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Impact of Iron Oxide Nanoparticles on Saline Solution's Electrical Conductivity, pH, Thermodynamics, and Kinetics

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Abstract

A comprehensive study was conducted on the effect of iron oxide nanoparticles added to a saline solution through the reaction kinetics and acid function with electrical conductivity.

Then, an examination was conducted of the changes resulting from the change in the properties of the materials under study when adding various amounts of iron nanoparticles. It was noted that with increasing the concentration of nanoparticles, a clear improvement in electrical conductivity was observed significantly, indicating that the ionic interactions resulting from the reaction in the solution have improved well.

The study also investigated how nanoparticles affect the reaction rate from a chemical kinetic perspective, which resulted in a significant change in reaction rates, noting that the pH was studied and how it was affected by nanoparticles added to the saline solution.

Keywords: Iron OxideNps, Adsorption Study, Kinetics, Thermal Properties, Conductivity Improvement

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دراسة شاملة حول تأثير إضافة جسيمات أكسيد الحديد النانوية على الموصلية الكهربائية وحركية المحلول الملحي ودرجة الحموضة

إيمان عبدالمنعم الجوادي [1]

المستخلص

أُجريت دراسة شاملة حول تأثير جسيمات أكسيد الحديد النانوية المضافة إلى محلول ملحي على حركية التفاعل ووظيفة الحمض مع التوصيل الكهربائي.

ثم أُجري فحص للتغيرات الناتجة عن تغير خصائص المواد قيد الدراسة عند إضافة كميات مختلفة من جسيمات الحديد النانوية. ولوحظ أنه مع زيادة تركيز الجسيمات النانوية، لوحظ تحسن واضح في التوصيل الكهربائي بشكل ملحوظ، مما يدل على تحسن التفاعلات الأيونية الناتجة عن التفاعل في المحلول بشكل جيد. كما بحثت الدراسة في كيفية تأثير الجسيمات النانوية على معدل التفاعل من منظور حركية التفاعل الكيميائي، مما أدى إلى تغير كبير في معدلات التفاعل، مع العلم أنه تمت دراسة الرقم الهيدروجيني (pH) وكيفية تأثره بالجسيمات النانوية المضافة إلى المحلول الملحي.

الكلمات المفتاحية: أكاسيد الحديد النانوية، دراسة الامتزاز، الحركية، الخواص الحرارية، تحسين الموصلية

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معلومات البحث
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Introduction

Nanomaterials play a major role in many fields due to their distinctive properties that facilitated their entry into the fields of industry, medicine, agriculture, environment and many different fields. Therefore, iron oxide nanoparticles are among the nanomaterials that have greatly affected scientific research [1-3] and have given distinctive results achieved through their entry into different systems of reactions, which makes it necessary to know their mechanism of action and behavior in different interactive environments, as the use of nanoparticles has become a basic support for

different fields in different specialties such as medicine[4,5] ,sensors[6, 7] and different environmental fields[8-10]in addition to many other fields[11,12].

Through studies, it was noted that iron oxide nanoparticles added to the reaction can have a clear effect on the electrical conductivity of the solution added to it. For example, it was noted through studies that adding nanoparticles at specific concentrations has improved the conductivity of the reaction and increased the effectiveness of the solution for the reaction within the environments dealt with industrially [1,5,13].

