Effect of Inhibitor Addition, pH, and Current Density on the Corrosion Rate of Fe Metals

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Abstract
Corrosion significantly impacts public safety and the economy, causing substantial financial losses, infrastructure damage, and hazardous incidents across various industries. Researchers investigated the effects of pH, current density, and corrosion inhibitors (potassium chromate and potassium nitrate) on iron corrosion by measuring weight loss of iron samples immersed in sulfuric acid over time. The addition of inhibitors showed that KNO_3 was more effective in reducing the corrosion rate, with values of 4.992068, 3.744051, 2.736034, 1.728017, and 0.608008 mpy, compared to K_2CrO_4, which resulted in 9.728132, 7.296099, 5.472066, 3.648033, and 1.216017 mpy. Corrosion rate increased as pH decreased, with Fe showing corrosion at pH 6.21, 5.18, 4.26, 3.85, and 3.22. The relationship between current density and corrosion rate was found to be proportional, with voltage values of 1.31, 2.24, 3.16, 5.11, and 7.1 A/m². This study confirms that inhibitor type, acidity (pH), and current density significantly influence corrosion behavior, where increasing pH and current density can accelerate corrosion, and potassium nitrate (KNO_3) demonstrates superior corrosion inhibition compared to potassium chromate (K_2CrO_4).

Keywords: Corrosion; Current density; Inhibitors; Metals; pH

1. Introduction

Corrosion presents significant economic and safety concerns worldwide, affecting infrastructure, industries, and public safety. Corrosion-related losses range between 1% and 5% of a nation's Gross National Product (GNP) annually, with the United States alone experiencing direct costs of approximately $300 billion per year (3.2% of GDP), impacting critical infrastructure such as bridges, chemical plants, and waste treatment facilities[1]. The oil and gas industry is particularly affected, with corrosion costs exceeding $1.4 billion annually, including expenses for equipment maintenance, replacement, and lost productivity. Beyond economic concerns, corrosion also poses serious safety risks. Corrosion-related failures have led to major industrial accidents, including oil spills, gas leaks, and pipeline explosions. In the aviation industry, corrosion contributes to structural failures in aircraft, endangering flight safety. Similarly, in the chemical industry, corrosion can result in hazardous chemical leaks, fires, and explosions, posing severe environmental and human health risks[2].

Corrosion can occur due to several factors, namely environmental conditions such as acidity (pH), the presence of aggressive ions like chloride, and external factors such as the current density applied within electrochemical systems. In acidic environments, the high reactivity of hydrogen ions significantly accelerates the corrosion process in metals like iron (Fe) and copper (Cu), resulting in an increased rate of metal ion dissolution. Studies have demonstrated that increased acidity directly enhances the corrosion rate, especially in metals that are sensitive to pH changes[3]. In addition, the effect of current density in electrochemical systems can exacerbate corrosion by facilitating the release of metal ions from the surface. High current densities can destroy protective oxide layers on metals, accelerating the corrosion process and reducing the effectiveness of corrosion inhibitors[4]

To mitigate the issue of metal corrosion, the use of corrosion inhibitors has been a widely adopted and effective solution. Corrosion inhibitors work by forming a protective layer on the surface of metals, reducing the dissolution rate and shielding them from aggressive ions in the environment. Numerous studies have highlighted their ability to improve corrosion resistance, even under harsh environmental conditions. For example, the addition of a bis-thiophene Schiff base copper complex effectively reduced the corrosion current density of metal surfaces and formed a dense adsorption film that enhanced corrosion protection. In acidic environments, metals like iron (Fe) and copper (Cu) are especially prone to corrosion due to the aggressive nature of hydrogen ions, which accelerate the electrochemical reactions that lead to metal degradation. The application of current density further compounds this effect, highlighting the need for inhibitors that can perform under such challenging conditions. In one study, the use of environmentally friendly inhibitors, such as guar gum, showed promise in industrial applications by significantly reducing current density and corrosion rate, demonstrating up to 65% efficiency in specific conditions. This study aims to explore the combined effects of inhibitor addition, pH variations, and current density on the corrosion rate of Fe and Cu metals[5]. Iron-based materials are widely used in industries such as construction, petrochemical, power generation, and transportation. However, their susceptibility to corrosion, especially in acidic environments, causes significant economic losses. Sulfuric acid (H_2SO_4) is commonly present in industrial operations like petroleum refining, mineral processing, and battery manufacturing. Its strong acidity and oxidizing nature make it a highly aggressive medium for iron corrosion, making this environment relevant for experimental study and the development of mitigation strategies. By examining these parameters in controlled environments, the goal is to identify strategies to improve metal longevity, particularly in acidic and high-stress conditions. This approach aligns with ongoing advancements in corrosion science and the development of sustainable solutions for industrial applications

