The Effect of pH on the Melting Time of Ice

Jhong D (djhong@student.ubc.ca), Mah J (jonma99@student.ubc.ca), Randhawa R (r.randhawa@student.ubc.ca)

Abstract

The melting point of ice is known to be affected by the presence of impurities. Research has demonstrated that salt can speed up the melting of ice (Kim and Yethiraj 1). However, there is not a lot of research available on the effects of pH on the melting point of ice. If low pH is shown to accelerate the melting of ice, it can have implications for the melting of glaciers as ocean acidification intensifies globally. In order to evaluate if lower pH ice cubes melt faster, acidic, basic, and neutral ice cubes were used to record melting time. The time it took for the ice to display the first signs of melting was measured simultaneously for the three types of ice cubes and a one-way ANOVA was run using the data collected. We predicted that acidic ice would melt faster than basic or neutral ice and that neutral ice would melt the slowest. The ANOVA found no significant difference (p-value = 0.744) in the melting time of the acidic ice compared to the neutral or basic ice. Therefore, whether acidic melts faster than basic or neutral ice could not be concluded and the null hypothesis was not rejected.

Introduction

One of the factors that affect the melting point of a solid is the presence of impurities (Gillespie, "What Factors Affect Melting Point"). A solid that contains impurities will melt at a lower temperature than a solid that is pure. This is because the impurities lead to structural deficiencies that decrease the strength of the intermolecular interactions holding the solid together (Gillespie, "What Factors Affect Melting Point"). Thus, an ice cube that contains impurities will likely melt faster than an ice cube made from water with no additional additives. This effect can be observed in ice cubes that contain salt. A study conducted by Kim and Yethiraj found that ice crystals melt rapidly in the presence of salt and this melting is largely due to the ion-water interactions. However, Kim and Yethiraj (6) also noted that the ions affect the melting of crystals differently. For example, in their study, they found that the Cl- ions affected the melting of ice more actively than Na+ ions because they are more readily accepted into the crystal lattice. In this study, we investigate the effect that pH may have on the melting time of ice cubes. Specifically, we designed this experiment to answer the following question: will an acidic ice cube melt faster than a basic or neutral ice cube? We also formulated the following hypothesis: if a lower pH speeds up the melting time of an ice cube then an acidic ice cube will melt faster than a basic or neutral ice cube. The null hypothesis is that the melting time of the acidic, basic and neutral ice cube does not differ significantly. We predicted that acidic ice would melt faster than basic or neutral ice and that neutral ice would melt the slowest. We are interested in studying these effects because prior research has focused solely on salt ions and research on the effects of pH on the melting of ice is lacking. We believe this topic can have important implications for the melting of glaciers. Over the years, anthropogenic CO2 levels have been rising. The polar seas are especially sensitive to acidification due to their weak carbonate buffering capacity due to lower alkalinity (Shadwick et al. 2013). With increasing ocean acidification, it is important to study the effects that acidic water can have on ice. If acids can speed up melting then the ice caps located in/near acidic waters will melt quicker. The melting ice from the glaciers will freshen up seawater and reduce the buffering capacity further leaving it more vulnerable to effects of acidification (Katz, “Why Rising Acidification Poses a Special Peril for Warming Arctic Waters.”).

Methods

In our kitchens, we first measured and poured one cup of water into three cups, labelling them as acidic, basic and neutral. In this case, neutral was our control group. Within the acidic cup, we added one teaspoon of vinegar then mixed it well. To create the basic cup, we poured another cup of water into a separate cup and added one drop of liquid soap and mixed well to create a soapy solution. We then took one teaspoon of that soapy solution and added that to the cup labelled as basic and mixed well. The neutral cup which serves as the control group will not have any solution added to it. An ice cube tray was labelled as Group A (acidic) for the first two molds, Group B (basic) for the second two molds, and Group C (neutral) for the next two molds (Figure 1). The solutions were then poured into the corresponding molds for a total of four ice cubes for each treatment group. The ice cube tray was then placed into the freezer until everything was completely frozen. A surface was then thoroughly cleaned and labelled with acid, basic and neutral prior to placing the ice cubes on it to be melted. One ice cube from each treatment group was placed above the correct labels and the time at which the "first melt" occurred was recorded. The "first melt" is described as the moment that there is a visible pooling around the ice cube. Ice cubes that were not being recorded at the moment are then placed back into the freezer for the next trial. The experiment was then repeated three more times, with the surface thoroughly cleaned between trials. Once the data was compiled, we ran a one-way ANOVA test. If the one-way ANOVA said the results were significantly different with an alpha value of 0.05 or less, then we planned on running a Tukey-Kramer test to find out which means are significantly different.

