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RESEARCH ARTICLE

Inhibition of mild steel corrosion in hydrochloric acid and phosphoric acid medium using Plectranthus Amboinicus (l) plant extract

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Abstract

The extract of *Plectranthus amboinicus* (l) was tested as corrosion inhibitor for mild steel in 1 M HCl and H_3PO_4 using weight loss method at four different temperatures, viz., 308, 318, 328 and 338 K, IR and UV studies. It is evident from the results that Plectranthus amboinicus (l) effectively inhibits the corrosion in both the acids through adsorption process. The corrosion protection efficiency is increased with increase in inhibitor concentration and temperature. On comparison of both acids 6% of Plectranthus amboinicus(l) extract is found to be more effective inhibitor in Hydrochloric acid with maximum efficiency observed 97.64% at 318 K whereas for phosphoric acid the extract is effective upto 3% with maximum efficiency 81.65% at 338 K.

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INTRODUCTION

Corrosion is the destruction of material resulting from exposure and interaction with the environment. It is a major problem that must be confronted for safety, environment, and economic reasons [1]. In many industries, mild steel (MS) is the material of choice in the fabrication of reaction vessels, storage tanks etc., which get corroded easily in the presence of acids [2]. The aggressiveness of these substances causes severe corrosion in the engineering structures of mild steel, which leads to huge financial and material losses.

A useful method to protect metals and alloys deployed in service in such aggressive environments against corrosion is addition of species to the solution in contact with surface in order to inhibit the corrosion reaction and reduce the corrosion rate. A number of organic compounds are known to be applicable as corrosion inhibitors for steel in acidic environments [3-10]. Many heterocyclic organic molecules having N, S, and O atoms have been shown to function as potential corrosion inhibitors [11, 12]. Although synthetic organic compounds have proved to be effective in inhibiting the corrosion of metals in acids corrosive environment, the high cost and toxic nature of some of the compounds have been seen as a major setback [13–15].

Plant extracts and organic species have therefore become important as an environmentally acceptable, readily available, and renewable source for a wide range of inhibitors [16-21]. Plectranthus amboinicus (l) is tender fleshy perennial plant which belongs to family lamiaceae with an oregano-like flavour and odour. Plectranthus amboinicus (l) are commonly known as Indian borage or Cuban oregano and grown as potted plant.Indian borage ideally should be grown in a semi-shaded and moist location as the leaves will remain a beautiful jade-green color.

These plants are cultivated in home-gardens and used in medicinal fields especially to treat malarial fever, hepatopathy, cough, chronic asthma, convulsions, and epilepsy, skin ulcerations, skin allergy, wounds, diarrhoea etc. Based on literature, it reveals that these plants have never been studied for the purpose of corrosion inhibition.

Hence, an attempt has been made to explore the inhibition efficiency of Plectranthus amboinicus (l) for mild steel corrosion in acidic medium solutions using gravimetric (weight loss) and spectral techniques.

Material and Methods

Plant description:

Name: Plectranthus Amboinius (L)
Filename: Plectranthus Amboinius (L)
Botanical name: Plectranthus Amboinicus (L) (Lour.) Spreng.
Family : Lamiaceae
Sanskrit synonyms: Coleus amoinicus Lour

Plectranthus amboinicus (l) is a large succulent herb, fleshy and highly aromatic, much branched, possessing short soft erect hairs with distinctive smelling leaves. The stem is fleshy about 30–90 cm either with long rigid hairs (hispidly villous) or tomentose. Leaves are simple, broad, egg/oval-shaped with a tapering tip (ovate) and they are pubescent (thickly studded with hairs) with the lower surface possessing the most numerous glandular hairs, giving a frosted appearance. The taste of this leaf is pleasantly aromatic with agreeable and refreshing odour.

Preparation of Mild steel specimen:

The test specimens of Mild steel were cut into apparent size of 5×1cm. The specimens were polished with different grades of emery papers namely 150, 650, 400, 800 and 1200. 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 44.5 ml of hydrochloric acid (AR) in 955.5ml in water.

Phosphoric acid:

The phosphoric acid (0.5 N) solution was also prepared by mixing 12.1ml of Phosphoric acid (AR) in 988.9 ml in water.

