Grade 4: Rocks, Minerals and Erosion

Lesson: Potash Solution Mining: Recovering Dissolved Potash

Overview

Students will discover through guided inquiry and teacher demonstration that Saskatchewan's valuable potash mineral sylvite is separated from the other salt halite, by dissolution and precipitation. They will compare the minerals in the potash ore and the resulting crystal precipitates.

Source: This lesson plan has been adapted from an activity developed by Murray Schultz (Chief Chemist, Mosaic Potash Belle Plaine) for the SMA Teacher GeoVenture Tour and Showcase 2008, and from a lesson plan developed by Larry Bogdan (Teacher, Avonlea School, Prairie South School Division).

Duration: One class period

Materials:

- 1 litre clear Pyrex measuring cup or glass coffee pot or beaker
- One litre of reserved solution from the lesson ***Potash Solution Mining Dissolving Potash*****. (**Method A)
  OR
- 500 ml of reserved solution from the lesson ***Potash Solution Mining Dissolving Potash*****.** (Method B)
- Approximately ¼ cup granular (75 – 80 g) Potash muriate (Method B)
- Thermometer
- Bowl of crushed ice/snow or bowl of water with ice cubes at approximately 5°C

- **Teacher's Sheets**
- **Student** Handouts
- **Potash Solution Mining in Saskatchewan diagram**
- **Photos**

Note to Teachers: This lesson is a follow up to the lesson ***Dissolving Potash.*** The solution used for the demonstration comes from the filtered solutions produced by the students when dissolving their potash sample.

In the upper grades two methods are explained for this activity. **Method A**: Requires reducing the 1000 ml of solution retained from the lesson ***Potash Solution Mining – Dissolving Potash,*** to 500 ml , which would take a few hours. For this lesson **Method B**, spiking the 500 ml of solution with processed granular Potash Muriate is preferred and described in **Teacher Preparation**.

Prior Knowledge:

Before attempting these activities students should have some understanding of the following:

- What potash is, where it is found
- Rocks and minerals

Instructional Methods:

- Brainstorming
- Discussion
- Guided inquiry
- Teacher Demonstration

Dredge on cooling pond. Mosaic Potash Belle Plaine

Photo: Mosaic Potash Belle Plaine

Learning Outcomes and Indicators

RM 4.1 Investigate physical properties of rocks and minerals, including those found in their local environment.

b) Document the locations and characteristics of rocks that exist in their local environment.

c) Observe and record physical properties of rocks and minerals such as colour, lustre, hardness, cleavage, transparency, and crystal structure.

d) Use appropriate tools (e.g., hand lens, safety glasses, brush, rock pick, knife, and gloves) safely while making observations and collecting information on the physical properties of rocks and minerals.

g) Record observations of rocks and minerals using jot notes, labelled diagrams, and charts.

Source: **Saskatchewan Evergreen Curriculum**

Other:

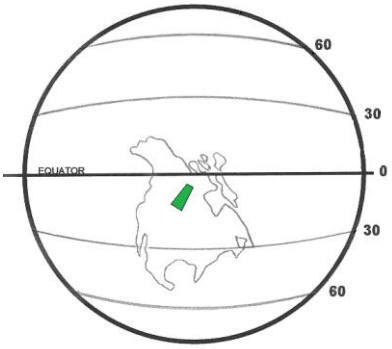
- Examine samples of potash ore and materials produced through dissolution and record qualitative physical properties of those objects in a chart.
- Describe how the mining company separates the desirable mineral sylvite from the salt halite in solution.

Big Picture Question

1. **How can the salt halite (NaCl) be separated from the valuable potash sylvite (KCl)?**

Background Information

Around 380 million years ago Saskatchewan was located south of the equator.



Devonian

(Modified from Storer, J., 1989)

It was a tropical time with coral reefs forming. A large salt water sea covered Saskatchewan stretching from the Arctic to the Gulf of Mexico.

