Deepwater Coral Expedition: Reefs, Rigs and Wrecks

Corrosion to Corals

Focus
Galvanic exchange and carbonate precipitation

Grade Level
7-8 (Physical Science)

Focus Question
What can cause electrical currents in deep oceans, and how might these currents affect reef-building corals?

Learning Objectives
Students will be able to describe galvanic exchange and explain how this process produces electric currents.

Given two dissimilar metals and information on their position in an Electromotive Series, students will be able to predict which of the metals will deteriorate if they are placed in a salt solution.

Students will be able to describe the effect of electric currents on the availability of metal ions, and how this might contribute to the growth of corals on shipwrecks.

Materials
Supplies for Part I (see Learning Procedure, Step 1):
- ❒ Voltmeter with at least 0.5 volt sensitivity
- ❒ Plastic cup (approximately 9 oz capacity)
- ❒ 3 oz seawater
- ❒ Approximately 3" length of pencil "lead"
- ❒ Several metals for testing (e.g., galvanized nail 3" length of copper wire, aluminum nail, lead fishing weight, brass screw, steel bolt)
- ❒ Copies of "Electrochemical Reactions Inquiry Worksheet," one copy for each student group
- ❒ 9-volt battery
- ❒ Two test leads with alligator clips on each end (available in packages of about a dozen from Radio Shack)
- ❒ Plastic cup (approximately 9 oz capacity)
- ❒ 3 oz seawater
- ❒ Galvanized nail
- ❒ 3" length of copper wire

Audio/Visual Materials
None

Teaching Time
One 45-minute class period

Seating Arrangement
Groups of 3-4 students

Maximum Number of Students
32

Key Words
Gulf of Mexico
Deepwater coral
Electrolytic cell
Galvanic exchange
Electrodeposition

Background Information
In recent years, rising costs of energy and a growing desire to reduce the United States' dependence upon foreign petroleum fuels have

led to intensified efforts to find more crude oil and drill more wells in the Gulf of Mexico. This region produces more petroleum than any other area of the United States, even though its proven reserves are less than those in Alaska and Texas. Managing exploration and development of mineral resources on the nation's outer continental shelf is the responsibility of the U.S. Department of the Interior's Minerals Management Service (MMS). Besides managing the revenues from mineral resources, an integral part of the Deepwater Coral Expedition: Reefs, Rigs, and Wrecks mission is to protect unique and sensitive environments where these resources are found.

To locate new sources of hydrocarbon fuels, MMS has conducted a series of seismic surveys to map areas between the edge of the continental shelf and the deepest portions of the Gulf of Mexico. These maps provide information about the depth of the water as well as the type of material that is found on the seafloor. Hard surfaces are often found where hydrocarbons are present. Carbonate rocks (such as limestone), in particular, are a part of nearly every site where fluids and gases containing hydrocarbons have been located. This is because when microorganisms consume hydrocarbons under anaerobic conditions, they produce bicarbonate which reacts with calcium and magnesium ions in the water and precipitates as carbonate rock. This rock, in turn, provides a substrate where the larvae of many other deep sea bottom-dwelling organisms may attach, particularly corals. In addition to carbonate rocks associated with hydrocarbon seeps, deepwater corals in the Gulf of Mexico are also found on anthropogenic (human-made) structures, particularly ship wrecks and oil platforms.

Deepwater coral reefs were discovered in the Gulf of Mexico nearly 50 years ago, but very little is known about the ecology of these communities or the basic biology of the corals that produce them. Recent studies suggest that deepwater reef ecosystems may have a diversity of species comparable to that of coral reefs in shallow waters, and have found deepwater coral species on continental margins worldwide. One of the most conspicuous differences between shallow- and deepwater corals is that most shallow-water species have symbiotic algae (zooxanthellae) living inside the coral tissue, and these algae play an important part in reef-building and biological productivity. Deepwater corals do not contain symbiotic algae (so these corals are termed "azooxanthellate"). Yet, there are just as many species of deepwater corals (slightly more, in fact) as there are species of shallow-water corals. Deepwater reefs provide habitats for a variety of plant, animal, and microbial species, some of which have not been found anywhere else. Branching corals and other sessile (non-motile) benthic (bottom-dwelling) species with complex shapes provide essential habitat for other organisms including commercially-important fishes such as longfin hake, wreckfish, blackbelly rosefish, and grenadiers. In addition, recent research has shown that less obvious, obscure benthic species may contain powerful drugs that directly benefit humans.

