Adsorption and Corrosion inhibition of Stainless steel in Hydrochloric acid by Sulphanilic acid

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ABSTRACT

The corrosion inhibition of sulphanilic acid for stainless steel in HCl solution has been evaluated by Weight loss study.   It is found that the inhibition efficiency of sulphanilic acid (SA) increases with increase in concentration. Surface analysis by SEM and EDAX confirms the formation of protective layer on the stainless steel surface.   Adsorption of sulphanilic acid on the surface of stainless steel follows Langmuir, Tempkin, Flory Huggins and El-Awady adsorption isotherm.

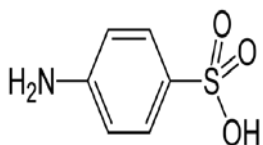**Keywords :** Stainless steel, Sulphanilic acid, Corrosion inhibition, SEM and EDAX

1 INTRODUCTION

Corrosion is the deterioration of essential properties of a material with its surroundings; Millions of dollars are lost each year because of corrosion [1].   Type 430 stainless steel can be readily formed and has good corrosion resistance to the atmosphere. This is one reason why it is most widely used in the automobile trim. The first chemical plant application of stainless steel is a type 430 tank for shipping nitric acid [2]. Most equipment failure in stainless steel is due to pitting corrosion, which is caused by chloride ions in acid solution [3].   To prevent the attack of acid, it is very important to add a corrosion inhibitor to decrease the rate of metal dissolution in such solutions. Thus, many studies concerning the inhibition of Stainless steel corrosion using organic substances are conducted in acidic and basic solution [4]. The inhibition of corrosion is mainly due to adsorption of inhibitor on the surface of the metal. The adsorption of inhibitor is related to the presence of heteroatoms such as nitrogen, oxygen, sulphur and aromatic ring in their molecular structure. Generally, a stronger co-ordinate bond causes higher inhibition efficiency [5]. It has been accepted that the corrosion inhibition results from the   formation of organic inhibitor film on the metal surface [6]. In this present work, the corrosion inhibition properties of sulphanilic acid against 430 stainless steel in acidic solutions have been investigated.

2 MATERIALS AND METHODS

2.1 Preparation of inhibitor

Commercially available Sulphanilic acid compound with molecular formula $C_6H_7O_3NS$ is used as such.   All the solutions are prepared from doubly distilled water.

Sulphanilic acid

2.2 Specimen preparation

Stainless steel 430 grade having composition of 0.12% C, 1.00% Si, 1.00% Mn, 16.00% Cr, 0.75% Ni, 0.04% P, 0.03% S and the remainder Fe, specimens are used.   In the weight loss experiments. They are mechanically cut from commercially available stainless steel samples into coupons of 4.0cm×1.5 cm×0.0457 cm dimensions, polished with soft 3M 1500 sand paper to a metallic shine, washed with acetone and double distilled water, dried to room temperature and stored in a moisture free desiccators before use in corrosion studies. The stainless steel specimens for the electro chemical measurements are machine cut from stainless steel sample into test electrodes of dimensions, 8.0cm×1.0cm×0.0457cm and coated with epoxy resin (araldite)leaving a surface area of 1cm^2. The corrosive medium, 1.0 M HCl solution are prepared from analytical grade 37% HCl by diluting with double-distilled water.

2.3 Weight – Loss Method

Stainless steel specimens are immersed in 100 mL of the 1.0 M HCl solution with and without inhibitor for 1h. The weight of metal specimens before and after immersion is determined by using Shimadzu Ay 220 model digital balance.   From the weight loss data corrosion rate and percent inhibition efficiency (IE %) are calculated.

Corrosion Rate = Weight loss / (surface area x time in hrs)   (1)

$$IE\% = \frac{CR_0 - CR_t}{CR_0} \times 100 \qquad (2)$$

Where, CR_0 and CR_t are the corrosion rates of the stainless steel in the absence and the presence of the inhibitor respectively.

2.4 SEM and EDAX investigation

The Stainless steel immersed in blank and in the inhibitor solution for a period of one hour is removed, rinsed with double distilled water, dried and analyzed using TES SCAN computer controlled scanning electron microscope with energy dispersive X-ray analyzer.