Figure 1. Reference diagram for labelling the ice cube tray.

Results

We find that basic ice cubes on average melted the fastest with a mean of 171.08 seconds (Figure 2). Basic ice cubes melt 18.6% faster than acidic cubes at 210.33 seconds and 12.5% faster than neutral cubes at 195.50 seconds. This suggests that the lower pH ice cubes melt slower than higher pH ice cubes. Using a one-way ANOVA test, we find that the p-value corresponding to the F-statistic of one-way ANOVA is 0.744. This p-value is higher than 0.05, our chosen alpha value.

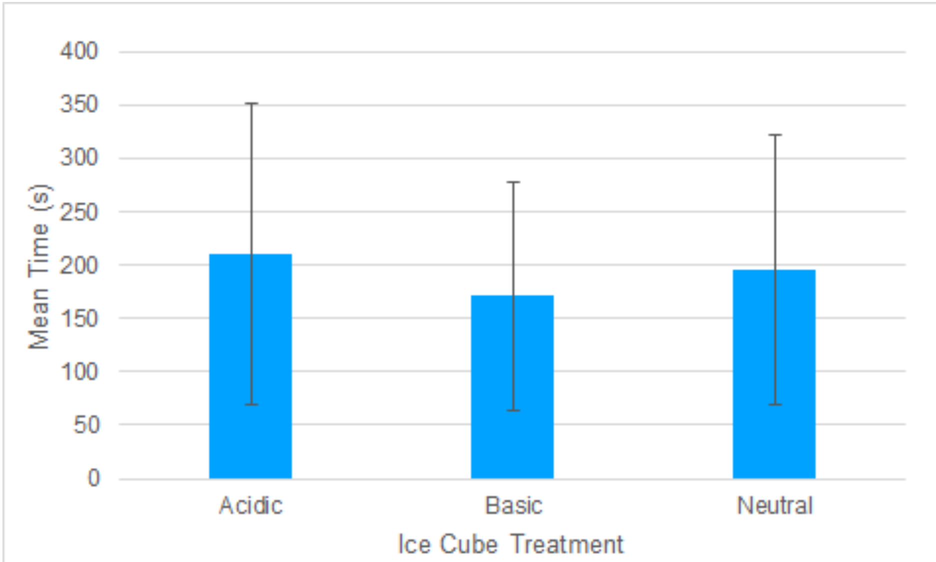

Figure 2. Mean time (s) of ice cubes melting time. Acidic (N=12) ice cubes frozen with 1 tsp of vinegar, Basic (N=12) ice cubes frozen with 1 tsp of soapy water, and Neutral (N=12) frozen from neutral water. Bars represent standard deviations of ±141.6143 s for the Acidic treatment, ±106.6212 s for the Basic treatment, and ±126.3807 s for the Neutral treatment.

$$SSW = \sum_{j=1}^{k} \sum_{j=1}^{l} \left(X - X_j'\right)^2$$

$$SSW = \left(\left(210.3333 - 192.3055\right)^2 + \left(171.08333 - 192.3055\right)^2 + \left(195.5000 - 192.3055\right)^2 \right) \cdot 12$$

$$SSW = 9427.0556$$

Figure 3. Sample Calculation for one-way ANOVA test, sum of squares within groups.