2. Method

2.1. Materials

The corrosion rate of Fe metal was observed under different conditions by varying the type of inhibitor, the volume of sulfuric acid (H_2SO_4), and the exposure time. Two inhibitors, potassium nitrate (KNO_3) and potassium chromate (K_2CrO_4), were used to assess their effectiveness in reducing corrosion. The experiment involved five different H_2SO_4 volumes: 0 mL, 10 mL, 20 mL, 30 mL, and 40 mL, to evaluate the influence of acid concentration on the corrosion process. Additionally, the corrosion behavior was monitored over seven different time intervals: 0, 94, 146, 192, 264, 312, and 360 hours. The Fe metal specimens were immersed in the respective solutions containing the inhibitors and varying acid volumes for the designated time periods.

2.2. Method

Ten iron samples were prepared to investigate how pH and current density affect corrosion, as well as the effectiveness of corrosion inhibitors. The Fe metal used in this study was low-carbon steel with the following composition (wt%): Fe (≥98%), C (0.08–0.12%), Mn (0.25–0.30%), with traces of Si, P, and S. Researchers began by sanding the metal surfaces to remove impurities and oxides, followed by cleaning with hydrochloric acid (HCl) to ensure surface cleanliness. They measured the length, width, and thickness of each sample and recorded their initial weights (W_0). After preparing a 1.5 N sulfuric acid (H_2SO_4) solution as the corrosive medium, they immersed five Fe samples in the solution with 3 mL of potassium chromate (K_2CrO_4) inhibitor (1.2 N) and the other five in the same solution with 3 mL of potassium nitrate (KNO_3) inhibitor (1.2 N). Potassium nitrate (KNO_3) and potassium chromate (K_2CrO_4) were selected as inhibitors due to their well-documented ability to reduce corrosion rates in acidic environments. Nitrate ions promote passivation by forming $Fe(NO_3)_2$ complexes, while chromate ions can form protective oxide layers through surface adsorption. The team conducted visual observations of the metal surfaces and solutions at intervals of 0, 94, 146, 192, 264, 312, and 360 hours. After six observations, they removed, dried, and weighed the samples to obtain final weights (W_t). Finally, they calculated the corrosion rate based on the metal's mass loss over time, considering both exposure duration and surface area. To clarify the experimental workflow, a schematic diagram of the procedure is provided in Figure 1.

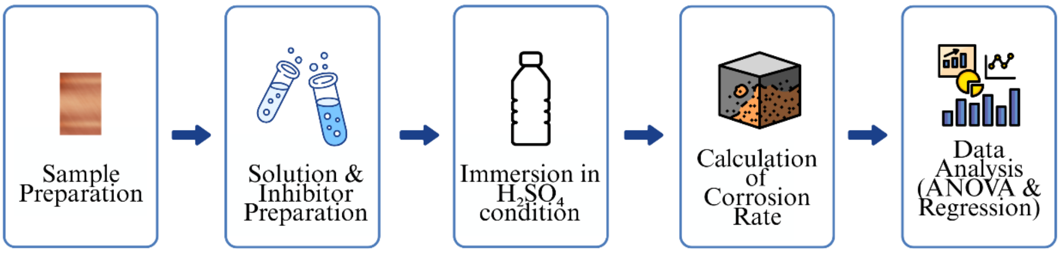


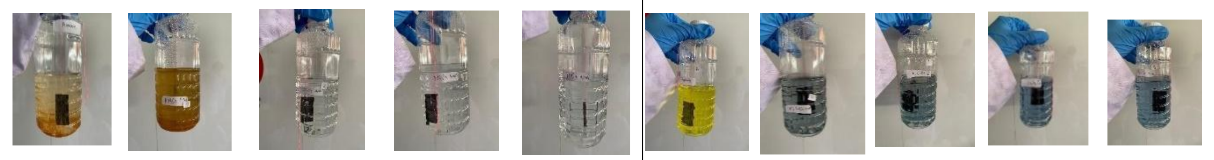
Figure 1. Schematic diagram of the experimental procedure

3. Results and Discussion

3.1. Result

In this study, color changes in the solution at various concentrations of sulfuric acid (H_2SO_4) and inhibitor (KNO_3 and K_2CrO_4) over exposure times of 0-360 hours. Observations were conducted under controlled laboratory conditions at room temperature, with consistent lighting and without external contamination. The observations of Fe metal in acidic conditions with KNO_3 and K_2CrO_4 inhibitors can be seen in Table 1.

