

#### Overview

Students will discover how mining companies process the raw ore of potash (sylvinite) to produce the desirable potassium chloride (KCl). The students are given the task of separating the valuable KCl (sylvite) from the NaCl (halite) and gangue minerals in the ore.

**Duration:** 2- 3 lab periods

#### Materials:

- Solubility Curves of KCl and NaCl
- Mosaic Potash PowerPoint BellePlaine PDF
- Muriate of Potash Chemical Analysis sheet
- Access to internet
- SMA Potash kit (see Resources)
- Ice/snow
- Lab equipment: clear beakers, stir sticks, filters, bowls, water, burner, Potash kit from SMA (samples of potash ore)

#### Prior Knowledge:

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

- Factors that affect solubility
- Solubility charts

#### Instructional Methods:

- Brainstorming/KWL
- Problem Based Learning

#### Note to Teacher:

This activity has been simplified and developed as three lessons for Grade 7 Mixtures and Solutions. These lessons can be found at [SMA Educational Resources \(http://www.saskmining.ca/news-article/Education-Outreach/For+Schools/Education+Resources/1/2011-06-09-posters.html\)](http://www.saskmining.ca/news-article/Education-Outreach/For+Schools/Education+Resources/1/2011-06-09-posters.html)

The Saskatchewan Mining Association would like your feedback in order to make this a better resource.

**Please send your comments to:**  
[education@saskmining.ca](mailto:education@saskmining.ca)

Dredge on Mosaic Belle Plaine Cooling Pond



Photo: Mosaic Potash Belle Plaine

#### Learning Outcomes and Indicators

**CH30-EQ2 Analyze aqueous solution equilibria including solubility-product constants.**

- Analyze how temperature and the common ion effect influence the solubility of substances in aqueous solution.
- Research applications of solution equilibria in Saskatchewan agriculture, resource extraction, manufacturing and chemical industries.
- Design and carry out a procedure to collect data in order to construct solubility graphs representative of the effects of temperature on the change in solubility of chemical compounds in water.
- Interpret solubility curves of selected substances.
- Calculate the solubility product constant ( $K_{sp}$ ) for saturated solutions, given solute concentrations.
- Calculate the solubility of substances in aqueous solutions, given  $K_{sp}$ .

Source: [Saskatchewan Evergreen Curriculum](#)

#### Big Ideas:

- Differences in solubility can result in the separation of substances.
- Solubility and solutions play important roles in mining and processing of Saskatchewan's mineral

resources.

### 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.

There are currently 10 potash mines in Saskatchewan; two are solution mines, and the remaining 8 are conventional mines.

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 sylvinitic 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).

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.

### Vocabulary

halite	ore
potash	solubility
sylvite	sylvinitic

### THE ACTIVITY

#### Separating KCl from the potash ore.

(Brainstorming, Problem Based learning)

#### 1. Introductory Activity: (KWL chart)

Have each lab pair create a KWL chart for potash before starting the task. This chart can be added to during the task as questions are answered and new questions formed.

#### 2. The Task

Explain to the students that they are taking on the role of the mining company's Chemist. Their task will be to determine how to separate the desired KCl (sylvite) from the rest of the ore rock sylvinitic.

Have the students work in pairs.

Hand out the Task sheets, background material and the samples of sylvinitic. Provide students access to lab equipment.

Inform students that a journal must be kept detailing their experiments. Have students add to their KWL charts as they answer questions and determine new questions.

The students must show you their plans for the experiment complete with hypothesis, materials, and method before they commence.

### Assessment Method and Evidence

- ✓ Scientific Inquiry Experiment rubric (such as in Pearson, Saskatchewan Science 8)
- ✓ Journal and KWL entries
- ✓ Student Self Evaluation Check list
- ✓ Experiment Results – production of confirmable KCl

#### Students will show they understand the principles of qualitative analysis of solutions by:

- Using solubility charts to determine the solubility of the KCl and NaCl.
- Describing how to separate the KCl and NaCl in solution by selective precipitation.

#### Students will show how they have used both intuitive, and imaginative thought and the ability to evaluate ideas, processes, and experiences in meaningful contexts by:

- Generating and evaluating alternative solutions to solve the problem of separating the KCl from NaCl in the ore.
- Analyzing the given data as well as produced data to create hypotheses, predictions and estimates to further progress with the experiments they develop to separate KCl from NaCl in solution.

