

Schiff Bases of Triethylenetetramine as Corrosion Inhibitors of Zinc in Hydrochloric Acid

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Abstract

The performance of triethylenetetramine-tribenzylidene (TTTB) and triethylenetetramine-trisallylidene (TTTS) as corrosion inhibitors for zinc in hydrochloric acid is investigated. At lower concentrations, both inhibitors accelerate the attack but inhibit corrosion at higher concentrations, e.g., 96–100% with 1.0% concentration in 0.5 M and 1.0 M HCl. The efficiency of TTTB decreases while that of TTTS remains almost constant ($\geq 99.7\%$) up to 120 minutes and in the temperature range 35 – 65 °C. The activation energies are higher in inhibited than in plain acid with both inhibitors. The free energy of adsorption (ΔG_{ads}) and heat of adsorption (Q_{ads}) are negative, which suggests that there is spontaneous adsorption on metal surface, and from the values of (ΔG_{ads}) and (Q_{ads}), the values of entropy of adsorption (ΔS_{ads}) were calculated. Galvanostatic polarization shows that corrosion is under mixed control with predominance of the cathodic part. In uninhibited 1.0 M HCl, complete cathodic protection is achieved at a current density of 4.2224 Adm^{-2} , but in presence of these inhibitors, much lower current densities are required. Plot of $\log(\theta/1-\theta)$ versus $\log C_{\text{inh}}$ gives a straight line, suggesting that inhibitors cover both the anodic and cathodic regions through general adsorption following Langmuir isotherm. The mechanism of inhibition has been proposed.

Keywords: corrosion, zinc, hydrochloric acid, inhibitor.

Introduction

Zinc is an active metal with numerous industrial applications and is mainly used for the corrosion protection of steel [1-7]. The zinc coated steel materials provide a greater resistance to corrosion but when exposed to humid atmosphere, they undergo rapid corrosion with the formation of a corrosion product known as

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white rust. The formation of white rust is generally observed in galvanized materials and renders the plated zinc materials unsuitable for industrial applications. Also, industrial processes such as scale removal and cleaning of zinc surfaces with acidic solutions expose zinc to corrosion. Therefore, in order to protect the metal from corrosion, the use of inhibitors is necessary [8].

The Schiff bases as inhibitors can offer a cheap, easy to apply and highly effective method of corrosion control when certain considerations are observed. Therefore, inhibitors have been used for many years to protect metals whose mechanical and physical properties must be retained for long periods of time [9]. A survey of literature [10-15] shows that the substances investigated as inhibitors include benzaldehyde and quinoline derivatives, quaternary salts of pyridine bases, triazoles, benzotriazoles and their derivatives, imidazole azo derivatives, quaternary imidazoline derivative, alkaloids, thiourea, benzenethiol, Schiff bases of chloroanilines and toluidenes and 2-mercaptobenzimidazol. It has also been reported [7,16,17] that the efficiency of Schiff bases is much better than the corresponding amines or aldehydes. In the present work the inhibitor efficiency of triethylenetetramine-tribenzylidene (TTTB) and triethylenetetramine-trisalicylidene (TTTS) for zinc in hydrochloric acid has been reported.

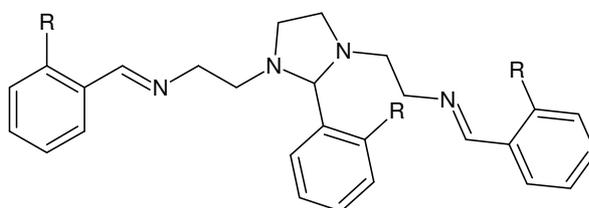
Methods and materials

Preparation of Schiff bases

The Schiff bases were synthesized by condensation of triethylenetetramine with the corresponding aldehydes (benzaldehyde and salicylaldehyde) in the presence of ethyl alcohol. The reactants were mixed at 0 – 5 °C and the mixture was refluxed on a water bath for an hour. After the completion of the reaction, the reaction mixture was treated with icecold-distilled water, when the crude solid product separated out. It was first washed with water and then with very dilute hydrochloric acid. Finally it was washed with distilled water then purified by repeated crystallization from ethanol [7].

Triethylenetetramine-tribenzylidene (white crystalline substance; m.p., 86 °C) and triethylenetetramine-trisalicylidene (yellow crystalline substance; m.p., 105 °C), are insoluble in water but soluble in ethanol.