Table 1. Observation of Fe Metal in Acidic Conditions with KNO_3 and K_2CrO_4 Inhibitors

Time (h)	**3 ml KNO_3 0,1N**					**3 ml K_2CrO_4 0,1N**				
	Sulphuric Acid (H_2SO_4) (ml)									
	0	**10**	**20**	**30**	**40**	**0**	**10**	**20**	**30**	**40**
1										
94										
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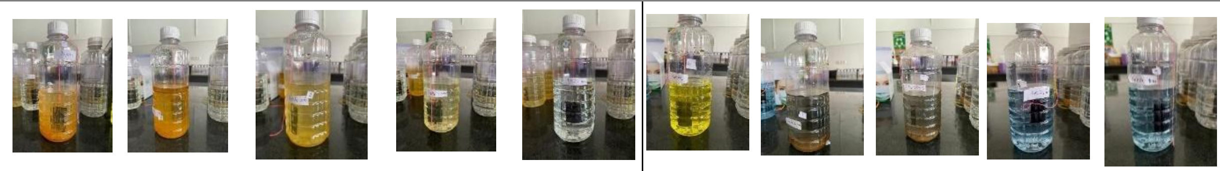
192										
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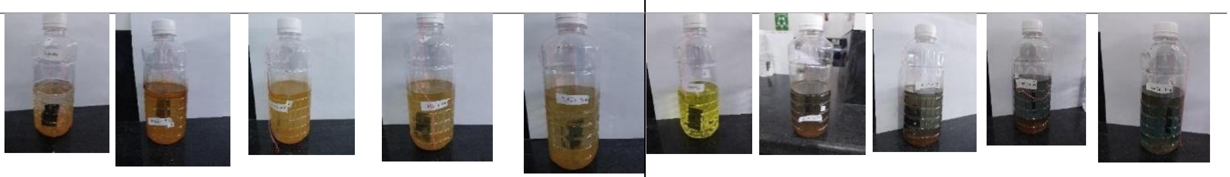
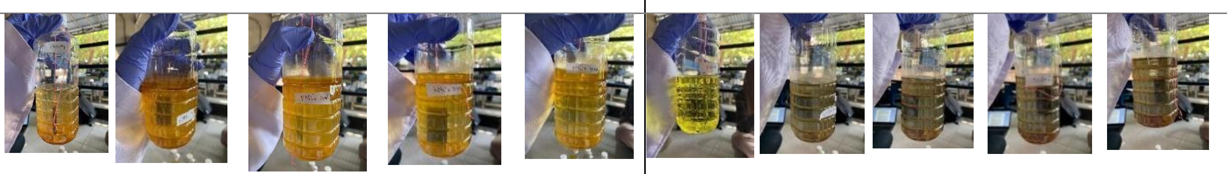
312										
360										

Table 1 presents the visual observations of Fe metal samples immersed in H_2SO_4 solution under different conditions with the addition of KNO_3 and K_2CrO_4 inhibitors over various exposure times (0–360 hours). The table records changes in the physical appearance of the solution and the metal surface, such as discoloration, turbidity, and formation of corrosion products. These qualitative observations served as preliminary indicators of corrosion progression before quantitative measurements were taken. Although this table does not provide numerical data for calculations, it establishes the basis for identifying time points at which significant corrosion occurred and confirms that environmental conditions were consistent throughout the experiment. After that, the observed metal samples were measured for their dimensions, including length (l), width (b), height (h), and weight (W), to assess changes before and after the experiment, as detailed in Table 2

Table 2. Dimensions of Fe Metal Before and After Observation

No	H_2SO_4 Variable	Before				After			
		l (cm)	b (cm)	h (cm)	W (g)	l (cm)	b (cm)	h (cm)	W (g)
1	0 + KNO_3	3,9	1,9	0,061	4,39	3,9	1,9	0,06	4,2
2	10 + KNO_3	4	1,9	0,06	4,37	3,9	1,9	0,06	4,33
3	20 + KNO_3	3,9	1,9	0,059	4,32	3,8	1,78	0,054	4,27
4	30 + KNO_3	4	1,9	0,062	4,37	4	1,9	0,05	4,3
5	40 + KNO_3	3,8	1,9	0,065	4,23	3,8	1,9	0,065	4,15
6	0 + K_2CrO_4	3,9	1,9	0,063	4,35	3,9	1,9	0,063	4,28
7	10 + K_2CrO_4	3,9	1,9	0,055	4,27	3,9	1,9	0,054	4,25
8	20 + K_2CrO_4	4	1,9	0,06	4,39	4	1,9	0,058	4,32
9	30 + K_2CrO_4	3,9	1,9	0,055	4,38	3,9	1,9	0,049	4,25
10	40 + K_2CrO_4	3,9	1,9	0,057	4,33	3,9	1,9	0,057	4,17

From the metal dimension data in Table 2, the surface area and weight difference were obtained, which were then used to calculate the corrosion rate, as presented in Table 3