According to the effect of nanoparticles on the reactions that occur in their presence, which supports the activity of the medium containing the reaction, This effect can be attributed to the increase in the number of free ions in the solution as a result of the interaction of nanoparticles with the components of the solution. In addition, several studies have been conducted on how nanoparticles affect the reaction rate. Through these studies, it was noted that nanoparticles have a distinct ability to affect the reaction kinetics and change the surface properties of the salt reaction solution, for example, which affected the rate of the chemical reaction in addition to its clear effect through increasing the efficiency of the reaction. Several studies have also been conducted that demonstrated the ability of nanoparticles to act as catalysts, which makes them accelerate the chemically resulting reactions in the salt solutions that were reacted with nanoparticles. Many research studies have also been conducted regarding the effect of the acid function on the reaction in the presence of nanoparticles, which showed the possibility of its effect on the reaction, [2] so an increase or decrease was observed due to the nature of the interactions between the elements entering the solution and the nanoparticles, which clearly changes and affects the chemical and physical properties of the reaction solution. Many applications in the field of environment and agriculture may be affected by this, especially by changing the acid function [3]. Studying and understanding the behavior of nanoparticles of iron oxides is of great importance for the purpose of improving the properties of the reactions of saline solutions, which results in advanced positive results in the possibility of these reactions entering into various fields and opening new horizons of scientific research such as water treatment and soil improvement, as well as health fields and many others. Therefore, it is necessary to conduct an in-depth study to understand the behavior of the interaction of iron nanoparticles with saline solutions, which is what the research highlighted through its effect on electrical conductivity, thermodynamics and kinetics, in addition to the acid function.

Practical part

Material's & Instruments

Iron (III)Oxide, Sodium Chloride ,Fe2O3(M 159.70) from sigma Aldrich& Merk.

Magnetic stirrer, Heating Oven, Electronic Balance, Conductivity Meter,pH meter were used in this study.

Method

1. Solution preparation: Saline solutions were prepared using sodium chloride at various concentrations (0.1 mol, 0.5 mol, 1 mol, 1.5 mol, and 2 mol).
2. Addition of nanoparticles
   The iron oxide nanoparticles were treated by

adding specific amounts of them to the saline solution with continuous mixing well to ensure the completion of the required reaction.

3. Electrical conductivity measurement:
   The electrical conductivity of the solutions was measured using a conductivity meter, with the values recorded at specific time intervals.
4. pH measurement:The pH of the solutions was measured using a pH meter before and after the addition of the nanoparticles.
5. Kinetic and thermometric measurement:
   The kinetic and thermometric measurements of the solutions after mixing them with the nanomaterials were measured before and after the addition.

Results and Discussion

In order to perform the required measurements, a series of saline solutions were prepared in distilled water at different concentrations (0.1M, 0.5M, 1M, 1.5M, 2M) to measure the required amounts of NaCl for each concentration for the purpose of using them for the following measurements:

The electrical conduction method is used as a fast, sensitive and accurate method to determine the reaction constants under study. For this purpose, the equivalent conductivity of the electrolyte must be extracted, expressed by the following relation equation (1).

$$\Lambda = 1000\ K/\ C \qquad (1)$$

Where

Λ isThe equivalent conductivity

κ is the measured conductivity (formerly known as specific conductance)

c is the molar concentration of the electrolyte.

To perform the required measurements, a series of saline solutions were prepared in distilled water at different concentrations (0.1 mol, 0.5 mol, 1 mol, 1.5 mol, 2 mol) to measure the required amounts of sodium chloride for each concentration. Since electrolytes, as is known in the literature, are of two types: strong electrolytes and weak electrolytes, at different temperatures the relationship between the equivalent conductivity of the electrolyte versus the square root of the concentration appears. For the purpose of using these measurements, the following equation (2) is applied to the measurements conducted at different temperatures:

$$\Lambda = \Lambda^{\circledR} - b\sqrt{Conc.} \qquad (2)$$

Equation (2) was applied at a constant temperature for each reaction separately, the results were as shown in Figure 1 before adding nano iron oxides and Figure (2) after adding nano iron oxide) at different temperatures