Modified from Globe and Mail, Friday, Nov. 05, 2010

Due to coral reefs occurring to the west and north of the Elk Point Sea and a land high towards the east, the flow of water into the sea became restricted with little to no influx into the deeper parts of the sea (the southern part of Saskatchewan). Concentrations of mineral salts increased until crystal layers began to form on the sea floor, similar to how salt or sugar crystals form in a glass when a saturated solution evaporates (Storer, J., 1989). The evaporites, which include Saskatchewan's potash deposits, formed for over 2 million years until normal circulation of the sea water returned as did sea life. No fossils are found in the Prairie Evaporite unit. It is thought that animals and plants could not live in the sea at that time due to the high salinity (Storer, J., 1989).

Potash is a general term covering several types of potassium salts, of which the most important is potassium chloride, the mineral sylvite (KCl). In Saskatchewan, potash is extracted from deep underground deposits (generally 1000 m or 1 km) using either conventional (mining machines) or solution mining (brine is used to remove the mineral in solution) techniques.

The largest potash solution mine in the world is in Saskatchewan. With this technique the potash is dissolved deep underground and the solution is pumped to the surface where the potash is removed. The same process can be used above ground to extract the potash from the sylvinite ore. After potash is mined, it is processed in a surface mill, where it is separated into product (KCl) and waste (tailings comprised of salt and clays).

In 2010 there were 10 potash mines in Saskatchewan; two are solution mines, and the remaining 8 are conventional underground mines that use machines to mine the ore.

Potash is a nutrient essential for plant growth, and is a main component of modern agricultural fertilizers. Roughly 95 per cent of world potash production goes into fertilizer, while the other five per cent is used in commercial and industrial products - everything from soap to television tubes.

Potash is a major export of Saskatchewan. It is transported by rail to the United States and to Canadian ports where it is shipped to other countries including China, Korea, Japan, Malaysia, India, Brazil and Australia. Canadian markets make up less than 5% of potash sales.

Safety concerns

- Do not eat potash sample
- Do not drink solution

Vocabulary

brine	dissolve
halite	ore
potash	solution
sylvite	sylvinite
waste rock	

ACTIVITY

Recovering Dissolved Potash

(Teacher Demonstration) (30 - 45 min.)

Teacher Preparation:

Method A: Requires reducing the 1000 ml of solution retained from the lesson ***Potash Solution Mining – Dissolving Potash****, to 500 ml. This should be done ahead of time, and may take a few hours. Reheat the solution during the lesson.*

Method B: Using 500 ml of solution retained from the lesson ***Potash Solution Mining – Dissolving Potash****,* warm the solution and slowly add the processed granular KCl until it will no longer dissolve. This causes the solution to become saturated. Amounts will vary each time this demonstration is done and should not exceed the ¼ cup of granular potash.

Motivational Set: (15 min.)

In some places in Saskatchewan, the potash resource is too deep to mine by the conventional underground method. As potash is very valuable, the mining companies have developed a method of mining by dissolving the potash ore underground and pumping it up to the surface.

1. Review: Potash ore (sylvinite) is a mixture of halite (table salt), sylvite (KCl) also a salt, clays and iron staining (red). Solution mining involves pumping warm water into the ore deposit, dissolving the salts and pumping the solution to the mill to be processed.
2. Explain that the mining companies are interested in separating the halite salt (NaCl) from the valuable potash (KCL) that is left in the solution after the waste minerals have been filtered out.

Brainstorm:

Key Questions:

- How do you get the salts out of solution and into a solid form?

  The students should know this as this is what they did at the end of the lesson Dissolving Potash, when they evaporated the solution causing the salts to precipitate. However, both salts (NaCl and KCl) precipitated as crystals. This would still leave the problem of separating the halite (NaCl) from the silvite (KCl)

- How can the salt halite (NaCl) be separated from the valuable potash sylvite (KCl)?

  The second question can be answered by presenting the teacher demonstration.