Discussion

The effect of salt ions on the melting time of ice has been studied extensively however there is not a lot of research that looks into the effects of pH of ice on its melting time. The purpose of our study was to address the lack of research on this topic and gain an understanding of how pH influences the melting time of ice. The results of our study were unexpected. The mean melting time was the highest for acidic ice cubes and the lowest for basic ice cubes. The effect observed was that lower pH increased melting time. We had predicted that the neutral ice cube would have the highest mean melting time because it did not contain any added impurities and thus would be relatively pure compared to the other two groups. Understanding how salt changes the freezing temperature of water led us to form predictions about how acids and bases might affect the melting time of ice. Salt lowers the freezing temperature of water by interfering with how water molecules enter and leave the crystal lattice structure of ice ("How Does Salt Lower the Freezing Point of Water?"). Salts reduce the number of water molecules that are present at the liquid/solid interface ("How Does Salt Lower the Freezing Point of Water?"). Through this interaction, salt can increase the melting of ice. The assumption that our prediction rested on was that adding acids and bases would interrupt the equilibrium of ice in the same way that salt does and thus result in faster melting times. Another assumption we made is that a lower pH will disrupt this equilibrium more than a higher pH. After running the one-way ANOVA test on the data collected, we obtained a p-value of 0.744. This reveals that the difference between the melting times of the acidic, basic, and neutral groups is not significant at the 0.05 significance level. Thus, we cannot reject our null hypothesis, and we also fail to support our alternative hypothesis that the melting time of the acidic, basic and neutral ice cubes does differ significantly.

In our experiment, one member found large discrepancies in their data as compared to the average datasets. That member's average melting time was found to be nearly 90% less than the other members' observed melting times. We hypothesized that water hardness could be an influencing factor and that the water that member's used was perhaps softer than the other two experimenters. According to John Tomcyk, hard water reduces the ice hardness and cooling capacity because of the higher mineral content in the ice. Vancouver has a range of hardness levels from 7.9-11.8 mg/L ("Water Hardness Level By City - British Columbia"). However, Surrey from its Water System Annual Report 2019, has an approximate water hardness level of 1.5-3.8 mg/L (City of Surrey). This shows approximately an 8 mg/L difference between the two city water hardness levels. The researcher that had large discrepancies in data used tap water from Surrey's system, whereas the other members had used tap water from Vancouver's system. Interestingly, the two experimenters that used tap water from Vancouver both have similar ranges of data. The lower level in water hardness could be an attribute that caused their ice cubes to melt significantly faster relative to ice cubes from a different region. This difference in data could also influence our ANOVA analysis which resulted in our data to be not significant.

One limitation of this study was that the experimental trials were conducted at three different locations which makes it difficult to control for different environmental factors such as the size of the ice cubes from the ice cube tray and pressure as well as standardized measurement equipment. A source of uncertainty stems from how we characterized melting time as it was still subjective to how we interpreted what a pool of liquid constitutes. A possible source of error was the inability to keep the ambient temperature constant which could cause big differences between melting times even between the same pH ice cubes for one member.

Conclusion

The results from our study on the effects of pH on the melting time of ice cubes did not provide support for our hypothesis nor did they allow us to reject the null hypothesis. We hypothesized that if lower pH speeds up the melting time of an ice cube then an acidic ice cube will melt faster than a basic or neutral ice cube. However, we found that basic ice cubes melted faster on average than both acidic and neutral ice cubes, and acidic ice cubes to melt slower on average contrary to our prediction. This means that our data does not support our prediction or hypothesis. The differences between the three groups (acidic, basic, or neutral ice cubes) were also found to be statistically insignificant, so we cannot say with certainty that pH is an influencing factor on melting ice. Further investigation is required in order to fully understand the effects of low pH on the melting of the polar ice caps.