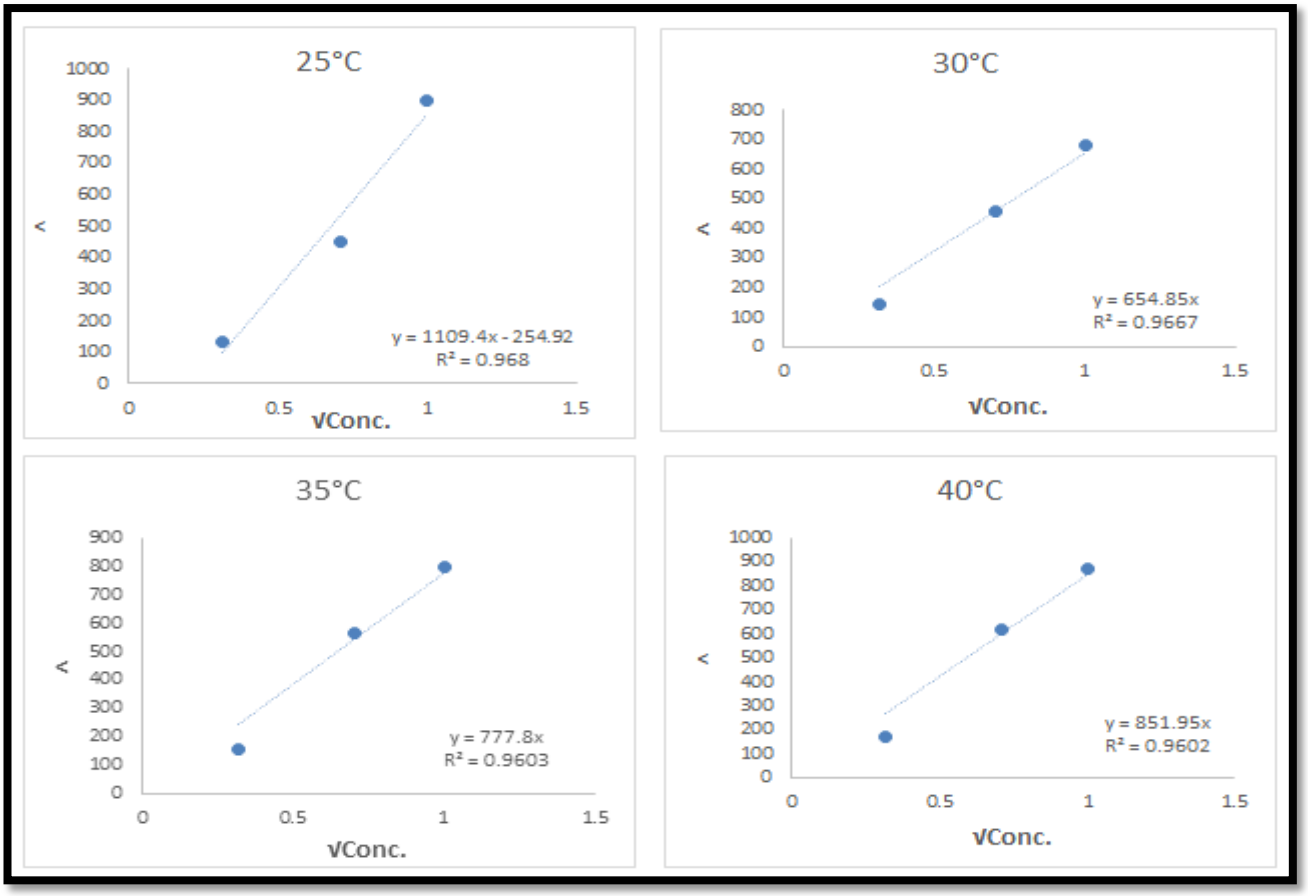

Figure (1): Relationship between Λ and √Conc at different temperatures (before adding nano iron oxides)

