Eco-friendly snow-melting agents without use of chloride

Abstract

In Hokkaido, snow melting agents are used for melting snow in winter. But, calcium chloride which is used as a snow melting agent is harmful for the environment. So, the purpose of this research is to find a substance which can be an alternative. Through this research, the freezing depression and effect on the metal corrosion was tested.

The result showed that calcium acetate has not as enough power to melt snow as calcium chloride.

Introduction

Background

The calcium chloride is a very effective snow melting agent. It is an essential substance to melt snow in Hokkaido. However, it has a bad point when used as a snow melting agent.First, the chloride ion damages plants and soils. If the calcium chlorides are solved in the water and it is soaked up in the ground, plants will wither.

Second, metal products rust easily by the chlorinated water. Residents in Hokkaido are troubled with the rust of vehicles. So, the trigger of this study was this problem. To solve this problem, some substance which can alter the past snow melting agent. Therefore, in this study, the new substance which has similar characteristics to calcium chloride was searched.

Hypothesis

One of the characteristics of snow melting agents is the high freezing point depression. Agents prevent the snow from freezing, so, the chemical which causes large freezing point depression has possibilities for alternating to chloride-based snow-melting

agents. Also, water which ionic compounds dissolved in has polarity. But the solution of glucose has no polarity. The solution of glucose also causes freezing point depression. The solution which is basic or acidic might have bad effects on the soils. So, mixtures of ionic compounds and glucose were expected to be useful and eco-friendly snow melting agents.

Overview of experiment

Experiment 1

Many substances' freezing depressions were measured, and each degree of depressions are compared with calcium chloride one. Various solutions are cooled and temperatures of which solution were measured when each solution frozen.

Experiment 2

Effects of metal corrosion of each solution which had high melting points depressions confirmed in experiment 1 was investigated. Also, solutions of mixtures of ionic compounds and glucose were prepared and also they were used in experiments.

Experiment 3

Effects of snow melting of substance which was found in experiment 2 and calcium chloride was investigated by spreading each substance on the snow.

Material

Experiment 1

- $CaCl_2$ …0.010mol
- $MgCl_2$…0.010mol
- CH_3COONa…0.010mol
- $(CH_3COO)_2Ca$…0.010mol

- $(CH_3COO)_2Mg$…0.010mol
- $C_6H_{12}O_6$…0.010mol
- NH_4Cl 100g
- NaCl …0.010mol
- KCl…0.010mol
- KNO_3 100g
- Water 200mL
- Thermometer ×2
- test tube ×10
- 200mL beaker×1
- iPad ×1
- Ice …about 50g

Experiment 2

- $C_6H_{12}O_6$…0.73mol
- $(CH_3COO)_2Ca$…0.45mol
- CH_3COONa…0.45mol
- $CaCl_2$…0.45mol
- Iron plates ×84piece
- Aluminum plates×84piece
- Water…210mL
- Petri dish × 28
- pipette × 14
- incubator ×1
- acetone 500mL

Experiment 3

- $CaCl_2$ 100g
- $(CH_3COO)_2Ca$ 100g
- Shovel ×1
- Measure ×1

Procedure

Experiment 1

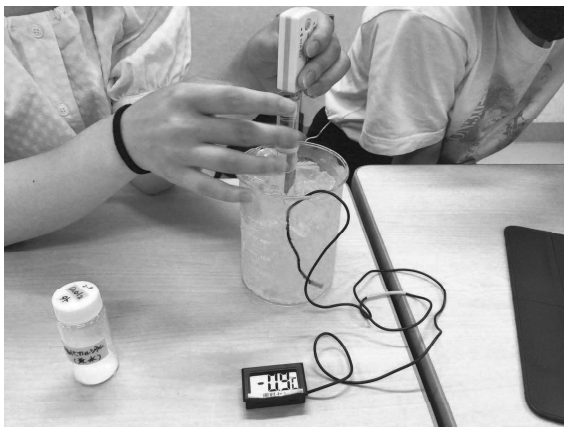
1)Solve each material 0.010mol (NaCl, KCl, $CaCl_2$, $MgCl_2 \cdot 6H_2O$, CH_3COONa, $(CH_3COO)_2Ca \cdot H_2O$, $(CH_3COO)_2Mg$, C_6H12O6) in to different which contains 20g water. Make water solutions (0.5mol/kg).

