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Amino acid and cinnamaldehyde conjugated Schiff bases as proficient corrosion inhibitors for mild steel in 1 M HCl at higher temperature and prolonged exposure: Detailed electrochemical, adsorption and theoretical study

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ABSTRACT

Three Schiff bases composing of cinnamaldehyde and three different amino acids, namely glycine (CGSB), histidine (CHSB) and tryptophan (CTSB) have been synthesized and investigated for their anti-corrosion propensity on mild steel in 1 M HCl. Both gravimetric and electrochemical experimentation establish the CTSB as superior inhibitor, while the CGSB as the least effective among the three. Effectiveness of the Schiff bases is tested upto 60 °C for an exposure of 6 h in HCl. Effect of various exposure times, maximum being 96 h, is also investigated at a fixed temperature of 30 °C. All the three inhibitors impart appreciable extent of corrosion inhibition efficiency under these extreme conditions. Thermodynamic adsorption and kinetic parameters ascertain chemisorption of these mixed-type corrosion inhibitors on mild steel. Mode and extent of interaction between Schiff bases and mild steel are evaluated from quantum mechanical calculation and molecular dynamics simulation.

1. Introduction

Evaluating structure-reactivity correlation remains an important aspect towards devising new and efficient organic corrosion inhibitors for potential industrial application [1–7]. Organic inhibitors available from bio-resources, including essential oils, have gained special attention for their sustainable availability, relative low cost and, most importantly environmental benign characteristics; and are termed as so-called green corrosion inhibitors [8–17]. Cinnamaldehyde, a major constituent of cinnamon oil, is an aromatic compound with a benzene ring and an aldehyde group attached to an unsaturated C = C bond at both ends. This unique combination has bestowed cinnamaldehyde some special properties conducive for its application in medicine [18], as well as in material science as corrosion inhibitor in high acid concentration and at elevated temperature [19–21]. To enhance solubility of cinnamaldehyde in aqueous medium and also to improve its other biological activities, cinnamaldehyde is derivatized in many ways, including formation of Schiff bases [22]. Some of these Schiff bases have been tested for anti-corrosion effectiveness [23–25]. But, no report on the corrosion mitigation by cinnamaldehyde and an amino acid conjugated Schiff base is available till now. As a matter of fact, such study involving an amino acid Schiff base is very limited. Whatever literature suggests includes benzaldehyde and vanillin as the corresponding aldehyde precursor [26,27]. Amino acids, in general provide relatively lower degree of protection from corrosion for mild steel in aqueous HCl [28]. A Schiff base derived from an amino acid and cinnamaldehyde is expected to yield significant corrosion protection, as it will possess high electron density due to the aromatic moieties and heteroatoms like nitrogen, in addition to C = C and the imine (C = N) bonds. This should facilitate bonding with the metal through transfer a part of excess charge. To accomplish this, we have selected three different amino acids, namely glycine, histidine and tryptophan, which represents gradual enhancement of structural complexity. Corresponding Schiff bases are shown in Table 1 along with their IUPAC nomenclature.

The main objectives of this work are to elucidate the influence of structural factor, spatial orientation, and intrinsic molecular properties of these synthesized Schiff bases towards their adsorption characteristics on mild steel in aqueous HCl (1 M) and the extent of corrosion protection of the metal. In addition, how the conjugation of two naturally available products influence the corrosion inhibitory effect for prolonged time and at higher temperature will be interesting to investigate.

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