ISSN (Online) : 2348 - 2001

International Refereed Journal of Reviews and Research

Volume 7 Issue 6 November 2019

International Manuscript ID : 23482001V7I6112019-618

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IMPACT OF TEMPERATURE AND CONCENTRATION ON THE CORROSION PROTECTING EFFICIENCIES OF (2-AMINO BENZYL) TRIPHENYLPHOSPHONIUM BROMIDE ON CARBON STEEL IN DILUTE SULPHURIC ACID

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Abstract

Using the weight loss technique, a quaternary phosphonium compound called (2-amino benzyl) triphenylphosphonium bromide (ABTPPB) was found to be an effective inhibitor of carbon steel (CS) corrosion in 0.5 M H_2SO_4. It is detected that increasing the inhibitor concentration results in an irregular increase in inhibition efficiency, whereas increasing the temperature results in the opposite pattern. The inhibitor had the highest inhibition efficiency of 97.26 percent at the concentrations

(10^{-2}M) at 298 K and the lowest inhibition efficiency of 45.16 percent at the concentration (10^{-5}M) at the highest temperature of 328 K. Maximum protection is observed at 298 K at the highest concentration of 10^{-2} M, while the least coverage is observed at 328 K at the lowest concentration of 10-^{5} M.

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

Introduction:

Corrosion is the undesirable loss of a material when it is exposed to its surroundings, [1]. Since ancient times, it has been a difficult material science problem, but in the current state, the problem has grown exponentially as the use of metals has increased to a large extent [2-5]. Corrosion failure costs countries a significant portion of their Gross Domestic Product (GDP). India loses 5-7% of total GDP due to corrosion as reported by International Zinc Association in media [6]. As a result, special strategies are required to deal with this unique issue, which would otherwise go unnoticed. The problem is not limited to a few sectors; rather, it affects almost every sector and industry, with chemical transportation, automobiles, and maritime being the most affected ones.

Because corrosion is an unstoppable process, the goal is to keep it to a minimum. Metals are the backbone of any industry, and structural failure can cause significant operational issues. Mild steel is the most commonly used metal in the construction of industrial structures due to its increased strength. However, due to the variety of corrosive environments, mild steel suffers from a variety of corrosion problems. The process of removing scale/corrosion products from metal surfaces is known as acid cleaning or descaling. Because of their low cost, sulfuric acid and hydrochloric acid are the best options for acid cleaning. Because of the high corrosiveness of these acids, the metal is at risk of further corrosion during the descaling process. therefore, to avoid this process further there is a need of adding some corrosion inhibitor into the acid solution.

Various corrosion inhibitors have been tried in the past for acidic corrosion, but organic compounds with aromatic rings or heteroatoms and bonds have proven to be the most effective. Better inhibitor properties are demonstrated by the effective interaction of inhibitor molecules' electron-rich centers with metal's vacant d orbitals. In general, heteroatoms such as N, S, O, and P attached to aromatic organic compounds performed better [7-27]. Adsorption of inhibitor molecules at the metal-solution interface is the general mechanism for corrosion protection.

Phosphorous and phosphonium moieties are widely known for biocidal and heat resistance properties [28-29]. An overview of corrosion inhibitor literature well-known shows that phosphonium compounds are a top-mark corrosion inhibitor for moderate metallic in acidic medium [30-32].

The adsorption behaviour of (2-amino benzyl) triphenylphosphonium bromide (ABTPPB) for carbon steel corrosion in 0.5 M H_2SO_4 was studied by gravimetric method for four concentrations at 298 K, 308 K, 318 K, and 328 K. The effect of concentration and temperature on inhibition efficiency was discussed as well as the calculation of various corrosion parameters.

Experimental:

The molecular structure of (2-amino benzyl) triphenylphosphonium bromide (ABTPPB) is shown in Fig 1:

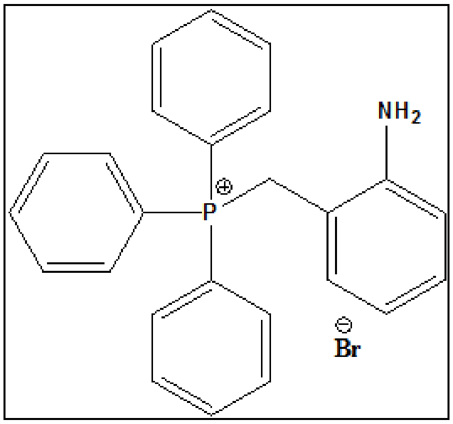

Fig. 1: The inhibitor structure of (2-aminobenzyl)triphenylphosphonium Bromide (ABTPPB)

The mild steel under consideration is used for structural applications. The weight loss studies were carried out on mild steel specimens with the chemical composition (in weight percent of mild steel) as follows:

