The Effect of Salt on Ice Melting

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ABSTRACT

According to the scientific exploration, some questions are raised about the happenings while sprinkling salt on ice. Then, some theories have been developed. some experiments were conducted to prove the presented theories. The rate and speed of ice melting depend on some factors like size of the ice, the temperature of the room, shape of the ice, etc, which were examined with the experiments. It was found by increasing the concentration of salt , the speed of ice melting will increase and type of salts are more useful for melting ices which include: NaCl-KCl-MgCl2 and CaCl2.

Key words: *Colligative properties, Salt, Ice cubes, Melting*

1 Introduction

This problem tries to tell us how salt can melt ice and what are these factors can affect this phenomenon. It relates to our daily live, for example in winter when it snows, we need to know which materials are better in terms of various criteria such as the availability of material or the speed and strength of melting snow and ice. First, we have to know salt is a mineral composed primarily of sodium chloride (NaCl), a chemical compound belonging to the larger class of salts; salt in the form of a natural crystalline mineral is known as rock salt or halite. Also, there are different types of salts categorized into monovalent, bivalent and other categorized according to the periodic table.

Colligative properties is the ratio of the number of solute particles to the number of solvent particles in a solution. These properties do not depend on the nature of the chemical species but the number of soluble particles affects the boiling point, freezing point, and vapor pressure. The higher the number of solute particles in a solution, the faster the dissolution. It is an important factor especially when we are comparing the salts based on their concentration. The next factor is the surface-to-volume ratio that checks the rate of one surface in which its volume helps us especially when we are comparing the speed of ice melting based on their size. In chemical reactions where a solid is in contact with a solution, the ratio of surface to volume is an important factor in reactivity. Consider a pot and a jug, the pot has a bigger surface than the jug. However, the volume of the pot is more than the jug. Therefore, if you fill both of them with water and return them simultaneously, you will see that the time for the jug to be empty will be shorter than the time needed for the pot. It means the surface-to-volume ratio of the jug is less than the surface-to-volume ratio of the pot (Fig.1).

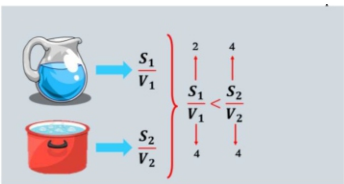


Fig. 1: Surface to volume ratio

Therefore, these rules can affect on our experiments. At first when the experiment starts, we can see temperature drops down for a time and then it is constant. The main factors are:

1- Concentration of salts
2- Size and shape of the ices
3- Different types of the salts

According to our experiments it is found NaCl is the most useful salt for melting the ice with smaller cubes (Fig. 2).

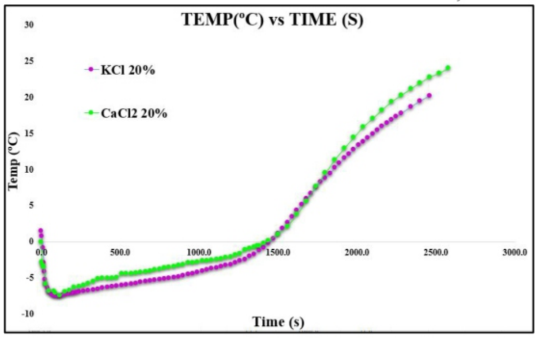


Fig. 2: Comparing two types of salt affecting on ice melting , KCl 20% and CaCl2 20%

2 Experiments and Methods

At first, it was observed that salt can melt ice in 2 forms when we sprinkle the salt on ice or dissolve it in water at room temperature. Then, some questions were asked and some hypotheses were assigned accordingly.

The first hypothesis was the rate and speed of the melting have a relationship with the size and shape of ices. Second hypothesis was the rate and speed of the melting have a relationship with the concentration of salts and the last one was the type of salts and other factors like room temperature or shape of containers that can affect this phenomenon.