Table 3. Corrosion Rate of Fe Metal

No	H_2SO_4 Variable	A ($inch^2$)	ΔW (mg)	pH	Current Density (A/m^2)	Corrosion Rate (mpy)
1	0 + KNO_3	2,917323	10	6,21	1,31	0,608008
2	10 + KNO_3	2,992126	40	3,48	4,3	2,371232
3	20 + KNO_3	2,917323	50	3,39	6,3	3,040041
4	30 + KNO_3	2,992126	70	3,31	6,5	4,149656
5	40 + KNO_3	2,84252	80	3,22	7,1	4,992068
6	0 + K_2CrO_4	2,917323	20	5,77	2,56	1,216017
7	10 + K_2CrO_4	2,917323	20	1,65	3,1	1,216017
8	20 + K_2CrO_4	2,992126	70	1,58	4	4,149656
9	30 + K_2CrO_4	2,917323	130	1,53	5,2	7,904107
10	40 + K_2CrO_4	2,917323	160	1,50	5,8	9,728132

3.2. *Effect of Inhibitor Addition on Corrosion Rate*

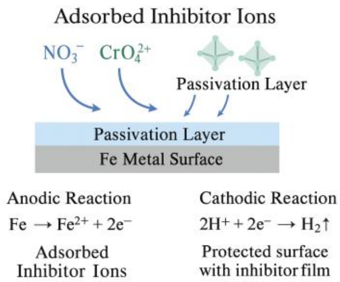


Figure 2. Schematic Reaction Mechanism

To clarify the protection mechanism, Figure 2 illustrates how inhibitor molecules interact with the Fe metal surface. Nitrate (NO_3^-) and chromate (CrO_4^{2-}) ions adsorb onto active sites of the metal, forming a passivation layer that hinders both anodic dissolution and the cathodic hydrogen evolution reaction

$$\begin{aligned} Fe\ (s) &\rightarrow Fe^{2+}\ (aq) + 2e^- \\ 2H^+\ (aq) + 2e^- &\rightarrow H_2\ (g) \end{aligned} \tag{1}$$

This process effectively reduces corrosion rates by minimizing the electrochemical activity at the metal-solution interface. Both KNO_3 and K_2CrO_4 function by adsorbing onto the metal surface and forming a protective passivation layer that reduces the accessibility of reactive sites to aggressive ions. Nitrate ions (NO_3^-) facilitate the formation of iron nitrate ($Fe(NO_3)_2$) complexes, while chromate ions (CrO_4^{2-}) tend to produce a thin chromium oxide film on the surface. This adsorbed layer acts as a barrier, suppressing anodic metal dissolution and slowing the cathodic hydrogen evolution reaction. Additionally, the inhibitors alter the local ion concentration at the interface, limiting the diffusion of H^+ ions and thereby decreasing corrosion kinetics

Based on the final experimental observations, the measured dimensions of the iron plate, as listed in Table 2, showed a reduction in length, width, thickness, and mass. From these measurements, the mass difference before and after the experiment was determined, serving as a key parameter for calculating the iron corrosion rate under different acid conditions and in relation to various indicator additions. The corrosion rate values for each variable are summarized in Table 3, from which the following graph was generated**,** illustrating the relationship between inhibitors and corrosion rate shown in Figure 3.

