

INTRODUCTION

1-INTRODUCTION

1.1. Surfactant Definition.

Surfactant is also called amphiphile [1]. The word is derived from the Greek word *amphi*, meaning both, and the term relates to the fact that all molecules consists of at least two parts, one which is soluble in a specific fluid (the lyophilic part) and one which is insoluble (the lyophobic part) when the fluid is water one usually talks about the hydrophilic and hydrophobic parts. The hydrophilic part is refereed to as the head group and the hydrophobic part as the tail see Figure (1).



Figure (1): Shape of a surfactant

The polar part of surfactant may be ionic or nonionic and the choice of polar group determines the properties to a large extent. For nonionic surfactant the size of the head group can be varied at will, for the ionic, the size of the head group is a fixed parameter.

A surfactant usually contains only one polar group. Recently there has been considerable research interest in certain dimeric surfactant containing two hydrophobic tails and two head group links together with short spacer these species generally known

under the name gemini surfactant .They are not yet of the commercial important.

Weakly surface active compounds which accumulate at interface but which do not readily form micelles are of interest as additives in many surfactants formulation they are referred to as hydrotropes and serve the purpose of destroying the packing ordinary surfactants .Thus addition of hydrotropes is a way to prevent the formation of highly viscous liquid crystalline phases which constitute a well-known problem in surfactant formulation. Xylen surfactant and cumene sulfonate are typical example of hydrotropes used, for instance in detergent formulation .Short chain alkyl phosphates have found specific used as hydrotropes for longer chain alcohol ethoxylates.

1.2. Surfactants Classification.

The primary classification of surfactant is mad on the basis of the charge of the polar head group [2]. It is common practice to dived the surfactant into classes; anionic, cationic, nonionic and zwitterionics. Surfactant belonging to the latter class contains both anionic and cationic charge under normal condition. In the literature they are often referred to as amphoteric surfactant but the term "amphoteric" is not always correct and should not be used as synonymous to zwitterionic.

Most ionic surfactants are monovalent but there are also important examples of divalent anionic amphiphiles. For ionic surfactant the choice of counter ion play a role in physicochemical properties. Most anionic surfactant have sodium counter ion but other cations such as Lithium, Potassium,

Calcium and protonated amines are used as surfactant counter ion for specialty purposes. The counter ion of cationic surfactant usually a halide or methyl sulfate.

The hydrophobic group is normally hydrocarbon (alkyl or alkylaryl) but may also be a polydimethylsiloxane or a fluorocarbon. The two latter types of surfactant are particularly effective in non-aqueous systems.

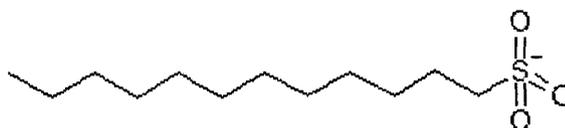
For few surfactants there is some ambiguity as to classification for example, amine oxide surfactant are sometimes referred to as zwitterionics, sometimes as cationic and sometimes as nonionic compound.

1.2.1. Anionic Surfactants.

Carboxylat, sulfate, sulfonat and phosphate are the polar group found in anionic surfactant. The structures of the more common surfactant belonging to this class are shown below [3].



Sodium oleate and sodium myristate



alkyl sulfonate

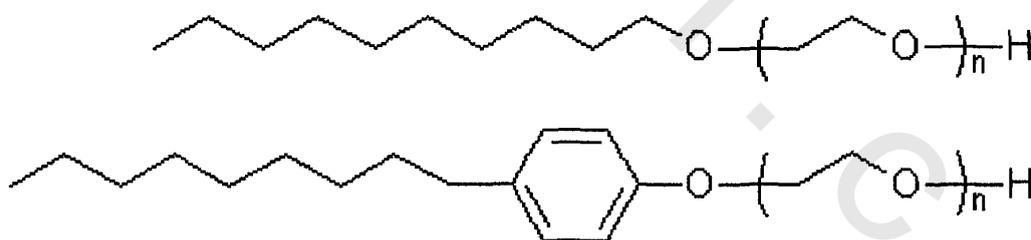
Anionics are used in greater volume than other surfactant. The estimated world wide surfactant production is two million tones

per year, out of which approximately 60% are anionic. Anionic are used in most detergent formation and the best detergency is obtained by alkyl and alkylaryl chains in the C12 –C18 rang.

The counter ion most commonly used are sodium , potassium ,ammonium ,calcium and various protonated alky amine .sodium and potassium impart water solubility whereas calcium and magnesium promote oil solubility. Amine /alkanalamin salts gives products with both oil and water solubility.

1.2.2. Non-ionic Surfactants.

Non-ionic surfactants have ether polyether or a polyhydroxyl as polar group .In the vast majority of non-ionic the polar group consists of oxyethelen unite made by the polymerization of ethelenoxid .Strictly speaking the prefixing "poly" is misnomer. The typical number of ethelenoxid unite in the polar chain is five to ten, although some surfactant e.g dispersants, often have much longer oxyethlen chain.



An alcohol ethoxylate and an alkylphenol ethoxylate

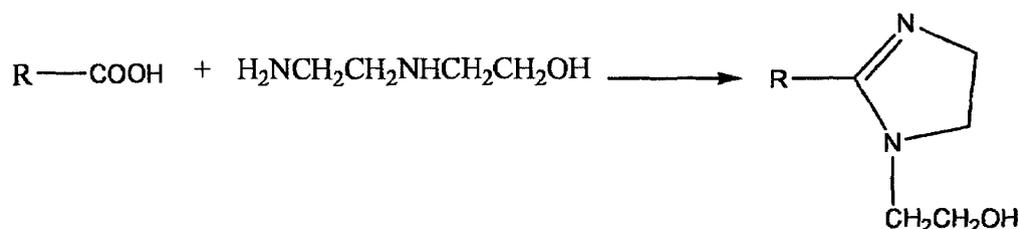
The non-ionic surfactants are normally compatible with all other type of surfactants; they are not sensitive to hard water. Contrary to ionic surfactant, their physicochemical properties are not markedly affected by electrolytes. The physicochemical

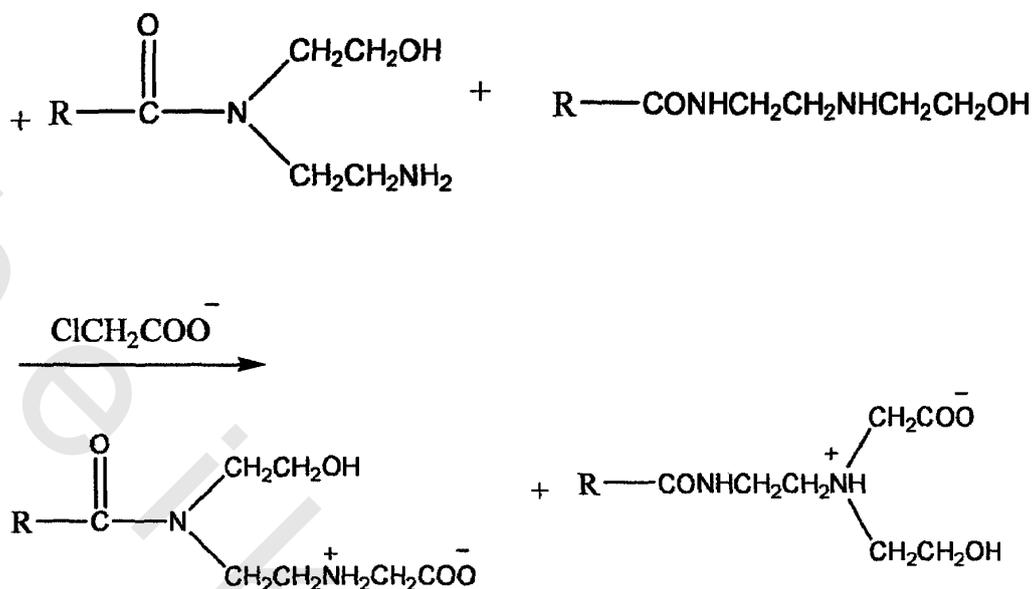
properties of ethoxylated compound very temperature dependent. Contrary to ionic compound they become less water soluble – more hydrophobic at higher temperature Sugar based non-ionic exhibit the normal temperature dependent [4].

1.2.3. Zwitterionic Surfactants.

Zwitterionic surfactants contain two charged group of different sign whereas the positive charge is almost invariably ammonium, the source of negative charge is may be vary, although carboxylat is by far the most common. Zwitterionics are often referred to as "amphoterics" but the term are not identical. An amphoteric surfactant is one that change from net cationic via zwitterionics to net anionic on going from low to high pH. Nether neither the acid nor the base site is permanently changed in the compound is zwitterionic over certain pH range.

Common type of zwitterionic surfactants are N-alkyl derivatives of simple amino acid such as glycine ($\text{NH}_2\text{CH}_2\text{COOH}$), betaine ($((\text{CH}_2)_2\text{NCH}_2\text{COOH})$) and amino proionic acid ($\text{NH}_2\text{CH}_2\text{CH}_2\text{COOH}$). Another common type of zwitterionic surfactant, usually referred to as imidazoline, is synthesized by reaction of fatty acid with aminoethylethanolamine followed by treatment with chloroacetate as shown in scheme (1). The zwitterionic surfactants are compatible with all other surfactants, they are also not sensitive to hard water [5].





Scheme (1)

1.2.4. Cationic Surfactants.

The vast majority of cationic surfactants are based on the nitrogen atom carrying the cationic charge. Both amine and quaternary ammonium based products are common. The amines only function as surfactants in the protonated state; therefore, they can not be used at high pH. Quaternary ammonium compound (quates) on the other hand is not pH sensitive. Non quaternary cationics are also more sensitive to polyvalent anions.

The following structures are for common surfactants belonging to this class.



N-Hexadecyltrimethylammonium chloride

The cationic surfactants are not compatible with anionics. The hydrolytically stable cationics show higher aquatic toxicity than most other classes of surfactants. They adsorb strongly to most surfaces and the main uses are related to in situ surface modification [6].

1.3. Characteristic Features of Surfactants.

A surfactant (surface active agent) is a molecule that, when added to a liquid at low concentration, changes its properties at surface or interface [7].

The general structure of a surfactant includes a hydrophilic portion and a hydrophobic portion as shown Fig.(1). The hydrophilic end is water soluble and is usually a polar or ionic group and the hydrophobic end is water insoluble and is usually a long fatty or hydrocarbon chain [8].

1.3.1. Adsorption.

Adsorption is the tendency for a surfactant molecule to collect at interface as shown in Fig. (2)

Adsorption is the taking up of a gas or liquid at the surface of another substance, usually a solid (for example, activated charcoal adsorbs gases). It involves molecular attraction at the surface.

The adsorption properties of surfactants mean that surfactant molecules are usually found at the interface between an oil phase and a water phase or a water phase and an air phase. This molecular property leads to the macroscopic properties of wetting, foaming, detergency and emulsion formation [9-12].

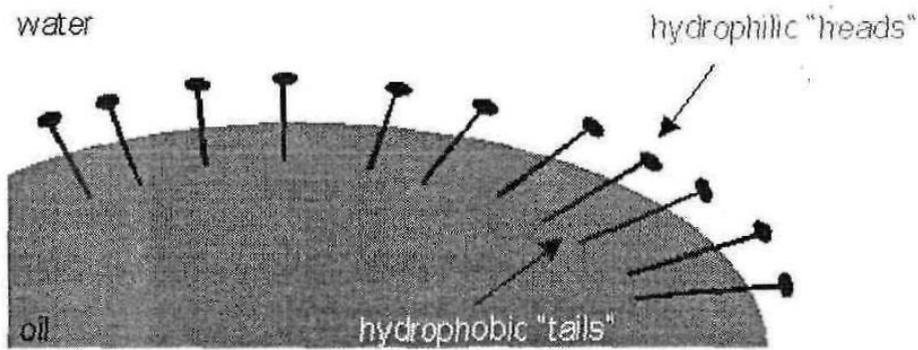


Figure (2): Surfactant molecules tend to adsorb to the surface of oil droplets. The hydrophilic heads stick out into the water phase, while the hydrophobic tails happily stick into the oil phase.

Adsorption is associated with significant energetic changes since the free energy of a surfactant molecule located at the interface is lower than that of a molecule solubilized in either bulk phase. Accumulation of amphiphiles at the interface (liquid/liquid or gas/liquid) is therefore a spontaneous process and results in a decrease of the interfacial (surface) tension [13].

