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RESEARCH ARTICLE

Comparative study of mild steel corrosion using hydrochloric acid and phosphoric acid medium with ocimum tenuiflorum (l) plant extract

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Abstract

Extracts of Ocimum tenuiflorum (l) as organic corrosion inhibitor of mild steel in corrosive media of Phosphoric acid (H_3PO_4) and hydrochloric acid (HCl) has been investigated at various temperature using gravimetric (weight loss) and spectral techniques. IR and UV–Visible spectral data confirms that the inhibition of corrosion of mild steel occurs through adsorption of the inhibitor molecules. The experimental results reveal that extract of Ocimum Tenuiflorum (l) has a good inhibiting effect on the mild steel tested in both acid solutions. Inhibition efficiency increased with increase in temperature and inhibitor concentration. On Comparison of two acid medium finally 4% Ocimum Tenuiflorum (l) extract is found to be good inhibitor in good inhibition of mild steel corrosion in 0.5 N Phosphoric acids at 93.40% at 328K.

INTRODUCTION

Industries depend heavily on the use of metals and alloys. One of the most challenging and difficult tasks for industries are the protection of metals from corrosion. Corrosion is a ubiquitous problem that continues to be of great relevance in a wide range of industrial applications and products; it results in the degradation and eventual failure of many components [1]. The study of corrosion of mild steel is a matter of tremendous theoretical and practical concern and as such has received a considerable amount of interest. Acid solutions, widely used in industrial acid cleaning, acid descaling, acid pickling, and oil well acidizing, require the use of corrosion inhibitors in order to restrain their corrosion attack on metallic materials [2].

The use of corrosion inhibitors is the most economical and practical method in reducing corrosive attack on metals. Corrosion inhibitors are chemicals either synthetic or natural which, when added in small amounts to an environment, decrease the rate of attack by the environment on metals [3].Most studies on corrosion inhibitor reported that a large number of inhibitors are organic compound with N, S, and O hetero atoms, they have higher electron density, and making them the reaction centers [4-8]. These compounds are adsorbed on the metallic surface and block the active corrosion sites; most of them are highly toxic to both human beings and the environment. This has prompted the search for green corrosion inhibitors. Green corrosion inhibitors are biodegradable and do not contain heavy metals or other toxic compounds. Green inhibitors include plant extracts and drugs [9–16].

Plant extract is low-cost and environmentally safe, and so the main advantage of using plant extract as the corrosion inhibitor is due to both economic and environmental benefits. Up to now, many plant extracts have been used as effective corrosion inhibitors of iron or steel in acidic media (Satapathyet al., 2009; Chellammal et al., 2010; Behpoura et al., 2012; Hamdy and El-Gendy, 2013; Sethuraman et al., 2013).

Ocimum tenuiflorum belongs to the family lamiaceae. Ocimum tenuiflorum are commonly known as Tulsi or Basil. The scientific name of Holy Basil is Ocimum Sanctum. Holy Basil is an aromatic small plant with small green leaves and hairy stems.

Basil herb has pleasing smell. There are a large number of varieties of basil that differ in taste, smell and color of leaves. Basil is considered to be a holy plant in Indian culture. Basil leaves and seeds have great medicinal values. This plant is widely used in herbal medicines and as a home remedy for treatment of many ailments.
It has several therapeutic properties and used in treatment of Common cold and fever, cough treatment, acne, relieving headache, relieving stress, curing mouth ulcers, respiratory problems, memory improvement and skin disorders. Perusal of literature revealed that these plants have never been studied for their corrosion inhibition properties which prompted us to carry out corrosion inhibition evaluation of these plants on mild steel in 0.5 N Phosphoric and hydrochloric acid medium using gravimetric techniques.

