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Corrosion inhibition of mild steel in sulphuric acid solutions by using tetra methyl ammonium bromide (TMAB)

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The corrosion inhibition of mild steel in one normal sulphuric acid solution by tetra methyl ammonium bromide (TMAB) has been studied in relation to the concentration of the inhibitor as well as the temperature using electrochemical polarization (galvanostatic and potentiostatic polarizations) techniques. The results were supplemented with scanning electron microscopy and infra-red spectroscopy. All the methods employed are in reasonable agreement. There is no particular relationship of inhibition with concentration and temperatures. The thermodynamic functions of dissolution and adsorption processes were calculated from experimental polarization data and the interpretation of the results are given. Adsorption of TMAB was found to follow the Langmuir’s adsorption isotherm. TMAB is a mixed type of inhibitor.

Key words: Tetra methyl ammonium bromide (TMAB), corrosion inhibitors, mild steel, sulphuric acid (H₂SO₄), thermodynamic functions, adsorption process, scanning electron microscope (SEM), infrared spectroscopy (IR) spectra.

INTRODUCTION

Acid solutions are generally used for the removal of rust and scale in several industrial processes. Inhibitors are generally used in these processes to control the metal dissolution. H₂SO₄ is widely used in the pickling of steel and ferrous alloys (Bentiss et al., 1999). To make secure from attack of acid, inhibitors are frequently used. Organic nitrogen compounds on the corrosion behavior of iron and steel in acidic solutions are usually employed for their rapid action (Chetouani et al., 2002). If we can prove that adsorption of certain atoms retards corrosion, this might be the easiest and cleanest, and probably the most economic, approach to corrosion inhibition. The use of inhibitors takes more and more attention until now. While there are differences among the theories developed to explain effects of some inhibitors, there is a common consensus about the manner in which the various kinds of inhibitors work (Tauhami et al., 2000). A study of the mechanism of the action of corrosion inhibitors has relevance both from the point of view of the search for new inhibitors and also for their effective use. Acid solutions are generally used for the removal of undesirable scale and rust in several industrial processes. Generally, the use of organic inhibitors to control the metal dissolution is one of the common techniques, and during the past decade many inhibitors have been studied in different media (Elkadì et al., 2000).

The aim of this work is to study the inhibiting effect of tetra methyl ammonium bromide (TMAB) on mild steel in one normal sulphuric acid solution. Galvanostatic and potentiostatic polarizations were done. The effects of inhibitor concentration at different temperatures were
studied. The results were supplemented by scanning electron microscope (SEM) and infrared spectroscopy (IR) spectra studies.

EXPERIMENTATION

Corrosion inhibitor compound

The organic additive tetra methyl ammonium bromide (TMAB) is used as the corrosion inhibitor.

Chemical composition of mild steel

Mild steel refers to low carbon steel which is usually used for structural applications. With too little carbon content to through harden it is weldable, which expands the possible applications of mild steel. The experiments were performed with cold rolled mild steel specimen. Mild steel coupons of chemical composition (C=0.20%, Mn=.1.00%, Si=0.05%, S=0.025%, P=0.25% and Fe=98%) have been used.

Solutions

The aggressive solutions were made of AR grade H2SO4. One normal concentration of acid was prepared using double distilled water. The concentrations of inhibitor employed were 10^{-3}, 10^{-5} and 10^{-2} M.

Electrodes

Working electrode

Design of working electrodes (WE) is diverse. Most commons in experiments are to study mechanism and kinetics in the laboratory. An essential feature is that the electrode should not react chemically with the solvent or solution components. It is desirable to have an even current and potential distribution and hence a cell to be designed, so that all points on working electrode surface are geometrically equivalent with respect to the secondary electrode.

Reference electrode

The role of the reference electrode (RE) is to provide a fixed potential which does not vary during the experiments. The RE serves dual purposes of providing a thermodynamic reference and also isolating WE from the system.

