Experiment C-3
Ions in Solution

Chemistry

Objectives

- To learn about strong electrolytes, weak electrolytes and non electrolytes.
- To learn about molar mass and unit conversion.
- To examine the conductivity of different substances dissolved in water.

Modules and Sensors

- PC + NeuLog application
- USB-200 module
- NUL-215 Conductivity logger sensor

Equipment and Accessories

▪ Utility stand	1
▪ Right angle clamp	1
▪ Extension clamp	1
▪ 50 ml beaker	4
▪ 250 ml beaker	1
▪ Pasteur pipette	4
▪ Wash bottle	1
▪ Plastic container	1

The items above are included in the NeuLog Utility accessories, UTL-KIT.

Materials

▪	5.4 g of $C_6H_{12}O_6$ (glucose)
▪	1.74 g of NaCl (sodium chloride)
▪	3.32 g of $CaCl_2$ (calcium chloride)
▪	0.95 g of $C_6H_8O_7$ (citric acid)
▪	250 ml of distilled water
▪	Distilled water for wash bottle

Introduction

An atom consists of protons, neutrons and electrons. All atoms of the same element have the same number of protons. While a neutral atom has the same number of protons and electrons, an Ion has either more or less electrons than protons. If the atom has more electrons than protons, it is called an anion (a negative ion). If it has fewer electrons than protons, it is called a cation (a positive ion).

Electrolytes are substances that produce ions in solution:

Strong electrolytes only exist as ions in a solution; these include strong acids, strong bases and salts.

Weak electrolytes partially dissociate in a solution, thus produce less ions than strong electrolytes. Weak electrolytes include weak acids and bases.

Non electrolytes dissolve in water but do not dissociate into ions. They are typically covalently bonded compounds.

A dissolved electrolyte forms an electrolytic solution which conducts electricity. The more ions there are in a solution, the more conductive this solution is.

In this experiment, we will measure the conductivity of distilled water and four solutions. The solutes differ in their ability to form ions.

Procedure

Experiment setup

> Caution:
>
> It is recommended to wear personal protective equipment. Material Safety Data Sheets (MSDS) are available online.

1. Make sure you have four 50 ml beakers with the relevant masses of each substance, according to the equations shown below. We use the molar mass of each substance in order to determine the right amount for each solution:

- $1\ M\ glucose = 1\ \frac{mol}{L}\left(\frac{180.16\ g}{mol}\right)\left(\frac{L}{1000\ ml}\right) = 0.18\ \frac{g}{ml}$
  $Mass\ of\ glucose\ in\ a\ 30\ ml\ solution: 0.18\ \frac{g}{ml} \cdot 30\ ml =$ $\mathbf{5.4\ g}\ (or\ about\ two\ teaspoons)$

  - Dimensional analysis is the analysis of the relationship between physical quantities. 1L=1000 ml, thus $\left(\frac{L}{1000\ ml}\right)$ is equal to 1. The rules of algebra allow multiplying an equation by 1 without changing it in order to convert units.

- $1\ M\ sodium\ chloride = 1\ \frac{mol}{L}\left(\frac{58.44\ g}{mol}\right)\left(\frac{L}{1000\ ml}\right) = 0.058\ \frac{g}{ml}$
  $Mass\ of\ sodium\ chloride\ in\ a\ 30\ ml\ solution: 0.058\ \frac{g}{ml} \cdot 30\ ml =$ $\mathbf{1.74\ g}\ (or\ about\ three\ quarters\ of\ a\ teaspoon)$

- $1\ M\ calcium\ chloride = 1\ \frac{mol}{L}\left(\frac{110.98\ g}{mol}\right)\left(\frac{L}{1000\ ml}\right) = 0.11\ \frac{g}{ml}$
  $Mass\ of\ calcium\ chloride\ in\ a\ 30\ ml\ solution: 0.11\ \frac{g}{ml} \cdot 30\ ml =$ $\mathbf{3.32\ g}\ (or\ about\ one\ teaspoon)$

  Solution for the challenge experiment:

- $0.1\ M\ citric\ acid = 0.1\ \frac{mol}{L}\left(\frac{192.12g}{mol}\right)\left(\frac{L}{1000\ ml}\right) = 0.019\ \frac{g}{ml}$
  $Mass\ of\ citric\ acid\ in\ a\ 50\ ml\ solution: 0.019\ \frac{g}{ml} \cdot 50\ ml =$ $\mathbf{0.95\ g}\ (or\ about\ half\ a\ teaspoon)$

2. Add distilled water from the 250 ml beaker to each 50 ml beaker so that the final volume in the first three solutions is

