EFFECT OF CONCENTRATION AND TEMPERATURE ON THE INHIBITION POWER OF (1-NAPTHYLMETHYL)-TRIPHENYLPHOSPHONIUM CHLORIDE FOR MILD STEEL CORROSION IN ACIDIC MEDIUM

Ajai Kumar[1, 2], Reena Jain[1], and Sudershan Kumar[1]*

[1]*Department of Chemistry, Hindu College, University of Delhi, Delhi-110007(India)*
[2]*Department of Applied Chemistry, Shri Venkateshwara University, Gajraula, UP-244236 (India)*
***Coressponding Author: sudershankumar@hindu.du.ac.in**

ABSTRACT
Quaternary phosphonium compound namely (1-NapthylMethyl)-triphenylphosphonium Chloride (NMTPC) is reported as a potential inhibitor for mild steel (MS) corrosion in 0.5 M H_2SO_4 using weight loss technique. It is observed that with an increase in the inhibitor concentration there is an irregular increase in the inhibition efficiency and the reverse trend is seen with an increase in the temperature. Highest Inhibition efficiency of 93.84% was observed at the concentration (10^{-2}M, 10^{-3}M) at 298 K and minimum Inhibition efficiency 66.18% was shown by inhibitor at the concentration of (10^{-5}M) at highest temperature of 328 K.Maximum protection is shown at 298 K at the highest concentration of 10^{-2} M and least coverage is observed at the lowest concentration of 10^{-5} M at 328 K.

KEYWORDS*:* Mild steel; Weight loss method; Acidic medium; Corrosion inhibition; phosphonium compounds

INTRODUCTION
Corrosion is the unwanted decay of the material when exposed to its surrounding atmosphere [i]. It is a challenging material science problem since ancient times but in the current scenario, the problem becomes vast as the use of metals increases manifolds [ii-v]. A big share of countries' GDP is lost due to corrosion failure. As reported in the media corrosion costs around Rs. 2 lakh crores loss a year of Indian economy [vi]. Therefore special strategies are required to deal with this special issue which is otherwise ignored. The problem is not limited only to selective sectors but more or less every sector and industries are facing the issue but industries like chemical transportation, automobiles, marine are the most affected ones.

Corrosion is an unstoppable process, so the target is to minimize it to the best level. Metals are the backbone of any industry and structural failure can create major problems in functioning. Mild steel due to extra strength is mostly used metal to make the industrial

structure. But due to various corrosive environments mild steel faces different types of corrosion problems. Acid solutions are used to remove the scale/corrosion product formed on the metal surface and the process is called acid cleaning or descaling. Sulfuric acid and hydrochloric acid are the best options available for acid cleaning due to low cost. During the descaling process the metal is under threat of further corrosion due to the high corrosiveness of the nature of these acids, therefore to prevent this further corrosion process need of adding some corrosion inhibitor into the acid solution. Various corrosion inhibitors are tried for acidic corrosion in past but the organic compound having aromatic rings or hetero atoms, and π bonds are the most effective. Better inhibitor properties are shown with effective interaction of electron-rich centres of inhibitor molecules with vacant d orbitals of metal. Generally, heteroatoms like N, S, O, and P attached to aromatic organic compounds have shown comparatively better results [vii-xxvii]. The corrosion protection mechanism is broadly by adsorption of inhibitor molecules at the metal-solution interface.

Phosphorous or phosphonium moieties are well known for providing biocidal properties and thermal stability [xxviii-xxix]. A literature survey of corrosion inhibitors clearly shows that the phosphonium compounds are a very good inhibitor for mild steel in acidic solution [xxx-xxxiii].

In this work, the adsorption behaviour of 1-NapthylMethyl)-triphenylphosphonium Chloride for mild steel corrosion in 0.5 M H2SO4 was studied for four concentrations at 298K, 308K, 318 K, and 328K by gravimetric method. Various corrosion parameters were calculated and the effect of concentration and temperature on inhibition efficiency was discussed.