2) Mix KNO_3 and NH_4Cl with water and ice in the 200mL beaker. This is cooler.

3) Put one of the test tube which includes solutions (prepared in process 1) in to cooler.

4) Put the thermometer in to test tube and measure the temperature. Temperature should be recorded.

5) Repeat procedure 3,4 until all of solution's freezing point has been recorded.



Experiment 2

1. Make solutions which is 0.5 mol ($CaCl_2$ aq /CH_3COONa aq /$(CH_3COO)_2Ca \cdot H_2O$ aq / $C_6H_{12}O_6$ aq / H_2O /$C_6H_{12}O_6$ +$CaCl_2$(1:3,1:1,3:1) / $C_6H_{12}O_6$ + CH_3COONa (1:3,1:1,3:1) / $C_6H_{12}O_6$ + $(CH_3COO)_2Ca \cdot H_2O$(1:3,1:1,3:1))
2. Divide the solution into Schale which contains 3 pieces of metal by using a pipette. 4 Shale are needed in each solution.
3. Put all Schale in to incubator(set up 2.0℃).
4. Pick them up in 4 days. After that, left them in air for 3day.
5. Repeat same process in half of them.
6. After drying, soak them into acetone and measure their weight.
7. Also, measure the ratio of rust.

Procedure of measuring the ratio of rust in Aluminum

(1) Manually carve a mass on the plate

(2) Visually check how much of the mass area is occupied by rust.

Procedure of measuring the ratio of rust in iron

(1) Take a photo of each plate.

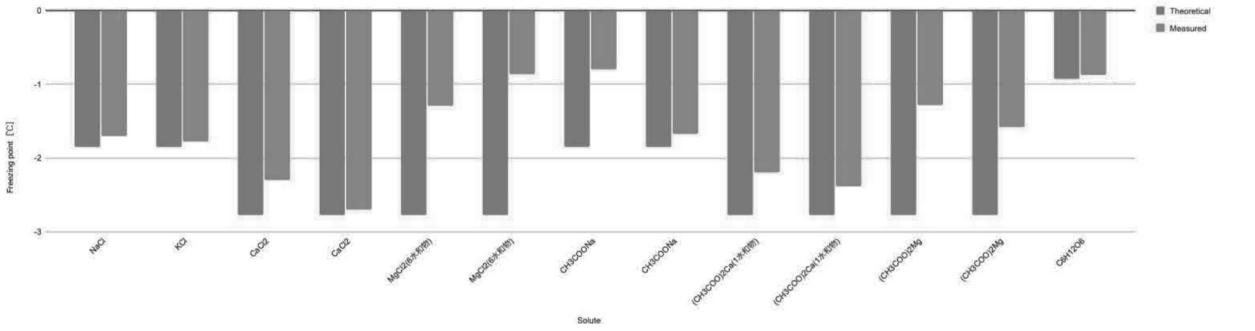
(2) Draw 8×8 grid lines on the images of all the plates using an image editing application.

(3) Visually check the percentage of rust that occupies each grid line.

Experiment 3

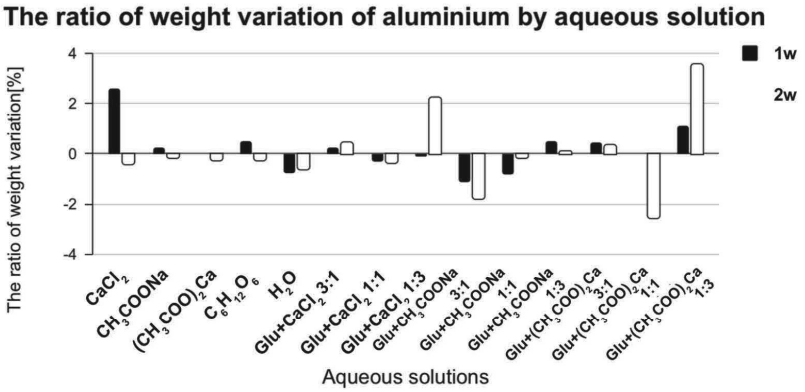
1. Make 6 areas which is 1m×1m on the snow.
2. Spread agents each area ($CaCl_2$: $(CH_3COO)_2Ca$) =(50g:0g),(25g:25g),(37.5g:12.5g), (12.5g:37.5g)(0g:50g),(0g:0g)
3. Observe how snow melted.