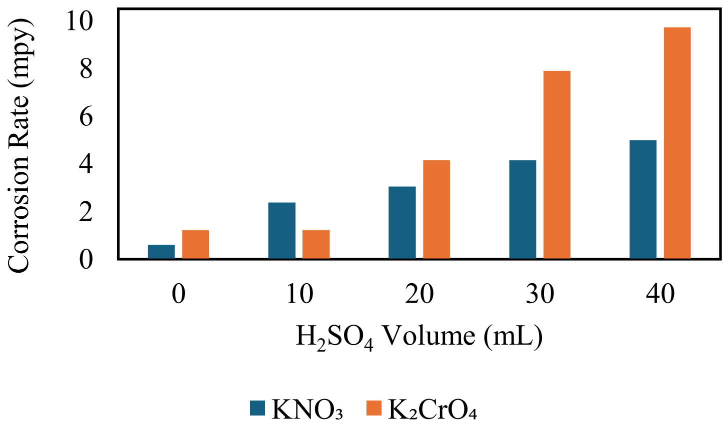


Figure 3. Effect of Adding Inhibitors on Corrosion Rate

Figure 3. is a graph of the effect of the addition of inhibitors on the corrosion rate of Fe metal with variable concentrations of H_2SO_4 in sequence, namely the results of the corrosion rate of the addition of KNO_3 inhibitors are 0,608008 mpy; 2,371232 mpy; 3,040041mpy; 4,149656 mpy; 4,992068 mpy and for the corrosion rate with the addition of K_2CrO_4 inhibitor are 1,216017 mpy; 1,216017 mpy 4,149656 mpy; 7,904107 mpy; 9,728132 mpy. From the data obtained, it can be observed that the corrosion rate of Fe metal decreased as the inhibitor concentration increased. When KNO_3 inhibitor was added, the corrosion rate decreased gradually, starting from 0,608008 mpy until it reached 4,992068 mpy. On the other hand, the addition of K_2CrO_4 inhibitor also showed a decrease in the corrosion rate, although to a different degree. The corrosion rate started from 1,216017 mpy to reach 9,728132 mpy with the addition of K_2CrO_4. Corrosion inhibitors are chemical compounds that are added to an environment containing metals or alloys in order to reduce or inhibit the corrosion rate of the metal. Corrosion inhibitors work by interfering with or reducing the chemical reactions that cause corrosion, protecting the metal from degradation caused by the external environment such as moisture, air, or corrosive solutions. This proves that the same inhibitor, with different conditions or amounts of acid will give different corrosion rate results, namely the higher the addition of acid, the faster the corrosion process will be [6]. This is because sulfuric acid (H_2SO_4) is a highly corrosive strong acid, which has the ability to damage protective coatings so that direct exposure will accelerate the corrosion reaction [7].

If compare the corrosion rate when using 1.2 N KNO_3 and 1.2 N K_2CrO_4 inhibitors on ferrous metal (Fe) against H_2SO_4 volume addition. The graph shows that when using K_2CrO_4 inhibitor, the corrosion rate of ferrous metal is higher than the use of KNO_3 inhibitor in this acidic environment. The graph is a comparison between the two inhibitors showing that KNO_3 has a more significant effect in reducing the corrosion rate of Fe metal compared to K_2CrO_4, especially at high concentrations of H_2SO_4 solution. This phenomenon indicates that KNO_3 has a better ability to reduce the corrosion rate of ferrous metals in a sulfuric acid environment when compared to K_2CrO_4. Because KNO_3 has the properties of nitrate ions that can form a protective layer on the surface of iron metal, forming iron nitrate compounds $Fe(NO_3)_2$ which form a protective layer thus blocking direct contact with sulfuric acid [8]. Then when it reacts with sulfuric acid, it will form a stable compound and has an inhibition against iron metal corrosion. Then it can be seen in the graph that the higher the addition of H_2SO_4 volume, which means the higher the concentration value, the higher the reaction rate that occurs, both with the addition of KNO_3 and K_2CrO_4 inhibitors. This shows that the concentration of sulfuric acid affects the corrosion rate of metals, and the addition of inhibitors can reduce the negative impact of increasing sulfuric acid concentration. The addition of KNO_3 inhibitor tends to produce a lower corrosion rate compared to the addition of K_2CrO_4 inhibitor at the same volume of H_2SO_4 solution, then the higher the concentration value in a chemical reaction, the higher the reaction rate that occurs due to several factors that affect the speed of the reaction, namely the number of particles or molecules of reactants in a certain volume also increases, molecular collisions between reactants that result in the formation of chemical bonds and the formation of products and the law of reaction rate, namely high concentration, the faster the chemical reaction takes place [9].

To complement the descriptive analysis and ensure scientific rigor, statistical evaluation was applied to determine whether the observed differences in corrosion rates between inhibitors were significant. A One-Way ANOVA was chosen because the study involved two categorical groups (inhibitor types: KNO_3 and K_2CrO_4) and a continuous response variable (corrosion rate). This method allows for testing whether the mean corrosion rates differ significantly between the two inhibitor treatments under varying acidic conditions.

Table 4. One-Way ANOVA Results for Corrosion Rate Factors

Factor	**F-Statistic**	**p-Value**	**Significance**
Inhibitor Type	0.918	0.366	Not significant
Volume H_2SO_4	3.794	0.088	Near significant

The ANOVA results (Table 4) show that inhibitor type did not significantly affect corrosion rate ($p = 0.366$), even though descriptive analysis indicated that KNO_3 tended to provide lower corrosion rates than K_2CrO_4. Similar observations were reported where different inhibitors exhibited varying but statistically non-significant differences in highly acidic environments[10]. In contrast, sulfuric acid volume exhibited a near-significant effect ($p = 0.088$), highlighting the dominant role of acidity in accelerating corrosion. This finding supports the electrochemical principle that increased proton concentration enhances metal dissolution[11], while the inhibitor effect becomes less pronounced at higher acidity. However, due to the lack of replication, these findings should be interpreted with caution, and further studies incorporating replicate samples and advanced electrochemical techniques are recommended. Electrochemical methods such as Tafel polarization and Electrochemical Impedance Spectroscopy (EIS) are widely used to better understand adsorption and inhibition mechanisms. While the statistical results validate the dominance of acid concentration over inhibitor type under these conditions, it is important to note the limitation of single observations per condition, which reduces the statistical power of the analysis. Future research should incorporate replicate samples and advanced electrochemical methods to confirm these trends and explore the interaction between inhibitors and acidity in greater detail [12]. Figure 4 visually compares the metal surface before and after inhibitor treatment. Without inhibitors, the surface exhibits corrosion products and localized pitting, indicative of active corrosion sites. In contrast, the addition of KNO_3 or K_2CrO_4 promotes the formation of a passivation film, which smooths the surface and blocks active sites, thereby reducing corrosion progression.

