Research Article

Schiff based corrosion inhibitors for metals in acidic environment: A review

Abstract

The main objective of the this review is the application of Schiff bases for the protection of different important metals such as aluminum, carbon steel, iron steel, stainless steel, steel, copper, magnesium and some examples on their alloys. In the beginning, review highlights the important of organic inhibitors for protection of metals in various corrosive media. This review is mainly devoted to different type of Schiff bases as corrosion inhibitors for above mentioned metals in only acidic medium. The corrosion inhibition activity (efficiency) of inhibitors is determined by different measurement techniques including WL, EIS and PDP and others two techniques such as EN, EFM and EQCM. The adsorption mechanism of inhibitors with free energy value is also presented. The high corrosion inhibition efficiency of inhibitors relies on the iminic bond and other hetero atoms such as O, N and S. The sulphur beared corrosion inhibitors displayed high corrosion inhibition than O and N.

Keywords: corrosion, inhibitor, organic schiff base, metal, efficiency

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Abbreviation: EDX, energy dispersive X-ray spectroscopy; EFM, electrochemical frequency modulation; EIS, electrochemical impedance spectroscopy; EN, electrochemical noise; EQCM, electrochemical quartz crystal microbalance; MNDO, modified neglect of diatomic overlap; NBDSI, N,N-(3-benzylidenepentane-2,4-diylidene)dipyridin-4-amine; NCDSI, N,N-[3-(4-chlorobenzylidene)pentane-2,4-diylidene]dipyridin-4-amine; NDSI, N,N-pentane-2,4-diylidenedipyridin-4-amine; NMDSI, N,N-[3-(4-methoxybenzylidene)pentane-2,4-diylidene]dipyridin-4-amine; OCP, open circuit potential; PDP, potentio dynamic polarization; PEO, polyethylene oxide; SEM, scanning electron microscope; WL, weight lost

Introduction

Metals and its alloys are easily undergone to the corrosion when they exposed to harsh condition such acidic, basic, saline water and other corrosion gases like CO_2, SO_2 etc. Corrosion inhibitors were played an important role to prevent corrosion in different corrosive media.[1] The applications of Organic compounds has been widely studied as corrosion inhibitors for metals and its alloys.[2] Finsgar et al.[2] recently published review on different classes of organic compounds such as mercaptos, azoles, organic dyes and different polymers as corrosion inhibitors for aluminum and its alloys in alkaline and chloride solutions.[3] Monticelli et al.[4] reported three Schiff bases such as such as N-2-mercaptophenylsalicylideneimine, N-2-aminophenylsalicylideneimine and N-2-hydroxyphenylsalideneimine as corrosion inhibitors for copper in aqueous alcoholic solution.[4] Gomma et al.[5] reported several Schiff bases for aluminum in 2N HCl. These investigated Schiff bases have been shown very good corrosion protection for aluminum metal.[5]

A biopolymer from tragacanth gum, arabinogalactan (AG), was studied for its adsorption and corrosion inhibition traits for carbon steel corrosion in 1M HCl. Potentio dynamic polarization measurements, gravimetric method, UV–visible spectroscopy, electrochemical impedance spectroscopy, scanning electron microscopy, and atomic force microscopy were used to investigate the adsorptive nature of AG in the acid solution. The inhibition efficiency improved with an increase in AG concentration and temperature of the acid solution.[6] 2-Amino-N′-((thiophen-2-yl)methylene)benzohydrazide (ATMBH) was synthesized by a conventional method, as well as by microwave (MW) irradiation. The MW assisted synthesis of ATMBH was found to have good yield and was more eco-friendly compared to the conventional method of synthesis. The corrosion inhibition performance of ATMBH in 0.5M H_2SO_4 was assessed by gravimetric and electrochemical methods. The potentiodynamic polarization study unleashed that ATMBH acted as a mixed type of inhibitor. The results obtained from these methods are in good agreement and are well supported by the contact angle measurements.[7] To the best of our knowledge, no review is available on applications of organic inhibitors especially on Schiff bases for metals such aluminum and its alloys, carbon steel, steel and its alloys, copper and other metals in acidic medium. For this purpose various corrosion evolution techniques including WL, EIS, PDP, EN, EQCM and EFM used to determine the corrosion inhibition efficiency are discussed in the review.

Schiff bases corrosion inhibitors for aluminum and its alloys

Schiff base o-Chloroaniline-N-benzylidene (o-CANB) has been shown good inhibitive effectiveness in 1M HCl.[8] Corrosion inhibition efficiency has been determined by WL method in the temperature range of 35-65°C. Others two electrochemical techniques such as EIS and PDP were employed for the determination of corrosion inhibition efficiency of o-CANB at 35°C.WL method reflected that corrosion inhibition efficiency of o-CANB increased with increasing concentration and highest corrosion inhibition efficiency is achieved at 0.5% concentration (%V/V). At this concentration and 35°C

temperature, corrosion inhibition efficiency of o-CANB was reported 99.4%. EIS method showed 94.2% at 0.1% concentration and 35°C temperature. PDP method displayed 93.7% corrosion inhibition efficiency at 0.05% concentration and at 35°C temperature. WL method was employed to study the effect of temperature on corrosion inhibition efficiency. The obtained result showed that as temperature increased in the range of 35 to 65°C, corrosion inhibition efficiency of o-CANB was decreased. ΔG^0_{ads} value of inhibitor was-32.6kJ/mol that showed about physicsorption.

Two Schiff bases prepared between two aldehydes such as 5-chlorosalicylaldehyde and 5-bromosalicylaldehyde with 1, 8-bis (o-aminophenoxy)-3, 6-dioxooctane to produced two corrosion inhibitors TC and TB respectively.[9] Corrosion inhibition efficiency of two Schiff bases has been studied in 0.1M HCl by EQCM and PDP methods at 25°C. A PDP method indicated that corrosion inhibition efficiency increased with concentration. At highest concentration 0.1mM, both inhibitors TC and TB showed 74.8% and 83.5% corrosion inhibition efficiency respectively. EQCM technique displayed 70.2% and 85.2% corrosion inhibition efficiency at 0.1mM. ΔG^0_{ads} values of both Schiff bases TC and TB were -59.8 and -60.57kJ/mol respectively. These values reflected about chemisorption of inhibitors on aluminium surface.

