ARTICLE IN PRESS

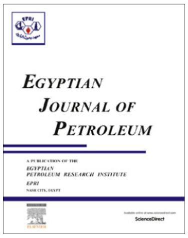
Egyptian Journal of Petroleum (2016) **xxx**, xxx–xxx

HOSTED BY

Egyptian Petroleum Research Institute

Egyptian Journal of Petroleum

www.elsevier.com/locate/egyjp
www.sciencedirect.com



FULL LENGTH ARTICLE

Tricine [*N-(Tri(hydroxymethyl)methyl)glycine*] – A novel green inhibitor for the corrosion inhibition of zinc in neutral aerated sodium chloride solution

H. Nady *

Chemistry Department, Faculty of Science, Fayoum University, Fayoum, Egypt
Chemistry Department, College of Science and Arts in Qurayate, Al Jouf University, 2014, Saudi Arabia

Received 28 September 2015; revised 21 January 2016; accepted 3 February 2016

KEYWORDS

Corrosion inhibition;
Zinc;
Sodium chloride;
Potentiodynamic polarization;
EIS;
Tricine

Abstract Corrosion and corrosion inhibition of zinc electrode were investigated in neutral chloride solution using electrochemical techniques. Increasing chloride concentration leads to an increase in the corrosion rate of the electrode. The corrosion inhibition characteristics of Tricine (*N-(Tri(hydroxymethyl)methyl)glycine*) have been studied as an eco-friendly green inhibitor for corrosion control of zinc electrode in 0.5 M NaCl corrosive solution using potentiodynamic polarization and electrochemical impedance spectroscopy (EIS) techniques. Tricine provided an inhibition efficiency of 86.7% at 3 mM which increased to about 90% with 10 mM. The corrosion inhibition mechanism of the protective layers is also discussed. The adsorption of Tricine on metal surface obeyed Langmuir's adsorption isotherm. Polarization measurements showed that the Tricine acted as anodic inhibitor in NaCl solution and the inhibitor molecules followed physical adsorption on the surface of zinc.

1. Introduction

Zinc is one of the most widely used metals. Its most important commercial application is in the corrosion protection of steel, for which it is extensively employed to coat or galvanize ferrous metallic products. However, it ranks fourth among the metals in worldwide production and consumption [1]. The uses of zinc can be divided into six major categories: (i) coatings; (ii) casting alloys; (iii) alloying element in brass and other alloys; (iv) wrought zinc alloys; (v) zinc oxide; and (vi) zinc chemicals [2]. The most important application of zinc is a coating for steel corrosion protection. In addition, zinc is an important component in paints, cosmetics, pharmaceuticals, storage batteries, electrical equipment and an endless list of other capital applications [3–5]. As a result of its importance, the zinc corrosion and electrochemistry has been studied extensively [6–10] and reviewed thoroughly up to year 1996 by Zhang [2]. Moreover, many investigations have been

---

* Address: Chemistry Department, Faculty of Science, Fayoum University, Fayoum, Egypt. Tel.: +20 1064941359, +966 535589807.
E-mail addresses: nhm00@fayoum.edu.eg, hashem_nady@yahoo.com.

Peer review under responsibility of Egyptian Petroleum Research Institute.

http://dx.doi.org/10.1016/j.ejpe.2016.02.004
1110-0621

Please cite this article in press as: H. Nady, Tricine [*N-(Tri(hydroxymethyl)methyl)glycine*] – A novel green inhibitor for the corrosion inhibition of zinc in neutral aerated sodium chloride solution, Egypt. J. Petrol. (2016), http://dx.doi.org/10.1016/j.ejpe.2016.02.004

conducted to determine the kinetic and thermodynamic characteristics of zinc electrode system. Extensive bibliographies of this work appear in the literatures [8,11].

The anodic dissolution of zinc has been investigated in different electrolyte media. Some examples are: in potassium hydroxide solutions [12–15], in potassium hydroxide in the presence of sodium metasilicate [16], in potassium hydroxide in the presence of carbonate ions [17], in potassium hydroxide in the presence of ZnO [18], in sodium hydroxide solutions [19], in sodium hydroxide in the presence of sodium silicate and sodium tetraborate [20], in sodium hydroxide in the presence of sulfur containing ions such as Na_2SO_4, Na_2SO_3, Na_2S, $Na_2S_2O_3$ or NH_4SCN [21], in saturated zinc sulfate solution [22], in aerated sodium sulfate solutions [23], in NH_4Cl and/or $NH_4Cl/ZnCl_2$ solutions [24,25], in $NH_4Cl + NiCl_2$ and $NH_4Cl + NiCl_2 + ZnCl_2$ electrolytes [26], in potassium nitrate solution [27], and in aqueous salt solutions such as Cl^-, Br^-, I^-, Ac^-, SO_4^{2-} and NO^{3-} [28]. The corrosion and electrochemical studies of zinc dissolution in sodium chloride solutions has been investigated in the literatures [29,30]. For $pH > 12$, a passive layer composed of zinc hydroxide and/or zinc oxide is formed on the surface of the zinc sample [30]. In an aerated acidic NaCl solution, the complexity of the layer formed on zinc sample exposed to NaCl media makes the corrosion mechanism of zinc difficult to be understood. It forms a complex layer composed from zinc oxide, zinc hydroxide and zinc hydroxide chloride or simonkolleite; $Zn_5(OH)_8Cl_2{\cdot}2H_2O$. The zinc hydroxide chloride and zinc oxide are the dominant corrosion products [31]. In ambient CO_2 levels, zinc hydroxide carbonate or hydrozincite; $(Zn_5(OH)_6(CO_3)_2{\cdot}H_2O$ were additionally observed [32], with the major compounds being zinc hydroxide chloride and zinc hydroxide carbonate [33].