Material and Methods

Plant description
Name : OCIMUM TENUIFLORUM
Filename : Ocimum tenuiflorum
Botanical name : Ocimum tenuiflorum.
Family : Lamiaceae
Sanskrit synonyms : Ocimum Sanctum

Ocimum tenuiflorum commonly known as Tulsi which is heavy branched having hair all over that belongs to the family Lamiaceae. It attains the height of about 75 – 90 cm. It has round oval shaped leaves which are up to 5 cm long. The leaves are 2- 4 cm in length. Its seeds are flat. Its flowers are purple – creamish in color. The Tulsi with the green leaves is called the Shri Tulsi and one with the reddish leaves is called the Krishna Tulsi. Its seeds are yellow to reddish in color.

Preparation of Mild steel specimen:

The test specimens of Mild steel were cut into apparent size of 5×1cm. The specimens of mild steel strip were polished successively using the emery paper of 150, 650, 400, 800, 1200 and 2000. The polished surface was degreased with trichloroethylene and washed with distilled water, dried and finally weighed.

Preparation of solution:

Hydrochloric acid:

The hydrochloric acid (0.5 N) solution was prepared by mixing 89ml of hydrochloric acid (AR) in 1000 ml in water.

Phosphoric acid:

The phosphoric acid (0.5 N) solution was also prepared by mixing 89ml of Phosphoric acid (AR) in 1000 ml in water.

Weight loss method:

Pure Mild steel specimens are cut to get length of 5 cm and widths of 1 cm were used for this study. They were pickled in pickling solution (conc. HCl + 50g $SnCl_2$ + 20g Sb_2O_3) for 3 minutes and washed with distilled water. They were then polished to a mirror finish by using 150, 320, 400, 800, 1200, and 2000 emery papers and degraded using trichloroethylene. Finally they were weighed in a single pan digital electronic balance.

The specimens were immersed in solution of various concentration of Ocimum tenuiflorum (l) (1%, 2%, 3%, 4% and 5%) as inhibitor for 3 hours.

Measurements of corrosion rate:

The corrosion rates were calculated in millimiles per year (mmpy) using the relation.

$$\text{Corrosion rate } (C_R) = \frac{87.6 \times W}{A \times T \times D} \text{ mmpy}$$

Where W = Weight loss of mild steel (mg),
A = Area of specimen,
T= the exposure time (h)
D = density of mild steel (gms/cm^3)

Determination of inhibitor efficiency:

Weight losses in the presence and in the absence of inhibitor were determined by weight loss method. The inhibitor efficiencies were obtained from the relationship.

$$\text{IE \%} = \frac{W_b - W_i}{W_b} \text{ x } 100$$

Where, W_b = weight loss without inhibitor in gms.
W_i = weight loss with inhibitor in gms

Determination of surface coverage:

The surface coverage was calculated from the rate of corrosion by using the following relation.

$$\theta = \frac{IE\%}{100}$$

Where,
W_b = weight loss without inhibitor in gms
W_i = weight loss with inhibitor in gms.

Result and Discussion

UV and FT-IR of extract of Ocimum tenuiflorum:

The recorded UV spectrum **(Figure 1 & 2)** of the compound show an absorbance around 280nm -300nm indicates that the non-bonding electron atom such as N, O is present in the ring or the hetero cyclic ring is possible.

The recorded IR spectrum **(Figure 3& 4)** of the compound showed a strong band around 1650-1750 cm^{-1} indicating the presence of NH_2 group and the absorption band around 1500-1620 cm^{-1} revealed the presence of carbonyl groups in the isolated compound. The strong band at 3600 cm^{-1} is corresponds to presence of aromatic OH group.

Corrosion rates and inhibition efficiency:

Weight loss values of mild steel specimens in both of the acid media with and without different concentrations of the extract were determined at various temperatures (308 -338 K). The rate of corrosion obtained from weight loss measurements are tabulated (Table-1). From the values of table1, it is clear that the rate of corrosion in both acids is found to be increasing with increasing in temperature (308K-338K) which indicates that the increasing in temperature enhanced the corrosion process. It is evident from the straight-line behavior obtained by plotting a graph with corrosion rate Vs temperatures ranges between 308 K-338 K as shown in figure 5.

