GROUNDRULES

ORE PROCESSING

Ore Processing

AGES 13-15

INTRODUCTION

As the demand for mined minerals increases, everyone—from students, to miners, to governments and global corporations—must understand how to work together to meet those needs while protecting the world in which we live.

Ground Rules: Mining Right for a Sustainable Future is a documentary film created by Caterpillar and Science North. It follows the development of new and operating mines as geologists, engineers and mine managers tackle complex problems. It draws on the experiences and achievements of modern mine sites to illustrate creative and core concepts of sustainable development and social responsibility.

This set of lesson plans was developed by Science North, commissioned by Caterpillar to accompany the *Ground Rules* film. It provides a tool for educators to further examine the themes and concepts presented in the film through a series of "hands-on" classroom activities. It introduces students to the various phases involved in mining, different types of mines, how ore is processed, how mineral deposits were formed, how modern mines can operate safely and sustainably, and why minerals are important to our everyday lives. This material also introduces students to a wide variety of mining careers.

The lesson plans have been designed to broadly complement the curriculum objectives for the United States, Canada, and Australia. However, the lesson plans are not region-specific and can be used by educators throughout the world. All of the lesson plans have strong linkages to the earth science curriculum, but many of the activities incorporate additional linkages to math, chemistry, data management, mapping, environmental studies, electricity, magnetism and problem-solving. The lesson plans can be easily adapted to meet specific local curriculum goals.

In each lesson plan, an introductory section provides the appropriate film chapter reference and describes the key concepts for the lesson. One or two activities are then described in a step-by-step format. These activities include experiments, demonstrations, games, building activities, and research projects. The lesson plans end with a discussion section that provides possible follow-up topics and questions for classroom discussion. Each lesson plan also includes curriculum linkages, a vocabulary list, a materials list, and approximate timelines for completion of each section. Teacher answer sheets or data sheets are appended, where appropriate.

The lesson plans are organized into five broad themes: Geology; Mining; Mining Processes; Ore Processing; and Minerals and Everyday Life. The lesson plans are further sub-divided into three age categories: 11 to 13 years; 13 to 15 years; and 15 to 18 years. In many cases, the same topics are covered in each age category. However, lesson plans in the older age categories contain additional activities, alternative age-appropriate activities, and/or enhanced complexity.

Theme: Ore Processing

This theme explores the different methods that can be used to extract and purify valuable minerals from mined ore. Students will conduct a series of experiments to learn about the processes of crushing, milling, extraction, leaching, flotation and purification. Younger students will also use magnetism to separate minerals, and will use froth flotation to separate coal from sand. The 15 to 18 year-old students will study the process of making steel, as well as the types of heavy equipment used to haul ore to processing facilities.

Ground Rules – Online Viewing and Learning Resources

As noted, these lesson plans are designed to be used with *Ground Rules: Mining Right for a Sustainable Future*. Multiple options are available for using the film in your classroom:

- **Order a free copy of the Ground Rules DVD**, containing both the English, Spanish and French versions of the film, from the Caterpillar web site, http://www.cat.com/groundrules.
- **View the full-length version of the film** in English, Spanish, French, as well as English with Chinese subtitles, online at http://www.cat.com/groundrules.
- **View individual chapters of the film** in English, Spanish and French, as referenced by individual lesson plans, on our You Tube channel, http://youtube.com/catgroundrules.

The full set of these lesson plans is available at http://www.cat.com/groundrules, and additional information and activities will be posted there as they become available.

Finally, follow *Ground Rules* online! Share your classroom experiences, feedback and ideas with us. Post photos of your projects and tell us about your successes!

Facebook: http://tinyurl.com/yzhxrva

Twitter: http://twitter.com/catgroundrules

About Caterpillar
For more than 80 years, Caterpillar Inc. has been building the world's infrastructure and, in partnership with its worldwide dealer network, is driving positive and sustainable change on every continent. With 2008 sales and revenues of $51.324 billion, Caterpillar is a technology leader and the world's leading manufacturer of construction and mining equipment, diesel and natural gas engines and industrial gas turbines. More information is available at www.cat.com.

About Science North
Science North, which opened in 1984 and is located in Greater Sudbury, is Northern Ontario's most popular tourist attraction and an educational resource for children and adults across the province of Ontario, Canada. Science North's drawing power lies with its unique approach to learning. The science centre has become world-renowned for its unique brand of hands-on science education and entertainment experiences which involve people in the relationship between science and everyday life.

