(RESEARCH ARTICLE)

Corrosion studies of various salt solutions on metals and alloys

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Abstract

corrosion refers to a chemical (dry corrosion) or electrochemical (wet corrosion) reaction of and the surrounding environment due to erosion of steel and its alloys or atmospheric gases causing substances used to break down or lose component atoms. Section Corrosion is also defined as an electrochemical process in which oxidation and reduction of metal occur simultaneously in the presence of an oxidizing agent such as oxygen. Section Dry corrosion and wet corrosion are two types. Oxidation of waste to form metal oxides; It is a good example of electrochemical dry corrosion, commonly known as rust. The loss of corrosion products often produces oxides or salts of the old metal. Corrosion cannot be prevented, but losses from corrosion can be minimized. Almost all materials, such as ceramics (concrete rusts) or polymers, corrode in one way or another, but in this case the word "degrades" is often used with . Section Corrosion is also defined as the loss of valuable properties. materials due to the attack of atmospheric gases. Surface corrosion of metals and their alloys due to atmospheric gases (wind and moisture), chemical or electrochemical reactions that cause corrosion (loss) of metals Atmospheric gases affect different metal alloys. Many processes alloys, moisture content, nature of disease, flow rate, etc. will corrode heavily, while others will corrode slightly. Corrosion rates can be greatly affected by exposure of to certain elements in the atmosphere. Corrosion occurs in many forms. Section Corrosion Similar to the diffusion control process as corrosion occurs in most materials and alloy . Main battery design is another cause of corrosion. The formation of primary cells in the body should be avoided as much as possible. Galvanic cells are created because when two dissimilar metals come into contact with each other, the formation of Section galvanic cells occurs, which causes galvanic corrosion. In galvanic cells, more reactive metals with hydrogen greater than in the EMF series will corrode at a high rate (anode), while noble metals with hydrogen less than in the EMF series will corrode at a slower rate (cathode). However, when they are separated, no galvanic cells are formed and each metal corrodes independently. The choice of metals and alloys used in industry prevents the Galvanic cell design from occurring, which can be done with the help of many galvanic cells. For example, zinc is often used as a sacrificial anode to protect steel and its alloys, to provide protection to steel structures. Galvanic Cell Corrosion Different factors affect the corrosion rate, such as the relative position of the anode, the type of metal , and physical conditions such as temperature, humidity, and salinity. The area between the anode and the cathode is also an important factor affecting the corrosion rate. Corrosion rate of records. Section Among the different factors affecting the corrosion rate, water in the air is the most important Section. Any metal electrode immersed in a standard ventilated environment such as steam Hot sea water in the house will be faster than the next Inert. . Chapter or more Chapter is being bullied as much as its position in the EMF series is different from When two dissimilar metals are in electrical contact with each other placed in the same electrolyte, and sharing the same electrons, there is competition between the two free electrons of the two materials. Item Electrolyte acts as a host for ions to flow in the same direction and eventually gains noble metal and takes electrons from active ions. The current generation can be scaled to increase or decrease data in the center of interest. There is a basic requirement that the metal be clean to reduce corrosion. Generally, corrosion products can be removed by chemical/physical means to obtain a clean surface , but one or another type of corrosion such as pitting corrosion may