The effect of temperature on inhibition of mild steel corrosion in 0.5N Hydrochloric acid with 0-5% of Ocimum tenuiflorum (l) extract between the temperature ranges from 308 K to 338 K has been studied and the results were tabulated (Table 2 & 3). From the table, it is clear that corrosion rate of mild steel in 0.5N HCl with Ocimum tenuiflorum (l) extract increases with respect to temperature. The rate of corrosion is found to be more effective in 0.5 N Hydrochloric acids up to 4 % and then further addition of 5 % corrosion rate decreases. This is due to desorption of the inhibitor constituents from the surface of the metal, due to the decrease in the strength of adsorption process. It is also evident from the graph obtained by plotting percentage of extract against the rate of corrosion which is shown in figure 6. The inhibitor efficiency of Ocimum Tenuiflorum (l) extract is found to be increased up to 4% with concentration of 0.5 N Hydrochloric acids and then further addition of 5 % extract decreases the inhibitor efficiency shown in figure 7. The efficiency observed is 93.4035 % and the surface coverage is equal to the inhibitor efficiency.

Similarly, the effect of temperature on inhibition of mild steel corrosion in 0.5N Phosphoric acid with 0-5% of Ocimum tenuiflorum(l) extract at various temperatures has been studied and results were tabulated (Table 4 & 5). From the table, it concludes that the rate of corrosion increases with respect to temperature. The rate of corrosion is decreased up to 5 % of the extract which confirms that the extract is found to be more effective in inhibition of mild steel. It is also evident from the graph obtained by plotting percentage of extract against the rate of corrosion which shown in figure 8. The effective inhibitor in inhibition of mild steel corrosion in 0.5 N Phosphoric acids up to 5% of extract and efficiency observed is 61.8070 %.

Table.1: **Corrosion rate of Mild Steel in 0.5N Hydrochloric and Phosphoric Acid with Ocimum tenuiflorum extract at various temperatures (308-338K)**

Temperature in 'K'	Weight loss method						Corrosion Rate (mmpy)	
	0.5N Hydrochloric acid			0.5N Phosphoric acid			0.5N Hydrochloric acid	0.5N Phosphoric acid
	Initial (g)	Final (g)	Difference (g)	Initial (g)	Final (g)	Difference (g)		
308	4.5822	4.3744	0.2078	3.5114	3.4866	0.0248	15.4395	1.8426
318	3.9870	3.7526	0.2344	4.0988	4.0256	0.0732	17.4159	5.4387
328	2.2018	1.4226	0.7792	3.9082	3.7820	0.1262	57.8947	9.3766
338	4.3338	3.1016	1.2322	4.0688	3.8640	0.2048	91.5527	15.2166

Table 2: Mild steel corrosion in 0.5 N Hydrochloric acid with Ocimum tenuiflorum (l) extract at (308 K & 318K)

S.No	Concentration of Ocimum tenuiflorum (l) extract (%)	Initial weight (g)	Final weight (g)	Weight loss (g)	Corrosion rate (mmpy)	Inhibitor Efficiency (%)	Surface coverage (g)
Room temperature 308 K							
1	0	4.5822	4.3744	0.2078	15.4395	-	-
2	1	4.6400	4.6054	0.0346	2.5707	83.3498	0.8334
3	2	4.5582	4.5386	0.0196	1.4562	90.5683	0.9056
4	3	4.2854	4.2706	0.0148	1.0996	92.8780	0.9287
5	4	4.5216	4.5074	0.0142	1.0550	93.1668	0.9316
6	5	4.4926	4.4652	0.0274	2.0358	86.8143	0.8681
Room temperature 318 K							
1	0	3.9870	3.7526	0.2344	17.4159	-	-
2	1	4.4770	4.3650	0.1120	8.3216	52.2183	0.5221
3	2	4.5743	4.5074	0.0669	4.9706	71.4594	0.7145
4	3	4.3560	4.3052	0.0508	3.7744	78.3278	0.7832
5	4	4.4466	4.4115	0.0351	2.6079	85.0257	0.8502
6	5	4.6622	4.6034	0.0588	4.3688	74.9148	0.7491