Teacher demonstration and student discussion

1. Have the students describe the solution.
   (clear and colourless).
2. Have the students discuss what they think would happen to the solution if it was cooled.
   Answers will vary, some may think it will freeze. What the students will learn in this demonstration is that crystals will precipitate out.
3. Take the temperature of the solution and record.
4. Set up an ice bath (crushed ice or a container with water and ice, or a bowl of snow in the winter).
5. Cooling the solution. Take the container with the saturated room temperature solution and place into the ice bath to cool rapidly. Stir the solution (use a stir stick and **NOT** the thermometer) to speed up the cooling process. Observe what happens to the

solution.
This process may take up to 30 minutes before any crystals form. The first sign may be a scum on the surface. When crystals form they will eventually drop to the bottom of the container.

6. When the solution has cooled to 0°C, leave for 30 minutes in the ice bath and observe.
The cold temperature will cause the KCL in the solution to precipitate out as crystals forming a crystal mush on the bottom of the container. Make sure to measure the temperature of the solution in the middle of the container.
7. When the solution has cooled to 0°C or less it could be filtered or it could be put into the freezer overnight to precipitate more crystals and filtered the next day.
8. When it appears as if the precipitation has stopped filter the solution.
9. Dry the filter with the residue/precipitate. Label it "**Potash- Sylvite"**
10. The precipitate in the filter is potash. Have the students describe what the dry crystals look like. Encourage them to use the magnifying lens and draw pictures. Compare these crystals with the ones that grew when the solution was evaporated.
11. Have students answer the discussion questions.
12. *Remind the students that in the winter the mining company brings the solution to the surface and pumps it into holding ponds where the cold temperature of the air cools the warm brine and causes the sylvite (KCl) to precipitate out. In the summer the precipitation is done inside the mill*.

Key Questions:

- If potassium chloride has precipitated out of the solution what is left?
The original solution was KCl + NaCl + H2O. The resulting solution is a NaCl rich brine with small amounts of KCl. The crystals that formed from the remaining solution in step 10 will mostly be the salt halite (NaCl).

- What could the company do with the warm brine?
They could evaporate it and recover the salt (halite – NaCl) OR they could reuse the brine to pump down into the ground to dissolve the potash ore.

12. Show the students the diagram of how the potash is extracted from the ground in solution.
13. Explain that this is one way that Mosaic Potash's mine at Belle Plaine separates the potash from the salt. Warm brine is injected down a well into the potash ore where it dissolves the salts NaCl and KCl. The solution is then pumped back up to the surface and to the mill where it is processed to recover the dissolved KCl. In the winter the KCl and NaCl rich brine solution from underground is pumped out into holding ponds where the cold temperature of the air cools the warm brine and causes the KCl to precipitate out. (See photo) In the summer the precipitation is done inside the mill.
14. Ask the students if they think more potash is produced in the winter or the summer.
More potash is produced in the winter because it is colder.
15. Have students write observations of the dried crystals in the filter and petri dish/jar. ***It may take a few days for the solution to evaporate.***
16. Have students do the Discussion Questions. They will not be able to answer question 2 until the filter is dry and the petri dish or jar with solution has evaporated.

Assessment Method and Evidence

✓Observation Chart:

- Students will document the characteristics of potash ore (sylvinite) and the potash mineral sylvite that occur in Saskatchewan and possibly in their local environment.
- Students will observe and describe the physical properties of the resulting salt precipitates and potash.
- Students will record their observations of the resulting precipitating crystals using jot notes and labelled diagrams on the Observation Chart.
- Students will compare the physical properties of the original materials, the resultant solution and precipitates and realize that the original potash ore differs from the precipitated salts.

✓Discussion questions:

- Student's answers will show their understanding that the potash mineral mined in Saskatchewan is a salt and can be separated from the potash ore by dissolution and precipitation from the solution when cooled.
- Students will be able to describe and compare the sylvite crystals precipitated from the cooled solution to the crystals formed by evaporation and to the original potash ore. They should understand that the crystals precipitated from solution are one mineral, from evaporation two minerals and

that the ore rock has four minerals.