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still occur. To reduce the corrosion of , different anti-corrosion agents should be used in the body; For example, phosphoric acid, usually in the form of dark blue glue, is used to surface ferrous equipment to remove rust. Different materials have different corrosion properties. For example, EMF and Galvanic series. Different types and alloys of series or reactive series metals can be prepared in different environments. Section will certainly help you understand the nature and type of rust. Among the different corrosion protection methods, the various methods for protecting carbon steel from corrosion include painting, hot dip galvanizing, anodic protection, altruistic protection, and a combination of methods.. More procedures can be used if more sensitive data is used. It is used to protect and components from damage during manufacture, transportation and storage. Section The most corrosion resistant materials are those that are thermodynamically unsuitable for corrosion. Any corrosion of gold or platinum will spontaneously convert to pure metal; therefore these elements can be found in the world in metallic form and are part of their true value. Article The more "base" metal can be preserved with longer use. Chapter Normal metals have slow reaction kinetics, but their corrosion is thermodynamically favored. These include metals such as zinc, magnesium and cadmium. The corrosion of these metals continues, but occurs at a lower rate. Section A 2002 study by the Federal Highway Administration entitled "Costs and Prevention in the United States" Section shows the direct costs associated with metal corrosion in virtually every industry in the United States. It showed that the estimated annual direct cost of corrosion in the United States in 1998 was .The United States is approximately $276 billion, of which is approximately 3.2% of US GDP. However, the cost directly related to the corrosion of steel is heavier. Failure is due to the loss of mechanical strength of the concrete structure due to corrosion. Corrosion limits the life of the concrete structure. As corrosion cannot be avoided, engineers will determine the service life of the model. Rust is one of the most common causes of bridge accidents. Article Harassment Corrosion was the main cause of the Milans River Bridge collapse in 1983 when internal corrosion at the bearings caused the angle of the road plate to come off its support. Meanwhile, three people driving on the road died when the stone slabs fell into the river below. NTSB research revealed that engineers blocked the drain in the road while renovating, but forgot to unclog it later, allowing water to seep into the hangers. Article It is also difficult for mechanics to find bearings by inspection. Section When rust builds up and the support is removed, it eventually causes serious damage to Section .There are many instances where rust was responsible for the tragic events of . Rust was a factor in the 1967 Silver Bridge disaster in West Virginia at ,when the steel suspension bridge collapsed in less than a minute, killing 46 drivers and passengers. Carbon and Mild Steel are the most common steels used in many industries as well as everyday life for the design and manufacture of in a variety of applications. Carbon steel and low carbon will corrode severely when exposed to corrosive medium, ie corrosive medium. is an acid, but their use is still mostly due to their low cost and good quality. Corrosion can cause loss of metals and their strength which can lead to serious accidents and loss of work, work and people. Scientists have always wanted to understand the corrosion process and ways to control it. Chapter A number of corrosion inhibitors have been reported to control the corrosion of steel and its alloys in different corrosion systems. Every step towards finding a new Corrosion Inhibitor for a corrosion remediation project will not only result in significant savings, but will also help engineers keep plants and machinery running smoothly as Corrosion occurs. Carbon Steel, Stainless Steel, and Mild Steel are the most common materials used in the design and manufacture of the Chloride ions can corrode steel, stainless steel, and mild steel and are found in plumbing, electrical equipment, boilers, condensing units, etc. can cause problems. The sea is also abundant in chloride , which is used for injection into water in oil for cooling, such as in desalination plants. Chemical corrosion inhibitors are generally used in manufacturing and processing. The challenge, however, is to develop a new corrosion inhibitor that will protect material and make it a good friend in many situations. Surfactants are environmentally acceptable as corrosion inhibitors and is very economical and readily available. The purpose of this article is to determine the ability of surfactants to prevent corrosion of on carbon, stainless and mild steel surfaces. Chapter The various uses and properties of various surfactants are also discussed. The effect of surfactant concentration, temperature and corrosion inhibition mechanisms, and type of adsorption are also discussed in this book. In this study, we try to study in detail surfactants as corrosion inhibitors to control corrosion of carbon steel, stainless steel and small iron in acidic environment. Chapter Experiments were performed using both gravitational and electrochemical polarization methods, and the results of all studied surfactants used in this study are discussed in detail.

1. Introduction

The corrosion especially due to salt formation. Corrosion is the deterioration of materials by chemical interaction with their environment. The term corrosion is sometimes also applied to the degradation of plastics, concrete and wood, but generally refers to metals. The most widely used metal is iron (usually as steel). For example ship propeller sinks into the sea water and in sea water, found the salt. Due to this salt formation in sea water, this affects the ship propeller. So, here totally describes the salt formation corrosion and other corrosion.

We have all seen corrosion and know that the process produces a new and less desirable material from the original metal and can result in a loss of function of the component or system. The corrosion product we see most commonly is the rust which forms on the surface of steel and somehow Steel → Rust

For this to happen the major component of steel, iron (Fe) at the surface of a component undergoes a number of simple changes. Firstly,

$$Fe \rightarrow Fe^{n+} + n \text{ electrons}$$
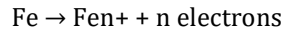
the iron atom can lose some electrons and become a positively charged ion. This allows it to bond to other groups of atoms that are negatively charged.

We know that wet steel rusts to give a variant of iron oxide so the other half of the reaction must involve water (H_2O) and oxygen (O_2) something like this

$$O_2 + 2H_2O + 4e^- \rightarrow 4OH^-$$
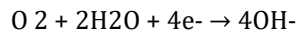
This makes sense as we have a negatively charged material that can combine with the iron and electrons, which are produced in the first reaction are used up. We can, for clarity, ignore the electrons and write
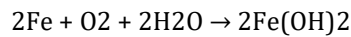
$$2Fe + O_2 + 2H_2O \rightarrow 2Fe(OH)_2$$

Iron + Water with oxygen → Iron Hydroxide

Oxygen dissolves quite readily in water and because there is usually an excess of it, reacts with the iron hydroxide. $4Fe(OH)_2 + O_2 \rightarrow 2H_2O + 2Fe_2O_3.H_2O$ Iron hydroxide + oxygen → water + Hydrated iron oxide (brown rust)

This series of steps tells us a lot about the corrosion process . Ions are involved and need a medium to move in (usually water) (2) Oxygen is involved and needs to be supplied (3) The metal has to be willing to give up electrons to start the process (4) A new material is formed and this may react again or could be protective of the original metal (5) A series of simple steps are involved and a driving force is needed to achieve them . The most important fact is that interfering with the steps allows the corrosion reaction to be stopped or slowed to a manageable rate.