Science North's attractions include a science centre, IMAX® theatre, butterfly gallery, special exhibitions hall, a digital Planetarium, and Dynamic Earth – a second science centre that offers visitors an up-close look at mining and the geological forces that continually shape the Earth. The same philosophies used to teach visitors about science at Science North are incorporated into every exhibit at Dynamic Earth, which first opened in 2003. This mining and geology centre combines above and underground experiences that allow visitors to work and play with real mining equipment and technologies. The site is also home to Sudbury's famous Big Nickel.

An agency of the provincial government of Ontario, Science North is overseen by the provincial Ministry of Culture. More information is available at http://sciencenorth.ca.

ELECTROWINNING EXPERIMENT

Description

Students will conduct an experiment to simulate the process of electrowinning that is used in the copper purification process.

VOCABULARY:

1. electrowinning
2. electroplating
3. anode
4. cathode
5. cation
6. anion
7. purification
8. electrolyte

MATERIALS:

- *Ground Rules* film
- Lab coats, safety goggles and gloves
- Copper electroplating solution
- Beaker
- 12 volt A/C power supply
- washer
- stainless steel spatula
- wooden holder for washer and spatula
- 2 alligator clamps to connect power supply
- 500 mL beaker

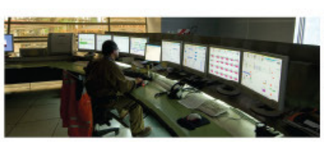
Introduction (Length: 30 minutes)

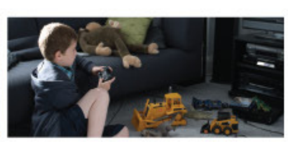
Watch Chapter 2, "Modern Mining" of the *Ground Rules* film. This chapter shows how copper is mined and processed at a large mine site in Chile.

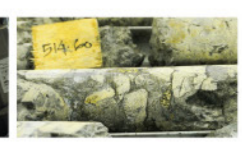
The most common source of copper ore is the mineral chalcopyrite ($CuFeS_2$). Approximately 50% of copper production throughout the world comes from this mineral.

Review the steps involved in processing copper ore, as mentioned in the film: crushing, extraction, concentration, smelting and purification (electrowinning). First the ore is crushed into a fine powder to increase the surface area for further processing. Next, the copper is extracted and concentrated by froth flotation in which ground ore is mixed with reagents in an aerated tank filled with water. The hydrophobic copper sulfide particles attach to the air bubbles and float to the surface where they form a froth that is skimmed off (see Lesson Plan on Copper Extraction for more details on this process). Next, the copper concentrate is smelted at high temperatures to form a liquid called copper matte, which is further purified by the removal of sulfur as sulfur dioxide, resulting in an end product called "copper blister" which is approximately 98-99% copper. Finally, in the purification process, copper is refined using a process called electrowinning. Explain that in this activity, they will be exploring the process of electrowinning.

Electrowinning is based on the process of electroplating. Ask the students if they know what electroplating is. Review the terms anion, cation, anode and cathode. Explain that electroplating involves movement of positively charged ions (cations) from an anode through a salt solution. The cations in the salt solution are then attracted to the cathode, where they deposit onto it in metallic form.





<u>The Electrowinning Process for Copper Purification:</u>
The copper blister is put into an anode furnace (i.e., a furnace that makes anodes) to burn off most of the remaining oxygen, usually done by blowing natural gas through the molten copper oxide. The anodes from the furnace are then placed into an aqueous solution of copper sulfate and sulfuric acid (electrolyte solution). The cathodes consist of thin sheets of pure copper. When connected to a power supply, the copper and other metals dissolve from the anode. The copper ions migrate through the electrolyte solution and plate out onto the cathode. The impurities (such as silver, gold, selenium and tellurium) settle to the bottom.

The chemical reactions in the electowinning process are:

Anode: $Cu_{(anode)} \rightarrow Cu^{2+}_{(aqueous)} + 2e-$

Cathode: $Cu^{2+}_{(aqueous)} + 2e- \rightarrow Cu_{(cathode)}$

The copper (at the cathode) is the final product of copper processing. It is usually prepared in sheets that are 1 cm thick and approximately 1 meter square, weighing approximately 200 pounds (as shown on the film).

Activity (Length: 30 minutes)

The objective of this activity is to simulate the electrowinning process involved in purifying copper. This activity can be done as a class demonstration or in student groups.

1. Put on a lab coat, safety goggles and gloves.
2. Attach one end of an alligator clamp to the spatula (anode). Attach one end of another alligator clamp to the washer (cathode).
3. Thread the spatula and washer through the wooden holder and place the holder horizontally on top of the beaker (as shown below).
4. Fill the beaker with enough electroplating solution to cover the washer.
5. Attach the other ends of the alligator cables to the power supply. Turn on the power (3 volts is usually sufficient) and observe what happens. Copper plating should begin to occur in a few seconds.
6. Leave the power on for the duration of the class and observe the plating on the washer at the end of class.

