Grade 7: Earth's Crust and Resources

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 due to differences in solubility.

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

Duration: 1 class

Materials:

- 1 litre clear Pyrex measuring cup or glass coffee pot or beaker
- 500 ml of reduced 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*** at room temperature (Method B)
- Approximately ¼ cup (75 – 80 g) granular KCl (Method B)
- Thermometer
- **Power Point Activity Refining Potash Stovetop 1**
- **Student Discussion Questions**
- **Teacher Answer Sheet**
- **Photos**
- **Potash Solution Mining in Saskatchewan diagram**

Prior Knowledge:

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

- Factors that affect solubility

Instructional Methods:

- Brainstorming
- Discussion
- Teacher demonstration
- Individual learning

Notes to Teacher:

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.

Two methods are explained for this activity. This activity could be done as a teacher demonstration or could be a student activity comparing the two methods.

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 the 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.

Dredge on cooling pond. Mosaic Potash Belle Plaine

Photo: Mosaic Potash Belle Plaine

Learning Outcomes and Indicators

EC7.2 Identify locations and processes used to extract Earth's geological resources and examine the impacts of those locations and processes on society and the environment.

- Relate processes used to extract primary mineral resources in Saskatchewan (e.g., open-pit mining, underground mining, and solution mining) to the location, type, and depth of the resource. (EC7.2e)
- Suggest solutions to economic and environmental issues related to the extraction of geological resources in Saskatchewan (e.g., managing mine tailings and pollutants; reclaiming open pit mining sites; ecological impact of pipelines; resource depletion; maintaining water quality; and increasing urbanization). (EC7.2i)

Source: **Saskatchewan Evergreen Curriculum**

Students will also:

- Describe the characteristics of the mineral precipitates and compare the physical properties of the original materials and the resultant precipitates.
- Students will learn that minerals allowed to crystallize over a longer period of time will be larger than those formed quickly
- Describe the methods used to separate the potash ore and KCl/NaCl solution using filtration, evaporation, and precipitation.
- Discuss the consequences of solution mining such as what to do with the remaining salt solution.
- Suggest solutions to environmental issues related to the extraction of potash in Saskatchewan (e.g., recycling the saline brine used in the mining process).
- Carry out an activity to simulate the work of a Geochemist/Chemical Engineer/Chemist/Chemical technician and general operations personnel in determining how to separate the valuable potash KCl from the NaCl in solution
- Understand that it is the role of Geochemists, Chemical Engineers, Chemists and Chemical technicians and general operations personnel to help in the development of mining methods for potash, monitor the quality of the potash produced and help find new and better ways to improve production and processing of potash.

Big Picture Question

1. How is the potash mineral sylvite separated from the potash ore?

Background Information

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
dense
dissolve
mixture
density
halite
ore

potash
solute
solvent
sylvite
Saturated solution
sylvinite

THE ACTIVITY

Recovering Dissolved Potash

(Brainstorming, teacher demonstration and hands on lab) (45 min.)

Teacher Preparation:

Method A:

1. Review the PowerPoint **Activity Refining Potash Stovetop 1**.
2. Before the lesson pour 1000ml of the previously filtered solution from the lesson ***Potash Solution Mining – Dissolving Potash*** into a large Pyrex measuring cup (a clear coffee pot would work) and place on a hot plate (a coffee machine would work as well or use a stovetop and pot as shown in the PowerPoint. Heat the solution to a gentle boil and reduce to half its volume (500 ml). This may take a while. If the solution becomes cloudy remove immediately from heat source. (It is starting to precipitate both salts). Continue on with the activity.

Method B: This method removes the need to boil the solution and reduction to half its volume.

Before the lesson warm 500 ml of solution and slowly add the processed granular KCl. When it takes longer for the powder to dissolve add only small amounts at a time. Stop when the powder no longer dissolves or if the solution starts to become cloudy. When the potash muriate no longer dissolves the solution is saturated. Amounts will vary each time this demonstration is done Continue on with the activity starting at step 4.