The two inhibitors may be represented by the general formula:



R = H in TTTB; and R = OH in TTTS

Preparation of specimens

Square specimens of zinc, of size 3 cm × 3 cm (thickness 0.16 cm), containing >99.5% of the electrolytic zinc were polished to mirror finish, degreased with A.R. carbon tetrachloride (sulphur free), and used for the weight loss method.

For polarization study, metal coupons of circular design, diameter 2.802 cm with a handle 3 cm long and 0.5 cm wide, were used. The working and auxiliary electrodes were coated with Perspex in such a way that only a circular portion having an area of 6.156 cm² was exposed to the matrix.

Weight loss method

Zinc specimen was immersed in 230 mL of the solution containing various concentrations of the inhibitors in the absence and presence of TTTB and TTTS, at 35 ± 0.5 °C, for an exposure period of 30 minutes. The weight of the specimen before and after immersion was determined using a mettler balance – M5 type. Inhibition efficiency (%IE) was calculated from the relationship $\%IE = (1 - W_i / W_u) \times 100$, where W_u = weight loss in uninhibited acid, and W_i = weight loss in inhibited acid.

Polarization study

Polarization study was carried out using a three electrode cell assembly. Zinc was used as working electrode, platinum as counter electrode and saturated calomel electrode (SCE) as reference electrode. The corrosion parameters such as corrosion potential (E_{corr}), corrosion current (I_{corr}) and Tafel plots were measured. In this study, the current density was varied in the range of 2×10^{-4} to 3.25×10^{-2} A cm⁻².

Results and discussion

Effect of inhibitor concentration

The results given in Table 1 show that a specimen of zinc immersed in 0.5 M hydrochloric acid suffered a weight loss of 957 mg dm⁻² in 30 minutes, whereas that in 1.0 M acid, suffered a weight loss of 3500 mg dm⁻² in 30 minutes. The results show that lower concentrations of the inhibitors accelerate the corrosion of zinc. The extent of acceleration at first increases with increase in inhibitor concentration, reaches a maximum, and then decreases in the case of TTTB. And in case of TTTS, acceleration decreases with increasing inhibitor concentration. Thus, 1.0% concentration of TTTB confers 96.3% and 97.6%, while TTTS confers 100.0% and 99.9% protection to zinc in 0.5 M and 1.0 M HCl, respectively. In 0.5 M HCl, it also appears that there is some threshold concentration, when the inhibition suddenly sets in. A similar behavior is observed in 1.0 M HCl but the onset of inhibition takes place at higher inhibitor concentrations. At lower concentration of the inhibitor, acceleration occurred, and at higher concentration inhibition is observed.

Table 1. Effect of inhibitor concentration on weight loss and inhibition efficiency for zinc in 0.5 M and 1.0 M hydrochloric acid. (Temperature: 35 ± 0.5 °C; exposure period: 30 min.).

Inhibitor concentration (% W/V)	0.5 M HCl		1.0 M HCl	
	Weight loss (mgdm ⁻²)	Inhibition efficiency (%)	Weight loss (mgdm ⁻²)	Inhibition efficiency (%)
Nil (HCl only)	957	-	3500	-
<i>Triethylenetetramine-tribenzylidene (TTTB)</i>				
0.05	10444	-991.3	27929	-698.0
0.10	12711	-1228.2	28493	-714.1
0.20	12595	-1216.1	28736	-721.0
0.30	10073	-952.6	28590	-716.9
0.50	45	95.3	24176	-590.7
0.80	40	95.8	121	96.5
1.00	35	96.3	83	97.6
<i>Triethylenetetramine-trisalicylidene (TTTS)</i>				
0.05	10951	-1044.3	28290	-708.3
0.10	2957	-209.0	27973	-699.2
0.20	758	20.8	14084	-302.4
0.30	15	98.4	2112	39.7
0.50	10	99.0	20	99.4
0.80	10	99.0	15	99.6
1.00	00	100.0	5	99.9

When plots of $\log \theta / 1-\theta$ vs. $\log C_{inh}$ (inhibitor concentration) (Fig.1) were drawn, straight lines were obtained, indicating that the inhibitors function through adsorption following Langmuir isotherm [18]:

$$C_{inh} = \frac{\theta}{K(1-\theta)} \quad (1)$$

However, when the surface coverage is very high and θ becomes constant, the plots deviate and run parallel to the abscissa.