Auxiliary electrode (counter electrode)

The purpose of the counter electrode (CE) is to supply the current required by the working electrode without limiting the measured response of the cell. It is essential that the electrode process is decomposition of the electrolyte, so that the current flows readily without the need for a large over potential.

Luggin capillary

The luggin capillary in a laboratory cell is made from glass. It is generally filled with the test solution. The luggin holds the reference electrode. The tip of the luggin capillary near the working electrode is open to the test solution. The reference electrode senses the solution potential at this open tip. Note that the luggin tip is significantly smaller than the reference electrode itself. The luggin capillary allows sensing the solution potential close to the working electrode without the adverse effects that occur when the large reference electrode is placed near the working electrode. A luggin capillary can be used to bring the potential measuring point in close proximity to the working electrode under investigation. Such a device can be made of any material provided it is inert to the electrolytic environment. It basically consists of a bent tube with a large enough opening to accommodate a reference electrode and a usually much smaller opening only large enough to insure diffusion movement of the electrolyte. The device minimizes any IR drop in the electrolyte associated with the passage of current in an electrochemical cell.

Surface treatments of the working electrode

The surfaces of carbon steel specimens were abraded successively by different grade of metallographic emery papers until the surfaces appear free from scratches and other apparent defects, then degreased in hot acetone, washed with bi-distilled water and finally dried. The surface treatment was carried out immediately before each experiment of corrosion tests (Abd El-Kader et al., 1998).

RESULTS AND DISCUSSION

Open circuit potential measurements

The electrochemical behavior of mild steel in 1 N H2SO4 was studied on the basis of the change in corrosion potentials (E_{corr}) with time. It is send that in absence of the inhibitor molecules, the open circuit potential tends from the moment of immersion towards more negative value. This behavior represents the break down of the pre-immersion, air formed oxide film on the mild steel surface. In presence of different concentrations of the inhibitor the steady state potentials of the working electrodes were shifted towards more positive values, denoting passivation of the mild steel (Putilova et al., 1960).

Galvanostatic polarization measurements

The cathodic and anodic polarization curves for these solutions with and without any inhibitor concentrations at 298, 308, 318 and 328K are plotted. Logarithms of current densities have been plotted against the corresponding potentials. From these graphs we obtained the values of corrosion potential (E_{corr}), corrosion current (log i_{corr}), anodic Tafel region (b_{a}), cathodic Tafel region (b_{c}), corrosion inhibition efficiency (%) and surface coverage (θ). These values are mentioned in Table.1. The one graph obtained at 298K is given in the Figure 1. At lower temperature the decrease in corrosion current with increase in TMAB concentrations is much more pronounced than that at higher temperatures. At a particular TMAB concentrations, the corrosion current is higher at higher temperature and this is observes at all
Table 1. Corrosion electrochemical parameters for mild steel grade IS-226 in 1 N H\textsubscript{2}SO\textsubscript{4} in the absence and in the presence of TMAB as additive.