Uniform corrosion, as the name suggests, occurs over the majority of the surface of a metal at a steady and often predictable rate. Although it is unsightly its predictability facilitates easy control, the most basic method being to make the material thick enough to function for the lifetime of the component. Uniform corrosion can be slowed or stopped by using the five basic facts;

- Slow down or stop the movement of electrons
  - Coat the surface with a non-conducting medium such as paint, lacquer or oil
  - Reduce the conductivity of the solution in contact with the metal an extreme case being to keep it dry. Wash away conductive pollutants regularly.
  - Apply a current to the material (see cathodic protection).
- Slow down or stop oxygen from reaching the surface. Difficult to do completely but coatings can help.
- Prevent the metal from giving up electrons by using a more corrosion resistant metal higher in the electrochemical series. Use a sacrificial coating which gives up its electrons more easily than the metal being protected. Apply cathodic protection. Use inhibitors.
- Select a metal that forms an oxide that is protective and stops the reaction. Control and consideration of environmental and thermal factors is also essential.

2. Material and methods

2.1. Experimental procedure

The stability and concentration of hydrochloric acid vary in industry. Therefore, it has different corrosive properties depending on the strength of hydrochloric acid. To overcome this problem, 1.0M concentration of hydrochloric acid was prepared. The experiments were carefully designed to evaluate the corrosion inhibiting effectiveness of surfactants as

corrosion inhibitors. We carefully monitored the consistency of the data by repeating the experiments and sometimes even making triplicate.

2.2. Materials

Carbon steel, mild steel and stainless steel used for investigations was in the form of sheet (0.25 mm thick) and had the following compositions.

Table1 Carbon steel, mild steel and stainless steel used for investigations was in the form of sheet (0.25 mm thick) and had the following compositions

ElementWeight %age(w/w)	C	Si	Mn	S	P	Ni	Cu	Cr	Fe
Carbon Steel	0.54	0.05	0.32	0.05	0.20	0.03	0.01	0.01	Balance
Stainless Steel	1.8	0.08	0.58	0.07	0.51	0.05	0.03	0.04	Balance
Mild Steel	0.21	0.03	0.27	0.06	0.34	0.07	0.01	0.11	Balance

2.3. Sample Preparations

2.3.1. Weight Loss Measurements

For the weight loss test, metal samples with a size of 3.0 x 1.5 cm2 were cut from the metal sheet with a sharp edged metal cutter, while samples with a size of 5.0 x 1.5 cm were taken for the electrochemical polarization experiment. After selecting several metal samples, they were mechanically polished with different emery papers of 150, 300 and 600 microns, respectively, and then thoroughly cleaned with triple distilled water and acetone. The sample was dried with a hot hair dryer and stored in a silica gel desiccator. The acid used is made from AR grade hydrochloric acid. Prepare 1.0 M hydrochloric acid using double distilled water .In acidic media, all organic surfactants are used as corrosion inhibitors in concentrations of 20 to 150 ppm.

After recording the initial weight of the metal sample on the Japanese Mettler Toledo AB 135-/ FACT single pan analytical balance (accuracy 0.01 mg), place the metal sample at an angle into a 250 ml Glass borosilicate beaker of 200 ml each. Acidic solution as corrosion medium with or without inhibitor. Weight loss corrosion experiments and electrochemical polarization experiments were carried out at different temperatures, that is, in a controlled heat exchanger.

30, 40 and 50 °C with an accuracy of ±0.1 °C. The samples were removed from the beakers after 24 hours of exposure and rinsed under running water. The loosely adhering corrosion products are removed with the help of rubber stoppers and the sample is rinsed again with triple distilled water, dried with a hot hair dryer and weighed again. Calculate the corrosion rate in mils per year (mpy) and the inhibition efficiency as a percentage using the formula below.

$$\text{Corrosion rate (mpy)} = \frac{534 \times W}{DAT} \dots\dots\dots..(1)$$

Where
W = Weight loss (mg),
D = Density of carbon steel (gm/cm3),
A = Area of specimen (sq. inch),
T = Exposure time (hours).

The extent of surface coverage (θ) by the organic surfactant molecule were calculated from the following equation:

$$\theta = \left[1 - \left(\frac{\Delta W_{Inh}}{\Delta W_{Free}}\right)\right] \quad\dots\dots\dots(2)$$

Where, ΔW_{Free} and ΔW_{Inh} are weight losses of metal per unit area in absence and presence of inhibitor at given time period and temperature, respectively.

Electrochemical polarization investigation were carried out in 500 ml glass cell specially designed for the purpose having three electrodes system assembly. Potentiostatic polarization of the working electrode was carried out by using a Potentiostat / Galvanostat PGS 201 T (Tacussel, France).The working electrode has an arrangement to hold the metal coupons under study, Platinum electrode/ auxiliary electrode was used as counter electrode.

Linear polarization resistance measurements were performed potentiostatically by scanning through a potential range of 14 mV above and below the OCP value in steps of 2 mV. Different electrochemical experiments were carried out in absence and presence of surfactant molecule at their different temperature at 30, 40 and 50℃. The resulting current is plotted against the potential and slope of the line is measured

The corrosion current, Icorr is related to the slope of the line by Stern-Geary equation.

$$\frac{\Delta E}{\Delta i} = \frac{\beta_a \times \beta_c}{2.303\, I_{corr}\,(\beta_a + \beta_c)}$$

$$................(3)$$

Where

$\Delta E / \Delta i$ is the slope which is linear polarization resistance (Rp), βa and βc are anodic and cathodic Tafel slopes respectively and Icorr is the corrosion current density in μA/cm2.