Acknowledgements

This work was supported by the University of British Columbia (UBC) who gave us the opportunity to conduct this research. We would like to thank Dr. Celeste Leander, as well as the entire teaching staff of BIOL342, Tessa Blanchard, and Anne Kim, for supporting, facilitating, and guiding us through this research process. We would also like to thank our peers for providing feedback on our draft. Finally, we would like to recognize that UBC Point Grey (Vancouver) campus sits on the traditional, ancestral, and unceded territory of the xwməθkwəy̓əm (Musqueam) People.

Literature Cited

"Water Hardness Level By City - British Columbia." *Aquatell Canada*, www.aquatell.ca/pages/water-hardness-level-by-city-british-columbia. Accessed 28 Nov. 2020.

"Water System Annual Report." City of Surrey, 2019.

Gillespie, Claire. "What Factors Affect Melting Point?" *Sciencing*, 2 Mar. 2019, sciencing.com/factors-affect-melting-point-8690403.html.

Katz, Cheryl. "Why Rising Acidification Poses a Special Peril for Warming Arctic Waters." *e360*, 24 Oct. 2019.

Kim, Jun S., and Arun Yethiraj. "The Effect of Salt on the Melting of Ice: A Molecular Dynamics Simulation Study." *The Journal of Chemical Physics*, vol. 129, no. 12, 2008, pp. 124504-124504-7.

Lei, Gui-Lin, et al. "Numerical Investigation on Heat Transfer and Melting Process of Ice with Different Porosities." *International Journal of Heat and Mass Transfer*, vol. 107, 2017, pp. 934-944.

Letcher, Trevor. M. *Climate Change: Observed Impacts on Planet Earth*. Elsevier, 2009.

Shadwick, E. H. et al. "Vulnerability of Polar Oceans to Anthropogenic Acidification: Comparison of Arctic and Antarctic Seasonal Cycles." *Scientific reports* vol. 3, 2013, doi:10.1038/srep02339. Accessed 20 Nov 2020.

Tomczyk, John. "The Professor: Hard Ice vs. Soft Ice." *ACHR News RSS*, ACHR News, 4 June 2012, www.achrnews.com/articles/120119-the-professor--hard-ice-vs--soft-ice.

Worldofchemicals. “How Does Salt Lower the Freezing Point of Water?” *Worldofchemicals.com*, Worldofchemicals, 14 Feb. 2017, www.worldofchemicals.com/558/chemistry-articles/how-does-salt-lower-the-freezing-point-of-water.html.

Appendix A

Darren's Data			
	Melting Time (s)		
Trial Number	Acidic	Basic	Neutral
Trial 1	292	252	260
Trial 2	285	242	254
Trial 3	280	242	244
Trial 4	282	244	240

Figure 4. Darren's individual trial data.

Reshmin's Data			
	Melting Time (s)		
Trial Number	Acidic	Basic	Neutral
Trial 1	28	36	40
Trial 2	23	38	30
Trial 3	28	26	45
Trial 4	26	34	15

Figure 5. Reshmin's individual trial data.

Jonathan's Data			
	Melting Time (s)		
Trial Number	Acidic	Basic	Neutral
Trial 1	362	269	335
Trial 2	238	146	222
Trial 3	288	279	317
Trial 4	392	245	344

Figure 6. Jonathan's individual trial data.

Combined Data		
Acidic	Basic	Neutral
292	252	260
285	242	254
280	242	244
282	244	240
28	36	40
23	38	30
28	26	45
26	34	15
362	269	335
238	146	222
288	279	317
392	245	344

Figure 7. Combined trial data.

Appendix B

	Acidic	Basic	Neutral
Mean	210.3333333	171.0833333	195.5
Std. Deviation	141.6143	106.6212	126.3807
Std. Error of Mean	40.8805	30.7789	36.483

Figure 8. Mean and standard deviation values calculated with GraphPad Prism.

ANOVA Table	SS	DF	MS	F (DFn, Dfd)	P value
Treatment (between columns)	9427.0556	2	4713.5278	0.2984	0.744
Residual (within columns)	521342.5833	33	15798.2601		
Total	530769.6389	35			

Figure 9. ANOVA Table results calculated with GraphPad Prism