- Students will come to the conclusion that potash ore sylvinite is a rock made up of minerals, the crystal of sylvite that precipitated out of the solution is a mineral that came from the rock.
- Students may come to the conclusion that the larger salt crystals formed by evaporation had more time to grow than the smaller sylvite crystals. There is a correlation between time and the size of crystals.
- Students understand that a Geochemist/Chemical Engineer/Chemist or Chemical Technician and chemistry are important in the production of potash.

Summary

In a combination of hands on investigation and teacher demonstration students have learned how too mine potash deposits that are too deep to mine conventionally and how to separate the salts and the valuable potash from the waste clays and iron oxides. Students compared the minerals in the potash ore samples to the minerals precipitated from solutions allowed to evaporate (halite and sylvite) and minerals precipitated due to cooling of a warm supersaturated solution (sylvite). If students also did the "Is There Potash Under My Feet" activity they would have investigated the location of potash deposits and mines in their area and the method used to mine the deposits.

Resources

Web Resources:

Agrium Website: http://www.agrium.com

Globe and Mail, (Nov. 05, 2010): Riches under the prairie: Where potash comes from. Available at: http://www.theglobeandmail.com/globe-investor/potash/riches-under-the-prairie-where-potash-comes-from/article1788180/

International Fertilizer Association Website: http://www.fertilizer.org/ifa/default.asp

MacKenzie, J. (2003): Nourishing the Crops of the World: Saskatchewan's Potash Industry; Western Development Museum. Available at: http://www.wdm.ca/skteacherguide/WDMResearch/Nourishing%20the%20Crops%20of%20the%20World%20-%20Saskatchewan's%20Potash%20Industry%20by%20Janet%20MacKenzie.pdf

Mining and milling processes used at the PotashCorp mines. http://www.potashcorp.com/media/POT_Mini_Mine_Tour_brochure.pdf

Mosaic Potash Company Website: http://www.mosaicco.com

Potash Corporation of Saskatchewan Website: http://www.potashcorp.com/

Saskatchewan Mining Association Website: http://www.saskmining.ca

Saskatchewan Potash Interpretive Centre: http://www.potashinterpretivecentre.com/index2.htm

Book/Report Resources:

Fuzesy, A. (1981): *Potash in Saskatchewan*; Saskatchewan Energy and Mines Report No.181, 44p.

Holter, M.E. (1969): *The Middle Devonian Prairie Evaporite of Saskatchewan*; Department of Mineral Resources-Geological Sciences Branch-Industrial Minerals Division-Province of Saskatchewan; Report No.123, 134p.

Storer, J. (1989): Geological History of Saskatchewan; Royal Saskatchewan Museum, Regina SK. 90p.

Description of sylvite crystals in filter

Observations (What you see)

Colour	Hardness	Crystal shape	Lustre	Transparency
Colourless to white	*Too small to test*	*Very small cubes, thin needles and irregular masses.*	*glassy*	*Transparent to translucent*

Drawing (please label)

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Discussion Questions: (answer in full and complete sentences)

1. Explain how the mining companies get the potash mineral sylvite to form.
   *The solution from the lesson **Dissolving Potash** was cooled to 0°C by placing it into crushed ice which caused the KCl crystals to form. The mining companies cool the solution to around 0°C degrees to have the sylvite precipitate out. Sometimes this is done outside in the winter.*

2. Describe what the sylvite crystals in the filter look like.

   Crystals are very small, some are cubes others are long needles up to 7 mm long. Most are colourless and transparent

3. What is the difference between the potash ore sylvinite and the potash sylvite in the filter?
   The potash ore sylvinite is a rock with the minerals sylvite, halite, iron-oxide minerals and clay Minerals (four minerals). The potash sylvite is a mineral.