The anodic and cathodic Tafel slopes were measured after recording anodic and cathodic polarization curves of the specimen up to a maximum shift of ± 140 mV from OCP value in steps of 10 mV. Experiments were carried out in absence and presence of the inhibitor at their 20 to 150 ppm concentrations at 30, 40 and 50 ℃ .

Rearranging the above equation:

$$I_{corr} = \frac{\beta_a \beta_c}{2.303(\beta_a + \beta_c)} \times \frac{1}{R_p}$$

$$................(4)$$

The corrosion current density Icorr., is related to the corrosion rate by the equation,

$$\text{Corrosion rate (C.R.) (mpy)} = \frac{0.1288 \times I_{Corr.} \times Eq.Wt.}{D}$$

$$................ (5)$$

The interaction of inhibitor molecules can be described by introducing of an parameter, obtained from the surface coverage values (q) of the anion, cation and both. Aramiki and Hackerman calculated the synergism parameter, S_θ , using the following equation.

$$S_\theta = \frac{1-\theta_{1+2}}{1-\theta'_{1+2}}$$

$$............(6)$$

$$\theta_{1+2} = (\theta_1 + \theta_2) - (\theta_1 \theta_2)$$

$$.................(7)$$

Where; $\theta_{1=}$ surface coverage by anion

$\Theta_2 = $ surface coverage by cation

$\Theta_{1+2} = $ measured surface coverage by both the anion and the cation

S_Θ values nearly equal to unity which suggests that the enhanced inhibition efficiencies caused by the addition of these anions to surfactants is due to mainly to the synergistic effect.

2.4. SADS, SADDS, SAHDS and SADDBS as Corrosion inhibitor for Stainless Steel

(a) Decyl sulphate ammonium salt (SADS).

(b) - Dodecyl sulphate ammonium salt (SADDS).

(c) - Hexadecyl sulphate ammonium salt (SAHDS).

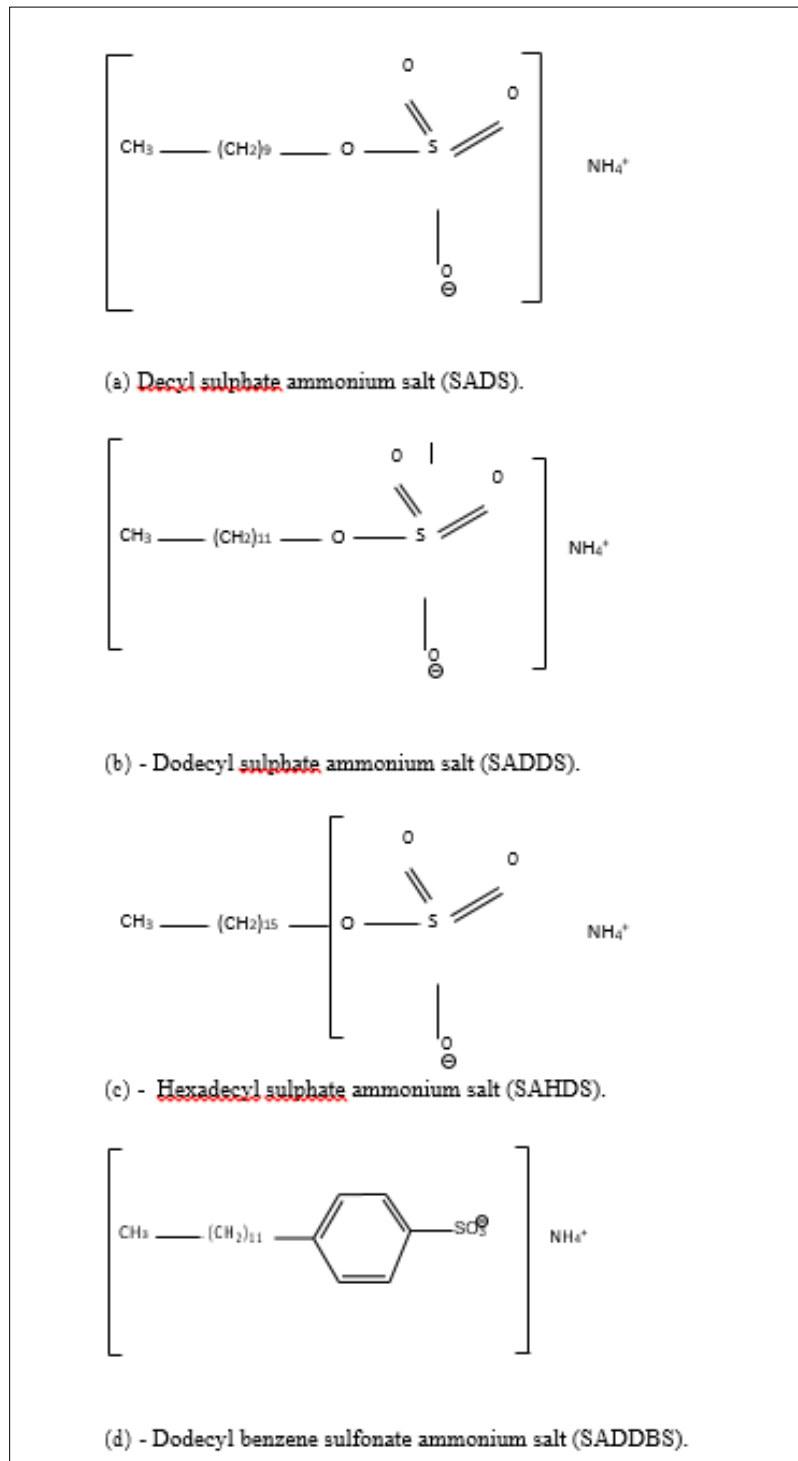(d) - Dodecyl benzene sulfonate ammonium salt (SADDBS).