Temkin adsorption isotherm is followed by both inhibitors. SEM study revealed about corrosion inhibition efficiency of both inhibitors. MNDO semi empirical method used for the calculation of various parameters such as EH, EL, EL-EH, dipolmoment and charge densities of Cl, Br, O and N atoms were investigated. Two electrochemical methods such as EIS and PDP were used for the evolution of corrosion inhibition efficiency of 1, 5-bis[2-(2-hydroxybenzylideneamino)phenoxy]-3-oxopentane,1,5-bis[2-(5-chloro-2 hydroxybenzylideneamino)phenoxy]-3-oxopentane and 1,5-bis[2-(5-bromo-2-hydroxybenz-ylideneamino)phenoxy]-3-oxopentane in 0.1M HCl at 25°C.[8–10] Both techniques revealed that corrosion inhibition efficiency increased with concentration. Highest corrosion inhibition efficiency was obtained at 100μm. Corrosion inhibition efficiency order of three Schiff bases is as 1, 5-bis [2-(5-bromo-2-hydroxybenzylideneamino)phenoxy]-3-oxopentane> 1, 5-bis[2-(5-chloro-2-hydroxybenzyli-deneamino) phenoxy]-3-oxopentane>1,5-bis[2-(2-hydroxybenzyliden-eimino) phenoxy]-3-oxopentaneThe values of ΔG^0_{ads} for three Schiff bases are ranged in between -49.38 to -57.49kJ/mol which showed that all three Schiff bases adsorbed on aluminium surface by chemisorption. Various quantum chemical parameters were calculated and support the corrosion inhibition efficiency by experiment methods. The three Schiff bases 2-[2-aza-2-(5-methyl(2-pyridly))vinyl]phenol(MP), 2-[2-aza-2-(5-methyl(2-pyridly))vinyl]-4-bromophenol(MBP) and (2-[2-aza-2-(5-methyl(2-pyridly))vinyl]-4-chloro-phenol)(MCP) were studied as corrosion inhibitors for Al in 0.1M HCl at 25°C.[11] Corrosion inhibition efficiency of three inhibitors was increased with concentration. MP showed highest corrosion inhibition efficiency 43.4% at 5×10^{-3}M as determined by EIS method. However PDP and LPR showed 80.2% and 58.7% corrosion inhibition efficiency at same concentration. Others two inhibitors MBP and MCP displayed 64.2% and 69.7% corrosion inhibition effectiveness as calculated by EIS method at 5×10^{-3}M. PDP and LPR method exhibited 84.3% and 60% corrosion inhibition efficiency at same concentration for MBP and MCP showed 69.7% corrosion inhibition efficiency at 5×10^{-3}M as investigated by EIS technique. PDP and LPR reflected 78.6% and 44.5 corrosion inhibition efficiency at 5×10^{-4}M for MCP. ΔG^0_{ads}

value of three compounds is less than -20kJ/mol indicated about physisorption of three compounds on Al surface. Various quantum chemical indices were evaluated for the determination of theoretical corrosion inhibition efficiency of inhibitors.

Li et al.[12] reported three oximes such as acetone oxime (AO), 2-butanone oxime(BO) and cyclohexanoneoxime (CO) for Al in 1-3M HCl.[12] The corrosion inhibition efficiency of three oximeswas determined by WL, EIS and PDP measurements. All three techniques revealed that corrosion inhibition effectiveness has been increased with concentration. Further all three investigated techniques confirmed that highest corrosion inhibition efficiency was attained at their highest 2mM concentration at 20°C in 1M HCl which is shown in Table 1. The effect of temperature was studied by WL method. The obtained results were indicating that as temperature increased from 20 to 50°C led to decrease corrosion inhibition efficiency. WL method revealed that immersion time of three inhibitors affected on corrosion inhibition activity. As immersion time increased from 0.5 to 2h, corrosion inhibition efficiency of three oximes was increased. After that further increased immersion time from 2 to 6h led to decreased in corrosion inhibition efficiency of three oximes. Corrosion inhibition efficiency order of three oximes is CO> BO>AO. ΔG^0_{ads} value of three oximeswas laid in between -29 to -30kJ/mol. Langmuir adsorption isotherm was consistent for all three oximes. Asincreased in acid concentration attributed to decrease corrosion inhibition efficiency of inhibitors. In 3M HC test solution, at2mM concentration and at 20°C, AO, BO and CO exhibited 22%, 35.5% and 41.2% corrosion inhibition efficiency as evaluated by WL method. Activation energy of three oximes in 1MHCl was lower than uninhibited system reflected about a physical barrier was formed on Al surface. PDP and OCP measurements showed that all three oximes acted as cathodic inhibitors. Various quantum chemical parameters were evaluated.

Table I Corrosion inhibition efficiency of inhibitors at their highest 2mM concentration

Name compounds	Techniques used for determination of corrosion inhibition efficiency		
	WL	**PDP**	**EIS**
AO	80%	85.70%	89.20%
BO	87%	93.50%	93.10%
CO	93.90%	98.40%	95.20%

Effects of various substituents such as methyl, chloride and nitro have been studied by Ashassi-Sorkhabi et al.[13] in 1M HCl[13] for aluminium. They prepared four Schiff bases such as benzylidene-(2-methoxy-phenyl)-amine(A),(2-methoxy-phenyl)-(4-methyl-benzylidene)-amine(B),(4-chloro-benzyli-dene)-(2-methoxy-phenyl)-amine(C) and (4-nitro-bezylidene)-(2-methoxy-phenyl)-amine (D). WL, EIS and PDP techniques were employed to assess the corrosion inhibition efficiency. The employed techniques showed that corrosion inhibition efficiency of inhibitors increased with concentration. The PDP method displayed 99.8%, 98.43%, 96.06% and 84.4% corrosion inhibition efficiency for Schiff bases A, B, C and D respectively at their highest concentration 10^{-2}M and at 25°C. EIS measurement showed 96.34%, 91.16%, 87.63% and 74.45% inhibitive effectiveness for Schiff bases A, B, C and D respectively at same temperature and concentration. However WL technique produced 94.7%, 92.3%, 92.3% and 69.2% corrosion inhibition efficiency at same concentration and temperature. PDP method was used to study the effect of temperature on corrosion inhibition efficiency. Increased

temperature from 25 to 45°C contributed to decreased corrosion inhibition efficiency. It was found that corrosion inhibition efficiency depended on substituents. Methyl group increased corrosion inhibition efficiency than Cl and NO_2 groups. In comparison between Cl and NO_2 groups on corrosion inhibition efficiency, Cl group enhanced the corrosion inhibition efficiency than NO_2 group. PDP profile classified inhibitors into mixed type of inhibitors. All four inhibitors followed Langmuir adsorption isotherm. ΔG^0_{ads} values of inhibitors were calculated at 25°C. ΔG^0_{ads} values for Schiff bases A, B, C and D were noted -27.65,-28.98, -26.10 and -13.5kJ/mol that reflected about physisorption of inhibitors. High values of Ea than uninhibited suggested about formation of physical barrier between inhibitors and corrosive media. Various quantum chemical parameters have been determined and theoretical corrosion inhibition efficiency has been investigated.

