GROUNDRULES

ORE PROCESSING

Ore Processing

AGES 15-18

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. They will also discuss the by-products of ore processing.

VOCABULARY:

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

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

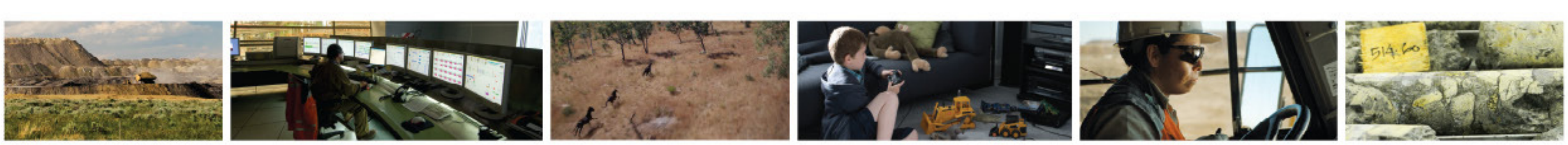
Introduction (Length: 30 minutes)

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.



The Electrowinning Process for Copper Purification:
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 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 horizontally on top of the beaker (as shown below).
4. Fill the beaker approximately 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.

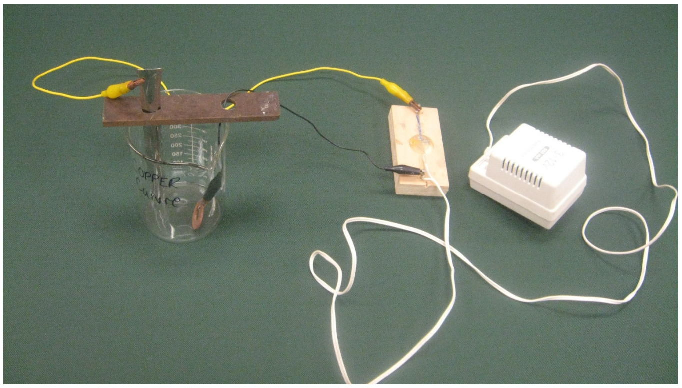


Figure 1 Experimental Setup

Discussion (Length: 30 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)?

What are the waste products produced at each step in copper ore processing? The by-product of extraction is tailings. The by-products of smelting are sulfur dioxide gas and slag. The by-product of electrowinning is anode mud which may include a variety of metals (silver, gold are the most valuable). The valuable metals may be extracted from the anode mud and form a secondary saleable product.

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 ORES

Description

Students will extract copper from sulfide ores by simulating the crushing, milling and flotation processes. In the second activity, they will research the remaining steps in the production of copper (smelting and electrowinning).

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
- Resource books or internet access

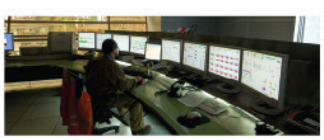
Introduction (Length: 15 minutes)

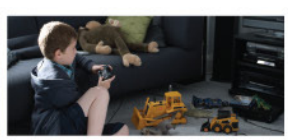
Watch Chapter 2 “Modern Mining” of the *Ground Rules* film. This chapter shows how copper is mined and processed at a large mine site in Chile.

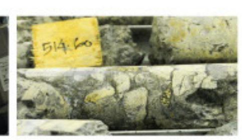
The most common source of copper ore is the mineral chalcopyrite ($CuFeS_2$). Approximately 50% of copper is produced from chalcopyrite.

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 I (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.

Activity II (Length: 30 minutes)

The objective of this activity is to research the remaining steps in the processing of copper ore. Students can work in pairs or alone.

1. Using resource books or internet access (as well as information from the *Ground Rules* film, Chapter 2), determine the remaining steps in the processing of copper ore. Answer the following questions:

    a. How pure is the copper after the flotation process (% of copper)?
    b. What is the next step in the processing of copper ore? Briefly describe this process. How pure is the copper after this step?
    c. What is the final step in the processing of copper ore to achieve pure copper? Briefly describe this process.
    d. How is copper typically packaged for distribution?
    e. What are some of the common uses of copper?

Discussion (Length: 30 minutes)

<u>Activity I:</u>
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.

Activity II:
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. As the film shows, the copper is prepared in square sheets and bundled for distribution. The most common uses of copper are in electrical wiring, currency and piping.

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?

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 and with other solvents.

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
- Weak sulfuric acid solution
- Safety goggles

Introduction (Length: 20 minutes)

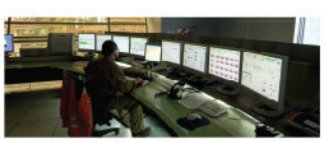
Watch Chapter 2 “Modern Mining” of the *Ground Rules* film. This chapter shows how copper is mined and processed at a large mine site in Chile.

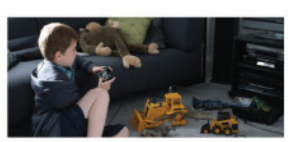
Ask students what leaching is and how it might be used in to process ore.