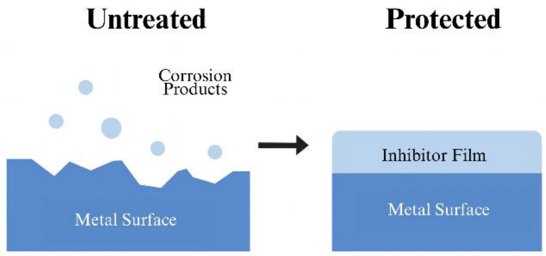


Figure 4. Schematic Illustration of The Metal Surface Condition Before and After Inhibitor Addition

3.3. Effect of pH Value on Corrosion Rate

Based on the final experimental observations, the measured dimensions of the iron plate, as listed in Table 2, showed a reduction in length, width, thickness, and mass. From these measurements, the mass difference before and after the experiment was determined, serving as a key parameter for calculating the iron corrosion rate under different H_2SO_4 volume variations. The corrosion rate values for each variable are summarized in Table 3, from which the following graph was generated, illustrating the relationship between pH and corrosion rate shown in Figure 5.

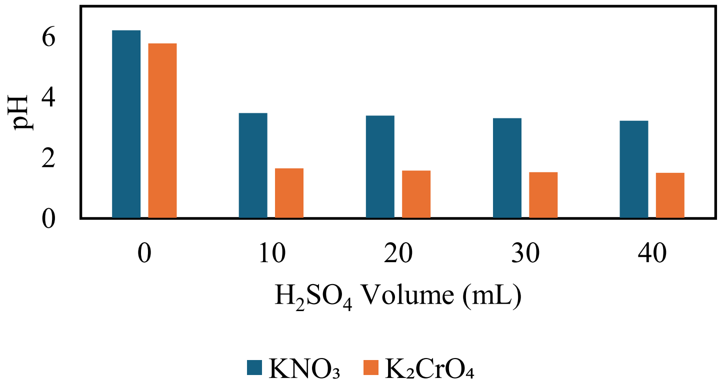


Figure 5. Relationship between pH and Corrosion Rate

In Figure 5. shows the results of immersion of Fe metals for 360 hours, corrosion experiments were conducted on two metals, namely iron (Fe) and copper (Cu), which were immersed in H2SO4 solution with various concentrations. For iron, the variation of H_2SO_4 solution concentration includes 0 mL, 10 mL, 20 mL, 30 mL, and 40 mL. With a pH of 6,21; 3,48; 3,39; 3,31; 3,22, respectively. the corrosion rate of the addition of KNO_3 inhibitors are 0,608008 mpy; 2,371232 mpy; 3,040041mpy; 4,149656 mpy; 4,992068 mpy and for the corrosion rate with the addition of K_2CrO_4 inhibitor are 1,216017 mpy; 1,216017 mpy 4,149656 mpy; 7,904107 mpy; 9,728132 mpy. The corrosion rate data is very important to evaluate the extent of corrosion resistance of the metal concerned in a sulfuric acid environment. Metal corrosion is an indirect event that occurs simultaneously with electron distribution in metals. As electrons move from the anode to the cathode, a corresponding current transfer occurs. The corrosion rate increases as the resulting pH increases, a high pH can create more corrosive conditions for the metal, accelerating the corrosion process. This is mainly related to the ability of hydrogen ions to permeate and damage the metal structure [13]. The higher the corrosion rate value, the more susceptible the metal is to corrosion under those conditions [14].