Effect of exposure period

The effect of exposure period on inhibitive efficiency of TTTB and TTTS at 35 °C and 1.0% concentration was studied. From the results (Table 2), it is evident that as the exposure period is increased from 30 minutes to 120 minutes, the loss in weight in uninhibited 0.5 M hydrochloric acid increases from 957 mg dm⁻² to 4848 mg dm⁻², and from 3500 mg dm⁻² to 24051 mg dm⁻² in 1.0 M acid.

The difference in the inhibitive efficiency of TTTB and TTTS is effectively reflected in 0.5 M hydrochloric acid, which is a little more corrosive compared to 1.0 M HCl. The inhibitor efficiency of TTTB in 0.5 M HCl decreases from 96.3% for 30 minutes to 95.9% for 120 minutes and that of TTTS decreases from 100.0% for 30 minutes to 98.8% for 120 minutes. In 1.0 M HCl, TTTS shows a very high efficiency of 99.7% for exposure periods extending up to two hours, i.e., as compared to TTTB, TTTS is more effective.

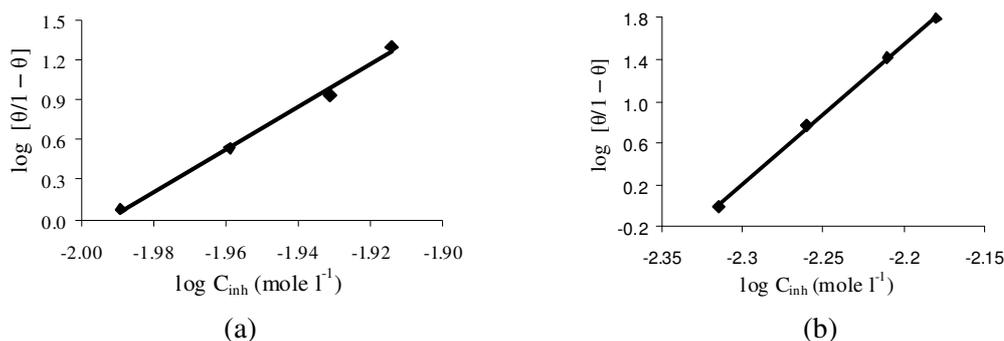


Figure 1. Langmuir plots for Schiff bases in 0.5 M hydrochloric acid at 35 °C. (a) TTTB and (b) TTTS.

Table 2. Effect of exposure period on weight loss and inhibitor efficiency for zinc in hydrochloric acid containing different inhibitors. (Temperature: 35 ± 0.5 °C; inhibitor concentration: 1.0% (W/V)).

Inhibitor	% Inhibition in 0.5 M HCl			% Inhibition in 1.0 M HCl		
	30 min	60 min	120 min	30 min	60 min	120 min
TTTB	35	73	201	83	95	299
	(96.3%)	(96.5%)	(95.9%)	(97.6%)	(99.2%)	(98.6%)
TTTS	00	13	58	5	15	95
	(100%)	(99.4%)	(98.8%)	(99.9%)	(99.9%)	(99.7%)

From the weight loss data, it may be generalized that where corrosion protection is desired for longer exposure periods, TTTS shows better performance. The result also shows that the incorporation of $-\text{OH}$ group in o-position in the benzyldinic-part of the Schiff base has better effect on the inhibitive efficiency of TTTS, particularly for longer exposure periods.

Effect of temperature

To determine the effect of temperature on inhibitive efficiency, weight losses were determined in 1.0 M HCl containing 1.0% of TTTB, and 0.4% and 0.5% of TTTS at solution temperatures of 35, 45, 55 and 65 °C for an exposure period of 60 minutes. From the results given in Table 3, it is evident that the extent of corrosion in inhibited as well as in uninhibited acid increases with a rise in temperature, the loss in weight being much higher in plain acid. The extent of inhibition is ranging from 95.1% (1.0% of TTTB) to 99.3% (0.5% of TTTS).

The E_a values have been calculated from the plots of $\log \rho$ (log corrosion rate, mg dm^{-2}) vs. $1/T$ (Fig. 2) and are given in Table 3. From the E_a values, it is apparent that for the corrosion of zinc in uninhibited acid the E_a value is 23.0 kJmol^{-1} , whereas in inhibited acid the values are higher (73.2 kJmol^{-1} for 1.0% TTTB, 82.8 kJmol^{-1} for 0.4% of TTTS and 71.1 kJmol^{-1} for 0.5% of TTTS). In inhibited acid, the E_a values thus vary and depend on the inhibitive power of the

inhibitor. It appears that the exponential term in the Arrhenius equation appreciably changes the E_a value with a slight change in the corrosion rate.