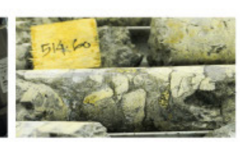
Leaching is one method that can be used to separate some metals from the ore in which they are found. The extraction of metals by use of chemical solutions is called hydrometallurgy. Leaching is one common example of hydrometallurgy.

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: 20 minutes, plus follow-up)

The objectives of this activity are to observe what happens to the copper ore in a sulfuric acid solution and what happens to materials containing iron and zinc when placed in a leaching solution.

Activity:

1. Put on safety goggles to avoid splashing acid solutions into eyes. Preferably complete this activity in a fume hood.
2. Repeat Activity I using a weak sulfuric acid solution as the leaching solvent. How do the results compare to Activity I?
3. Prepare another two beakers with 50 mL of hot vinegar or the sulfuric acid solution.
4. Add a steel nail to one beaker and a zinc coated nail to the other. What happens?
5. Leave the materials in the solution for a few days and make daily observations.

Discussion (Length: 30 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 or sulfuric acid. Leaching can also be used to extract iron and zinc from ore.

What happened to the copper ore in the sulfuric acid solution? How did the results compare to the vinegar solution? Which solution was more effective in leaching the copper ore?

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.

AGE: 15 TO 18 | LENGTH: 1.5HR | CURRICULUM: earth science, metals, alloys

MAKING STEEL AND STEEL ALLOYS

Description

Students will explore the process of steel production from iron ore. They will learn about metal alloys and how metal alloys are used to make stainless steel. They will also learn how steel can be recycled.

VOCABULARY:

1. Iron ore
2. Nickel
3. Chromium
4. Titanium
5. Silicon
6. Alloy
7. Corrosion resistance
8. Ingot
9. Ductile
10. Pig iron
11. Blast furnace

MATERIALS:

- Resource books or internet access
- Variety of objects made of steel

Introduction (Length: 15 minutes)

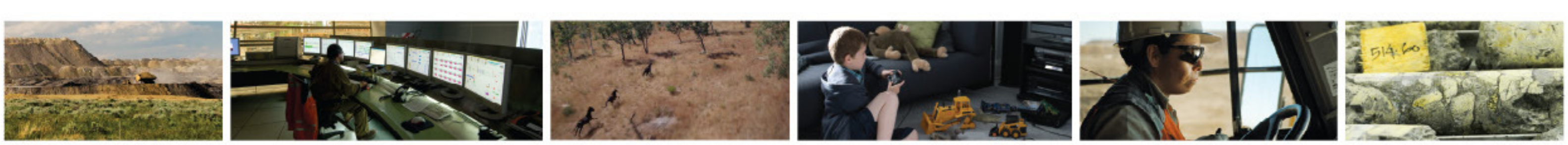
Ask the students if they know what an alloy is and to give an example of an alloy. An alloy is a mixture of two or more metals or elements. Some examples include brass, which is an alloy of copper and zinc, and bronze, which is an alloy of copper and tin.

Steel is also an alloy. What is the most common metal used in steel? Iron.

Pass around some objects made of different types of steel. Ask the students what is different about the types of steel used to make those objects.

Explain that the basic steel alloy includes iron and carbon. Steels are classified according to the amount of carbon they contain. The more carbon the steel has, the harder and more durable the steel is. Mild steels (the least durable steels) contain up to 0.25% carbon. Medium steels contain 0.25 to 0.45% carbon and high carbon steels contain up to 1.5% carbon.

A variety of other metals can be added to the basic steel alloy to make specific kinds of steel. Ask the students if they know what metals are added to make stainless steel (nickel and chromium).



Activity (Length: 45 minutes)

The objectives of this activity are to learn how iron ore is processed into steel, to learn about various steel alloys, and to learn how steel can be recycled.

1. Using resource books or internet access, research how iron ore is processed into steel. Answer the following questions:

    a. What is the name given to impure iron ore that is used in the steel-making industry?
    b. What is an ingot?
    c. How are the iron ore ingots melted?
    d. What type of furnace is used to melt the iron ore?
    e. How are the impurities removed from the iron ore?
    f. Name three elements that can be added to steel and what properties these metals provide to the steel.
    g. Name five uses of steel. What type of steel is used for each?
    h. How is steel made into sheets?
    i. How can scrap metals be used in the production of steel?
    j. How can steel be recycled into new steel?
    k. What percentage of steel is made from recycled metal in your country?
    l. Could steel be considered to be a renewable resource? Explain why or why not.

Discussion (Length: 30 minutes)

Discuss the process of making steel from iron ore. Explain that pig iron, an impure form of iron ore, is used to make steel. An ingot is a metal that is cast into a specific shape suitable for further processing. Iron ingots are melted in a blast furnace. Scrap or recycled iron can be added at this step and melted with the pig iron.

Limestone chunks are added to the blast furnace to remove impurities. The acidic impurities bind to the limestone and float to the top of the blast furnace. They are then skimmed off the top of the molten iron. Oxygen is blow into furnace to aid in removing the impurities.