The graph presents data from the corrosion experiment of iron (Fe) metals immersed in H_2SO_4 solution for 360 hours. The observed variables include solution volume (mL), acidity level (pH), and corrosion rate. For ferrous metal (Fe), it can be observed that as the immersion time increases, the pH of the solution decreases gradually. Initially at 0 mL, the pH of the Fe solution with adding KNO_3 inhibitor was about 6,21, and decreased The graph presents data from the corrosion experiment of iron (Fe) and copper (Cu) metals immersed in H_2SO_4 solution for 360 hours. The observed variables include solution volume (mL), acidity (pH), and corrosion rate. For ferrous metal (Fe), it can be observed that as the immersion time increases, the pH of the solution decreases gradually. Initially at 0 mL, the pH of the Fe solution was about 6,21, and decreased to 3,22 at 30 mL of solution. In general, ferrous metals tend to experience increased corrosion as the pH decreases [7]. The corrosion rate of Fe also showed an increasing trend along with the immersion time, from 0,000265579 at 0 mL to 0,080853911 at 30 mL. Meanwhile, the Fe metals with adding K_2CrO_4 inhibitor shows different behavior. In addition, temperature and pressure variability in the experiment can also have an impact on the corrosion rate. At 0 mL, the pH of the Fe solution was high at about 5,77, but the corrosion rate at this point was 0. This indicates that the solution contained distilled water with 0% H_2SO_4 concentration and therefore did not cause corrosion to the copper metal. The corrosion rate of Fe then increased at 10 mL, reaching a value of 2,371232, but did not follow the decreasing pH trend. Corrosion of iron metals is a natural process that occurs due to interaction with the surrounding environment. In iron, corrosion generally occurs in the form of rust or oxidation of iron (Fe_2O_3). This process begins with the formation of anodes and cathodes on the metal surface. The anode undergoes oxidation and releases electrons, while the cathode accepts electrons and engages in a reduction reaction. As a result, iron ions are oxidized and form corrosive iron oxide compounds [15]. Factors such as humidity, environmental acidity, and the presence of corrosive substances can accelerate the corrosion process of iron[16].

To quantitatively assess the relationship between pH and corrosion rate, a linear regression analysis was performed. This approach was chosen because pH is a continuous variable rather than categorical, making regression the most appropriate method for determining the strength and direction of the relationship. The statistical outcome is presented in Table 5.

Table 5. Regression Analysis for pH and Corrosion Rate

Variable	**Relationship**	**R2**	**p-Value**	**Significance**
pH vs corrosion	Negative	0.89	< 0.01	Significant

The strong negative correlation between pH and corrosion rate ($R^2 = 0.89$, $p < 0.01$) indicates that acidity is a critical factor influencing corrosion behavior. This trend supports the hydrogen evolution mechanism, where higher proton availability accelerates the cathodic reaction and overall corrosion process [17]. Lower pH also promotes dissolution of protective films, further increasing the susceptibility of metal surfaces to attack. While both inhibitors reduced corrosion at higher pH values, their efficiency decreased in strongly acidic environments. This observation is supported by literature showing that nitrate inhibitors maintain passivity better than chromates under moderate acidity but lose effectiveness at very low pH. These findings highlight the need for dual-functional inhibitors that combine surface passivation with acid neutralization to maintain protection under severe conditions. Controlled pH experiments were not performed independently of acid volume, making it difficult to isolate pH as a sole factor[18]. Future research should include controlled buffering systems and replicate testing to strengthen the analysis.

3.4. Effect of Current Density on Corrosion Rate

Based on the final experimental observations, the measured dimensions of the iron plate, as listed in Table 2, showed a reduction in length, width, thickness, and mass. From these measurements, the mass difference before and after the experiment was determined, serving as a key parameter for calculating the iron corrosion rate under different H_2SO_4 volume variations. The corrosion rate values for each variable are summarized in Table 3, from which the following graph was generated, illustrating the relationship between current density and corrosion rate shown in Figure 6.

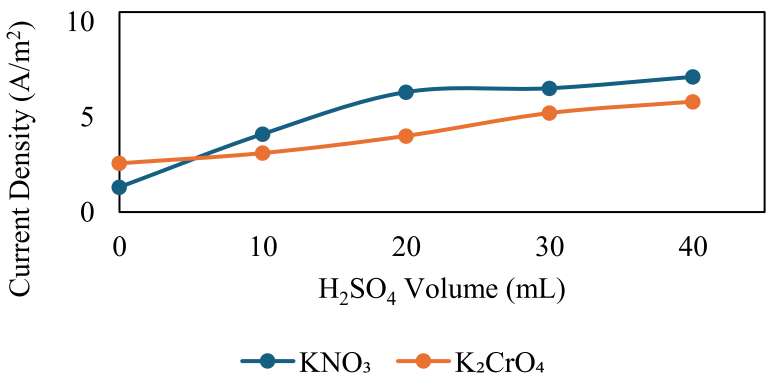


Figure 6. Relationship between Current Density and Corrosion Rate

In the results that have been obtained for iron samples, the voltage values are 1,31; 4,3; 6,3; 6,5; 7,1 A/m^2 with corrosion rate values 0,608008 mpy; 2,371232 mpy; 3,040041mpy; 4,149656 mpy; 4,992068 mpy, respectively. Figure 3 shows the relationship between current voltage and corrosion rate is directly proportional, where the greater the current voltage, the greater the corrosion rate of iron. Indicators of the effectiveness of inhibitor adsorption can be seen from the density and thickness of the passivation layer, as well as the corresponding reduction in corrosion rate. Some of the factors that affect the current stress with iron corrosion rate are iron thickness, which includes current strength, voltage, coating duration, electrolyte type, and environmental factors. The relationship between current strength and time suggests that higher electrochemical activity influences the stability and thickness of the passivation layer formed by the inhibitor on the metal surface. The reason is because with an increase in the strength of the electric current flowing, the number of ions involved becomes greater, so that more ions are released from the solution and deposited on the cathode or workpiece[19]. The increase in corrosion rate in the initial experiment was due to the state of the metal surface which was initially clean and a corrosion layer had not yet formed on the steel. Therefore, when first dipped, contact and reaction with the environment is still effective because there is no corrosion barrier formed on the metal surface [20].