3 Results and Discussion

3.1 Weight loss method

The Weight loss studies are carried out with various concentrations of sulphanilic acid ranging from 0.57- 5.7 mM in 1M HCl at 303 K for a period of 1 hour. The corrosion parameters obtained from weight loss measurements for Stainless steel in 1 M HCl containing various concentration of Sulphanilic acid are listed in the table-1. It is found that with increase in concentration of the Sulphanilic acid from 0.57-5.7 mM, the inhibition efficiency increases. This trend may result from the fact that adsorption and surface coverage increases with the increase in the concentration of inhibitor. Thus the metal surface is efficiently separated from the corroding medium [7, 8 & 9]. At 5.7 mM concentration of the inhibitor maximum inhibition efficiency of 68% is achieved. Further increase in concentration of the inhibitor increases the inhibition efficiency. Hence the optimum concentration of the inhibitor for maximum inhibition efficiency is found to be 5.7 mM.

Table 1: Inhibition of corrosion of stainless steel in 1.0 M HCl by Sulphanilic Acid

Concentration of inhibitor (mM)	% Inhibition efficiency (303 K)
0.57	55
1.41	56
1.71	56
2.28	57
2.85	58
3.42	59
3.99	60
4.56	64
5.13	66
5.7	68

3.2 Adsorption parameters

Adsorption isotherms are very important in determining the mechanism of organo-electrochemical reaction [10, 11]. The inhibition of the corrosion of stainless steel in 1 M HCl with addition of different concentration of the sulphanilic acid increases the fraction of the surface covered by the adsorbed molecule (θ). Therefore, the adsorption isotherm describes the

relationship between the coverage of interface with the adsorbed species and the concentration of species in solution. The value of the surface coverage (θ) at different concentrations of the inhibitor in 1M HCl solution is made to fit to various adsorption isotherms. In this study, Langmuir, Tempkin, Flory Huggins and El-Awady isotherms are found to be suitable for the experimental findings. The isotherm is described by the equations are given by [12, 13, & 14]

$$C/\theta = 1/K_{ads} + C \quad \text{----------------------------- (3)}$$
$$\text{Log } (c/\theta) = \text{Log } C - \text{Log } K_{ads} \quad \text{----------------------------- (4)}$$
$$\text{Log } \theta/C = \text{Log } (xK) + x \text{ Log } (1-\theta) \text{ ----------------------------- (5)}$$
$$\text{Log } (\theta/1-\theta) = \text{Log } K + y \text{ Log } C \quad \text{----------------------------- (6)}$$

Where C is the inhibitor concentration, K_{ads} is the adsorption equilibrium constant, K is Constant, and θ is the surface coverage.

The estimated value of Correlation coefficient R^2 for Sulphanilic acid at 303 K is shown in Table2:

Names of Adsorption isotherms	R^2
Langmuir	0.975
Tempkin	0.894
El-Awady	0.894
Flory Huggins	0.98

The plots support the fact that the mechanism of corrosion inhibition is due to the formation of a protective film on the metal surface, and the additive covers both the anodic and cathodic sites through uniform adsorption [15, 16, 17 & 18]. The fit of the experimental data to these isotherms provide evidence for the role of adsorption in the observed inhibitive effect of the Sulphanilic acid.
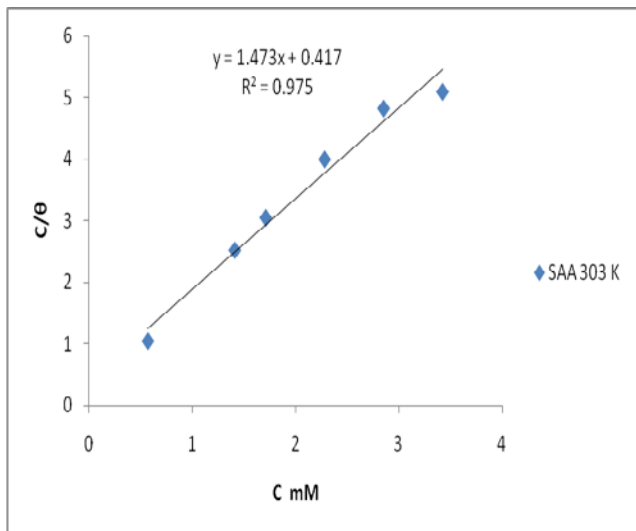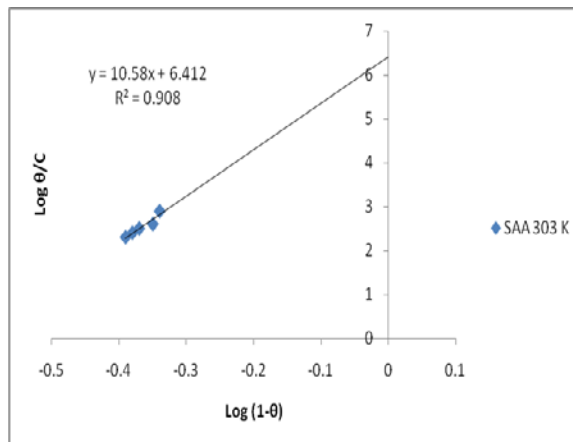
Fig 1a-Langmuir isotherm for SA