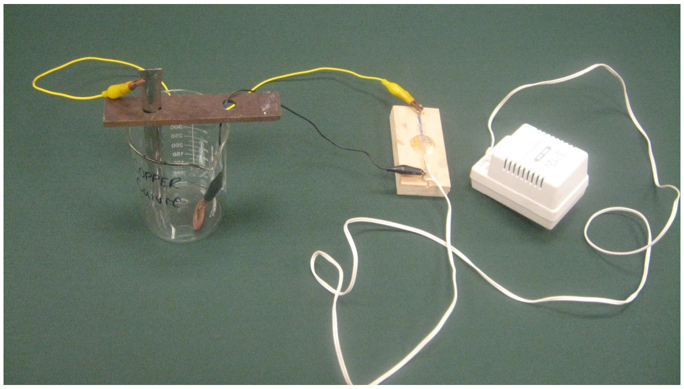


Figure 1 Experimental Setup

Discussion (Length: 15 minutes)

Ask the students to explain what happened in the experiment. How does this experiment demonstrate the process of electrowinning used in the copper purification process? Why is it necessary to remove the impurities from the copper using this process (i.e., why is 98-99% copper purity insufficient)?

Visit cat.com/groundrules for more information, to provide feedback, to view the *Ground Rules* film on-line, or to order a copy of *Ground Rules* on DVD.

GROUNDRULES

ORE PROCESSING	AGE: 13 TO 15	LENGTH: 1.5HR	CURRICULUM: earth science, ore processing

EXTRACTING COPPER FROM SULFIDE ORES

Description

Students will extract copper from sulfide ores by simulating the crushing, milling and flotation processes. They will discuss the remaining steps involved in copper production.

VOCABULARY:

1. Crushing
2. Milling
3. Froth Flotation
4. Sulfide ores
5. Copper
6. Slurry
7. Hydrophobic
8. Hydrophilic
9. Surfactant
10. Tailings
11. Waste rock

MATERIALS:

- *Ground Rules* film
- Hammer
- Large container
- Old socks
- Safety glasses
- Sulfide ore
- Plastic container (shoebox size), water
- 4 plastic cups (8 oz), plastic jar with lid
- Steel shot (1/2 - 1 cm; 1/4 - 3/8 inch)
- Wire mesh screen (1/2 cm; 1/4 inch)
- Small bottle of bubble bath liquid
- 2 index cards, laminated
- Drinking straws, teaspoons, paper towels

Introduction (Length: 15 minutes)

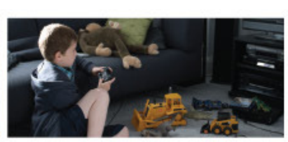
Watch Chapter 2 “Modern Mining” of the *Ground Rules* film. This chapter shows how copper is mined and processed at a large mine site in Chile.

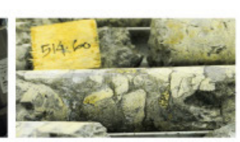
The most common source of copper ore is the mineral chalcopyrite ($CuFeS_2$). Approximately 50% of copper is produced from chalcopyrite.

Pass around a piece of sulfide ore. Tell the class there is copper in the ore. Ask them how they think they could liberate the copper particles from the ore? Discuss the crushing process used in mining to extract valuable minerals from waste rock. The crushing process involves breaking up the ore into small pieces (up to 20 cm or 8 inches in diameter), so it can be handled effectively in the next phase of ore processing: milling.

Ask the class if they know what happens in the milling process. The milling process breaks the ore pieces into fine particles. In milling, the crushed ore and liquid are put into large rotating drums called mills. There are a variety of different types of mills. Typically, steel balls or rods are added to the mills. Why? The steel collides with the ore and assists in breaking it into smaller pieces. At the end of the milling process, a slurry of fine particles and water is produced. In the final step of the milling process, chemicals are added to the slurry to prepare the copper minerals for separation from the powdered rock.





Ask the class how they think the copper can be separated from the rest of the slurry. In the next phase of ore processing, copper minerals can be removed by flotation. A detergent-like substance called a frother and chemical reagents called collectors are added to the slurry. The collectors adhere only to the copper minerals, not the other particles of rock. When air is forced through the slurry, the mixture attaches to the air bubbles and floats to the top of the liquid. The copper then ends up in the froth which floats on the surface of the tank and is skimmed off the top. The substance that is skimmed off the top is call "copper concentrate". The copper concentrate is cleaned, dewatered, filtered, dried and shipped to a smelter.

Explain that the students will be conducting an experiment to simulate the processes of crushing, milling and froth flotation.