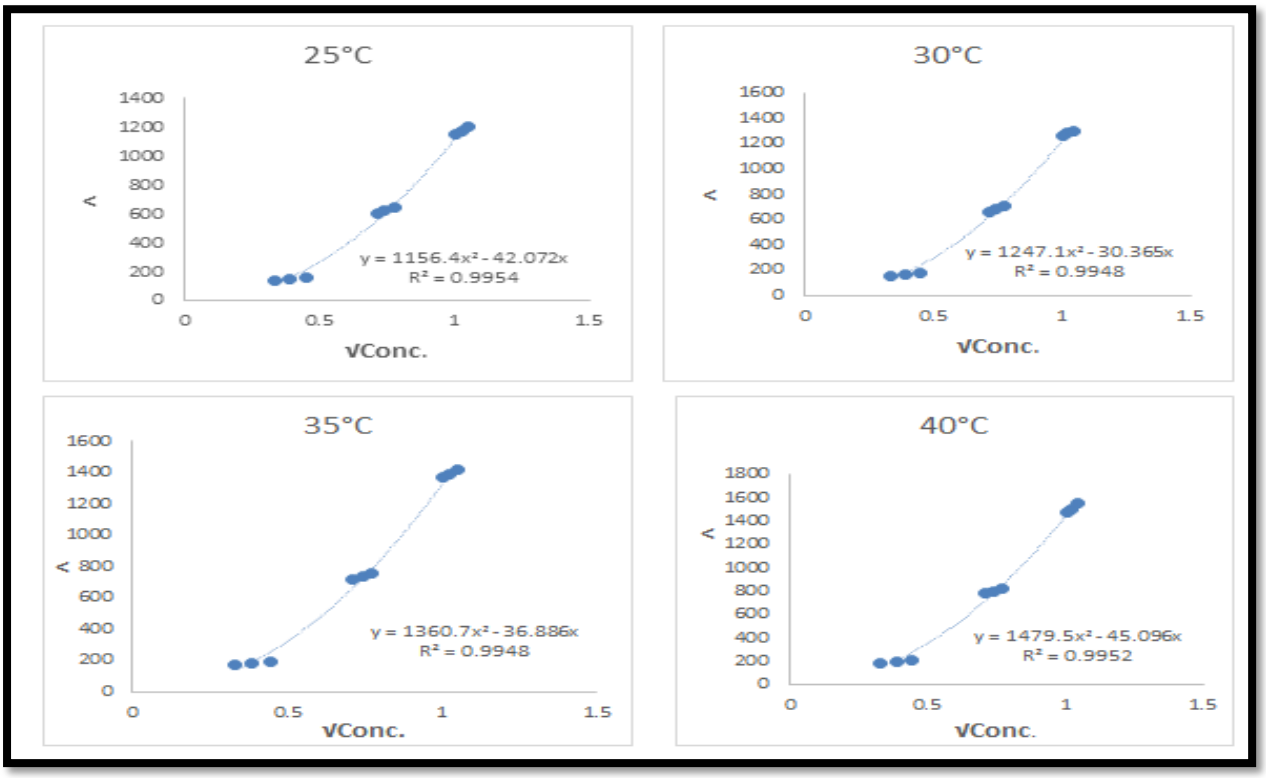

Figure (2): Relationship between Λ and √Conc at different temperatures(after adding nano iron oxides)

The results are shown in Figure 1 before adding nano iron oxides and Figure 2 after adding nano iron oxides and the linear equations show that adding nano iron oxide particles leads to an additional increase in electrical conductivity. This indicates that nano particles improve the movement of ions in the solution. It is observed from the electrical conductivity values that they increase with increasing temperature. This is due to the faster movement of ions at higher temperatures, which facilitates electrical conductivity, from this we conclude that the higher the concentration of NaCl and the concentration of iron oxide nanoparticles, the greater the electrical conductivity. This indicates that the system can be improved by using both elements together.

Effect of adding iron oxide nanoparticles on electrical conductivity and pH in saline solution

A study was conducted on the effect of adding iron oxide nanoparticles on electrical conductivity and changing the acidity function pH in the saline solution. The results showed that pH may be affected by increasing temperature, with slight changes in pH values observed at different temperatures before adding iron oxide nanoparticles, while the results of measuring pH indicate that adding iron oxide nanoparticles leads to a decrease in the solution pH, which may explain the effect of the potential ions released by the particles as in Figure (3).