The Schiff bases 2-hydroxyacetophenoneetansulphonylhydrazone, salicylaldehydeetansulphonylhydrazon, 5-bromosalicylaldehydeetansulphonylhydrazone and 5-chlorosalicyaldehyeetansulphony-lhydrazoneshowed good corrosion activity on AA3102 aluminium alloy in 0.1MHCl at room temperature by hydrogen gas evolution and impedance techniques.[14] Corrosion inhibition efficiency of four inhibitors determined at lowest and highest concentration is shown in the Table 2. Table 2 displayed that there is no regular trend in corrosion inhibition efficiency with increased inhibitors concentration. 5-chlorosalicylaldehydeetansulphonylaldehyde and 5-bromosalicyaldehydeetansulphony-ldehyde have shown high corrosion inhibition than salicyalde hydeetan sulphonyl hydrazone and 2-hydroxyacetophenoneetansulphonylhydrazone. Corrosion inhibitor 5-bromosalicyaldehydeetansulpho-nylaldehydeshowed high corrosion inhibition efficiency than 5-chlorosalicyaldehydeetansulphonylal-dehyde was due

to high molecular weight of 5-bromosalicyaldehydeetansulphoylaldehyde. Inhibition efficiency of various amphiphiles of p-aminobenzaldehyde has been reported as corrosion inhibitors.[15] The Schiff bases were synthesized by reaction between p-methoxy benzaldehyde and p-amino benzoic acid. Synthesized Schiff bass was pegalyated with different molecular weight and different alkylated chains. These Schiff bases are SB-400-16, SB-2000-10, SB-2000-16, SB-2000-18, SB-2000-oleate and SB-3000-16. Corrosion inhibition efficiency of parent Schiff bases and its non-ionic amphiphiles was evaluated by WL and hydrogen gas evolution measurements for aluminium in 4N HCl at 25°C for aluminium AA3102. Various parameters such as alkyl chain length, polyethylene oxide chain length and inhibitor concentration attributed on the corrosion inhibition efficiency. Corrosion inhibition efficiency of prepared non-ionic Schiff bases amphiphiles having constant ethylene oxide content (n=45EOunits). It was observed that increasing repeated methylene groups in the hydrophobic chains led to increase corrosion inhibition efficiency. Different hydrophobic chain length showed the following trend on corrosion inhibition efficiency: oleate >stearate>palmitate>decanoate. The corrosion inhibition efficiency was increased by decreasing PEO content. Higher PEO content led to increased hydrophilicity which led to decrease corrosion inhibition efficiency. At high concentration of amphiphiles (400ppm) was contributed to decrease corrosion inhibition efficiency. In further decreased in concentration from 400 to 200 and 100ppm enhanced corrosion inhibition efficiency. Maximum corrosion inhibition efficiency was achieved at 100ppm and deceased in concentration from as decreased from 100ppm to 50, 25 and 10ppm led to decrease corrosion inhibition efficiency but it was higher than 400ppm. The concentrations 150ppm is considered as a critical concentration and at this concentration high corrosion inhibition efficiency was achieved. It is due to micelle formation near this concentration.

Table 2 Corrosion inhibition efficiency of Schiff bases for AA3102 aluminum alloy

Name of compounds	Techniques used for determination of corrosion inhibition efficiency			
	Hydrogen gas evolution		Impedance method	
	10ppm	50ppm	10ppm	50ppm
Salicylaldehydeetansulphonylhydrazone	70%	59%	76%	94%
5-chlorosalicylaldehydeetansulphonylaldehyde	72%	61%	94%	91%
5-bromosalicylaldehydeetansulphonylhydrazone	89%	69%	100%	97%
2-hydroxyacetophenoneetansulphonylhydrazone	28%	70%	-	91%

Schiff bases for carbon Steel

Schiff base 2,2'-(heptanes-1,7-diylbis(azanylylidene)bis-(methanylylidene))diphenols (HAMD) has showed excellent corrosion inhibition performance on carbon steel in 0.5mol H_2SO_4 at 30°C.[14] WL and electrochemical techniques such as EIS and PDP were have been used to determine corrosion inhibition efficiency of inhibitor. All techniques showed that corrosion inhibition efficiency has increased with concentration. HAMD showed 93.6%, 94.9% and 93.1% corrosion inhibition efficiency at its highest concentration 10^{-3}M asdetermined by WL, PDP and EIS methods respectively. PDP

profile and Open circuit potential (OCP) revealed that HAMD was acted as mixed type of inhibitor. ΔG^0_{ads} value of HAMD was-33.5kJ/mol. This value is less than -40kJ/mol suggested that HAMD adsorbed on carbon steel by physical adsorption mechanism with followed langmuir adsorption isotherm. SEM and EDX techniques also proved corrosion inhibition activity of HAMD.

Corrosion inhibitove performance of Schiff base (E)-N-((E)-3-(phenylallylidene)-2-(phenylthi-o)aniline (2-PTA) has been studied by PDP, EIS and LPR for low carbon steel in 1M HCl at temperature from 30 -60°C.[15] All three techniques showed that corrosion inhibition efficiency increased with concentration. The inhibitor 2-PTA showed

excellent corrosion inhibition efficiency at low concentration 0.1mM. At its highest concentration 2.5mM did not great change in corrosion inhibition as compared to its low concentration. The corrosion inhibition efficiency of 2-PTA at 0.1mM and 2.5mM was noted 96.9% and 99.5% at 30°C as investigated by PDP method. Other two techniques EIS and LPR produced nearby corrosion inhibition efficiency at same concentration and temperature. The temperature effect reflected that as temperature increased from 30 to 60°C led to decrease corrosion inhibition efficiency. But this change is not a great change comparatively. It is observed that at high concentration, a little decreased in corrosion inhibition efficiency with increased temperature EFM measurement showed that 2-PTA was excellent and stable corrosion inhibitor. Corrosion inhibition efficiency of 2-PTA was recorded 99.6% and 99.8% at 24h and 120h respectively at its 2mM concentration. EIS method was also used to calculate various adsorption parameters. ΔG^0_{ads} values were found -40, -37.8,-40.4 and -42.9kJ/mol at temperature range of 30-60°C. This high values of ΔG^0_{ads} also gave proof of high corrosion activity of 2-PTA.

Schiff bases 1-(2-hydroxybenzylidene)-3-(2, 5-dioxoimidazolidin-4-yl) urea (ALS) was studied as a corrosion inhibitor on carbon steel in 1M HCl by PDP, EIS and LPR measurements. The temperature ranged was chosen from 200C to 50°C.[16–18] PDP measurement showed that corrosion inhibition efficiency increased with concentration. At 10^{-5}M, 5×10^{-5}M and 10^{-4}M concentrations, corrosion inhibition efficiency increase with increased temperature from 20°C to 40°C. At these concentrations and at 50°C, corrosion inhibition efficiency is decreased. But higher concentrations such as 5×10^{-4}M and 10^{-3}M corrosion inhibition efficiency increased as temperature increased from 20°C to 50°C. PDP confirmed that at lower concentration and low temperature, ALA exhibited high corrosion inhibition efficiency as compared to high concentration and at high temperature. However at high concentration, corrosion inhibition efficiency increased with temperature. EIS and LPR techniques produced similar trend of temperature on corrosion inhibition efficiency as PDP technique. Corrosion inhibition efficiency of ALA was recorded 96%, 94% and 95% as determined by PDP, EIS and LPR at highest concentration 10^{-3}M and 50°C respectively. ΔG^0_{ads} values of ALA were noted -37.8, 40.4, -41.3 and -30.8kJ/mol at temperature rang 20-50°C. Theses high values showed that ALA inhibitor adsorbed on metal surface through chemisorptions. Langmuir adsorption isotherm is obeyed by ALA inhibitor.