4. What is the difference between the crystals that formed in this demonstration and the ones that grew in your jar?

   Why do you think they could be different looking? (Think about time, temperature and what the crystals are made of)
   The crystals in the jar will be a mixture of halite and sylvite - two minerals. The crystals in the demo filter will be sylvite – one mineral. The crystals in the jar took a long time to form and are bigger. The crystals that formed when cooled, formed quickly and are smaller.
   The crystals in the jar are whitish, milky- opaque with a cubic habit

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Observations (What you see)

Colour	Hardness	Crystal shape	Lustre	Transparency

Drawing (please label)

Discussion Questions: (answer in full and complete sentences) Name:_____

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2. Describe what the sylvite crystals in the filter look like.

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4. What is the difference between the crystals that formed in this demonstration and the ones that grew in your jar?

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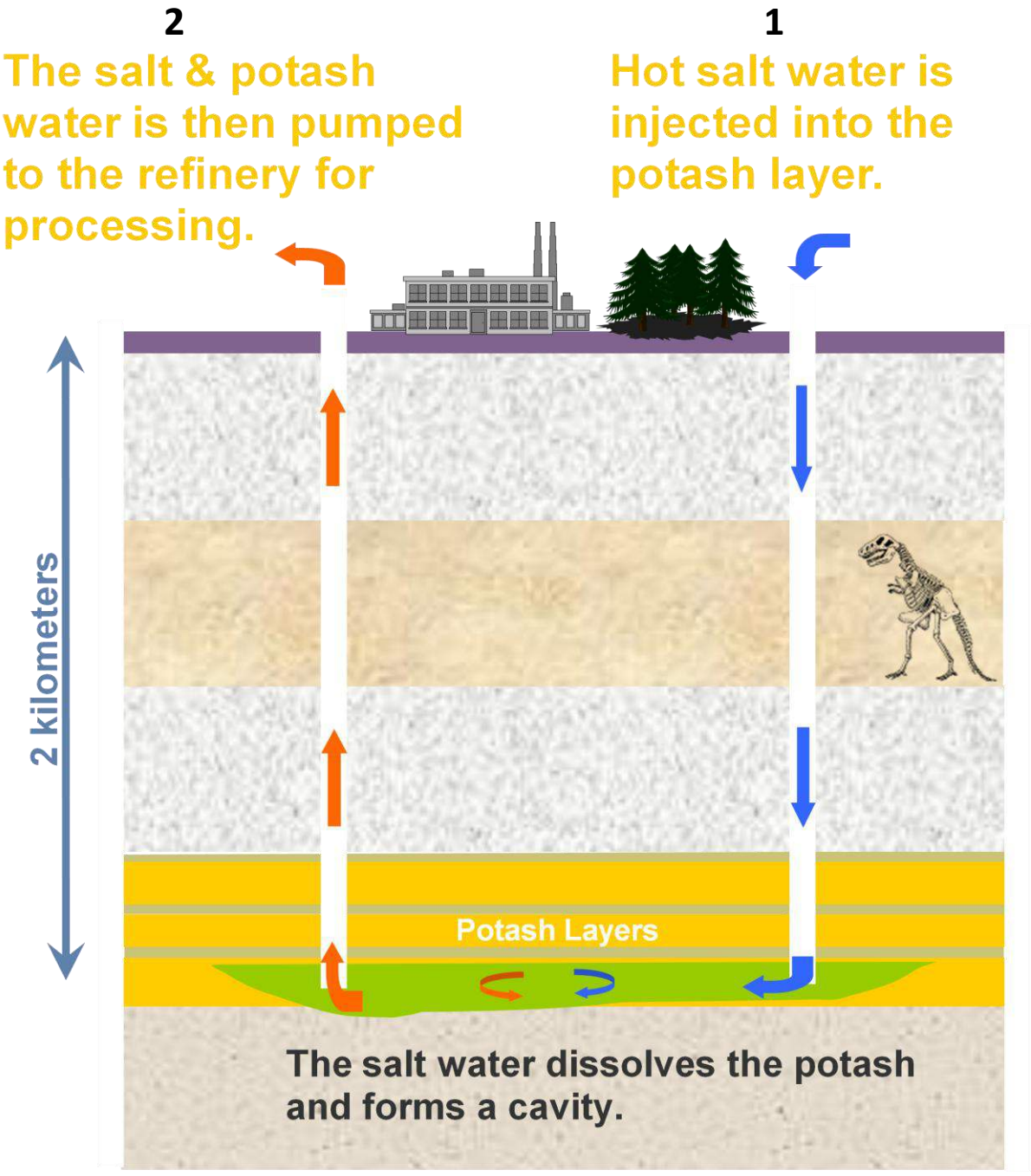
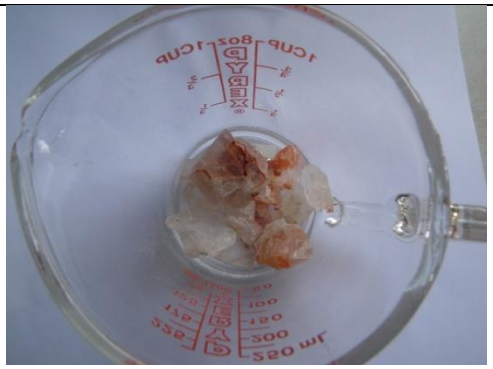
Potash Solution Mining in Saskatchewan