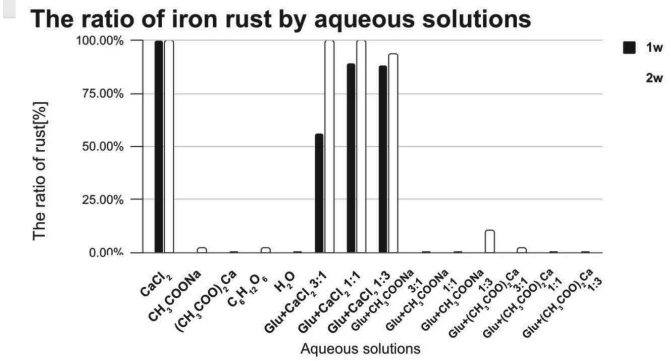
Results

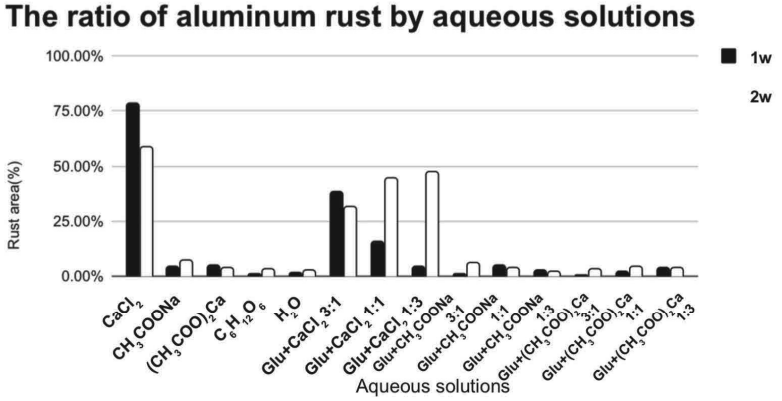


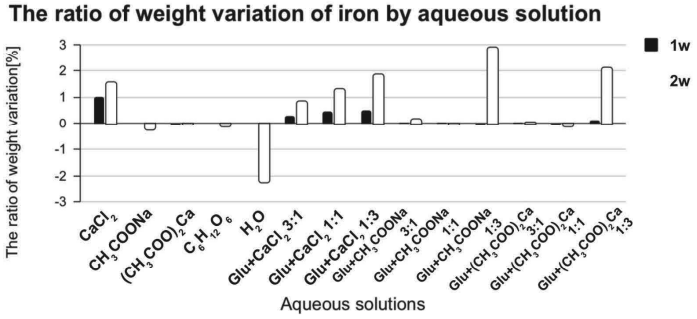
Agent	NaCl	KCl	CaCl2	CaCl2	MgCl2・6H2O ①	MgCl2・6H2O ②	CH3COONa ①	CH3COONa ②	(CH3COO)2Ca・H2O①	(CH3COO)2Ca・H2O②	(CH3COO)2Mg ①	(CH3COO)2Mg ②	C6H12O6
degree of ionization	0.838	0.924	0.743	0.960	0.197	decrease	decrease	0.805	0.689	0.787	0.192	0.354	
degree of association						0.141	0.270						

The solution of CaCl2 showed the highest freezing point depression. $(CH_3COO)_2Ca$ showed the second highest freezing point depression. It froze at -2.38°C. All other aqueous solutions froze at temperatures above -2°C.