1.3.2. Self-Assembly.

Surfactant molecules are composed of a polar head that is compatible with water and a non polar or hydrophobic part that is compatible with oil. This dual nature endows the Surfactants with their unique solution and interfacial characteristics. Among these, the most noteworthy is the behavior in dilute aqueous solutions, where the surfactant molecules self-assemble to form aggregates so as to achieve segregation of their hydrophobic parts from water [14]. Various molecular architectures result from this self assembly. Depending upon the type of surfactant and the solution

conditions, the aggregates may be spherical, globular, or rod like or have the structure of spherical bilayers. The closed aggregates with hydrophobic interiors are known as micelles as show in fig. (3). While the spherical bilayers containing an encapsulated aqueous phase are called vesicles.

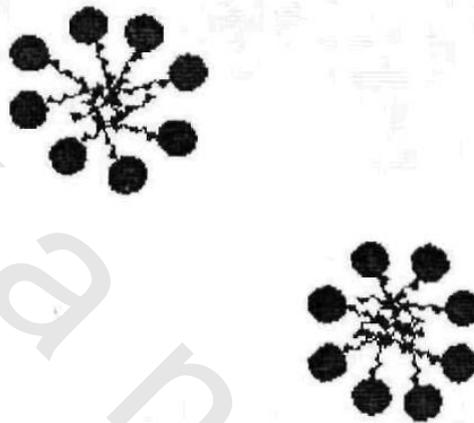


Figure (3): Surfactants can aggregate to form micelles. Forming a micelle allows the hydrophobic tails to get out of the water but still allows the hydrophilic heads to stay in the water.

1.3.3.The Micelle and Critical Micelle Concentration.

A micelle is an aggregated unit composed of a number of molecules of a surface active material as shown in the drawing in Fig. (3). Micelles solubilize dirt and oils by lifting these species of the surface and dispersing them into solution. Micelle formation enables emulsification, solubilization, and dispersion of otherwise non-compatible materials [15]. Critical micelle concentration (CMC) is the concentration of an amphiphilic component in solution at which the formation of aggregates (micelles, round rods, lamellar structures etc.) in the solution is initiated [16-17].

Critical micelle concentration (CMC) is a measure of surfactant efficiency. A lower CMC indicates less surfactant is needed to saturate interfaces and form micelles. Typical CMC values are less than 1% by weight (e.g., TRITON X-100 Surfactant has a CMC of 0.0130%). To obtain optimal cleaning performance, concentrations of 1-5% are common. This concentration is higher than that needed to achieve micelle formation; therefore, providing a reservoir of additional surfactant molecules to form micelles. These micelles solubilize and disperse species leading to detergency [18-20]. CMC values provide a valuable guideline for comparing surfactant detergency. Other formulation components and temperature may affect micelle formation.

All surfactants possess the common property of lowering surface tension when added to water in small amounts. The characteristic discontinuity in the plots of surface tension against surfactant concentration can be experimentally determined. The corresponding surfactant concentration at this discontinuity corresponds to the critical micelle concentration (CMC), see Fig. (4).

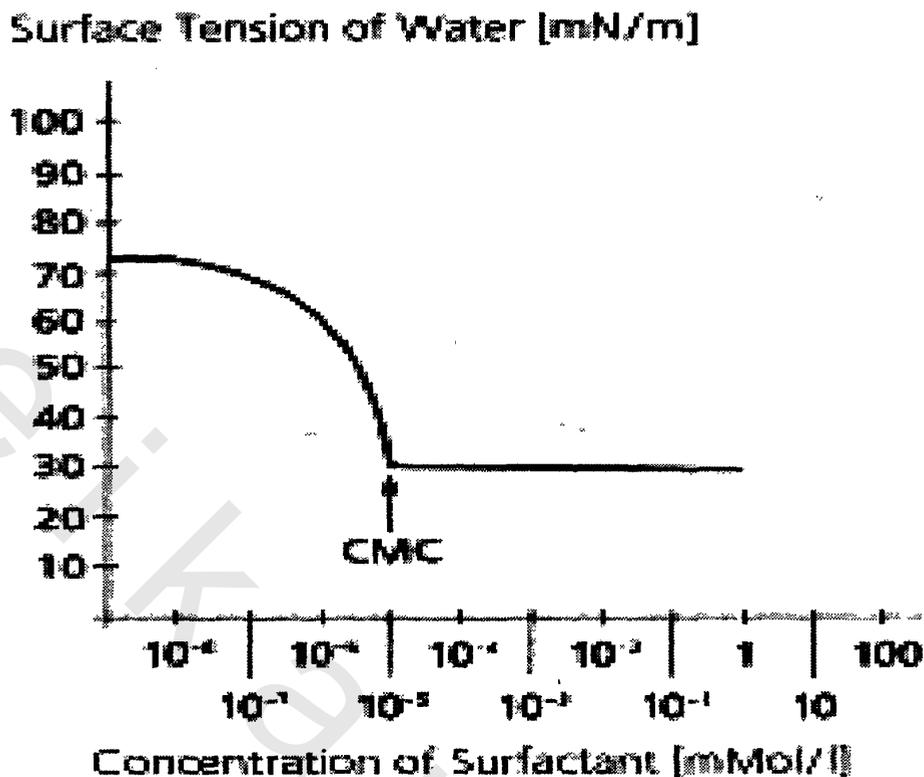


Figure (4): Typical decrease of the surface tension of water by surfactants.

At surfactant concentrations below the CMC, the surfactant molecules are loosely integrated into the water structure (monomer see Fig. (5)). In the region of the CMC, the surfactant water structure is changed in such a way that the surfactant molecules begin to build up their own structures micelles in the interior and monolayers at the surface, as shown in Fig. (5).

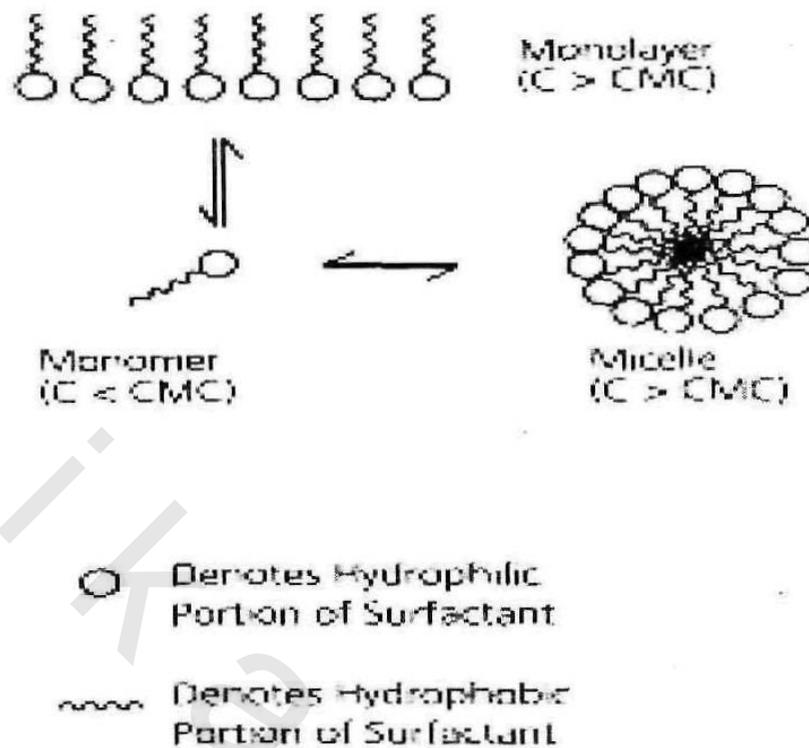


Figure (5): Equilibrium between the surfactant monomer, surface mono layers and micelle in an aqueous medium.

The micelle existed in solution in different forms [21] as shown Fig. (6).

The various forms of micelle can be illustrated as follow:

- (a) Spherical micelles with an interior composed of the hydrocarbon chains and a surface of the polar head groups (pictured as spheres) facing water. Spherical micelles are characterized by a low surfactant number and a strongly positive spontaneous curvature. The hydrocarbon core has a radius close to the length of the extended alkyl chain.

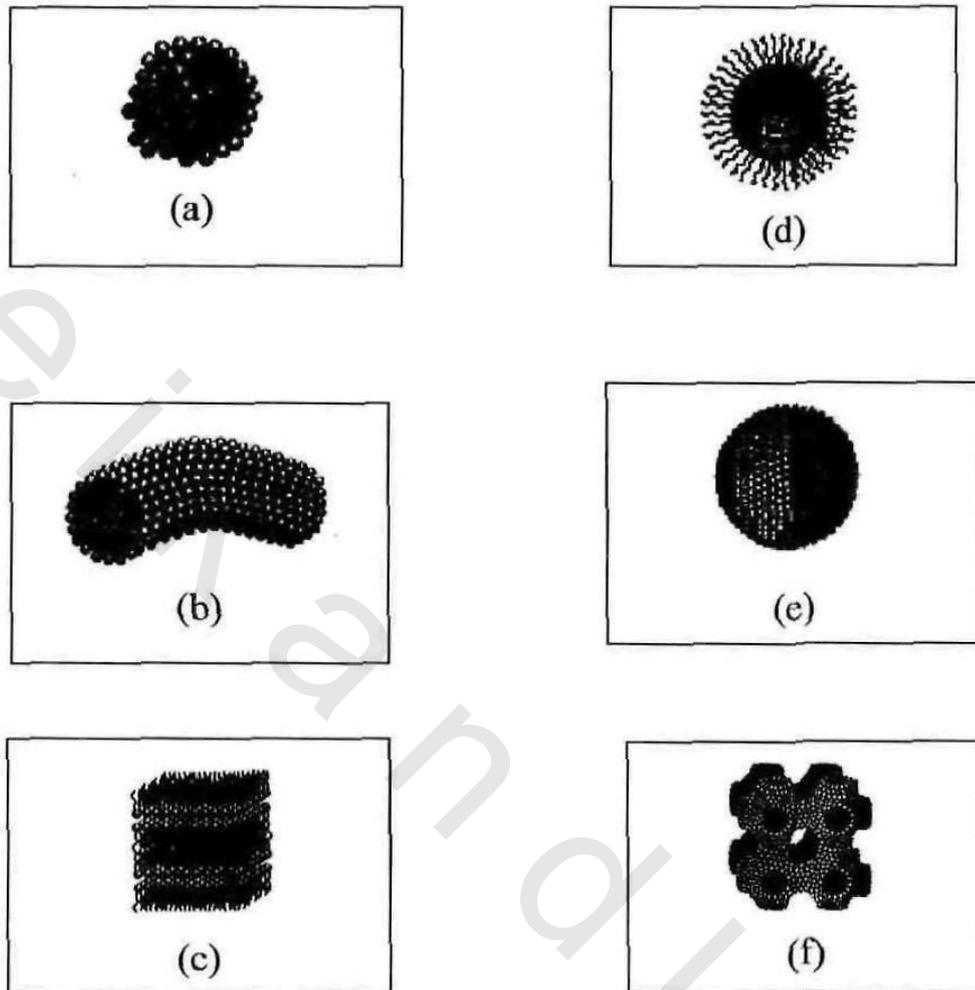


Figure (6): Surfactant self-assembly leads to different shape.

- (b) Cylindrical micelles with an interior composed of the hydrocarbon chains and a surface of the polar head groups (pictured as spheres) facing water. The cross-section of the hydrocarbon core is similar to that of spherical micelles. The micelles length is highly variable so that micelles are poly disperse.
- (c) Surfactant bilayers which build up lamellar liquid crystals have for surfactant-water systems a hydrocarbon core with

thickness of 80% of the length of two the extended alkyl chains.

- (d) Reversed or inverted micelle has a water core surrounding surfactant polar head groups [22]. The alkyl chains together with a non-polar solvent make up the continuous medium.
- (e) Vesicles are built from bilayers similar to those of the lamellar phase and are characterized by two distinct water compartments, one forming the core and the other the external medium. Vesicles may have different shapes and there are reversed-type vesicles.
- (f) A bicontinuous structure with the surfactant molecules aggregated into connected films characterized by two curvatures of opposite sign. The mean curvature is small (zero for minimal surface structure).

The most complete listing of critical micelle concentrations found in the United States Department of Commerce Publication [23].