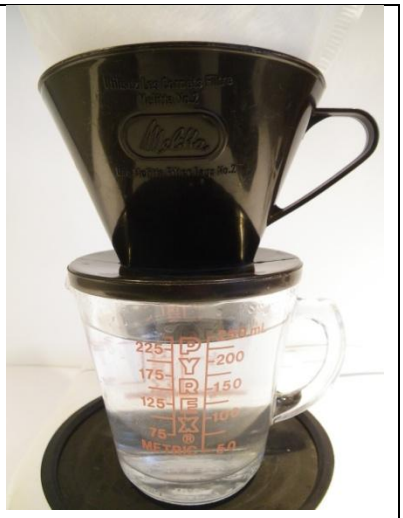
From: Mosaic Potash PowerPoint BellePlaine

Photos: Teacher Demo



In the the lesson ***Dissolving Potash*** a sample of potash ore was put into 250 ml of water to be dissolved. The iron oxide and clay minerals, which do not dissolve, were then filtered out.

This left approximately 250 ml of a clear, colourless solution. 1000 ml of solution was collected and granular KCl was added to the room temperature solution "spiking it"



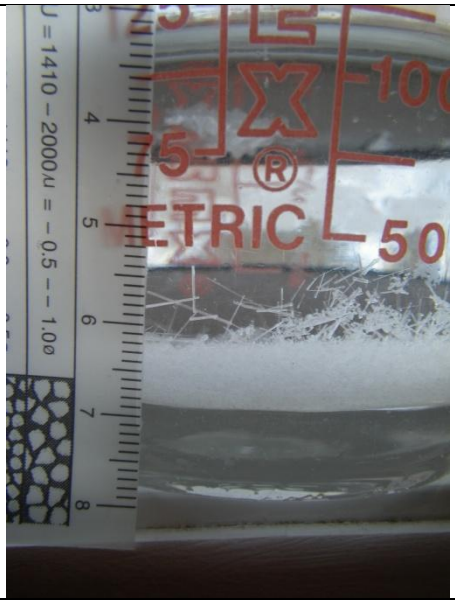
The solution was inserted into an ice bath. In these photos snow was used.

The solution was stirred to speed up cooling. A small raft of crystals started to form on the surface of the solution as well as very small crystals accumulating on the bottom of the measuring cup after approximately 9 minutes.

Over a period of 34 minutes, KCl (sylvite) crystal precipitation became more visible as the temperature cooled.