Table 3. Effect of temperature on weight loss and inhibitor efficiency for zinc in 1.0 M hydrochloric acid. (Exposure period: 60 min.; values in brackets show inhibition %).

Inhibitor Concentration (%W/V)	Weight loss (mgdm ⁻²) at a temperature of				E_a kJ/mole
	35 °C	45 °C	55 °C	65 °C	
Nil	11252	16058	20299	25424	23.0
TTTB (1.0%)	95 (99.2%)	166 (99.0%)	371 (98.2%)	1240 (95.1%)	73.2
TTTS (0.4%)	52 (99.5%)	137 (99.1%)	437 (97.8%)	858 (96.6%)	82.8
TTTS (0.5%)	15 (99.9%)	30 (99.8%)	77 (99.6%)	171 (99.3%)	71.1

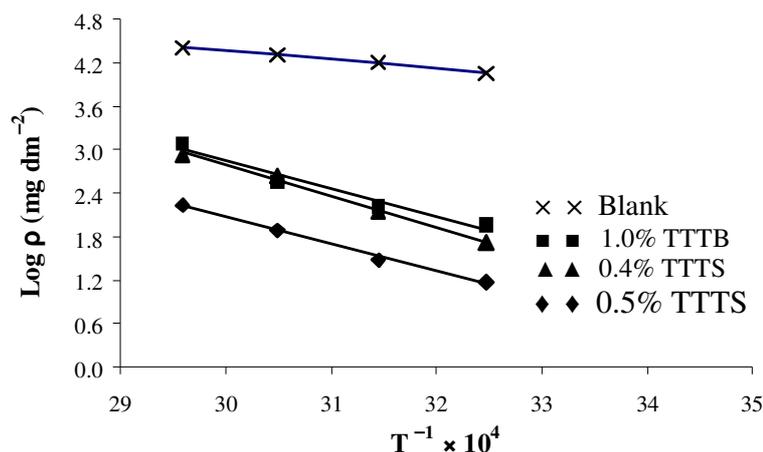


Figure 2. Arrhenius plots for zinc in 1.0 M hydrochloric acid in the presence and absence of inhibitors.

The higher values of activation energy in inhibited acid suggest that the adsorption of the inhibitor on the metal surface may be physical or weak in nature [19]. The efficiency of the inhibitor decreases with increase in temperature. The activation energies are higher in inhibited than in uninhibited acid. E_a decreases with an increase in inhibitor concentration and temperature due to physisorption. The same behavior mentioned above was also observed by Putilova et al. [20].

Thermodynamic parameters

The heat of adsorption, (Q_{ads}), was calculated following Hoar and Holiday equation [21], while the free energy of adsorption, (ΔG_{ads}), was calculated as given by Vashi et al. [22]. From the values of (Q_{ads}) and (ΔG_{ads}), the values of entropy of adsorption (ΔS_{ads}) were also calculated. The results given in Table 4

show that the (Q_{ads}) and (ΔG_{ads}) values are negative for both the inhibitors. The Q_{ads} values are more negative for an efficient inhibitor, which suggests a strong interaction of the inhibitor molecules with the metal surface resulting in the spontaneous adsorption, and also indicates that the adsorption of these two inhibitors on the zinc surface is exothermic.

The values of free energy of adsorption (ΔG_{ads}) around -20 kJmol^{-1} or lower are consistent with physisorption, while those around -40 kJmol^{-1} or higher involve chemisorption [10]; it also suggests that adsorption of the inhibitor is a spontaneous process [23]. Almost similar values (in case of TTTB and TTTS) of (ΔG_{ads}) also suggest that the two inhibitors are almost equally bonded to the metal surface. The values of entropy of adsorption (ΔS_{ads}) are positive and the values are higher in case of TTTS and show a tendency to decrease with an increase in inhibitor concentration. The results show that a good inhibitor is characterized by negative value of free energy of adsorption, positive value of entropy of adsorption and higher (more negative) heat of adsorption.

Table 4. Free energy of adsorption ΔG_{ads} , entropy of adsorption ΔS_{ads} and heat of adsorption Q_{ads} for the corrosion of zinc in 1.0 M hydrochloric acid. (Exposure period: 60 min; temperature range: 35 - 65 °C).