Figure 1 Various salt solutions of Ammonium

In other words, corrosion is the wear and tear of metal due to chemical or electrochemical reactions that occur as a result of air attack on metal. Many metal structures will only rust when exposed to moisture in the air, but exposure to certain substances can affect the process. Corrosion can cause pits or cracks in areas or spread over a large area, more or less eroding the surface. Since corrosion is a diffusion-controlled process, it occurs in the right place. Therefore, methods that reduce the activity of exposed surfaces, such as passivation and chromate conversion, can increase the corrosion resistance of materials. However, some corrosion developments are less obvious and difficult to predict. Galvanic corrosion occurs when two dissimilar metals are in physical or electrical contact with each other and placed in an electrolyte or when the same metal is exposed to different concentrations of electrolytes. In a galvanic couple, the active metal (anode) corrodes rapidly, while the more noble metal (cathode) corrodes at a slower rate. Each metal will corrode at its own pace when immersed separately. Which type of metal to use can be easily determined by following a few galvanic series. For example, zinc is often used as a sacrificial anode in metal structures. Galvanic corrosion is a major problem in the marine industry and wherever water (consisting of impurities such as salt) comes into contact with pipes or steel. Relative Factors such as the anode, metal type, and operating conditions (temperature, humidity, salinity, etc.) can affect galvanic corrosion. The ratio of the anode and cathode surface directly affects the corrosion of the product. Galvanic corrosion is often used on sacrificial anodes. Corrosion products can often be removed with chemicals to maintain a clean surface, but rust lines such as pitting can occur. For example, phosphoric acid in the form of navy glue is often used to remove rust from ferrous tools or surfaces. Corrosion removal should not be confused with electropolishing, which removes some layers of the underlying metal to smooth the surface. For example, phosphoric acid can (again) be used to electropolize copper, but it does so by removing copper instead of copper corrosion products. Some metals are inherently more corrosion resistant than others, either because of the basis of the electrochemical process involved or the nature of the chemical reaction produced. For example, the Galvani series. There are many ways to protect carbon steel from corrosion, such as painting, hot dip galvanizing, and combinations of these methods. If more sensitive materials are used, there are many methods that can be used to prevent damage to the product during its manufacture and use. The most corrosion resistant materials are thermodynamically unfavorable corrosion. All corrosion products of gold or platinum spontaneously decompose into pure metal, so these elements can be found on earth in metal form and account for a large part of their value. The more "basic" metal can be protected from time to time by various methods. Normal metals have slow reaction kinetics, but their corrosion is thermodynamically favored. These include metals such as zinc, magnesium and cadmium. Although the corrosion of these metals is continuous, it takes place gradually. The greatest example of this is graphite, which releases a lot of energy when oxidized, but has slow kinetics, thus preventing electrochemical corrosion under normal conditions. Section In 2002, the Federal Highway Administration published a study entitled Corrosion Costs and Prevention Strategies in the United States that examined the direct costs associated with corrosion in all areas of the United States. Total estimated annual direct cost of corrosion in the United States in 1998The US is about $276 billion (about 3.2% of US GDP). rust is one of the most common causes of bridge accidents. Because rust is more common than metal, products can also grind the gap, causing failure. This is what caused the Mianus River Bridge to collapse in 1983; Corrosion in the bearing caused the corner of the road sign to detach from its support. At that time, three drivers on the road died when the rock fell into the river. A later NTSB investigation revealed that the gutters in the road were closed by re-paving the road and were not lifted, allowing water to enter the hangers. It is also difficult for technicians to check bearings by walking inspection. Rust was also a factor in the 1967 Silver Bridge disaster in West Virginia, in which a steel suspension bridge collapsed in less than a minute, killing all 46 drivers and passengers on the bridge. Likewise, corrosion of the steel and metal covered by the concrete will cause the concrete to spill and cause serious problems. It is one of the most common types of damage in continuous concrete. Half-cell-based measurements are capable of identifying corrosion points before concrete samples fail. Carbon and mild steel are the best metal materials used in the design and manufacture of products in many industries and modern life. Carbon monoxide and small metals corrode severely when exposed to corrosive environments.to. However, their use is still mostly due to their low cost and high quality. Stainless steel is widely used in kitchens, sinks, nuts and bolts, engine parts, etc. widely used. Coating, painting and enamel coating are the most commonly used to prevent corrosion. They work by providing anti-corrosion materials and building materials at the site of damage. In addition to cosmetic issues and manufacturing, there is also a tradeoff between simple mechanics, wear resistance and high temperature. Coating is usually only possible on small areas, and if the coating is nobler than the substrate (such as chromium on iron), the galvanic couple will cause the areas to corrode faster than the uncoated surface. So it is good to coat with active metals like zinc or cadmium. Paint rollers or brushes are best for small areas; Spraying is required for larger areas such as steel floors and paper benches. Flexible polyurethane coatings such as Durabak-M26 can provide corrosion protection with excellent film properties. The paint is easy to apply and has a fast drying time, but temperature can increase the drying time. The study published in the journal of this section is to investigate the effectiveness of various organic surfactants such as ammonium decyl sulfate (SADS), ammonium dodecyl sulfate (SADS), ammonium cetyl sulfate (SADS), and ammonium dodecylbenzenesulfonate (SADD). Corrosion inhibitors for stainless steel in acidic environments. The effect of concentration and temperature on the corrosion inhibiting efficacy of research surfactants as carbon steel corrosion inhibitors was also evaluated. The effect of different surfactants on the corrosion of carbon steel is measured at 1.0 M HCl in the presence and absence of surfactants in the