<table>
<thead>
<tr>
<th>Temperature (K)</th>
<th>Concentration (M)</th>
<th>Corrosion potential (E_{corr}) (mV)</th>
<th>Log (i_{corr}) ((\mu A/cm^2))</th>
<th>(b_c) (mV/dec)</th>
<th>(b_a) (mV/dec)</th>
<th>Corrosion inhibition efficiency (I%))</th>
<th>Surface coverage ((\theta))</th>
<th>1/(1-\theta)</th>
</tr>
</thead>
<tbody>
<tr>
<td>298</td>
<td>0</td>
<td>490</td>
<td>3.00</td>
<td>80</td>
<td>35</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>(10^{-7})</td>
<td>460</td>
<td>2.60</td>
<td>125</td>
<td>100</td>
<td>60.2</td>
<td>0.602</td>
<td>1.51</td>
</tr>
<tr>
<td></td>
<td>(10^{-5})</td>
<td>460</td>
<td>2.60</td>
<td>145</td>
<td>103</td>
<td>60.2</td>
<td>0.602</td>
<td>1.51</td>
</tr>
<tr>
<td></td>
<td>(10^{-3})</td>
<td>460</td>
<td>2.40</td>
<td>155</td>
<td>103</td>
<td>74.0</td>
<td>0.740</td>
<td>2.84</td>
</tr>
<tr>
<td>308</td>
<td>0</td>
<td>520</td>
<td>3.00</td>
<td>115</td>
<td>85</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>(10^{-7})</td>
<td>464</td>
<td>2.12</td>
<td>140</td>
<td>100</td>
<td>86.9</td>
<td>0.869</td>
<td>6.63</td>
</tr>
<tr>
<td></td>
<td>(10^{-5})</td>
<td>456</td>
<td>2.75</td>
<td>148</td>
<td>78</td>
<td>43.8</td>
<td>0.438</td>
<td>0.77</td>
</tr>
<tr>
<td></td>
<td>(10^{-3})</td>
<td>452</td>
<td>2.05</td>
<td>148</td>
<td>100</td>
<td>88.8</td>
<td>0.888</td>
<td>7.92</td>
</tr>
<tr>
<td>318</td>
<td>0</td>
<td>520</td>
<td>3.12</td>
<td>125</td>
<td>80</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>(10^{-7})</td>
<td>480</td>
<td>2.75</td>
<td>56</td>
<td>40</td>
<td>57.9</td>
<td>0.570</td>
<td>2.32</td>
</tr>
<tr>
<td></td>
<td>(10^{-5})</td>
<td>400</td>
<td>2.75</td>
<td>124</td>
<td>48</td>
<td>57.0</td>
<td>0.570</td>
<td>2.32</td>
</tr>
<tr>
<td></td>
<td>(10^{-3})</td>
<td>406</td>
<td>2.50</td>
<td>188</td>
<td>400</td>
<td>76.0</td>
<td>0.76</td>
<td>3.12</td>
</tr>
<tr>
<td>328</td>
<td>0</td>
<td>500</td>
<td>3.00</td>
<td>165</td>
<td>76</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>(10^{-7})</td>
<td>500</td>
<td>2.68</td>
<td>304</td>
<td>24</td>
<td>52.2</td>
<td>0.522</td>
<td>1.09</td>
</tr>
<tr>
<td></td>
<td>(10^{-5})</td>
<td>500</td>
<td>2.55</td>
<td>136</td>
<td>72</td>
<td>64.4</td>
<td>0.644</td>
<td>1.80</td>
</tr>
<tr>
<td></td>
<td>(10^{-3})</td>
<td>540</td>
<td>2.50</td>
<td>124</td>
<td>124</td>
<td>68.4</td>
<td>0.684</td>
<td>2.16</td>
</tr>
</tbody>
</table>

Figure 1. Galvanostatic polarization curves of mild steel in one normal solution containing different concentrations of tetra methyl ammonium bromide (TMAB) at 298K. Where \(\Delta\) is for 1 N H\textsubscript{2}SO\textsubscript{4}, \(\Box\) is for \(10^{-7}\) M TMAB solution, + is for \(10^{-5}\) M TMAB solution, x is for \(10^{-3}\) M TMAB solution.

Concentrations. In the corrosion process the little change in the corrosion potentials suggest that TMAB controls both the cathodic hydrogen evolution as well as iron dissolution reactions. The inhibitor at higher temperature exerts a greater influence on the cathodic process than that the anodic process. During metal dissolution, reaction metal oxide and metal hydroxide reaction starts the chemical association of TMAB molecules, with the metal surface through the oxygen lone pair of electron interaction turning to chemical reaction and probably,
forming intermediates species (M-In)\textsubscript{ads} or (M-In-OH)\textsubscript{ads} or (M-H-In)\textsubscript{ads} and thereby resulting in irregular slopes. Corrosion current density decreases with concentration and its inhibition efficiency decreases with the rise of temperature.

