Electrical conductivity of salt solutions

Solutions

Aim

To construct a calibration curve of **current (A)** versus **salt concentration (%m/m)** for an aqueous solution and to determine the relationship between ion concentration and current.

Background

The electrical current through an aqueous salt solution is proportional to the number of ions present. Increasing the concentration of a soluble ionic compound, such as NaCl, increases the number of charge carriers which in turn increases the current measured flowing through the solution at a fixed voltage.

Materials

- 2 X Electrodes (carbon)
- 4 X alligator leads to connect ammeter to power supply
- 1 X Power supply (DC)
- 1 X Ammeter (or multimeter set to current)
- 4 X Beakers (50 mL)
- 6 X Beakers (200 mL)
- Sodium chloride (NaCl) solid
- 1 X spatula
- 1 X electronic balance (+/- 0.01 g)
- Distilled water
- 1 x Stirring rod
- Water-proof marker or adhesive labels
- 1 X 100mL measuring cylinder
- 50mL each of two standard salt solutions with concentrations 23% m/m and 13% m/m.

Safety

-Handle electrical equipment with care.
-Avoid spilling water near electrical connections.
-Wear lab coat, safety goggles and gloves.
-Do not exceed low voltage (6 V) to prevent hazards.

Method

1. **Preparation of Standard Solutions**

   Prepare a series of NaCl solutions of known concentrations (%m/m)

2. Place a 200 mL beaker on an electronic balance and add exactly 100 g of distilled water at room temperature .

3. While the beaker is on the electronic balance carefully add 1.00 gram of NaCl using a small spatula.

4. Stir the solution with the stirring rod until all the salt is dissolved.

5. Using the water proof marker label the beaker with the correct salt concentration (%m/m) and set aside.

6. Repeat steps 2 - 5, five more times with salt masses of 5.00g, 10,00g, 15.00g, 20.00g and 25.00g.
7. Connect the circuit shown in fig. 1.

8. Take the beaker with the 100g of distilled water and 1.00 g of salt and measure out 50mL of solution into each of the 4 100 mL beakers using the measuring cylinder.

9. Stir each solution gently to ensure uniform ion distribution.

10. Apply a constant voltage (6V) across the electrodes.

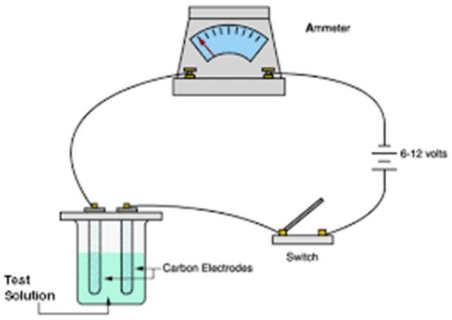

Figure 1 – setup of the apparatus

11. Record the **current (A)** from the ammeter of each of the four 50 mL solutions

12. Repeat step 8-11 with the four other concentrations.

1. On this page construct an appropriate, well formatted table of data for your investigation. *4 marks*

1-----mark Heading with IV and DV

1-----mark Correctly labelled columns and rows with units shown only at the top of each column or row. (eg. Current (A) , Salt concentration (%m/m)

1-----mark Results averaged

1-----mark Clearly ruled rows and columns.

2. On the next page is graph paper to be used for the construction of a properly formatted graph to represent the data you have collected. *4 marks*

Graph

- Heading *1-----mark if IV and DV are included*
- Plot Average Current (A) on the y-axis *1-----mark if axis has equal increments awith equal spacing and is labelled with units.*
- Plot NaCl Concentration (M) on the x-axis *1-----mark if axis has equal increments awith equal spacing and is labelled with units.*
- Draw a line of best fit *1-----mark if line is continuous and represents the trend of the results. No mark if line goes through every point unless it is a straight line linear relationship between the IV and DV.*

3. Write a hypothesis for this task.

1-----mark if IV identified and DV are included
1-----mark if it is written in the If…..then….because format.
1-----mark if it has a scientific reasoning
eg. If the concentration of sodium chloride in an aqueous solution is increased, then the electrical current measured through the solution will increase, because a higher concentration produces more mobile ions to carry charge.
-1-----mark if pronouns such as i, we, they, my are included.

