surface to the deep.

Eddies and winds can pull water away from the coastline. To replace this water, deep, nutrient-rich water is drawn to the surface in a process called upwelling. The deepwater is enriched in nutrients like nitrate and phosphate from the degradation of detrital rain. Several regions in the Gulf are affected by upwelling water. For example, in the east, water moves up the DeSoto Canyon towards Mobile, Alabama.

NATURALLY OCCURRING OIL SEEPS

Oil is not only found deep below the Earth’s surface; some of it seeps into Gulf waters through cracks and fissures in the seafloor. Oil seeps can cause natural slicks at the surface and are responsible for much of the tar found on beaches. The hydrocarbons (oil) also provide a source of chemical energy that supports a lush habitat of mussels, worms, crustaceans, and fish.

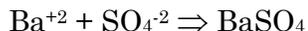
The oil slicks formed by these natural seeps can be used as indicators of oil deposits below the seafloor. NASA is using satellite images of the sea surface to locate and track the oil slicks. The sea surface information can then be used to locate the oil seeps at the seafloor.

The fauna that live around the oil seeps are very similar to those found near hydrothermal vents in the Pacific Ocean in 1979. The larger creatures are supported by a symbiotic relationship with bacteria, where the bacteria are living within the animals and use energy from the oxidation of reduced compounds such as hydrogen sulfide. The fauna can also plug the cracks and fissures through the precipitation of calcium carbonate, a metabolic by-product, thus trapping the oil below the surface.

BARITE CHIMNEYS

Along with hydrocarbon seeps, small chimney-like structures have been discovered on the seafloor. These structures are formed from a mineral called barite (BaSO_4). The barium (Ba^{+2}) comes from dissolving Jurassic salt domes below the seafloor. The salt migrates towards the seafloor through cracks in the sediment and escapes. Once the barium comes in contact with the sulfate-rich (SO_4^{-2}) seawater, barium sulfate precipitates to form

chimneys. The structures are 10-30 cm and consist of tiny crystal rosettes of barite that link together to form long chains of the mineral.



This equation demonstrates the process that forms ocean-floor barite (barium sulfate) chimneys.

GAS HYDRATES AND CHEMOSYNTHETIC COMMUNITIES

Gas hydrate is an ice-like substance that forms by inclusion of hydrocarbon molecules into a lattice of water molecules under the conditions of low temperature and high pressure. In ocean sediments, gas hydrates are found at water depths greater than 300-500 m and are detected by seismic reflection data. The molecules trapped in the lattice structure can be methane, carbon dioxide, ethane, butane, and even isopropane.

Gas hydrates are of interest for several reasons. They are a potential energy resource, they can be hazards to seafloor structures, and they may play a role in climate change. As a potential energy resource, it has been estimated that gas hydrates are a reservoir of organic carbon greater than twice all the known oil and gas resources. Gas hydrates are also metastable; i.e., they can return to the water and gas that originally formed the ice as a result of only small changes in the surrounding temperature and pressure conditions. When gas hydrates dissociate, they potentially cause underwater subsidence or landslides. An oil platform or pipeline located on top of gas hydrate formations that suddenly “melted” could collapse into the sea or break apart. Further, this sudden dissociation of gas hydrate could result in the release of large quantities of methane, a greenhouse gas, which is partially responsible for global warming.

Additionally, gas hydrates support small microcosms known as chemosynthetic communities. These animals form a symbiotic relationship with bacteria that use chemicals rather than light to generate food. Tube worms and mussels are the primary inhabitants of these communities.

NATURALLY OCCURRING BRINE POOLS

Below the Gulf of Mexico is a layer of salt that was formed during the Jurassic period. The salt bed structure is deformed by the addition of sediments into the Gulf basin. The deformations take the shape of domes of salt. The displacement of the salt domes results in cracks and fissures in the overlying sediment. Sometimes, the salt migrates to the surface and creates naturally occurring, dense brine pools in topographic depressions along the seafloor of the Gulf of Mexico. Some of these brine pools have mussels that live around them.

One example of a brine pool is Orca Basin. Discovered in the 1970's, this basin has been extensively studied because of its unique characteristics. The brine is approximately seven times as salty as seawater. Nothing can live within the brine and the pool acts like a trap for sediment and organic matter falling from the ocean's surface; the result is a well-preserved record of this material.