**The students will show that their use of numbers and numerical data to strengthen understanding of the concept of solubility by:**

- Being able to read and interpret the solubility charts for KCl and NaCl to determine the best method to separate the KCl from the NaCl.
- Students will be able to describe how lowering the temperature to precipitate KCl is the method used by potash mining companies to separate the valuable KCl from a saturated solution containing both KCl and NaCl.

This kit contains: 1 teacher hand sample; 15 student samples and 75 – 80 g (¼ cup) of potassium muriate. Kits will be sent to your division Science Consultant upon request. For more information contact: [education.sma@sasktel.net](mailto:education.sma@sasktel.net)

### Resources

Mining and milling processes used at the Potash Corp mines.

<http://minetour.potashcorp.com/>

Mosaic Company Potash 101: YouTube video:

<http://www.youtube.com/watch?v=ULLLmm6cCJ8>

Saskatchewan Mining Association Website:

[http://www.saskmining.ca/commodity\\_info/Commodities/1/potash.html](http://www.saskmining.ca/commodity_info/Commodities/1/potash.html)

Saskatchewan Mining Association Educational

Resources: [http://www.saskmining.ca/news-](http://www.saskmining.ca/news-article/Education-)  
[article/Education-](http://www.saskmining.ca/news-article/Education-)

[Outreach/For+Schools/Education+Resources/1/201](http://www.saskmining.ca/news-article/Education-)  
[1-06-09-posters.html](http://www.saskmining.ca/news-article/Education-)

#### **Grade 7 Mixtures and Solutions lesson plans:**

Grade 7 MS Potash Solution Mining Dissolving Potash.

Grade 7 MS Potash Solution Mining Recovering Dissolved Potash.

Grade 7MS Potash Solution Mining How do we Know it's KCL?

Saskatchewan Mining Association **Potash Kit**

### Vocabulary

**Halite:** Is the mineral name for Sodium chloride (NaCl). It typically occurs as colourless cubic crystals. We know it as salt.

**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, clay, and iron oxides.

**Solubility:** The solubility of a substance is the amount of that substance that will dissolve in a given amount of solvent. A substance is said to be soluble if more than 0.1 g of that substance dissolves in 100mL solvent.

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

**Sylvite:** Is the mineral name for potassium chloride (KCl). It forms very similar to normal rock salt, halite (NaCl). Sylvite is colorless to white with shades of yellow and red due to inclusions. Sylvite has a salty taste with a distinct bitterness. Its principal use is as a potassium fertilizer.

## INFORMATION FOR TEACHERS

**As a result of this Problem Based Learning experience students will:**

**Know:** Potash mined in Saskatchewan is composed of two salts, NaCl and KCl. KCl is the valuable product. KCl can be separated from the NaCl by dissolving the ore in water, filtering off the insoluble clays and iron ore, heating the solution to saturate it and reducing the volume then cooling the resultant NaCl - KCl rich solution to precipitate the KCl leaving the NaCl in solution. Students will understand that KCl precipitates first when cooling by reading the solubility curves for both NaCl and KCl. Students will know how to test the resultant powder using a flame test. They will know that KCl burns violet in a flame test.

**Be able to:** Design and run an experiment to separate two variables in solution, read solubility curves, do a flame test. They will be able to detail the process of their thoughts, experiment and outcomes in a journal.

### The Task:

The students are given the task to develop a process to separate the valuable potash mineral (KCl) from the rest of the sylvinite ore and provide a method to determine if the resultant crystalline material is KCl.

The students will be given a sample of ore, background information, a list of resources to consult, and use of the lab equipment. Students will be able to discuss their progress and questions with the teacher. The teacher cannot tell the student how to run their experiment, then can however step in when safety is a concern or can suggest resources the student could access/read

Goal: Students will produce KCl as a crystalline powder.

Problem: How to separate the KCl from the NaCl and other minerals in sylvinite (potash ore).

Challenge: Both KCl and NaCl are salts soluble in water.

Students must submit their initial plan for the experiment to the teacher for approval prior to commencing any experiments. Any changes to the plan or retrials must also be approved by the teacher.

Detailed notes must be kept in a journal and submitted to the teacher upon completion of the research task.

KWL charts are to be included in the journals and updated as questions are answered or new questions are formed.

## Chemistry 30 Solubility and Solutions: Removing the KCl From the Ore

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### Product:

The student will design and test an experiment to separate the KCl from the rest of the ore rock. They will also perform a flame test to confirm that the product is KCl. The resultant product will be a crystalline powder KCl.

The student will keep a journal recording all hypothesis, equipment, procedures, observations, results and conclusions as well as their KWL chart.