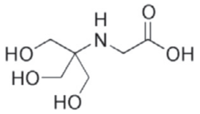
The corrosion of zinc in the atmosphere has been addressed in field exposures as well as in laboratory investigations in controlled environments [34–36]. Besides the strong humidity dependence it is generally agreed that deposition of sulfur dioxide and chloride as well as the pH in rain are major factors determining the corrosion rate of zinc. The influence of NaCl on the atmospheric corrosion of zinc at 22 °C has been investigated in a previous study by Falk et al. [36]. One of the main accelerators of the corrosion of zinc in the atmosphere is soluble chloride, e.g., NaCl. Sodium chloride attracts water vapor from humid air to form a solution. The presence of a surface electrolyte greatly increases the corrosion rate and also affects the composition of the corrosion products. However, zinc is a kind of active metal and can be easily corroded in acid medium. The searching of an effective inhibitor to zinc is significant for the protection during zinc corrosion [37]. The effect of organic inhibitors [38] such as, sodium benzoate (NaBz) and Sodium N-dodecanoylsarcosinate (NaDS), S-Octyl-3-thiopropionate (NaOTP), 8-quinolinol (8-QOH) and 1,2,3-benzotriazole (BTAH) on corrosion of zinc in aerated 0.5 M NaCl solution was investigated by potentiodynamic polarization measurements. Cerium (III) chloride $CeCl_3$ and sodium octylthiopropionate $C_8H_{17}S(CH_2)_2COONa$ (NaOTP) [39] are effective inhibitors for zinc corrosion in 0.5 M NaCl. The inhibition effects of chromate-free [40], environmentally acceptable anion inhibitors were examined on corrosion of zinc in an aerated 0.5 M NaCl solution by polarization measurements, Sodium silicate $Na_2Si_2O_5$ and phosphate Na_3PO_4 were remarkably effective on zinc corrosion. Recently, Plant extracts have again become important as an environmentally acceptable, [41,42] readily available and renewable source for a wide range of needed inhibitors. The aqueous extract of the leaves of henna (lawsonia) [43] was tested as corrosion inhibitor of zinc in neutral solutions, using the polarization technique. It was found that the extract acts as a good corrosion inhibitor in the tested media.

In this paper we are introducing eco-friendly amino acid derivative, namely Tricine (*N*-(*Tri*(*hydroxymethyl*)*methyl*)*glycine*) inhibitor to control the corrosion of Zinc in a stagnant naturally aerated neutral NaCl solution. The corrosion rate and corrosion inhibition efficiency were calculated using different concentrations of the inhibitor. In this respect, conventional electrochemical techniques such as potentiodynamic polarization and electrochemical impedance spectroscopy, EIS, were used. The experimental impedance data were fitted to theoretical values according to equivalent circuit models enables understanding the corrosion inhibition mechanism and the suggestion of the suitable model that explains the electrochemical behavior of the metal/solution interface under different conditions.

2. Experimental

The inhibitor molecule used in this paper was purchased from Sigma–Aldrich and have the structure presented in Fig. 1. As can be seen, they have different active groups, which can act as adsorption centers. The working electrodes were made as massive rods from commercial grade Zn electrode. The electrodes were mounted into glass tubes by two-component epoxy resin leaving a surface area of 0.2 cm^2 to contact the corrosive medium. The electrochemical cell was a three-electrode all-glass cell, with a platinum counter electrode and saturated calomel reference electrode. Before each experiment, the working electrode was mechanically polished using successive grades of emery papers down to 2000 grit, rubbed with a smooth polishing cloth, then washed thoroughly with triple distilled water and transferred quickly to the electrochemical cell. The measurements were carried out in aqueous solutions, where analytical grade reagents and triply distilled water were always used. The effect of chloride ion concentration was studied in solutions containing various amounts of NaCl (0.1–0.5 M). The corrosion inhibition by Tricine, was carried out in solutions containing 0.5 M NaCl.

The polarization experiments and electrochemical impedance spectroscopic investigations, EIS, were performed using a VoltalabPGZ 100 “*All-in-one*” potentiostat/Galvanostat system. The potentials were measured against and referred to the saturated calomel electrode, SCE (0.245 V vs. NHE). To achieve quasi-stationary condition, the polarization experiments were carried out using a scan rate of $10\,mV\,s^{-1}$. Actually, a scan rate between 1 and 10 mV did not show remarkable difference in the polarization curves. The



Tricine(N-(Tri(hydroxymethyl)methyl)glycine)

Figure 1 Chemical structure of inhibitor.

Please cite this article in press as: H. Nady, Tricine [*N*-(*Tri*(*hydroxymethyl*)*methyl*)*glycine*] – A novel green inhibitor for the corrosion inhibition of zinc in neutral aerated sodium chloride solution, Egypt. J. Petrol. (2016), http://dx.doi.org/10.1016/j.ejpe.2016.02.004