Preparation of plant extract:

Fine powder from the shadow dried leaf of Plectranthus amboinicus (L) (100g) was extracted to exhaustion with water using a soxhelet apparatus in heating with three cycles. The extract is filtered using filter paper.

Plectranthus amboinicus (L) extract solution of 1% was prepared by dissolving 1ml of Plectranthus amboinicus (L) extract in 99ml of0.5N Hydrochloricand Phosphoric acid solution. Similarly 2%, 3%, 4%, 5%, 6%, 7% Plectranthus amboinicus (L) extract solution were prepared.

Weight loss method:

Pure Mild steel specimens cut to get length of 5 cm and widths of 1 cm were used for this study. They were pickled in pickling solution (conc. H_2SO_4 + 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 and 1200 emery papers and degraded using trichloroethylene. Finally they were weighed in a single pan digital electronic balance. The specimens were immersed in solution of variousconcentrations of Plectranthus amboinicus (L) (1%, 2%, 3%, 4%, 5%, 6% and 7%) 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 Plectranthus amboinicus:

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:

The weight loss method of monitoring corrosion rate is useful because of its simple application and reliability. The corrosion rate of mild steel in the absence and presence of Plectranthus amboinicus (l) was studiedusing the weight loss method.Table 1 shows the calculated values of corrosion rates from weight loss method. 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 0-7% of plectranthus amboinicus (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 reveals that corrosion rate of mild steel in 0.5N HCl with Plectranthus amboinicus (l) extract increases with increase in temperature.Results in the table indicate that the extracts act as good corrosion inhibitor for mild steel in 0.5 N HCl solution given that the corrosion rate was reduced in the presence of the extracts compared to their absence.Corrosionrate is more effective in 0.5 N Hydrochloric acids up to 6% and then further addition of 7 % 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 plectranthus amboinicus (l) extract is found to be increased up to 6% with concentration of 0.5 N Hydrochloric acids and then further addition of 7% extract decreases the inhibitor efficiency shown in figure 7. The efficiency observed is 97.64 % and the surface coverage is equal to the inhibitor efficiency.

Similarly, the corrosion inhibition for mild steel specimen in 0.5N Phosphoric acid with 0-7% of Plectranthus amboinicus (l) extract was also studied and results were tabulated (Table 4 & 5). From the table, it concludes that the rate of corrosion increases with respect to temperature. From the values obtained, it is obvious that there is a decrease in the corrosion rate of mild steel in the presence of plectranthus amboinicus (l) when compared to the blank. 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 4% of extract and efficiency observed is 81.65%.

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 Plectranthus amboinicus (l) extract. Plectranthus amboinicus (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 6% Plectranthus amboinicus (l) extract is found to be good inhibitor in good inhibition of mild steel corrosion in 0.5 N HCl at 97.64% at 318 K.

Table.1: Corrosion rate of Mild Steel in 0.5N Hydrochloric and Phosphoric Acid with Plectranthus amboinicus (l) 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	4.1276	3.9980	0.1296	3.5754	3.5494	0.0260	9.629	1.9318
318	3.9870	3.7526	0.2344	4.2086	4.1278	0.0808	17.41	6.0034
328	3.7430	2.9568	0.7862	4.2314	4.1006	0.1308	58.41	9.7184
338	2.9012	1.8004	1.1008	4.2660	4.0534	0.2126	81.78	15.7962

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

S.No	Concentration of Plectranthus amboinicus (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	4.1276	3.9980	0.1296	9.62	-	-
2	1	7.5170	7.4800	0.037	2.74	71.51	0.7151
3	2	7.3214	7.2980	0.0234	1.73	82.01	0.8201
4	3	7.4524	7.4366	0.0158	1.17	87.83	0.878
5	4	7.3804	7.3660	0.0144	1.06	88.98	0.8898
6	5	6.3190	6.3092	0.0098	0.72	92.51	0.9251
7	6	4.2722	4.2176	0.0546	4.05	57.90	0.5790
8	7	4.4496	4.4024	0.0476	3.53	63.30	0.6330
Room temperature 318 K							
1	0	3.9870	3.7526	0.2344	17.41	-	-
2	1	7.4778	7.3656	0.1122	8.33	52.15	0.5215
3	2	7.2928	7.2156	0.0772	5.73	67.08	0.6708
4	3	7.4336	7.3724	0.0612	4.54	73.92	0.7392
5	4	7.5534	7.3062	0.0472	3.50	79.89	0.7989
6	5	6.3024	6.2800	0.0224	1.66	90.46	0.9046
7	6	4.3004	4.2948	0.0056	0.41	97.64	0.9764
8	7	4.2500	4.2438	0.0062	0.46	93.30	0.9330