Different determined parameters included:

- Concentration of salts
- Shape, size, and color of containers
- Different types of salts
- Room temperature
- Shape and size of ices

First Experiment: , the distilled water had been put in two different ice molds and not just for once because the number of ices was a lot and put them in the freezer to make ices. Then with a digital scale, the amount of salt was chosen (20% and 40%). The ice molds were divided into crushed ice and ice cubes which was the variable parameter and the melting ice was measured in different times (Fig. 3).

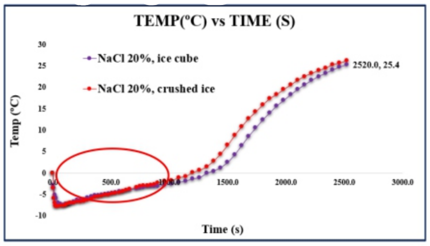


Fig. 3: Temperature versus time in ice melting by sodium chloride 20%

It's clear that starting point of each line is 0 ^{0}C (because the temperature of the water was 0 ^{0}C and one of the fixed parameters) and also both of the lines have a minimum which is lower in the crushed ice .Then the temperature is getting higher and higher but in the part that shows in a chart with the red circle, the fluctuations are low. This part is calling the latent heat. We have different latent heat, like latent heat of fusion, latent heat of vaporization, etc., however, the duration of the latent heat of the salts are the same. These experiments have been done with 20% and 40% of sodium chloride for both crushed and ice cube with the same results (Fig. 4).

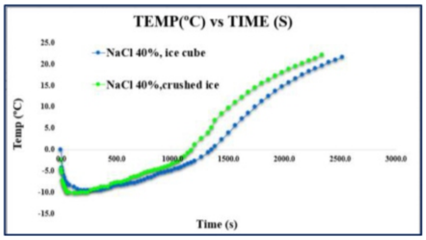


Fig.4: Temperature versus time in ice melting by sodium chloride 40%

Also, these experiments were done with two types of salts which were Calcium chloride (CaCl2) (20% and 40%) in order to make sure that the results are the same for each type of salts and concentration (Fig. 5).

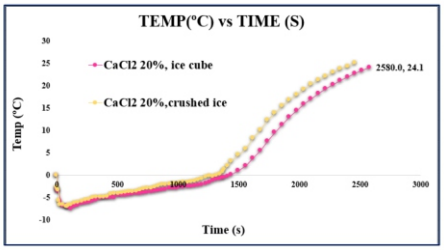


Fig. 5: Calcium chloride (20%) on ice melting.

Second Experiment: The second experiment is about salt concentration affecting on ice melting, requirements for doing these experiments were the same as the previous section only four types of salt are used (NaCl -KCL-MgCl2 and CaCl2) . The results for 0/2/4/6 and 8 % of sodium chloride in one diagram are compared with each other better (Fig.6).

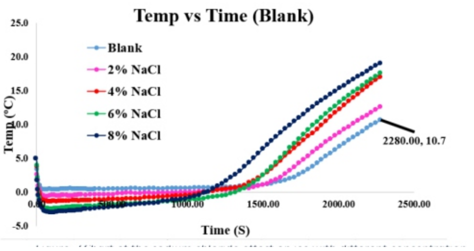
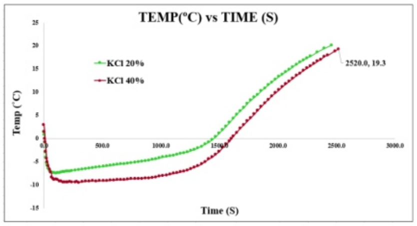
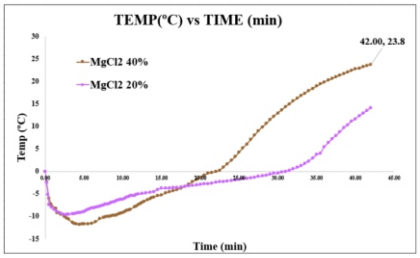


Fig.6: Sodium Chloride on ice with different concentration

According to the different concentrations of salt, the temperature gradient is different which is more in 8% sodium chloride salt compared to the other percentages. It is repeated again for other kinds of salt (Figs.7 a,b,c).



(a)



(b)

Fig.7: a)Potassium Chloride and b) Magnesium Chloride on ice with different concentration

Third Experiment: In this experiment, monovalent and bivalent salts (Fig. 8) at a same concentration are compared in ice melting.