Table 3: Mild steel corrosion in 0.5 N Hydrochloric acid with Ocimum tenuiflorum (l) extract at (328 K – 338 K)

S.No	Concentration of Ocimum tenuiflorum (l) extract (%)	Initial weight (g)	Final weight (g)	Weight loss (g)	Corrosion rate (mmpy)	Inhibitor Efficiency (%)	Surface coverage (g)
Room temperature 328 K							
1	0	2.2018	1.4226	0.7792	57.8947	-	-
2	1	4.1192	3.9978	0.1214	9.0200	84.4199	0.8441
3	2	3.8174	3.7530	0.0644	4.7849	91.7351	0.9173
4	3	3.9434	3.8816	0.0618	4.5917	92.0688	0.9206
5	4	4.5294	4.4780	0.0514	3.8190	93.4035	0.9340
6	5	4.0066	3.9428	0.0638	4.7403	91.8122	0.9181
Room temperature 338K							
1	0	4.3338	3.1016	1.2322	91.5527	-	-
2	1	3.9190	3.6200	0.2990	22.2157	75.7345	0.7573
3	2	3.7068	3.4816	0.2252	16.7324	81.6909	0.8169
4	3	3.9326	3.7552	0.1774	13.1808	85.6030	0.8560
5	4	3.8378	3.7222	0.1156	8.5891	90.6184	0.9061
6	5	3.9520	3.8350	0.1170	8.6931	90.5048	0.9050

Table 4: Mild steel corrosion in 0.5 N Phosphoric acid with Ocimum tenuiflorum (l) extract at (308 K & 318K)

S.No	Concentration of Ocimum tenuiflorum (l) extract (%)	Initial weight (g)	Final weight (g)	Weight loss (g)	Corrosion rate (mmpy)	Inhibitor Efficiency (%)	Surface coverage (g)
Room temperature 308 K							
1	0	3.5114	3.4866	0.0248	1.8426	-	-
2	1	3.9332	3.9090	0.0242	1.7980	2.4204	0.2420
3	2	3.9436	3.9200	0.0236	1.7534	4.8409	0.0484
4	3	3.3274	3.3042	0.0232	1.7237	6.4528	0.0645
5	4	3.9320	3.9088	0.0232	1.7237	6.4528	0.0645
6	5	4.1588	4.1378	0.0210	1.5603	15.3207	0.1532
Room temperature 318 K							
1	0	4.0988	4.0256	0.0732	5.4387	-	-
2	1	4.1372	4.0884	0.0488	3.6258	-	-
3	2	4.1492	4.1020	0.0472	3.5069	-	-
4	3	4.1140	4.0712	0.0428	3.1800	41.5301	0.4153
5	4	4.1156	4.0720	0.0436	3.2394	40.4379	0.4043
6	5	4.0900	4.0502	0.0398	2.9571	45.6285	0.4562

Table 5: Mild steel corrosion in 0.5 N Phosphoric acid with Ocimum tenuiflorum (l) extract at (328 K & 338K)