The long-term goal of the Deepwater Coral Expedition: Reefs, Rigs, and Wrecks is to develop the ability to recognize areas where deepwater corals are "likely to occur" in the Gulf of Mexico. Achieving this goal involves three objectives:

- Discover and describe new locations in the deep (greater than 300m depth) Gulf of Mexico where there are extensive coral communities;
- Gain a better understanding of the processes that control the occurrence and distribution of deepwater coral communities in the Gulf of Mexico; and
- Study the relationships between coral communities on artificial and natural substrates with respect to species composition and function, genetics, and growth rates of key species.

In addition to field investigations, the Deepwater

Coral Expedition will include a series of laboratory studies to determine the effects of temperature, pH, dissolved oxygen, and electrical current on growth and survival of *L. pertusa*. Studies of tropical corals have shown higher growth rates in the presence of an electrical field due to the increased abundance of dissolved mineral ions (such as calcium) for calcification. Since the metal components of shipwrecks often produce electric currents, these wrecks might create conditions favorable to higher-than-normal growth rates. In this activity, students will investigate the electrochemical activity of several metals, and how electrical currents might enhance the growth of corals.

Learning Procedure

1. To prepare for this lesson, review introductory essays for the Deepwater Coral Expedition: Reefs, Rigs, and Wrecks at http://oceanexplorer.noaa.gov/explorations/08lophelia/welcome.html.

   You may also want to visit http://www.bio.psu.edu/cold_seeps for a virtual tour of a cold seep community in the Gulf of Mexico, and http://oceanexplorer.noaa.gov/gallery/livingocean/livingocean_coral.html for images of deep-sea corals and their communities.

   Review instructions on the "Electrochemical Reactions Inquiry Worksheet." To do Part I as a student activity, you will need several voltmeters. Ideally each student group should have their own meter, but it is possible for two groups to share a single meter. If only one voltmeter is available, do Part I as a demonstration, and have each student group do Part II individually.

2. Briefly introduce the mission Deepwater Coral Expedition: Reefs, Rigs, and Wrecks, emphasizing that very little is known about deep-water coral communities, but these communities may be important to humans in a variety of ways, including their potential as sources for new drugs to treat human diseases (for more information on this point, see the 2003 Ocean Explorer Deep Sea Medicines expedition, http://oceanexplorer.noaa.gov/explorations/03bio/welcome.html).

   Tell students that one of the primary objectives of the Deepwater Coral Expedition is to determine the effects of temperature, pH, dissolved oxygen, and electrical current on growth and survival of deepwater corals. Ask students why electrical currents might be important, and where electrical currents might come from in the deep ocean. Make a list of students' ideas, but do not comment on shipwrecks as a potential source of electrical currents at this point.

3. Provide each student group with a copy of the "Electrochemical Reactions Inquiry Worksheet" and materials needed for Part I, or complete Part I as a demonstration. Review the basic concept of oxidation and reduction. Be sure students understand the role of seawater in the experimental procedures, and that while oxygen is often involved in oxidation-reduction reactions, "oxidation" means loss of electrons. Students should realize that different combinations of metals produce different voltages. You may want to show students a table of reduction potentials, and ask them to compare their results with results that would be expected from this table.

4. Review students' ideas about sources of electrical currents in the deep ocean, and results of Part I. Discuss the concept of "galvanic exchange" (or "galvanic coupling" or "galvanic corrosion"). This process results from different metals in electrical contact with each other in seawater. Metals can be classified into an "Electromotive Series" according to the strength with which they "hold on" to their electrons. Metals lower in the Series tend to give up their electrons more readily than metals that are higher in the Series. When two metals with different electromotive strengths are electrically connected and submerged in an electrolyte

(such as seawater), electrons will flow from the metal lower in the electromotive series, creating an electric current (and also causes the process we know as corrosion). Besides the iron in its hull, a typical shipwreck contains many other metals such as lead, bronze, copper, and brass that are higher in the electromotive series than iron. As a result, the steel in the ship's hull is degraded as iron is replaced by other compounds formed through galvanic exchange. Students should now identify shipwrecks as a potential source of electrical currents.