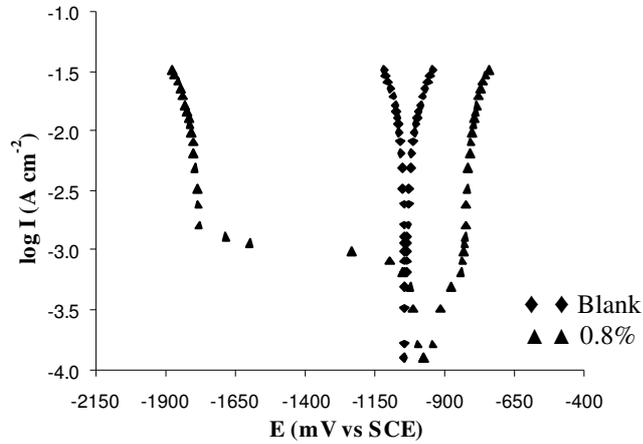
Inhibitor and its concentration	ΔG_{ads} (kJmol^{-1})	ΔS_{ads} (Jmol^{-1})	Q_{ads} (kJmol^{-1})
TTTB (1.0%)	-31.3	261.5	-52.7
TTTS (0.4%)	-35.1	294.9	-60.2
TTTS (0.5%)	-38.9	269.8	-48.5

Polarization behavior

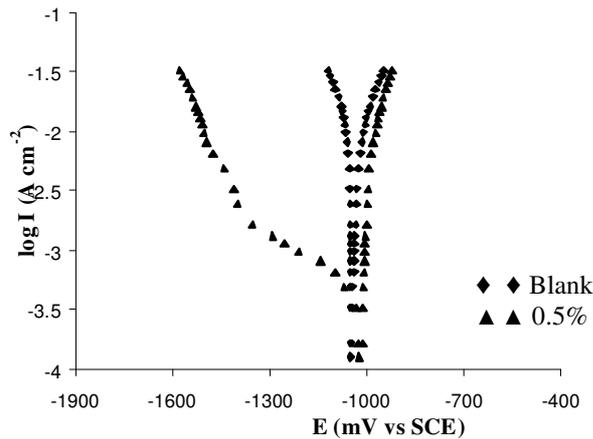
The influence of current density on the cathodic and anodic potentials of zinc in 1.0 M hydrochloric acid in the presence and absence of inhibitors is shown in Fig. 3. The galvanostatic polarization data show that TTTB and TTTS are mixed type inhibitors with predominant action on local cathodes. The corrosion potential (E_{corr}) of zinc in 1.0 M hydrochloric acid is -1048 mV with reference to SCE. Tafel plots efficiencies agree well with those obtained from weight loss data.

At effective concentrations of TTTB (0.8%) and TTTS (0.5%), both the cathode and anode are polarized, but the cathode is significantly polarized to a much greater extent. With both the inhibitors at effective concentrations, there is a sudden shift in the cathode polarization and the cathode polarization curve shifts in such a manner that it intersects the corrosion potential at very low current density. At 0.8% of TTTB in 1.0 M HCl, the corrosion of zinc is protected to an extent of 96.5% (from weight loss data). Similar protection has been observed both from extrapolation of cathodic Tafel line or from the extrapolation of the anodic Tafel line to corrosion potential. This may indicate that TTTB is a mixed one. In the presence of 0.5% TTTS in 1.0 M HCl, the corrosion of zinc is

protected to an extent of 99% (from loss in weight data). 99% inhibition efficiency is also obtained from the extrapolation of the cathodic Tafel line to E_{corr} and 66% inhibition efficiency is obtained from the extrapolation of the anodic Tafel line to E_{corr} . This may again indicate that TTTS is a mixed type with predominance on cathodic part.



(a)



(b)

Figure 3. Effect of current density on the cathodic and anodic potentials of zinc in 1.0 M hydrochloric acid alone and in the presence of inhibitors. (a) TTTB and (b) TTTS.

In Table 5, Tafel parameters and inhibitor efficiencies of TTTB and TTTS for zinc in 1.0 M HCl are given. It is to be noted that at higher concentrations of TTTB and TTTS, the corrosion of zinc is inhibited. The inhibition obtained from extrapolation of the cathodic Tafel line compares excellently well with the efficiency obtained from weight loss data (30 minutes). This may again indicate that TTTB and TTTS are mixed type inhibitors with predominant effect on the cathode.