4. Identify the:

DV _*Sodium chloride concentration (% m/m)* and IV__*Electric current (A)*

1-----mark if correct IV and DV

1-----mark if units are specified.

5. Identify four controlled variables

1-----mark for each of the four. May include but not limited to:

- *Applied voltage*
- *Volume of solution tested*
- *Distance between electrodes*
- *Type and material of electrodes*
- *Temperature of solution*
- *Same container size*

6. Consider the calibration curve produced by your data.
    a. Explain the need for a calibration curve

A calibration curve is required to establish the quantitative relationship between current and salt concentration for the specific experimental setup. 1-----mark
This allows unknown concentrations to be determined by comparison with measured current values. 1-----mark

    b. Another group using the same setup but different ammeter and power source conducts the same experiment on a different day and obtains precise results for the conductivity of two unknown salt solutions.
        i. Define precision.

Precision refers to how close repeated measurements are to each other when the same quantity is measured multiple times.

        ii. Define validity

Validity refers to how well an experiment measures the quantity it is intended to measure.

iii. Explain whether your calibration curve could be reliably used by the other group to determine the concentration of an unknown salt solution. In your answer, refer to the factors that may affect the validity of the calibration curve.

The calibration curve could not be reliably used by the other group
1-----mark
because it depends on the specific equipment and conditions under which it was produced. Differences in the ammeter, power supply, electrode condition, electrode spacing, or temperature would affect the measured current.
1-----mark
As a result, the relationship between current and concentration would change, reducing the validity of using this calibration curve for their measurements.
1-----mark

7. Write a discussion.

1-----mark for explaining the type of relationship between the DV and IV using specific data points to verify the relationship.
1-----mark A sound scientific explanation for trend.
1-----mark Accuracy and validity.
1-----mark Sources of error.
1-----mark for any limitation
1-----mark for improvement or any future investigation that would add value to the investigation just conducted.

Below is a possible example of a discussion.
The data showed a directly proportional relationship between sodium chloride concentration (% m/m) and the electrical current (A). For example, the current increased from 0.02 A at 1% NaCl to 0.12 A at 25% NaCl, indicating that higher concentrations of NaCl produced higher currents (1 mark).

This trend occurs because increasing the salt concentration increases the number of free ions in the solution, which act as charge carriers. More ions allow more charge to flow at a constant applied voltage, resulting in higher current readings (1 mark).

The calibration curve produced is reasonably accurate and valid within the range of concentrations tested. The average measured currents for the two standard solutions (13% m/m and 23% m/m) closely

matched the expected values, showing that the method reliably measures conductivity for solutions within this range (1 mark).

Sources of error include slight variations in electrode placement, minor temperature fluctuations, and potential reading errors on the ammeter. These could cause small deviations between trials and slightly affect the calibration curve (1 mark).

A limitation of this investigation is that the calibration curve is only valid for concentrations within the measured range (1%–25% m/m). Using the curve to predict concentrations outside this range would require extrapolation, which may be less reliable (1 mark).

An improvement for future investigations would be to maintain constant temperature using a water bath and to use a more precise ammeter. Additionally, testing more concentrations within the range would produce a smoother calibration curve and improve the reliability of the measurements (1 mark).

8. Write a conclusion

1-----mark briefly referencing the aim/hypothesis stating if it was supported or not

1-----mark describe the observed results with scientific explanation.

9. Using the two standard solutions provided for you,
    a. test the accuracy of your calibration curve by comparing the derived results with the true value.

1------mark for suggesting the degree of accuracy.
1-----mark for giving a valid reason for the suggestion based on known values and experimental values.

    b. discuss which one of the two has the greater validity and explain why.

The standard solution whose measured current falls within the range of concentrations used to construct the calibration curve has greater validity. 1-----mark
This is because the calibration curve is most accurate for interpolation between measured points, whereas extrapolating beyond the measured range reduces the reliability of the predicted concentration 1-----mark