5. Have each student group complete Part II, and lead a discussion of students' observations. Students should identify "something in the seawater"and metals in the nail or wire as likely sources of the precipitates observed around the pencil "lead." Tell students that seawater contains many different chemical substances, but most of these are in very small quantities. Students should also realize that since the precipitate formed near the pencil lead, which was connected to the negative terminal of the battery, that the materials forming the precipitate may have received electrons from the pencil "lead." From the information presented in Table 1, students might hypothesize that one or more of the elements that exist as positive ions in seawater may be involved in the precipitate. If you tell students that sodium and potassium cannot exist as pure solids in water, they should identify calcium and magnesium as the most likely components of the precipitate.

   Tell students that corals reproduce by means of free-swimming larvae, and that for coral reefs to form there must be a suitable surface on which these larvae may settle. Say that limestone rocks provide a very good surface for coral larvae, and that two of the main components of limestone are calcium and sometimes magnesium. Remind students that corals also produce limestone skeletons. Ask whether this information combined with their experimental observations suggests why shipwrecks might be good places to look for corals. Students should realize (perhaps with a few more clues) that electrical currents resulting from electrochemical reactions between dissimilar metals on shipwrecks could favor formation of suitable substrate and/or aid corals in producing limestone skeletons.

Table 1
Some Chemical Components of Seawater

Component	Concentration (mol/kg)
H_2O	53.6
Cl^-	0.546
Na^+	0.469
Mg^{2+}	0.0528
SO_4^{2-}	0.0282
Ca^{2+}	0.0103
K^+	0.0102

The Bridge Connection

www.vims.edu/bridge/ – Click on "Ocean Science" in the navigation menu to the left, then "Ecology," then "Coral" for resources on corals and coral reefs.

The "Me" Connection

Have students write a short essay on how better understanding of deep-sea coral communities might be personally beneficial.

Connections to Other Subjects

English/Language Arts, Earth Science, Life Science

Assessment

Student discussions provide opportunities for assessment.

Extensions

1. Have students visit http://oceanexplorer.noaa.gov/explorations/08lophelia/welcome.html to find out more about the Deepwater Coral Expedition: Reefs, Rigs, and Wrecks and to learn about opportuni-

ties for real-time interaction with scientists on the current expedition.

2. Have students investigate the biography of Wolf Hilbertz, who has written extensively and holds several patents dealing with the use of electrochemically deposited minerals from seawater as building materials.

Multimedia Learning Objects

http://www.learningdemo.com/noaa/ Click on the links to Lessons 3, 5, 6, 11, and 12 for interactive multimedia presentations and Learning Activities on Deep-Sea Corals, Chemosynthesis and Hydrothermal Vent Life, Deep-Sea Benthos, Energy from the Oceans, and Food, Water, and Medicine from the Sea.

Other Relevant Lesson Plans from NOAA's Ocean Exploration Program

Shipwreck Mystery

(10 pages, 322k) (from AUVfest 2008)
http://oceanexplorer.noaa.gov/explorations/08auvfest/background/edu/media/shipwreck.pdf

Focus: Marine Archaeology (Earth Science/Physical Science/Social Science)

In this activity, students will be able to draw inferences about a shipwreck given information on the location and characteristics of artifacts from the wreck; use a grid system to document the location of artifacts recovered from a model shipwreck site; and identify and explain types of evidence and expertise that can help verify the nature and historical content of artifacts recovered from shipwrecks.

I, Robot, Can Do That!

(9 pages, 357k) (from the 2005 Lost City Expedition)
http://oceanexplorer.noaa.gov/explorations/05lostcity/background/edu/media/lostcity05_i_robot.pdf

Focus - Underwater Robotic Vehicles for Scientific Exploration (Physical Science/Life Science)

In this activity, students will be able to describe and contrast at least three types of underwater robots used for scientific explorations, discuss the advantages and disadvantages of using underwater robots in scientific explorations, and identify robotic vehicles best suited to carry out certain tasks.

Sonar Simulation

(PDF, 308kb) (from the Bonaire 2008: Exploring Coral Reef Sustainability with New Technologies Expedition)
http://oceanexplorer.noaa.gov/explorations/08bonaire/background/edu/media/sonarsim.pdf

Focus: Side scan sonar (Earth Science/Physical Science)

In this activity, students will describe side-scan sonar, compare and contrast side-scan sonar with other methods used to search for underwater objects, and make inferences about the topography of an unknown and invisible landscape based on systematic discontinuous measurements of surface relief.