VOCABULARY

Accrete—the process by which inorganic bodies grow larger by the addition of fresh material to the outer surface.

Chemosynthetic—the ability to synthesize organic compounds by energy derived from chemical reactions.

Degradation—the reduction in complexity of a chemical compound.

Detrital—(1) nonliving; (2) from land.

Hypothesis—a tentative assumption that is tested through observation and experimentation.

Metastable—having a slight margin of stability.

Phytoplankton—single-celled plants that have weak swimming ability.

Turbidity—a cloud of suspended material.

Upwelling—to move or flow upward.

Zooplankton—the animal and protozoan members of the plankton.

SUGGESTED TOPICS FOR TERM PAPERS

Precipitation/Dissolution—carbonates, barite

Adsorption—metals adsorb onto settling particles

Organic compounds in a polar solvent

Trace metals—iron as a nutrient

Respiration—what are the processes, products of reaction?

Degradation—breakdown of organic matter

Water quality—define

pH—seawater is buffered by the carbonate system

Ions—ionic strength, dissolved solids, brines

Oxygen—dissolved gases in seawater

Solids—barite chimneys, suspended sediments

Oxidation-reduction—sediment reactions

Constancy of composition—chemical equilibrium

Electrochemical cells—seawater conducting electricity

Periodic table—everything in seawater except...

Photosynthesis

Hydrocarbon seeps—compare natural input to oil spills

Remote sensing—use of satellites to study oceans

ACTIVITIES

ACTIVITY 1—WHY IS THE SEA SALTY?

Purpose: The purpose of this activity is to understand the composition of seawater, the sources of the material, and balances in nature.

Materials: Graph paper

Major dissolved constituents in seawater with a chlorinity of 19 ‰ and a salinity of 34.32 ‰.			
Dissolved substance	Ion or compound	Concentration (grams per kilogram)	Percent by weight
Chloride	Cl ⁻	18.980	55.04
Sodium	Na ⁺	10.556	30.61
Sulfate	SO ₄ ²⁻	2.649	7.68
Magnesium	Mg ²⁺	1.272	3.69
Calcium	Ca ²⁺	0.400	1.16
Potassium	K ⁺	0.380	1.10
Bicarbonate	HCO ₃ ⁻	0.14	0.41
Bromide	Br ⁻	0.065	0.19
Boric Acid	H ₃ BO ₃	0.026	0.07
Strontium	Sr ²⁺	0.013	0.04
Fluoride	F ⁻	0.001	0.0
<i>Totals</i>		34.482	99.99

Class Discussion

Discuss the chemical definition of a salt. Include in the discussion the concept of ions and precipitation of salts.

Where do the salts come from?

How do they get to the ocean?

What processes increase salinity?

What processes decrease salinity?

How would the weather conditions this past spring affect salinity?

Seawater has a fairly constant salinity; why might this be?

Given the following table, have the class plot salinity vs. depth using the salinity values in column two. Put the salinity units on the x-axis across the top and depth on the y-axis, increasing from top to bottom. See the poster for an example of how to plot the depth.

Depth (meters)	Salinity—#1 (parts per thousand)	Salinity—#2 (parts per thousand)
0	37.2	10.5
20	36.8	20.5
50	35.9	32.5
100	34.9	33.8
200	34.8	34.9
500	34.5	35.2
1000	34.9	34.9

1. Describe the distribution of salinity with increasing depth.
2. What might be causing the variations at the surface?
3. Why is the salinity constant at depth?
4. Plot the salinity from column three on the same sheet of paper but with a different color pencil.
5. What is the difference between the two plots?
6. What process is responsible for the salinity values in the surface water?

ACTIVITY 2—BARITE CHIMNEYS—A CASE STUDY OF PRECIPITATION

Purpose: The purpose of this activity is to understand saturation, precipitation, and how deposits are formed in the ocean.

Materials

Water
Barium chloride
Calcium sulfate
2 1-liter flasks
1 1-liter beaker
Stir bar

Class Discussion

Discuss the process of precipitation.

What is chemical equilibrium?

What is saturation?

How can the ocean become saturated in a salt?

Why does accretion occur?

Why don't the deposits dissolve again?

