

OBTAINING CORROSION INHIBITORS CONTAINING NITROGEN AND PHOSPHORUS BASED ON AROMATIC COMPOUNDS

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Abstract:

This study focuses on the synthesis of novel corrosion inhibitors containing nitrogen and phosphorus based on aromatic compounds. The research investigates the chemical modification of aromatic amines and phosphates, their incorporation into inhibitor formulations, and their effectiveness in protecting metal surfaces from corrosion. Electrochemical studies and immersion tests revealed that the obtained inhibitors significantly reduce the corrosion rate in aggressive environments. The combination of nitrogen and phosphorus functional groups provides synergistic effects, enhancing adsorption on metal surfaces and forming stable protective films.

Keywords: Aromatic compounds, Corrosion inhibitors, Nitrogen, Phosphorus, Metal protection, Adsorption, Electrochemical analysis.

Introduction

Corrosion of metals is a persistent and widespread problem in industrial, marine, and urban environments. It not only causes significant economic losses but also compromises the structural integrity and safety of metal equipment, pipelines, and infrastructures. According to recent studies, the global cost of corrosion is estimated to be several billion dollars annually, emphasizing the urgent need for efficient and environmentally friendly corrosion protection strategies. Traditional methods, such as coatings, cathodic protection, and corrosion inhibitors,



have been extensively used. Among these, chemical corrosion inhibitors are particularly attractive due to their relatively low cost, ease of application, and ability to form protective films on metal surfaces. Aromatic compounds have attracted considerable attention in the development of corrosion inhibitors. Their planar conjugated structures facilitate adsorption on metal surfaces via π -electron interactions. Additionally, aromatic scaffolds can be chemically modified to incorporate functional groups that enhance metal binding and corrosion protection. Amines, amides, imines, and heterocyclic aromatic compounds are widely used due to their high electron density and strong adsorption capabilities. The incorporation of heteroatoms such as nitrogen and phosphorus into aromatic molecules further improves their corrosion inhibition efficiency. Nitrogen atoms act as electron donors, forming coordinate bonds with metal surfaces, while phosphorus groups can enhance the formation of stable protective layers and improve the barrier properties of coatings. The synergy between nitrogen and phosphorus functional groups is particularly effective. Nitrogen alone can facilitate adsorption, but in combination with phosphorus, the inhibition efficiency is significantly enhanced. Phosphorus not only increases the adsorption strength but also participates in the formation of metal-phosphate complexes, which are chemically stable and resistant to aggressive environments. This synergistic effect results in a dense, cohesive, and durable protective film on the metal surface, minimizing both uniform and localized corrosion. In addition to their chemical properties, aromatic nitrogen-phosphorus compounds offer flexibility in molecular design. Substituents on the aromatic ring can be tuned to adjust hydrophobicity, solubility, and electronic properties, allowing for the development of inhibitors suitable for different metals and environmental conditions. For instance, electron-donating substituents can increase adsorption efficiency, while bulky groups can provide steric protection against corrosive agents. The molecular versatility of aromatic compounds thus enables the design of inhibitors with tailored properties for specific industrial applications. Recent research has focused on the synthesis of novel aromatic nitrogen-phosphorus derivatives and their evaluation as corrosion inhibitors in acidic and saline media. Studies have demonstrated that these compounds can significantly reduce the corrosion rate of carbon steel, mild steel, and low-alloy steels. Electrochemical methods such as potentiodynamic polarization and electrochemical impedance spectroscopy (EIS) have been widely used to quantify inhibition efficiency and study the mechanism of action. Surface characterization techniques, including scanning electron microscopy (SEM) and energy-dispersive X-ray spectroscopy (EDX), provide additional insight into the protective films formed on metal surfaces. Despite significant progress, challenges remain in the development of effective nitrogen-phosphorus aromatic inhibitors. Issues such as environmental compatibility, long-term stability, and cost-effectiveness need to be addressed. Furthermore, understanding the adsorption mechanism at the molecular level, including the role of specific functional groups and the influence of environmental factors, is crucial for optimizing inhibitor performance. Research combining experimental studies with computational modeling can provide valuable insights into the design of next-generation inhibitors with enhanced efficiency and durability. The present study aims to address these



challenges by synthesizing new nitrogen-phosphorus aromatic corrosion inhibitors and evaluating their effectiveness in acidic and saline environments. The work focuses on the chemical modification of aromatic amines and phosphates, the formulation of inhibitor solutions, and the systematic investigation of their corrosion inhibition performance. By combining chemical synthesis, electrochemical evaluation, and surface characterization, this study provides a comprehensive understanding of the potential of nitrogen-phosphorus aromatic compounds as efficient corrosion inhibitors.

Materials and Methods.

1. Raw Materials

- Aromatic amines (aniline, p-toluidine, etc.)
- Phosphoric acid, phosphorus oxychloride
- Solvents: ethanol, acetone, distilled water
- Catalysts: triethylamine, pyridine
- Metal substrates: mild steel, low-alloy steel

2. Synthesis of Nitrogen-Phosphorus Aromatic Inhibitors

2.1. Phosphorylation of Aromatic Amines

Aromatic amines were reacted with phosphoric acid or phosphorus oxychloride at 60–80°C to form aromatic phosphoramidates. The reaction was monitored using FT-IR spectroscopy to confirm the introduction of phosphorus groups.