This Old Ship

(9 pages, 272 kb) (from the 2006 Phaedra Expedition)
http://oceanexplorer.noaa.gov/explorations/06greece/background/edu/media/old_ship.pdf

Focus: Ancient and Prehistoric Shipwrecks

In this activity, students will be able to describe at least three types of artifacts that are typically recovered from ancient shipwrecks, explain the types of information that may be obtained from at least three types of artifacts that are typically recovered from ancient shipwrecks, and compare and contrast, in general terms, technological features of Neolithic, Bronze Age, Hellenistic, and Byzantine period ships.

Mapping the Aegean Seafloor

(8 pages, 288 kb) (from the 2006 Phaedra Expedition)
http://oceanexplorer.noaa.gov/explorations/06greece/background/edu/media/seafloor_mapping.pdf

Focus: Bathymetric mapping of deep-sea habitats (Earth Science)

In this activity, students will be able to create a two-dimensional topographic map given bathymetric survey data, create a three-dimensional model of landforms from a two-dimensional topographic map, and interpret two- and three-dimensional topographic maps.

Monsters of the Deep

(6 pages, 464k) (from the Expedition to the Deep Slope 2007)
http://oceanexplorer.noaa.gov/explorations/07mexico/background/edu/media/monsters.pdf

Focus: Predator-prey relationships between cold-seep communities and the surrounding deep-sea environment (Life Science)

In this activity, students will be able to describe major features of cold seep communities, and list at least five organisms typical of these communities; and will be able to infer probable trophic relationships among organisms typical of cold-seep communities and the surrounding deep-sea environment. Students will also be able to describe the process of chemosynthesis in general terms, contrast chemosynthesis and photosynthesis, and describe at least five deep-sea predator organisms.

One Tough Worm

(8 pages, 476k) (from the Expedition to the Deep Slope 2007)
http://oceanexplorer.noaa.gov/explorations/07mexico/background/edu/media/worm.pdf

Focus: Physiological adaptations to toxic and hypoxic environments (Life Science)

In this activity, students will be able to explain the process of chemosynthesis, explain the relevance of chemosynthesis to biological communities in the vicinity of cold seeps, and describe three physiological adaptations that enhance an organism's ability to extract oxygen from its environment. Students will also be able to describe the problems posed by hydrogen sulfide for aerobic organisms, and explain three strategies for dealing with these problems.

Let's Go to the Video Tape!

(11 pages; 327kb PDF) (from the Cayman Islands Twilight Zone 2007 Expedition)
http://oceanexplorer.noaa.gov/explorations/07twilightzone/background/edu/media/videotape.pdf

Focus: Characteristics of biological communities on deepwater coral habitats (Life Science)

In this activity, students will recognize and identify some of the fauna groups found in deep-sea coral communities, infer possible reasons for observed distribution of groups of animals in deep-sea coral communities, and discuss the meaning of "biological diversity." Students will compare and contrast the concepts of "variety" and "relative abundance" as they relate to biological diversity, and given abundance and distribution data of species, will be able to calculate an appropriate numeric indicator that describes the biological diversity of a community.

Treasures in Jeopardy

(8 pages; 278kb PDF) (from the Cayman Islands Twilight Zone 2007 Expedition)
http://oceanexplorer.noaa.gov/explorations/07twilightzone/background/edu/media/treasures.pdf

Focus: Conservation of deep-sea coral communities (Life Science)

In this activity, students will compare and contrast deep-sea coral communities with their shallow-water counterparts and explain at least three benefits associated with deep-sea coral communities. Students will also describe human activities that threaten deep-sea coral communities and describe actions that should be taken to protect resources of deep-sea coral communities.

Come on Down!

(6 pages, 464k) (from the 2002 Galapagos Rift Expedition)
http://oceanexplorer.noaa.gov/explorations/02galapagos/background/education/media/gal_gr7_8_l1.pdf

Focus: Ocean Exploration

In this activity, students will research the development and use of research vessels/vehicles used for deep ocean exploration; students will calculate the density of objects by determining the mass and volume; students will construct a device that exhibits neutral buoyancy.

Living by the Code

(5 pages, 400k) (from the 2003 Deep Sea Medicines Expedition)
http://oceanexplorer.noaa.gov/explorations/03bio/background/edu/media/Meds_LivingCode.pdf

Focus: Functions of cell organelles and the genetic code in chemical synthesis (Life Science)

In this activity, students will be able to explain why new drugs are needed to treat cardiovascular disease, cancer, inflammation, and infections; infer why sessile marine invertebrates appear to be promising sources of new drugs; and explain the overall process through which cells manufacture chemicals. Students will also be able to explain why it may be important to synthesize new drugs, rather than relying on the natural production of drugs.