Demonstrate the Precipitation of Barium Sulfate

In a flask, dissolve 2 g of barium chloride in one liter of water. In a second flask, dissolve 0.5 g of calcium sulfate. Pour some of the barium chloride solution into a beaker; add the calcium sulfate solution. A white cloud of barium sulfate will appear.

Suggested Hypothesis (solution for question 5 on the next page)

Fluids rich in barium from below the seafloor escape through cracks, where the barium precipitates with the sulfate in seawater.

Test the hypothesis:

Prepare artificial seawater. In two separate beakers, add the barium chloride solution to one beaker and the calcium sulfate solution to the other. The barium chloride/seawater mixture should result in the formation of a precipitate of barium sulfate. This result supports the hypothesis that the barium comes from some other source and reacts with the sulfate in the seawater.

1. Write the equation for the precipitation of barium sulfate.
2. What ions are involved in this reaction?
3. What is the oxidation state of each ion?
4. How do you think chimneys are formed? Draw a diagram to illustrate the process.
5. Develop a hypothesis for how the chimneys are formed. How would you test your hypothesis?

ACTIVITY 3—HYPOXIA

Purpose: To understand the processes that result in hypoxia and the effects of humans on the environment. To understand the concept of stakeholders and that solutions are a result of compromise.

Note: This activity involves role playing by the students. The activity will not be successful if it is presented that any one stakeholder is more in the right than others. All have their perspectives that are valid.

This activity requires that the students research their roles and understand the position. The activity may take several weeks to complete.

The Scenario: A panel is convened that must decide what to do about the hypoxia that occurs in the Gulf of Mexico, if anything. The stakeholders include Federal and State governments, scientists, farmers, shrimpers, oil industry, and fishermen. Citizens, the media, environmental groups, and fertilizer industry can be included. The stakeholders form both the panel that will decide and the people that will present their viewpoint to the panel. Once all viewpoints have been heard, the panel will deliberate and present its decision to everyone.

The Roles

Panel Members: The panel members would be government officials and scientists who must submit a report to the President recommending the action to be taken. They should represent States along the Mississippi River, in particular Louisiana, Mississippi, Kansas, and Minnesota. The Federal Government should be represented with someone from the Environmental Protection Agency (EPA) and National Oceanic and Atmospheric Administration (NOAA). The scientists are described below. The students should learn about the State or agency they represent and the position of the State or agency on the issue. This information is readily available on the web by searching for “Gulf of Mexico Hypoxia.”

Scientists: The scientists must understand the research and the problem. They should be able to describe how hypoxia is formed, where it is found, and what factors control it. At least one scientist should be on the panel making the decision. The students should use recent scientific literature to gain an understanding of the problem.

Farmers: The farmers grow the food that feeds the Nation; they also use the fertilizer that is thought to be a major contributor to the hypoxia. Students who are playing farmers must understand the use of fertilizer for crops, the amount of food produced by the farmers, and their position on using fertilizer. Information about the farmers’ position can be found on the web.

Shrimpers: The shrimpers rely on the Gulf shrimp for their livelihood. The hypoxia drives the shrimp into other areas. An opportunity to hear the shrimpers’ point of view is available at the website: <http://www.smm.org/> under Mississippi River Tour and the Dead Zone. Information about the shrimpers’ viewpoints can also be found at other websites.

Oil Industry: The oil industry has many visible platforms off the coast of Louisiana. It is a natural reaction to assume platforms contribute to hypoxia because they are a human intrusion into the skyline and do discharge produced waters directly into the hypoxic zone. The students should learn about the platforms, their discharges, and governmental limits on their discharges. The public and other stakeholders may wish to attempt to associate the platforms with hypoxia while the oil industry describes the relative insignificance of its discharges and its excellent environmental record. Information on this topic may be found at www.mms.gov.

Fishermen: The Gulf Coast region is the primary source of fisheries for the United States. Besides shrimp, there are many other commercial species of fish. Recreational fishermen find the Gulf of Mexico an excellent place for the sport. The hypoxia affects where and when they can fish. The students can represent fishermen, either commercial or recreational, and how the hypoxia inconveniences them. They can read about fishing along the Gulf in many popular magazines and newspapers.

