Journal of Industrial and Engineering Chemistry 22 (2015) 384–389

Contents lists available at ScienceDirect

Journal of Industrial and Engineering Chemistry

journal homepage: www.elsevier.com/locate/jiec

Egyptian licorice extract as a green corrosion inhibitor for copper in hydrochloric acid solution

M.A. Deyab *

Egyptian Petroleum Research Institute (EPRI), Nasr City, Cairo, Egypt

ARTICLE INFO

Article history:
Received 23 April 2014
Received in revised form 17 July 2014
Accepted 20 July 2014
Available online 25 July 2014

Keywords:
Acid solutions
Copper
EIS
Polarization
Licorice extract

ABSTRACT

The inhibition of copper corrosion in 0.1 M HCl by Egyptian licorice extract was investigated by dc polarization, ac impedance techniques. A significant decrease in the corrosion rate of copper in 0.1 M HCl was observed in the presence of licorice extract. The corrosion rate was found to depend on the concentration of licorice extract, temperature and extraction solvent composition. The adsorption of licorice extract on copper surface obeys Temkin isotherm. Polarization data indicated that the licorice extract acts as a mixed-type inhibitor. The values of activation energy for copper corrosion and various thermodynamic parameters were calculated and discussed.

Introduction

Copper is an important material for use in many applications, such as production of wire, sheets, and pipes. Furthermore, copper is used as a construction metal in the cooling systems of nuclear installations, automobile industry and oil refineries. Copper is resistant toward the influence of atmosphere and many chemicals, however, it is known that in aggressive media it is susceptible to corrosion. Diluted hydrochloric acid is normally used to clean copper surface. The use of inhibitors in such conditions is necessary added to avoid the action of this acid on the copper [1]. Employment of inorganic inhibitors [2] or organic compounds and their derivatives such as azoles [3,4], amines [5], amino acids [6] is one of the most significant strategies for protecting copper against corrosion.

Most of the copper corrosion inhibitors are synthetic chemicals, expensive, and very hazardous to environments. Therefore, the research in the field of eco-friendly corrosion inhibitors has been addressed toward the goal of using cheap and non-toxic inhibitors.

The objective of the present investigation is to explore the inhibitory properties of Egyptian licorice extract as a cheap, raw and non-toxic corrosion inhibitor on copper corrosion in hydrochloric acid. The data regarding the use of licorice extract as a corrosion inhibitor appears to be very poor.

Licorice, the root of the glycyrrhiza plant species, has been used medicinally for more than 4000 years [7]. Glycyrrhizic acid (Fig. 1A) and Glabridin (Fig. 1B) are the most active constituent of licorice [8]. Kyung Ho Row et al. reported the simple and convenient method for the extraction of glycyrrhizic acid and glabridin from licorice [9]. Mixture of ethanol/water and extraction time 60 min under 50 °C is the optimum condition to extract glycyrrhizic acid and glabridin from licorice. The extracted amounts are 2.39 and 0.92 mg/g, respectively.

In the present work, the corrosion inhibition efficiency of Egyptian licorice extract (with different compositions of ethanol/water) on copper in hydrochloric acid solution was investigated utilizing potentiodynamic polarization and electrochemical Impedance techniques (EIS).

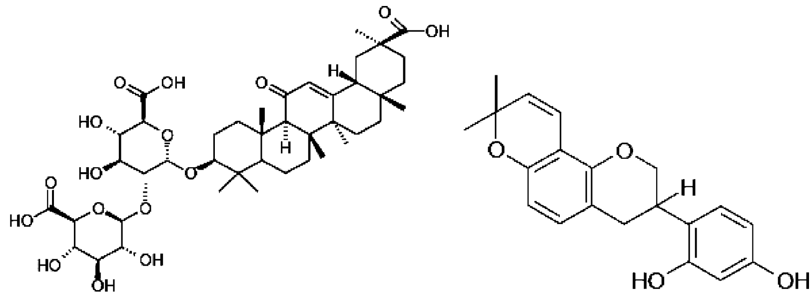
Experimental method

Inhibitor

Egyptian licorice powder was purchased from a local market. 100 ml different compositions of ethanol/water (90:10, 70:30, 50:50, 30:70, 10:90 v/v) were mixed with 1.0 g licorice for 60 min at 50 °C [9]. Table 1 shows the extracted amounts of glycyrrhizic acid and glabridin with different compositions of ethanol/water using high-performance liquid chromatography (HPLC) analysis (MODEL: 1100, Agilent, ITALY). Fig. 2 displays HPLC chromatogram for extracted amounts of glycyrrhizic acid and glabridin with different compositions of ethanol/water (EXT2 as an example).