Fig 1b-Tempkin isotherm for SA

Fig-1c El-Awady isotherm for SA

Fig-1d Flory Huggins isotherm for SA-

3.3 SEM and EDAX analysis

Both SEM and EDAX investigations are carried out to verify whether the inhibitor is adsorbed on stainless steel surface. The SEM micrograph for stainless steel in the absence and presence of optimum concentration of SA is shown in Fig-2(a-c). The SEM micrographs of polished stainless steel surface in Figure 2(a) shows the smooth surface of the metal. The stainless surface in the absence of inhibitor is found to be severely affected in 1M HCl (Fig-2b). The roughness seems to be reduced in the presence of SA (Fig-2c). A comparison of SEM micrographs obtained in the absence and in the presence of the SA reveals a significant inhibiting effect of SA.
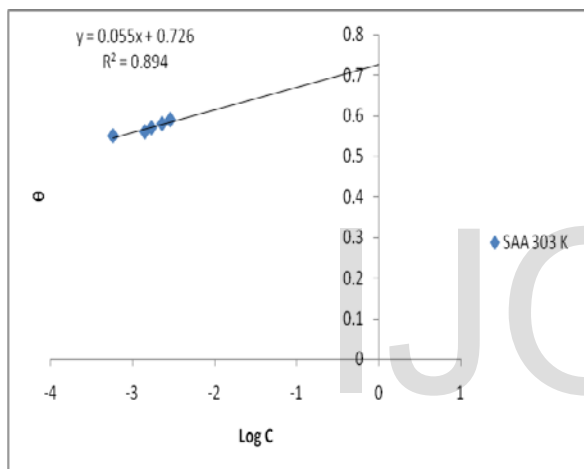

Fig – 2a

Fig – 2b

Fig- 2c
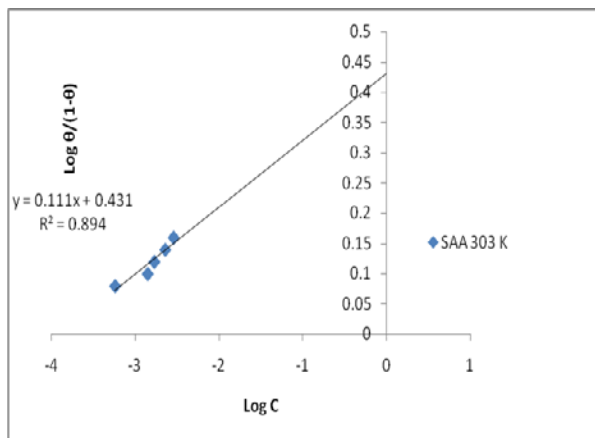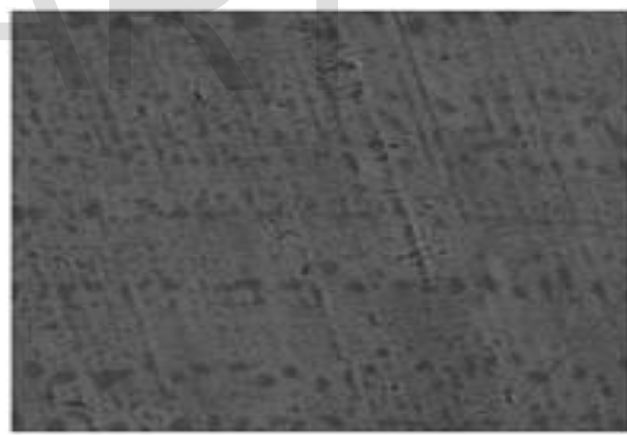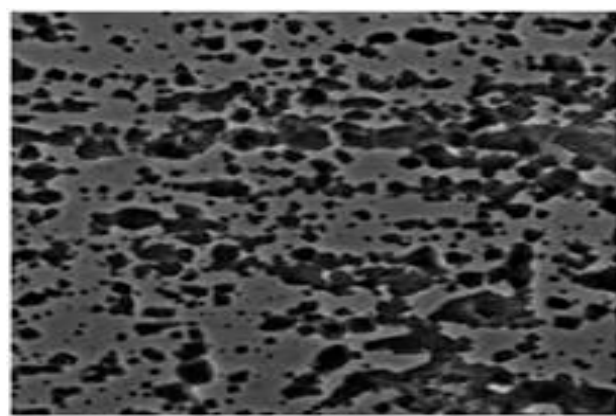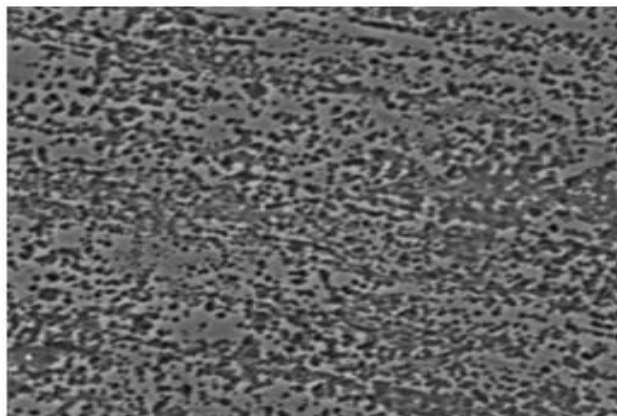
Figure 2 (a) SEM image of stainless steel before
            Immersion.
         (b) SEM image of stainless steel immersed in 1.0 M
            HCl (Blank).
         (c) SEM image of stainless steel immersed in 1.0M
            HCl+ SA

