Corrosion Behavior of Copper and Carbon Steel in Acidic Media

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Abstract:

The corrosion behavior of copper and carbon steel in 1M concentration of hydrochloric acid (HCl) and sulphuric acid (H_2SO_4) has been studied. The corrosion inhibition of copper and carbon steel in 1M concentration of hydrochloric acid (HCl) and sulphuric acid (H_2SO_4) by Ciprofloxacin has been investigated. Specimens were exposed in the acidic media for 7 hours and corrosion rates evaluated by using the weight loss method. The effect of temperature (from 283 ºK to 333 ºK), pH (from 1to 6), inhibitor concentration (10^{-4} to 10^{-2}) has been studied. It was observed that sulphuric acid environment was most corrosive to the metals because of its oxidizing nature, followed by hydrochloric acid. The rate of metal dissolution increased with increasing exposure time. Corrosion rates of carbon steel in the acidic media found to be higher.

Key words: corrosion, copper, carbon steel, acidic media.

Introduction:

The exposures can be severed to the properties of the metals and thus lead to sudden failure of materials in service, therefore the need to study the corrosion behavior of metals when exposed to various environments, as this is an important factor in material selection that determines the service life of the material [1-5].

Acidic solutions are extensively used in industry, the most important of which are acid pickling, industrial acid cleaning, acid-descaling and oil well acidizing. The commonly used acids are hydrochloric acid, sulphuric acid, nitric acid, etc. Inhibitors are usually used to minimize the corrosive attack on metallic materials, and Inhibitors are widely used in the corrosion protection of metals in several environments [6-9].

This work examines the corrosion behavior of copper and carbon steel when exposed to 1M of hydrochloric acid and sulphuric acid. The effects of immersion time, temperature, pH and inhibitor concentration were also studied. The corrosion rates in these media are also calculated to study their stability when similar industrial environments are encountered. The drug Ciprofloxacin has been investigated as inhibitor to copper and carbon steel and the inhibition efficiency was obtained.

Materials and Methods:

Composition of material samples

The chemical composition of copper specimens used in this work is shown in table 1.

Table 1. Chemical composition of copper samples.

Material	Compositions, wt (%)					
	Zn	Cd	S	P	Pb	Cu
Cu	0.0005	0.003	0.0015	0.02	0.001	rest

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The chemical composition of carbon steel specimens used in this work is shown in table 2.

Table 2. Chemical compositions of carbon steel samples.

Material	Compositions, wt (%)								
	C	Si	Mn	P	S	Cu	N	Cr	Fe
Cs	0.7	0.18	0.5	0.017	0.005	0.03	0.007	16.5	rest

Preparation of the Specimen

Copper and carbon steel specimens of the dimensions 2 cm × 2 cm × 0.05 cm were polished to a mirror finish and washed in absolute ethanol and acetone, dried at room temperature and stored in a moisture free dessicator before their use in corrosion studies.

Weight-Loss Method

The weight loss (gravimetric method) is probably the most widely used method of inhibition assessment [10]. The simplicity and reliability of the measurement offered by the weight loss method is such that the technique forms the baseline method of measurement in many corrosion monitoring programs [11].

Weight loss measurements were conducted under total immersion using 250 mL capacity beakers containing 200 mL test solution at 30 ºC maintained in a thermostated water bath. Copper and carbon steel coupons were weighed and suspended in the beaker with the help of rod and hook.

The coupons were retrieved at 1 hour interval progressively for 7 hours, washed thoroughly in 20% NaOH solution containing 200 g/L of zinc dust with bristle brush, rinsed severally in deionized water, cleaned, dried in acetone, and re-weighed. The weight loss in (g) was taken as the difference in the weight of the coupons before and after immersion in different test solutions.

The corrosion rate (in g/ cm^2 h) was calculated from the following equation [12]:

$$CR = \frac{W_b - W_a}{At} \quad \dots \quad (1)$$

Where W_b and W_a are the coupons weight before and after immersion in the tested solution, A the total area of one coupon, and t is the immersion time.