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

S.No	Concentration of Plectranthus amboinicus (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	3.7430	2.9568	0.7862	58.41	-	-
2	1	7.3584	6.9916	0.3668	27.25	53.34	0.5334
3	2	7.2056	6.9664	0.2392	17.77	69.57	0.6957
4	3	7.3652	7.1796	0.1856	13.79	76.39	0.769
5	4	7.3018	7.1430	0.1588	11.79	79.81	0.7981
6	5	6.2722	6.1748	0.0974	7.236	87.61	0.8761
7	6	6.3126	6.2031	0.1095	8.08	86.15	0.8615
8	7	6.3529	6.2608	0.0921	6.86	88.25	0.8825
Room temperature 338K							
1	0	2.9012	1.8004	1.1008	74.89	-	-
2	1	6.9344	6.0922	0.8422	62.57	16.45	0.1645
3	2	6.9414	6.4268	0.5146	38.23	48.95	0.4895
4	3	7.1530	6.8000	0.3530	26.22	64.98	0.6498
5	4	7.1208	6.7934	0.3274	24.32	67.52	0.6752
6	5	6.1462	5.9234	0.2228	16.55	77.90	0.7790
7	6	6.7404	6.4370	0.3034	22.61	69.80	0.6980
8	7	6.4124	6.1624	0.2500	18.73	74.98	0.7498

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

S.No	Concentration of Plectranthus amboinicus (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	3.5754	3.5494	0.0260	1.93	-	-
2	1	3.8084	3.7844	0.0240	1.78	7.81	0.0781
3	2	3.6786	3.6630	0.0156	1.15	39.97	0.3997
4	3	4.1740	4.1522	0.0218	1.61	16.15	0.1615
5	4	3.9952	3.9784	0.0168	1.24	35.70	0.3537
6	5	3.9848	3.9660	0.0188	1.39	27.70	0.2770
7	6	4.0926	4.0726	0.0200	1.48	23.04	0.2304
8	7	4.2368	4.2154	0.0214	1.59	17.65	0.1765
Room temperature 318 K							
1	0	4.2086	4.1278	0.0808	6.0	-	-
2	1	4.2204	4.1712	0.0492	3.65	39.16	0.3916
3	2	4.0470	4.002	0.0438	3.25	45.83	0.4583
4	3	4.2120	4.1718	0.0402	2.98	50.33	0.5033
5	4	4.1982	4.1574	0.0408	3.03	49.5	0.495
6	5	4.1932	4.1580	0.0352	2.61	56.5	0.565
7	6	4.1890	4.1540	0.0350	2.60	56..66	0.5666
8	7	4.2130	4.1786	0.0344	2.55	57.5	0.5750

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

S.No	Concentration of Plectranthus amboinicus (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	4.2314	4.1006	0.1308	9.71	-	-
2	1	2.6226	2.5914	0.012	2.318	76.12	0.7612
3	2	4.2298	4.1472	0.0826	6.137	36.79	0.3679
4	3	4.0310	3.9632	0.0678	5.037	48.12	0.4812
5	4	4.0552	4.0002	0.0550	4.086	57.91	0.5791
6	5	4.0150	3.9640	0.0510	3.789	60.97	0.6097
7	6	4.1880	4.1288	0.0592	4.398	54.70	0.5470
8	7	4.2000	4.1536	0.0464	3.447	64.50	0.6450
Room temperature 338 K							
1	0	4.2660	4.0534	0.2126	15.79	-	-
2	1	4.2600	4.1042	0.1556	11.56	26.78	0.2678
3	2	4.2780	4.1214	0.1566	11.63	26.34	0.2634
4	3	2.6744	2.6354	0.0390	2.897	81.65	0.8165
5	4	4.2950	4.1942	0.1008	7.489	52.57	0.5257
6	5	4.1382	4.0360	0.1022	7.593	51.91	0.5191
7	6	4.1894	4.1006	0.0888	6.597	58.22	0.5822
8	7	4.1882	4.1022	0.0860	6.389	59.53	0.5953