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 dissolution.

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) and that the classroom will be simulating the process used by the mining companies to recover the valuable KCl (sylvite).

Brainstorm:

Key Questions:

- How do you get the salts out of solution and into a solid form?
  Evaporate the solution to precipitate the salts however both salts (NaCl and KCl) would precipitate 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 (30 min.) Method A start at step 1. Method B start at step 4.

1. If not already hot, heat the solution to just below boiling. Explain to students that the 1000ml of solution had been reduced to 500ml earlier. By boiling off the water, the solution has been reduced to half the amount and is now supersaturated – it can not hold any more salts.
2. Have the students describe the solution.
   (clear and colourless).
3. While the solution is reheating white crystals may be forming along the edge of the measuring cup/pan.
   As the liquid evaporates a skin appears on the surface. These are salt crystals forming due to evaporation. The salt forming is NaCl. There may also be white solid particles accumulating on the bottom of the pot. (NaCl crystals sinking)
4. Have the students discuss what they think would happen to the solution if it was cooled.
   Crystals should precipitate out. Discuss why. As a supersaturated or saturated solution cools it is unable to keep the amount of salt in solution and it precipitates.
5. Take the temperature of the solution and record.
6. Set up an ice bath (crushed ice or a container with water and ice, or a bowl of snow in the winter).
7. Cooling the solution. Take the container with the reduced solution (method A) or the saturated room temperature solution (method B) 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.

8. 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 and do not filter until it has reached 0°C.
9. When it appears as if the precipitation has stopped filter the solution.
10. Pour some of the remaining solution into a petri dish or clear jar and leave to evaporate.
11. Dry the filter with the precipitate.

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

✓**Key Questions**

- Students will be able to explain that the potash mineral mined in Saskatchewan is a salt which can be mined and separated from other minerals through dissolution in warm water, filtration, and precipitation

✓**Teacher Demonstration**

- Students will see how NaCl (halite) is separated from the salt rich solution, by evaporation when viewing the crystallization of the solution spatters when the solution is being reduced in Method A, as well as when the final solution is allowed to evaporate.

✓**Discussion questions:**

- Students will be able to explain that the potash mineral mined in Saskatchewan is a salt which can be mined and separated from other minerals through dissolution.
- Students will be able to describe the methods used to separate the potash ore (mechanical mixtures) and KCl/NaCl solution using filtration, evaporation, and precipitation.
- Students will be able to discuss the consequences of solution mining such as what to do with the remaining salt solution.
- Students will be able to suggest solutions to environmental issues related to the extraction of potash in Saskatchewan (e.g., recycling the saline brine used in the mining process).
- Students will describe the properties of the original potash ore and the resultant halite and sylvite precipitates and determine that the ore is made up of large inter grown crystals of halite, sylvite, iron oxides and clay minerals whereas the mineral precipitates from solution are very fine grained pure crystalline minerals separate from each other.
- Students should able to apply their understanding of solution mining and processing of the potash to come up with some of the effects this processes may have with respect to themselves , the community, and the environment. Such as; solution mining has a smaller overall surface footprint than conventional mining

therefore the land surface can be used for other things such as farming.

- Students will be able to discuss some of the consequences of solution mining such as what to do with the remaining salt solution and be able to suggest solutions to environmental issues related to the extraction of potash in Saskatchewan (e.g., recycling the saline brine used in the mining process)
- Students will understand that it is the role of Geochemists, Chemical Engineers, Chemists and Chemical technicians and general operations personnel to help in the development of mining methods for potash, monitor the quality of the potash produced and help find new and better ways to improve production and processing of potash.

✓Observation Chart (including ***Dissolving Potash***)

- Students will be able to describe the characteristics of the mineral precipitates, salts and the potash ore rock.