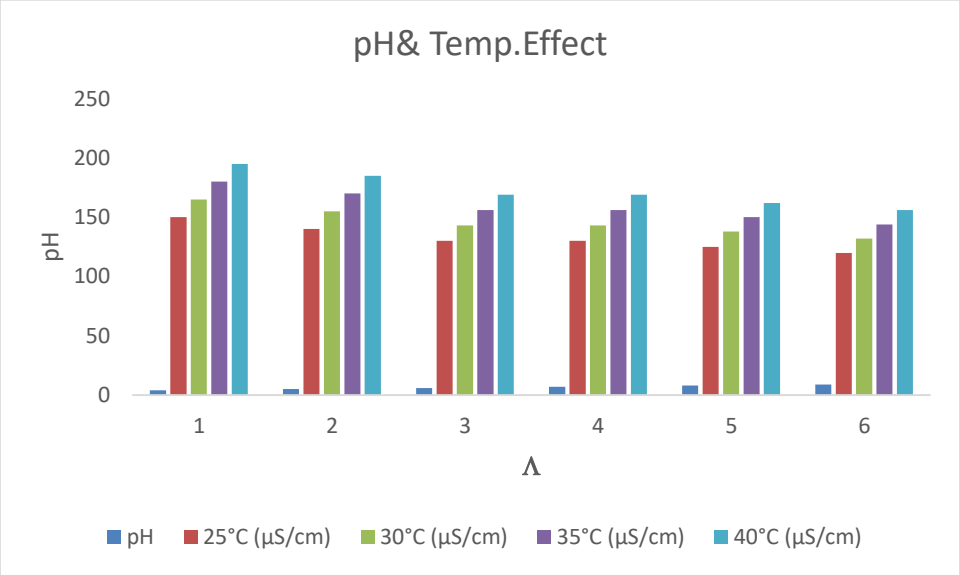

Figure (3): Relationship between Λ and pH at different temperatures

The values of conductivity before addition reflect the level of ions in the solution, indicating a limited number of ions, but an increase in electrical conductivity is observed after adding iron oxide nanoparticles, indicating that these particles have contributed to improving the movement of ions in the solution.

Also, the pH change before addition was observed. Values such as 6.8 and 6.5 reflect the acidity level of the solution, which is almost neutral, while the gradual decrease in pH observed after addition of iron oxide nanoparticles could indicate the interaction of these particles with ions in the solution, which enhances the acidity of the solution (i.e., decrease in pH). This could be due to

the release of hydrogen ions from the nanoparticles into the solution.

Study the effect of time on interaction (Reaction Kinetics)

The effect of time on the electrical conductivity and reaction rate was studied when adding iron oxide nanoparticles by adding a fixed amount of saline solution (0.1M) with 0.1g/L of iron oxide nanoparticles and then measuring the electrical conductivity at different time periods (such as 0, 10, 20, 30, 60 minutes) to study the reaction kinetics, as shown in Figure (4).

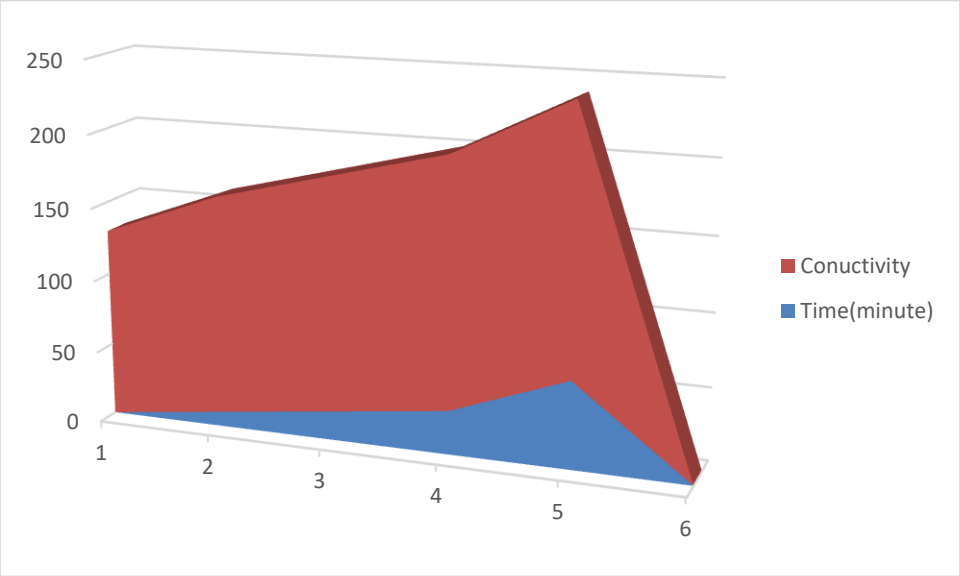

Figure (4): Effect of time

The data indicate that the conductivity increases with time as shown in Figure 4, indicating that the reaction is still kinetically ongoing and that iron oxide nanoparticles continue to affect the solution, which gives an opportunity to improve the reaction. The longer the reaction period, the greater the electrical conductivity, indicating that the ions increase in the solution.