S.No	Concentration of Ocimum tenuiflorum (l) extract (%)	Initial weight (g)	Final weight (g)	Weight loss (g)	Corrosion rate (mmpy)	Inhibitor Efficiency (%)	Surface coverage (g)
Room temperature 328 K							
1	0	3.9082	3.7820	0.1262	9.3766	-	-
2	1	4.0652	3.9846	0.0806	5.9886	36.1325	0.3613
3	2	4.0474	3.9748	0.0726	5.3941	42.4727	0.4247
4	3	3.8294	3.7812	0.0482	3.5812	61.8070	0.6180
5	4	3.9026	3.8468	0.0558	4.1459	55.7846	0.5578
6	5	3.4138	3.3620	0.0518	3.8487	58.9542	0.5895
Room temperature 338 K							
1	0	4.0688	3.8640	0.2048	15.2166	-	-
2	1	4.0478	3.8812	0.1666	12.3784	18.6519	0.1865
3	2	3.8804	3.7542	0.1262	9.3766	38.3791	0.3837
4	3	4.1522	4.0498	0.1024	7.6083	50	0.5
5	4	4.0278	3.8400	0.1878	13.9535	8.3008	0.0830
6	5	3.8578	3.7766	0.0812	6.0331	60.3518	0.6035

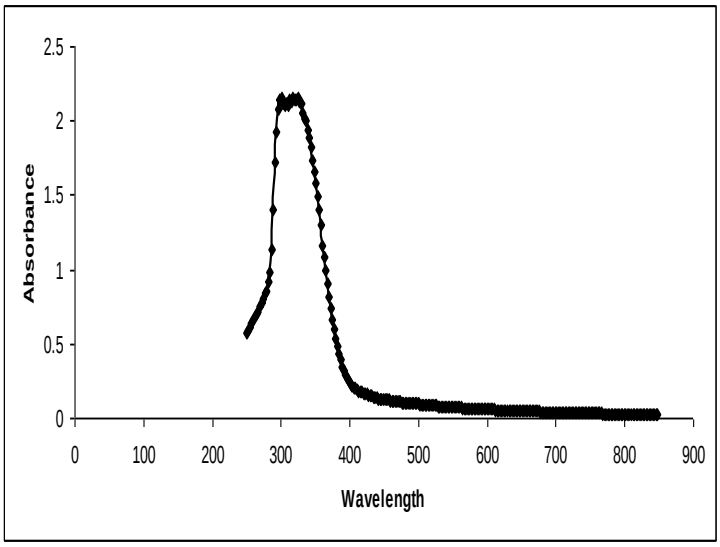

Fig.1. Ocimum tenuiflorum(l) H_2O spectrum

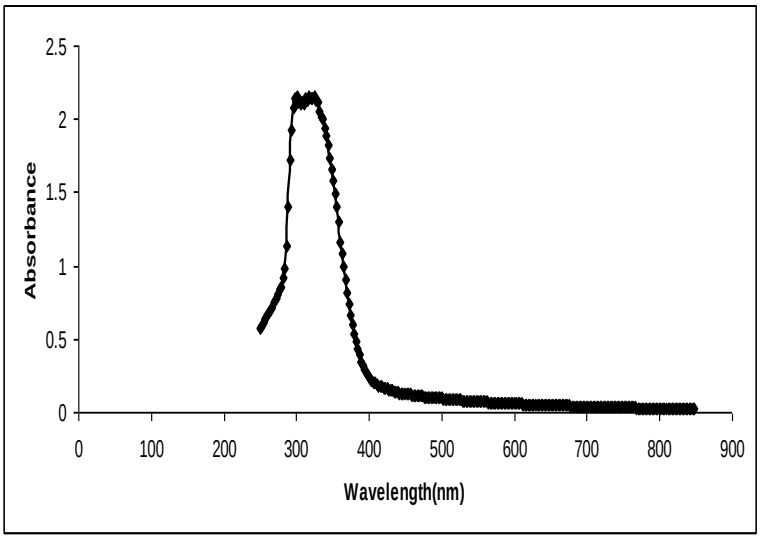

Fig.2. Ocimum tenuiflorum(l) H_3PO_4 spectrum

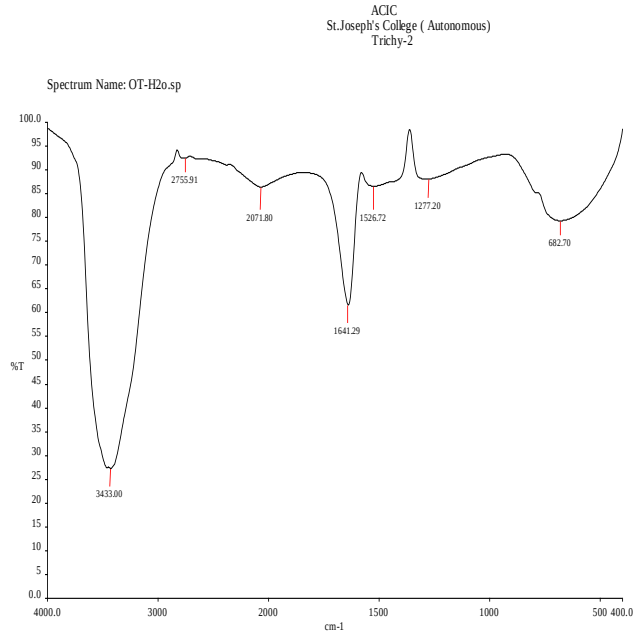

Fig.3. IR spectrum: Ocimum tenuiflorum(l) H_2O spectrum

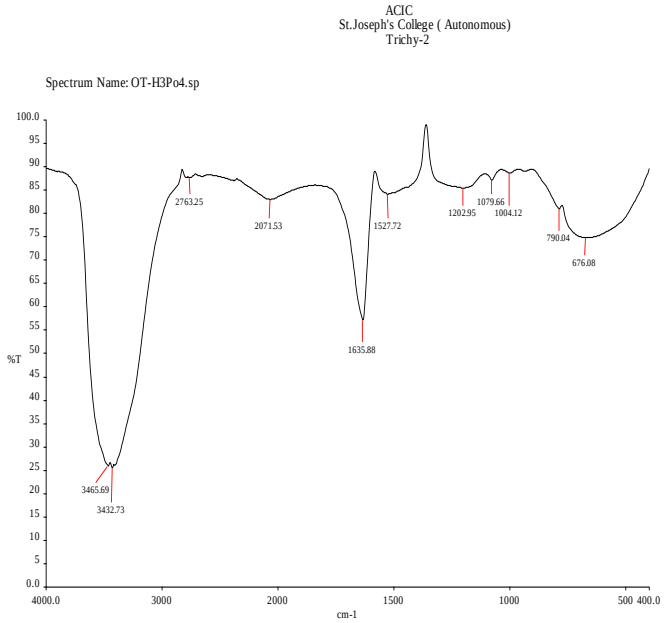