Citizens: The concerned citizen can express to the panel any point of view. A student playing a concerned citizen should read anything available and form his or her own opinion.

Media: The media are responsible for asking probing questions and reporting the viewpoints. A student playing a media person may want to write press releases, ask the panel pertinent questions, and may be required to prepare a newsletter summarizing the information given to the panel and the decision of the panel.

Environmental Groups: Students could represent environmental groups such as the Sierra Club. The students would need to research the group, understand the tactics, and represent the position of the group.

Fertilizer Industry: The fertilizer industry is concerned because a requirement that farmers use less fertilizer would result in fewer sales. Fewer sales, in turn, could mean lower profits, plant closures, job loss for people, etc. Students representing the fertilizer industry would need to research the industry and understand how much they sell to Midwestern farmers.

INTERNET ACTIVITY: GAS HYDRATES

INTERNET SOURCES

What are gas hydrates?

<http://woodshole.er.usgs.gov/project-pages/hydrates/>

Hydrates

<http://www.hydrate.org/>

Gas Hydrates -- a Possible Future Energy Resource?

<http://walrus.wr.usgs.gov/resources/hydrate.html>

Using information found on the Internet, answer the following questions:

1. What is a gas hydrate?
2. What gases can be trapped in the lattice structure?
3. At what temperatures and pressures do gas hydrates form?
4. Why are gas hydrates a potential energy resource?
5. How could gas hydrates contribute to global warming?

SUPPLEMENTARY RESOURCES

General Oceanographic Information for Teachers

<http://www.vims.edu/bridge/>

http://seawifs.gsfc.nasa.gov/OCEAN_PLANET/HTML/search_educational_materials.html

<http://www.epa.gov/ow/kids/watered2.html>

Why is the Ocean Salty?

http://www.palomar.edu/oceanography/salty_ocean.htm

Chemosynthetic Communities and Brine Pool

<http://www.bio.psu.edu/People/Faculty/Fisher/fhome.htm>

<http://www.gomr.mms.gov/homepg/regulate/environ/chemo/chemo.html>

Hypoxia in the Gulf of Mexico

<http://www.smm.org/DeadZone/top.html>

http://www.nos.noaa.gov/products/pubs_hypox.html

Phytoplankton

<http://www.childrenoftheearth.org/Kid's%20Entries/phytoplankton.htm>

For great lesson plans, search for phytoplankton on this website:

<http://www.vims.edu/bridge/>

Ocean Currents

<http://oceanexplorer.noaa.gov/explorations/02mexico/background/currents/currents.html>

Naturally Occurring Oil Seeps

http://www-gerg.tamu.edu/irm/sliktrak/SciAmer_web/index.html

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The Department of the Interior Mission

As the Nation's principal conservation agency, the Department of the Interior has responsibility for most of our nationally owned public lands and natural resources. This includes fostering sound use of our land and water resources; protecting our fish, wildlife, and biological diversity; preserving the environmental and cultural values of our national parks and historical places; and providing for the enjoyment of life through outdoor recreation. The Department assesses our energy and mineral resources and works to ensure that their development is in the best interests of all our people by encouraging stewardship and citizen participation in their care. The Department also has a major responsibility for American Indian reservation communities and for people who live in island territories under U.S. administration.



The Minerals Management Service Mission

As a bureau of the Department of the Interior, the Minerals Management Service's (MMS) primary responsibilities are to manage the mineral resources located on the Nation's Outer Continental Shelf (OCS), collect revenue from the Federal OCS and onshore Federal and Indian lands, and distribute those revenues.

Moreover, in working to meet its responsibilities, the **Offshore Minerals Management Program** administers the OCS competitive leasing program and oversees the safe and environmentally sound exploration and production of our Nation's offshore natural gas, oil and other mineral resources. The MMS **Minerals Revenue Management** meets its responsibilities by ensuring the efficient, timely and accurate collection and disbursement of revenue from mineral leasing and production due to Indian tribes and allottees, States and the U.S. Treasury.

The MMS strives to fulfill its responsibilities through the general guiding principles of: (1) being responsive to the public's concerns and interests by maintaining a dialogue with all potentially affected parties and (2) carrying out its programs with an emphasis on working to enhance the quality of life for all Americans by lending MMS assistance and expertise to economic development and environmental protection.