concentration range (20 to 150 ppm) by weight loss and electrochemical polarization processes. competence. . The name and molecular structure of carbon steel corrosion inhibitor anionic surfactant in acidic medium are mentioned in Figure 1 .

3. Results and discussion

Table 2 gives the percentage of corrosion inhibition efficiency values of the investigated surfactant compounds at different temperatures of 30 °C. Figure 2 shows the percentage of corrosion inhibition efficiency of all four organic surfactants on stainless steel in the presence of 1.0 M hydrochloric acid solution. at 30 °C. From Table 2 and Figure 2 it can be seen that the concentration of corrosion inhibitor increased from 20 ppm to 150 ppm, the weight decreased, the percentage of anti-corrosion effectiveness increased and thus the corrosion inhibition increased. This may be due to increased adsorption and surface protection with increasing concentration of surfactant molecules. As a result, the metal is well protected and isolated from the corrosive environment. Line changes in weight loss over time in unconstrained and inhibited 1.0 M HCl indicate that there is no non-toxic film during corrosion. It can be clearly seen from Table 2 that the percentage of anti-corrosion effectiveness increases with the concentration of different surfactants as corrosion inhibitors. The percentage of anti-corrosion effectiveness of different anionic surfactants as corrosion inhibitors increases in the following order: SADDBS > SAHDS > SADDS > SADS. Table 3 shows the percentage Figure 3 shows KMnO$_4$ on percent corrosion inhibition activity of all four organic surfactants on stainless steel in a 30 °C 1.0 M hydrochloric acid solution. show a synergistic effect .It can be seen from Table 3 and Figure 3 that the addition of KMnO$_4$ increases the percentage of the protective activity of surfactant molecules. The research synergistic effect of surfactant molecules and KMnO$_4$ is due to the action of chemically absorbed I- and organic compounds . The stability of organic cations adsorbed on the stainless steel surface may be due to the electrostatic interaction of surfactant molecules with I-ions, which makes the metal surface more may result in better protection and therefore better corrosion protection than metal. Table 4 shows the combined effect (S$_\Theta$) of adding 1.0 × 10-3 m KMnO$_4$ at different concentrations of the tested surfactants on the corrosion of stainless steel alloys after immersion in 1.0 M HCl for 24 hours at 30 °C. . 5.Figure 4 shows current-potential electrochemical polarization studies of stainless steel alloys at 1.0 M HCl in the absence and presence of organic surfactant molecules at various concentrations. Values of electrical parameters such as current density (icorr.), corrosion potential (Ecorr.), Tafel slope and corrosion inhibition efficiency (percent) as a function of surfactant "SADDBS" (1) concentration.0 M HCl is given in Table (5). It is clear from Table 5 that there is no significant change in the Tafel constant as the concentration of surfactant molecules increases. It is seen from the Tafel curve that the inhibitors are of mixed type as they improve the anodic and cathodic polarization equally, but the anodic polarization is higher when the size of the external current increases. The decrease in the corrosion current rate (icorr) as the concentration of surfactant compounds increases from 20 ppm to 150 ppm indicates that the presence of surfactant molecules minimizes the dissolution of the stainless steel in 1.0M HCl, and the concentration-dependent amount inhibits corrosion. between surfactant and surfactant molecule. By increasing the concentration of surfactant molecules from 20 ppm to 150 ppm, the negative open circuit potential (Ecorr) value decreases. The effect of temperature on the corrosion behavior of stainless steel was investigated by weight loss method in the presence and absence of different surfactants (SADDBS) in 1.0 M HCl solution at different temperatures between 30-50 °C. The percentage of anti-corrosion effectiveness of surfactant molecules (SADDBS) is shown in Table 5. It is clear from Table 5 that the percentage of corrosion inhibition efficiency increases with increasing surfactant molecule concentration and decreases with increasing temperature from 30 °C to 50 °C. Decrease in the adsorption of inhibitors, which leads to an increase in the process of metal fragmentation. The calculated results of the apparent activation energy E*, activation enthalpy ΔH * and activation entropy ΔS * are shown in Table 6. Addition of organic surfactant molecules as corrosion inhibitors to corrosive media changes the E* values. This can be attributed to the adsorbing of inhibitors to the stainless steel surface, thus increasing the percentage of corrosion inhibition effectiveness. This shows that the process is under control. activation entropy (ΔS *) is large and negative in null solution and solution, indicating that the activation mechanism represents organization rather than individual interaction. The corrosion protection mechanisms of all four investigated organic surfactants can be explained by their molecular size and adsorption sites. Organic surfactant compound (SADDBS) should be the best inhibitor despite having two adsorption sites. The high anti-corrosion efficiency of this compound (SADDBS) may be due to its size or the β electron donation to the adsorption site of the benzene ring. The percent order of corrosion inhibition efficiency is based on molecular size.