Table 5. Tafel parameters and inhibition efficiencies at higher concentrations of TTTB and TTTS for zinc in 1.0 M hydrochloric acid. (Temperature: 35 °C ± 0.5 °C).

Inhibitor and its concentration (%W/V)	Tafel slope b		Corrosion current, A/cm ² from		Inhibition efficiency (%) from		Weight loss data (30 min)
	Anodic (b _a)V/decade	Cathodic (b _c)V/decade	Extrapolation of cathodic Tafel line at	Extrapolation of anodic Tafel line at	From (4)	From (5)	
			E _{corr}	E _{corr}			
1	2	3	4	5	6	7	8
Nil (only HCl)	0.124	0.108	7.9 × 10 ⁻³	5.1 × 10 ⁻³	-	-	-
TTTB (0.8%)	0.087	0.138	1.0 × 10 ⁻⁸	1.0 × 10 ⁻⁴	>99.9	98.0	96.5
TTTS (0.5%)	0.061	0.126	1.6 × 10 ⁻⁶	1.6 × 10 ⁻³	>99.9	66.6	99.4

Cathodic protection

When an external cathodic current was applied to zinc in uninhibited 1.0 M HCl, complete cathodic protection could be achieved at a current density of 4.2224 Adm⁻² (Table-6). In inhibited acid the protective currents are less than those in uninhibited solutions and the reduction in current requirements is greater, the higher the inhibitor concentration.

In the case of TTTB and TTTS which accelerate the corrosion at 0.1% concentration, complete protection could be achieved with current densities of 3.7352 and 2.2736 Adm⁻², respectively, the corresponding reduction in current requirements being 11.5% and 46.2%. With 0.8% TTTB, complete protection is achieved at the current density of 0.0487 Adm⁻², which corresponds to 98.8% reduction in the current requirement. TTTS confers 39.7% protection at 0.3% concentration without any applied current, but it inhibits the corrosion completely at a current density of 0.1299 Adm⁻², i.e., the current requirement is reduced by 96.9% of that in uninhibited acid. Thus, the adsorption characteristics of the inhibitor are so changed under the influence of the current that it covers greater areas of the metal surface.

Table 6. Weight loss in the absence and presence of protective cathodic current, protective potentials and inhibition efficiencies with zinc in 1.0 M hydrochloric acid. (Exposure period: 30 min.; temperature: 35 °C ± 0.5 °C).

Inhibitor and its concentration (% W/V)	Without external cathodic current			With external cathodic current		
	Weight loss mgdm ⁻²	Inhibition efficiency (%)	E _{corr} , mV (vs. S.C.E.)	Current for complete protection Adm ⁻² (i _p)	% Reduction in current due to inhibitor	Protective potential (E _p), mV (vs. S.C.E.)
Nil (HCl only)	3500	-	-1050	4.2224	-	-1337
TTTB (0.1%)	28493	-714.1	-920	3.7352	11.5	-1403
TTTB (0.8%)	121	96.5	-927	0.0487	98.8	-1463
TTTS (0.1%)	27973	-699.2	-921	2.2736	46.2	-1546
TTTS (0.3%)	2112	39.7	-984	0.1299	96.9	-1474

If I₀ is the inhibitive efficiency without current, I₁ is the percent protection at the various current densities in uninhibited acid, and I_{obs} is the total protection due to

the conjoint action of the current and the inhibitor, then the conjoint effect may be considered as:

- (i) synergistic, if $I_{\text{obs}} > (I_0 + I_1)$;
- (ii) additive, if $I_{\text{obs}} \approx (I_0 + I_1)$;
- (iii) antagonistic, if $I_{\text{obs}} < (I_0 + I_1)$.

The conjoint effect of external cathodic current and these inhibitors is observed to be either synergistic, or additive, or antagonistic (Table 7). In the present case, the total protection due to the conjoint action of the current and inhibitor is found to be greater than the sum of the protection conferred by each of the individual factors. This suggests that under the influence of an external cathodic current, the adsorption characteristics of the inhibitor are so improved that an accelerator of corrosion functions as an inhibitor. The results are in conformity with Machu [24], Hackermann [25], and also Antropov [26].

Table 7. Conjoint action of inhibitor and cathodic current on the corrosion of zinc in 1.0 M hydrochloric acid containing inhibitors. (Exposure period: 30 min.; temperature: 35 °C \pm 0.5 °C).