* Tel.: +20 1006137150; fax: +20 2 22747433.
E-mail address: hamadadeiab@yahoo.com

http://dx.doi.org/10.1016/j.jiec.2014.07.036
1226-086X/



(A) (B)

Fig. 1. Molecular structures of glycyrrhizic acid (A) and glabridin (B).

Material and medium

The copper used for probes was 99.98% purity. Prior to each experiment, the copper electrodes were first briefly abraded with different emery papers up to 1200 grade, cleaned with acetone, washed with doubly distilled water and finally dried. The working copper specimen is covered in Teflon so that its cross sectional area 0.542 cm^2 was in contact with the solution. Experiments were carried out at different temperatures using a calibrated thermostat. Analar grade hydrochloric acid (Merck) and doubly distilled water were used to prepare 0.1 M acid solutions for all experiments.

Electrochemical measurements

For the electrochemical measurement, the arrangement used was a conventional three-electrode Pyrex glass cell with a platinum counter electrode and a saturated calomel electrode (SCE) as reference. The potentiodynamic polarization experiments were carried out using potentiostat/galvanostat (EG&G model 273) with M352 corrosion software. The potentiodynamic current–potential curves were swept from −0.25 to +0.25 V (SCE) with respect to OCP at a scan rate of 1.0 mV/s.

For electrochemical impedance spectroscopy measurements, the experiments were performed at open circuit potential with voltage amplitude 10 mV in the frequency range of 1 Hz to 30 kHz. EIS Measurements were performed using Gill AC Serial no. 947 (ACM instruments) with Sequencer software. EIS measurements were initiated about 30 min after the working electrode was immersed in solution to stabilize the steady state potential.

Results and discussion

Potentiodynamic polarization measurements

Effect of licorice extracts concentration

Fig. 3 shows a series of potentiodynamic polarization curves of copper electrode in aerated 0.1 M HCl solution at 298 K in the absence and presence of different concentrations of licorice extract EXT2 as an example. Analogous potentiodynamic polarization curves were obtained for other licorice extracts (EXT1, EXT3, EXT4 and EXT5) over the same concentration range. It is clearly observed that there is an increase in the solution color (light brown) with increasing concentration licorice extracts.

Various corrosion parameters such as corrosion current density (j_{corr}) and corrosion potential (E_{corr}) are given in Table 2. Analysis of the results showed that the presence of licorice extract reduces the corrosion current density j_{corr} and the suppression in current increases as the licorice extract concentration increases. The decrease in corrosion current density j_{corr} values with increasing licorice extract concentration was associated with shift of corrosion potential E_{corr} to more positive potential.

Table 1
The amount of the extracted materials form Egyptian licorice root with different compositions of ethanol/water.

Compositions of ethanol/water (v/v)	Glycyrrhizic acid (mg/g)	Glabridin (mg/g)	Abbreviation
(10/90)	2.25	0.79	EXT1
(30/70)	2.93	0.88	EXT2
(50/50)	1.05	0.89	EXT3
(70/30)	0.94	0.89	EXT4
(90/10)	0.75	0.90	EXT5

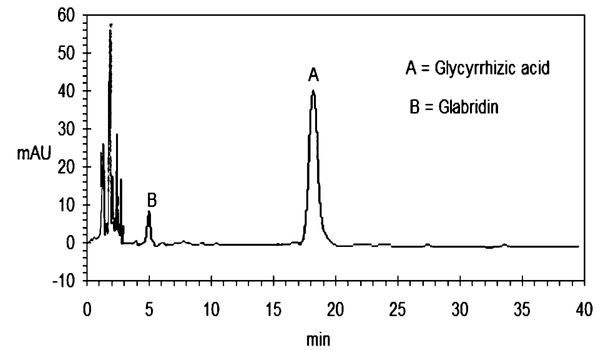


Fig. 2. Displays HPLC chromatogram for extracted amounts of glycyrrhizic acid and glabridin with different compositions of ethanol/water (EXT2).

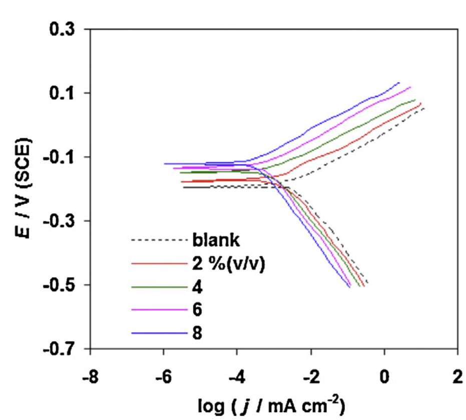


Fig. 3. Potentiodynamic polarization curves for copper in 0.1 M HCl solution at 298 K in the absence and presence of different concentrations of licorice extract EXT2.