One class of additives is proteins. Their interaction with surfactant systems has received increasing attention in recent years, both for normal [24] and reversed micelles [25].

1.4. Corrosion and Corrosion Inhibitors.

1.4.1. Definition of Corrosion.

The word corrosion stands for material or metal deterioration or surface damage in an aggressive environment. Corrosion is a chemical or electrochemical oxidation process, in which the metal transfers electrons to the environment and undergoes a valence change from zero to a positive value.

The environment may be a liquid, gas or hybrid soil-liquid. These environments are called electrolytes since they have their own conductivity for electron transfer.

An electrolyte is analogous to a conductive solution, which contains positively and negatively charged ions called cations and anions, respectively. An ion is an atom that has lost or gained one or more outer electron (e) and carries an electrical charge. Thus, the corrosion process which can be chemical in nature or electrochemical due to a current flow requires at least two reactions that must occur in a particular corrosive environment. These reactions are classified as anodic and cathodic reactions and are defined below for a metal M immersed in sulfuric acid solution as an example. Hence, metal oxidation occurs through an anodic reaction and reduction is through a cathodic reaction as shown below.



Where M = metal

M^{+z} = metal cation

H^{+} = hydrogen cation

z = valance oxidation state

The interpretation of the above equations indicates that an anodic reaction, which is equivalent to what is known as oxidation, loses metal electrons and the cathodic reaction accepts or gains electrons for reducing pertinent ions [26]. Consequently, both anodic and cathodic reactions are coupled in a corrosion process. Adding eqs. (1) and (2) yields eq. (3). Thus, REDOX

(RED = reduction and OX = oxidation) is the resultant reaction equation, eq. (3), and represents the overall reaction at equilibrium where the anodic and cathodic reaction rates are equal. Observe that the anodic reaction is also referred to as an oxidation reaction since it has lost electrons, which has been gained by the cathodic reaction. Thus; a cathodic reaction is equivalent to a reduction reaction.

1.4.2. Corrosion Types.

There is not a unique classification of the corrosion types, but the following classification is the more acceptable.

1.4.2.1 . General Corrosion.

This is the case when the exposed metal/alloy surface area is entirely corroded in an environment such as a liquid electrolyte (chemical solution, liquid metal), gaseous electrolyte (air, CO₂ and SO₂ etc.), or a hybrid electrolyte (solid and water, biological organisms, etc.). Some types of general corrosion and their description are given below [27].

Atmospheric Corrosion on steel tanks, steel containers, parts, Al plates, etc.

Galvanic Corrosion between dissimilar metal/alloys or microstructural phases (pearlitic steels, copper alloys and lead alloys).

High temperature corrosion on carburized steels that forms a porous scale of several iron oxide phases.

Liquid metal corrosion on stainless steel exposed to a sodium chloride (NaCl) environment.

Molten salt corrosion on stainless steels due to molten fluorides (LiF and BeF₂, etc.).

Biological corrosion on steel,

Atmospheric Corrosion.

This is a uniform and general attack, in which the entire metal surface area exposed to the corrosive environment is converted into its oxide form, provided that the metallic material has a uniform microstructure.

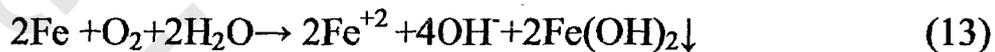
Aqueous corrosion of iron (Fe) in H₂SO₄ solution and of Zn in diluted solution are examples of uniform attack since Fe and Zn can dissolve (oxidize) at a uniform rate according to the following anodic and cathodic reactions, respectively [28].



Where H₂ is hydrogen gas. The cathodic reaction is the common hydrogen evolution process. In fact, the aggressiveness of a solution to cause a metal to oxidize can be altered by additions of water, which is an amphoteric compound because it can act as an acid or base due to its dissociation as indicated below



Atmospheric corrosion of a steel structure is also a common example of uniform corrosion, which is manifested as a brown-color corrosion layer on the exposed steel surface. This layer is a ferric hydroxide compound known as Rust. The formation of Brown Rust is as follows



Where $2\text{Fe}(\text{OH})_2$ = Ferroushydroxide (unstable compound)

$2\text{Fe}(\text{OH})_3 \cdot 3\text{H}_2\text{O}$ = Hydrated Ferric hydroxide

\downarrow = The compound precipitates as a solid

Galvanic Corrosion.

Galvanic corrosion is either a chemical or an electrochemical corrosion. The latter is due to a potential difference between two different metals connected through a circuit for current flow to occur from more active metal (more negative potential) to the more noble metal (more positive potential).

The galvanic corrosion can be predicted by using the electromotive force (EMF) or standard potential series for metal reduction. These reactions are reversible. The standard metal potential is measured against the standard hydrogen electrode (SHE), which is a reference electrode having an arbitrary standard potential equals to zero.

In selecting two metals or two alloys for a galvanic coupling, both metals should have similar potentials or be close to each other in the series in order to suppress galvanic corrosion. For example, Fe-Cr or Cu -Sn (bronze) couplings develop a very small potential differences since they are close to each other in their respective standard potential series. The closer the standard potentials of two metals the weaker the galvanic effect; otherwise, the galvanic effect is enhanced [29].

Eventually, galvanic coupling can be used for cathodic protection purposes. In fact, in coupling two different metals the metal with the lowest standard potential acts as the anode and its standard potential sign is changed.

1.4.2.2 Localized Corrosion.

This term implies that specific parts of an exposed surface area corrodes in a suitable electrolyte. This form of corrosion is more difficult to control than general corrosion. Localized corrosion can be classified as [30]

Crevice corrosion which is associated with a stagnant electrolyte such as dirt, corrosion product, sand, etc. It occurs on metal/alloy surface holes, underneath a gasket, lap joints under bolts, under rivet heads.

Filiform corrosion is basically a special type of crevice corrosion, which occurs under a protective film. It is common on food and beverage cans being exposed to the atmosphere.

Pitting corrosion is an extremely localized corrosion mechanism that causes destructive pits.

Oral corrosion occurs on dental alloys exposed to saliva.

Biological corrosion due to fouling organisms non-uniformly adhered on steel in marine environments.

Selective leaching corrosion is a metal removal process from the base alloy matrix, such as dezincification (Zn is removed) in alloys and graphitization (Fe is removed) in cast irons.

1.4.3. The Methods Used for Corrosion Protection Studies:

There are different techniques which can be used to determine the corrosion rate.

1.4.3.1. Weight Loss:

(a)-Directly by measuring the loss of weight sample due to its corrosion

(b)-indirectly by monitoring the free ion in solution (Fe_2O_4) by titrating against $\text{K}_2\text{Cr}_2\text{O}_7$

1.4.3.2. Gasometry

In most corrosion processes either (H_2) or (O_2) is evolved and can be used as measure for corrosion. It is generally detected by collecting the gas over aqueous solution and the volume of the collected gases read directly.

1.4.3.3. Polarization technique.

The polarization resistance (R_p) of a metal/electrolyte system and the pitting or breakdown potential (E_b) can be determined using at least two-electrode system [31]. Subsequently, the rate of metal dissolution or corrosion rate is calculated using a function of the form $i_{\text{corr}} = f(\beta, R_p) \cdot i_0$. The methods are

a. Linear Polarization.

The linear polarization is confined to a small magnitude of the overpotentials η_a and η_c respectively, using linear coordinates.

This technique allows the determination of i_{corr} using a potential range of ± 10 mV from the E_{corr} [32]. Prior to determining the polarization resistance is estimated from the linear slope of the curve as

$$R_p = \Delta E / \Delta i \quad (15)$$

b. Tafel Extrapolation.

This method involves the determination of the Tafel slopes b_a and b_c as well as E_{corr} and i_{corr} from a single polarization curve. This curve is known as the Stern diagram (non-linear polarization). This non-linear curve is divided into two parts. If $E > E_0$ the upper curve represents an anodic polarization behavior for oxidation of the metal M. On the contrary, if $E < E_0$ the lower curve is a cathodic polarization for hydrogen reduction as molecular gas (hydrogen evolution). Both polarization cases deviate from the electrochemical equilibrium potential (E_{corr}) due to the generation of anodic and cathodic overpotentials [33]. Both anodic and cathodic polarization curves exhibit small linear parts known as Tafel lines, which are used for determining the Tafel slopes b_a and b_c diagram. These slopes can be determined using either the Evans or Stern diagram.

Extrapolating the Tafel or Evans straight lines until they intersect define the $E_{\text{corr}}, i_{\text{corr}}$ point.

1.4.3.4. Electrochemical Impedance Spectroscopy.

The electrochemical impedance spectroscopy (EIS) technique is very useful in characterizing an electrode corrosion behavior. The electrode characterization includes the determination of the

polarization resistance (R_p) corrosion rate and electrochemical mechanism [34-38]. The usefulness of this method permits the analysis of the alternating current (AC) impedance data, which is based on modeling corrosion process by an electrical circuit. Several review papers address the electrochemical impedance technique based on the alternating current (AC) circuit theory [39-42].

Electrochemical impedance is usually measured by applying an AC potential to an electrochemical cell and measuring the current through the cell. Assume that we apply a sinusoidal potential excitation. The response to this potential is an AC current signal. This current signal can be analyzed as a sum of sinusoidal functions (a Fourier series).

Electrochemical Impedance is normally measured using a small excitation signal. This is done so that the cell's response is pseudo-linear. In a linear (or pseudo-linear) system, the current response to a sinusoidal potential will be a sinusoid at the same frequency but shifted in phase.

The excitation signal, expressed as a function of time, has the form

$$E_t = E_0 \sin(\omega t) \quad (16)$$

E_t is the potential at time t , E_0 is the amplitude of the signal, and ω is the radial frequency. The relationship between radial frequency ω (expressed in radians/second) and frequency f (expressed in hertz) is:

$$\omega = 2\pi f \quad (17)$$

In a linear system, the response signal, i_t , is shifted in phase (ϕ) and has a different amplitude, i_0

$$i_t = i_0 \sin(\omega t + \phi) \quad (18)$$

An expression analogous to Ohm's Law allows us to calculate the impedance of the system as:

$$Z = i_t / E_t = E_0 \sin(\omega t) / i_0 \sin(\omega t + \phi) = Z_0 \sin(\omega t) / \sin(\omega t + \phi) \quad (19)$$

The impedance is therefore expressed in terms of a magnitude, Z_0 , and a phase shift, ϕ .

1.4.4. Corrosion Inhibitors.

Corrosion of metallic surfaces can be reduced or controlled by the addition of chemical compounds to the corrodent. This corrosion control is called inhibition and the compounds added are known as corrosion inhibitors. These inhibitors will reduce the rate of either anodic oxidation or cathodic reduction, or both. The inhibitors themselves form a protective film on the surface of the metal. It has been postulated that the inhibitors are adsorbed into the metal surface either by physical (electrostatic) adsorption or chemisorption [43-46].

Physical adsorption is the result of electrostatic attractive forces between the organic species and the electrically charged metal surface. Chemisorption is the transfer, or sharing of the inhibitor molecule's charge to the metal surface, forming a coordinate-type bond. The adsorbed inhibitor reduces the corrosion rate of the metal surface either by retarding the anodic dissolution reaction of the metal by the cathodic reaction, or both. Inhibitors can be used

at pH values of acid from near neutral to alkaline. They can be classified in many different ways according to

1. Their chemical nature (organic or inorganic substances)
2. Their characteristics (oxidizing or nonoxidizing compounds)
3. Their technical field of application (pickling, descaling, acid cleaning, cooling water systems, and the like)

1.4.5. Classification of Inhibitors

Inhibitors can be classified in several ways as previously indicated. The inhibitors will be classified as following:

1. Passivation inhibitors
2. Organic inhibitors
3. Precipitation inhibitors

Passivation Inhibitors.

Passivation inhibitors are chemical oxidizing materials such as chromate $K_2Cr_2O_7$ and nitrite KNO_2 or substances such as Na_3PO_4 or $NaBrO_7$. These materials favor adsorption on the metal surface. These are the most effective and, consequently, the most widely used type of inhibitors [47].

Organic Inhibitors

These materials build up a protective film of adsorbed molecules on the metal surface that provide a barrier to the dissolution of the metal in the electrolyte. Since the metal surface covered is proportional to the inhibitor concentration, the concentration of the inhibitor in the medium is critical [48].