Summary

In a combination of teacher demonstration and guided inquiry students learned how to how to separate the valuable potash mineral sylvite (KCl) from the halite (NaCl) in solution. They have compared the properties of the original potash ore and the resultant halite and sylvite precipitates and determined that the precipitates are minerals with different properties than the minerals composing the potash ore. Students have applied their understanding of solution mining and processing of the potash to come up with some of the effects these processes may have with respect to themselves, the community, and the environment as well as some of the solutions.

Extension Activities

1. Students could investigate a career as a Chemical Engineer, Chemical Technologist, Chemical Technician, Chemist, and Geochemist by going to Future Paths http://www.futurepaths.ca/storage/CareerTree-Mining.pdf

2. Students could go through the process from dissolution of the potash ore to the precipitation of mineral sylvite (KCl) and describe the path of the particles using the particle model of matter.

Resources

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

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

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

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

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

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

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

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

Discussion Questions Teacher Answer Sheet

1. Why is it necessary to use the solution mining method for potash in Saskatchewan?
   In the southern part of the Potash unit the potash is too deep to mine by conventional methods. It is greater than 1 km deep.

2. Go back to your observations when you dissolved the potash sample. What is the difference between the original potash ore and the resulting precipitate crystals and the crystals due to evaporation?

Potash Ore sample	KCl precipitate crystals	Crystals due to evaporation
The original potash sample was made up of 4 minerals, KCl and NaCl, (colourless or white, translucent or opaque), clay (grey) and iron oxide (red). The mineral crystals were large.	*The resulting precipitate does not include the oxide and clay minerals as they were filtered out in the **"Dissolving Potash"** lesson. The resulting sylvite (KCl) precipitate is made up of very small crystals (<1mm – 3mm). They vary from colourless to white cubic crystals. Occasionally some long crystals form.*	*The crystals resulting from evaporation of the remaining solution are larger colourless, cubic crystals more commonly in the 2-4 mm range.*

3. Why do you think the size of the crystals due to evaporation is different from the size of the crystals due to precipitation? *Size will vary depending upon how long the solution took to evaporate. Some crystals may grow quite large if sitting in the solution for a long period of time. The KCl crystals were filtered and not allowed to grow for any length of time.*

4. Describe the method used to separate the potash mineral (KCl) from the salt (NaCl).
   Method A: The solution from Activity 1 was gently boiled until the amount was about half of the original amount (1000ml). This caused the solution to become supersaturated in NaCl and KCl. It was then cooled to 0^oC by placing it into crushed ice which caused the KCl crystals to form. Method B: Granular KCl was stirred into the room temperature solution from Activity 1 (1000ml) saturating the solution with KCl. It was then cooled to 0^oC by placing it into crushed ice which caused the KCl crystals to precipitate forming a crystal mush at the bottom of the container.

5. If most of the KCl (potassium chloride) has precipitated out of the solution what is left? *The solution is NaCl (sodium chloride) and water with some unrecoverable KCl. Not all KCl comes out of solution.*

6. Name some consequences of solution mining (positive and negative).
   Student answers may vary.
   Positive: - Solution mining allows mining companies to mine the valuable mineral sylvite from deposits that are too deep to mine by going underground.
   - Solution mining leaves a smaller footprint on the earth's surface.
   - The salt halite can be sold to other companies to be made into table salt.

- Less energy is used than at conventional mines.

Negative: - Solution mining produces a lot of halite (NaCl) more than can be used in Saskatchewan.
- More natural gas is used in the processing than is used in conventional mining methods.

7. Suggest solutions to any environmental issues or negative consequences related to the extraction of potash by the solution method (e.g. what can be done with all the salt (NaCl) rich solution?)

Answers will vary.
- The mining companies recycle the salt (NaCl) rich water (brine) by pumping it back into the ground to dissolve more potash ore.
- The salt is sold to other companies to refine into products such as table salt and road salt.
- If the mining companies improve their energy efficiency then they will use less gas.