Mapping Deep-sea Habitats in the Northwestern Hawaiian Islands

(7 pages, 80kb) (from the 2002 Northwestern Hawaiian Islands Expedition)
http://oceanexplorer.noaa.gov/explorations/02hawaii/background/education/media/nwhi_mapping.pdf

Focus: Bathymetric mapping of deep-sea habitats (Earth Science - This activity can be easily modified for Grades 5-6)

In this activity, students will be able to create a two-dimensional topographic map given bathymetric survey data, will create a three-dimensional model of landforms from a two-dimensional topographic map, and will be able to interpret two- and three-dimensional topographic data.

Life is Weird

(8 pages, 268k) (from the 2006 Expedition to the Deep Slope)
http://oceanexplorer.noaa.gov/explorations/06mexico/background/edu/GOM%2006%20Weird.pdf

Focus: Biological organisms in cold seep communities (Life Science)

In this activity, students will be able to describe major features of cold seep communities, and list at least five organisms typical of these communities. Students will also be able to infer probable trophic relationships among organisms typical of cold-seep communities and the surrounding deep-sea environment, and describe the process of chemosynthesis in general terms, and will be able to contrast chemosynthesis and photosynthesis.

Other Resources

The Web links below are provided for informational purposes only. Links outside of Ocean Explorer have been checked at the time of this page's publication, but the linking sites may become outdated or non-operational over time.

http://celebrating200years.noaa.gov/edufun/book/welcome.html#book – A free printable book for home and school use introduced in 2004 to celebrate the 200th anniversary of NOAA; nearly 200 pages of lessons focussing on the exploration, understanding, and protection of Earth as a whole system

http://news.nationalgeographic.com/news/2007/12/071204-AP-bali-electrified.html – Electricity Revives Bali Coral Reefs Pemuteran Bay, Indonesia, December 4, 2007

http://www.gomr.mms.gov/index_common.html – Minerals Management Service Web site

http://www.gomr.mms.gov/homepg/lagniapp/chemcomp.pdf – "Chemosynthetic Communities in the Gulf of Mexico" teaching guide to accompany a poster with the same title, introducing the topic of chemosynthetic communities and other ecological concepts to middle and high school students.

http://www.gomr.mms.gov/homepg/lagniapp/lagniapp.html – Kids Page on the Minerals Management Service Web site, with posters, teaching guides and other resources on various marine science topics

http://www.coast-nopp.org/ – Resource Guide from the Consortium for Oceanographic Activities for Students and Teachers, containing modules, guides, and lesson plans covering topics related to oceanography and coastal processes

http://cosee-central-gom.org/ – Web site for The Center for Ocean Sciences Education Excellence: Central Gulf of Mexico (COSEE-CGOM)

National Science Education Standards

Content Standard A: Science as Inquiry
- Abilities necessary to do scientific inquiry
- Understandings about scientific inquiry

Content Standard B: Physical Science
- Properties and changes of properties in matter

Content Standard C: Life Science
- Populations and ecosystems

Content Standard E: Science and Technology
- Understandings about science and technology

Content Standard F: Science in Personal and Social Perspectives
- Populations, resources, and environments
- Risks and benefits
- Science and technology in society

Ocean Literacy Essential Principles and Fundamental Concepts

Essential Principle 1.
The Earth has one big ocean with many features.

Fundamental Concept g. The ocean is connected to major lakes, watersheds and waterways because all major watersheds on Earth drain to the ocean. Rivers and streams transport nutrients, salts, sediments and pollutants from watersheds to estuaries and to the ocean.

Fundamental Concept h. Although the ocean is large, it is finite and resources are limited.

Essential Principle 5.
The ocean supports a great diversity of life and ecosystems.

Fundamental Concept b. Most life in the ocean exists as microbes. Microbes are the most important primary producers in the ocean. Not only are they the most abundant life form in the ocean, they have extremely fast growth rates and life cycles.

Fundamental Concept c. Some major groups are found exclusively in the ocean. The diversity of major groups of organisms is much greater in the ocean than on land.

Fundamental Concept d. Ocean biology provides many unique examples of life cycles, adaptations and important relationships among organisms (such as symbiosis, predator-prey dynamics and energy transfer) that do not occur on land.

Fundamental Concept e. The ocean is three-dimensional, offering vast living space and diverse habitats from the surface through the water column to the seafloor. Most of the living space on Earth is in the ocean.