5-bromo-2-[(E)-(pyridin-3-ylimino)methyl]phenol(HBSAP)and5-bromo-2-[(E)-(quinolin-8-yiimino)methyl]phenol (HBSAQ) have been investigated as corrosion inhibitors on carbon steel (C1018) in 3.5%+NaCl+0.1M HCl solution. EIS and PDP measurements indicated that corrosion inhibition efficiency of both inhibitors increased with concentration.[19] EIS method showed that corrosion inhibition efficiency decreased with increased temperature in the temperature range of 20°Cto 50°C. At 50°C and inhibitors higher concentration (10^{-3}M), HBSAP and HBSAQ showed 91% and 92.8% corrosion inhibition efficiency as evaluated by EIS method. At same conditions HBSAP and HBSAQ inhibitors displayed 91.36% and 92.64% corrosion inhibition efficiency as determined by PDP method. Effect of immersion time studied for HBSAQ by EIS method. Increased time from 2 to 120h, corrosion inhibition efficiency of HBSAQ increased and after 120h, it remained constant. An Ea value of HBSAQ was higher than uninhibited system and increased with

concentration. High values of E as suggested that physical barrier is formed between inhibitor and metal surface. ΔG^0_{ads} values of HBSAP and HBSAQ are found -35.12 and -35.36kJ/mol respectively. These values showed that both inhibitors adsorbed on carbon steel by mixed type of chemical and physical adsorption mechanism with followed by langmuir adsorption isotherm.

Corrosion inhibitors N, N'-ortho-phenylenacetyle acetone imine (S1) and 4-[(3-{[1-(2-hydroxy phenyl)methylidene]amino}propyl] ethanemidol]-1, 3-benzenediol (S_2) have been studied as corrosion inhibitors on two different microstructures by impedance method in 1MHCl.[20] Two different microstructures are produced by different heat treatment process. These two structures are martensite and perlite. Both Schiff bases enhanced corrosion inhibition efficiency as increased their concentration for both martensite and perlite. Schiff base S1 showed 82.6% and 80.9% corrosion inhibition efficiency for martensite and perlite at 400ppm respectively. Schiff base S_2 displayed 53.7% and 55.6% corrosion inhibition efficiency for same microstructures at same concentrations.PDP measurement classified both inhibitors into mixed type of inhibitors. ΔG^0_{ads} values of both inhibitors indicated that they are adsorbed on metal surface through mixed physiochemical adsorption mechanism. Langmuir adsorption isotherm obeyed by two inhibitors.

WL, EIS and PDP measurements are used to study the corrosion inhibition efficiency of four Schiff bases such as 2-((pyridine-2-ylimino)methyl)phenol, 2-((hexadecylimino) methyl)phenol, 2-((4-hydroxyphenylimino)methyl)phenol and 1-(4-(2-hydroxybenzylideneamino)phenyl)ethanonein 1M HCl.[19] Corrosion inhibition efficiency of all inhibitors increased with concentration. The highest corrosion inhibition efficiency is achieved at 10-2M. All techniques revealed that corrosion inhibition efficiency order of inhibitors 2-((hexadecylimino) methyl) phenol>2-((4-hydroxyphenylimino)methyl)phenol>2-((pyridin-2-ylimino)methyl) phenol>1-(4-(2-hydroxybenzylideneamino)phenyl)e-thanone. Temperature increase led to decrease corrosion inhibition efficiency of inhibitors as confirmed by WL measurement. ΔG^0_{ads} values were laid between -29.4 to -34kJ/mol/. It showed about physical and chemical adsorption mechanism of inhibitors. All four Schiff bases are followed by langmuir adsorption isotherm. Ea values of all inhibitors were higher than uninhibited system reflecting about formation of physical adsorption barrier between inhibitors and corrosive media.

The corrosion inhibitive effect of Schiff bases whose general structure is shown in the Figure 1were checked on carbon steel in 1M HCl by WL, EIS and PDP methods at 25°C.[20–22] The inhibitors are synthesized direct by esterification reaction between schiff base of vanillin –glycine and polyethylene glycol –fatty acids. The four different fatty acids are dodecyl (VGOD), hexadecyl (VGOH), octadecyl (VGOO) and oleic acid (VGOL). These four Schiff bases are abbreviated as VGOD, VGOH, VGOO and VGOL. Corrosion inhibition performance of all four non -ionic Schiff bases of vanillin glycine –peg-fatty acids increased with concentration. Highest corrosion inhibition efficiency is achieved at 400ppm. Effect of immersion time has been studied by WL method. It reflected that as immersion time increased from 1h to 24h lead to increased corrosion inhibition efficiency of all inhibitors. It is clear that corrosion inhibition efficiency of investigated inhibitors depend on the alkyl chain length. An Alkyl chain length increase attributed to

increase corrosion inhibition efficiency. ΔG^0_{ads} values are investigated and predicted that all inhibitors followed mixed type of physis and chemisorption mechanism with followed by langmuir adsorption isotherm. The corrosion inhibition efficiency order of inhibitors is as VGOL> VGOO> VGOH> VGOD.
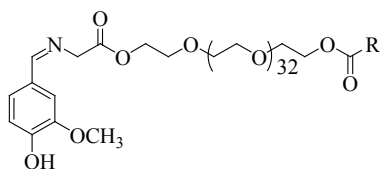
R= dodecyl (VGOD), Hexadecyl (VGOH) ,Octadecyl (VGOD) and linoyl (VGOL)

Figure 1 General structures of non-ionic Schiff bases

Four Schiff bases 2-((1E)-2-aza-2-pyrimidine-2-ylvinyl) thiophene(PT),2-((1Z)-1-aza-2-(2-pyridyl)vinyl)pyrimidine(PP),2-((1E)-2-aza-2-(1,3-thiazol-2-yl)vinyl)thiophene(TT)and2-((1Z)-1-aza-2-(2-thienyl)vinyl)benzothiazole(TBT) are shown corrosion activity on carbon steel in 0.1M HCl.[23] Corrosion inhibition efficiency increased with concentration as verified by PDP and EIS measurements. At 20°C PDP methods displayed that corrosion inhibition efficiency of inhibitors are decreased with increased temperature range from 20°C to 60°C. At concentration 1×10^{-5}M, all inhibitors exhibited high corrosion inhibition efficiency. Inhibitors PT, PP, TT and TBT showed 83.3%, 71.8%.64.4% and 49.5% inhibition efficiency at this concentration and 20°C temperature. EIS reflected 58.3%, 54.6%, 50.2% and 33.7% corrosion inhibition efficiency at similar conditions. PDP technique classified inhibitors into anodic nature. ΔG^0_{ads} values of all four inhibitors are higher than -40kJ/mol that conformed for chemisorptions of inhibitors. Temkin adsorption isotherm is obeyed by all inhibitors.

Two homologous Classes of quaternary isoxazolium Schiff base series are prepared and tested their corrosion inhibition efficiency by WL, EIS and PDP methods respectively.[24] Total eight Schiff bases, four from each class have been reported. The genera structure of both series is shown in the Figure 2. These six Schiff bases are OA12, OA14, OA16 and OA18 and OB12, OB14, OB16 and OB18.The corrosion inhibition efficiency is determined by WL, PDP and EIS at 25°C. All methods showed that corrosion inhibition efficiency increased with concentration and alkyl chain length at 25°C. Comparison between two series, OB showed high corrosion inhibition than OA. WL method indicates that weight loss increased with increased temperature from 25-40°C that reflected about corrosion inhibition efficiency decreased with temperature. WL method also showed that increased immersion time from 4h to 8h, increased in weight lost which attributed to increase corrosion inhibition efficiency. ΔG^0_{ads} values are ranged in between -37.3 to -40.5kJ/mol that reflected about mixed type of physical and chemical adsorption mechanism.