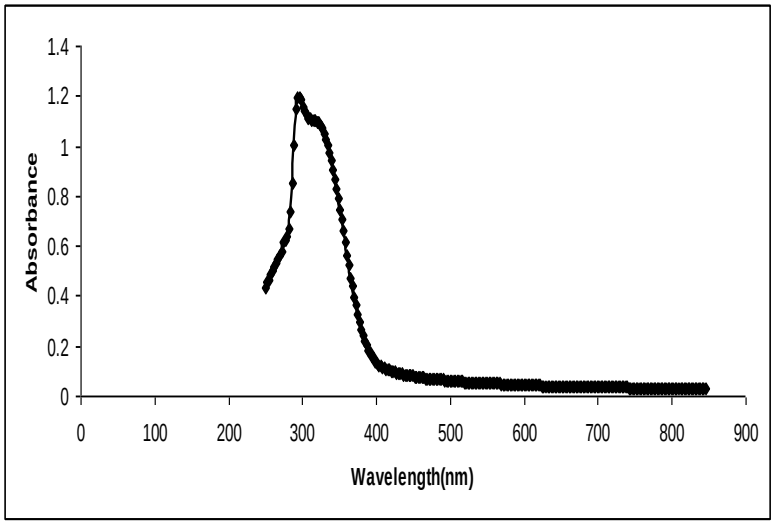

Fig.1. Plectranthus amboinicus (l) H_2O spectrum

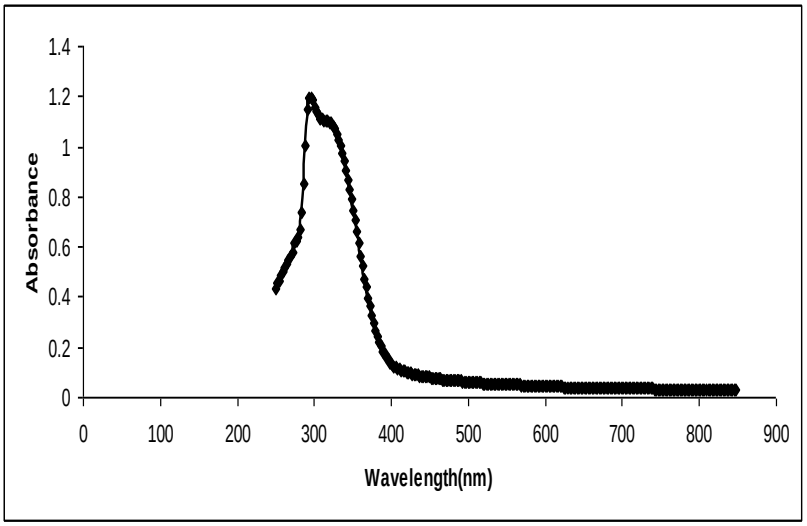

Fig.2. Plectranthus amboinicus (l) H_3PO_4 spectrum

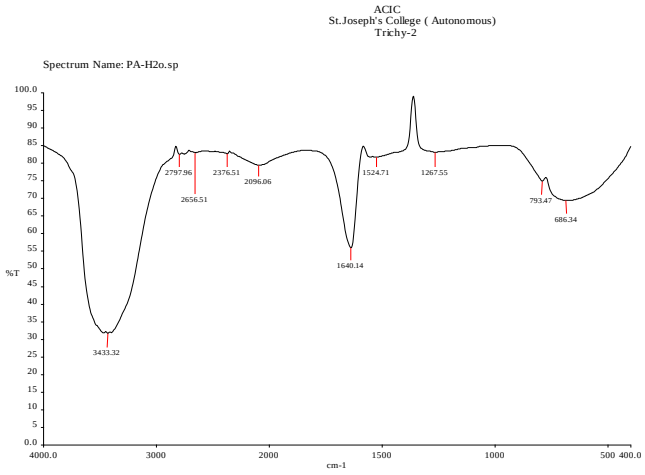

Fig.3. IR spectrum: Plectranthus amboinicus (l) H_2O spectrum

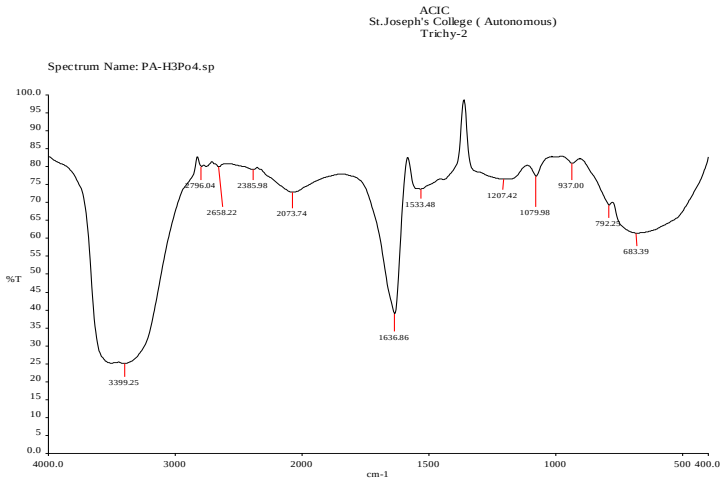

Fig.4. IR spectrum: Plectranthus amboinicus (l) H_3PO_4 spectrum

