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ORIGINAL ARTICLE

Corrosion inhibition of aluminum in 1 M H_3PO_4 solutions by ethanolamines

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Abstract The inhibitive effect of the investigated compounds (ethanolamine (I), diethanolamine (II) and triethanolamine (III)) on the corrosion behavior of aluminum in 1 M H_3PO_4 solution using weight loss, galvanostatic polarization and quantum chemical calculation methods was studied. The inhibition efficiency was found to depend on type and concentration of the additives and also on temperature. The effect of addition of halide ions to various concentrations of these compounds has also been studied. The apparent activation energy (E_a) and other thermodynamic parameters for the corrosion process have also been calculated and discussed. The galvanostatic polarization data indicated that these inhibitors were of mixed-type. The slopes of the cathodic and anodic Tafel lines (β_c and β_a) are approximately constant and independent of the inhibitor concentration. The adsorption of these compounds on aluminum surface has been found to obey the Freundlich adsorption isotherm. Some quantum chemical parameters and Mulliken charge densities for investigated compounds were calculated by the AM1 semi-empirical method to provide further insight into the mechanism of inhibition of the corrosion process. The theoretical results are then compared with experimental data.

1. Introduction

Aluminum has a remarkable economic and industrial importance owing to its low cost, light weight (d = 2.71 g/cm^3), and high thermal and electrical conductivity. Most of well-known acid inhibitors are organic compounds containing nitrogen, sulphur and oxygen (Fox and Bradley, 1980; El Sayed, 1992; Schmitt, 1984; Sykes, 1990; Chatterjee et al., 1991; Rengamani et al., 1994; Gomma and Wahdan, 1994; Ajmal et al., 1994). Aluminum is used in hydrogen peroxide (H.T.P) processing and storage equipment partly because of its high corrosion resistance but also because it does not cause degradation of the peroxide. Aluminum has good resistance to petroleum products, and an Al–2Mg alloy is used for

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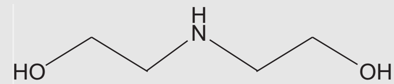
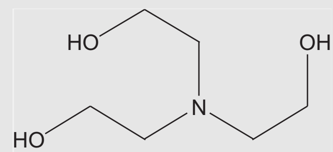
Table 1 Chemical and molecular structures of ethanolamines.

Inhibitor	Name	Structure	Mol. Wt.
(I)	Ethanolamine		61.083
(II)	Diethanolamine		105.136
(III)	Triethanolamine		149.189

tank-heating coils in crude-oil carriers. Aluminum is also used in the petroleum industry for sheathing for towers, heat exchangers, transport and storage tanks, and scrubbers. Most of well-known acid inhibitors are organic compounds containing N, S and O atoms (Aytac et al., 2005; Salghi et al., 2004; Muller, 2004; Foad El-Sherbini et al., 2003; Metroke et al., 2004; McCafferty, 2003; Bereket and Pinarba, 2004; Oguzie, 2007; Yurt et al., 2006; Cook and Taylor, 2000; Garrigues et al., 1996; Fouda et al., 1986; Metikos-Hukovic et al., 1998, 1995, 1994a,b; Abdel-Aal et al., 1990). The majority are nitrogen-containing compounds. Many N-heterocyclic compounds with polar groups and or π-electrons are efficient corrosion inhibitors in acidic solutions. Organic molecules of this type can adsorb on the metal surface and form a bond between the N electron pair and/or the π-electron cloud and the metal, thereby reducing the corrosion in acidic solution.

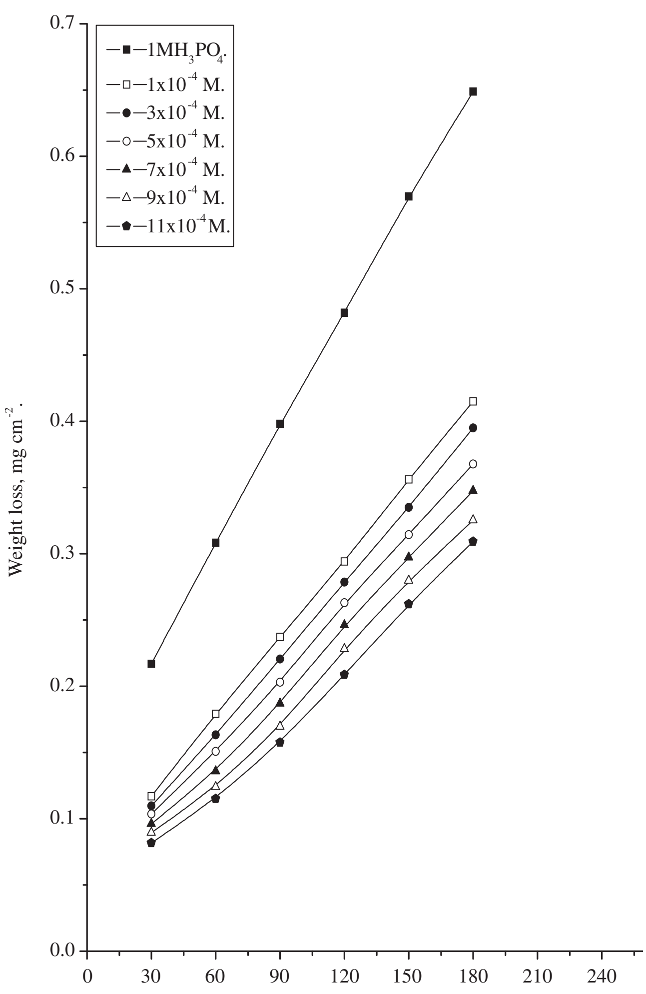


Figure 1 Weight loss–time curves for the corrosion of aluminum in 1 M H3PO$_4$ in the absence and presence of different concentrations of compound (III) at 30 °C.

Quantum-chemical calculations have been widely used to study reaction mechanism. They have also proved to be a very important tool for studying corrosion inhibition mechanism (Obot and Obi-Egbedi, 2008a,b; Obot et al., 2009).

The present study aimed to investigate the efficiency of ethanolamines as corrosion inhibitors for aluminum in 1 M H_3PO_4 solutions at different temperatures and in presence of halide ions by different techniques.

2. Experimental techniques

2.1. Materials

Chemical composition of aluminum is (wt.%): Si 0.4830, Fe 0.1799, Cu 0.0008, Mn 0.0083%, Mg 0.4051, Zn 0.0165, Ti 0.0145, Cr 0.0040, Ni 0.0047, Al the remainder.

Table 2 Values of % inhibition efficiencies of inhibitors for the corrosion of aluminum in 1 M H_3PO_4 from weight loss measurements at different concentrations at 30 °C.

Concentration (M)	% Inhibition efficiency (% IE)		
	(I)	(II)	(III)
1×10^{-4}	13.0	28.6	40.1
3×10^{-4}	17.6	31.5	43.2
5×10^{-4}	22.3	31.8	44.6
7×10^{-4}	27.1	36.5	48.8
9×10^{-4}	32.3	41.6	52.8
11×10^{-4}	37.2	45.6	56.8