The Schiff bases NDSI, NBDSI, NMDSI and NCDSI are reported as corrosion inhibitors for carbon steel in 1M HCl.[23,25] The corrosion inhibition efficiency increased with concentration as checked by WL, EIS and PDP techniques at 25°C. WL technique showed that as increased immersion time from 1h to 25h led to enhance the corrosion inhibition efficiency. The corrosion inhibition order of inhibitors is as: NMDSI >NBDSI >NDSI >NCDSI. The investigated ΔG^0_{ads} values

showed that inhibitors followed mixed type of physical and chemical adsorption mechanism. Langmuir adsorption isotherm is followed by all inhibitors.PDP measurement classified all inhibitors into mixed type of inhibitors.

Schiff base such as bis(p-(N,N,N-decyldimethylammonium bromide)benzylidne)thiourea(10-S-10) ,bis(p-(N,N,N-dodecyldimethylammoniumbromide)benzylidene)thiourea(12-S-12) and bis(p-N,N,N-tetradecyldimethylammonium bromide) benzylidene)thiourea (14-S-14) as corrosion inhibitors on carbon steel in 1M HCl by PDP , EIS and WL methods respectively at 25°C.[26] All these techniques showed that corrosion inhibition efficiency increased with concentration. WL method displayed 94.09%, 94.83% and 98.6% corrosion inhibition efficiency for 10-S-10, 12-S-12 and 14-S-14 respectively at 5×10^{-3}M.Both electrochemical techniques PDP showed 94.58%, 96.06 and 97.75 and EIS reflected 94.79%, 94.9% and 95.53% corrosion inhibition efficiency for Schiff bases 10-S-10 , 12-S-12 and 14-S-14 at 5×10^{-3}M. ΔG^0_{ads} values of three gemini Schiff bases 10-S-10, 12-S-12 and 14-S-14 are reported -35.99, -36.35 and -37.37kJ/mol. These values predicted about mixed type of physical and chemical adsorption mechanism of three inhibitors. Langmuir adsorption isotherm is followed by three Schiff bases. SEM micrographs also supported the corrosion property of all three Schiff bases. PDP technique classified three inhibitors into mixed type of inhibitors.

Similar three cationic Schiff bases such as N,N-dimethyl-4-(((1-methyl-2-phenyl-2,3-dihydro-1H-pyrazol-4-yl)imino)methyl)-N-octylbenzenaminiumbromide(APS-8),N,N-dimethyl-4-(((1-methyl-2-phenyl-2,3-dihydro-1H-pyrazol-4-yl)imino)methyl)-N-dodecylbenzenaminiumbromide (APS-12) and N,N-dimethyl-4-(((1-methyl-2-phenyl-2,3-dihydro-1H-pyrazol-4-yl)imino)methyl)-N-hexadecyl-benzenaminiumbromide (APS-16) for carbon steel in 1M HCl.[27] The three investigated techniques WL, EIS and PDP showed that corrosion inhibition efficiency of all three inhibitors increased with concentration at 20°C as determined by WL and at 25°C as determined by EIS and PDP measurements. The highest corrosion inhibition efficiency achieved at 5×10^{-3}M. Influence of temperature is studied by WL method and obtained results showed that corrosion inhibition efficiency increased with increased temperature in the temperature range 20-60°C. This trend indicated about chemisorption of three inhibitors at higher temperature which also supported by the values of ΔG^0_{ads}. ΔG^0_{ads} values of three inhibitors were higher than-40kJ/mol at 600C. These three inhibitors followed the corrosion inhibition efficiency order as: APS -16>APS-12>APS-18.
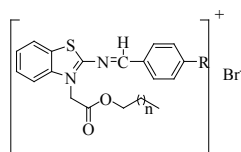
Benzimidazole based two series of cationic Schiff bases 2-(benzylideneamino)-3-(2-oxo-2-alkoxyethyl)-1,3-benzothiazol-3-ium bromide and 2-[(4-methoxybenzylidene)amino]-3-(2-oxo-2-alkoxyethyl)-1,3-benzothiazol-3-ium bromide were reported as corrosion inhibitors for carbon steel in 0.5M HCl.[28–30] The general structure of inhibitors is shown in Figure 3. Total eight Schiff base four from each have been synthesized. These six inhibitors are abbreviated as SBAD, SBAT, SBAH and SBAO (four from, R=H) and SBBD, SBBT, SBBH and SBBO (four from, R=O Me). The corrosion inhibition efficiency of all eight corrosion inhibitors is increased with concentration at 25°C as evaluated by WL and PDP methods. Effect of temperature and immersion time has been studied on corrosion inhibition efficiency at 30 and 40°C and 4h and 8h immersion time

at two different concentration 200 and 400ppm by WL measurement. Temperature effect showed that at both concentrations and 4h and 8h immersion time, corrosion rate increased with temperature i.e corrosion inhibition efficiency decreased with increased temperature and immersion time increased from 4 to 8h led to decreased corrosion inhibition efficiency of inhibitors. PDP measurement classified all eight inhibitors into mixed type of inhibitors. Corrosion inhibition efficiency order of Schiff bases are SBAO>SBAH>SBBO>SBBH >SBBT>SBBD>SBAT>SBAD. ΔG^0_{ads} values of all eight inhibitor are laid in ranged -14.61 to -20.41kJ/mol reflects about physisorption of all inhibitors with followed by Langmuir adsorption isotherm. Corrosion inhibition efficiency of these all these surfactants increased the carbon length of surfactant impart to increase corrosion inhibition efficiency.
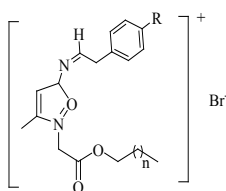
R=H:3-benzylideneamino-2-(2-alkyloxy-2-oxoethyl)-5-methyl-1,2-oxazol-2-iumbronide n= 10 (dodecyl- OB12),12 (tetradecyl- OB14), 14 (hexadecyl- OB16) and 16 (octadecyl- OB18). R = OCH3: 3-(4-methoxybenzylideneamino)-2-(2-alkyloxy-2-oxoethyl)-5-methyl-1,2-oxazol-2-ium bromide n= 10 (dodecyl- OA12), 12 (tetradecyl- OA14), 14 (hexadecyl- OA16) and 16 (octadecyl- OA18).