The inhibition efficiency (% IE) was calculated as follows [13]:

$$\%\ IE = \frac{CR1 - CR2}{CR1} \times 100 \quad \dots (2)$$

Where CR1 and CR2 are the corrosion rates of the coupons in the absence and presence of inhibitor respectively.

The degree of surface coverage of the investigated surfactant compounds were calculated from the following equation [14]:

$$\theta = \frac{CR1 - CR2}{CR1} \quad \dots \quad (3)$$

Inhibitor

Inhibitors are compounds that control, reduce, or prevent reactions between a metal and its surroundings when added to the medium in small quantities. The use of inhibitors is one of the most practical methods for protection against corrosion, especially in acidic media [15]. Ciprofloxacin hydrochloride monohydrate is $C_{17}H_{18}FN_3O_3$, HCl (1-cyclopropyl-6-fluoro-1, 4-dihydro-4-oxo-7-(1piperazinyl)-3-quinolinecarboxylic acid hydrochloride monohydrate). The molecular weight of the ciprofloxacin hydrochloride monohydrate is 385.82. It is a Pale yellow, crystalline, slightly hygroscopic powder, soluble in water and its chemical structure is shown in figure 1[16].

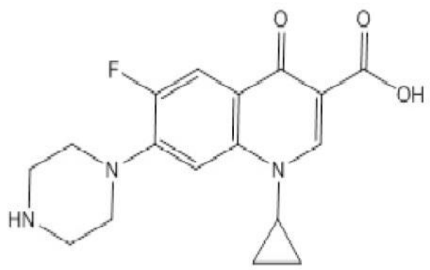

Fig. 1 Chemical structure of Ciprofloxacin inhibitor.

Results and Discussion:

Corrosion Rates Study

The corrosion rates of copper and carbon steel after 7 hours in 1M HCl and 1M H_2SO_4 was shown in figures 2 and 3 respectively.

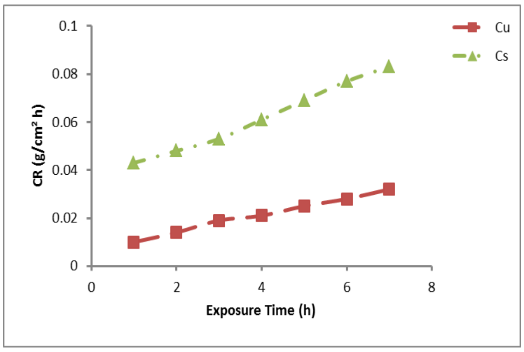

Fig. 2 The corrosion rates copper and carbon steel as a function of time in 1M HCl.

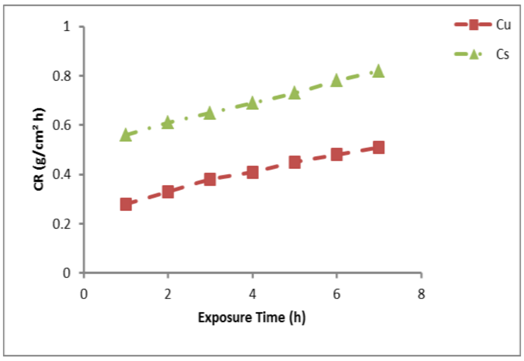

Fig. 3 The corrosion rates copper and carbon steel as a function of time in 1M H_2SO_4.

Copper and carbon steel were found to corrode in 1M concentrations of HCl and H_2SO_4 solutions. This was evidenced by the increasing of corrosion rate of the metal coupons. H_2SO_4 was found to be more corrosive, followed by HCl. This figures show carbon steel has more corrosion rate followed by copper, increased with exposure time.

The effect of temperature

The effect of temperature from 283 ºK to 333 ºK on the corrosion rates of copper and carbon steel was directly observed by increasing the corrosion rates in the metals with increasing the temperature as shown in figures 4 and 5 respectively. The corrosion rate was raised due to oxygen diffusion on the metal surface, the oxygen content of the water directly affects the corrosion rate because the solubility of oxygen is decreased with increasing temperature; Steels and copper are particularly insensitive to temperature effects in normal immersion [17].