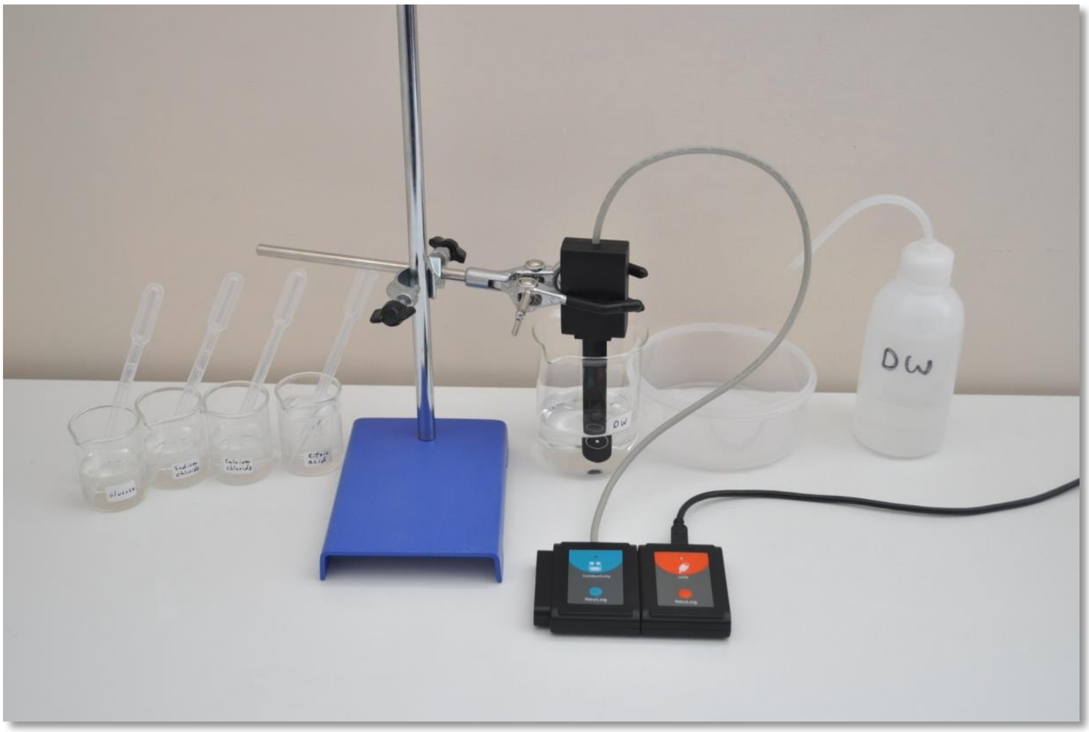
30 ml and the citric acid solution's volume is 50 ml. Eventually all the solutions will have a concentration of 0.1 M (because of its low pH, the citric acid solution is prepared in only one step).

3. Gently stir each beaker with its pipette in order to fully dissolve the substances.

4. Attach the conductivity sensor to the utility stand using the extension clamp.

5. Wash the conductivity sensor probe with the wash bottle.

6. Insert the probe into the distilled water.



7. Make sure that the electrodes (in the shape of a circle with a dot inside it) are covered with water.

Sensor setup

8. Connect the USB-200 module  to the PC.

9. Check that the conductivity sensor  is connected to the USB-200 module.

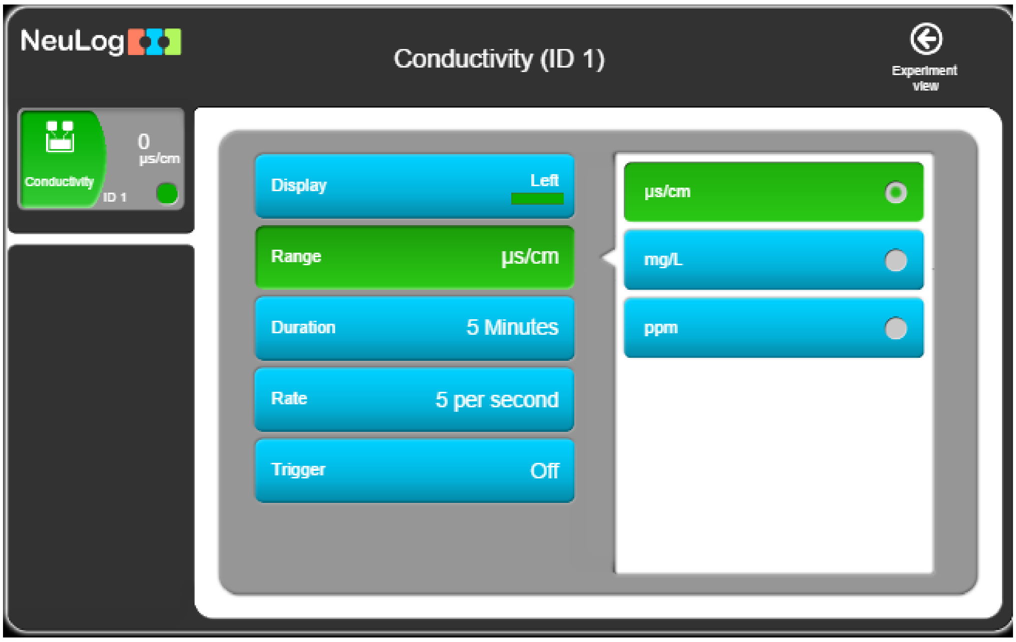
> Note:
>
> The following application functions are explained in short. It is recommended to practice the NeuLog application functions (as described in the user manual) beforehand.