Figure 2 General structure of isoxazolium cationic Schiff bases

R= H: 2-(Benzylidene)amino)-3-(2-oxo-alkyloxyethyl)1,3-benzothiazol-3-ium bromide n= 10 (SBAD,) n=12 (SBAT), n=14 (SBAH) & n=16 (SBAO)R = OCH3: 2-((4-Methoxybenzylidene)amino)-3-(2-oxo-alkyloxyethyl)-1,3-benzothiazol-3-ium bromide n= 10 (SBBD), n= 12 (SBBT), n= 14 (SBBH), n= 16 (SBBO)

Figure 3 General structure of benzimidazole Schiff bases

Schiff bases for iron steel, stainles steel and steel

Schiff bases N-(2-hydroxyphenyl) salicyaldimine and N, N'-bis (salicyaldehyde)-1, 3-diamino-propaneevaluated as corrosion inhibitors for iron metal which contains 99.9% pure iron in 1M HCl.[29]A corrosion performance of these two Schiff bases was determined by WL, EIS, PDP and LPR methods at 30°C. Schiff baseN-(2-hydroxyphenyl) salicyaldimine showed 40.3% corrosion inhibition efficiency at 5×10^{-3}M and 24h of immersion time. N-bis-(salicyaldehyde)-1, 3-diaminopropane displayed 78.8% corrosion inhibition efficiency at 5×10^{-3}M and 24h immersion time as determined by WL measurement. WL measurement reflected that corrosion inhibition efficiency of both Schiff bases increased with raised immersion from 24 h to 168h. EIS, PDP and LPR measurements showed that corrosion inhibition efficiency of two Schiff bases increased with concentration. The highest corrosion inhibition efficiency is achieved at highest concentration 5×10^{-3}M. Schiff bases N-(2-hydroxyphenyl) salicyaldimine and N-bis-(salicyaldehyde)-1,3-diaminopropane exhibited 57% and 77% corrosion inhibition efficiency at 5×10^{-3}M as determined by PDP measurement. However EIS displayed 56% and 83% corrosion inhibition efficiency at $5\times10^-$

^{3}M. LPR displayed 59.4% and 84.2% corrosion inhibition efficiency for Schiff bases N-(2-hydroxyphenyl) salicyaldimine and N, N-bis-(salicyaldehyde)-1, 3-diaminopropane.Langmuir adsorption isotherm is followed by two Schiff bases.

Sulphur bases three Schiff bases such as N-[(Z)-1-phenylmethyleidene]amino}phenyl)disulfanyl]phenyl}amine(I) , 2-[({2-[(2-{[(Z)-1-(2-hydroxyphenyl)methylidene]amino}phenyl) disulf-anyl]phenyl}imino)methyl]phenol (II) and N-[(Z)-1-(4-methylphenyl)methylidene]-N-{2-[(2-{[(Z)-1-(4-methlphenyl) methylidene]amino}phenyl)disulfanyl]phenyl}amine(III) showed corrosion inhibiti-veeffectiveness on stainless steel 304 in 15% HCl at 30°C. The main chemical composition of stainless steel 304 is 18.2% of Cr, 8.48% of Ni, 2% of Mn and 30% of Fe and rest of other impurities. The investigated techniques WL, EIS and PDP reflected that corrosion inhibition efficiency of inhibitors increased with concentration. At 5×10^{-3}M highest concentration all three inhibitors exhibited highest corrosion inhibition efficiency. The corrosion inhibition efficiency of three Schiff bases is shown in the Table 3 as investigated by above mentioned techniques at their highest concentrations. Table 3 reflects that all three Schiff bases showed excellent corrosion inhibition efficiency. WL method indicated that as immersion time increased from 1h to 2h, didn't changed so much in corrosion inhibition efficiency. WL method further showed that corrosion inhibition increased with of temperature range of 35 to 65°C. ΔG^0_{ads} values of three Schiff bases are laid in between -38 to -40kJ/mol reflecting about mixed type physical and chemical adsorption mechanism but. ΔG^0_{ads} values are very close to -40kJ/mol revealed about Schiff bases adsorbed more chemical than physical adsorption. This argument is also support by Ea values. Ea values decreased in the presence of inhibitors. Various quantum chemical parameters are also evaluated. The calculated values of quantum chemical indices support corrosion inhibition efficiency of inhibitors.

Table 3 Corrosion inhibition efficiency of sulphur based inhibitors at 0.005 M

Name of compounds	Techniques used to determine corrosion inhibition efficiency		
	WL	**EIS**	**PDP**
I	96.90%	95.50%	96.40%
II	95.60%	95.30%	97.10%
III	95.70%	94.40%	97.20%

N, N-bis(4-formylphenol)-trimethylenediamine(4-FPTMD) Schiff base displayed corrosion inhibition effectiveness on API 5L grade B steel in 1M HCl.[31] The corrosion inhibition efficiency of 4-FPTMD increased with concentration at 25°C. Schiff bases showed 94% and 85% corrosion inhibition efficiency at highest concentration 2×10^{-3}M as determined by PDP and EIS measurements. The effect of temperature studied at 45°C and 65°C by PDP techniques. The corrosion inhibition efficiency decreased with increased temperature. The ΔG^0_{ads} values of 4-FPTMD reported -35.77,-36.82 and -37.48kJ/mol at 25°C, 45°C and 65°C respectively.. These values indicated about physisorption of 4-FPTMD.Ea values of 4-FPTMD is higher than uninhibited system showed about formation of physical barrier between metal and corrosive media. The various quantum chemical parameters such as EHOMO, ELUMO, ΔE and others are evaluated by different methods. SEM and AFM techniques also provided the evidence of corrosion inhibition performance of 4-FPTMD.

Two Schiff bases 2-{[(4-methoxyphenyl)imino]methyl}phenol and 1-{[(4-methoxyphenyl)imino]methyl}-2-naphthol are evaluated as corrosion inhibitors for steel in 0.1M and 1M H_2SO_4 at room temperature.[30]The corrosion inhibition efficiency of both Schiff bases was determined at different concentrations by PDP and LPR methods. Both inhibitors enhanced their corrosion inhibition action in both test solutions. Both inhibitors showed high corrosion inhibition efficiency in 0.1M H_2SO_4 than 1M H_2SO_4. PDP reflected 84.8% and 92.2% and LPR showed 84% and 93% corrosion inhibition efficiency for 2-{[(4-methoxyphenyl) imino]methyl}phenol and 1-{[(4-methoxypheny-l)imino]methyl}-2-naphthol in 0.1M H_2SO4 at 20mM.The Schiff bases2-{[(4-methoxyphenyl)imino]methyl} phenol and 1-{[4-methoxypheny)imino]methyl}-2-napthol displayed 83.5% and 91.3% corrosion inhibition efficiency as determined by PDP method in 1M H_2SO_4. The LPR technique showed 78% and 88% corrosion inhibition efficiency for 2-{[(4-methoxyphenyl) imino] methyl} phenol and 1-{[(4-methoxypheny-l) imino] methyl}-2-naphthol in 1M H_2SO_4 at 20mM. The corrosion inhibition efficiency of 1-{[(4-methoxypheny-l) imino] methyl}-2-naphthol is higher than 2-{[(4-methoxyphenyl) imino] methyl} phenol in both test solutions. The ΔG^0_{ads} values of 2-{[(4-methoxyphenyl) imino] methyl} phenol and 1-{[(4-methoxypheny-l) imino] methyl}-2-naphthol are noted -6 and -7.9kJ/mol strongly indicated about physical adsorption mechanism. SEM micrograph also displayed corrosion inhibition efficiency of both Schiff bases. The calculated quantum chemical parameters indicated about high corrosion inhibition efficiency of 1-{[(4-methoxypheny-l)imino]methyl}-2-naphthol than2-{[(4-methoxyphenyl) imino] methyl} phenol. The high molecular weight of -{[(4-methoxyphenyl) imino] methyl} phenol is responsible for its high corrosion inhibition efficiency.