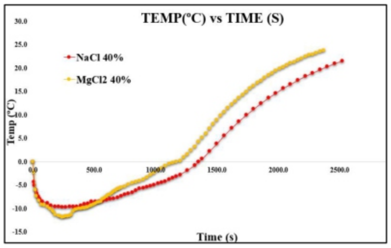


Fig. 8: Comparing between monovalent and bivalent salts in ice melting

In this case, according to the periodic table, monovalent salts are in one column & bivalent salts are in one column and according to the colligative properties the salts in one column in general form has the same structure and molecules so in this case, monovalent and bivalent salts are used together.

3 Discussion and Results

In our experiments, when the size of ice gets smaller, it can melt earlier and faster. Because by increasing the size

size of ices, the molecules of ice get more because they have more volume and they can have more overlap with water and hydrogen molecules, therefore, they would melt faster.

In all diagrams all lines start at 0.5 ^{0}C & all had a negative gradient in temperature due to the heat energy from the overlap of ice molecules with salt, which generates heat and lowers the temperature. According to the different concentrations of salt, this gradient is different, which by increasing of salt concentration, it becomes more severe. This gradient in 4% is twice more than 2% or 8% is four times more than 2% because of colligative properties. By increasing the concentration of salts, the time of latent heat decreases and then temperature increases.

According to these properties, the higher the number of particles in the ingredient, the more it reacts with other molecules. In this case, more concentrated salt would overlap and overheat faster which leads to produce energy and the ice melts faster and the latent heat lasts less. After latent heat, the slope of the sodium chloride diagram in 8% is higher because more heat is generated and therefore, the temperature rises more.

In the monovalent section, sodium locates above potassium, and in each column in periodic table , the more we go down, the more will be metallic characteristic. Potassium has more metallic features than sodium due to its position so the temperature gradient of potassium is more than sodium and the latent heat of that is shorter too. But, according to this, the overlap of potassium salt with ice is more exothermic and releases more heat. Therefore, it would reach the exothermic point sooner and after that, it is less inclined to continue the reaction due to the production of stable ions. For this reason, sodium chloride can act more than potassium chloride.

The negative gradient temperature for magnesium is more than sodium , because magnesium is bivalent and sodium is monovalent. Therefore, the number of $MgCl_2$ atoms is higher than NaCl so it overlaps with more molecules of ice.

Due to the higher number of particles, we consider the latent heat for magnesium runs out sooner but, the time of latent heat is the same too which of these two salts reaches a temperature of ^{0}C sooner? Sodium chloride. In Mendeleev's table, the more we move from left to right, the higher mass of the metal will be. After the latent heat, Magnesium salt which has the less metallic features does not tend to continue the overlap since more heat is generated and the time of latent heat for sodium makes less or the same as magnesium, and temperature increases for sodium to get more. Therefore, sodium is more effective in ice melting.

According to the table of solubility of salts in water (25 ^{0}C) in ambient temperature, for example, NaCl dissolves only 35.9 grams in 100 cc of 25 ^{0}C water , but magnesium can be dissolved up to 52.9 g, which means that when we do this with 40% concentration of these salts, some of the NCL salt is precipitated and its molecules are not released so that they can overlap with the ice molecules.

Due to the overlap of (water, hydrogen) molecules with ions and electrons of salt, ice melts by produced heat.Actually, the time and speed of ice melting belongs to the following factors :

- Ambient temperature
- Level of the ambient light
- The amount of solvent (cc)
- Salt concentration
- ice material
- type of salt
- shape and size of ices
- the place and wheatear
- the type of water

We concluded that although the size of ice gets smaller, the amount and speed of melting the ice increases. According to the colligative properties, when the number of Solvent molecules gets more, it can react with non-metal such as ice.

Type of salts can affect this phenomenon and with NaCl sodium chloride) we could melt more ice and also it is the most available salt in the world that we use in our daily lives. So according to the following order salts can be used on ice melting as: **NaCl>KCl>MgCl2>CaCl2**

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