Table 2 Percentage corrosion inhibition efficiency at different concentrations of anionic surfactant for the corrosion of stainless steel after immersion in 1.0 M HCl at 30 °C.

Conc. of Surfactant (ppm)	Percentage Corrosion Inhibition Efficiency of Surfactants			
	(a)	(b)	(c)	(d)
20	70.5	71.4	72.1	73.0
40	72.6	74.5	73.0	76.2
60	74.7	77.2	79.8	81.2
80	76.2	79.5	81.5	84.7
100	81.1	83.4	85.6	87.5
150	84.3	85.1	87.0	91.0

Table 3 Percentage corrosion inhibition efficiency at different concentrations of the four investigated surfactants (a to d) with addition of 1.0×10^{-3} m $KMnO_4$ for the corrosion of stainless steel after 24 hours of immersion in 1.0 M HCl at 30 °C.

Conc. of Surfactant(ppm)	Percentage Corrosion Inhibition Efficiency of Surfactants			
	(a)	(b)	(c)	(d)
20	81.3	83.6	85.2	87.3
40	84.2	85.4	87.3	88.5
60	86.8	88.5	89.3	91.3
80	88.4	89.6	92.6	83.6
100	91.5	92.3	93.0	85.7
150	92.1	93.8	95.6	97.8

Table 4 The effect of concentrations of compound (d) on the free corrosion potential (Ecorr), corrosion current density (icorr), %age corrosion inhibition efficiency (%age CIE) and degree of surface coverage (q) for the corrosion of stainless steel in 1.0 M HCl at 30 °C.

Conc. of Surfactant (d)(ppm)	$-E_{corr}$, mV	i_{corr}, (µA /cm²)	q	Percentage CIE
Blank	735	68.5	-	-
20	728	40.0	0.713	76.6
40	727	38.7	0.733	78.8
60	726	35.0	0.734	82.1
80	725	33.1	0.764	83.3
100	724	31.2	0.780	86.1
150	723	28.5	0.813	91.7

Table 5 The effect of temperature on the percentage corrosion inhibition efficiency of organic surfactant (SADDBS) for stainless steel at different concentrations and temperatures .

Concentration of Surfactant(SADDBS) (ppm)	30 ℃	40 ℃	50 ℃
20	73.0	51.2	29.0
40	78.2	55.3	37.6
60	81.2	60.4	46.1
80	84.7	65.1	51.2
100	87.5	70.7	56.4
150	91.0	72.8	61.6

Table 6 Activation parameters of the corrosion of carbon steel in 1.0 M HCl in absence and presence of different concentrations of compound (SADDBS) .

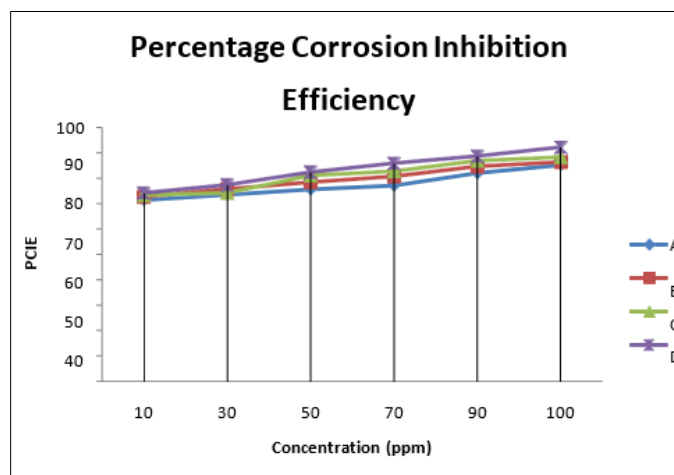| Conc. of Surfactant (SADDBS) (ppm)	E^*_a (kJmol^{-1})	ΔH * (kJmol^{-1})	$-\Delta S$ * (Jmol^{-1}K $^{-1}$)
20	60.12	57.31	165.42
40	62.43	60.23	160.13
60	63.64	62.32	157.21
80	65.31	62.03	155.10
100	67.60	64.72	152.14
150	70.15	65.00	150.77

