Saskatchewan's Mineral Resources
Lesson: Physical Separation of Minerals

Overview
Students design a process to separate the four components of a mixture containing iron filings, salt, sand and sawdust.

Source: This lesson has been adapted for Saskatchewan. The original lesson is from the EdGeo Publication Bringing Earth Science to Life.

Duration: Two classes

Materials:
- Student Activity Page – Separation Challenge
- Iron filings
- Salt
- Sand
- Sawdust
- Sample of copper wire 2-3 inches
- Sample of pyrite and if possible chalcopyrite
- Magnet
- Filter paper
- Beakers/containers, small plastic containers
- measuring cylinders, or measuring cups
- pH test strips
- sieves – (sieve, colander, screening, needle point plastic, stockings, cheese cloth)
- 4 small zip lock bags per student.

Instructional Methods: Inquiry, lab activity, discussion

Floatation Process at Rocanville Potash Mine

Safety: Review each student's proposed method for separation before the actual procedure is carried out. Modify where needed to ensure safe practice.

Learning Outcomes and Indicators

Grade 7: Mixtures and Solutions:
MS7.1Distinguish between pure substances and mixtures (mechanical mixtures and solutions) using the particle model of matter.
a. Examine a variety of objects and materials, and record qualitative (e.g., colour, texture, and state of matter) and quantitative (e.g., density, melting point, and freezing point) physical properties of those objects in a chart or data table.
b. Describe the characteristics of pure substances, mechanical mixtures, and solutions.

MS7.2Investigate methods of separating the components of mechanical mixtures and solutions, and analyze the impact of industrial and agricultural applications of those methods.
a. Describe methods used to separate the components of mechanical mixtures and solutions, including mechanical sorting, filtration, evaporation, distillation, magnetism, and chromatography.
d. Design and conduct an experiment to determine the effectiveness and/or efficiency of one or more methods of separating mechanical mixtures and solutions.
e. Report the strengths and limitations of a chosen experimental design to determine the effectiveness and/or efficiency of one or more methods of separating mechanical mixtures and solutions.
j. Use a technological problem-solving process to design, construct, and evaluate a prototype of a process or device for separating a mechanical mixture or solution (e.g., purifying drinking water, separating household waste).
Grade 10: Chemical Reactions:

CR1 - Observe common chemical reactions in your world
1. Provide examples of how science and technology are an integral part of our lives and community.
9. Identify examples of technologies or technological processes that were developed based on scientific understanding of chemical reactions.

Energy and Resources 10,20,30
Goal - Awareness**: To provide students with an awareness of the nature, technology and products of Saskatchewan's energy and mining industries, as well as the related goods, services and processes that support those industries.**

Module: 13, 24

Source: **Saskatchewan Evergreen Curriculum**

Big Picture Question

1. How do you extract the valuable minerals from the rock?

Background Information

Most economic natural resources are not found in the Earth in a native (pure) state, but are extracted from mineral-bearing rocks and processed to extract the resource. There are many physical and chemical separation techniques, and these are continually being redesigned to improve efficiency and percentage returns, or to diminish any environmental impact.

Each extraction process is specific to the mineral being extracted and the host rock.

THE ACTIVITY

(Independent learning, Guided Inquiry, Discussion)

Teacher Preparation
1. Reproduce copies of the Student Activity Page and provide a range of suitable laboratory equipment to inspire the students' methods. Set out the laboratory materials listed above, plus other common equipment
2. Fill small containers with a mixture of iron filings, salt, sand and sawdust. If you would like the students to determine efficiency of their experiment measure the amount/weight of each material in the mixture.

Motivational Set (5 minutes)
Show students a sample of pyrite or chalcopyrite, along with some copper wire. Explain that pyrite and chalcopyrite both occur in copper ores, and that copper rarely exists in a pure form in the Earth. Pyrite and chalcopyrite must be processed to extract their copper content. Processing uses the physical or chemical properties of an economic mineral like copper to separate (or extract) it from its host ore.

Activity:

Students to work in pairs or small groups.