10. Run the NeuLog application and check that the conductivity sensor is identified.

Settings

11. Click on the **Sensor's Module** box.

12. Select the µs/cm button to change the sensor's mode.



13. This experiment is done in single step mode so the experiment duration and sample rate will not be set.

Testing and measurements

14. When the reading stabilizes, click on the **Single Step** icon in order to measure the conductivity of distilled water.

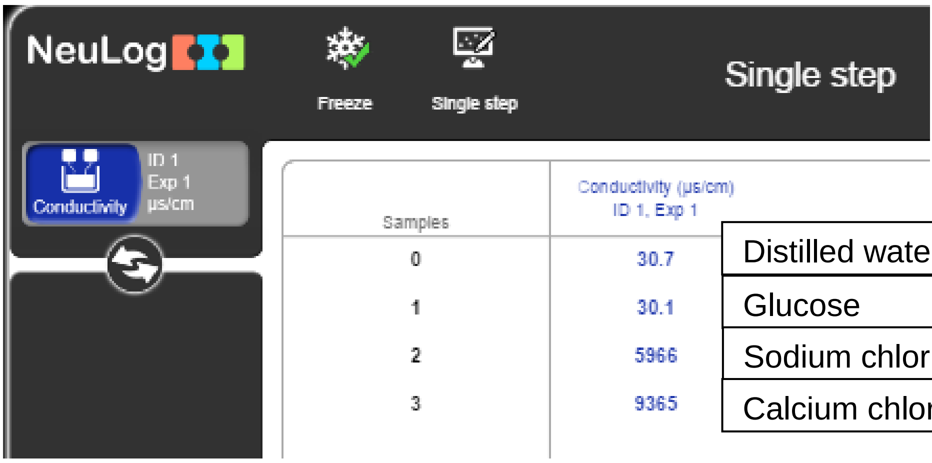
15. Click on the **Table** icon on the bottom part of the screen. A table will be displayed for data record.

16. Dilute the concentrations of the glucose, sodium chloride and calcium chloride solutions, as follows: take out three ml of the solution with the Pasteur pipette, pour the rest of the solution into the plastic container and pour back the three ml into the empty beaker. Then fill the beaker with the distilled water until the total volume reaches 30 ml. This will dilute the solution by 10 and the concentration will be 0.1 M.

17. Replace the distilled water with the glucose solution and click on the **Single Step** icon.

18. Wash the sensor probe with the wash bottle and proceed with the sodium chloride and the calcium chloride measurements.

19. Your data should be similar to the following.



Samples	Conductivity (μs/cm) ID 1, Exp 1	
0	30.7	Distilled water
1	30.1	Glucose
2	5966	Sodium chloride
3	9365	Calcium chloride

20. Click on the **Export** Icon and then on the **Save value table (.CSV)** button to save your graph.

21. Fill the following table with your results.

	Strong/weak/non electrolyte	Conductivity [µs/cm]
Distilled water		
Glucose		
Sodium chloride		
Calcium chloride		
Citric acid		

22. We can see that glucose is a non electrolyte since its conductivity is very low (like the distilled water).

23. The sodium chloride and calcium chloride are both strong electrolytes, thus have relatively high conductivity levels.

Challenge research

24. Measure the citric acid solution with the conductivity sensor. Try to estimate its conductivity level before the measurement.

Summary questions

1. Write your results with a significant figure of 1 (for example 9365 changes to 9000). In how many orders of magnitude one measurement is greater than the other? (Compare measurements that are significantly different)

2. What is the reason for the difference between the sodium chloride and the calcium chloride measurements?

3. What were the results of the challenge experiment? Explain.

4. How can you use this sensor to determine the concentration of a salt solution?