The peculiar behavior of TMAB at higher temperatures may be due to the joint effects of:

(i) reaction of the inhibitor with electrode surface
(ii) decomposition of inhibitor to the some other compound in the acid solutions and thereby changing the kinetics of cathodic and anodic reactions in a different manner.

The graph between corrosion current and concentration is plotted in Figure 1 and the graph between inhibition efficiency with concentration is plotted in the Figure 2. It shows that there is no regular order of inhibition efficiency with concentration.

TMAB affects the corrosion of mild steel in acid medium in the form of protonated organic molecule and the prevailing inhibitor effect is anodic rather than cathodic at ordinary temperature (298K) and at lower concentrations. At higher temperatures the inhibitor acts both in cathodic as well as in the anodic. At all temperatures it is seen that inhibition effect is more at higher concentration than at lower concentration. At all concentrations of TMAB, the change in corrosion potentials from that in uninhibited solution is lower except at higher temperature where it remain unchanged. This indicates that it is a mixed type of inhibitor with a slight predominance of anodic effect except at 328K.

Effect of temperature and adsorption isotherm

In order to study the effect of temperature on corrosion inhibition of mild steel in the acid reaction and to determine the activation energy of the corrosion process, the galvonostatic polarization studies were done at various temperatures (298 to 328K) in the absence and in the presence of TMAB at different concentrations. The corresponding results were given in Table 1. The change of corrosion current with temperature is plotted in the Figure 3. We note that the corrosion rate increases with rise of temperature both in inhibited and uninhibited acid solutions. Figure 4 shows the change of surface coverage with temperature whereas Figure 5 shows a plot of log (θ/1-θ) versus log C, where θ is the surface covered by inhibitor molecules and C is the inhibitor concentration in mol\textsuperscript{-1}. The Gibbs energy of adsorption (ΔG\textsubscript{ads}) was calculated for the following equation:

\[ \frac{θ}{1-θ} = 1/55.55 \exp \left( -\frac{ΔG_{ads}}{RT} \right) \]

The surface coverage value θ was evaluated using values of inhibition efficiency.

The inhibition behaviour of TMAB at different concentrations and different temperatures assuming change in the mechanism of both the hydrogen evolution reaction and iron dissolution and the degree of coverage θ can be obtained using the equation

\[ θ = 1 - \left( \frac{i_{inh}}{i_{uninh}} \right) \]

It is assumed that inhibitor gives monolayer adsorption.
coverage at any instant fraction ($\theta$) of the metal surface in a uniform or random manner and that the free fraction ($1-\theta$) of the metals surface reacts with and as it does in the absence of inhibitor. The ($1-\theta$) can be assured to be equal to $i_c/i_0$ and $\theta$ can be calculated readily from the results within a certain range of inhibitor. The surface coverage due to the progress of adsorption and desorption also changes with temperature. It shows that this inhibitor belong to the second category of Putilova’s classification of inhibitor, which characterized by no effect on the temperature coefficient. This type of inhibitor according to Putilova retards corrosion at ordinary temperature but efficiency is not reduced considerably at elevated temperature (Schweinsberg et al., 1988). The
series of isotherm obtained over a range of temperature that is, 298, 308, 318 and 328K yielded reasonable values of heats of adsorption when the function of log (θ /1- θ) plotted against the reciprocals of absolute temperature. Plots of inhibited corrosion rates versus the reciprocal of temperatures for a series of constant inhibitor concentration show that the net activation energy of corrosion energy of corrosion process shows irregular trend with concentration of TMAB in 1 N H₂SO₄ solution. The corrosion behavior of mild steel surface and surface coverage shows irregular relationship with inhibitor concentration. The values of activation energy (Eₐ) were calculated using the Arrhenius equation:

\[ E_a = \frac{-2.3003 \times R \times \frac{d (\log i_c)}{d (1/T)}}{\frac{d (\log \theta /1- \theta)}{d (1/T)}} \]