EDAX spectra are used to determine the elements present on the stainless steel surface before and after exposure to the inhibitor solution. [19, 20 & 21] Fig.3 (a-c) presents the EDAX spectra for the samples in the absence and presence of optimum concentration of SA. In the absence of the inhibitor, oxygen, nitrogen and sulphur atoms are not found on the stainless steel surface. In the presence of the optimum concentration of the inhibitor, oxygen, nitrogen and sulphur atoms are found to be present on the stainless steel surface. This indicates that the inhibitor molecules are adsorbed on the stainless steel surface and hence protect the stainless steel surface against corrosion.
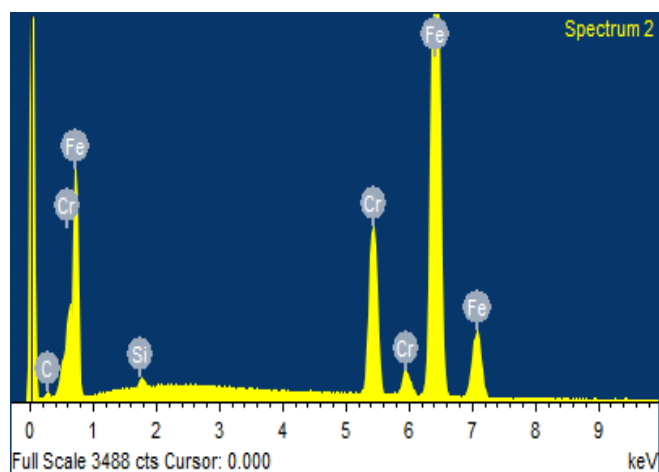

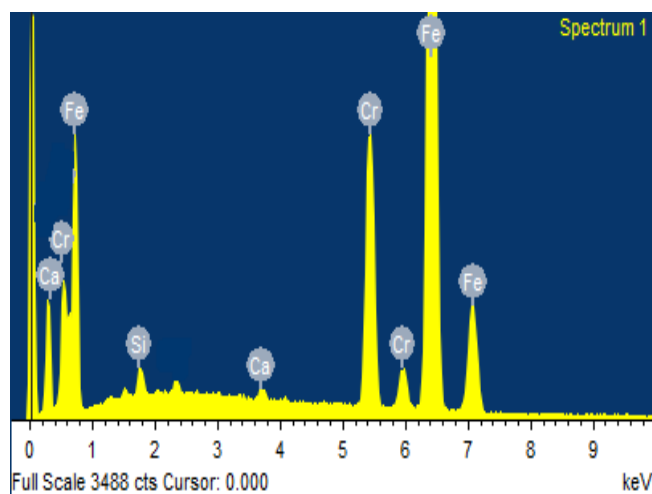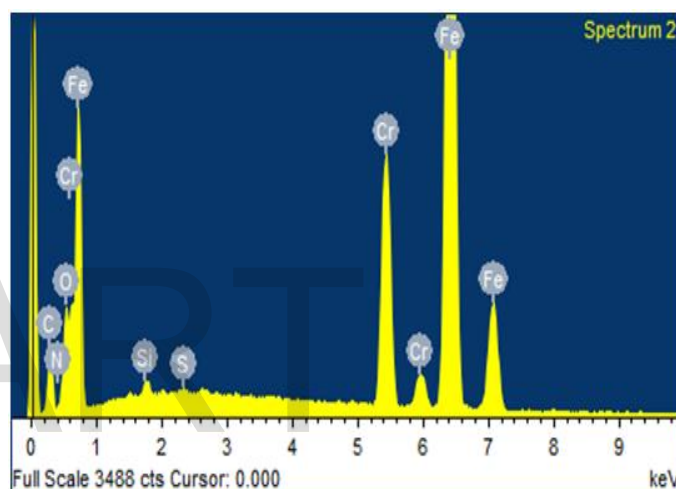Fig – 3a

Fig – 3b

Fig – 3c

Figure: 3 (a) EDAX spectra of stainless steel before immersion
         (b) EDAX spectra of Stainless steel sample
            after immersion in 1 M HCl.
         (c) EDAX spectra of Stainless steel sample after
            immersion in 1 M HCl with SA.