EIS and PDP method were used to determine the corrosion inhibition efficiency of 3-morpholinopropan-1-amine inhibitors whose structure is shown in the Figure 4 in 0.5 M H_2SO_4 at 25°C for X65 steel.[33]The Fe content is 98% in the X65steel. The corrosion inhibition efficiency increased with concentration. At 0.0500M of concentration, all three inhibitors exhibited high corrosion inhibition as verified by PDP and EIS methods. The corrosion inhibition efficiency of three compounds 1, 2 and 3 are shown in the Table 4. Table 4 reveals that compound 3 showed high corrosion inhibition efficiency than compounds 2 and 1. N, N- dimethyl group of compound 3 enhanced the corrosion inhibition efficiency of compound 3. Compound 2 displayed high corrosion inhibition efficiency than compound 1 was due to presence of pyridine ring. The nitrogen atom of pyridine ring strongly bound to metal. The synergistic effect also studied by KI. The presence of KI showed remarkable effect on corrosion inhibition efficiency. The 0.05MKI and 0.0005 M Schiff bases are prepared to study the corrosion performance of three Schiff bases. The corrosion inhibition efficacy of Schiff bases 1,2 and 3 increased up to 98.6%, 98.9% and 99.4% as compared to 57.6%, 84.7% and 89.5% in the presence of 0.0005 M concentration of three Schiff bases as determined by PDP method. The EIS method also agreed with the results obtained by PDP method in the presence of same concentration of KI and Schiff bases. The PDP method classified compound 1 into anodicinhibitor and compounds 2 and 3 into mixed type of inhibitors. The ΔG^0_{ads} values of three compounds are higher than -40kJ/mol strongly predicted about chemisorption of three compounds. The Langmuir adsorption

isotherm is followed by three compounds. The SEM studied also reveals about corrosion inhibition action of three inhibitors.

Corrosion inhibition efficiency is influenced by the position of chloride group for steel in 5% HCl at 20°C.[34] The PDP and EIS techniques were employed to determine the corrosion inhibition efficiency of four inhibitorsThe corrosion inhibition efficiency of four Schiff bases such as salicyaldimine, N-(2-chlorophenyl) salicyaldimine (2Cl-R) N-(3-chlorophenyl) salicyaldimine (3Cl-R) and N-(4-chlorophenyl) salicyaldimine (4Cl-R) was found to increase with concentration. The corrosion inhibition efficiency order of four Schiff bases are 2-Cl –R>4-Cl –R>3-Cl –R>R as evaluated by EIS and PDP measurements of concentration ranged 1×10^{-4}M to 5×10^{-3}M. At highest 5×10^{-3}M concentration, all inhibitors salicyaldimine, N-(2-chlorophenyl) salicyaldimine (2Cl-R),N-(3-chlorophenyl) salicyaldimine (3Cl-R) and N-(4-chlorophenyl) salicyaldimine (4Cl-R) showed 91% , 95% , 91% and 94% corrosion inhibition efficiency as determined by PDP technique. All four inhibitors followed Langmuir adsorption isotherm. N, N'-bis-(salicylaldehyde)-1, 3-diaminopropane(Salpr) and its cobalt complex showed corrosion inhibitive property on steel in 1M H_2SO_4 at 20°C.[35] The structure of cobalt complex is shown in the Figure 5. PDP measurement and its cobalt complex exhibited that corrosion inhibition efficiency of Salpr and its cobalt complex increased with concentration. PDP measurement displayed 73.41% corrosion inhibition efficiency at 35mol/L. However EIS measurement showed 84.3% and 83.2% corrosion inhibition efficiency at same concentration and temperature. The bulky nature of cobalt complex attributed its high corrosion inhibition efficiency. The Langmuir, Flory–Huggins and the kinetic–thermodynamic model indicate about non-ideal behaviour of cobalt complex in adsorption process.
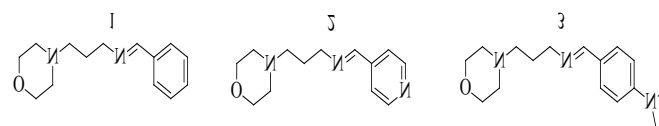

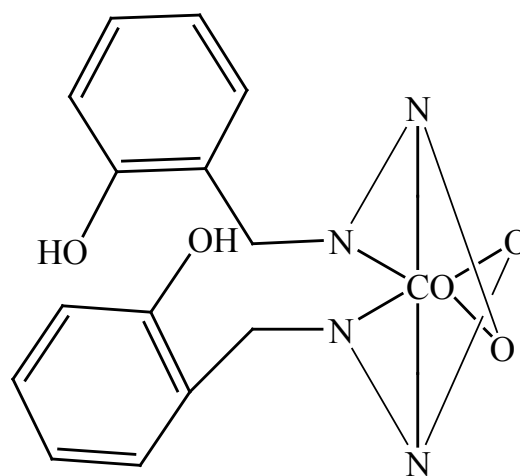**Figure 4** The structures of Schiff bases of 3-morpholinopropan-1-amine

Figure 5 The structures of cobalt complex

Schiff bases for others metals

The Schiff bases N, N-ethylen-bis(salicylidenimine) and N,N'-ortho-phenylen-bis(salicylideni-(imne)tested as corrosion inhibitors for copper in 0.5M H_2SO_4.[36] The copper electrode coated with epoxy resin called SAMs (self-assembled monolayer). PDP and EIS were employed for evaluation of corrosion inhibition efficiency of both Schiff bases. The corrosion inhibition efficiency of both inhibitors increased with concentration at 23°C. At highest concentration 300ppm, schiff base N,N'-ethylen-bis(salicylidenimine) showed 93.68% and Schiff base N, N'-ortho-phenylen-bis-(salicylidenimine)displayed 96.41% corrosion inhibition efficiency as determined by EIS measurement. The Schiff base N,N'-ethylen-bis (salicylidenimine) showed 78% corrosion inhibition efficiency at its 300ppm concentration as calculated by PDP measurement. The synergistic effect has been studied by propanethiol and 1-dodecanethiol. The presence of both propanethiol and 1-dodecanethiol improved corrosion property of both inhibitors. Langmuir adsorption isotherm is followed by both inhibitors.

2-({-1-methyl-3-[(2-sulfanylphenyl)imino]butylidene}amino)-1-benzenethioland2-({-1,2-diphenyl-2-[(2-sulfanylphenyl)imino] ethylidene}amino)-1-benzenethiol were evaluated as corrosion inhibitors for copper in 15% HCl.[37] The corrosion inhibition efficiency of both inhibitors increased with concentration. The EIS method displayed 95.94% and 96.75% corrosion inhibition efficiency at highest 500ppm of concentration for 2-({-1-methyl-3-[(2-sulfanylphenyl)imino]butylidene}amino)-1-benzenethiol and 2-({-1,2-diphenyl-2-[(2-sulfanylphenyl)imino]ethylidene}amino)-1-benzenethiol respectively. However PDP reflected 87.47 % and 88.59 % at same concentration for both inhibitors respectively. Langmuir adsorption isotherm us followed by both inhibitors.