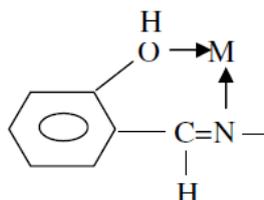
Inhibitor and its concentration (% W/V)	Applied current density Adm^{-2}	Weight loss in inhibited acid mgdm^{-2}	Protection (%) due to current in plain acid I_1	Observed protection (%) due to current +inhibitor I_{obs}	I_0+I_1	Conjoint action $\{I_{\text{obs}}-(I_0+I_1)\}$
1	2	3	4	5	6	7
<i>Nil</i>	<i>Nil</i>	3500	--	--	--	--
<i>Triethylenetetramine-tribenzylidene (TTTB)</i>						
0.1	0.0000	27973	-	-699.2(I_0)	-	-
	0.8120	27323	34.7	-680.7	-664.5	-16.2(Ant)
	1.6240	26235	57.3	-649.6	-641.9	-7.7(Ant)
	2.1924	2989	65.6	14.6	-633.6	648.2(Syn)
	2.2736	00	66.7	100.0	-632.5	732.5(Syn)
0.3	0.0000	2112	-	39.7(I_0)	-	-
	0.0812	1754	2.5	49.9	42.2	7.7(Syn)
	0.0974	536	3.9	84.7	43.6	41.1(Syn)
	0.1299	00	5.8	100.0	45.5	54.5(Syn)
<i>Triethylenetetramine-trisalicylidene (TTTS)</i>						
0.1	0.0000	28493	-	-714.1(I_0)	-	-
	0.8120	27924	34.7	-697.8	-679.4	-18.4(Ant)
	2.4360	26430	68.9	-655.1	-645.2	-9.9(Ant)
	3.2480	25699	82.6	-634.3	-631.5	-2.8(Add)
	3.7027	520	94.0	85.1	-620.1	705.2(Syn)
	3.7352	00	94.5	100.0	-619.6	719.6(Syn)
0.8	0.0000	121	-	96.5(I_0)	-	-
	0.0325	33	1.1	99.1	97.6	1.5(Add)
	0.0487	00	1.6	100.0	98.1	1.9(Add)

Mechanism of inhibition

Both TTTB and TTTS contain eleven conjugated double bonds (three in each of the aromatic rings and two in the iminic group) and have five anchoring sites (two iminic $>\text{C}=\text{N}-$, and three aromatic rings). The plots of $\log \theta/1-\theta$ vs. $\log C_{\text{inh}}$ are found to be linear, which indicates that the inhibitors function through adsorption following Langmuir isotherm. As suggested by Hackermann and

Kaesche [27], it is likely that the cationic form of the inhibitor or its free base may be adsorbed. Further, the π -electrons of the aromatic ring will help the inhibitor molecule to get anchored on the anodic areas of the metal surface. Thus, the inhibitor would cover both the anodic as well as the cathodic areas and functions as a mixed type inhibitor.

The better inhibitive power of the inhibitors, when present in adequate amounts, may be traced to the preferential adsorption through the iminic group. The higher and almost constant efficiency of TTTS in the temperature range 35 to 65 °C may be due to the presence of the –OH group in the ortho-position, which would facilitate the formation of a six-membered chelate of the type



and help the chemisorption process. According to March [28], the –OH group with +R, –I effect will change the electron density and activate the aromatic ring.

Conclusions

1. TTTB and TTTS confer more than 96% protection to zinc in hydrochloric acid under a variety of conditions.
2. Between the two inhibitors, the efficiency of TTTS remains almost constant, while that of TTTB decreases with increase in the exposure period and temperature. This suggests that TTTS functions through chemisorption and TTTB functions through physisorption (weak adsorption bond).
3. It appears that an efficient inhibitor is characterized by negative value of free energy of adsorption, positive value of entropy of adsorption and higher (more negative) heat of adsorption.
4. The galvanostatic polarization data indicate that these are mixed type inhibitors with predominant effect on the cathode.
5. Cathodic protection in the presence of these inhibitors is achieved at potentials much less negative than that for plain acid. The protective potential corresponding to the protective current is not a constant value and varies with each system. The protective potential changes with the inhibitor concentration.
6. TTTS behaves as an efficient inhibitor because –OH group in ortho-position would facilitate the formation of a chelate having a six-membered ring.

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