Fig.4. IR spectrum: Ocimum tenuiflorum(l) H_3PO_4 spectrum

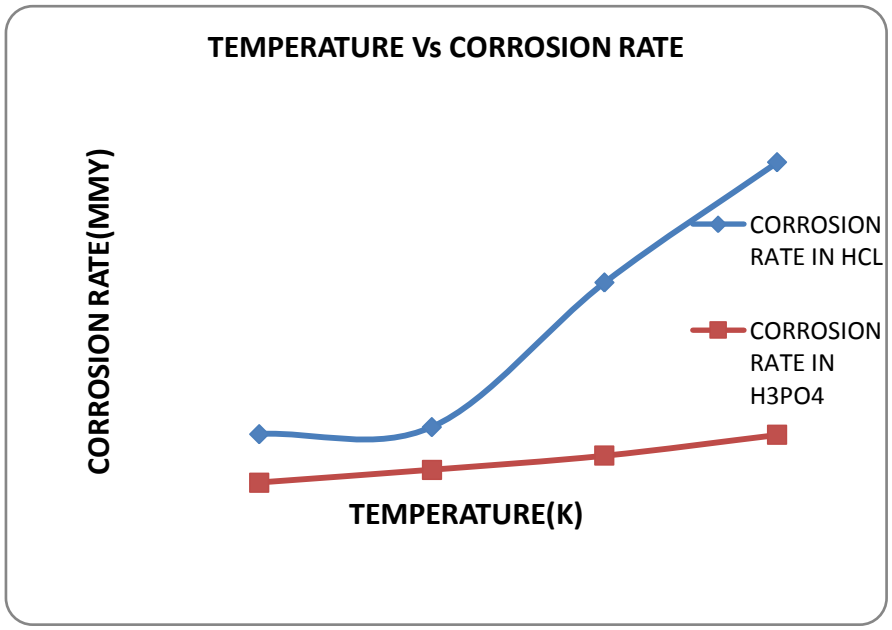

Fig.5. Corrosion rate of Mild Steel in 0.5N Hydrochloric acid & Phosphoric Acid with Ocimum tenuiflorum (l) extract at various temperatures (308-338K)

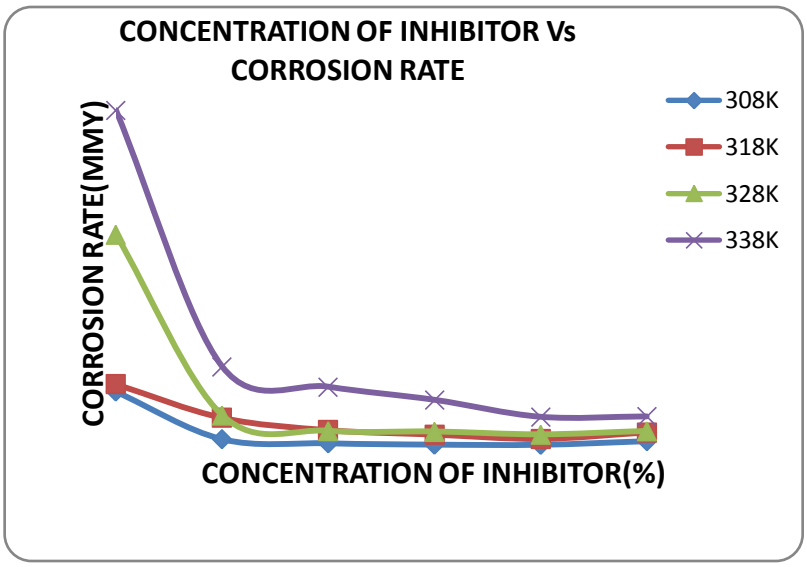

Fig.6. Concentration of inhibitor vs corrosion rate at various temperature (hydrochloric acid)

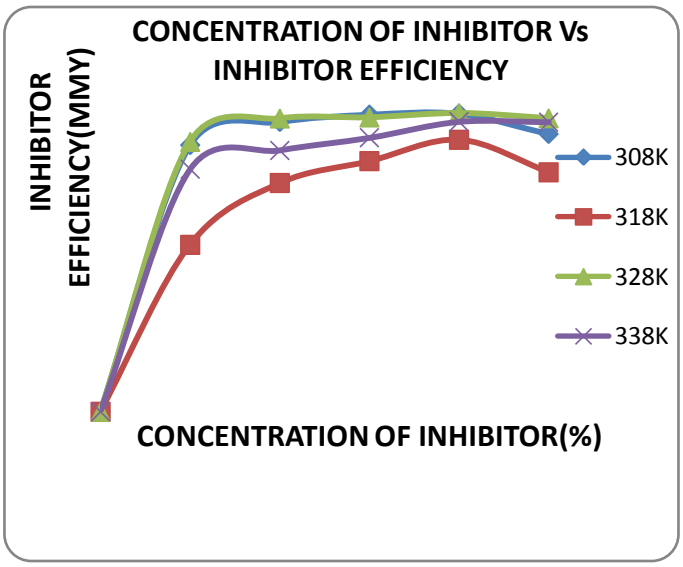

Fig.7. Concentration of inhibitor vs inhibitor efficiency at various temperature (hydrochloric acid)