Precipitation Inhibitors

Precipitation inhibitors are compounds that cause the formation of precipitates on the surface of the metal, thereby, providing a protective film. Hard water that is high in calcium and magnesium is less corrosive than soft water because of the tendency of the salts in the hard water to precipitate on the surface of the metal and form a protective film.

1.5. Literature survey

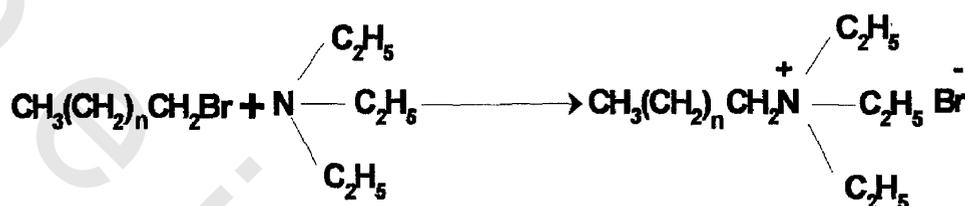
Nabel.A.Negm and Ismail.A.Aiad [49] prepared a series of cationic surfactants using economical raw materials. The chemical structures of the prepared compounds were confirmed using elemental analysis, FTIR and $^1\text{H-NMR}$ spectra, and melting point determination. The synthesized surfactants were evaluated as oil-field protective additives. In this regard, several surface properties of the synthesized surfactants were studied including surface tension, critical micelle concentration, effectiveness, efficiency, maximum surface excess and minimum surface area. The results obtained from the surface activity measurements were correlated to their chemical structures. The emulsification power measurements for solutions of these surfactants showed their low emulsifying tendency towards paraffin and crude oil. The synthesized surfactants also exhibited high biocidal activity towards gram-positive and gram-negative bacteria and fungi. This activity was increased by increasing the hydrophobic chain length. The corrosion inhibition measurement of these surfactants for mild steel alloys in acidic media using a weight loss technique showed good protection of mild steel alloys against acidic environments. These properties qualify the synthesized compounds as economical oil-field protective additives.

Ismail Aiad and Nabil Nigm[50] prepared two series of Schiff base amphiphiles throughout condensation of benzaldehyde or anisaldehyde and three different fatty amines with various alkyl chain length; namely: dodecyl, hexadecyl and octadecyl amine. The chemical structures of the prepared schiff

bases were confirmed using elemental analysis, FTIR and $^1\text{H-NMR}$ spectra. The data of structural analysis for these compounds were confirmed the chemical structures and the purity of the synthesized amphiphiles. The synthesized Schiff base amphiphiles were evaluated as corrosion inhibitors for low carbon steel (mild steel) in various acidic media (HCl and H_2SO_4) using weight loss technique. The corrosion inhibition measurements of these inhibitors showed high protection of the low carbon steel alloys against corrosion process in the tested acidic media at different periods as well as they have good biocidal effect against SRB. The discussion was correlated the efficient corrosion inhibition of these inhibitors to their chemical structures.

Hassan A. Shehata et al., [51] prepared cationic surfactants were evaluated as multifunctional compounds (corrosion inhibitors and biocides) the prepared materials are decyl, dodecyl, hexadecyl and octadecyl triethyl ammonium bromide. The inhibitor concentration was ranging from 0 up to $40 \times 10^{-4} \text{M}$ in 0.5 M H_2SO_4 and the solution temperature is ranging from 25 up to 55°C . The results indicate that the biocidal activity of the tested surfactants increased towards gram positive, gram-negative and fungi, so these compounds can be used as bacteriostatic and bactericidal; it was found also that the efficiency increases as increasing the hydrophobic part. The corrosion inhibition measurements of these surfactants showed that they have higher tendency towards protection of mild steel alloys against acidic environments. The thermodynamic parameters of adsorption mainly; standard free energy ΔG° , enthalpy ΔH° , and entropy ΔS°

were calculated. The results obtained from surface measurements, biological activity and polarization technique qualified the synthesized cationic surfactants to be applicable as multifunctional compounds.



$n = 8, 10, 14$ and 16

Dorna Asefi et al.[52] studied the corrosion inhibition effect of cationic surfactants, DTAB (Dodecyl Trimethyl Ammonium Bromide) and TTAB (Tetradecyl Trimethyl Ammonium Bromide), on low carbon steel was studied using weight loss, open circuit potential (OCP) and electrochemical impedance spectroscopy (EIS) measurements. The effect of chain length compatibility on corrosion inhabitancy of surfactant and co-surfactant was investigated by C_7OH (1-heptanol), C_{12}OH (1-dodecanol) and C_{15}OH (1-pentadecanol) as nonionic co-surfactants in acidic media at different concentrations of DTAB and TTAB. Data represented that the corrosion rate decreased by increasing concentration of DTAB and TTAB, independently. The effect of chain length compatibility on surfactant behavior was discussed. Decreasing of corrosion rate for DTAB + C_{12}OH was more pronounced than other mixtures.

Everlane Ferreira Moura et al., [53] examined the anticorrosion ability of three novel surfactant molecules synthesized from ricinoleic acid, a castor oil derivative. The surfactants are: sodium 12-N,N-diethylamino-9-octadecenoate (AR1S), sodium 12-N,N-diethylamino-9,10-dihydroxy-octadecanoate (AE2S) and sodium 12-N,N-diethylamino-9-octadecanoate (AE1S). Their ability to inhibit corrosion in AISI 1010 carbon-steel has been investigated by preparing specific micellar solutions and microemulsion systems. Adsorption phenomena have been electrochemically studied with the Frumkin model, indicating that the surfactant solutions tested can inhibit corrosion with levels as high as 95%. On the other hand, the microemulsion systems, although featuring relatively lower performance, are advantageous in that they are able to dissolve more active matter. These results are useful as a basis to propose and study particular applications such as the transport of oil in petrochemical industries.

M.A. Migahed et al., [54] synthesized dodecylcysteine hydrochloride surfactant. The surface properties of this surfactant were studied using surface tension technique. The nanostructure of this surfactant with the prepared gold nanoparticles was investigated using TEM technique. The synthesized surfactant and its nanostructure with the prepared gold nanoparticles were examined as non-toxic corrosion inhibitors for carbon steel in 2 M HCl solution using potentiodynamic polarization and electrochemical impedance spectroscopy techniques. The results show that the percentage inhibition efficiency for each inhibitor

increases with increasing concentration until critical micelle concentration (CMC) is reached. The maximum inhibition efficiency approached 76.6% in the presence of 175 ppm of dodecylcysteine and 90.8% in the presence of the same concentration of dodecylcysteinehydrochloride self-assembled on gold nanoparticles. Polarization data indicate that the selected additives act as mixed type inhibitors. The slopes of the cathodic and anodic Tafel lines (bc and ba) are approximately constant and independent of the inhibitor concentration. Analysis of the impedance spectra indicates that the charge transfer process mainly controls the corrosion process of carbon steel in 2 M HCl solution both in absence and presence of the inhibitors. Adsorption of these inhibitors on carbon steel surface is found to obey the Langmuir adsorption isotherm. From the adsorption isotherms the values of adsorption equilibrium constants (K_{ads}) were calculated. The relatively high value of (K_{ads}) in case of dodecylcysteinehydrochloride self-assembled on gold nanoparticles reveals a strong interaction between the inhibitor molecules and the metal surface.

M.A. Hegazy[55] investigated the corrosion inhibition characteristics of the synthesized cationic gemini surfactants, namely bis(p-(N,N,N-decyldimethylammonium bromide)benzylidene thiourea (10-S-10), bis(p-(N,N,N-odecyldimethylammoniumbromide)benzylidene thiourea(12-S-12) and bis(p-(N,N,N-tetradecyldimethylammonium bromide)benzylidene thiourea (14-S-14) on the carbon steel corrosion in 1 M hydrochloric acid at 25 °C by weight loss,

potentiodynamic polarization and electrochemical impedance spectroscopy (EIS) techniques. The inhibition efficiencies obtained from all methods employed are in good agreement with each other. The obtained results show that compound 14-S-14 is the best inhibitor with an efficiency of 97.75% at 5×10^{-3} M additive concentration. Generally, the inhibition efficiency increased with increase of the inhibitor concentration. Changes in impedance parameters (charge transfer resistance, R_{ct} , and double-layer capacitance, C_{dl}) were indicative of adsorption of 14-S-14 on the metal surface, leading to the formation of a protective film. The potentiodynamic polarization measurements indicated that the inhibitors are of mixed type. The adsorption of the inhibitors on the carbon steel surface in the acid solution was found to obey Langmuir's adsorption isotherm. The free energy of adsorption processes were calculated and discussed. The surface parameters of each synthesized surfactant were calculated from its surface tension including the critical micelle concentration (CMC), maximum surface excess (Γ_{max}) and the minimum surface area (A_{min}). The free energies of micellization (ΔG_{mic}^0) were calculated. The surface morphology of carbon steel sample was investigated by scanning electron microscopy (SEM).

W.J. Soer et al., [56] obtained surfactant-free latexes from anhydride-containing polymers, including poly(styrene-alt-maleic anhydride) (PSMA), maleinized polybutadiene (PBDMA), and poly(octadecene-alt-maleic anhydride) (POMA). The barrier property of these coatings was studied with electrochemical

impedance spectroscopy in NaCl solutions on pretreated aluminum substrates. PSMA and PBDMA-based coatings demonstrated good barrier property, indicated by the absence of corrosion after 1-month immersion in NaCl solutions, which was comparable to that of a commercially available polyester coating. The polyester coating, however, was found to hydrolytically degrade when immersed in a NaCl solution, which was not observed for these latex-based coatings. The POMA-based coating showed inferior barrier property on un-pretreated aluminum, likely due to inhomogeneous film formation and poor adhesion to the substrate, but the adhesion could be improved by an alkali pretreatment of the substrate. In comparison, PBDMA and PSMA-based coatings showed much better adhesion toward the aluminum substrates. The anti-corrosion behavior appeared to be closely related to both the barrier and adhesion properties of the coatings on the metal substrate.

R. Fuchs-Godec [57] investigated the corrosion inhibition characteristics regarding mixtures of cationic/zwitterionic types of surfactant (Myristyltrimethylammonium bromide/Palmitylsulfo-betaines), and non-ionic surfactant TRITON-X-405 mixed with 1 mM of KBr, as corrosion inhibitors for stainless steel (SS) (type X4Cr13) in aqueous solutions of 2 M H_2SO_4 using potentiodynamic polarization measurements. The polarization data showed that mixtures of the surfactants used in this study acted as mixed-type inhibitors, adsorbing on the stainless steel surface in agreement with the Flory–Huggins adsorption isotherm. The tensiometric results of this study suggest the

existence of a second state of aggregation for zwitterionic/cationic surfactant mixtures. From these values of the free energy of adsorption, which in both mixtures decreased with respect to a single surfactant, they concluded that the adsorption in mixtures was stronger. The mixtures studied here showed good inhibition properties for ferritic stainless steel type X4Cr13 in 2 M H₂SO₄ solution.

O. Zubillaga et al., [58] electrochemically synthesized anodic alumina films containing polyaniline and either TiO₂ or ZrO₂ nanoparticles on an AA2024T3 Aluminum alloy by a single step anodizing procedure in an oxalic acid electrolyte. The morphology and composition of the films were examined by SEM, TEM, GDOES and XPS. The resultant coatings, of thickness about 2.2 μm, displayed a nanoparticle -rich layer in the near surface-regions, of thickness in the range 100–250 nm. Potentiodynamic polarization behavior revealed that the polyaniline and TiO₂-containing films on the AA2024T3 Aluminum alloy show a passive current density two orders of magnitude lower than for films with ZrO₂ nanoparticles and films without nanoparticles. The coatings with TiO₂ nanoparticles, but without polyaniline, showed intermediate behavior, with a passive current density one order of magnitude lower than the coatings with polyaniline and TiO₂ nanoparticles. The improved barrier protection offered by the TiO₂ nanoparticle containing coatings is attributed to the presence of the nanoparticle-rich layer formed on the outer part of the coating that blocks access to the pores of the anodic alumina film.