EXPERIMENTAL:
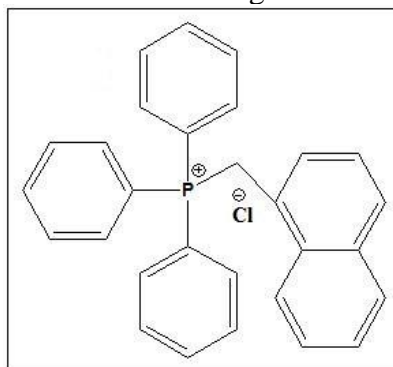The molecular structure of NMTPC is shown in Fig 1:

Fig 1: Molecular structure of the studied inhibitor NMTPC

Mild steel under consideration is the one used for structural applications. The Weight loss studies were performed with mild steel specimen having the chemical composition (in wt% of mild steel) as given below:

C	Si	S	P	Mn	Fe
0.15	0.31	0.025	0.025	1.02	Balance

All observations were recorded in the corrosive acidic solution. The acidic solutions (test solutions) were made from AR grade H_2SO_4. 0.5 molar concentration of acid was prepared by diluting AR acids with double distilled water. The phosphonium compound NMTPC (Aldrich, >98 %) was used as an inhibitor as received. Various concentrations of NMTPC

(10^{-2}, 10^{-3}, 10^{-4}, and 10^{-5}) molar were prepared by dissolving the calculated weights in 0.5 M H_2SO_4 solution.

Weight Loss Technique

The gravimetric study was performed at four temperatures viz. 298, 308,318, and 328 ± 2 K for four concentrations of additive NMTPC with a plunging duration of 6 hours. For each set of measurements, a well-polished cubic coupon having surface area $1cm^2$ was immersed into 50 mL of test acidic solution; two sets of the experiment were performed to reproduce the result under similar experimental circumstances. The rate of corrosion process C_R is calculated by using the formula i.e C_R=W/At where W (mg) is the actual weight loss, of coupons with surface Area, A (cm^2) and t is the exposure time, (in hours)[xxxiv]. The corrosion inhibition efficiency IE_{WL} (%) was calculated by using the formula:

$$IE_{WL}(\%) = \frac{C_R - C_R(i)}{C_R} x100 \qquad (1)$$

Where C_R is the corrosion rate in the presence of 0.5 M H_2SO_4 solution only and C_R (i) is the corrosion rate with the addition of the inhibitor in 0.5 M H_2SO_4 solution. The degree of surface coverage (θ) of phosphonium molecules on the mild steel surface was calculated by using the following equation:

$$θ = IE_{WL}(\%)/100 \qquad (2)$$

Where IE is the inhibition efficiency of NMTPC.

RESULTS AND DISCUSSION

Effect of Concentration on Inhibition Efficiency:

The inhibition efficiencies for mild steel corrosion in 0.5 M H_2SO_4 for all studied concentrations of NMTPC at four considered temperatures (298 K, 308 K, 318 K, and 328 K) are tabulated in Table 1, and various parameter as well variation of percentage inhibition efficiencies (IE %) against the concentration of inhibitor and temperature is also tabulated. The variation of efficiencies of corrosion inhibition against the various studied concentrations is given in Fig.2. It is observed from Table 1 that weight loss with addition of inhibitor decrease consequently IE % increases although the trend is not regular one. Highest Inhibition efficiency of 93.84% was observed at the concentration (10^{-2}M, 10^{-3}M) at 298 K and minimum Inhibition efficiency 66.18% was shown by inhibitor at the concentration of (10^{-5}M) at highest temperature of 328 K. The values of surface coverage (θ) up to 0.90 clearly indicate that adsorption of phosphonium compound molecules on the vacant site of the mild steel surface.

After a deep analysis of Table 1 it was observed that weight loss decreases after the addition of inhibitor into the corrosive solution further the corrosion rate is found to be decreased with an increase in the concentration of NMTPC as compare to blank acid solution at all four temperatures. The inhibition efficiencies increases with addition of more amount of additive so for every set of experiments more or less inhibition efficiency is maximum for highest concentration 0f 10^{-2} and minim for lowest concentration of 10^{-5} temperature. Therefore it can assumed that that with addition of more and more inhibitor molecules there is formation of a protective layers of the molecules till an optimum concentration and the interaction of metal surface to the corrosive solution can be hindered to a large extent which stop the corrosion process by stopping either anodic or cathodic reactions. At lower concentrations the degree of surface coverage is not enough to protect the complete corrosion process so there is unprotected surface which his prone to further corrosion resulting in lesser inhibition efficiency.