Fundamental Concept f. Ocean habitats are defined by environmental factors. Due to interactions of abiotic factors such as salinity, temperature, oxygen, pH, light, nutrients, pressure, substrate and circulation, ocean life is not evenly distributed temporally or spatially, i.e., it is "patchy". Some regions of the ocean support more diverse and abundant life than anywhere on Earth, while much of the ocean is considered a desert.
Fundamental Concept g. There are deep ocean ecosystems that are independent of energy from sunlight and photosynthetic organisms. Hydrothermal vents, submarine hot springs, and methane cold seeps rely only on chemical energy and chemosynthetic organisms to support life.

Essential Principle 6.
The ocean and humans are inextricably interconnected.

Fundamental Concept b. From the ocean we get foods, medicines, and mineral and energy resources. In addition, it provides jobs, supports our nation's economy, serves as a highway for transportation of goods and people, and plays a role in national security.
Fundamental Concept e. Humans affect the ocean in a variety of ways. Laws, regulations and resource management affect what is taken out and put into the ocean. Human development and activity leads to pollution (such as point source, non-point source, and noise pollution) and physical modifications (such as changes to beaches, shores and rivers). In addition, humans have removed most of the large vertebrates from the ocean.
Fundamental Concept g. Everyone is responsible for caring for the ocean. The ocean sustains life on Earth and humans must live in ways that sustain the ocean. Individual and collective actions are needed to effectively manage ocean resources for all.

Essential Principle 7.
The ocean is largely unexplored.

Fundamental Concept a. The ocean is the last and largest unexplored place on Earth—less than 5% of it has been explored. This is the great frontier for the next generation's explorers and researchers, where they will find great opportunities for inquiry and investigation.
Fundamental Concept b. Understanding the ocean is more than a matter of curiosity. Exploration, inquiry and study are required to better understand ocean systems and processes.
Fundamental Concept c. Over the last 40 years, use of ocean resources has increased significantly, therefore the future sustainability of ocean resources depends on our understanding of those resources and their potential and limitations.
Fundamental Concept d. New technologies, sensors and tools are expanding our ability to explore the ocean. Ocean scientists are relying more and more on satellites, drifters, buoys, subsea observatories and unmanned submersibles.
Fundamental Concept f. Ocean exploration is truly interdisciplinary. It requires close collaboration among biologists, chemists, climatologists, computer programmers, engineers, geologists, meteorologists, and physicists, and new ways of thinking.

Send Us Your Feedback

We value your feedback on this lesson.
Please send your comments to:
oceanexeducation@noaa.gov

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Student Handout

Electrochemical Reactions Inquiry Worksheet

Part I

Electricity is a flow of electrons. In a battery, two different metals are placed in a solution in which electrons can flow. Usually, one metal will have a stronger attraction for electrons, and electrons will flow to the metal with the stronger electron attraction from the metal with the weaker electron attraction. This produces an electrical current.

Your assignment is to investigate the electrical currents (if any) produced by different combinations of metals when they are placed in seawater.

1. Start with a copper wire and a pencil "lead" (it's really carbon, not lead). Set the voltmeter at its lowest setting, and connect one probes from the voltmeter to the copper wire, and the other probe from the voltmeter to the pencil "lead."

2. Pour about 3 ounces of seawater into a plastic cup. Place the copper wire and pencil "lead" into the seawater so they are not touching, but are about 1 cm apart. Record the voltage reading on the voltmeter. If the needle on the voltmeter goes down, reverse the probes.

3. Repeat Steps 1 and 2 with the other metals provided by your teacher. It's a good idea to rub each metal briefly with a small piece of emery paper just before testing (it isn't necessary to do this with the pencil "lead," however).

Part II

1. Connect the alligator clip on one end of a connecting wire to a pencil "lead". Connect the alligator clip on the other end to the negative (-) terminal of a 9-volt battery.

2. Connect the alligator clip on one end of a connecting wire to a nail, and connect the alligator clip on the other end to the positive (+) terminal of the battery.

3. Pour about 3 ounces of seawater into a plastic cup. Put the pencil "lead" and the nail into the seawater so they are not touching, but are about 1 cm apart.

4. Observe what happens in the seawater over the next 20 minutes. Record your observations every five minutes.

5. What happens around the end of the pencil "lead" in the seawater?

6. Did the same thing happen near the nail?

7. If you have time, repeat Steps 2 through 6 with a copper wire or nail. Are the results different?