Figure 2 Percentage corroison inhibition efficiency of all the four organic surfactants for Stainless steel at 30 **℃** in presence of 1.0 M hydrochloric acid solution .
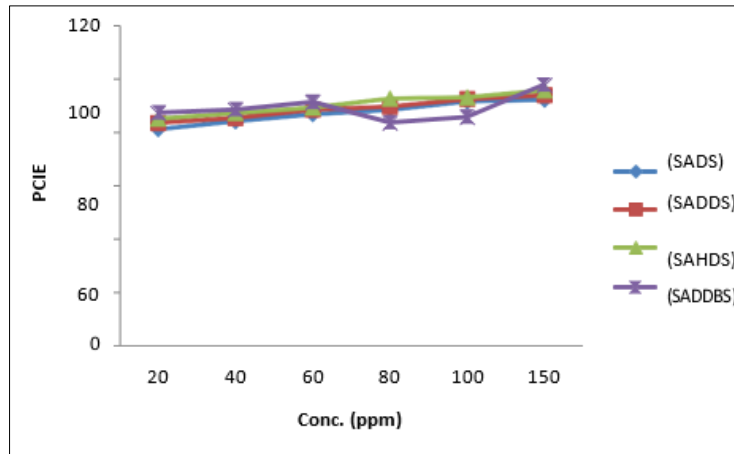
Figure 3 Synergistic effect of KMnO₄ on the percentage corroison inhibition efficiency of all the four organic surfactants for stainless steel at 30 °C in 1.0 M hydrochloric acid solution .
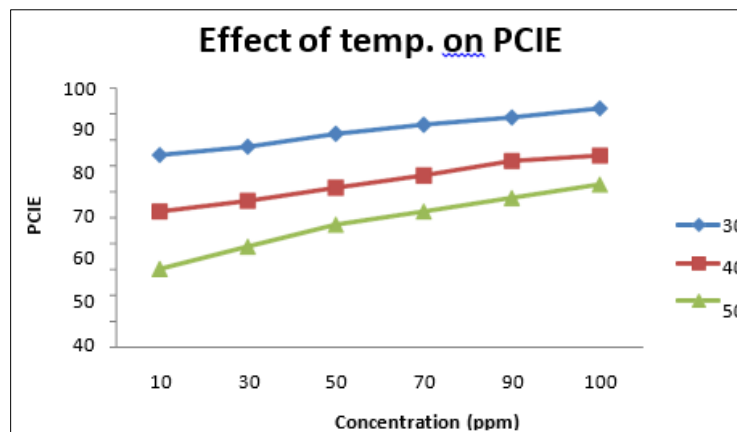

Figure 4 Effect of increasing temperature i.e. 30 to 50 **°C** on percentage corrosion inhibition efficiency of surfactant (SADDBS) in case of stainless steel .
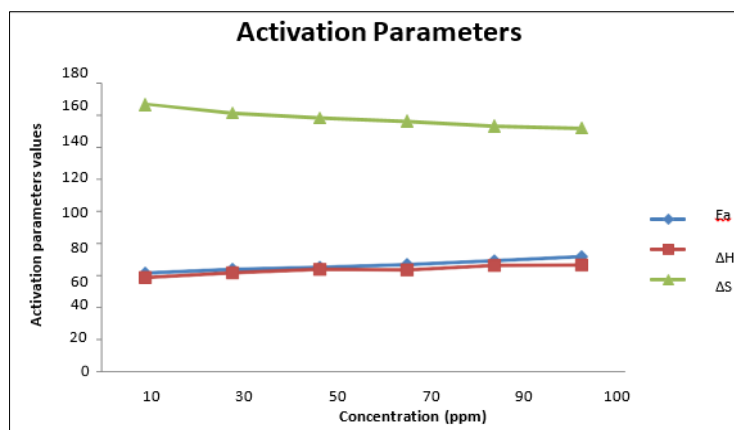

Figure 5 Activation parameters i.e. activation energy, change in enthalpy and change in entropy for stainless steel in case of surfactant (SADDBS) at different concentrations

4. Conclusion

Four different organic surfactant molecules were tested as corrosion inhibitor for stainless steel in acidic environment at 30 °C. The four organic surfactant molecules acted as corrosion inhibitors for carbon steel in hydrochloric acid solution, and the corrosion inhibition efficiency increased as the surfactant increased. values increased. concentration increased from 20 ppm to 150 ppm. The surfactant molecules increase the strength of the anti-corrosion agent, so that the decomposition of metal impurities in the HCl solution is slowed down, so that the decomposition of the metal in the acidic environment is reduced. All four investigated surfactant molecules act as hybrid corrosion inhibitors. Inhibition results obtained from polarization and weight measurements are in agreement with each other. An increase in temperature leads to a decrease in the corrosion of carbon steel in the HCl solution. The addition of $KMnO_4$ to the anti-corrosion process showed a small synergistic effect on the corrosion resistance of organic surfactants on stainless steel.

Compliance with ethical standards

Disclosure of conflict of interest

There are no conflicts of interest in this manuscript.

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