Recovering Dissolved Potash Discussion Questions

Name: _____

1. Why is it necessary to use the solution mining method for potash in Saskatchewan?

2. Go back to your observations when you dissolved the potash sample. What is the difference between the original potash ore and the resulting precipitate crystals and the crystals due to evaporation?

Potash Ore sample	KCl precipitate crystals	Crystals due to evaporation

3. Why do you think the size of the crystals due to evaporation is different from the size of the crystals due to precipitation?

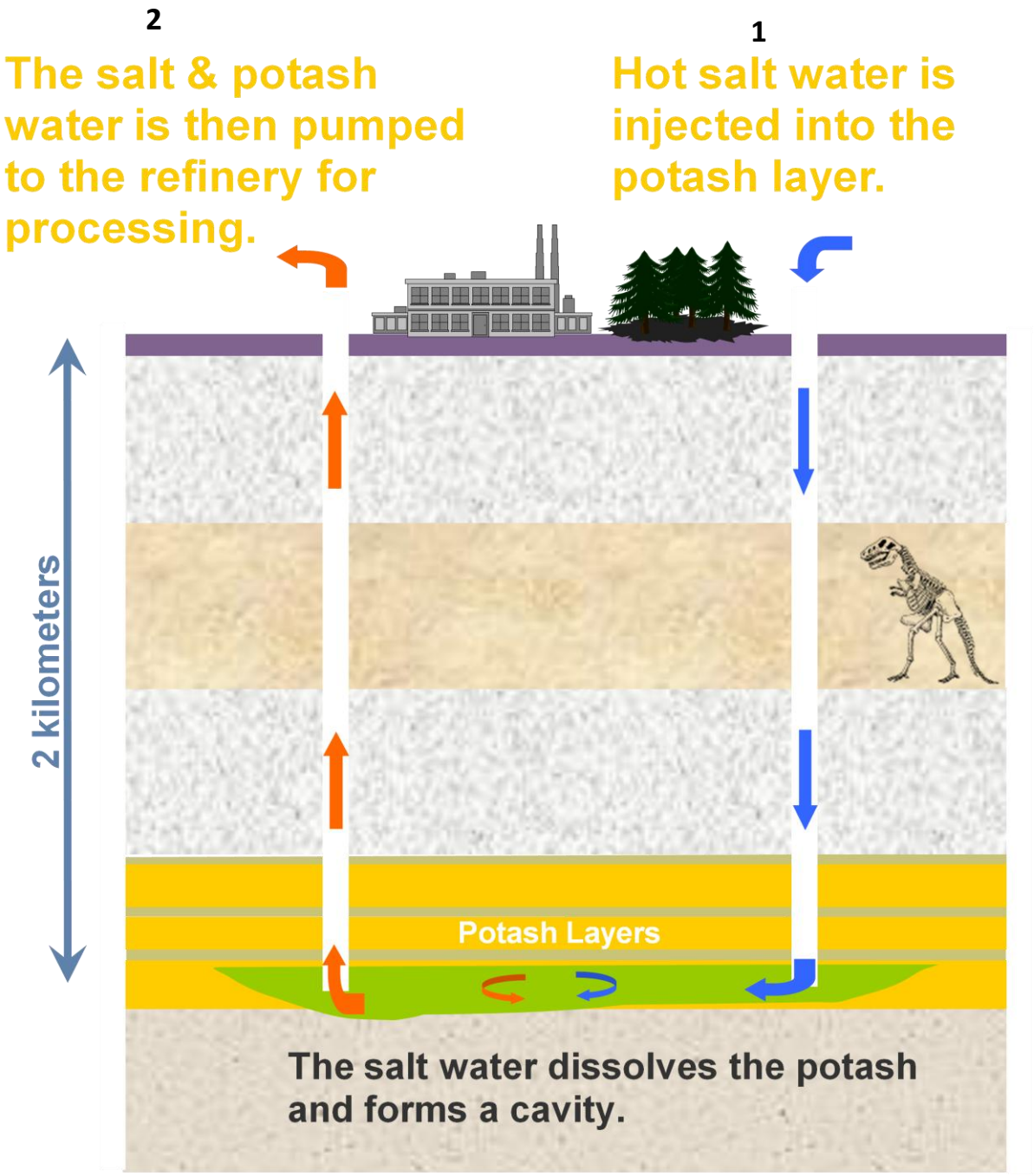
4. Describe the method used to separate the potash mineral (KCl) from the salt (NaCl).