Figure 1 Froth Flotation Tank

Activity (Length: 45 minutes)

The objective of this activity is to extract copper from sulfide ore by simulating the crushing, milling and flotation processes.

Divide the class into groups of 3 students.

Step 1: Crushing Process

1. Put on safety glasses to protect eyes from flying bits of rock. Keep them on at all times during this activity.
2. Place a few pieces of sulfide ore inside an old sock.
3. Place the sock containing the sulfide ore pieces on a hard, flat surface.
4. Use a hammer to crush the sulfide ore into quarter-sized and smaller pieces.
5. Place all of the pieces of ore that are quarter-sized or smaller into the large container.
6. Answer the question on the data sheet under "Crushing Process".

Step 2: Milling Process

1. Using a marker, label three 8 oz plastic cups as 1, 2 and 3.
2. Fill the jar approximately 1/3 full with crushed sulfide ore and steel shot. Keep a few pieces of the ore and steel shot aside.
3. Add water to the jar until the ore and shot are submerged by approximately 1 cm. Screw the lid tightly onto the jar.
4. Wrap the jar in the towel and shake for 2 minutes.
5. Place the wire mesh screen over the shoebox sized container. Pour the mixture from the jar onto the screen.
6. Pour the liquid from the shoebox-sized container into the 8 oz plastic cup labeled "1". Check to make sure you have gotten all of the fine material out of the container. Observe the ore, the steel shot and the water. Compare the ore and steel shot to the pieces set aside and record observations on the data table in the space labeled "Trial 1".
7. Return oversize pieces of ore to the jar and repeat steps 3 to 6 two more times. Pour the slurry from Trials 2 and 3 into the plastic cups labeled "2" and "3", respectively.
8. After each trial, compare the reserved steel shot, the ore and the water in each cup. In the data table on the milling process section of the data sheet, record any noticeable changes in the size and shape of the ore and steel shot and any changes in the water.
9. Set aside all three cups of slurry for the Flotation Process.
10. Separate remaining large pieces of ore from the steel shot. Place both materials on a paper towel to dry.
11. When all materials are dry, return them to the original containers.
12. Clean the jar and shoebox container being careful not to wash any of the remaining slurry into a drain.
13. Answer the questions in the "Milling Process" section of the data sheet.

Step 3: Flotation Process

1. Each group should designate one student as the "recorder" who will record observations for the group and two students as the "experimenters" who will conduct the experiment.
2. Set aside slurry cup "1" from the Milling Process for observation.
3. Add 4 to 6 teaspoons of the bubble bath liquid into slurry cup "2" and stir the contents.
4. Place one straw each into slurry cups "2" and "3". The two experimenters in each group should blow gently but steadily through each straw for 30 seconds.
5. Use the index cards to scrape any bubbles off the top of the slurry in each cup and place them on separate paper towels to dry. Label the deposited bubbles as "Trial 1".
6. The recorder of each group should record the group's observations for "Trial 1" on the data sheet while the experimenters should proceed immediately to Step 7. Don't allow the cups to "rest" between trials.
7. The experimenters should begin "Trial 2" by repeating steps 4 to 6. Then repeat again for "Trial 3" and "Trial 4". After each trial, the recorder should record the group's observations on the data sheet.
8. Dispose of the slurries by placing them in a garbage receptacle lined with a strong plastic bag. Do not pour slurry into a drain.

9. Answer the questions in the “Flotation Process” section of the data sheet.

Discussion (Length: 30 minutes)

Review the observations made by each of the groups and the answers to the questions on the data sheet.

What happens to the remaining rock fragments left behind at the bottom of the flotation tank? This mixture, known as tailings, is typically pumped to a tailings impoundment where the water is removed and recycled back into the flotation process. The remaining waste rock must be stockpiled and eventually incorporated into the reclaimed landscape after mining operations have ceased.

Review the process of froth flotation in more detail. Why are the copper particles collected on the bubbles? Why does the addition of soap help separate the copper particles? What is the purpose of the air? Review the terms hydrophobic and hydrophilic. The soap is a surfactant which has a hydrophobic end and a hydrophilic end. In actual copper flotation processes, a specific surfactant is added that binds to the copper making it hydrophobic. The remainder of the solution remains hydrophilic. The hydrophobic mineral particles then attach to the air bubbles and float to the surface.

Briefly discuss the next steps involved in processing copper. After flotation, the copper concentrate contains only 20 to 40% pure copper. The next step in the process is to convert the copper concentration to 99% pure copper. This is accomplished in the smelting process where high temperatures are used to roast the concentrate, smelt it in a furnace and oxidize and reduce the molten material to progressively remove the unwanted elements, such as sulfur, iron, silicon and oxygen. Relatively pure copper (99%) is left behind. The final step in the process is called electro-refining or electro-winning. In this process, copper is purified through electrolysis. An electric current is passed through the material which separates the copper ions from the impurities.