Sayed S. Abd El Rehim et al., [59] reported the results of potentiodynamic polarization and electrochemical impedance spectroscopic (EIS) measurements on the corrosion inhibition of Al (Al-2.5% Cu and Al-7.0% Cu) alloys in 1.0 M H₂SO₄ solution carried out in different concentrations of linear-sodium dodecyl benzene sulfonate as an anionic surfactant (LAS) and temperature range from 10 to 60 °C. The data revealed that the inhibition efficiency increases with increasing surfactant concentration and time of immersion, and decreases with solution temperature. Energy dispersion X-ray (EDX) observations of the electrode surface confirmed the existence of (LAS)adsorbed film on the electrode surface. The surfactant acted mainly as cathodic inhibitor. Maximum inhibition efficiency of the surfactant is observed at concentration around its critical micelle concentration (CMC). The inhibition occurs through adsorption of the surfactant on the metal surface without modifying the mechanism of the corrosion process, which tested by UV-spectroscopy. The potential of zero charge (PZC) of aluminum and Al-7.0% Cu was studied by ac-impedance, and the mechanism of adsorption is discussed. The adsorption isotherm is described by Temkin adsorption isotherm. Thermodynamic functions for activation and adsorption process were determined

Yiwei Ren, et al., [60] obtained lignin terpolymer by grafting copolymerization of both dimethyl diallyl ammonium chloride (DMDAAC) and Acrylamide (AM) onto lignin. The corrosion inhibition properties of the terpolymer were tested. The results showed that the highest corrosion inhibition percentage was over

95% in 10% HCl acid medium at 25 °C and 80 °C. The lignin terpolymer inhibitor adsorption followed Temkin isotherm at 25 °C and 80 °C, and the adsorption capability was in reverse proportion to the temperature according to $-\Delta G_{\text{ads}}$. The effects of corrosion inhibition are the comprehensive synergistic effect through the graft reaction among lignin, (AM) and (DMDAAC).

Abdelkader Laatiris, et al., [61] synthesized Some α,ω -alkanediylbis(dimethylammonium bromide) compounds (gemini surfactants) referred as “*m-s-m*”, then purified and characterized by usual spectroscopic methods. These compounds have been screened for antibacterial activity against *Escherichia coli*, *Pseudomonas aeruginosa* and *Staphylococcus aureus*. Their activity was compared. The compounds tested showed excellent in vitro antibacterial activity against *Staphylococcus aureus* ranging from 1.5 to 20 $\mu\text{g/ml}$ and had variable activity against *E. coli* with minimum inhibitory concentration (MIC) of 50 $\mu\text{g/ml}$. These compounds are less active against *P. aeruginosa*. On the other hand, contrary to the antibacterial activity of these products against *S. aureus*, a relation between the MIC and the critical micellar concentration (CMC) was found and relationship between chain's length and antibacterial activity was found.

Xianghong Li et al., [62] Studied the synergistic inhibition effect of rare earth cerium(IV) ion and anionic surfactant of sodium oleate(SO)($\text{C}_{17}\text{H}_{33}\text{COONa}$), on the corrosion of cold rolled steel (CRS) in H_2SO_4 solution by weight loss and potentiodynamic polarization methods. The results revealed that SO had a moderate inhibitive effect, and the adsorption of SO

obeyed the Freundlich adsorption isotherm. For the cerium (IV) ion, it had a negligible effect. However, incorporation of Ce^{4+} with SO significantly improved the inhibition performance, and produced strong synergistic inhibition effect. Depending on the results, the synergism mechanism was proposed.

F. Kellou-Kerkouche et al., [63] studied the influence of sodiumdodecylbenzenesulfonate (SDBS) on the corrosion behavior of an elaborated annealed Fe-1Ti-20C alloy presenting a cementite phase (Fe_3C), in 0.5 M H_2SO_4 solution using electrochemical techniques. The results showed that this anionic surfactant inhibits the sulfuric acid corrosion of the ternary alloy. The inhibition occurs through adsorption of the surfactant on the metal surface without modifying the mechanism of corrosion process. The studied surfactant acts predominately as cathodic inhibitor by blocking effect on the cementite cathodic sites. The inhibition efficiency increases with increasing surfactant concentrations and decreases with increasing temperature. Maximum inhibition is observed at concentration above its critical micelle concentration (CMC). Temkin adsorption isotherm fit well with the experimental data.

F.G. Liu et al., [64] studied the electrochemical behavior of carbon steel in saltwater saturated with CO_2 with/without an new synthesized imidazoline inhibitor using polarization and electrochemical impedance spectrum (EIS), and the inhibitive ability of the inhibitor was evaluated by weight-loss method in 298–328 K temperature range. Results showed that the inhibition efficiency is up to above 80%, and imidazoline is a kind of mixed

type inhibitor. It was seen that the adsorption of imidazoline on Q235 steel can be fitted to Frumkin isotherm equation. Quantum chemistry calculation results show that the imidazoline ring and heteroatoms are the active sites of the inhibitors

Jui-Ming Yeh, et al., [65] evaluated the corrosion protection effect of waterborne polyurethane (WPU)/Na⁺-montmorillonite (Na⁺MMT) clay nanocomposite coating. Typically, a series of waterborne polyurethane (WPU)/Na⁺montmorillonite (Na⁺MMT) clay nanocomposite materials have been successfully prepared by effectively dispersing the inorganic nanolayers of commercially purified Na⁺MMT clay in WPU matrix through direct aqueous solution dispersion technique. First of all, WPU was prepared by polymerizing PCL, DMPA and H₁₂MDI, followed by characterized by nuclear magnetic resonance (¹H NMR), Fourier transform infrared (FTIR) and gel permeation chromatography (GPC). Subsequently, the as-prepared PU/Na⁺MMT clay nanocomposite (Na⁺PCN) materials were subsequently characterized by FTIR, X-ray diffraction (XRD) patterns and transmission electron microscopy (TEM). PCN materials in the form of coating at low Na⁺MMT clay loading up to 3 wt% coated on the cold rolled steel (CRS) coupons were found to exhibit superior corrosion protection effect over those of neat WPU based on a series of electrochemical measurements of corrosion potential, polarization resistance, corrosion current and impedance in 5 wt% aqueous NaCl electrolyte.

Katerina Bílková and Egil Gulbrandsen [66] investigated the kinetics of the corrosion inhibition of carbon dioxide (CO₂) on high purity iron (Fe) electrodes by cetyltrimethyl ammonium bromide (CTAB) in order to elucidate the mechanism of inhibition. The test condition was: 25 °C, 3 wt.% NaCl brine, pH 4, 1 bar CO₂ partial pressure. The inhibition process was studied by electrochemical methods and by X-ray photoelectron spectroscopy (XPS). The inhibition was found to be a combination of two processes: first a rapid process (order of minutes) connected to diffusion limited adsorption of the inhibitor, leading to the inhibition of the anodic part reaction, and a second slower process (order of hours) leading to a reduction in the corrosion rate.

Ling-Guang Qiu et al., [67] investigated the inhibitive synergistic effect between a cationic gemini surfactant, 1,3-propane-bis(dimethyldodecylammonium bromide) (12-3-12), and bromide ion for the corrosion inhibition of cold rolled steel in 0.5 mol L⁻¹ H₂SO₄ by weight loss, potentiodynamic polarization method and electrochemical impedance spectroscopy (EIS). The inhibition system composed by 12-3-12 and bromide ion is efficient. The adsorption mechanism of the 12-3-12 and bromide ion on steel in acidic medium is discussed on the basis of experimental data and an adsorption model is proposed. Adsorption of inhibitor system on the mild steel surface in acidic medium obeys Langmuir's adsorption isotherm. In addition, potentiodynamic polarization studies show that the system acts as a mixed-type inhibitor. Electrochemical impedance spectroscopy

also suggests the formation of a protective layer on the steel surface by the adsorption of surfactant molecules and bromide ions.

H. Tvakoli, et al.,[68] studied the inhibition effects of sodium dodecylbenzenesulphonate (SDBS) and 2-mercaptobenzoxazole (2-MBO) on corrosion of copper in sulphuric acid using electrochemical impedance spectroscopy (EIS) and Tafel polarization measurements. For 2-MBO, a monotonous increase in inhibition efficiency was observed as a function of concentration. For SDBS, however, an optimum in the inhibition efficiency was observed for a certain concentration, which is ascribed to the formation of hemi micellar aggregates that provoke inhibitor desorption from the metal/solution interface at higher concentrations. Upon mixing 2-MBO and SDBS inhibitors, concentrations range showing synergistic inhibition behaviour were identified, and it is concluded that electrostatic interactions between the adsorbed ions. Different adsorption isotherms were tested for describing the adsorption behaviour of both 2-MBO and SDBS.

Nabel A. Negm and Mohamed F. Zaki [69] synthesized a novel series of self-assembled nonionic Schiff base amphiphiles and their chemical structures were confirmed using elemental analysis, FTIR spectroscopy and ^1H NMR spectra. The surface activities of these amphiphiles were determined based on the data of surface and interfacial tension, critical micelle concentration, effectiveness, efficiency, maximum surface excess and minimum surface area. Thermodynamics of adsorption and micellization

processes of these amphiphiles in their solutions were also calculated. The surface and thermodynamic data showed their higher tendency towards adsorption at the interfaces. The synthesized amphiphiles were evaluated as corrosion inhibitors for aluminum (3SR) at different doses (10 – 400ppm) in acidic medium (4N HCl) using weight loss and hydrogen evolution techniques. The corrosion measurements showed that the synthesized nonionic Schiff bases could serve as effective corrosion inhibitors. The surface and corrosion inhibition activities were correlated to the chemical structures of the inhibitors.

Xueming Li, et al., [70] studied the influence of chloride ions on inhibitive performance of cetyl trimethyl ammonium bromide (CTAB) in 1.0–4.0 M of phosphoric acid (H_3PO_4) for cold rolled steel using weight loss and Tafel polarization techniques. The effect of acid concentration on corrosion inhibition and the effectiveness of inhibitors at 1.0–4.0 M of H_3PO_4 have been examined. The results reveal that a synergistic effect has been observed for CTAB with NaCl at each acid concentration. In 1.0 M H_3PO_4 , the polarization curves show that the complex is a mixed-type inhibitor

Karpagavalli Ramji et al., [71] investigated polyoxyethylene sorbitan monooleate (Tween-80) using potentiodynamic polarization, X-ray photoelectron spectroscopy and inductively coupled plasma analysis. Analysis of the results revealed that the addition of MBT and Tween-80 inhibits the corrosion of brass in 0.2 M NaCl. Potentiodynamic polarization measurements showed

that MBT acts as a mixed-type inhibitor and Tween-80 as an anodic inhibitor. Corrosion inhibition occurs through adsorption of the inhibitor on brass surface without modifying the corrosion mechanism. The adsorption of MBT and Tween-80 both follow Langmuir adsorption isotherm. Potentiodynamic polarization results suggested that the mixture of MBT and Tween-80 acts as a mixed-type inhibitor. Inhibition efficiency of 79.0 and 62.5% were obtained in the presence of optimum concentration of MBT and Tween-80, respectively. The addition of the mixture of MBT and Tween-80 enhanced the inhibition efficiency to 94.0% and showed a synergism of inhibition. XPS analysis indicated that MBT adsorbed on brass surface along with Tween-80 in the presence of the mixture of MBT and Tween-80. The results of solution analysis using ICP showed that the mixture of MBT and Tween-80 effectively controlled the dezincification of brass.

L. Románszki et al.,[72] studied the properties of mono- and multilayer of different amphiphiles in order to choose the appropriate compounds and experimental conditions, which would allow the formation of highly ordered, well-packed protective films on copper which could control the chemical and microbiological corrosion. Previous investigations of this group have shown the anticorrosion efficiency of some alkyl hydroxamic acid nanolayers. Here, they present the experimental results performed with several, systematically changed long-chained carboxylic (CA) and hydroxamic acids (HA), saturated and unsaturated ones, respectively, in order to find the most proper amphiphiles for preparation of compact nanolayers.

Essential differences were found between the isotherms of saturated and unsaturated amphiphilic CAs and HAs, which were even more visible on the compression moduli graphs. The liquid state was much longer at the saturated CAs than at the saturated HAs. Additional two carbon atoms in the chain resulted in an increased collapse pressure at the CAs and HAs, as well. The change in the temperature affected the isotherms both of the CAs' and HAs' layers. Sum frequency generation spectroscopic (SFG) measurements revealed high molecular ordering in the films of the saturated CAs and HAs, while low ordering in the films of the unsaturated analogues. The results predict that only the nanolayers of the saturated carboxylic and hydroxamic acids could be applied as potential anticorrosive and bacterial adhesion preventing coatings.