5. If most of the KCl (potassium chloride) has precipitated out of the solution what is left?

6. Name some consequences of solution mining (positive and negative).

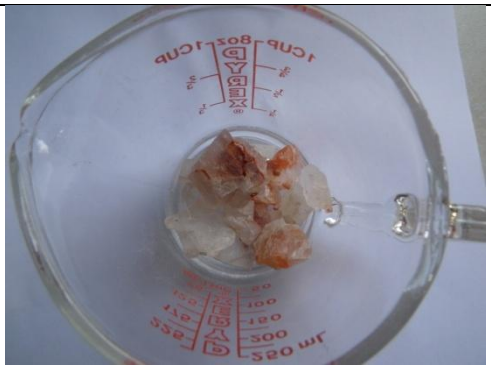
7. Suggest solutions to any environmental issues or negative consequences related to the extraction of potash by the solution method (e.g. what can be done with all the salt (NaCl) rich solution?)

Potash Solution Mining in Saskatchewan



From: Mosaic Potash PowerPoint –Showcase Belle Plaine

Photos



In the "***Dissolving Potash"*** lesson a sample of potash ore was put into 250 ml of water to be dissolved. The insoluble iron oxide and clay minerals were then filtered out.

This left approximately 250 ml of a clear, colourless solution.

In Method A the solution was gently boiled until reduced to 50%.

In Method B granular KCl was added to the room temperature solution.

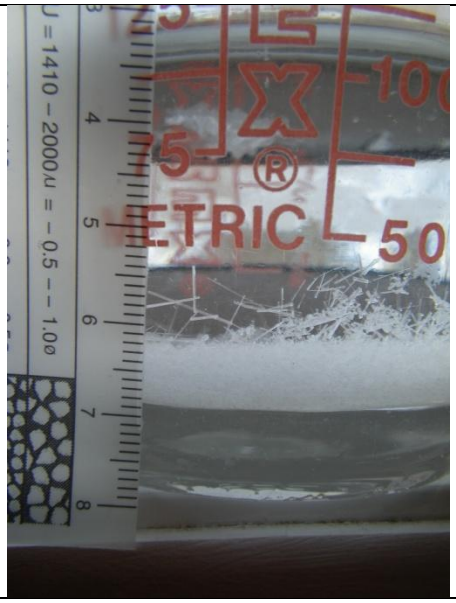
The solutions were inserted into an ice bath. In these photos snow was used.

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.