Effect of different types of iron oxide nanoparticles

Study the effect of different types of iron oxide nanoparticles (such as magnetic iron oxide, iron(III) oxide) on conductivity and reaction rate. By adding 0.1M saline solution

with 0.1g/L of each type (such as magnetic iron oxide, iron(III) oxide). As shown in the figure(5)

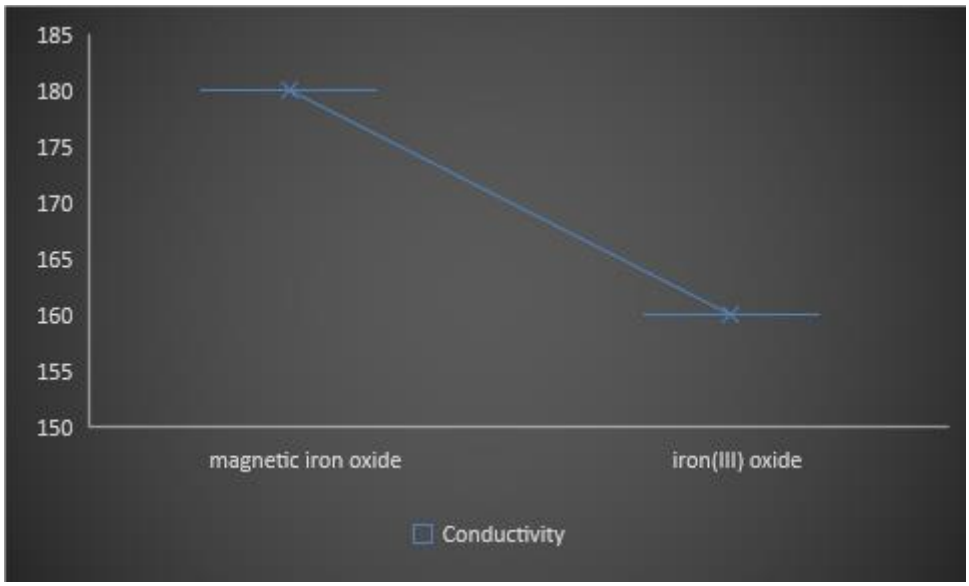

Figure (5): Effect of different types of iron oxide nanoparticles

Effect of pressure

Study the effect of pressure on conductivity and reaction rate when adding iron oxide nanoparticles.

As shown in Figure 6 by using the controller to adjust the pressure to 1 bar, 2 bar, 3 bar.