After 50 minutes sitting in the cold bath/snow.

A layer of potash crystalline mush has formed on the bottom of the measuring cup.

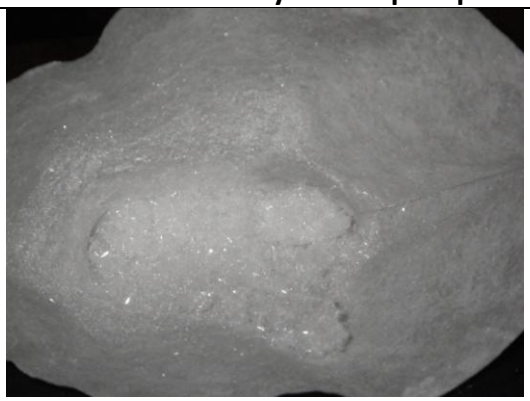


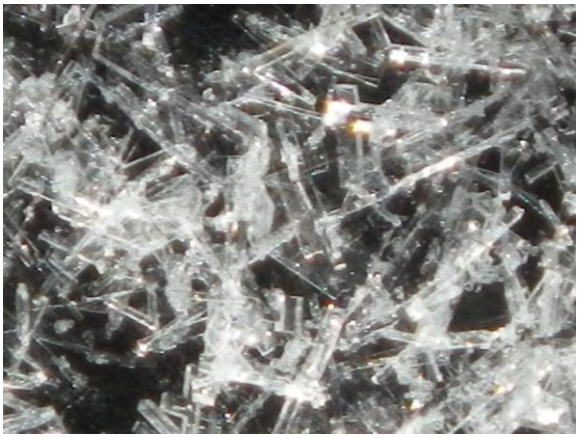
After 90 minutes, long (up to 7mm) crystals were observed forming and settling to the bottom.

The solution was placed in the freezer over night. After 22 hours the amount of crystal mush had about doubled. Most of the remaining KCl had crystallized out. An unfrozen NaCl rich solution remains.

View from the top after being in the freezer overnight. There are still some crystals forming a raft on top of the solution.

Filtered and dried KCl crystalline precipitate mush.





Crystals are very small, some are cubes others are long needles. Most are colourless and transparent.

Vocabulary

Brine: Salty water**.** The water of a sea or an ocean is a brine.

Dissolve: To break apart and become liquid forming a solution.

Halite: A mineral, we know it as salt. It is made up of **s**odium and chlorine (NaCl). It normally occurs as colourless to whitish, cubic crystals.

Ore: Is rock that contains important minerals including metals**.** The ore is extracted through mining and processed to take out the valuable mineral(s). Ore contains minerals that can be mined to make money.

Potash: Is Saskatchewan's provincial mineral. Potash is the common name for the potassium rich ore mined in Saskatchewan. It is made up of the minerals sylvite, halite, clay and iron oxides.

Solution: A liquid with something dissolved in it.

Sylvinite: Sylvinite is the most important ore for the production of potash. It is a mixture of sylvite (KCl, or potassium chloride) and halite (NaCl, or sodium chloride).

Sylvite: Sylvite is the name of the potash mineral It is made up **of** potassium chloride (KCl). It forms very similar to normal rock salt, halite (NaCl). Sylvite is usually colorless to white. It has a Mohs hardness of 2.5. Sylvite has a salty taste with a distinct bitterness. Its principal use is as a potassium fertilizer.

Waste rock: This is the rock that has been mined, but is not of value to the mining company. It is removed ahead of the milling processes.

Source:

Wikipedia. Available at: http://en.wikipedia.org/wiki/

Dictionary of Mining, Minerals and Related Terms. Available at: http://xmlwords.infomine.com/xmlwords.htm

Oxford English Dictionary on-line: Available at: http://oxforddictionaries.com

Yahoo Kids: Available at: http://kids.yahoo.com/reference/dictionary/english/