Three Schiff bases such as N, N'-p-phenylen-bis (3-methoxy-salicylidenimine) (V-pph-V), N, N'-o-phenylen-bis(3-methoxysalicylidenimine(V-oph-V) and N'-histidine-3-methoxysalicylidenimine(V-his) are evaluated as corrosion inhibitors for copper in 5% HCl.[38] Impedance method showed that corrosion inhibition efficiency of three inhibitors was higher than 80%. The corrosion inhibition efficiency of all inhibitors is shown in Table 5.The order of corrosion inhibition efficiency of three inhibitors followed as V-oph-V>V-pph-V>V-his. The PDP method classified into mixed type with more cathodic characteristic.

The Schiff base whose structure is shown in Figure 6 showed the corrosion inhibitive property on magnesium (99.12%) in 0.01MHCl at room temperature.[39] The corrosion inhibition efficiency is determined by PDP, EIS and EN methods. All three methods revealed that corrosion inhibition efficiency increased with concentration. The Schiff base showed 93.68%, 95.1% and 97.84% corrosion inhibition efficiency at highest concentration 0.005M as calculated by PDP, EIS and EN methods respectively. The ΔG^0_{ads} value of Schiff base is reported to -22.96kJ/mol. This value is close to -20kJ/mo lindicating physisorption. ΔG^0_{ads} value showed that Schiff base was adsorbed on metal surface through physisorption followed by Freundlichisotherm. PDP result showed that Schiff base acted as mixed type of inhibitor. SEM result also provides the evidence for corrosion action of Schiff base.

The WL, EIS and PDP measurements are employed for the determination of corrosion inhibitive action of Schiff base (4Z)-4-(3-phenyl allydene amino)-3-hydroxy naphthalene-1-sulfonic acid for AZ31 magnesium alloy in 0.05 mol/L at room temperature.[40] The chemical composition of AZ31 magnesium alloy is Al: 2.89%, Zn:1.15, Mn: 0.2% and rest of Mg. All three techniques demonstrated that corrosion inhibition efficiency of inhibitor increased with concentration. At highest concentration 10mmol, WL, PDP and EIS showed 62.79%, 84.42% and 88.1% corrosion inhibition efficiency. PDP measurement indicated that Schiff base acted as mixed type of inhibitor. ΔG^0_{ads} values of Schiff base was laid in between -22 to -26.76kJ/mol at different concentrations such as 2.5,5, 7.5 and 10mmol which revealed about physical adsorption mechanism with Langmuir adsorption isotherm is obeyed by inhibitor.
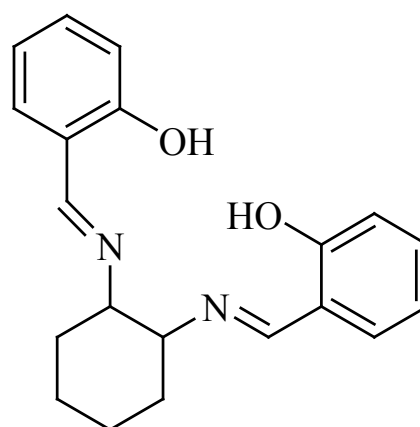

Figure 6 Schiff bases of 2-hydroxybenzaldehyde with cyclohexane-1, 2-diamine

Table 4 Corrosion inhibition efficiency of 3-morpholinopropan-1-amine based inhibitors

S.no	At maximum concentration 0.05M.	Techniques used to determine corrosion inhibition efficiency	
		PDP	EIS
1		89.70%	76.60%
2		98.50%	93.10%
3		99%	96.80%

Table 5 Corrosion inhibition efficiency of V-oph-V, V-his and V-pph-V determination by impedance method

Name of compounds	Concentration	Temperature	Corrosion inhibition efficiency
V-oph-V	4-Oct	20	97.50%
V-his	4-Oct	20	80.70%
V-pph-V	4-Oct	20	92.50%
V-pph-V	3-Oct	20	99.40%
V-pph-V	5-Oct	20	85%
V-pph-V	3-Oct	30	98.80%
V-pph-V	3-Oct	50	95.60%
V-oph-V	4-Oct	20	97%
V-his	4-Oct	20	87.60%

Conclusion

This review involving the summary of various articles on the Schiff bases as corrosion inhibitors for metals in acidic environment. The main focused of review is provided the corrosion inhibition efficiency and adsorption mechanism. The corrosion inhibition efficiency of inhibitors was evaluated by different measurements such as WL, EIS, PDP, EQCM and EN. The corrosion inhibition efficiency depends on the concentration and temperature. It has been observed that corrosion inhibition efficiency of inhibitors increased with concentration in the most cases. In some cases like inhibitors 2-hydroxyacetophenoneetansulphonylhydrazone, salicyaldeheetansulphoylhydrazone, 5-bromosalicylaldeheetansulphonylhydrazone and 5-chlorosalicyaldhydeetansulphonylhydrazone in which hydrogen evolution technique exhibited high corrosion inhibition efficiency at low concentration and impedance method showed high corrosion inhibition efficiency at high concentration. Inhibitor 2-PTA displayed high corrosion inhibition efficiency at low concentration and did not affect so much in corrosion inhibition efficiency at high concentration. The temperature studied showed that in most of cases corrosion inhibition efficiency decreased with increased temperature. In this case ΔG^0_{ads} values of most of inhibitors are laid in between -20 to -40kJ/mol which indicates about mixed type of physical and chemical adsorption mechanism and few examples those ΔG^0_{ads} values are less than -20kJ/mol or very near to it. In this case inhibitors follow physical mechanism and ΔG^0_{ads} values are greater than -40kJ/mol, corrosion inhibitors followed chemical adsorption mechanism. Corrosion inhibition efficiency increased with temperature shows that ΔG^0_{ads} values are higher than -40kJ/mol or very nearer to -40kJ/mol which was also indicated about chemisorption. For inhibitor ALA, at concentration 10^{-5} M, 5×10^{-5}M and 10^{-4}M corrosion inhibition efficiency increase with increased temperature from increased temperature from 20°C to 40°C. At same concentrations and at 50°C corrosion inhibition efficiency is decreased. But higher concentrations such as 5×10^{-4}M and 10^{-3}M corrosion inhibition efficiency increased as temperature increased from 20°C to 50°C. Immersion time increased leads to increase corrosion inhibition efficiency at some extent and decreased or remains constant in corrosion inhibition efficiency further increased immersion time. Schiff bases of Benzimidazole surfactants, corrosion inhibition efficiency decreased with increased immersion time. Synergistic effect enhanced the corrosion inhibition efficiency. Langmuir adsorption isotherm is followed by all most inhibitors expect fews. Temkin adsorption isotherm is obeyed by TC&TB, PT, PP, TT and TBT. Freundlich isotherm is followed by Schiff base shown in Figure 6.

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None.

Conflict of interest

Authors declare that they have no conflict of interest.

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