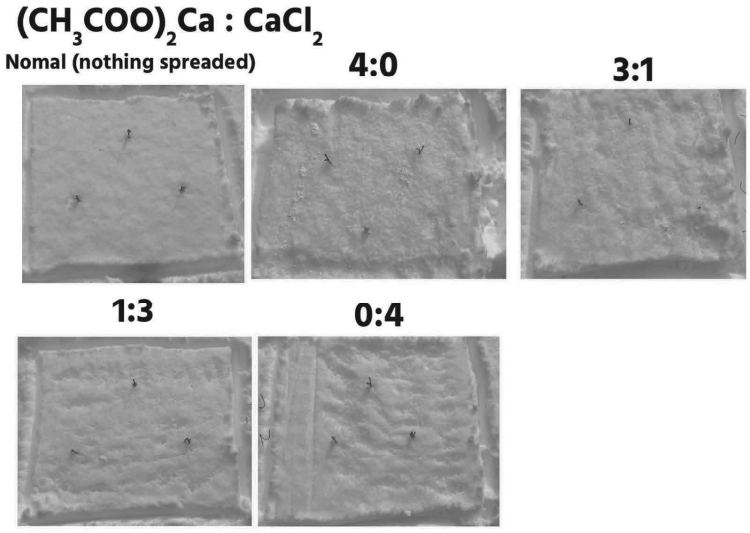




About the ratio of weight variation, both aluminum and iron showed inconsistent variation in positive and negative.

About the ratio of aluminum rust, aluminum soaked in solutions which include $CaCl_2$ showed more rust. Also, some of them in 1w had more rust than 2w.

About the ratio of iron rust ,iron soaked in solutions which include $CaCl_2$ showed more rust.



Experiment3

$CaCl_2$ could melt more snow than (CH3COO)2Ca.

Discussion

Experiment 1

The reason for the result was thought to be due to the high degree of ionization of $CaCl_2$ and $(CH_3COO)_2Ca$. Sugar did not show much freezing point depression because it is not an electrolyte.

Experiment 2

First, any consistency wasn't found in the positive or negative direction for the rate of mass change. The increase of weight could be caused by the precipitation of substances which were dissolved in the water.The decrease of weight could be caused by the solving of red rust (Fe_2O_3). Red rust can dissolve into water easily. From the above, various factors

could be considered which interfere with the weight variation and the amount of rust was not suitable to measure how much rusts are generated.

Secondly , considering the area of rust, for aluminium, more occurrence of corrosion was observed in aqueous solutions containing chlorides, but more rust occurred in one cycle than in two cycles. The reason for this was considered that the way to measure by manual and visual was not accurate measurements. This result is different from the actual data. Based on this, for iron, the accuracy was increased by using an image editing application. In iron , the ratio of rust exceeded 50% for both one and two cycles in the aqueous solutions containing chloride ions. Other materials did not exceed 25%. And, as for those containing acetate ions, In the other aqueous solutions, the solution was considered to be negatively biased when considered electrically because the solution was made of a weak base. In other words, it was thought that the metal was less likely to become a metal ion because it was less likely to emit electrons.In addition to this, it is thought that an oxide film had formed on the surface of the metal, and that the metal was resistant to rusting because it did not contain chloride ions that would have destroyed it. However, whether or not an oxide film was formed has not been verified, and future experiments are needed to confirm this.

Experiment 3

Although calcium acetate and calcium chloride were thought to be equally effective in melting snow in previous experiments, this demonstration showed that calcium chloride is much more effective in melting snow. Unlike calcium chloride, calcium acetate does not emit much heat of fusion, so it is thought that it only contributes to snow melting by lowering the freezing point. Therefore, it is thought that the percentage of melted snow was observed to decrease as the percentage of calcium acetate increased in this experiment as well.

Conclusion

In conclusion, $(CH_3COO)_2Ca$ was not able to be used as a snow-melting agents. Also it was considered that chloride causes the rust and there were a few differences in the percentage of the rust in other materials.Therefore, a suitable alternative is $(CH_3COO)_2Ca$, which had the lowest freezing point of the aqueous solutions, except for $CaCl_2$.

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