RESEARCH ARTICLE

MEASUREMENT OF CONDUCTIVITY OF AN AQUEOUS SOLUTION AND NATURE OF COMBINED MATERIALS, ELECTRODES

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ABSTRACT

The present work aims to determine the influence of the nature of the combined materials on the measurement of the conductivity of an aqueous ionic solution. In this study, 4 types of electrodes (iron (Fe), copper (Cu), aluminum (Al) and lead Pb) were used. Correlation curves, current intensities and the degree of mineralization of the solution were layout. The correlation coefficients varying between 0.9877 and 1 indicate a very good correlation between the degree of mineralization of the ionic solution and the intensity of the measured direct current and the reliability of the method. The results show that for the same solution, the current intensity is a function of the nature of the two combined electrodes.

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INTRODUCTION

Electrical conductivity (EC) is a precision parameter of all dissolved ionic species (salts, acids, bases and organic substances) in a solution. It is an interesting tool for monitoring of different types of water (pure water, drinking water, natural water, treated water, etc.) and other solvents (Lamia, 2012; Miomadre, 2014; Mettler, 2022). It is used to determine the concentrations of conductive chemical substances and physicochemical information from electrolytic solutions (Hocine, 2016; Miomandre *et al.*, 2014; Dunod, 2009). The applied methods use materials generally of the same nature (Marion, 2020). The objective of this work is to determine the influence of the nature of the combined materials on the conductivity of an ionic aqueous solution. Different types of materials were used for determine the conductivity of many solutions.

MATERIALS AND METHODS

MATERIALS

All current intensity measurements were performed with the DIGITAL MULTIMETER (DT9205A). The experimental setup consists of a measuring cell connected to the multimeter. In this cell, a two-electrode system is used and measurements are performed in direct current mode. The materials used in this study include an iron (Fe) electrode, a copper (Cu) electrode, an aluminium (Al) electrode and a lead (Pb) electrode.

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METHODS

Preparation of the different solutions and measurement of the intensity: KCl salt was used as a source of mineralization of distilled water. To obtain different degrees of mineralization, the following masses: 0.01g; 0.02g; 0.03g; 0.04g and 0.05g of KCl salt were weighed using a single-plate balance, each introduced into a 100mL beaker containing 100mL of distilled water. Four metal plates (iron, copper, aluminum and lead) were used as electrodes. To determine the influence of the nature of the two combined electrodes on the current, electrodes of the same nature and different natures were used. The reference electrode and the indicator electrode are separated by a distance of 2 cm. The combined electrodes are connected to a multimeter of the Digital Multimeter DT9205A type. The following combinations: Fe-Fe, Fe-Cu, Fe-Al, Fe-Pb, Al-Cu, Al-Pb and Cu-Pb were used. To measure the current intensity as a function of mineralization, the two electrodes are immersed in the KCl salt solutions contained in the beakers, from the least concentrated solutions to the most concentrated, and the current intensity is read on the multimeter, in direct current mode. The current intensity measurements were carried out at room temperature in the laboratory. The intensity was read 20 seconds after introduction of the electrodes. Finally, the influence of the standard potential of the metals was determined. The standard potentials of the metals used are: 0.34 V; -0.13 V; -0.44 V and -1.16 V respectively for Cu, Pb, Fe and Al. The curves were layout with Excel software.

Correlation curves and determination of the influence of intensity: To determine the correlation between current intensity and degree of mineralization, correlation curves (current intensity and mass of salt introduced) were plotted. The salt used as a source of mineralisation

is KCl (99%, M.W.: 74.45). The curves were layout with Excel software.

RESULTS AND DISCUSSION

Correlation: direct current intensity-mass of analytical KCl

Correlation: direct current intensity-mass of KCl with two electrodes of the same nature (Fe-Fe): Figure 1 below shows the correlation between the intensity (I) of the measured direct current and the mass (m) of solute (KCl salt) using two electrodes of the same nature (Fe-Fe).
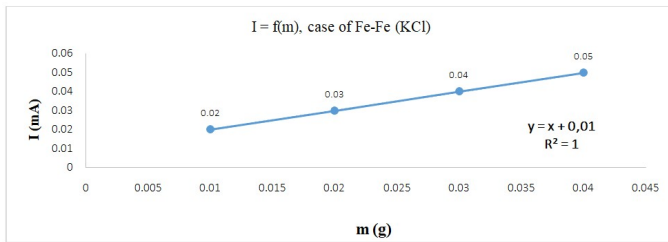