Visit cat.com/groundrules for more information, to provide feedback, to view the *Ground Rules* film on-line, or to order a copy of *Ground Rules* on DVD.

Extracting Copper from Sulfide Ore Data Sheet

Crushing Process:

Was it easy or difficult to crush the sulfide ore into small pieces?

Milling Process:

Trial	Changes in Sulfide Ore	Changes in Steel Shot	Changes in Water
1			
2			
3			

What does the jar represent?

What is the purpose of the steel shot?

What is the purpose of the screen?

Why is the milling process necessary?

Flotation Process:

Record the behavior of each slurry cup after each trial in the following table:

Trial	Slurry Cup 1 (slurry only; control)	Slurry Cup 2 (slurry with bubble liquid and air)	Slurry Cup 3 (slurry with air)
1			
2			
3			
4			

What was observed collecting onto the bubbles?

What was the purpose of injecting air into the slurry cups? What happened to the ore in the cups when air was added? Why?

Was there a difference in what was collected on the bubbles from Slurry Cups 2 and 3?

Was all of the copper in the slurry collected after 4 trials? Is this “pure” copper?

ORE PROCESSING	AGE: 13 TO 15	LENGTH: 1.5HR	CURRICULUM: earth science, ore process, mixtures

FLOATING COAL

Description

Students will explore the process of froth flotation to separate coal from a mixture of coal and sand. They will learn about how coal is processed.

VOCABULARY:

1. Froth flotation
2. Hydrophobic
3. Hydrophilic
4. Surface tension
5. Slurry
6. Concentrate
7. Tailings
8. Mixtures

MATERIALS:

- *Ground Rules* film
- Clear glass jar
- Liquid detergent and eye dropper
- Vegetable oil and eye dropper
- Stirring rod
- Silica sand (approx. same size as coal particles)
- Powdered coal, with some larger flakes
- Filter paper (can use coffee filters)
- Data sheet (provided)
- Resource books or internet access

Introduction (Length: 15 minutes)

Watch Chapter 8 “Reclamation” of the *Ground Rules* film. This chapter shows how coal is mined at a mine site in the United States.

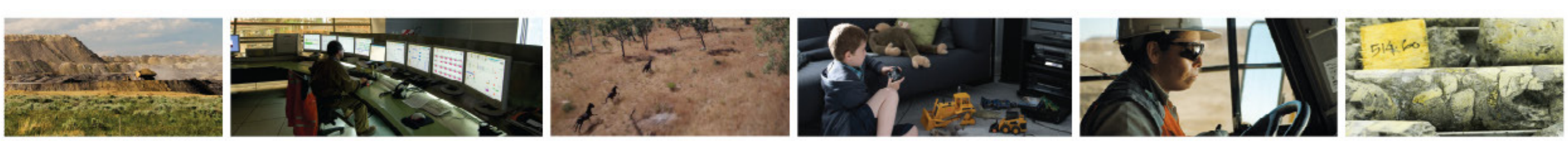
Pass around a mixture of sand and coal. Ask the students how they think they could extract the coal from the sand. Suggest the idea of using a sieve to separate the particles. Ask the students if that would work. Explain that a sieve would not work because some of the sand particles are the same size as the coal particles.

Explain that froth flotation is a process that is used to remove coal from the sand. This process can also be used to separate valuable metals from ore (see Lesson plan on copper extraction for more details). Explain that the students will be conducting an experiment to separate coal from a coal-sand mixture using the process of froth flotation.

Activity I (Length: 30 minutes)

The objective of this activity is to separate coal from a coal-sand mixture using the process of froth flotation.

1. Divide the class into groups of two.
2. Have each group fill the glass jar approximately 2/3 full with tap water, secure the lid and shake vigorously. Stop shaking and let stand for a few seconds. Answer the questions in Section A of the data sheet.



3. Add 2 drops of detergent to the tap water, secure the lid and shake vigorously. Stop shaking and let stand for a few seconds. Answer the questions in Section B of the data sheet.
4. Empty the jar and rinse with tap water.
5. Place an equal amount of sand and coal in the bottom of the jar. Fill the jar 2/3 full with water. Shake gently to wet all of the sand and coal particles.
6. Add 2 drops of vegetable oil and gently stir with a stir stick for 2 to 4 minutes to allow it to mix with the sand and coal particles.
7. Add 2 drops of detergent and replace the lid. Vigorously shake for 2 to 3 minutes. Stop shaking and let stand for a minute.
8. Open the jar and gently scrape some of the froth onto a filter paper and let it dry.
9. Answer the questions in Section C of the data sheet.