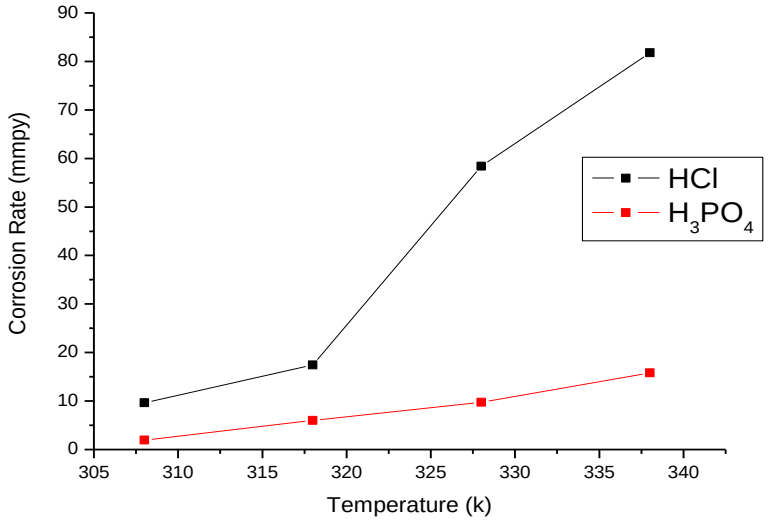

Fig.5. Corrosion rate of Mild Steel in 0.5N Hydrochloric acid & Phosphoric Acid with Plectranthus amboinicus (l) extract at various temperatures (308-338K)

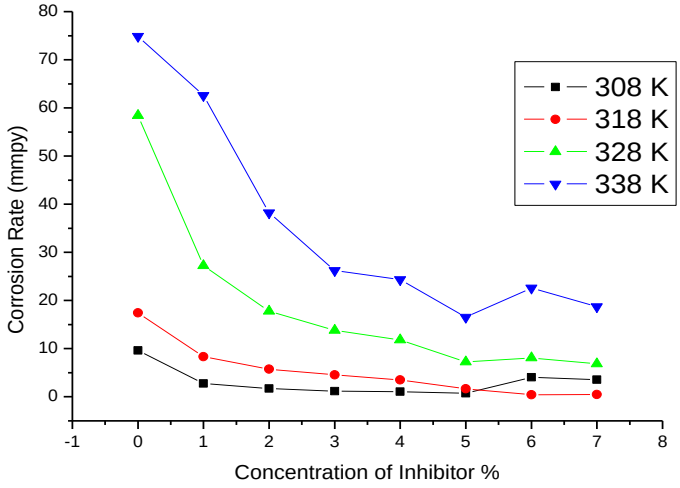

Fig.6. Concentration of inhibitor vs corrosion rate at various temperature (hydrochloric acid)