1. Distribute the Student Activity Page and prepared mixtures.
2. Encourage students to observe the four separate components carefully to establish the physical properties of each that would be useful for designing a separation process. Be prepared to offer hints and instruction about laboratory techniques. *(See Teacher Answer Sheet – Separation methods. Note: the sample method is not intended as a prescriptive solution, and there is plenty of room for student design and innovation).*
3. Allow time for students to complete their observations and plan a separation process for each of the four components in their mixtures.
4. Approve the planned methods and provide students with the equipment they need to carry out their methods.
   The salt separation may take several days to fully evaporate and crystallize.
5. Once the students have finished their separations have them look at the methods used to separate gold, diamonds, uranium, and potash from the host rock.
6. Have students answer the discussion questions.
7. Ask students to hand in their approved planning sheet, questions sheet as well as the sample of

the separated materials.

Assessment Method and Evidence

✓ **Separation Activity**

- The students will describe the characteristic of the mechanical mixture.
- The students will examine and record the physical properties of the iron filings (magnetic), sand (insoluble, dense, grain size), salt (soluble in water, grain size) and sawdust (insoluble, floats in water), and decide upon the property(s) of each material that will allow them to separate it from the rest of the mixture.
- Students will develop a plan describing the methods they will use to separate the various components of the mechanical mixture. Methods used will be a variety of sorting (grain size, density), filtration (grain size, solubility), evaporation (solubility in water), and magnetism.
- Students will design and conduct an experiment to determine the effectiveness and/or efficiency of one or more methods of separating mechanical mixtures and solutions.
- An effective experiment will separate the four materials. If the teacher has measured the amounts of each material in the initial mixture, measurement of the product will determine the efficiency of each method.
- Students will be able to describe the steps involved when using technological problem-solving process to design, construct, and evaluate a prototype of a process or device for separating a mechanical mixture or solution.

✓ **Discussion Questions**

- The students will look at the methods of separating the ore minerals uranium, potash, diamonds and gold from the waste rock and make comparisons with their separation activity.
- Students will assess and report on the strengths and limitations of their methods of separation.

✓ **Processing Methods for Saskatchewan Mines**

- Students will realize that knowledge of chemistry and technology is an integral part of the processing of mineral resources.
- Students will be able to explain how the separation of uranium, gold and potash from the rock is a result of chemical reactions and physical separation and that these processes were developed based on scientific understanding of chemical reactions.

Resources

Bringing Earth Science To Life. Using Natural Resources. EdGeo Canadian Earth Science Teacher Workshop Program. Available at: http://www.edgeo.org/images/pdf/bringing-earth-science-to-life/natural-resources.pdf

How Products are Made. 1. Available at: http://www.madehow.com/Volume-1/

Names: _____

SEPARATION CHALLENGE

You are going to design a process that will separate the four components of your mixture:
iron filings, salt, sand and sawdust.

Materials
Mixture: iron filings, salt, sand, and sawdust
Beakers/containers
Separation equipment of your choice

Instructions
1. From your experience or observation, describe the properties of the four parts of the mixture.

Iron filings:

Salt:

Sand:

Sawdust:

2. Based on the properties that you have described, and using the technological method of problem solving (below), design a series of steps that will separate the mixture into its four parts. Draw diagrams to help with your explanation.

3. Have your process approved, and then carry out the steps that you have designed.

4. Place the four separated substances into 4 separate, zip lock bags. Label the bags with your names and the substance. Staple the bags to this sheet, your plan and your answers to the discussion questions and hand in to your teacher.

The Technological Method of Problem Solving

Procedure
1. Identify what the problem is.
2. Write down what you want to accomplish. What are some of the things that might prevent you from accomplishing it?
3. How are you going to know that you have accomplished the task?
4. Identify what you know about the problem. This could be things you know from past experiences, classes, etc.
5. Identify what information you need to learn to solve the problem.
6. Brainstorm possible solutions. List and sketch as many solutions as you can think of.
7. Identify the pros and cons of each solution.
8. Make a choice based on the pros and cons.
9. Test and evaluate the solution you have chosen.
10. How would you modify the solution for different or better results?

Names:_____

Questions for Discussion

1. How important is the sequence of the steps that you have chosen?

2. How might you change the sequence and still have successful results?

3. How effective was your method?

4. How efficient was your method? How can you measure this?

5. What could you do to improve your method?

Teacher Answer Sheet

Sample Separation Methods

1. Wrap a magnet in a plastic bag and pass it through the mixture. When all the iron filings have been collected, turn the bag inside out to contain iron filings.