Activity II (Length: 30 minutes)

The objective of this activity is to learn how coal is processed for use as fuel and for use as coke in the steel making industry.

Using resource books or the internet, answer the following questions:

1. What are the major uses of coal?
2. How is coal processed for use as fuel?
3. How is coal processed to make coke? What is coke used for?
4. How much of your country's energy comes from burning coal?

Discussion (Length: 15 minutes)

Activity I:
Discuss the questions and answers on the data sheet. Explain what is happening in each stage of the experiment.

Remind students that in the first step of the experiment, there is not only water in the bottle, but also air. When they shake the bottle, they are mixing the air and water. However, the mixture quickly separates into two phases (liquid and gas) as soon as mixing ceases.

When detergent is added to the air-water mixture and the mixture is shaken, a froth forms at the top surface. Explain that detergent molecules reduce the surface tension and help stabilize the bubbles. Detergent has a hydrophobic end and a hydrophilic end. So, part of the detergent molecule wants to stay in the water, but part of it wants to go into the air. The froth represents the hydrophobic portion of the detergent molecules that are mixed with air.

Vegetable oil is hydrophobic. When vegetable oil is added to a mixture of sand, coal and water, it selectively coats the coal particles making their surface hydrophobic. Because these particles are now hydrophobic, they attach to the air bubbles and are carried to the surface, forming a froth layer.

The large coal particles do not float because they are too big for the bubbles to lift them to the surface. This is why it is important to crush the coal into very small particles prior to froth flotation.

The sand particles settle to the bottom of the jar because they are not hydrophobic, so they do not attach to the air bubbles. If some sand particles get to the froth phase during shaking, they quickly fall back into the water phase when shaking ceases.

In ore processing, the froth layer would be skimmed off the surface and the remainder of the mixture would be disposed of as tailings.

Activity II:
Coal that will be used as fuel does not require a lot of processing prior to use. However, impurities must be removed and coal is usually graded into various size fractions. Crushing, followed by flotation or screening techniques can be used to separate size fractions.

Coal is processed into coke for use in steel production. To make coke, the volatile constituents of the coal are driven off by baking in an anaerobic oven at high temperatures. The remaining ash is coke. Coke can also be used as a fuel and as a reducing agent in the iron smelting process.

Discuss the reliance of your country on coal as an energy source.

Visit cat.com/groundrules for more information, to provide feedback, to view the *Ground Rules* film on-line, or to order a copy of *Ground Rules* on DVD.

Floating Coal Data Sheet

A) Mixing Air and Water:

1. What happens when you shake the jar of tap water and air?

2. What happens when you stop shaking them?

B) Mixing Detergent, Air and Water:

1. What happens when you shake the jar of water, detergent and air?

2. Why does the froth layer form at the top of the solution?

C) Mixing Sand, Coal, Water, Vegetable Oil and Detergent:

1. What forms at the top surface of the mixture?

2. Where does the coal go? Why?

3. Where does the sand go? Why?

4. What was on the filter paper?

5. Why don't the large coal particles float? What could be done to make them float?

GROUNDRULES

ORE PROCESSING	AGE: 13 TO 15	LENGTH: 1 HR	CURRICULUM: earth science, chemistry, ore process

LEACHING TO SEPARATE METALS FROM ORE

Description

Students will conduct a leaching experiment to extract copper from copper ore. They will also experiment with materials containing iron and zinc.

VOCABULARY:

1. Ore
2. Ion
3. Leaching
4. Solution
5. Solvent
6. Hydrometallurgy
7. Acid
8. Precipitation

MATERIALS:

- *Ground Rules* film
- Finely crushed copper ore
- 100 mL Pyrex beaker or cup
- Plastic spoon
- ½ cup white vinegar
- Hot plate
- Saucepan
- Aluminum wire or aluminum foil
- Steel nail
- Zinc coated nail
- Copper wire
- Safety goggles

Introduction (Length: 15 minutes)

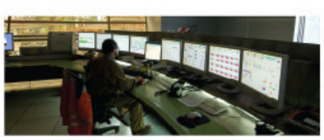
Watch Chapter 2 “Modern Mining” of the *Ground Rules* film. This chapter shows how copper is mined and processed at a large mine site in Chile.

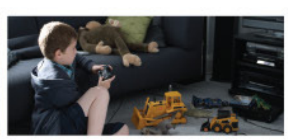
Ask students what leaching is and how it might be used in to process ore.

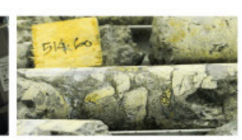
Leaching is one method that can be used to separate some metals from the ore in which they are found. The extraction of metals by use of chemical solutions is called hydrometallurgy. Leaching is one common example of hydrometallurgy.