Where R is the universal gas constant and T is the temperature in Kelvin. The average activation energy of TMAB is 66.72 kJmol⁻¹. The heat of adsorption Q at different temperatures were calculated from Langmuir’s adsorption isotherm equation

\[ \log \frac{\theta}{1-\theta} = \log A + \log C - \frac{Q}{R}T \]

The average heat of adsorption for TMAB is 28.33 kJmol⁻¹. From the surface coverage data of the TMAB, it is inferred that the adsorption of the TMAB on the iron surface inhibits corrosion. Generally, four types of adsorption may take place, involving organic molecule at the metal solution interface (Fouda et al., 1986).

(i) The electrolytic attraction between charged molecule and the charged metal.
(ii) Interaction of unshared electron pairs in the molecules with the metal
(iii) Interaction of pi electrons with metal and
(iv) Combination of the above points.

Inhibition efficiency depends on several factors, such as the number of adsorption sites and their charge density, molecular size, heat of hydrogenation, mode of interaction with the metal surface and the formation of metallic complexes (Hackerman et al., 1966). The action of amine inhibitor molecules is due to the adsorption of the inhibitor molecules on exposed metal surface. Amines may be adsorbed over the metal surface in the form of neutral molecules involving replacements of water molecules from the metal surface as:

\[ \text{Amine(s)} + n\text{H}_2\text{O}_{\text{ads}} \rightleftharpoons \text{Amine}_{\text{ads}} + n\text{H}_2\text{O (s)} \]

And sharing of electron between the ‘N’ atom the inhibitor molecules and metal surface or by the electrostatic interaction between the positively charged ‘N’ atom and negatively charged metal surface. The inhibitive properties of amines are mainly dependent on the electron densities around the nitrogen atoms; the higher the electron densities around the nitrogen atoms, more effective are inhibitor. Due to adsorption, inhibitor molecules block the reaction sites and reduce the rate of corrosion reaction.

The inhibitor molecules inhibit the corrosion of mild steel by adsorption on the mild steel-solution surface; the adsorption provides the information about the interaction...
around the adsorbed molecules themselves as well as their interaction with electrode surface. A correlation between θ and concentration of inhibitor in the electrolyte can be represented by the Langmuir’s adsorption equation as

\[ θ = KC (1 + KC) \]

According to Bockris and Drazic, the inhibition mechanism could be explained by Fe-(Inh)\(_{ads}\) reaction intermediated as below.

\[ \text{Fe} + \text{Inh} \Leftrightarrow (\text{Inh})_{ads} \Leftrightarrow \text{Fe}^{0+} + \text{ne}^- + \text{Inh} \]

The adsorbed layer combats the action of sulphuric acid solution and enhances protection of the metal surface. When there is sufficient Fe(Inh)\(_{ads}\) to cover the metal surface (if the inhibitor concentration was low or the adsorption rate was slow), metal dissolution would take place at sites on the mill steel surface which are free of Fe-(Inh)\(_{ads}\) which are free of Fe-(Inh)\(_{ads}\). With high inhibitor concentration a compact and coherent inhibitor over layer forms on mild steel surface, reducing chemical attack on the metal. The adsorption of an organic molecule on the surface of the mild steel is regarded as a substitution of adsorption process between the organic compound in the aqueous phase (Org\(_{aq}\)) and the water molecules adsorbed on the mild steel surface (H\(_2\)O\(_{ams}\)).

\[ \text{Org}_{aq} + x \text{H}_2\text{O}_{ams} \Leftrightarrow \text{Org}_{ams} + x \text{H}_2\text{O}_{aq} \]

Where x is the size ratio, in terms of the number of water molecules replaced by an adsorbate molecules. When the equilibrium of the process described in the above equation is reached, it is possible to obtain different expression of the adsorption isotherm plots.

