Introduction/Rationale

The principle that guides how effectively de-icing agents perform their work is freezing point depression. Freezing point depression represents a colligative property of solutions. These solutions depend on the number of solute particles in a solvent and not on the identity of those particles. Water naturally freezes at 0 degrees Celsius, turning into ice. Once such solutes as salt are dissolved in water, the solute particles interfere with the formation of ice. The resulting solution requires a lower temperature to complete the transition into ice. To define the extent of this temperature drop, $\triangle Tf$, it is directly correlated with the molality, m, in the formula: $\triangle Tf = i \times Kf \times m$.

The use of chemicals to melt ice dates back centuries, but the use of de-icing agents on a wide scale became critical during the rise of modern vehicular transportation in order to keep people safe. Historically, simple table salt-sodium chloride, NaCl, was the most common and cost-effective choice for road treatment. While sodium chloride is effective, its efficiency falls dramatically below about –6 degrees Celsius. It has detrimental environmental impacts-including corrosion of metal infrastructure and contamination of local water sources and vegetation. These limitations have spurred the adoption of alternative de-icing compounds that are effective at lower temperatures and less corrosive, including magnesium chloride ($MgCl_2$) and calcium chloride ($CaCl_2$).

The primary differences between the compounds lie in their molar mass, dissociation characteristics (the i value), and their hygroscopic nature (their ability to attract and hold water). For instance, calcium chloride is highly hygroscopic, meaning it

releases heat when dissolving, which accelerates the melting process, which is a significant advantage in extreme cold. By comparison, organic compounds like urea, which are most often used in airport applications due to their lower corrosivity to aircraft metal, have a value of i = 1. They do not dissociate into ions and are less chemically efficient at lowering the freezing point. Understanding these trade-offs is crucial. The “best” solvent for melting ice has to balance superior freezing point depression (scientific efficacy) with cost, and how it impacts the environment.

This research has significant importance in public safety, economic, and environmental problems. Determining the optimal solvent would therefore allow communities to make science-based decisions regarding winter road maintenance that will directly enhance safety for both pedestrians and motorists by reducing the accumulation of ice. Secondly, proper selection of solvents is critical for reducing two significant negative externalities: decreasing the billions of dollars spent yearly in rebuilding corroded infrastructure or bridges, roads, and utility lines brought about by caustic salts; and minimizing the environmental damage from runoff chemicals into watersheds and roadside vegetation. Therefore, my project offers a path toward a more sustainable and efficient winter management strategy that helps as much or more efficiently as road salt while having crucial preservation efforts.

One of the most significant societal impacts of this research relates to infrastructure preservation. The use of highly corrosive salts, mainly sodium chloride, leads to the quick deterioration of concrete, steel bridges, and rebar, often used in road construction, leading to massive maintenance costs and reduced structural lifespan. By

identifying a solvent that provides superior freezing point depression at lower, more cost-effective concentrations. A solvent that would be less corrosive and causes less damage, such as calcium magnesium acetate $C_{12}H_{18}CaMg_2O_{12}$ would fit this category. Success in this area could translate into millions of dollars saved annually in infrastructure repair budgets, allowing those funds to be used for other important community services.

Hypothesis, Independent/Dependent Variables, and Research Question

How do different solvents affect how much time it takes for water to melt?

Independent variable: Solutes, (Solutes include Salt (NaCl), White Vinegar, Sugar ($C_{12}H_{22}O_{11}$). These solutes will be added to the water to see how it affects the time it takes the ice to melt.

Dependent variable: Water's freezing point, the temperature at which the water freezes being affected by the solutes and how long it takes for the ice to melt due to the change in the freezing point.

If 25 mL of white vinegar is added to tap water at a base measurement of 50 mL, then it will cause ice to melt the fastest.

Materials List

- Test Solutes: Salt (NaCl), Sugar ($C_{12}H_{22}O_{11}$) and White Vinegar, used to pour into water and change the freezing point
- Tap Water: 50 milliliters for each ice sample, used to create ice samples
- Ice Cube Tray: Used to create 12 uniform, standardized ice cubes of known volume (fill line)
- Measuring cups: 3, 50 mL, 15 mL, and ½ teaspoon, used to accurately measure water and solutes to provide fair trials
- Scale: 1, used to measure amount of vinegar
- Beaker: 1, used to pour vinegar into and transfer to cup
- Stopwatch/Timer: 1, Used to measure the elapsed time for an ice cube of each solution
- Plastic bags (medium sized): 4, Used to create contain solutions
- Freezer: 1, Used to keep ice cubes at a consistent cold temperature
- Plastic bin: used to place ice cubes and pour solutions into for experiment

Procedures

A. Preparation of Standardized Ice Samples
    1. The water was poured into individual compartments of the ice cube mold to the fill lines.
    2. This process was repeated until 12, identical, standardized ice samples were created.
    3. The ice mold was placed in a freezer, and the samples were allowed to freeze for a minimum of 24 hours to ensure consistent initial temperature and crystalline structure.
B. Preparation of Solute Solutions
    1. 50 mL of tap water was poured into a cup (repeated 4 times into four different cups)
    2. 15 mL of the first solute (NaCl) was measured using a measuring cup.
    3. The measured solute was poured into a cup of measured tap water.
    4. The cup was stirred using the spoon to dissolve the solute into the water.
    5. The solution was transferred to a medium-sized plastic bag for containing.
    6. Steps 2–5 were repeated for Sugar ($C_{12}H_{22}O_{11}$)
    7. A control is created by leaving aside a cup with 50 mL of tap water.
    8. 25 mL of White Vinegar poured into a beaker and measured using a scale that reads in mL
    9. Steps 3-5 were repeated for White Vinegar
    10. The control is also transferred to a medium-sized plastic bag for containing.
C. Experiment Process
    1. One standardized ice cube was removed from the freezer and immediately placed into a plastic container
    2. ½ teaspoon of the salt solute was measured and poured onto the ice cube
    3. The time it took the ice to melt was recorded with a stopwatch on a phone.

4. The time was written down.
5. The melted ice cube and solution in the bin were washed out.
6. Steps 1–4 were repeated two more times for the solution to obtain three replicate trials.
7. Steps 1–5 were repeated for each of the remaining test solutions (White Vinegar, Sugar ($C_{12}H_{22}O_{11}$) and the control solution.)
8. After every trial was completed, the average of every solution was calculated ((Trial 1 + Trial 2 + Trial 3) / Number of Trials = Average Time)

D. Potential Risks
- Contact with the solutions might cause minor skin or eye irritation.
- Slipping hazard if the solutions or ice were spilled onto the floor.
- Glassware (cups that were used during the stirring of the solutions) may fall and break creating an unsafe environment.

E. Safety Precautions
- Keep the distance between my face and the experiment pretty far in order to make sure it doesn't splash into my eye.
- Stop with the experiment when a spill happens and mop it up before continuing.
- Have adult supervision (mom) near if a glass cup breaks to make sure no harm was inflicted and to safely clean up the broken glass.

F. Data Collection
- The data was collected by recording the time it took for the ice to melt into a notebook for each trial for each solution.
- The average for each solution was calculated.
- The data from the notebook was placed into Microsoft excel and was then made into a table.
- The averages were taken and placed into a line graph.

Solution	Trial 1 Melting Time	Trial 2 Melting Time	Trial 3 Melting Time	Average Melting Time
Control				
Salt				
Sugar				
Vinegar				

Solute	Water Base	Added Component
Control	50 mL	Nothing
Salt	50 mL	15 mL

Sugar	50 mL	15 mL
Vinegar	50 mL	25 mL

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