

# Freezing and Melting of Water

## Introduction

The water molecule ( $\text{H}_2\text{O}$ ) is formed by one atom of oxygen, bound to two atoms of hydrogen. The hydrogen atoms are "attached" to one side of the oxygen atom, resulting in a water molecule having a positive charge on the side where the hydrogen atoms are and a negative charge on the other side, where the oxygen atom is. Since opposite electrical charges attract, water molecules tend to attract each other. All these water molecules attracting each other mean they tend to clump together.

Earth's water (about 70 percent of the Earth's surface is water-covered) is constantly interacting, changing, and in movement.

The freezing temperature (the temperature that a substance turns from a solid to a liquid) is  $0^\circ$  on the Celsius scale, and  $100^\circ$  is water's boiling point (at sea level; 1 atmosphere pressure, 76mm Hg or 101.3 KPa.).

Another important characteristic is that water has a high specific heat index. This means that it can absorb a lot of heat before it begins to get hot. The high specific heat index of water helps regulate the rate at which air changes temperature, which is why the temperature change between seasons is gradual rather than sudden, especially near the oceans.

## Aim

To investigate the cooling and warming behaviour of water. By examining graphs of the data, the freezing and melting temperature were determined and compared.

## Apparatus

- LabPro
- TI Graphing Calculator
- DataMate Program
- Temperature Probe
- Ring stand
- Utility clamp
- 400-ml beaker
- 10-ml graduated cylinder
- test tube
- salt
- ice
- water

## Procedure

### **Part I Freezing**

1. A 400-ml beaker was filled 1/3 full with ice, then 100-ml of water was added
2. 5-ml of water was put into a test tube and a utility clamp was used to fasten the test tube to a ring stand. The test tube was situated above the water bath.
3. The Temperature Probe was plugged into Channel 1 of the LabPro. The link cable was used to connect the TI Graphing Calculator to the interface.
4. The calculator was turned on and the DATAMATE program was started.
5. The calculator and the interface were set up for the Temperature Probe and for the data-collection mode.
6. Finally, data started to be collected. The test tube was immersed in the ice-water bath.
7. Then, 5 spoons of salt were added. The Temperature Probe was stirred for 10 minutes and, when the 10 minutes had gone by, we stopped moving the probe.
8. The data collection was stopped after 15 minutes.
9. The flat part of the graph was analysed to determine the freezing temperature of water.

### **Part II Melting**

1. 250-ml of warm tap water was obtained in the beaker. When 12 minutes had passed the test and its contents were immersed into the warm-water bath.
2. Data collection was stopped after 15 minutes.
3. The flat part of the graph was analysed to determine the melting temperature of water.
4. The melting and freezing curves were compared.
5. A graph of *temperature vs. time* (with two curves displayed) was printed.

## Data Analysis

### Questions

1. *Explain the shape of the curves in terms of the energy changes that are occurring in the sample as it heats up and melts and as it cools down and freezes.*
2. *Explain how an increase in the amount of water used would affect the shape of the curves.*
3. *Explain in your own words what is going on at the molecular level as liquid water cools and freezes.*
4. *Construct a model that illustrates the energy effects and the structural changes that occur during a change of state.*

### Answers

1. Analysing the shape of the curve of the melting graph, we can conclude that when you heat a solid, its particles vibrate more rapidly and begin to spin as their kinetic energy increases. In only 175 seconds, water reached 0° (the initial temperature was approximately -7°). At this temperature the liquid and solid substance are in equilibrium with each other. To definitely turn to liquid, a certain heat has to be given. In the case of water, this value is 336 kJ/kg. The latent heat was reached only after 675 seconds. Finally, the water turned to liquid, the kinetic energy of the particles kept increasing more and more. In 225 seconds the temperature changed in 23° Celsius.

The freezing graph shows us the reverse process: the particles were in this case losing the motion as we can see in the graph. In just 200 seconds the temperature decreased in 21° Celsius, reaching 0°, the equilibrium temperature. After 415 seconds, water turned solid (ice). The kinetic energy had dramatically decreased, justifying the inclined shape of the graph.

2. Increasing the amount of water in the experiment, the processes of melting and freezing would spent more time, then we would not have dramatically changes such as we can see in our graphs. Water has the highest specific heat of almost all substances (4.18 J/g x °C). Heat affects the temperature of objects with a high specific heat much less than the temperature of those with a low specific heat. Since it takes a lot of energy to raise the temperature of water, water releases a lot of heat energy as it cools. Therefore, the water cools slowly.

3. The molecules that constitute liquids are in constant motion; they are free to slide past one another. The attractive forces between the molecules prevent most of them from escaping the liquid. However, when the water cools down and freezes, the molecules became strongly attracted to each other. The motions of the particles turned minimum and now they tend to vibrate about fixed points. That's why a solid has a definite shape and volume and the liquid has a fixed volume and takes the shape of its container.

## Discussion

In the first part of the experiment, problems occurred with the TI Graphing Calculator. When finally the calculator was correctly set up, then the experiment went very well.

## Conclusion

In this experiment essential findings were discovered, such as the flat part of the graph when the substance (in this case, the water) is changing state. Analysing the melting and freezing graphs, we found the flat part between 200 and 375 seconds at  $0^{\circ}$  (in the freezing graph) and between 200 and 675 seconds at approximately  $0^{\circ}$  (in the melting graph). The inclined parts of the graphs are obviously because the increasing or decreasing of kinetic energy of the particles.

The experiment was well conducted and the aim, to investigate the cooling and warming behaviour of water, was achieved. The steps were correctly followed.