2. Add water to the mixture to dissolve the salt. Filter the solution to separate salt (in liquid form) from the sand and sawdust. Allow the liquid to evaporate to collect the salt crystals.

3. Add new water to the sand and sawdust mixture. The sawdust will float, and the sand will sink. Decant off the top part of the liquid containing sawdust. Filter to collect the sawdust.

4. Filter the remaining liquid to collect the sand.

Other possible suggestions:

Sorting by density using a bag and shaking. Iron filings and sand and salt will occur at the bottom, saw dust on top. Then hand sort – pick out the saw dust (not all sawdust will be removed)

Once salt has been dissolved and decanted, add water and swirl in a pan or a bowl with a crease. The heavy iron filings should collect along the bottom, make sure when spilling the water off it is collected in a filter to collect remaining sawdust.

Use a series of sieves to sort the different materials. Salt and sand may be similar in grain size.

Properties:

Iron filings: *very fine, heavy, when shaken dry would sink to the bottom, would sink in water, attracted to magnets*
Salt: *fine grained, dissolves in water, when water evaporates would crystallize as salt.*
Saw dust: *very light, less dense than other materials, floats on water, when shaken dry, would rise to the top*
Sand: *heavier than salt and sawdust, does not float, does not dissolve.*

Discussion Question **Answers will vary.**

1. How important is the sequence of the steps that you have chosen?
   This will vary depending upon the sequence.
   Removing the iron filings with a magnet must be done before water is added otherwise it is much more difficult attracting the magnetic filings as they cling to the wet particles.

2. How might you change the sequence and still have successful results?

3. How effective was your method?

4. How efficient was your method? How can you measure this? *If the materials were measured before mixing, the student could measure the amount they separated out and compare.*

5. What could you do to improve your method?

Processing methods for Saskatchewan's Mines

Once the gold, diamond, or uranium ore has been mined, it usually is washed and filtered at the mine as a preliminary refinement technique. It is then shipped to mills, where it is first combined with water and ground into smaller chunks. The resulting mixture is then further ground in a ball mill—a rotating cylindrical vessel that uses steel balls to pulverize the ore. This mixture goes on to several different process for the valuable ore mineral to be recovered. Potash and coal have different process as seen below.

Ore	Method
Gold	The gold is refined with one of five main processes: floatation, amalgamation, cyanidation, carbon-in-pulp and smelting. Each process relies on the initial grinding of the gold ore, and more than one process may be used on the same batch of gold ore. 1. **Floatation** involves the separation of gold from its ore by using certain chemicals and air. The finely ground ore is dumped into a solution that contains a frothing agent (which causes the water to foam), a collecting agent (which bonds onto the gold, forming an oily film that sticks to air bubbles), and a mixture of organic chemicals (which keep the other contaminants from also bonding to the air bubbles). The solution is then aerated—air bubbles are blown in—and the gold attaches to the air bubbles. The bubbles float to the top, and the gold is skimmed off. 2. **Cyanidation** also involves using chemicals to separate the gold from its contaminants. In this process, the ground ore is placed in a tank containing a weak solution of cyanide. Next, zinc is added to the tank, causing a chemical reaction in which the end result is the precipitation (separation) of the gold from its ore. The gold precipitate is then separated from the cyanide solution in a filter press. A similar method is amalgamation, which uses the same process with different chemicals. First, a solution carries the ground ore over plates covered with mercury. The mercury attracts the gold, forming an alloy called an amalgam. The amalgam is then heated, causing the mercury to boil off as a gas and leaving behind the gold. The mercury is collected, recycled and used again in the same process.