Leaching is used in approximately 15% of world-wide copper production. Most of these operations are in Chile, Arizona and Australia.

Leaching utilizes a chemical solvent to dissolve or separate (leach) the metal from the ore, forming a solution from which the metal can be collected. The ore is piled onto a surface known as the “leaching pad” and it is then sprayed with the chemical and allowed to dissolve and drain. The concentrate solution can then be processed to recover the desired metal. Sulfuric acid for example, is often used to leach uranium, copper, and zinc ore. An aqueous solution of sodium or potassium cyanide is used to leach some gold and silver ores.





Activity I (Length: 20 minutes, plus follow-up)

The objective of this activity is to dissolve copper ions and extract them from the solution onto an aluminum wire.

Teacher Preparation:

1. Heat the vinegar in a sauce pan on the hot plate until it is boiling. This should be done in a fume hood prior to the activity.

Activity:

1. Put on safety goggles to avoid splashing vinegar solution into eyes. Preferably complete this activity in a fume hood.
2. Pour approximately 50 mL of hot vinegar into the Pyrex beaker or cup. This is the leaching solution. Note the color of the solution.
3. Add a tablespoon of the crushed copper ore to the Pyrex container (enough to cover the bottom).
4. Note the color of the leaching solution after the addition of the ore. What is happening?
5. Add a piece of aluminum wire or foil (3-4 inches long) with part of the wire in the solution and part hanging over the edge of the beaker.
6. Add a piece of copper wire as a control to demonstrate what happens to copper-containing materials in the reaction.
7. After a few minutes, remove the aluminum from the solution. Did the portion that was in the solution start to change color? If so, why?
8. Replace the aluminum in the solution and check after 30 minutes. Has a color change occurred? What is happening?
9. Leave the materials in the solution for a few days and make daily observations.

Activity II (Length: 10 minutes, plus follow-up)

The objective of this activity is to observe what happens to materials containing iron and zinc when placed in a leaching solution.

1. Put on safety goggles to avoid splashing vinegar solution into eyes. Preferably complete this activity in a fume hood.
2. Prepare another two beakers with 50 mL of hot vinegar solution.
3. Add a steel nail to one beaker and a zinc coated nail to the other, with a portion in the solution and a portion outside the solution. What happens?
4. Leave the materials in the solution for a few days and make daily observations.

Discussion (Length: 15 minutes)

Activity I:

Ask the students to explain what is happening in the beaker. What is vinegar composed of? Vinegar is a weak solution of acetic acid in water. What does the vinegar do to the copper ore? What form is the copper in when it is in solution? Discuss the term “ion”.

What color is the solution? Copper acetate ions have a blue-green color. How does the solution change over time?

Why was the aluminum wire added to the beaker? Did the aluminum wire change color? Why? Some of the copper ions in the solution precipitated onto the aluminum wire.

Why didn't the aluminum leach from the wire? When aluminum is exposed to oxygen, it forms a thin layer of aluminum oxide on its surface which is relatively resistant to the corrosive effects of acetic acid.

Activity II:
What happened to the steel nail (containing iron) and the zinc coated nail? Iron and zinc are easily corroded by acetic acid.

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ORE PROCESSING	AGE: 13 TO 15	LENGTH: 1.5HR	CURRICULUM: earth science, ore process, magnets

MAGNETIC SEPARATION

Description

Students will explore the properties of magnetite and use a magnet to separate magnetite from sand. They will calculate the grade of magnetite ore in their sample. They will research the properties, mining areas and uses of magnetite.

VOCABULARY:

1. Magnetite
2. Magnetism
3. Ore grade
4. Magnetic separation

MATERIALS:

- *Ground Rules* film
- Magnetite rock sample
- Non-magnetic rock sample
- Ground magnetite
- Sand
- Strong magnet
- Ziplock bag
- Balance
- Filter paper or paper towel
- Shallow tray or pie plate
- Mineral identification guide or internet access
- Calculators
- Data sheet (provided)

Introduction (Length: 10 minutes)

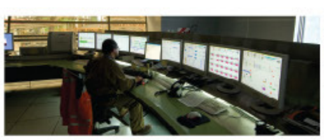
Watch Chapter 2 “Modern Mining” of the *Ground Rules* film. This chapter shows how copper is mined and processed at a large mine site in Chile.

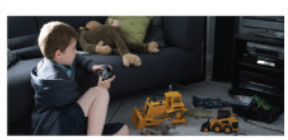
Review mineral properties. Ask students to name some properties that can be used to identify minerals (e.g, hardness, colour, luster, streak, magnetism).