Figure 1. Variation of intensity (I) as a function of mass (m), case of Fe-Fe electrode

Figure 1 illustrates the effect of increasing the amount of ion (increasing the mass of solute) on the current intensity of an electrolyte solution (KCl). It is observed that the intensity of the measured current increases with the increase in the mass of the solute. This variation depends mainly on the mineralization of the electrolyte. Figure 1 obtained with a correlation coefficient ($R^2 = 1$) and a linear equation line show a proportionality between these variables. The correlation coefficient obtained indicates a very good correlation between the intensity of the measured current and the mineralization. The conductivity of a solution is a function of mineralization. These results indicate the possibility of determining the conductivity of a solution in direct current with two metal plates of the same nature (Fe-Fe).

Correlation: direct current intensity-mass of KCl with two electrodes of different natures (Fe-Al): Figure 2 below shows the correlation between the measured direct current intensity (I) and the mass (m) of solute (table salt) using an iron electrode combined with an aluminum electrode (Fe-Al).
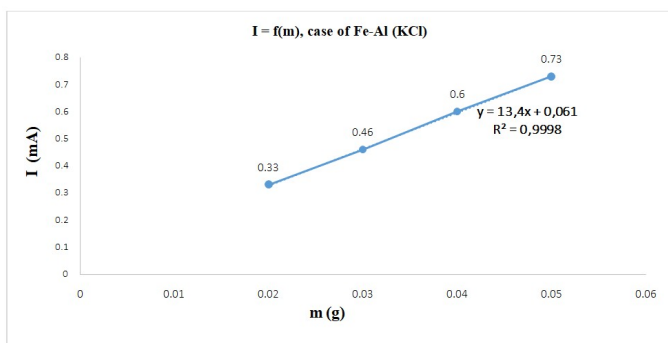

Figure 2. Variation of intensity (I) as a function of mass (m), case of Fe-Al electrode

The measurements of the intensity of the direct current carried out using the multimeter are represented as a function of the mass of dissolved solute over a range between 0.01g and 0.05g, the intensity of the measured current goes from 0.33 to 0.73 mA. The curve obtained (Fig. 2) shows that the intensity of the measured current increases as a function of the mass of dissolved solute. The correlation coefficient ($R^2 = 0.9998$) indicates a very good correlation between mineralization and the intensity of the measured current. The

conductivity of a solution is a function of the amount of ion. These results indicate the possibility of determining the conductivity of a solution in direct current with two plates of metals of different natures (Fe-Al).

Correlation: direct current intensity-mass of KCl with two electrodes of different natures (Fe-Cu): Figure 3 below shows the correlation between the measured direct current intensity (I) and the mass (m) of solute (KCl) using a copper electrode combined with an iron electrode (Fe-Cu).
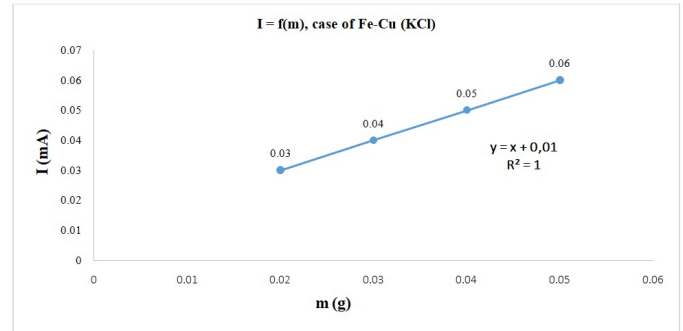

Figure 3. Variation of intensity (I) as a function of mass (m), case of Fe-Cu electrode

The shape of the graph (Fig. 3) shows that the intensity of the direct current of the solutions measured as a function of the mass of dissolved solute (KCl), presents a straight line with a linear equation of correlation coefficient ($R^2 = 1$). It shows a proportionality between the intensity of the measured current and the mineralization. The correlation coefficient obtained indicates a very good correlation between the mineralization and the measured intensity of the measured current. The conductivity of a solution is a function of the quantity of ions. These results indicate the possibility of determining the conductivity of a direct current solutions with two metal plates of different natures (Fe-Cu).