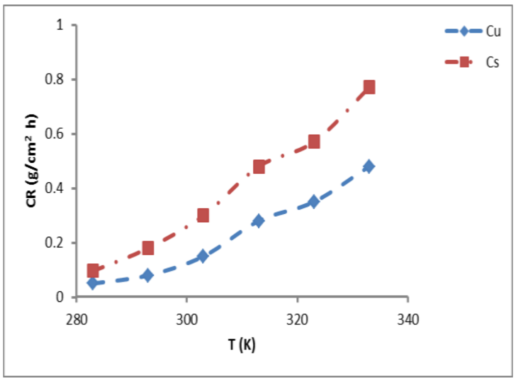

Fig. 4 The corrosion rates copper and carbon steel as a function of temperature in 1M HCl.

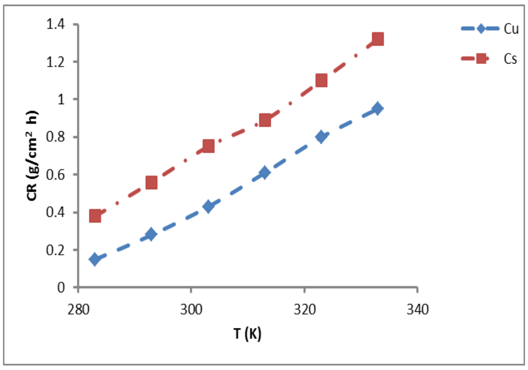

Fig. 5 The corrosion rates copper and carbon steel as a function of temperature in 1M H_2SO_4.

pH effect

The effect of pH on the range 1 to 6 to the corrosion rates of copper and carbon steel was directly observed by reduce the corrosion rates of the metals with increasing the pH as shown in figures 6 and 7 respectively. At lower pH, the corrosion rate was activation therefore; the corrosion rate is high.

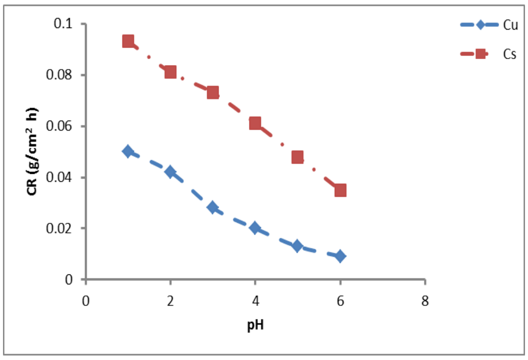

Fig. 6 The corrosion rates copper and carbon steel as a function of pH in 1M HCl.

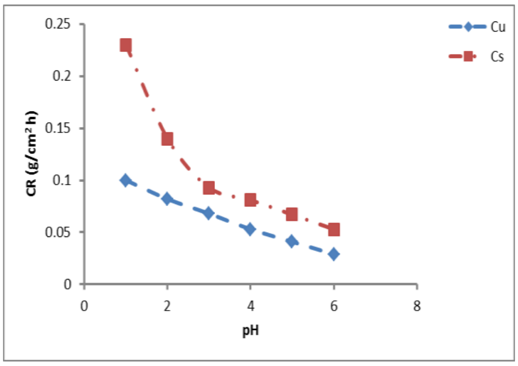

Fig. 7 The corrosion rates copper and carbon steel as a function of pH in 1M H_2SO_4.

Inhibitor effect

Corrosion rates, inhibitor efficiencies, and surfaces coverage of copper and carbon steel are shown in table 3.

Table 4. corrosion rates, inhibitor efficiencies, and surfaces coverage of copper and carbon steel.

