

# Separating Substances Into Ions In Solution



## Topic

Theory of ionic dissociation

## Introduction

Water is a poor conductor of electricity, but its conductivity can be increased by dissolving other substances in it, such as salt (sodium chloride) or copper sulfate. These substances are called electrolytes, and their effect on conductivity was recognized early in the nineteenth century when scientists first started investigating electricity using voltaic piles (see experiment 2.12). By the late nineteenth century, however, scientists still could not explain what was happening to the atoms of electrolytes in a solution when electricity was passed through it. In 1883 the Swedish scientist Svante Arrhenius proposed an explanation in his “theory of dissociation.” Arrhenius suggested that when substances like sodium chloride (salt) were dissolved in water, their molecules broke up or “dissociated” into electrically charged fragments, which he called ions. They could be positive or negative, depending on the element. Sodium ions, for example, are positive, while chloride ions are negative. These ions conduct electricity through the solution. One way Arrhenius tested his theory was by measuring freezing-point depression. Scientists had known for some time that adding electrolytes to water would lower, or depress, its freezing point. In this experiment, Arrhenius showed that the freezing point depression caused by a substance depends on the number of ions produced by that substance when it dissolves.

## Time required

1½ hours

## Materials

wide-necked insulated flask or  
insulated ice container  
dry ice (solid carbon dioxide)  
3 Pyrex test tubes  
test tube rack  
piece of foam, about 10 cm square  
and 2–3 cm thick  
scissors  
awl  
Celsius thermometer reading down  
to  $-20^{\circ}\text{C}$

oven mitts or insulated gloves  
sodium chloride (salt)  
sodium sulfate  
distilled water  
teaspoon or metal spatula  
filter paper  
2 × 100 ml beakers  
50 ml graduated cylinder  
waterproof marker  
safety glasses

## Safety note



**Teacher supervision is required. On no account touch the dry ice with bare hands – it will burn. Wear oven mitts or insulated gloves when handling containers of dry ice. Wear safety glasses.**

## Procedure



1. Use the marker to label one beaker “sodium chloride solution” and the other “sodium sulfate solution.”

2. Make up a 1 molar (1M) solution of sodium chloride as follows. Using the scale, filter paper, and a teaspoon or spatula, weigh out 2.93 grams of sodium chloride. Place it in the beaker marked “sodium chloride.” Measure out 50ml of distilled water in the graduated cylinder. Add the water to the beaker and stir with the teaspoon or spatula until the solid has dissolved.

3. Wash and dry the spoon or spatula, then repeat stage 2 to make up a 1M sodium sulfate solution in the other marked beaker using 7.1 grams of sodium sulfate.

4. Use the marker to label the three test tubes “DW,” “SC,” and “SS.”

5. Fill the DW test tube one-third full with distilled water. Put the test tube in the test tube rack.

6. Repeat stage 5 for the two test solutions, putting the sodium chloride solution in test tube SC and the sodium sulfate solution in test tube SS.



7. With the scissors, cut three cubes of foam to fit snugly into the tops of the test tubes. Make a hole through the center of each piece of foam using the awl. Take special care doing this to avoid injury.

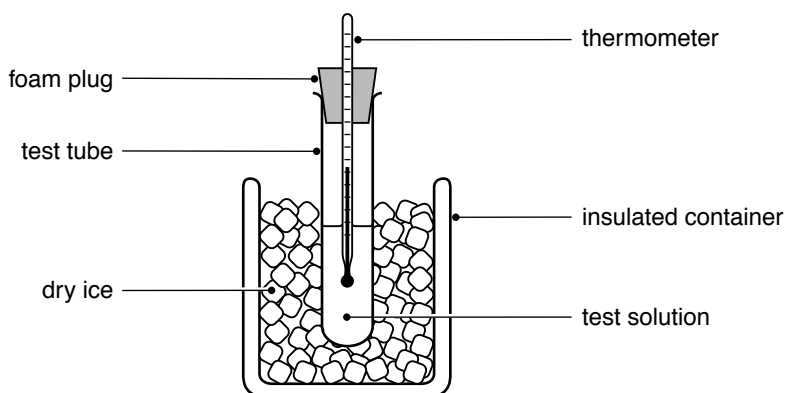
8. Push the thermometer through the hole in one of the pieces of foam. Put the foam into the DW test tube. Adjust the position of the thermometer so that its bulb is in the distilled water but is not touching the side or bottom of the test tube.



9. Put on the oven mitt or insulated glove, and safety glasses. Place the dry ice in the insulated flask or container, taking care not to allow any bare skin to touch the ice.



10. Still wearing the mitt and safety glasses, push the DW test tube down into the dry ice so that all the liquid in the test tube is below the ice level. Make sure the test tube is upright, and that the thermometer bulb is still submerged in the test liquid and not touching the side or bottom of the test tube.



11. After 10 minutes, remove the test tube from the dry ice, make sure its contents are frozen, read the temperature, and record it.



12. Repeat stages 8 to 11 for the other two test tubes. Record your results.

### Analysis

1. Draw up a list of the solutions and their freezing points from the highest (nearest to 0°C) to the lowest.
2. Do some further research on solutes and freezing points. Why do you think some solutes depress the freezing point of water more than others?

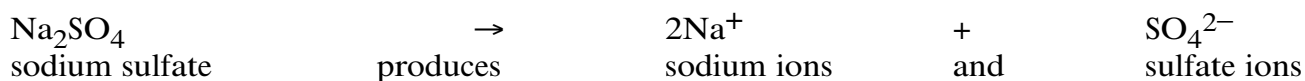
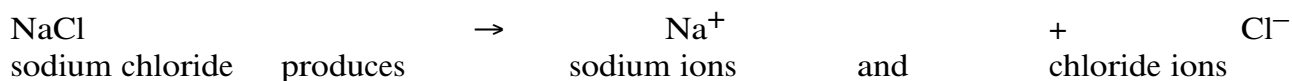
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## 2.13 Separating Substances Into Ions In Solution

1. The order should be, from highest to lowest: distilled water (at 0°C), then sodium chloride, then sodium sulfate.
2. The more ions there are in a solution, the more the solution's freezing point will be depressed. Distilled water is ion-free. Sodium sulfate produces more ions in solution than sodium chloride, which explains why the sodium sulfate solution produced a greater depression of the freezing point than sodium chloride.

The breakdown of the solutes is represented like this:



Arrhenius used these results to show that ionic dissociation takes place when solutes are added to water and that different solutes produce different numbers of ions.