### Success:

The student will have successfully separated the valuable KCl from the ore rock. It will look like a white crystalline powder which will flame violet in a flame test. The amount of crystalline powder will vary depending upon the amount of KCl in the original sample and how long the students left the precipitation stage. The students will compile complete notes and diagrams of their experiments/tests including failures, in a journal. Success would be a complete set of instructions that another chemist could replicate and come to the same conclusions.

Knowledge and Skills Needed	Already Have Learned	Taught Before the Project	Taught During the Project
1. Soluble and insoluble	x		
2. Water is a solvent	x		
3. Potash ore is made up of the minerals sylvite (KCl), halite (NaCl), clays and iron oxides			x
4. KCl and NaCl are salts and soluble in water	x	x	
5. Clays and iron oxides are insoluble in water			x
6. How to do a flame test	?	?	

### Resources:

School-based Individuals: Chemistry teacher,

Technology: Computer access, Internet web sites, PowerPoint

Community: Local geoscientists, chemists, potash mining companies

## Chemistry 30 Solubility and Solutions: Removing the KCl From the Ore

Materials: Potash kit from SMA, chemistry lab equipment (Bunsen burner or hot plate, beakers or metal containers, stir rods, filter paper, ice, bowls, mortar and pestle, scale)



Belle Plaine

CHEMICAL ANALYSIS		
Component	Symbol	Typical %
Potassium Oxide Equivalent	K <sub>2</sub> O	62.50
Potassium Chloride	KCl	98.83
Potassium	K	51.88
Sodium Chloride	NaCl	0.90
Moisture at 130° C	H <sub>2</sub> O	0.050
Chloride	Cl	47.60
Sodium	Na	3500 PPM
Calcium	Ca	200 PPM
Magnesium	Mg	100 PPM
Bromide	Br	400 PPM
Sulfate	SO <sub>4</sub>	400 PPM
Water Insoluble	—	100 PPM

PARTICLE SIZE DISTRIBUTION CUMULATIVE %				
Tyler Mesh	US Mesh	Opening (mm)	Typical Range	Typical
20	20	0.850	0-2	0.2
28	30	0.600	0-20	3
35	40	0.425	5-50	14
48	50	0.300	35-85	60
65	70	0.212	50-95	72
100	100	0.150	80-100	92

PHYSICAL PROPERTIES	TYPICAL
Bulk Density (Loose)	
- lb/cu foot	76
- kg/cu meter	1169
Angle of Repose	27 Degrees

OTHER SIZING CHARACTERISTICS	
Parameter	Typical
Size Guide Number (SGN)	30
Uniformity Index (UI)	27

Product analyses are typical as tested on a composite sample. Grab samples or individual shipment analyses may vary from typical values. Handling and transportation may affect analysis of the delivered product.

Note: The term "Untreated" in Untreated White Fine references that the Untreated White Fine product contains no anticaking agent.

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**Student Self Assessment Things to Consider**

Did we discuss the purpose for doing the activity?	<b>Yes</b>	<b>No</b>			
Did we develop a clear plan before we began?	<b>Yes</b>	<b>No</b>			
Was a hypothesis developed and recorded?	<b>Yes</b>	<b>No</b>			
How well did we predict what took place?	<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>	<b>5</b>
Did we re-examine our initial hypothesis?	<b>Yes</b>	<b>No</b>			
Did we account for experimental error?	<b>Yes</b>	<b>No</b>			
Were the conclusions consistent with the data?	<b>Yes</b>	<b>No</b>			
Was relevant research used to support our work ?	<b>Yes</b>	<b>No</b>			
How complete are the data records?	<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>	<b>5</b>
How confident were we using the equipment and materials?	<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>	<b>5</b>
Were measurements made accurately?	<b>Yes</b>	<b>No</b>			
Did we follow all safety precautions?	<b>Yes</b>	<b>No</b>			
Did we clean up thoroughly after the activity?	<b>Yes</b>	<b>No</b>			
Did each member have specific things to do?	<b>Yes</b>	<b>No</b>			
Were we able to work together as a team?	<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>	<b>5</b>

**Bar scale**

**Not so well**   **1**   **2**   **3**   **4**   **5**   **Very well**

**KWL Chart Example**

<b>KNOW</b>	<b>WANT TO KNOW</b>	<b>LEARNED</b>
Potash is mined in Saskatchewan	How does potash occur in the ground	
Potash is used for fertilizer	What is the potash mineral	
Some of the potash companies are Mosaic, Potash Corp, Agrium,	What other minerals occur in the potash ore(rock)	
Potash deposits occur in Southern Saskatchewan	What are the properties of the potash mineral?	
Potash is the provincial mineral	What are the properties of the other minerals in the ore?	
	How do you separate KCl from the NaCl in solution?	