Gülşen Avcı [73] investigated corrosion inhibition of indole-3-acetic acid on mild steel in acidic medium (0.5 M HCl) containing the desired amount of inhibitor at different temperatures by using potentiodynamic polarization, electrochemical impedance spectroscopy, and polarization resistance measurements. The experimental results showed that corrosion potential shifted toward a more negative potential region in the presence of indole-3-acetic acid than that of blank solution. According to the obtained results from all measurements, inhibition efficiency was about 77% with 1.7×10^{-3} M inhibitor present, increasing to about 93% at the 1×10^{-2} M inhibitor concentration. Potentiodynamic polarization measurements showed that the current at anodic and cathodic

regions obtains a smaller value in the presence of inhibitor at almost all potentials than that of the blank solution. The degree of the surface coverage was determined by using the calculated corrosion current, and it was found that adsorption process of the studied inhibitor on mild steel surface obeys the Langmuir adsorption isotherm. Corrosion of the mild steel increased with a rise in temperature both in the presence and absence of the inhibitor. Activation energy (E_a), Gibbs free energy (ΔG_{ads}), enthalpy (ΔH_{ads}), and entropy (ΔS_{ads}) of corrosion process were calculated by using experimental measurements. Effect of immersion time to corrosion of mild steel was also tested in this study.

S.A. Ali, et al., [74] obtained excellent yields by the cycloaddition reactions of the cyclic nitrones 1-pyrroline 1-oxide and 3,4,5,6-tetrahydropyridine 1-oxide with alkenes, 11-phenoxy-1-undecene and 11-*p*-methoxyphenoxy-1-undecene, afforded cyclo addition products (bicyclic isoxazolidines) in excellent yields. One of the cycloadducts on reaction with propargyl chloride and ring opening with zinc in acetic acid afforded quaternary ammonium salt and aminoalcohol, respectively. All the new inhibitor molecules in the presence of 400 ppm at 60 °C achieved inhibition efficiencies, determined by gravimetric method, in the range 99–99.6% and 85–99% for mild steel in 1 M HCl and 0.5 M H₂SO₄, respectively. Comparable results were obtained by the electrochemical methods using Tafel plots and electrochemical impedance spectroscopy for the synthesized

compounds. The isoxazolidine derivatives were also found to be good inhibitors of mild steel corrosion in synthetic brine. Negative values of $\Delta G_{\text{ads}}^{\circ}$ in the acidic media ensured the spontaneity of the adsorption process. While the corrosion inhibition by these molecules was predominantly under cathodic control in 1 M HCl, the inhibition in 0.5 M H₂SO₄ was found to be under anodic control. The isoxazolidines and their derivatives were found to be among a rare class of molecules, which provide suitable inhibition mechanism for the corrosion inhibition in HCl as well as in H₂SO₄ media.

G.A. Zhang, and Y.F. Cheng., [75] used rotating disk electrode technique to study the effects of fluid hydrodynamics on corrosion of X-65 steel in the simulated oil sand slurry by potentiodynamic polarization curve and electrochemical impedance spectroscopy measurements. In the absence of sands, the cathodic polarization current increases with the increasing electrode rotating speed due to the accelerated oxygen diffusion and reduction. However, the anodic polarization current decreases because of the improved oxidation of the steel. Although the oxygen diffusivity increases with temperature, the resultant oxidation of steel by oxygen is not sufficient to offset the enhanced reactivity of steel at an elevated temperature. The presence of oils is believed to form a layer of oily phase on the steel surface, facilitating the cathodic reduction of oxygen and inhibiting dissolution of the steel. With the increasing sand content and size in the solution, the corrosion of steel is enhanced.

M.Z.A. Rafiquee et al., [76] evaluated the corrosion inhibition characteristics of 2-aminophenyl-5-mercapto-1-oxa-3,4-diazole (AMOD) on mild steel in HCl solution by weight loss studies and potentiodynamic polarization. AMOD is a good corrosion inhibitor in HCl solution and its inhibition efficiency is increased markedly in presence of surfactants (SDS, CTAB, TX-100). TX-100 is found to be most effective among the tested surfactants. Weight loss measurements showed that the inhibition efficiency increased with the increasing surfactant concentration and attained a maximum value around 0.2 mol dm^{-3} . In presence of surfactant, the adsorption of AMOD on the mild steel surface obeyed Langmuir's adsorption isotherm. The influence of inhibitor concentration, solution temperature, and acid concentration on the corrosion rate of mild steel has also been investigated. The deduced thermodynamic parameters for adsorption reveal a strong interaction between the inhibitor and mild steel surface. The negative values of G_{ads} indicate the spontaneous adsorption of inhibitors on the mild steel surface. Potentiodynamic polarization studies show that these surfactants are mixed-type inhibitors.

Guannan Mu et al., [78] studied the inhibition effect of Tween-20 as a nonionic surfactant on the corrosion of cold rolled steel (CRS) in 1.0–8.0 M HCl at different temperatures (20–50 °C) by weight loss and potentiodynamic polarization methods. Atomic force microscope (AFM) provided the CRS surface conditions. The results show that Tween-20 is a good inhibitor in 1.0 M HCl, and the inhibition efficiency (IE) increases with the inhibitor

concentration, while decreases with increasing the hydrochloric acid concentration and temperature. Effect of immersion time was also studied and discussed. The adsorption of inhibitor on the CRS surface obeys the Langmuir adsorption isotherm equation. Both thermodynamic and kinetic parameters have been obtained by adsorption theory and kinetic equations. The inhibition effect is satisfactorily explained by the parameters. Polarization curves show that Tween-20 is a mixed-type inhibitor in hydrochloric acid. The results obtained from weight loss and polarization was in good agreement, and Tween-20 inhibition action could also be evidenced by surface AFM images.

R. Solmaz, G. et al., [78] studied adsorption of 2-amino-5-mercapto-1,3,4-thiadiazole (2A5MT) on mild steel (MS) surface in 0.5 M HCl solution and its corrosion inhibition effect in both short and long immersion times (over 120 h). For this purpose, a series of techniques, such as potentiodynamic polarization, electrochemical impedance spectroscopy (EIS), linear polarization resistance (LPR), thermo gravimetric analysis (TGA), surface photographs, hydrogen evolution (V_{H_2-t}) and change of open circuit potential with immersion time (E_{ocp-t}) were utilized. The values of activation energy for MS corrosion and the thermodynamic parameters, such as adsorption equilibrium constant (K_{ads}), free energy of adsorption (ΔG_{ads}), adsorption heat (ΔH_{ads}) and adsorption entropy (ΔS_{ads}) values were calculated and discussed. The potential of zero charge (E_{pzc}) of MS in inhibited solution was studied both after short and long immersion times by EIS method, and a mechanism of adsorption

process was proposed. Results showed that 2A5MT performed excellent inhibiting effect for the corrosion of MS in 0.5 HCl solution and inhibition efficiency is higher than 99% after 120 h at 1.0×10^{-2} M. The high inhibition efficiency was discussed in terms of strongly adsorption of inhibitor molecules on the metal surface and forming a protective film. Surface photographs showed a good surface coverage on the metal surface. TGA results indicated that the surface inhibitor film has relatively good thermal stability.

Jui-Ming Yeh et al., [79] prepared a series of poly(o-methoxyaniline) (PMA)/Na⁺montmorillonite(MMT) clay nanocomposite (Na⁺PCN) materials by in situ emulsion polymerization in the presence of inorganic nanolayers of hydrophilic Na⁺MMT clay with DBSA and APS as surfactant and initiator, respectively. The as-synthesized Na⁺PCN materials were characterized by Fourier-transformation infrared (FTIR) spectroscopy, wide-angle powder X-ray diffraction (XRD) and transmission electron microscopy (TEM). Na⁺PCN materials in the form of coatings with low loading of Na⁺MMT clay (e.g., 5 wt.%, CLMA5) on cold rolled steel (CRS) were found much superior in corrosion protection over those of neat PMA based on a series of electrochemical measurements of corrosion potential, polarization resistance, corrosion current and impedance spectroscopy in 5 wt.% aqueous NaCl electrolyte.

Kung-Chin Chang et al., [80] prepared a series of polyaniline (PANI)/Na⁺montmorillonite(MMT) clay and PANI/organo MMT nanocomposite materials by in situ emulsion polymerization in

the presence of inorganic nanolayers of hydrophilic Na^+ MMT clay or organophilic organoMMT clay with DBSA and KPS as surfactant and initiator, respectively. The as-synthesized Na^+ PCN and organoPCN materials were characterized and compared by Fourier transformation infrared (FTIR) spectroscopy, wide-angle powder X-ray diffraction (XRD) and transmission electron microscopy (TEM). Na^+ PCN materials in the form of coatings with low loading of Na^+ MMT clay (e.g., 3 wt.%, CLAN3) on cold-rolled steel (CRS) were found much superior in corrosion protection over those of organoPCN materials with same clay loading based on a series of electrochemical measurements of corrosion potential, polarization resistance, corrosion current and impedance spectroscopy in 5 wt.% aqueous NaCl electrolyte.

R. Fuchs-Godec and V. Doležal, [81] studied the effect of sodium dodecylsulfate (SDS) on copper corrosion in a solution of $0.5 \text{ M H}_2\text{SO}_4 + x \text{ M SDS}$ using electrochemical polarization measurements. The critical micelle concentration (CMC) of SDS in $0.5 \text{ M H}_2\text{SO}_4$ is $8 \times 10^{-4} \text{ M}$, and the experimental concentrations of SDS were in the range below and above the CMC. It was found that SDS is a good anodic inhibitor at lower anodic overpotentials, i.e. very close to the rest potential. Adsorption of the inhibitor obeys the Langmuir isotherm. Plots of $\log [\theta/(1-\theta)]$ versus $\log c$ yielded straight lines with a slope change at the CMC. Accordingly, the CMC could be determined from these electrochemical measurements. The values of ΔG_{ads} calculated from the Langmuir plots are negative, suggesting that the inhibitive action of SDS in $0.5 \text{ M H}_2\text{SO}_4$ results from the

electrostatic adsorption of $C_{12}H_{25}SO_4^-$ ions onto the positively charged copper surface.

M.A.Migahed [82] investigated the effect of non-ionic surfactant, namely N,N-di(poly oxy ethylene) amino lauryl amide, on the corrosion rate of carbon steel in produced water by various corrosion monitoring techniques. The strong adsorption ability of the surfactant molecules leads to formation of a mono-layer, which isolates the surface from the environment and thereby reduces the corrosion attack on the surface. The adsorption process was found to obey the Langmuir adsorption isotherm. The potentiostatic polarization results clearly revealed that the inhibitor behaves as a mixed type. The maximum percentage inhibition efficiency approached 94.87% in presence of 250 ppm of the inhibitor molecules. The effect of temperature on the corrosion rate of carbon steel was studied in the temperature range from 30 to 70 ° C. Finally, scanning electron microscopy was used to examine the surface morphology of carbon steel samples in absence and presence of the inhibitor.

Michael L. Free [83] found that corrosion inhibition by surfactant molecules is related to the surfactant's ability to aggregate at interfaces and in solution. Understanding the factors that affect aggregation as well as the state of aggregation of surfactant molecules on metal surfaces is, therefore, an important prerequisite to understanding corrosion inhibition by surfactant molecules. This article investigates the relationship between surfactant aggregation and mild steel corrosion inhibition in

acidic medium using cetyl pyridinium chloride and cetyl trimethyl ammonium bromide.

Wan Lin Wang and Michael L. Free [84] prepared a corrosion inhibitor from surfactants by varying alkyl hydrocarbon chain lengths in various solution media with different ionic strengths. This article utilizes recently developed methodology and equations to predict mild steel corrosion inhibition by alkanol nonionic surfactants. Also the relationship between surfactant concentration, surfactant critical micelle concentration (CMC), and corrosion inhibition is analyzed in this paper. The results from this paper can be applied to relevant industrial uses of surfactants for corrosion inhibition.