### Potentiostatic polarization measurements

A detailed study of steady state potentiostatic polarization behavior of anodic dissolution of mild steel in the presence of TMAB was made in 1 N H\(_2\)SO\(_4\) solution at room temperature (298K). The graph between potential and current density is plotted for 1 N H\(_2\)SO\(_4\), 10\(^{-7}\) M, 10\(^{-5}\) M and 10\(^{-3}\) M solution of TMAB plotted in Figure 6 and the values of critical current density (i\(_{crit}\)), passive current (i\(_p\)) and passivation potential (E\(_{pp}\)) are mentioned in the Table 2. It is seen from the table and figure that i\(_p\), E\(_{pp}\) become

![Figure 6. Potentiostatic polarization curves of mild steel in one normal solution containing different concentrations of tetra methyl ammonium bromide (TMAB). Where Δ is for 1 N H\(_2\)SO\(_4\), □ is for 10\(^{-7}\) M TMAB solution, + is for 10\(^{-5}\) M TMAB solution, x is for 10\(^{-3}\) M TMAB solution.](image)

### Table 2. Passivation data for TMAB obtained by potentiostatic polarization.

<table>
<thead>
<tr>
<th>Additive</th>
<th>Critical current density, i(_{crit}) (µA/cm(^2))</th>
<th>Passivation current density, i(_p) (µA/cm(^2))</th>
<th>Ranges of E(_{pp}) (V)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1N H(_2)SO(_4)</td>
<td>79.4</td>
<td>50.1</td>
<td>110-1340</td>
</tr>
<tr>
<td>10(^{-7}) M</td>
<td>380</td>
<td>1.58</td>
<td>400-1396</td>
</tr>
<tr>
<td>10(^{-5}) M</td>
<td>380</td>
<td>1.85</td>
<td>380-1462</td>
</tr>
<tr>
<td>10(^{-3}) M</td>
<td>380</td>
<td>1.58</td>
<td>60-</td>
</tr>
</tbody>
</table>
lower and $i_c$ becomes higher on comparison with the dissolution in the absence of the TMAB. Hence it can be concluded that TMAB is a good passivator. $H_2O$, $H_2SO_4$, $SO_4$ and OH ions present in the solution interfere with formation of resistance layer because of adsorption of TMAB on the metal surface with the help of already adsorbed anions present in the solution. It is commonly accepted that kinetic of iron anodic oxidation in acid depends on the adsorbed intermediates FeOH$_{ads}$. An iron anodic oxidation mechanism, which is valid in the presence of inhibitor, could be similar to that discussed by MacCafferty and Hackerman (1973).

$$\begin{align*}
  Fe + H_2 & \leftrightarrow Fe.H_2O_{ads} \quad (1) \\
  Fe.H_2O + X & \leftrightarrow FeOH^+ + H_2O \quad (2) \\
  Fe.H_2O_{ads} + X & \leftrightarrow FeX_{ads} + H_2O \quad (3) \\
  FeOH^+_{ads} & \leftrightarrow FeOH_{ads} + e^- \quad (4) \\
  FeX_{ads} & \leftrightarrow FeX^+_{ads} + e^- \quad (5) \\
  FeOH_{ads} + FeX^+_{ads} & \leftrightarrow FeX_{ads} + FeOH^+ \quad (6) \\
  FeOH^+ + H^+ & \leftrightarrow FeX^+ + H_2O \quad (7)
\end{align*}$$

