



Corrosion inhibition of mild steel by natural product compound

M.A. Ameer*, A.M. Fekry

Chemistry Department, Faculty of Science, Cairo University, Giza 12613, Egypt

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ABSTRACT

Corrosion inhibition of mild steel in H_3PO_4 containing chloride or sulphate ions have been studied using different electrochemical techniques. The corrosion and hydrogen evolution of mild steel alloy in 2 M H_3PO_4 acid containing 0.5 M NaCl can be effectively inhibited by addition of natural product compound, Thymol (IPMP), of different concentrations. However, in 2 M H_3PO_4 containing 0.5 M Na_2SO_4 corrosion cannot be effectively inhibited. The results of electrochemical impedance spectroscopy (EIS) and potentiodynamic polarization measurements confirm the synergistic effects which describe the increase in the effectiveness of a corrosion inhibitor in the presence of Cl^- ions in the corrosive medium. At any temperature, an increase in it leads to an increase of the corrosion rate and hydrogen evolution on mild steel. Polarization and EIS results are in good agreement with each other. The obtained results were confirmed by surface examination using scanning electron microscope.

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1. Introduction

The use of inhibitors for the control of corrosion for metals and alloys which are in contact with aggressive environment is an accepted practice. Large numbers of organic compounds were studied to investigate their corrosion inhibition potential. All these studies reveal that organic compounds especially those with N, S and O showed significant inhibition efficiency. But, unfortunately most of these compounds are not only expensive but also toxic to living beings [1]. It is needless to point out the importance of cheap, safe inhibitors of corrosion. Plant extracts have become important as an environmentally acceptable, readily available and renewable source for wide range of inhibitors. They are the rich sources of ingredients which have very high inhibition efficiency. Acid solutions are widely used in many industrial processes [2]. Besides hydrochloric acid, phosphoric acid and sulphuric acid are regular aggressive solutions for acid cleaning and acid descaling due to their special chemical properties. The use of corrosion inhibitor is one of the most practical methods for protecting the corrosion of metal and decreasing hydrogen evolution. As a result, corrosion inhibitors for hydrochloric acid, phosphoric acid and sulphuric acid have attracted increasing attention due to their extended applications [1–5]. The protection of metals against corrosion by H_3PO_4 has been the subject of much study since it has been used in many industrial processes especially in fertilizer production

[6–11]. It is well known that halide ions improve the inhibition efficiency of organic molecules through synergism, but the data on the synergism between organic corrosion inhibitor and halide ions on metal corrosion in H_3PO_4 solution are meager. Corrosion inhibitors can be used to prevent metal from corrosion in corrosive media and decrease hydrogen evolution. Generally the studies on corrosion inhibitors are mainly focusing on three domains: one is to find appropriate inhibitor among the known compounds, and the next is to synthesize new compounds under the direction of theoretical calculation, and the last is searching the synergistic action among various compounds to expand the range of inhibitor applications. Many works have studied the influence of organic compounds containing nitrogen, sulphur, oxygen, and phosphorus on the corrosion of steel in acidic media. The results show that most organic compounds employed as corrosion inhibitors can adsorb on the metal surface through heteroatoms such as nitrogen [10], sulphur [12–15], oxygen [13], phosphorus [16] and multiple bonds etc. preventing steel from corrosion. Different concentrations of Thymol were investigated as corrosion inhibitors for mild steel in 2 M H_3PO_4 solution at different temperatures using AC impedance spectroscopy and polarization techniques. AC impedance results were interpreted using an equivalent circuit in which a constant phase element (CPE) was used in place of a double layer capacitance (C_{dl}) in order to give more accurate fit to the experimental results. The experimental results showed that the compound inhibits the corrosion to some extent. The study was carried out in the absence and presence of chloride or sulphate ions. The inhibition efficiency increased with concentration in the presence of Cl^- ions. The scheme of Thymol (IPMP) is as follows:

* Corresponding author. Tel.: +20 10 1675085.

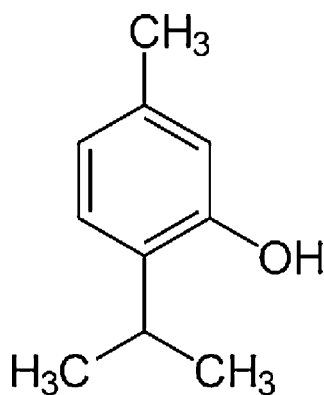
E-mail address: mameer_eg@yahoo.com (M.A. Ameer).

Table 1

The chemical compositions of mild steel (wt%).

C	Si	Mn	P	S	Cu	Cr	Mo	Ni	Sn	V
0.31	0.21	0.81	0.014	0.017	0.06	0.02	0.01	0.02	0.0	0.002

The balance is the wt% of Fe in the steel.