Concentration (M)	metals	CR (mm/yr)	% IE	θ
10^{-4}	Cu	1.15	78	0.78
	Cs	7.75	73.5	0.735
10^{-3}	Cu	0.96	82.7	0.827
	Cs	6.43	78.1	0.781
10^{-2}	Cu	0.78	87.6	0.876
	Cs	5.42	83.4	0.834

The effect of inhibitor with concentration 10^{-2} M on the corrosion rates of copper and carbon steel was directly observed by reduce the corrosion rates with good efficiency in the metals as shown in figures 8 and 9 respectively.

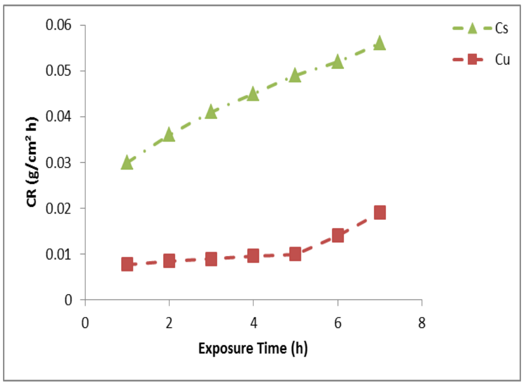

Fig. 8 The corrosion rates of copper and carbon steel in 1M HCl with inhibitor concentration 10^{-2} M at constant temperature and pH.

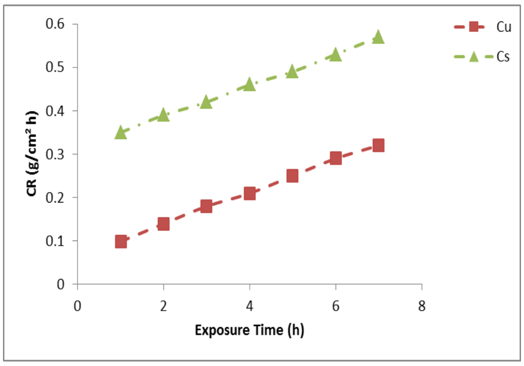

Fig. 9 The corrosion rates of copper and carbon steel in 1M H_2SO_4 with inhibitor concentration 10^{-2} M at constant temperature and pH.

Conclusion:

The results from this work have clearly shown the following:

-The corrosion rates increased with increasing exposure time.

- Corrosion of carbon steel is significant in sulphuric acid and hydrochloric acid as compare with copper that apparent the loss ratio of corrosion rates.
- The effect of increasing temperature cause increasing in the corrosion rates was shown especially above 320 ^{o}K.
- The corrosion rate depending on pH and increasing highly at pH < 2.
- The concentration of inhibitor affected on the inhibitor efficiency by increasing it when it increases.
- Sulphuric acid being most corrosive media, followed by hydrochloric acid.
- The comparison of corrosion rate by weight loss and mathematical model methods. The observed corrosion rate values from the experimental data were in a good agreement with that predicated by the mathematical equation.

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سلوك تأكل النحاس، وكاربون الحديد في وسط حامضي

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الخلاصة:

تم دراسة سلوك تأكل النحاس، وكاربون الحديد في تركيز 1 مولاري من حامض الهايدروكلوريك وحامض الكبريتيك. وقد اقترح المثبط (Ciprofloxcin) لتأكل النحاس وكاربون الحديد في تركيز1 مولاري في حامض الهايدروكلوريك وحامض الكبريتيك. وباستخدام طريقة فقدان الوزن تم حساب نسب التأكل لعينات موضوعة لمدة 7 ساعات في وسط حامضي. تم دراسة تأثير درجة الحرارة (من 283 الى 333) كلفن ودرجة الحامضية (من 1 الى 6) وتركيز المثبط (من 10^{-4} الى 10^{-2}) مولاري. قد لوحظ بان حامض الكبريتيك أكثر أكل للمعادن بسبب طبيعة تأكسده متبوعا بحامض الهايدروكلوريك و إن نسبة التحلل للمعدن تزداد بزيادة زمن التعرض. وكما وجد بأن نسب تأكل كاربون الحديد عالي في جميع الأوساط الحامضية.