4 Conclusions

Sulphanilic acid has proved to be a good inhibitor for the corrosion of Stainless steel in 1 M HCl. IE is found to increase with increase in concentration of inhibitor. The inhibition of Stainless steel in 1M HCl is found to obey Langmuir and Flory – Huggins adsorption isotherm fairly well. Surface morphological studies such as EDAX and SEM analysis shows that the formation of a film containing the inhibitor.

5 Acknowledgments

6 References

[1].P.Selvakumar and B.Balanaga karthick et.al, *Res.J.Chem.Sci.,* vol. 3(4), 87-95, April (2013

[2]. M.G. Fontana, Corrosion Engineering, New York, Mc Graw-Hill, **1967**, p.226-227.

[3]. S.A.M. Refaey, F. Taha and A.M. Abd El-Malak, *Int. J.Electrochem. Sci.*, 1, 80-91, **2006.**

[4]. Diwan Singh Rajan and Dr. Shiv Darshan Malik, *Journal of Pure and Applied Science & Technology,* Vol.1 (2), pp.23-35, **2011**.

[5]. S.M.A. Hosseini, A. Azimi, I. Sheikhshoaei and M. Salari, *J.Iran. Chem.Soc.* Vol.7, No.4, pp.799-806, **2010.**

[6]. S M A Hosseini & M Salari, *Indian Journal of Chemical Technology,* Vol.16,pp: 480 - 485, **2009.**

[7]. Diwan Singh Rajan and Dr. Shiv Darshan Malik, *Journal of Pure and Applied Science & Technology,* Vol.1 (2), pp.23-35, **2011.**

[8]. *N* S Patel1, S Jauhariand1, G N Mehta1, S. S. Al-Deyab3, I. Warad3 , B. Hammouti2,* *Int. J. Electrochem. Sci.,* 8 2635 – 2655, **2013.**

[9]. Shanmugam Rajendran*, C. Thangavelu, A. Angamuthu and S. Jayakumar *Arch. Appl. Sci. Res., 5 (1): 202-212,* **2013.**

[10]. E.F.Olasehinde et.al, *Journal of Applied Chemistry*. Vol 2, 6, 2012, pp 15-23.

[11]. N S Patel, S Jauhariand, G N Mehta, S.S. Al-Deyab, I. Warad, B. Hammouti, *Int. J. Electrochem. Sci.,* 8, 2635 – 2655, **2013.**

[12]. X. Joseph Raj and N. Rajendran, *Int. J. Electrochem. Sci.,* 6, 348 – 366, **2011**

[13]. S. Leelavathi, R. Rajalakshmi, *J. Mater. Environ. Sci.* 4(5), 625-638, **2013.**

[14]. Iloamaeke I.M, Onuegbu T.U., Umeobika U.C., Umedum N.L., *Int. Journal of Sci. and Modern Eng. (IJISME)*, Vol.1, 3, **2013.**

[15].A. Jamal A bdul Nasser et.al, *International Journal of Engineering Science and Technology*, vol. 2(11), 2010, 6417-6426.

[16]. X. Joseph Raj and N. Rajendran *Int. J. Electrochem. Sci.,* 6,348 – 366, **2011**.

[17]. N Santhini, T. Jeyaraj, *Archives of Applied Science Research*, 4(5):2213-2222, **2012**.

[18]. T. Umasankareswari and T. Jeyaraj, *Jornal of Chemical and Pharmaceutical Research*, 4(7):3414-3419, **2012.**

[19]. Christoph Gabler, Christian Tomastik, Josef Brenner, Lucia Pisarova, Nicole Doerr and Guenter Allmaier, *Green Chem.,* 13, 2869-2877, **2011.**

[20]. A.Sahaya Raja, S.Rajendran, P.Sathiyabama, *Journal of Chemistry.* 8, **2013**.

[21]. X. Joseph Raj and N. Rajendran, *Int. J. Electrochem. Sci.,* 6, 348 – 366, **2011.**