## INFORMATION FOR STUDENTS

### BACKGROUND

#### Potash Mining in Saskatchewan

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

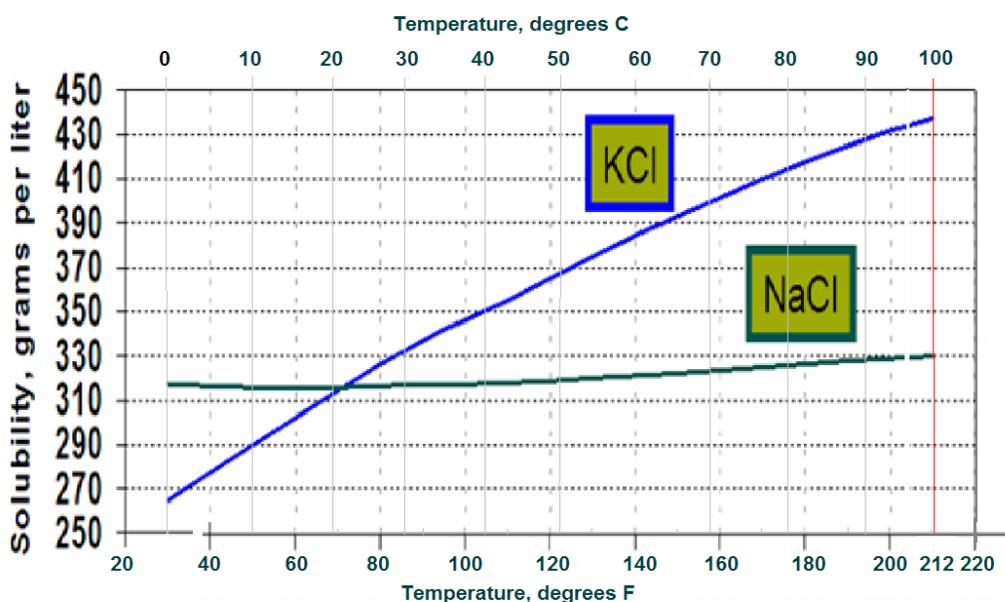
The largest potash solution mine in the world is in Saskatchewan. With this technique the potash is dissolved deep underground and the solution is pumped to the surface where the potash is removed. The same process can be used above ground to extract the potash from the sylvinite ore. After potash is mined, it is processed in a surface mill, where it is separated into product (KCl) and waste (tailings comprised of salt (NaCl) 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% of world potash production goes into fertilizer, while the other 5% 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.

**Solubility Curves of KCl (sylvite) and NaCl (halite)**



Modified from: Mosaic Potash PowerPoint –Showcase Belle Plaine

**Websites:**

Mining and milling processes used at the PotashCorp mines.

<http://minetour.potashcorp.com/>

Mosaic Company Potash 101: YouTube video: <http://www.youtube.com/watch?v=ULLLmm6cCJ8>

Saskatchewan Mining Association Website:

[http://www.saskmining.ca/commodity\\_info/Commodities/1/potash.html](http://www.saskmining.ca/commodity_info/Commodities/1/potash.html)

### Task Sheet for Students

#### TASK

You are to design an experiment to separate the valuable potash mineral (KCl) from the rest of the ore and provide a method to determine if it is KCl.

You will be given a sample of ore, background information, a list of resources to consult, and use of the lab equipment.

The initial plan for the experiment must be submitted to your teacher for approval prior to commencing. The teacher can be consulted but it is not their job to tell you how to do your research. Any changes to the plan or retrials must also be approved by the teacher.

You will keep a journal recording all hypothesis, equipment, procedures, observations, results and conclusions. The journal will be submitted to the teacher upon completion of the research task.

In a mining operation it is not uncommon that Chief Engineers, head Chemists and Safety personnel visit the company labs to determine the safety in the lab. Please ensure that during your experiments you keep safety protocols in mind.

#### SUCCESS

Experiment: The resulting KCl will be a white crystalline powder. The amount of crystalline power will vary depending upon the amount of KCl in the original sample and how long it has been processed. You will be able to perform a test to indicate that the crystalline material is KCl and not NaCl.

Journal: The journal should contain complete instructions so another chemist could replicate the experiments exactly and come to the same conclusions.

#### ASSESSMENT

Scientific Inquiry Experiment Rubric

Journal Rubric

Self Assessment Rating Scale