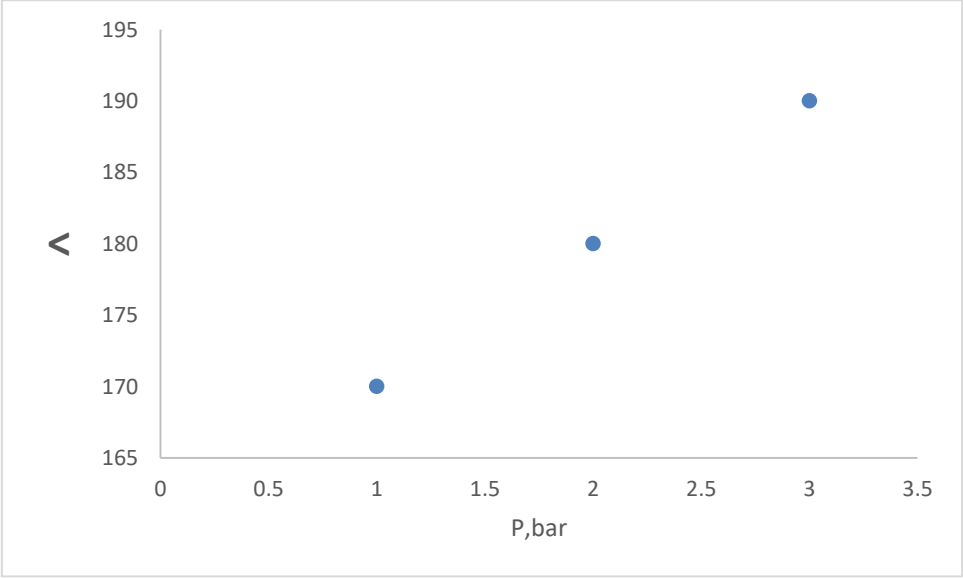

Figure (6): Effect of pressure

The data in Figure 6 indicate that increasing pressure leads to an increase in conductivity, indicating that ions move faster under higher pressure

Use of iron oxide nanoparticles in the treatment of a sample of industrial wastewater

A wastewater sample was taken from an industrial source of a chemical plant and nano iron oxide particles were added to the wastewater sample at different concentrations (e.g. 0.01g/L, 0.05g/L, 0.1g/L) and the solution was left to mix for 30 minutes with a magnetic stirrer after which the conductivity was measured after treatment using

an electrical conductivity meter. As shown in the figure (7)

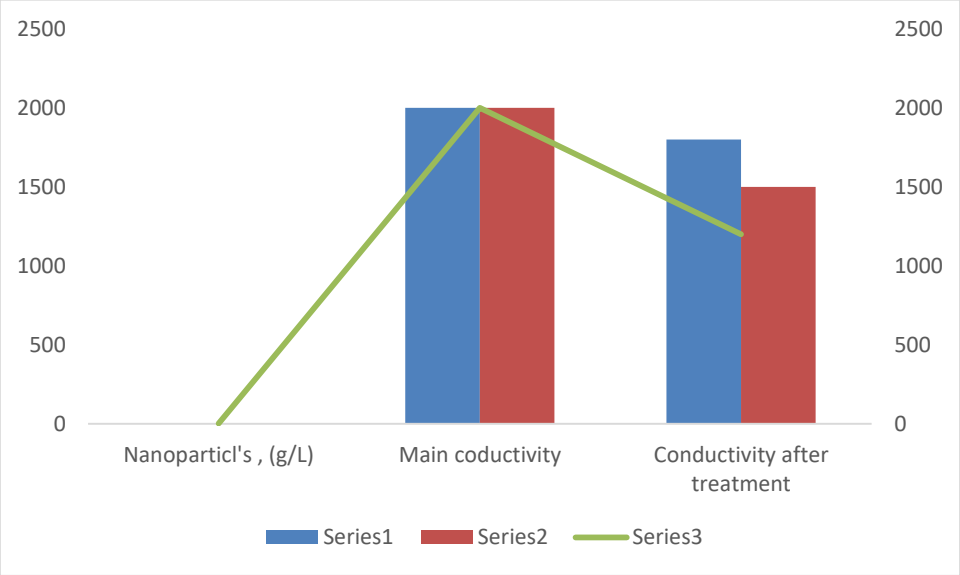

Figure (7):Effect of use of iron oxide nanoparticles in the treatment of a sample of industrial wastewater

Adding iron oxide nanoparticles resulted in a significant decrease in electrical conductivity, which means that high concentrations of heavy ions were reduced by precipitation or absorption by the nanoparticles, indicating that iron oxide nanoparticles are effective in removing pollutants from wastewater

Conclusions

It was concluded from the experimental values of conductivity measured before and after adding iron oxide nanoparticles and controlling the different conditions of changing the temperature, reaction kinetics, acid function, and changing the pressure applied to the reaction that iron oxide nanoparticles had a significant positive role in understanding the mechanism of reactions and how to increase their positive effect on the obtained results, which played a major role in applying them practically to an experimental sample in order to treat industrial wastewater, because electrical conductivity is used as an indicator to determine water quality, and low conductivity indicates the presence of fewer polluting ions, which means improving water quality. Thus, it is possible to use the results of this study in developing industrial wastewater treatment technologies, as iron oxide nanoparticles can be used as an effective means to reduce pollution and improve water quality. This application enhances environmental understanding.

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