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

In the corrosive acidic solution, all observations were recorded. The acidic solutions (test solutions) were made with AR-grade H_2SO_4. Diluting AR acids with double distilled water yielded an acid concentration of 0.5 molar. As received, the phosphonium compound ABTPPB (Aldrich, > 98 percent) was used as an inhibitor. Various concentrations of ABTPPB (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 Method:

The gravimetric study was carried out at four temperatures, namely 298, 308, 318, and 328 ± 2 K, for four concentrations of phosphonium compound ABTPPB with a plunging duration of six hours. A well-polished cubic coupon with a surface area of 1cm^2 was immersed in 50 mL of test acidic solution for each set of measurements; two sets of the experiment were performed to replicate the result under similar experimental conditions. 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) [33-34]. 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:

$$\theta = IE_{WL}(\%)/100 \qquad (2)$$

Where IE is the inhibition efficiency of ABTPPB.

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 ABTPPB at four considered temperatures (298 K, 308 K, 318 K, and 328 K) are tabulated in Table 1, and various parameters 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 the addition of inhibitor decrease consequently IE % increases although the trend is not a regular one. The highest Inhibition efficiency of 97.26% was observed at the concentration (10^{-2}M) at 298 K and minimum Inhibition efficiency of 45.16% was shown by inhibitor at the concentration of (10^{-5}M) at the highest temperature of 328 K. The values of inhibition efficiencies up to 95 and above clearly indicate that adsorption of phosphonium compound molecules on the vacant site of the mild steel surface and maximum surface coverage up to 90%,

Following a comprehensive inspection of Table 1, it was noticed that the weight loss decreases after the addition of the inhibitor into the corrosive solution, and the degradation rate decreases with an increasing concentration of ABTPPB in reference to the blank acid solution at all four temperatures. The inhibition efficiencies increase with the addition of more additives, so for each set of experiments, the inhibition efficiencies are maximum for the highest concentration of 10^{-2} and lowest for the lowest concentration of 10^{-5} temperature. As a result, it can also be assumed that as more inhibitor molecules are introduced, shielded layers of the molecules form unless an optimum concentration is attained, and the interaction of the metal substrate with the corrosive solution can be hindered to a large extent which stops 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 an unprotected surface that is 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 (2-aminobenzyl)triphenylphosphonium Bromide (ABTPPB)

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	11.6341	11.6211	0.0130	2.16	-
308	0.5	12.4602	12.4430	0.0172	2.86	-
318	0.5	10.2503	10.2320	0.0183	3.05	-
328	0.5	11.6562	11.6356	0.0206	3.43	-
			ABTPPB			
298	10^{-2}	10.3485	10.3482	0.0003	0.059	97.26
	10^{-3}	11.4461	11.4453	0.0008	0.134	93.77
	10^{-4}	11.5367	11.5343	0.0012	0.209	90.31
	10^{-5}	10.9909	10.9884	0.0025	0.432	80.00

308	10^{-2}	10.4582	10.4575	0.0007	0.121	95.74
	10^{-3}	10.6699	10.6686	0.0013	0.225	92.12
	10^{-4}	10.6573	10.6554	0.0019	0.316	88.95
	10^{-5}	10.9029	10.8988	0.0041	0.693	75.76
318	10^{-2}	11.9588	11.9566	0.0022	0.376	87.67
	10^{-3}	10.7765	10.7743	0.0025	0.420	86.21
	10^{-4}	11.3381	11.3332	0.0049	0.823	73.00
	10^{-5}	11.2425	11.2345	0.0080	1.339	56.07
328	10^{-2}	10.1259	10.1213	0.0046	0.779	77.27
	10^{-3}	11.1266	11.1211	0.0055	0.929	72.73
	10^{-4}	10.4851	10.4765	0.0086	1.432	58.23
	10^{-5}	12.3335	12.3222	0.0113	1.881	45.16