In the results that have been obtained Fe samples with adding K_2CrO_4, obtained current voltage values of 2,56; 3,1; 4; 5,2; 5,8 A/m^2 obtained corrosion rate data respectively 1,216017 mpy; 1,216017 mpy 4,149656 mpy; 7,904107 mpy; 9,728132 mpy. The current voltage and the corrosion rate of this sample is inversely proportional, where the greater the current voltage, the increase and decrease in the corrosion rate of copper. The decrease in the corrosion rate value is caused by the thicker metal layer formed. The higher the current density, the lower the corrosion rate. The longer the inhibitor adsorption process or the more stable the passivation layer, the lower the corrosion rate observed [21]. Changes in the composition of the H_2SO_4 solution affect the corrosion rate due to variations in the stability and protective ability of the passivation layer formed by inhibitor adsorption. The greater the composition of the solution, the less effective the passivation layer becomes leading to a higher corrosion rate, because the addition of solutes will cause the vapor pressure to decrease and the boiling temperature to increase so that more solutes will precipitate at the bottom of the solvent. Therefore, the composition contains little solute so the corrosion rate will be lower. Meanwhile, if the solute is high, the corrosion rate will be higher because there will be a change in the colligative properties of the solution, causing the solution temperature to be higher than the solvent temperature [22]. Current density plays a critical role in determining corrosion rates, as it directly correlates with the rate of electrochemical reactions. Higher current densities accelerate both anodic and cathodic processes, increasing Fe^{2+} ion release and hydrogen gas evolution. This elevated electrochemical activity can disrupt the stability of the passivation layer, exposing new active sites and reducing the efficiency of the inhibitor. Consequently, under conditions of high current density, corrosion progresses more rapidly, emphasizing the need for inhibitor formulations capable of maintaining protective layers even under intense electrochemical stress.

To evaluate this relationship quantitatively, Pearson correlation and linear regression were applied because current density is a continuous variable. This analysis allows for determining how strongly current density affects corrosion rate under experimental conditions. The results are shown in Table 6.

Table 5. Regression Analysis for Current Density and Corrosion Rate

Variable	Relationship	R2	p-Value	Significance
Current Denisty vs Rate	Positive	0.95	< 0.01	Significant

The very strong positive correlation between current density and corrosion rate ($R^2 = 0.95$, $p < 0.01$) confirms the electrochemical theory that corrosion rate is directly proportional to current density according to Faraday's law. Higher current densities accelerate the anodic dissolution of iron, increase electron flow, and destabilize protective layers formed by inhibitors. This behavior was particularly evident in conditions with high acid concentration, where both inhibitors became less effective. This result aligns with previous findings in electrochemical systems where external factors such as applied potential or conductivity directly influence corrosion kinetics. Although inhibitors can delay the onset of corrosion by reducing active sites, they cannot completely counteract the effect of increased current density, especially under severe acidic conditions[23]. Current density in this study was derived indirectly from experimental conditions and not controlled as an independent variable. Advanced electrochemical measurements, such as Tafel polarization and EIS, are recommended to validate these results and provide mechanistic insight into inhibitor performance at different current densities.

4. Conclusions

From the research conducted, the following conclusions can be drawn: investigated the effect of inhibitors, pH, and current density on the corrosion rate of iron (Fe) in H_2SO_4 solution. The addition of inhibitors showed that KNO_3 was more effective in reducing the corrosion rate, with values of 4.992068, 3.744051, 2.736034, 1.728017, and 0.608008 mpy, compared to K_2CrO_4, which resulted in 9.728132, 7.296099, 5.472066, 3.648033, and 1.216017 mpy. Corrosion rate increased as pH decreased, with Fe showing corrosion at pH 6.21, 5.18, 4.26, 3.85, and 3.22. The relationship between current density and corrosion rate was found to be proportional, with voltage values of 1.31, 2.24, 3.16, 5.11, and 7.1 A/m^2. The study confirms that inhibitor type, acidity, and current density significantly influence corrosion behavior. This research provides insights into cost-effective and practical corrosion mitigation strategies for acidic environments. The findings can reduce maintenance costs, improve process efficiency, and support the development of new technologies for corrosion control, thereby enhancing operational safety in industries handling aggressive media such as H_2SO_4.

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