Correlation: direct current intensity-mass of KCl with two electrodes of different natures (Fe-Pb): Figure 4 below shows the correlation between the measured direct current intensity (I) and the mass (m) of solute (table salt) using an iron electrode combined with a lead electrode (Fe-Pb).
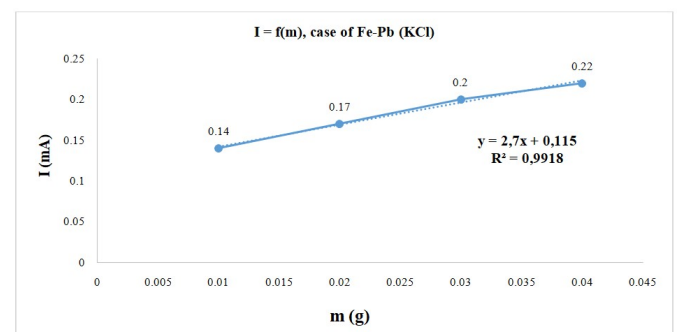

Figure 4. Variation of intensity (I) as a function of mass (m), case of Fe-Pb electrode

The graph in Figure 4 shows the continuous, almost linear increase in the direct current intensity of the measured solutions with increasing mass of the solute in solution. The shape of the curve implied a proportionality between them. The linear equation line obtained (Fig. 4) with a correlation coefficient ($R^2 = 0.9918$), indicates a very good correlation between the intensity of the measured current and the mineralization. The conductivity of a solution is a function of the quantity of ion. These results indicate the possibility of measuring the conductivity of a solution in direct current with two metal plates of different nature (Fe-Pb).

Correlation: direct current intensity-mass of KCl with two electrodes of different natures (Al-Cu): Figure 5 below shows the correlation between the measured direct current intensity (I) and the mass (m) of KCl using a copper electrode combined with an aluminum electrode (Cu-Al).
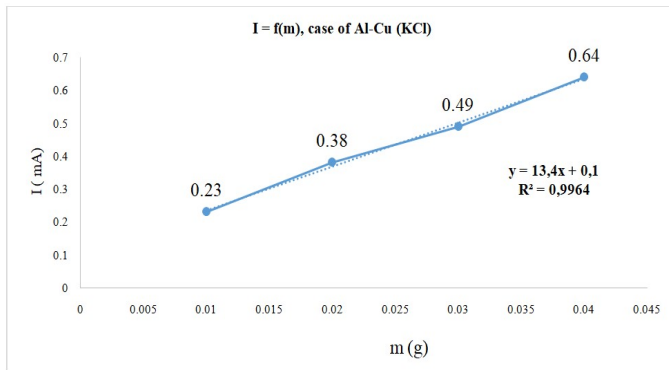

Figure 5. Variation of intensity (I) as a function of mass (m), case of Al-Cu electrode

Figure 5 shows a nearly linear regression line between the measured direct current intensity and the solute mass. It also shows that the DC current intensity is a function of the dissolved solute mass. The regression line obtained with a correlation coefficient (R^2 = 0.9964) shows a very good correlation between the intensity of the measured current and the mass of dissolved solute. It also indicates a proportionality between them. The conductivity of a solution is a function of the quantity of ion. These results indicate the possibility of determining the conductivity of a direct current solution with two metal plates of differennt nature (Al-Cu).

Correlation: direct current intensity-mass of KCl with two electrodes of different natures (Al-Pb)

Figure 6 below shows the correlation between the measured direct current intensity (I) and the mass (m) of KCl using an aluminum electrode combined with a lead electrode (Al-Pb).
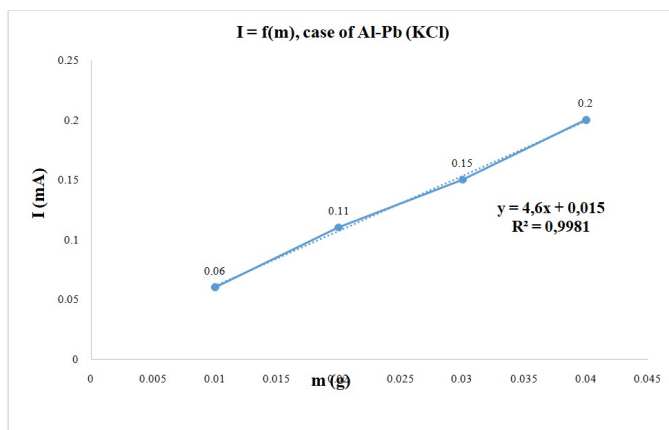