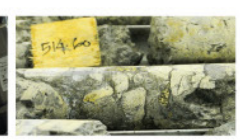
Explain that after ore is mined, the valuable minerals have to be extracted from the rest of the ore. This can be done in a variety of ways. Explain that in this experiment, students will be using the property of magnetism to separate a magnetic mineral from an ore mixture.

Activity I (Length: 30 minutes)

The objectives of this activity are to examine the properties of magnetite, to separate powdered magnetite from sand, and to determine the grade of magnetite.





Preparation:

1. Mix together sand and ground magnetite in a container. The amounts don't have to be measured, but ensure that the mixture includes at least 50% magnetite.

Activity:

1. Divide the class into groups of two.
2. Each group should test the two rock samples with their magnet. Which rock sample is magnetic? Use a mineral identification guide or the internet to determine the name of the magnetic mineral. Provide your answers in Section A of the data sheet.
3. Label a piece of paper towel or a filter paper as "mixture". Weigh the paper towel/ filter paper on the balance and record the weight in Section B of the data sheet.
4. Add 5 tablespoons of sand and magnetite mixture to the paper towel and record the weight. Subtract the weight of the paper towel from the weight of the mixture and paper towel to get the weight of the mixture. Record in Section B of the data sheet.
5. Carefully dump the contents of the paper towel into a shallow tray or pie plate.
6. Put the magnet into a ziplock bag and seal tightly.
7. Label a piece of paper towel or filter paper as "magnetite". Weigh the paper towel/ filter paper on the balance and record the weight in Section C of the data sheet.
8. Move the bagged magnet across the top of the sand and magnetite mixture. What happens?
9. Carefully, move the bagged magnet over the paper towel/filter paper. One person should carefully open the ziplock bag. The other person should remove the magnet being careful not to touch the magnetite particles or they will stick to the magnet. Without the magnet in the bag, the particles of magnetite should drop from the outside of the bag onto the paper towel.
10. Repeat steps 8 and 9 until virtually all of the magnetite has been removed from the sample.
11. Weigh the paper towel containing the magnetite and record in Section C of the data sheet. Subtract the weight of the paper towel from the weight of the paper towel containing magnetite to get the weight of the magnetite. Record in Section C of the data sheet.
12. Calculate the "grade" of magnetite as the percentage of magnetite in the mixture. Record in Section C of the data sheet.

Activity II (Length: 30 minutes)

The objective of this activity is to research the properties, mining areas and uses of magnetite.

Using resource books or the internet, answer the following questions:

1. Name three properties of magnetite other than magnetism.
2. What type of rocks can magnetite be found in?
3. How and where is magnetite mined?
4. Describe the process whereby magnetite is used to extract coal from pyrite-rich ore. How is the property of magnetism used in this process?
5. What types of products contain magnetite? What properties of magnetite make it useful for these products?
6. What mineral is magnetite often found in association with?

Discussion (Length: 20 minutes)

Activity I:
Discuss the questions and answers on the data sheet. Explain what is happening in each stage of the experiment. How useful is magnetic separation? How many minerals have magnetic properties?

Why is ore grade important? Discuss the economic and technical considerations involved in deciding whether to mine a deposit. If each of the samples evaluated in the experiment represented an individual mine site, which would be the best site to mine?

Activity II:
Discuss the answers to the questions. Magnetite is found in igneous, metamorphic and sedimentary rocks. It is mined in Australia, Switzerland, South Africa and the United States. It is used in abrasives, toner, fertilizers, paint pigments, and in aggregates for high density concrete. Magnetite is often found in iron-containing ores.

Explain that magnetite is sometimes used to separate pyrite from coal. A slurry of magnetite and water is heavy and allows finer particles of coal to float to the top. The heavier pyrite particles settle to the bottom. A magnetic drum is used to extract the magnetite from the slurry after use.

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Magnetic Separation Data Sheet

A) Magnetic Test:

1. Which rock sample is magnetic?

2. What is the name of the magnetic mineral? How did you determine that?

B) Sand and Magnetite Mixture:

1. Weight of Paper Towel ("Mixture"): ______________________________
2. Weight of Mixture and Paper Towel: ______________________________
3. Weight of Mixture: ______________________________

4. Describe the mixture. What are the dark particles? What are the lighter particles? Which part of the mixture is magnetic?

C) Grade of Magnetite:

1. What happens when you move the bagged magnet across the top of the mixture? Why?

2. Weight of Paper Towel ("Magnetite"): ______________________________
3. Weight of Magnetite and Paper Towel: ______________________________
4. Weight of Magnetite: ______________________________
5. What is the grade (%) of magnetite in your sample? (show the calculation)