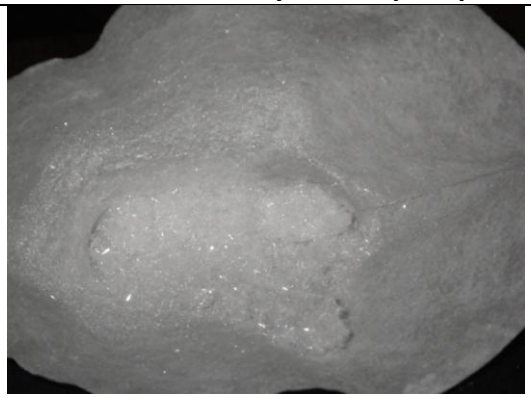


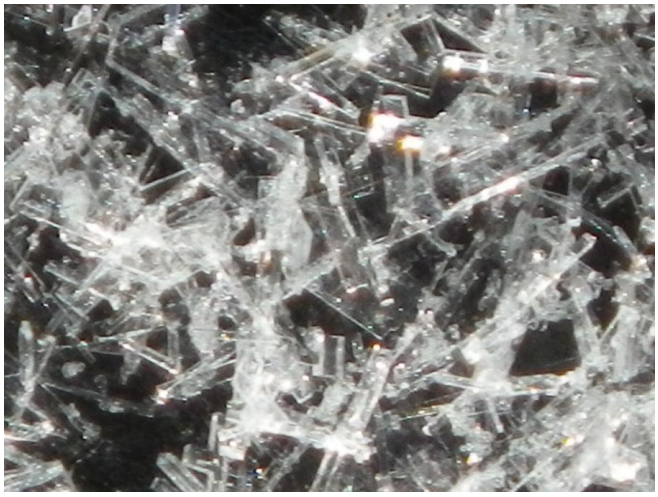
After 90 minutes, long (up to 7mm) crystals were observed forming and settling to the bottom.

The solution was placed in the freezer over night. After 22 hours the amount of crystalling much had about doubled. Most of the remaining KCl had crystallized out.

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

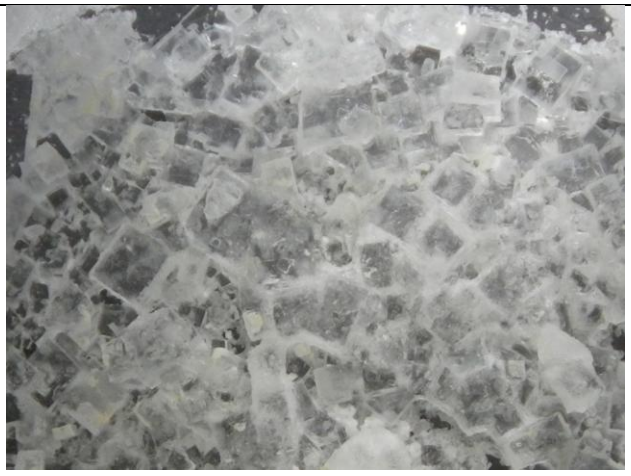
Filtered and dried KCl crystalline precipitate mush.





Evaporated NaCl rich Solution

Looking into the jar: Halite (NaCl) salt crystals formed when the water evaporated.



Taking a closer look at the salt crystals.

Taking an even closer look at the salt crystals. Note the cubic crystal habit

Vocabulary

Brine: Water saturated with or containing large amounts of a salt, especially sodium chloride. The water of a sea or an ocean is a brine.

Dense: Closely packed. Having relatively high density.

Density: The measure of the compactness of a substance, expressed as its mass per unit volume.

Dissolve: To break into component parts to become incorporated into a liquid so as to form a solution.

Halite: Sodium chloride (NaCl) as a mineral, typically occurring as colourless cubic crystals; what we know as salt.

Mixture: is a material system made up by two or more different substances which are mixed together but are not combined chemically

Ore: Is rock that contains important minerals including metals**.** The ore is extracted through mining and processed to extract the valuable element(s). Ore contains minerals that can be mined at a profit.

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, sometimes carnallite, clay and iron oxides.

Saturated: If saturated, it has absorbed the maximum amount of something that it can**.**

Solute: A substance dissolved in solvent, forming a solution

Solution: A liquid with something dissolved in it. It is a homogeneous mixture composed of two or more substances. In such a mixture, a **solute** is dissolved in another substance, known as a **solvent**.

Solvent: is a liquid, solid, or gas that dissolves another solid, liquid, or gaseous solute,

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

Sylvite: is potassium chloride (KCl) in natural mineral form. It forms very similar to normal rock salt, halite (NaCl). Sylvite is colorless to white with shades of yellow and red due to inclusions. It has a Mohs hardness of 2.5. Sylvite has a salty taste with a distinct bitterness. Sylvite is one of the last evaporite minerals to precipitate out of solution. As such, it is only found in very dry saline areas. Its principal use is as a potassium fertilizer.

Waste rock: Barren or submarginal rock or ore that has been mined, but is not of sufficient value to warrant treatment and is therefore 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/