Figure 6. Variation of intensity (I) as a function of mass (m), case of Al-Pb electrode

Figure 6 illustrates the effect of increasing solute mass on the current intensity of electrolytic solutions (KCl). One explanation is that an increase in the mass of salt in solution causes an increase in the amount of ion capable of conducting the current. The shape of the curve (Fig. 6) shows a proportionality between the intensity of the measured current and the mineralization. The correlation coefficient obtained (R^2 = 0.9981) with a linear equation line indicates a very good correlation between the mineralization and the intensity of the measured current. The conductivity of a solution is a function of the amount of ion in solution (mineralization). These results indicate the

possibility of determining the conductivity of a direct current with two plates of metals of different nature (Al-Pb).

Correlation: direct current intensity-mass of KCl with two electrodes of different natures (Cu-Pb): Figure 7 below shows the correlation between the measured direct current intensity (I) and the mass (m) of KCl using a copper electrode combined with a lead electrode (Cu-Pb).
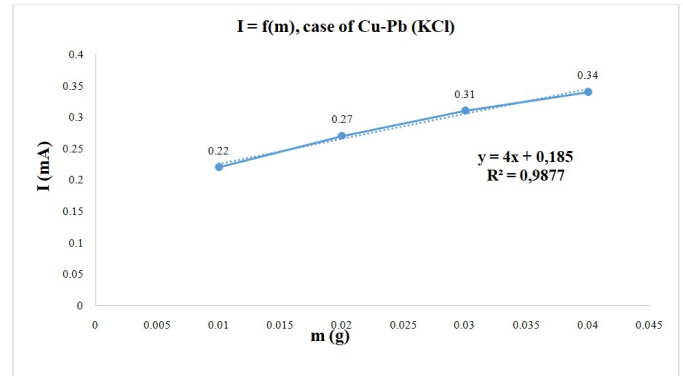

Figure 7. Variation of intensity (I) as a function of mass (m), case of Cu-Pb electrode

Figure 7 shows a nearly linear regression line between directcurrent intensity and solute mass. It also shows that direct current intensity is a function of dissolved solute mass. This regression line obtained with a correlation coefficient (R^2 = 0.987) shows a very good correlation between the intensity of the measured current and the mass of dissolved solute. It also indicates a proportionality between them. These results indicate the possibility of determining the conductivity of a direct current solution with two metal plates of different nature (Cu-Pb).

Regression curves: direct current intensity as a function of solute mass (KCl) and standard potential of redox couples of combined plates (Al-Fe; Al-Cu; Al-Pb): Figure 8 shows the variation of the direct current intensity as a function of the redox potentials of the combined electrodes of different natures.
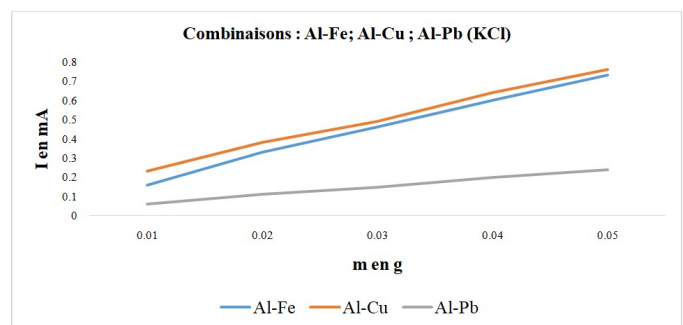

Figure 8. Variation of current intensity as a function of solute mass and redox potential

Figure 8 shows that the current intensity can be a function of the standard redox potential of the electrodes. Indeed, the Al-Cu combination (fig. 8) with a potential difference (ΔE = 1.50) gives the highest intensities compared to the Al-Pb and Al-Fe combinations with potential differences of 1.13 V and 0.72 V respectively.

CONCLUSION

This work aims to determine the influence of the nature of materials on the measurement of the conductivity of an ionic aqueous solution. The correlation coefficients vary between 0.9877 and 1 show a proportionality between the measured direct current and degree of

mineralization of the solution. Its also shows the possibility of measuring conductivity from combined materials of different nature. However, for the same solution, the intensity of the measured direct current depends on the nature of the materials combined. The standard potentials of the materials used seem to have an influence on the intensity of the measured current.

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