Table 1: Corrosion parameters of mild steel in 0.5 M H_2SO_4 in the presence 1-NapthylMethyl)-triphenylphosphonium Chloride (NMTPC)

| Temp. (K)	Conc. (M)	Initial Weight I_w (g)	Final Weight F_w (g)	Weight Loss (g)	C_R (mgcm^{-2}h^{-1})	IE (%)
H_2SO_4						
298	0.5	11.6211	11.6341	0.0130	2.16	-
308	0.5	12.4430	12.4602	0.0172	2.86	-
318	0.5	10.2320	10.2503	0.0183	3.05	-
328	0.5	11.6356	11.6562	0.0206	3.43	-
NMTPC						
298	10^{-2}	10.4580	10.4588	0.0008	0.133	93.84
	10^{-3}	12.3454	12.3462	0.0008	0.133	93.84
	10^{-4}	12.3619	12.3630	0.0011	0.183	91.52
	10^{-5}	10.4612	10.4625	0.0013	0.216	90.00
308	10^{-2}	10.7736	10.7749	0.0013	0.216	92.44
	10^{-3}	10.7844	10.7863	0.0019	0.316	88.95
	10^{-4}	11.3909	11.3935	0.0026	0.433	84.86
	10^{-5}	10.4613	10.4646	0.0033	0.550	80.76
318	10^{-2}	10.9519	10.9538	0.0019	0.316	89.63
	10^{-3}	10.6739	10.6760	0.0021	0.350	88.52
	10^{-4}	11.4516	11.4538	0.0022	0.366	88.00
	10^{-5}	10.8416	10.8445	0.0029	0.483	84.16
328	10^{-2}	10.8642	10.8689	0.0047	0.783	77.17
	10^{-3}	10.5216	10.5272	0.0056	0.933	72.79
	10^{-4}	11.4618	11.4681	0.0063	1.050	69.38
	10^{-5}	10.3427	10.3497	0.0070	1.160	66.18
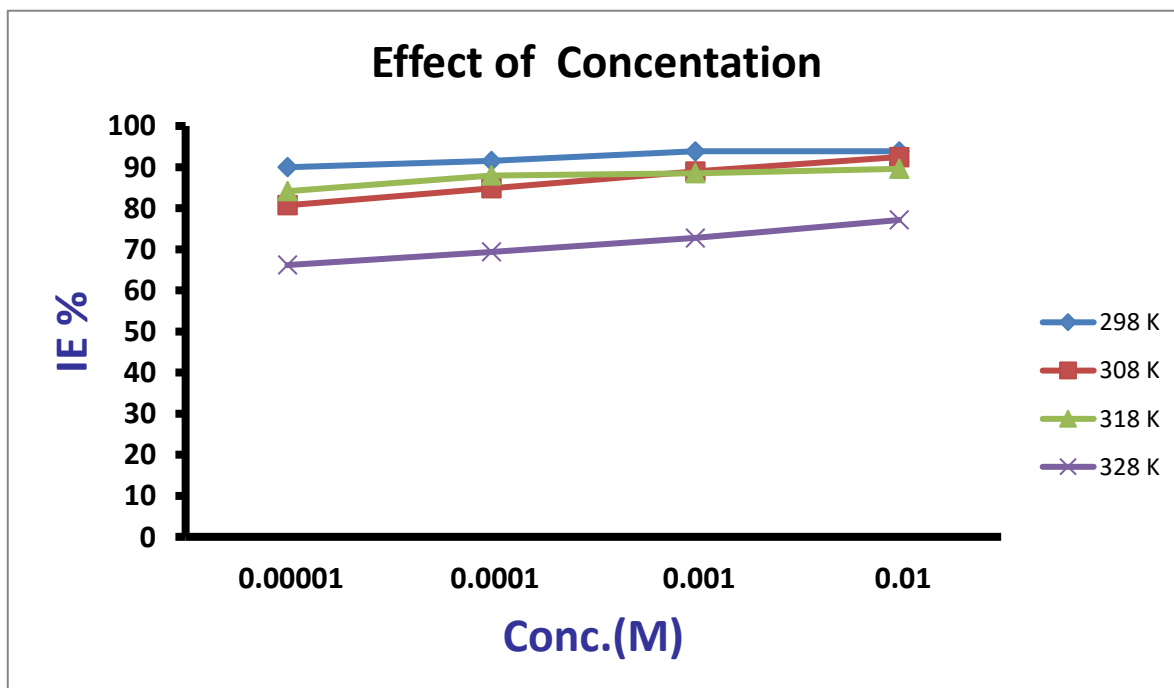
Fig 2. Effect of inhibitor concentration on corrosion inhibition efficiency for NMTPC at 298 K, 308 K, 318 K and 328 K

Effect of Temperature on Inhibition Efficiency:

This is well known fact that rate of reaction is higher at elevated temperature and this phenomenon is also carried out in corrosion process as mobility of ions at the metal electrolyte interface is fast enough to induced corrosion mechanism. It is clearly seen from Fig. 3 that even at highest studies temperature of 328 K the inhibition efficiencies are 77.17 % And 66.18 % for highest and lowest concentration respectively. At lower temperature the adsorbed molecules of phosphonium compounds are well arranged to form a protective thin layer on the mild steel surface. Further as temperature increases the movements of ions takes place with inhibitor molecules and and more or less breakage of layer or film takes place and corrosion mitigation is effected to some extent. Moreover lower surface coverage at high temperature specifies that elevated temperature fast ionic mobility leads to the dissolution of the film on the metal surface. The decrease in inhibition efficiency with increasing temperature may be due to decreasing the tendency of the inhibitor to be adsorbed on the mild steel surface [xxxv]. With dissolution of thin layer, corrosion can speed up if dissociation of inhibitor molecules takes place but as observed that even at high temperature the corrosion inhibition efficiency is respectively higher that observed in other organic compounds, this might t be due to the reason that phosphonium compounds are thermally more stable and do not dissociate at studied higher temperature. So this inhibitor can show good corrosion mitigation properties at higher temperature also.
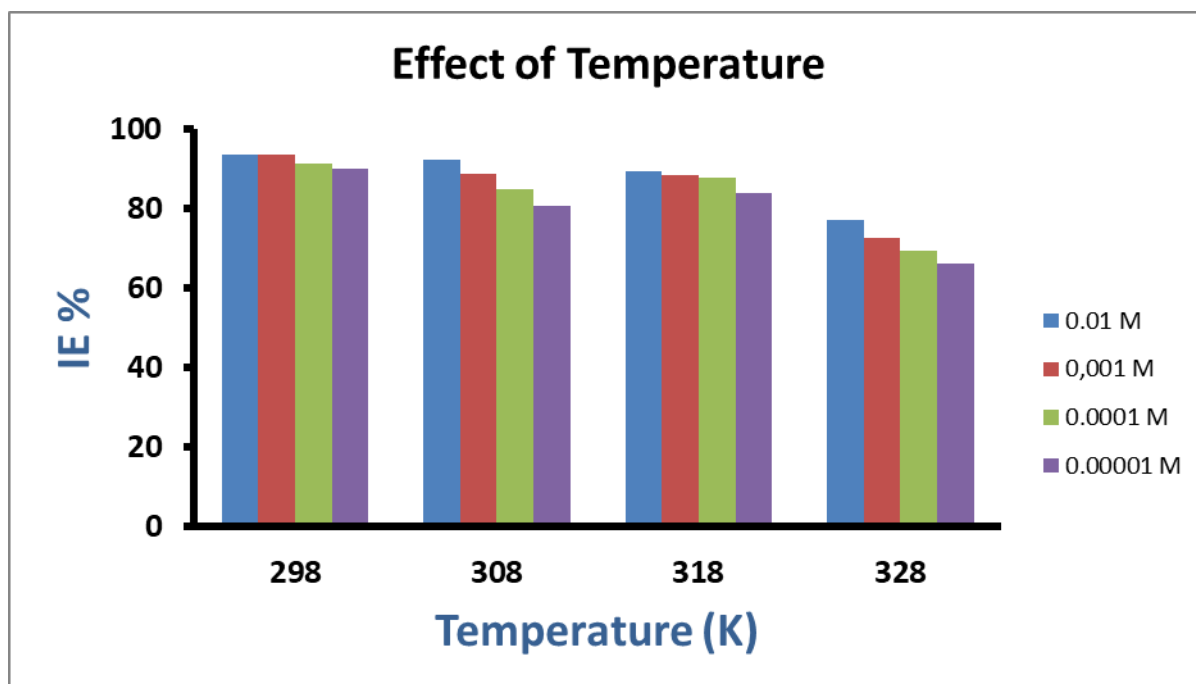
Fig 3. Effect of temperature on corrosion inhibition efficiency for NMTPC at , 10^{-2} M ,10^{-3} M,10^{-4} M, and 10^{-5} M

CONCLUSION

Phosphonium salt NMTPC has indicated potential inhibitor properties against mild steel corrosion in 0.5 M H_2SO_4 at all studied four temperatures 298 K, 308 K, 318K and 328K. Compound has shown it efficiency both at lower and elevated temperatures. It is observed that with an increase in the inhibitor concentration there is an irregular increase in the inhibition efficiency and the reverse trend is seen with an increase in the temperature.

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