	3. The **Carbon-in-pulp** method also uses cyanide, but utilizes carbon instead of zinc to precipitate the gold. The first step is to mix the ground ore with water to form a pulp. Next, cyanide is added to dissolve the gold, and then carbon is added to bond with the gold. After the carbon particles are removed from the pulp, they are placed in a hot caustic (corrosive) carbon solution, which separates the gold from the carbon. 4. In **amalgamation**, the gold ore is dissolved in solution and passed over mercury-covered plates to form a gold/mercury amalgam. When the amalgam is heated, the mercury boils off as a gas and leaves behind the gold. 5. **Smelting** involves heating the gold with a chemical substance called flux. The flux bonds with the contaminants and floats on top of the melted gold. The gold is then cooled and allowed to harden in molds, and the flux-contaminant mixture (slag) is hauled away as a solid waste.
Diamonds	1. **Crushing:** In the crushing operation, large chunks of kimberlite are broken up into more easily transportable segments. After an initial crushing, the kimberlite passes through a grizzly, or a set of iron bars. If the crushed chunks do not pass through the grizzly, they are still too large, and they are sent back for further crushing. Crushing is done so as not to damage the potential gems inside. 2**. Separating:** The diamonds must be separated from the rock that surrounds them. A gravity-based device is used to sort the diamond-containing portions—called the concentrate—from the waste rock. One of the most commonly used methods to separate the two is a type of washing pan. The crushed kimberlite and water is put into the pan and swirled about. The lighter particles will rise to the top, but the diamonds and other heavy minerals will descend to the bottom of the pan. 3. **Separation using iron-silicon powder**. A slurry of water added to the crushed kimberlite along with ferro (iron) – silicon powder, which has a heavy density. The slurry is agitated or spun about creating a vortex so that the lighter rock fragments separate from the heavier diamond

	rich particles. 4. **Greasing:** The diamond rich concentrate then moves to a greasing area. Mixed with water, the kimberlite-and-diamond mixture is placed on a greased belt or table. This device is usually slanted and vibrated. The method operates on the premise that diamonds newly excavated will not become wet when brought into contact with water. Instead they will stick to the grease. The water then carries away the remaining non-diamond particles. The diamond-laden concentrate is then swept off the table and boiled to remove the traces of grease. 5. In a newer method, **X-ray technology** is used to determine which of the concentrate is diamond. X-ray is used to fluoresce the diamond in a dark chamber. A detector in the chamber senses the light emitted by the diamond and triggers a gate ejecting the diamond away from the waste rock.
Uranium	1. **Thickener**: Ore is ground to a fine powder then water is added to make a slurry. Excess water is removed. 2. **Leaching Tanks**: The slurry is leached with sulphuric acid. 3. **Wash Tanks**: Un-dissolved ore is separated from this solution. Waste goes to the tailings pond 4. **Sand filter:** The solution is filtered. 5. **Solvent Extraction**: Uranium is extracted with a kerosene solution. 6. **Precipitation:** Ammonia is used to precipitate the uranium out of the solution. 7. **Thickener:** A thickener is added and excess water is removed. 8. **Centrifuge:** Uranium is separated from the solution. 9. **Dryer:** Uranium is dried at 700oC to produce concentrate – Yellow cake.
Potash	**Conventional Mining** 1. **Crushing and sizing:** The large chunks are broken down to help separate the potash from salt and clay. 2. **Removing clay and de sliming:** 3. **Heavy media:** Sometimes the ore is mixed with a magnetite and salt brine. This mixture is spun in a cyclone resulting in the heavier salt and magnetite accumulating in the bottom and the potash floating to the top.

	4. **Flotation:** Separation of potash and salt occurs in the flotation cells. Various chemical reagents are added to the slurry and attach to the potash. The slurry is agitated and the salt crystals sink to the bottom. The air bubbles stick to the potash crystals floating them to the top where they are skimmed off. 5. **De-brining:** A centrifuge spins the brine out of the potash brine mixture. 6. **Drying:** The remaining potash is sent to the gas fired dryers. Dryers are kept around 100^{o}C. 7. **Sizing:** The potash crystals go through a series of screens (sieves) to sort them by size. Granular, Coarse, Standard, and Fine. 8. **Compaction:** The dried fines and dust are compacted by high pressure rollers into thick flakes which are then ground to form Granular potash. **Solution Mining** 1. **Crystallization:** The saturated brine is cooled under pressure in a large vessel. This causes the potash to precipitate out as very pure white crystals. 2**. De-brining:** A centrifuge spins the brine out of the potash brine mixture 3. **Drying:** The remaining potash is sent to the gas fired dryers. Dryers are kept around 100^{o}C. 4. **Sizing:** The potash crystals go through a series of screens (sieves) to sort them by size. Granular, Coarse, Standard, and Fine 5**. Compaction:** The dried fines and dust are compacted by high pressure rollers into thick flakes which are then ground to form Granular potash.
Coal	1. **Separation** from rocks and dirt. 2. **Sizing** by screens or floatation.