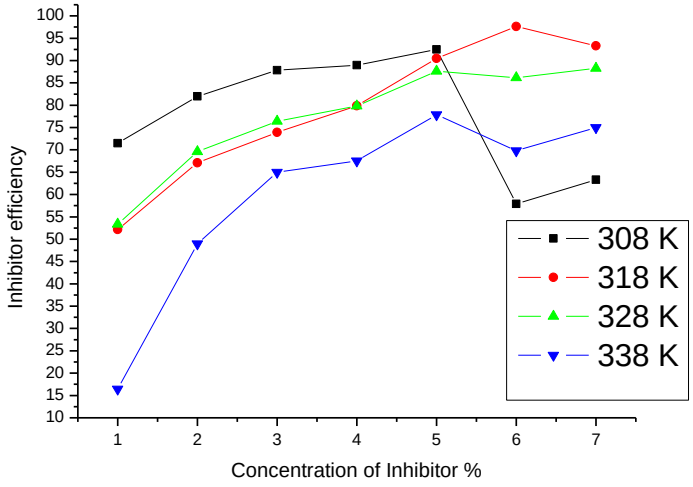

Fig.7. Concentration of inhibitor vs inhibitor efficiency at various temperature (hydrochloric acid)

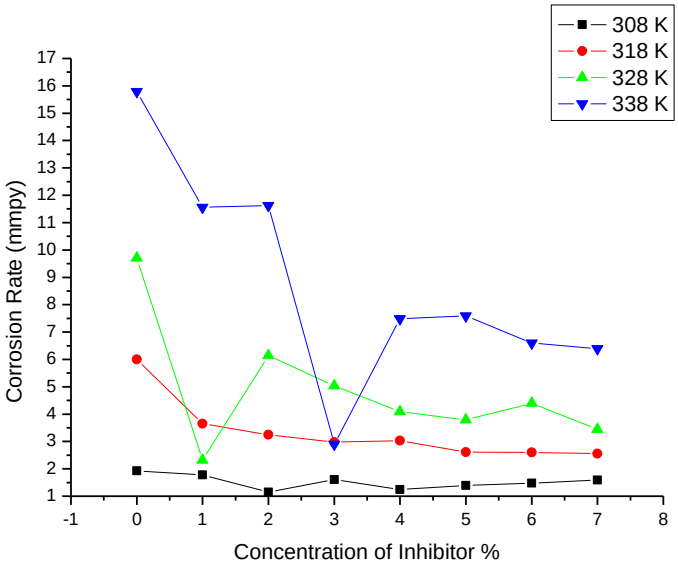

Fig.8. Concentration of inhibitor vs corrosion rate at various temperature (Phosphoric acid)

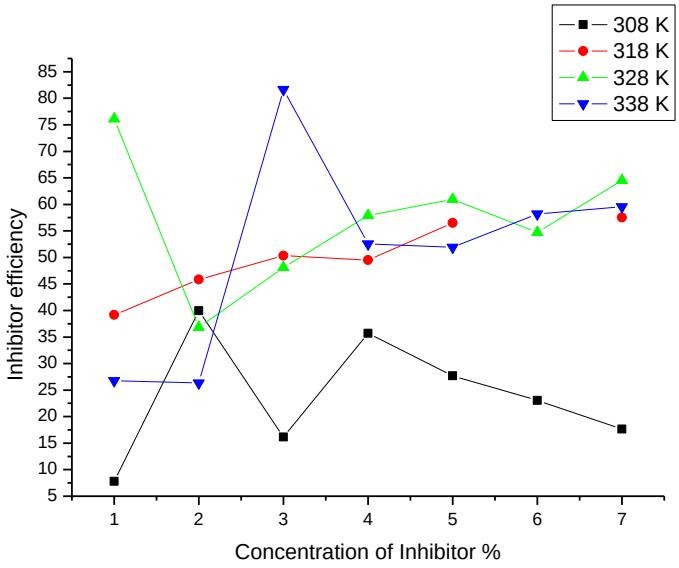

Fig.9. Concentration of inhibitor vs corrosion rate at various temperature (Phosphoric acid)

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