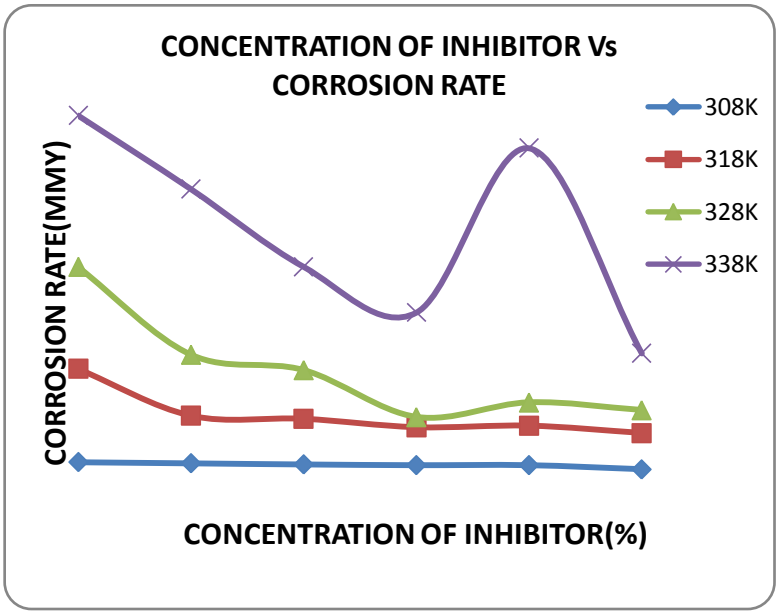

Fig.8. Concentration of inhibitor vs corrosion rate at various temperature (Phosphoric acid

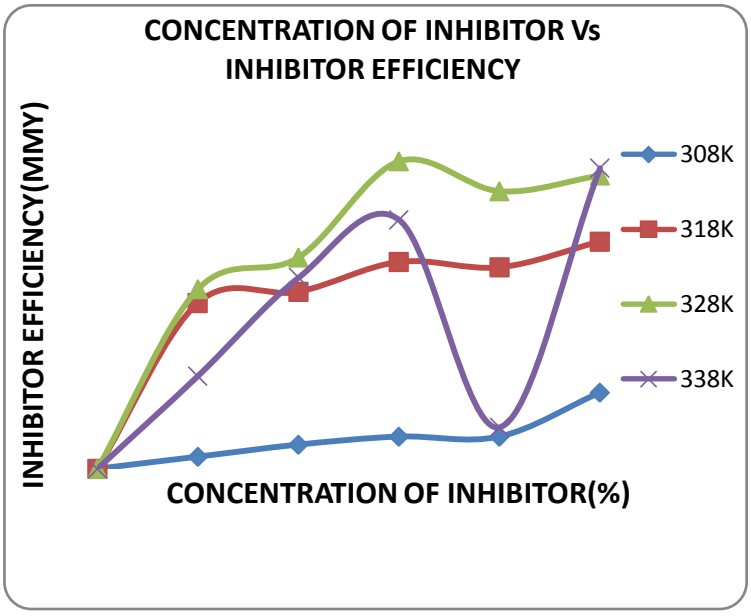

Fig.9. Concentration of inhibitor vs corrosion rate at various temperature (Phosphoric acid)

Conclusion

The study of Corrosion rates of mild steel in 0.5N Hydrochloric and Phosphoric acid medium are found to be increased with increase in temperature using Ocimum Tenuiflorum(l) extract. Ocimum Tenuiflorum(l) extract is found to be a good inhibitor for mild steel corrosion in both acid medium. In addition to that the spectral studies thus conforms the presence of corrosion inhibition character in plant material. Finally, on comparing the two acid

medium 4% Ocimum Tenuiflorum (l) extract is found to be good inhibitor in good inhibition of mild steel corrosion in 0.5 N Phosphoric acids at 93.4035 at 328K.

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