A. Lalitha et al., [85] investigated the influence of derivatives of 1,2,4-triazole, 3-amino-1,2,4-triazole (TAT), 3-amino-5-mercapto-1,2,4-triazole (AMT) and 3-amino-5-methylthio-1,2,4-triazole (AMTT) and ionic surfactants cetyl trimethyl ammonium bromide (CTAB) and sodium dodecyl sulphate (SDS) on the corrosion control of copper in acidic solution by gravimetric and electrochemical methods. The combined effect of triazoles and surfactants was also evaluated. Electrochemical parameters like corrosion potentials, corrosion current density, corrosion rates and inhibition efficiencies were determined. The results reveal the fact that of all triazoles AMTT shows best inhibition and anionic surfactant SDS protects the surface better than the cationic surfactant CTAB. The polarization data reveal that all inhibitors behave as a mixed type inhibitor. Adsorption of these inhibitors

on the surface of copper is found to obey the Langmuir adsorption isotherm. A marked inhibition synergism effect is shown by all the combinations of triazole and surfactant.

Ling-Guang Qiu et al.,[86] studied the adsorption and corrosion inhibition of the gemini surfactants 1,2-ethane bis(dimethyl alkyl ($C_n H_{2n}$) ammonium bromide) on the steel surface in 1 M hydrochloride acid(HCl) using the weight loss method. It was found that the adsorption of the gemini surfactants on the steel surface is the main reason to cause the steel corrosion inhibition in hydrochloride acid, and the inhibition efficiency increases with the increase of surfactant concentration and reaches the maximum value near the CMC. A possible adsorption model of gemini surfactant onto the metal surface was also discussed.

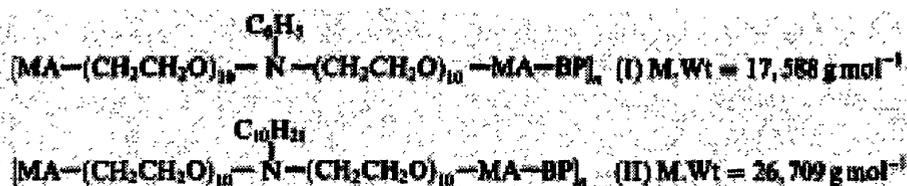
R. Fuchs-Godec[87] investigated the corrosion inhibition characteristics of non-ionic surfactants of the TRITON-X series, known as TRITON-X-100 and TRITON-X-405, on stainless steel (SS) type X4Cr13 in sulphuric acid by potentiodynamic polarization measurements. It was found that these surfactants act as good inhibitors of the corrosion of stainless steel in 2 mol L^{-1} H_2SO_4 solution, but the inhibition efficiency strongly depends on the electrode potential. The polarization data showed that the non-ionic surfactants used in this study acted as mixed-type inhibitors and adsorb on the stainless steel surface, in agreement with the Flory-Huggins adsorption isotherm. Calculated ΔG_{ads} values are $-57.79 \text{ kJ mol}^{-1}$ for TRITON- X-100, and $-87.5 \text{ kJ mol}^{-1}$ for TRITON-X-405. From the molecular structure it can be supposed

that these surfactants adsorb on the metal surface through two lone pairs of electrons on the oxygen atoms of the hydrophilic head group, suggesting a chemisorption mechanism.

A. Tizpar and Z. Ghasemi. [88] investigated the inhibition action of the citric acid and three surfactants: sodium dodecyl sulfate (SDS), t-octyl phenoxy polyethoxyethanol (Triton X-100), sodium dodecyl benzene sulphonate (SDBS) on the corrosion behavior and gas evolution of Pb–Sb–As–Se in 12.5 M H₂SO₄ solution with linear sweep polarization, cyclic voltammetry and weight loss measurements methods. The results drawn from different techniques are comparable. It was found that these surfactants and citric acid act as good inhibitors for the corrosion of lead alloy in H₂SO₄ solution. SDS inhibited most effectively the lead alloy corrosion among the three surfactants and citric acid. The inhibition efficiency for the inhibitors decreases in the order: SDS > SDBS > Triton X-100 > citric acid > blank. The inhibition efficiency increases with rising of the inhibitor concentration. In this work, the effect of the inhibitors on hydrogen and oxygen evolution was studied. In addition, it was found that the adsorption of used inhibitors on lead alloy surface follows Langmuir isotherm.

M.A. Migahed et al., [89] examined the effect of gamma-ray-pre-irradiation on the efficiency of two types of polymeric surfactants, (I and II) as corrosion inhibitors for 304 stainless steel in 2M hydrochloric acid solution. The inhibition efficiency of the undertaken additives was evaluated using both chemical and

electrochemical techniques. The chemical structure of the two polymeric surfactants is illustrated as follows:



Where MA $\frac{1}{4}$ maleic anhydride; BP $\frac{1}{4}$ block polymer of polyoxyethylene-polyoxypropylene (M.Wt $\frac{1}{4}$ 5000 g mol⁻¹). The obtained corrosion data, indicated that the corrosion inhibition efficiency of the inhibitor (II) was obviously not affected by gamma-ray-irradiation, meanwhile the efficiency of the inhibitor (I) demonstrated a remarkable decrease. Scanning electron microscope (SEM) was used to examine the surface morphology of stainless steel samples after immersion in 2M HCl solution in absence and presence of the inhibitors at concentration of 400 ppm before and after exposure to gamma-ray-radiation up to a total dose of 100 kGy.

Houyi Ma et al., [90] investigated the inhibitive action of the four surfactants, cetyltrimethylammonium bromide (CTAB), sodium dodecyl sulfate, and sodium oleate and polyoxyethylene sorbitan monooleate (TWEEN- 80), on the corrosion behavior of copper in aerated 0.5 mol H₂SO₄ solutions, by means of electrochemical impedance spectroscopy. These surfactants acted as the mixed-type inhibitors and lowered the corrosion reactions by blocking the copper surface through electrostatic adsorption or

chemisorption. The inhibitor effectiveness increased with the exposure time to aggressive solutions, reached a maximum and then decreased, which implies the orientation change of adsorbed surfactant molecules on the surface. CTAB inhibited most effectively the copper corrosion among the four surfactants. The copper surface was determined to be positively charged in sulfuric acid solutions at the corrosion potential, which is unfavorable for electrostatic adsorption of cationic surfactant, CTAB. The reason why CTAB gave the highest inhibition efficiency was attributed to the synergistic effect between bromide anions and positive quaternary ammonium ions. $C_{16}H_{33}N(CH_3)_4$ ions may electrostatically adsorb on the copper surface covered with primarily adsorbed bromide ions. On the basis of the variation of impedance behaviors of copper in the surfactant-containing solutions with the immersion time, the adsorption model of the surfactants on the copper surface was proposed.

Ling-Guang Qiu et al., [91] synthesized a triazole-based cationic gemini surfactant, 3,5-bis(methylene octadecyl dimethylammonium chloride)-1,2,4-triazole (18-triazole-18), and its effect on corrosion inhibition of A 3 steel in 1 M HCl has been studied using the weight-loss method. The result showed that 18-triazole-18 acted as an excellent inhibitor in 1 M HCl. It was found that the adsorption mechanism of 18-triazole-18 on the steel surface in acid medium was quite different from that of cationic gemini surfactants containing dimethylene as a spacer, as well as that of conventional cationic single-chained surfactants,

which is due to unique molecular structure of 18-triazole-18. 18-Triazole-18 may be adsorbed on the steel surface in acid medium through a maximum of four atoms or groups, i.e., the two nitrogen atoms of triazole ring and two quaternary ammonium head groups. Four regions of surfactant concentration could be divided to illustrate the adsorption of 18-triazole-18 on the steel surface, and four different adsorption mechanisms may take place in different regions of surfactant concentration.

M.A. Migahed et al., [92] prepared the anionic surfactant [p-myristyloxycarbonylmethoxy-p-sodiumcarboxylate-azobenzene]. The surface tension at 298 K was measured; the critical micelle concentration (CMC) and some surface active parameters were calculated. The inhibition efficiency of this surfactant has been studied by both chemical and electrochemical techniques at 25 °C. A significant decrease in the corrosion rate was observed in presence of the investigated inhibitor. The galvanostatic polarization curves showed that, the inhibitor behaves as mixed type but the cathodic effect is more pronounced. Tafel slopes are approximately constant and independent on the inhibitor concentration. The observed corrosion data indicate that, the inhibition of mild steel corrosion is due to the adsorption of the inhibitor molecules on the surface, which follow Langmuir adsorption isotherm. The surface morphology of mild steel samples in absence and presence of the inhibitor was examined using scanning electron microscopy.

Ling-Guang Qiu et al., [93] studied corrosion inhibition of carbon steel in 1 M hydrochloride acid by gemini surfactants

alkanediy1-a,v-bis(dimethyl dodecylammonium bromide) with different spacer lengths (designated as 12-s-12, $s = 2, 3$ or 6) using the weight loss method. When monolayer forms on the metal surface below or near critical micelle concentrations (CMC) of the gemini surfactants, it can be found that gemini surfactant with long spacer (12-6-12) tends to be adsorbed with two hydrophilic ionic groups onto the metal surface site, while gemini surfactants with short spacer (12-2-12 and 12-3-12) tend to be adsorbed with one hydrophilic group onto the metal surface site and the other hydrophilic group is free in solution phase, and further increase in surfactant concentration results in the formation of multilayer.

M. El Achouri et al., [94] prepared three new gemini surfactants in the series of alkanediy1--bis-(dimethylalkyl ammonium bromide) and tested as corrosion inhibitors of iron in hydrochloric acid medium using gravimetric, electrochemical polarization and electrochemical impedance spectroscopy (EIS) measurements. Results obtained show that the surfactants studied are good cathodic inhibitors and act on the cathodic hydrogen reaction without modifying its mechanism. EIS results show that the changes in the impedance parameters (R_t and C_{dl}) with concentration of surfactants studied is indicative of the adsorption of molecules of surfactant leading to the formation of a protective layer on the surface of iron. The effect of the temperature on the iron corrosion in both 1 M HCl and 1 M HCl with addition of various concentrations of 1,2-ethane bis-(dimethyl tetradecyl ammonium bromide) in the range of temperature 20–60°C was

studied. The associated apparent activation corrosion energy has been determined.

R.A. El-Ghazawy [95] synthesized three series of novel polyoxyethylenated trimethylolpropane (TMP) monoester surfactants and their molecular weights were evaluated experimentally by GPC. Also, their HLB values were determined from ^1H NMR charts. The CMC's of the surfactants, obtained from surface tension measurements, are low in the order of 10^{-5} M. On the other hand, from surface tension – ln molar concentration plots, the minimum area/surfactant molecule (A_{min}) for the investigated surfactants were found to be increased with increasing the molecular weight of the incorporated ethylene oxide. The thermodynamic parameters of micellization (ΔG_{mic} , ΔH_{mic} and ΔS_{mic}) and that for adsorption (ΔG_{ad} , ΔH_{ad} and ΔS_{ad}) were also calculated. The more negative Gibb's free energy of adsorption values than those of micellization suggest that these surfactants favor adsorption to micellization.

A.S. Algaber et al., [96] evaluated a non-ionic surfactant, octylphenol polyethylene oxide (OPPEO), as an Inhibitor for corrosion of low-carbon steel in 0.5 M H_2SO_4 . Potentiodynamic and potentiostatic methods and scanning electron microscopy were used to study the inhibition effectiveness of the surfactant. The inhibition efficiency was found to increase with the inhibitor concentration and decrease with temperature. OPPEO showed higher constant protection efficiency near its critical micelle concentration. The activation energy of corrosion was found to be higher in presence than in absence of the inhibitor. The

experimental data were fitted with the Flory–Huggins isotherm at a molecular ratio of 5:1. The Gibbs energy of adsorption decreases with the temperature. The inhibitor has relatively lower inhibition efficiencies at ambient and higher temperature. This was attributed to the molecular structure of the inhibitor.