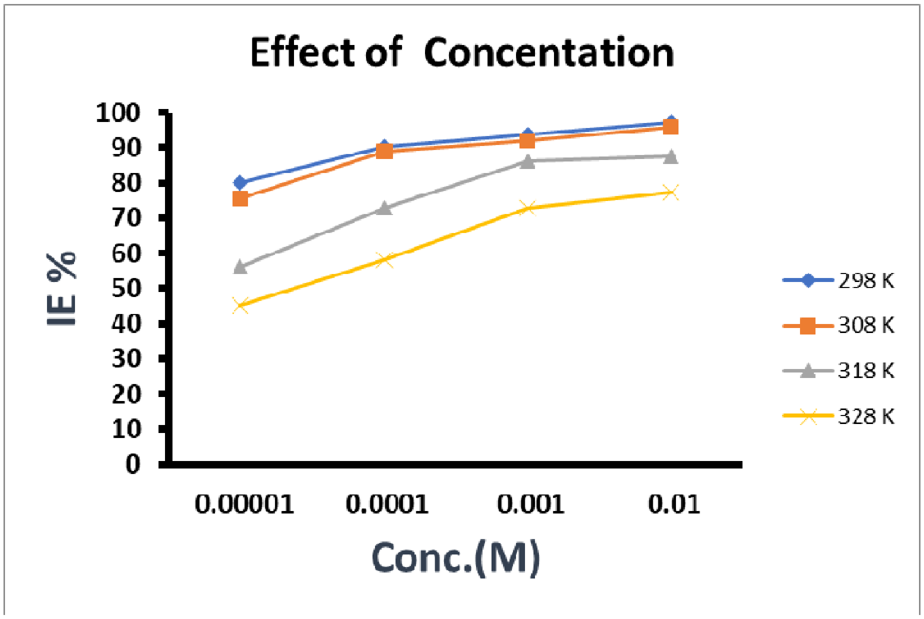

Fig 2. Effect of inhibitor concentration on corrosion inhibition efficiency for ABTPPB at 298 K, 308 K, 318 K, and 328 K

Effect of Temperature on Inhibition Efficiency:

The fact that reaction rates are faster at higher temperatures is well known, and this phenomenon occurs in the corrosion process as well, because ion mobility at the metal electrolyte interface is fast enough to initiate corrosion mechanisms. Even at the highest study temperature of 328 K, the inhibitory efficiencies are 77.27 percent and 45.16 percent for the highest and lowest concentrations, respectively, as shown in Fig. 3. The adsorbed molecules of phosphonium compounds produce a protective thin coating on the mild steel surface at lower temperatures also. Further, as the temperature rises, ions interact with inhibitor molecules, with an increase in the randomness of molecules, causing more or less layer or film breaking and, as a result, corrosion prevention is affected to some level. Furthermore, lesser surface coverage at high temperatures indicates that at high temperatures, fast ionic mobility causes the layer on the metal surface to dissolve. The decline in inhibition efficacy as temperature rises could be attributable to the inhibitor's tendency to be adsorbed on the mild steel surface [35]. Corrosion can speed up with the dissolution of a thin layer if inhibitor molecules dissociate, but it has been observed that the corrosion inhibition efficiency of phosphonium compounds is higher than that of other organic compounds, which could be due to the fact that phosphonium compounds are thermally more stable and do not dissociate at the higher temperatures studied. As a result, this inhibitor can mitigate corrosion at higher temperatures as well.

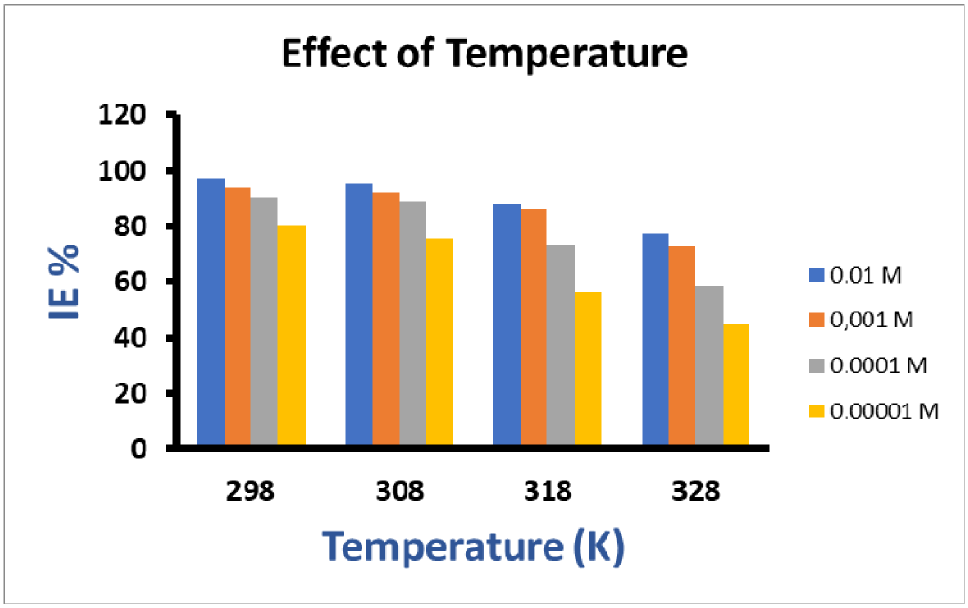

Fig 3. Effect of temperature on corrosion inhibition efficiency for ABTPPB at, 10^{-2} M, 10^{-3} M, 10^{-4} M, and 10^{-5} M

CONCLUSION

In 0.5 M H_2SO_4, the phosphorus additive ABTPPB exhibited potent inhibitor characteristics against mild steel corrosion at all four temperatures studied: 298 K, 308 K, 318 K, and 328 K. Compound has established its efficiency at both low and high temperatures. When the inhibitor concentration is increased, the inhibition effectiveness increases regularly, and when the temperature is increased, the inhibition efficiency decreases irregularly.

Acknowledgment

The authors are grateful to the Department of Chemistry Hindu College and the University of Delhi, India for providing infrastructure and instrumental facilities for the research work

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