where the species X are the inhibitor molecule, in our case. This mechanism shows that the anodic reaction kinetics is affected by two intermediates: one involving adsorbed hydroxyl (FeOH$_{ads}$) and the other involving the adsorbed inhibitor molecule (FeX$_{ads}$). The main effect of the petroleum content on the value of corrosion rate may account for the high effect exerted by the organic inhibitor molecule on the anodic reaction. The rate of anodic dissolution (step 4) depends on the product of step (2), but the two competitive steps (2) and (3) are based on the FeH$_2O_{ads}$. Displacements of the adsorbed water molecule by the species X, can have effect on the step (4). Every condition, such as molecular shape or localized partial charges or by another view, strict hindrance of X molecule to the metal surface, can variegate the above competition. The influence of two solvents on each inhibitor molecule causes dispersion of inhibition ability. This dispersion may accelerate from the adsorption of the inhibitor molecule onto the different metal surface sites having different activation energies for chemisorptions (lattice planes, edges, kinks, dislocations, inhomogeneities, etc.). The passive film on mild steel is a hydrated oxide film having a gel like structure and protons present in the passive film are pulled out by the anodic polarizations. As per Pyun hydrogen is ionized to protons in the passive film due to anodic character of the passive film. As hydrogen is charged into passive film, the average concentration of protons increases the amount of hydrogen containing species such as $H_2O$ and OH within the passive films and with the increase of potential beyond passive ranges the passive films brake to give trans-passive region with evolution of oxygen in this range.

It may be noted that TMAB form a passive layer or resistive; layer with the help of already adsorbed anions present in the solutions. The cooperative adsorption leads to formation of the complexes of the types (M-In-OH)$_{ads}$, (M-OH-In)$_{ads}$ or (M-In-A)$_{ads}$, where A is any of the already adsorbed anions on the metal surface which gives large potential regions.

**Scanning electron microscopy (SEM)**

In the present work SEM was operated at 10 KV, since the secondary electrons emanate from a depth of about 10 Å or less from corroded surface. Figure 7 (A) shows...
the micrographs by SEM of the unexposed surface of the uncorroded surface of mild steel which is found to be absolutely free from any noticeable defect such as cracks and pits. Polishing scratches are also visible. Figure 8 (B, C, and D) show micrographs by SEM of mild steel specimens exposed in 1 N H₂SO₄, 10⁻⁷ M TMAB, 10⁻⁵ M TMAB, and 10⁻³ M TMAB solutions at a magnification of 2000. Uniform corrosion was observed. Flakes are seen which show corrosion products are observed in the micrographs. The electron micrographs reveal that, the surface was strongly damaged owing to corrosion in absence of the inhibitor but in the presence of inhibitor there is a much less damage on the surface. This is attributed to the formation of a good protective film on the carbon steel surface. It is quite apparent from the micrographs the uniform products like metal hydrides and oxide are also visible. On comparison TMAB act as good inhibitor at higher concentration. The extent of inhibitor is reduced considerably in the presence of lesser concentration of TMAB.

Infra-red spectroscopy

Silica gel was specially chosen because finally divided silica gels crystals have larger surface area for adsorption of organic molecules. Thus sufficient adsorbed material can be included in the sample to yield a spectrum of moderate intensity. Further with such finally divided materials radiations loses by scattering are not large especially at frequencies below 3000 cm⁻¹. The various peaks in the spectra of pure TMAB and TMAB adsorbed over silica gel are given in the Figures 8 and 9. The peaks have been tabulated in the Table 3. On comparing the spectra of pure silica with the spectra of adsorbed TMAB molecule over silica, it is observed that certain peaks have been disappeared completely and some have shifted to higher frequency region proving that some adsorption has been taken place over the solid surface. The spectra of TMAB indicate that the disappearance of C-C, C-O and N-H bands completely while that N-C shifts to higher frequencies. This again proves the adsorption over solid surface through C-C, C-O and N-H groups.

Conclusions

1. Tetra methyl ammonium bromide (TMAB) is very effective corrosion inhibitor of mild steel in acidic medium particularly at 298K and at higher concentrations.
2. The inhibition efficiency increases with the increase in concentrations, whereas its inhibition efficiencies almost
remaining same with increase temperature.
3. This is a mixed type inhibitor.
4. It mainly acts by blocking the active sites on the cathodic and anodic regions.

REFERENCES