Nickel and chromium can be added to create stainless steel. Most stainless steels contain approximately 18% chromium and 8% nickel. Nickel increases the ductile nature of the steel, while chromium provides corrosion resistance.

Titanium can also be added to steel to increase the strength of the steel. This type of steel is used for making airplanes and spacecraft. Silicon may be added to steel to make it softer and more pliable and to increase resistivity and permeability. Silicon steels are used in transformers, generators, motors, etc.

Recycling is an integral component of the steel making industry. Scrap iron can be added to the blast furnace and melted in the same manner as pig iron. In addition, steel can be recycled into new steel simply by melting it and reforming it into steel sheets. Steel is one of the most recycled materials in the world. The recycling rate of steel is typically quite high (>50% in most industrialized countries).

Discuss the students ideas on whether steel is a renewable resource. What is a renewable resource? A renewable resource is one that can be replenished at a rate comparable to or faster than its rate of consumption. Is this true for steel? Some people think that since steel can be recycled into new steel indefinitely, it could be considered to be a renewable resource. However, if our consumption of steel exceeds the rate at which it is recycled, then the steel making process continues to use raw materials harvested from the earth, which are not renewable.

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.

MINING EQUIPMENT

Description

Students will explore the types of equipment used on mine sites to load and haul ore to processing facilities, including trucks, loaders, drag-lines and remote-controlled vehicles.

VOCABULARY:

1. Loader
2. Excavator
3. Drag-line
4. Haul truck
5. Bucket wheel
6. Remote-controlled vehicles
7. Safety

MATERIALS:

- *Ground Rules* film
- Resource books or internet access

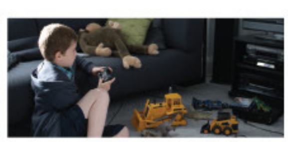
Introduction (Length: 30 minutes)

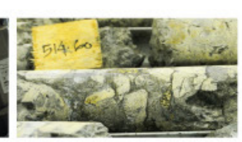
Watch Chapter 2 "Modern Mining", Chapter 5 "Going Underground" and Chapter 8 "Reclamation" of the *Ground Rules* film. Chapter 2 shows haul trucks and draglines that are used to load and haul copper ore at an open pit mine in Chile. Chapter 5 shows some of the equipment that is used at an underground mine in Canada. Some of this equipment is remote-controlled to ensure worker safety (remote-controlled loaders). Chapter 8 shows a dragline in use at the Black Thunder mine in the United States. The dragline is used to scoop the coal out of the mine and stockpile it for hauling.

Discuss the importance of heavy equipment to the mining industry. Safety is one of the major considerations in the design of modern mining equipment. As shown in the film, equipment operators receive health and safety training and must follow strict health and safety protocols while operating heavy equipment on a mine site. The equipment must be continually inspected to ensure that is it working properly and safely.

Review the concepts of simple and complex machines and mechanical advantage. Explain that we can measure the effectiveness of a machine by calculating the mechanical advantage. The mechanical advantage can be used to determine how much easier a job has become with the help of the machine. The mechanical advantage equals the number of times a machine multiplies your effort (or force).





To calculate the mechanical advantage, divide the load by the force, as follows:

$$\text{Mechanical Advantage} = \frac{\text{Load}}{\text{Force}}$$

Give an example on the board: If a rock weights 100 lbs (load) and we create a simple machine that requires us to use 50 lbs of our force to lift the rock, then the mechanical advantage of our machine would be 2 (i.e., 100 / 50 = 2). In other words, the simple machine multiplied our effort by 2. It allowed us to do the work using half the effort it would have taken us to do the work without the machine.

As the mechanical advantage increases, the machine becomes more efficient and less effort is expended by the miner. This allows more work to be done. Engineers can use the mechanical advantage formula to make modifications to existing machines to further enhance efficiency.

Activity (Length: 60 minutes)

The objective of this activity is to learn about the equipment used to load and haul ore at mine sites. This activity can be done individually or in groups.

1. Each student or group of students should select a type of mining equipment used to load or haul ore. If possible, they should each select a different type of mining equipment.

2. Prepare a research report on this piece of equipment by answering the following questions:

    a. What is the purpose of this piece of equipment? What activities does it perform at a mine site?
    b. What type of mine would use this piece of equipment? (open pit, underground)
    c. What are the potential safety issues associated with using this piece of equipment at a mine site? What aspects of this piece of equipment enhance the safety of its operation?
    d. How big is this piece of equipment? How heavy a load can it lift or haul?
    e. Briefly describe how the equipment operates.
    f. What types of simple machines are used in this complex machine?
    g. How does this piece of equipment increase mechanical advantage?

Discussion (Length: 30 minutes)

Have the students present their findings to the class. Discuss the importance of these pieces of equipment to the functioning of mine sites. What are the safety issues associated with use of this equipment? What measures can be used to enhance the safe operation of mining equipment?

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.