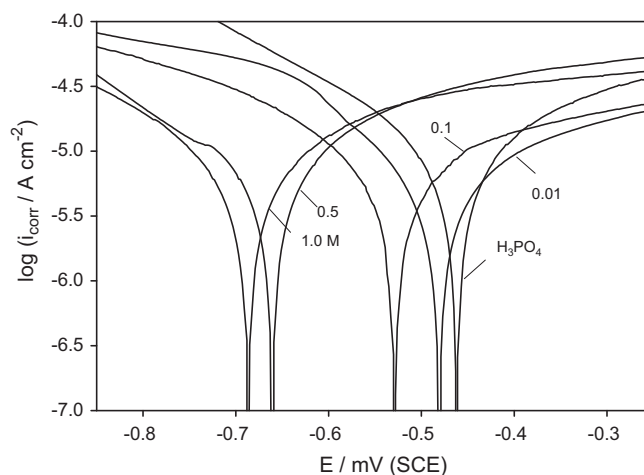
IPMP

IPMP is 2-isopropyl-5-methylphenol, (IPMP) (molar mass = 150.22 g mol⁻¹) which is a natural monoterpene phenol derivative of cymene, C₁₀H₁₄O, isomeric with carvacrol, found in oil of thyme, and extracted as a white crystalline substance of a pleasant aromatic odor and strong antiseptic properties.

The main aim of this research work is to study the electrochemical behavior of mild steel in different concentrations of naturally aerated NaCl or Na₂SO₄ in 2 M H₃PO₄ solutions at different temperatures using electrochemical techniques and surface examination. Also, the effect of adding IPMP as corrosion inhibitor for mild steel is studied.

2. Material and methods

The steel rod was tested in the present study with its cross-sectional area of 0.47 cm². The chemical composition of the steel, as given by the supplier, is listed in Table 1. The test aqueous solutions contained H₃PO₄, NaCl (Aldrich), Na₂SO₄ (BDH) and IPMP with different concentrations. Triple distilled water was used for preparing all solutions. In all measurements, mechanically polished

**Fig. 1.** Potentiodynamic polarization curves of steel in 2 M H₃PO₄ with different concentrations of SO₄²⁻.

electrode was used. Polishing was affected using successively finer grade of emery papers (600–1200 grade). Polarization and electrochemical impedance spectroscopy (EIS) measurements were carried out using the electrochemical workstation IM6e Zahner-electrik GmbH, Meßtechnik, Kronach, Germany. The excitation AC signal had amplitude of 10 mV peak to peak in a frequency domain from 0.1 Hz to 100 kHz. The EIS was recorded after reading a steady state open-circuit potential. The scanning was carried out at a rate of 30 mV min⁻¹ over the potential range from –1000 to 0 mV vs. saturated calomel electrode (SCE). Prior to the potential sweep, the electrode was left under open-circuit in the respective solution for ~1 h until a steady free corrosion potential was recorded. Corrosion current density, *i*_{corr}, which is equivalent to the corrosion rate, is given by the intersection of the Tafel lines extrapolation. Because of the presence of a degree of nonlinearity in the Tafel slope part of the obtained polarization curves, the Tafel constants were calculated as a slope of the points after *E*_{corr} by ±50 mV using a computer least-squares analysis. *i*_{corr} were determined by the intersection of the cathodic Tafel line with the open-circuit potential. To study the effect of temperature, the cell was immersed in water thermostat in the temperature range of 298–328 K. For surface examination, the electron microscope used is JEOL-JEM-100s type with magnification of 100×.

Table 2Equivalent circuit and corrosion parameters of mild steel after 1 h immersion for different concentrations of Na₂SO₄, NaCl or 0.5 M NaCl containing different concentrations of IPMP, in 2.0 M H₃PO₄ at 298 K.

[conc.] (M)	<i>R</i> ₀ (Ω cm ²)	<i>R</i> ₁ (kΩ cm ²)	<i>Q</i> ₁ (Ω ⁻¹ s ^α cm ⁻²)	<i>α</i> ₁	<i>R</i> ₂ (kΩ cm ²)	<i>Q</i> ₂ (Ω ⁻¹ s ^α cm ⁻²)	<i>α</i> ₂	<i>i</i> _{corr} (μA cm ⁻²)	<i>E</i> _{corr} (V)
[H ₃ PO ₄]									
2.0	6.6	3.11	6.5	0.93	0.341	17.2	0.99	0.23	–0.46
[NaCl]									
0.01	3.6	16.83	35.0	0.83	0.164	278.8	0.99	0.35	–0.65
0.10	3.0	3.84	100.4	0.83	0.097	342.5	0.84	2.06	–0.72
0.50	3.1	3.29	480.8	0.89	0.090	952.2	0.83	2.75	–0.81
1.00	2.6	20.63	36.5	0.91	0.276	38.2	0.81	0.27	–0.49
[Na ₂ SO ₄]									
0.01	11.2	16.11	18.0	0.81	0.170	152.2	0.96	0.28	–0.48
0.10	1.8	15.23	27.3	0.86	0.123	321.1	0.99	0.41	–0.53
0.50	1.2	9.09	33.5	0.84	0.098	322.4	0.99	0.56	–0.66
1.00	1.2	5.75	34.1	0.84	0.063	370.1	0.96	0.90	–0.69
[IPMP] (mM) in presence of 2 M H ₃ PO ₄ + 0.5 M Cl ⁻									
0.1	15.3	9.49	115.1	0.89	2.045	515.1	0.97	1.09	–0.78
0.1	8.6	9.30	117.1	0.89	0.723	541.3	0.96	0.852	–0.76
5.0	5.5	21.50	119.6	0.89	5.114	552.4	0.98	0.475	–0.74
10.0	3.3	29.80	214.2	0.95	8.608	570.1	0.99	0.264	–0.69

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