2.2. Formation of Nitrogen-Containing Derivatives

Aromatic compounds were further modified by forming amide or imine linkages, enhancing the nitrogen content and providing additional adsorption sites.

3. Preparation of Inhibitor Solutions

Synthesized inhibitors were dissolved in water or ethanol at concentrations of 0.1–1.0 wt% for testing.

4. Corrosion Testing

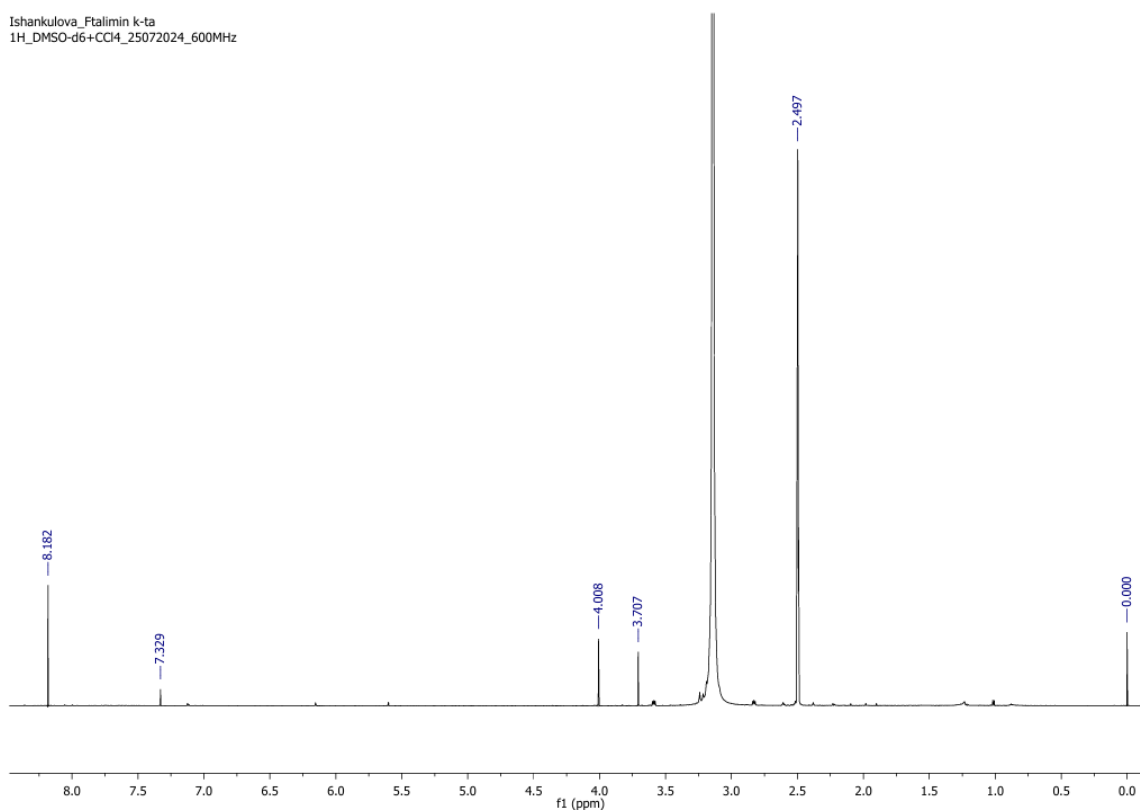
- Weight loss measurements: Metal coupons were immersed in 0.5 M HCl and 3.5% NaCl solutions for 24–168 hours.
- Electrochemical tests: Potentiodynamic polarization and electrochemical impedance spectroscopy (EIS) were used to assess corrosion inhibition efficiency.
- Surface analysis: SEM and EDX were employed to observe metal surface morphology and confirm inhibitor adsorption.



Results and Discussion

1. Structural Analysis. FT-IR spectra confirmed the presence of P=O, P–O–C, N–H, and C=N functional groups. The presence of both nitrogen and phosphorus groups promotes strong adsorption onto metal surfaces, forming protective films.
2. Corrosion Inhibition Efficiency. Weight loss tests indicated that the inhibitors reduced the corrosion rate by 70–90% depending on the concentration and type of metal substrate. Electrochemical studies showed increased polarization resistance and decreased corrosion current density.
3. Synergistic Effect of Nitrogen and Phosphorus. The combination of nitrogen and phosphorus groups provided a synergistic effect, enhancing adsorption and forming a dense, stable barrier. Nitrogen groups facilitate electron donation to the metal, while phosphorus groups improve binding strength and film stability.
4. Surface Morphology. SEM images showed that metal surfaces treated with nitrogen-phosphorus inhibitors were smoother and free of pitting compared to untreated samples. EDX analysis confirmed the presence of phosphorus and nitrogen elements on the metal surface, indicating strong inhibitor adsorption.

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1H_DMSO-d6+CCl4_25072024_600MHz



This is the FT-IR spectrum of phthalamic acid obtained on the basis of DMSO (dimethyl sulfoxide)



Conclusion

The study successfully synthesized nitrogen-phosphorus corrosion inhibitors based on aromatic compounds. These inhibitors exhibit high efficiency in protecting metal surfaces from corrosion in acidic and saline environments. The synergistic effect of nitrogen and phosphorus functional groups enhances adsorption, forming stable protective films. Aromatic compounds serve as effective scaffolds, allowing for chemical modification and improved corrosion inhibition. These findings suggest that nitrogen-phosphorus aromatic inhibitors are promising materials for industrial corrosion protection applications.

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