L. Chaal et al., [97] erosion–corrosion is a complex materials degradation mechanism involving the combined effects of mechanical erosion and electrochemical corrosion. It is known to be induced by high shear stresses in strong flows. One way to mitigate this phenomenon is to use additives reducing the turbulent Reynolds stresses. Oleyltrimethyl ammonium cationic surfactant and sodium salicylate as counter-ion known to form thread-like micelles behaving as drag reducers were tested in this work and successfully imaged by using AFM technique. A shear stress mapping in the rotating cage using an electrochemical method was implemented in the absence and in the presence of surfactant, showing drag reduction amounts up to 65%. In a second step, erosion corrosion of Cu in Na₂SO₄ 0.1 M in the presence of small amounts of NaCl (1 mM) was investigated on Cu microelectrodes located at different positions on plastic coupons in the cage. The surfactant effect was found to be beneficial by preventing the removal of the pre-existing oxide films, otherwise observed in the absence of surfactant. Tests performed with benzotriazole known as a good corrosion inhibitor for Cu, could not prevent either the breaking of the oxide film in strong flow conditions

Zhenqiang Wei et al., [98] used organic surfactants as pitting inhibitors but the understanding of the inhibition mechanisms is mainly speculative. In this study the inhibition of the pitting corrosion of 304 stainless steel by N-lauroylsarcosine sodium salt (NLS) in 0.1 M NaCl solutions at neutral pH was studied using an approach that combines surface chemical techniques with electrochemical ones. It was found that NLS increases the pitting resistance of 304 stainless steel, with possible complete inhibition at high NLS concentration (30 mM). Adsorption of NLS on 304 stainless steel particles was directly measured. NLS adsorbs significantly on 304 stainless steel with maximum adsorption density close to bilayer coverage. Electrophoretic mobility data for 304 stainless steel particles show that the surface of 304 stainless steel is negative in NaCl solution at neutral pH. The adsorption of NLS makes the interfacial charge even more negative. The relationship between pitting inhibition and adsorption density of NLS suggests that NLS does not adsorb preferentially on the pit nucleation sites and complete inhibition requires that the whole surface be covered completely by NLS. The inhibition mechanism of NLS is proposed to be due mainly to the blocking effect of a negatively charged NLS adsorption layer. This study shows that in addition to the adsorption amount of surfactant, interfacial charge also plays an important role in pitting inhibition.

Catherine Dagbert et al., [99] found that some microorganisms are able to surface active compounds called biosurfactants (BS), which reduce the surface tension of water.

BS characteristics depend on which microorganism produce them and therefore, on the microorganism culture conditions (temperature, pH, C, N-source). Numerous applications are known for these biomolecules, such as cleaning, bioremediation, and their use as a detergent, or in cosmetic formulations. Recently, a large amount of literature has been edited on the influence of BS on the interactions between pathogenic bacteria and inert surfaces. It has been shown that the modifications of surface properties by the adsorption of BS can reduce microbial adhesion. Some other studies on chemical surfactants have shown that the adsorption of surface-active compounds plays a major role in corrosion; they are indeed used as an interesting corrosion inhibition tool. Therefore, it seems very interesting to study the impact of BS as environment-friendly (since biological and biodegradable) corrosion inhibitors. In the present work, an attempt was made to study the corrosion behaviour of AISI 304 stainless steel in presence of BS produced by a Gram- negative bacteria, *Pseudomonas fluorescens* (Pf495). Corrosion tests were achieved on several surface oxidation states. The surface morphology of the corroded specimens was investigated using SEM.

A.M. Alsabagh et al., [100] investigated the effect of deferent concentrations, 40–200 ppm, of various polyester aliphatic amine surfactants on inhibition of the corrosion of carbon steel in the formation water (deep well water). These surfactants exhibit deferent levels of inhibition particularly at high concentration

(200 ppm). Inhibition efficiencies in the range 86–96% were determined by weight loss method. Comparable results were obtained from electrochemical measurements using Tafel extrapolation and polarization resistance methods. It was shown that all the investigated surfactants act primarily as anodic inhibitors; however, they also affect the rate and mechanism of the cathodic reaction. These compounds function via adsorption on reactive sites on the corroding surface reducing the corrosion rate of the metal. It was revealed that the adsorption of these surfactants obey Langmuir adsorption isotherm. The inhibition effectiveness increases with the length of the aliphatic hydrocarbon chain, being a maximum in the presence of surfactant IV (96% efficiency). The corrosion inhibition feature of this compound is attributed to the presence of a long hydrocarbon chain that ensures large surface

Xianghong Li and Guannan Mu., [101] studied the inhibition action of a non-ionic surfactant of tween-40 on the corrosion of cold rolled steel (CRS) in 0.5–7.0 M sulphuric acid H_2SO_4 by weight loss and potentiodynamic polarization methods. Atomic force microscope (AFM) provided the surface conditions. The inhibition efficiency increases with the tween-40 concentration, while decreases with the sulphuric acid concentration. The adsorption of inhibitor on the cold rolled steel surface obeys the Langmuir adsorption isotherm equation. Effect of immersion time was studied and discussed. The effect of temperature on the corrosion behavior of cold rolled steel was also studied at four temperatures ranging from 30 to 60 °C, the thermodynamic

parameters such as adsorption heat, adsorption free energy and adsorption entropy were calculated. A kinetic study of cold rolled steel in uninhibited and inhibited acid was also discussed. The kinetic parameters such as apparent activation energy, pre-exponential factor, rate constant, and reaction constant were calculated for the reactions of corrosion. The inhibition effect is satisfactorily explained by both thermodynamic and kinetic parameters. Polarization curves show that tween-40 is a cathodic-type inhibitor in sulphuric acid. The results obtained from weight loss and potentiodynamic polarization are in good agreement, and the tween-40 inhibition action could also be evidenced by surface AFM images.

Y. Reyes et al., [102] found that the physicochemical features of a surfactant are quite important in the formulation of polymer water-borne coatings mainly due to the strong influence of the micelles on the nucleation and stability of dispersed polymer particles. In consequence, micellar transitions must be determined in order to obtain aqueous dispersions of spherical shaped particles with high monodispersion in size, which allows obtaining coatings with an improved performance. Besides, depending on its chemical structure, the surfactant could also have anticorrosive properties. In this work, a phosphate-based surfactant was characterized and its electrochemical properties were evaluated in order to use it as a stabilizer agent of a series of monodisperse styrene-acrylic lattices, synthesized by semi-continuous emulsion polymerization. EIS was used to evaluate the

anticorrosive properties of coatings obtained from polymeric dispersions.

D. Chebabe et al., [103] synthesized triazole bolaamphiphiles in the series of 1,n-bis(1,2,4-triazolyl)alkane where en. The purity of surfactants synthesized was checked by rutinary methodologies (IR, ^1H NMR, ^{13}C NMR, mass spectra and elemental analysis). The aggregation of 1,n-bis(1,2,4-triazolyl)alkane have been determined by surface tension at the air-HCl 1 M interface. The inhibiting action of these compounds towards the corrosion of carbon steel in 1 M HCl solution was investigated using gravimetric, potentiodynamic and electrochemical impedance spectroscopy measurements. Polarization data indicate that these compounds act as very good cathodic inhibitors for carbon steel in 1 M HCl. The values of the transfer resistance, obtained from impedance plots of carbon steel, increase by increasing product concentration. From all measurements carried out, the variation of the inhibition efficiency versus concentration shows the same trend. The electrochemical study shows that DTC12 is the best inhibitor and its efficiency increases with concentration and the highest value obtained is around 94%.

Z. Ait Chikh et al., [104] found that, 12-bis (1,2,4-triazolyl)dodecane (dTC12) is an excellent corrosion inhibitor for carbon steel in 1 M HCl solution. In this work electrochemical and analytical techniques were used to study the inhibition of corrosion on carbon steel in acidic medium. The carbon steel corrosion inhibition of dTC12 was attributed to the synergistic effect between chloride anion and quaternary ammonium ion. The

protective efficiency of the film was higher than 90%, indicating that corrosion of carbon steel in 1 M HCl is reduced by dTC12. The effect of dissolved oxygen on the inhibition efficiency was also investigated. The results show that the inhibition efficiency increases in early stage and decreases for a long immersion time.

Shan-Zhuo Yao et al., [105] synthesized 1,4/1,6-Bis(octylpyridinium)butane/hexanedibromide. The inhibitive effect of the two Gemini surfactants for A3 steel in 20% hydrochloric acid solution medium was investigated by mass loss, Tafel extrapolation method and electrochemical impedance spectroscopy. The result of mass loss indicated that the inhibitive efficiency of the surfactants increases with the rise of concentration; decreases with the rise of temperature and is up to the highest at a concentration of surfactants much less than their critical micelle concentration. Polarization data indicates that these compounds act as very good inhibitors of iron in 20% HCl both for cathode and anode. Electrochemical impedance spectroscopy has the same trend of inhibitive effect as that of the polarization data, which indicate the formation of a protective layer on the iron surface by the adsorption of surfactants molecules.

N. Muthukumar et al., [106] found that biodegradation occurs at the interface between diesel and water. The microbial contamination can result in inhibitor/fuel degradation that leads to the unacceptable level of turbidity, filter plugging, corrosion of storage tanks, pipeline and souring of stored products. Hence, selection of biocides/inhibitors is an important aspect in

petroleum product transporting pipeline. Three biocides (cationic and nonionic) were employed to study the biodegradation of diesel in diesel–water interface. The biocidal efficiency on biodegradation of diesel was examined using Fourier transform infrared spectroscopy (FTIR), nuclear magnetic resonance spectroscopy (NMR) and gas chromatography mass spectrometry (GC–MS). Polyoxyethyleneglycol dodecylether [BRIJ-35] and polyethylene glycol-p-isooctylphenyl ether [TRITON-X-100] had higher bactericidal efficiency than Dodecyl ethyl dimethyl ammonium bromide [DDAB]. But the cationic biocide (DDAB) gave good biocidal efficiency at the interface. The data are explained in terms of a model that postulates the formation of “micelle” at the diesel–water interface

N.T.L. Hien et al., [107] electrochemically synthesized duplex polypyrrole (PPy) films on iron to be used as protective coatings against corrosion. The inner film was doped with tetraoxalate anions and the outer one with dodecyl sulfate anions. The protection against corrosion of this coating was tested in sodium chloride solutions: an increase in the protection time by one order of magnitude with respect to an oxalate-doped PPy film of the same total thickness was measured. The proposed mechanism was based on a change in the permselectivity of the film from anion exchange to cation exchange, thus preventing from the ingress of corrosive chloride anions

Deyang Q. [108] studied adsorption and desorption of Dinonylphenol Phosphate Ester (DPE), on the surface of a zinc anode in alkaline solution during discharge, AC impedance and

numerical fitting techniques. The processes were found reversible only during the initial oxidation. The mechanism of the corrosion inhibition caused by the surfactant was investigated and it was found that both the geometrically blocking effect and the increase of hydrogen evolution overpotential might contribute to the reduction of the corrosion rate. The initial potential “dip” during the discharge of an alkaline zinc cell was found to have resulted from surface coverage of the surfactant.

Aim of the work

Corrosion protection of steel in acidic media is of great important both for industrial facilities and theoretical aspects. The use of inhibitor is one of the most practical methods for protection of steel against corrosion in acidic media. Among all inhibitors, the most important are the organic ones, also called adsorption inhibitors. They control corrosion, acting over the anodic or the cathodic surface or both. As a representative type of these organic inhibitors, quaternary ammonium salts have been demonstrated to be highly cost-effective and used widely in various industrial processing for preventing corrosion of iron and steel in acidic media.

So this work aimed to the following:

1- Preparation of some cationic surfactants mainly:

- a- Benzyl-decyl-bis-(2-hydroxy-propyl)-ammonium chloride
- b- Benzyl-dodecyl-bis-(2-hydroxy-propyl)-ammonium chloride
- c- Benzyl-hexadecyl-bis-(2-hydroxy-propyl)-ammonium chloride
- d- Benzyl-octadecyl-bis-(2-hydroxy-propyl)-ammonium chloride

2- Structure confirmation of the prepared cationic surfactants using the following spectroscopic techniques:

- a- Micro elemental analysis
- b- FTIR

- c- $^1\text{H-NMR}$
- 3- **Determination of critical micelle concentration (CMC) and Interfacial Tension of the prepared compounds.**
- 4- **Evaluation of the prepared compounds as corrosion inhibitor of steel by three techniques.**
 - a- Weight loss measurements.
 - b- Polarization measurements.
 - c- Electrochemical impedance measurements.
- 5- **Determination of the activation energy (E_a) for the prepared surfactant in corrosion process.**
- 6- **Determination of thermodynamic parameters of adsorption such as standard free energy (ΔG^0), enthalpy (ΔH^0), and entropy (ΔS^0) of the prepared surfactants.**
- 7- **Evaluation of the prepared surfactants as biocide for**
 - a- Pathogenic bacteria
 - b- Pathogenic fungi
 - c- Sulfate reducing bacteria