

〈研究論文〉

알카리용액中 페놀파라유도체에 의한
알루미늄板 부식억제 효과

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P-Substituted phenols as corrosion inhibitors for
aluminium sheet in alkali solution

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초 록

市中 알루미늄板에 대한 NaOH 용액中에서의 腐蝕 및 페놀파라유도체 (phenol, p-nitro phenol, p-cresol, hydroquinone, p-chlorophenol, p-aminophend 등)에 의한 腐蝕抑制效果를 조사한 결과 抑制劑의 一定濃度에서는 NaOH 의 농도에 따라 腐蝕性이 커지며 抑制劑의 농도가 0.5~2.0% w/w에서는 그濃度에 따라 抑制效果가 상승하여 2 %에서는 最大效率를 보였다.

그러나 抑制劑의 농도가 0.01~0.1% 범위에서는 오히려 腐蝕을 助長하였다.

抑制劑 濃度 2%에서의 抑制效果의 크기는 다음과 같은 순서이었다. p-aminophenol (85.6%) < p-cresol < hydroquinone < phenol < p-nitrophenol < p-chlorophenol (98.6%)

反應溫度와 時間에 따른 抑制效果의 變化는 큰 차이가 없었고 液性도 역시 마찬가지였다.

同一 mole 濃度에서의 페놀의 p-치환체의 抑制效果는 다음과 같은 순서이었다. p-aminophenol (77.8%) < phenol < hydroquinone < p-chlorophenol < p-cresol < p-nitrophenol (96.1%).

Abstract

The inhibition of corrosion of the aluminium sheet (commercial) in solutions of sodium hydroxide was studied by weight loss methods and the variation of pH value of the corrosion solution was detected.

At constant alkali concentration the inhibitor efficiency increased with increase in the concentration of the inhibitor. (When the inhibitor concentration was 0.5% and above.)

But at low concentrations of the inhibitors (0.1% and below) the efficiency decreased to minus values.

At 2.0% concentrations of inhibitors, the inhibitive efficiencies of the inhibitors increased in the order, p-aminophenol (85.6%) < p-cresol < hydroquinone < phenol < p-nitrophenol < p-chlorophenol (98.6%)

At constant inhibitor concentration the efficiency decreased with increase in alkali concentration. An increase in exposure period or temperature did not appear to have any marked effect on inhibitive efficiency.

The variation of pH values in the solution had also a small effect. As for the effect of substituent groups, when

an equal number of molecules of each of the compounds was present in the alkaline solution the efficiency of different para-compounds increased in the order: p-aminophenol (77.8%) < phenol < hydroquinone < p-chlorophenol < p-cresol < p-nitrophenol (96.1%).

Introduction

In all parts of the world the consumption of aluminium for industrial and domestic purposes has increased enormously in recent years.

The aluminium metal is stable in air because of the formation of an extremely thin, but remarkably tight and adherent, oxide film on the metal surface. The film is generally stable in solutions of pH 4.5~8.5 but, due to its amphoteric nature, it fails to protect aluminium in strongly acidic or strongly alkaline media.¹⁾

The pickling of aluminium in caustic alkalies for degreasing prior to anodizing, or to give an attractive matt finish, is common practice; for light cleaning, mixtures of sodium carbonate and phosphate are also used.^{1,2,3)} As the solution rate of aluminium in aqueous sodium hydroxide is very high, it may be desirable to inhibit the solution used for pickling. Satisfactory inhibitors for this purpose are very rare if not unknown, though the corrosion of B265 aluminium with dihydroxy-benzenes and of 3S aluminium with some aromatic dyes in NaOH solutions containing various protective colloids has been reported.^{1,3,4)}

The present work was undertaken to study the role of some p-substituted phenols (Hydroquinone, p-chlorophenol, p-cresol, p-cresol, p-aminophenol, p-nitrophenol and phenol) in inhibiting the corrosion of aluminium sheet in aqueous sodium hydroxide solutions.

Experimental Method

Rectangular specimens of the aluminium sheet of size 50 × 40mm and thickness 0.8mm, with a small hole of about 10mm diameter near the upper edge of the specimen, were used for the determination of the corrosion rate.

The composition of the aluminium sheet was found to be as follows: Si 0.09%; Fe 0.17%; Ti ≤ 0.03%; Al remainder.

The specimens were cleaned according to the method described earlier.⁵⁾

Namely, the surface of specimen was first washed

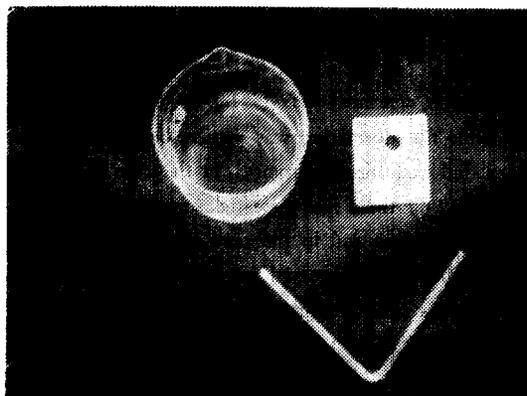


Fig. 1,

in distilled water and dried. It was then polished with ethylalcohol gauze and then rinsed with trichloro ethylene, ethylalcohol and ether in turn and dried in the air.

The specimens were exposed to caustic soda solutions within the concentration range 0.1~1.0M, containing controlled additions (0.01~2.0%) of the inhibitor.

The compounds studied as inhibitors included: phenol, p-cresol, p-aminophenol, hydroquinone, p-chlorophenol and p-nitrophenol. One specimen only was suspended by a glass hook in each beaker containing 250ml of the solution at 17±0.5°C (unless otherwise specified) open to the air. (which is shown in Fig 1.)

The specimens were cleaned after the tests in tap water.⁶⁾ Duplicate experiments were performed in each case and the mean values of the weight losses were recorded.

In order to assess their effect as corrosion inhibitors, phenols and various p-substituted phenols were added, in concentrations ranging from 0.01 to 2.0%, to sodium hydroxide solutions of different molarities.

The pH values of 1.0% solutions of the inhibitors in distilled water ranged from 4.5 (p-nitrophenol) to 7.3 (p-aminophenol) and were non-corrosive to aluminium.

The pH values of inhibited alkaline solutions (0.1M NaOH + 1% inhibitor) were observed to be 10.7 (+1

% hydroquinone), 11.7 (+1% p-nitrophenol), 11.1 (+1% p-cresol), 10.4 (+1% phenol), 11.3 (+1% p-chlorophenol) and 11.0 (+1% p-aminophenol).

The specimens exposed to NaOH solutions containing 0.01~0.5% of the inhibitor were covered with a faintly greyish film which could be easily removed with tap water.

At higher concentrations ($\geq 1.0\%$) of the inhibitor, no visible film formation was present but the specimen had a dull metallic appearance. In the case of p-chlorophenol (2%) there also appeared some white spots on the metal surface and in the case of p-nitrophenol the cleaned specimens appeared as bright as before. But the solutions became more colorful from bright to yellow, grey and dark.

Experimental results and discussion.

The results are given in Fig 2~5 and table.

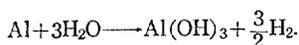
Inhibitor efficiency, I, is defined as:

$$I = \frac{W_u - W_I}{W_u} \times 100\%$$

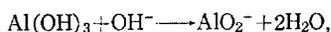
where W_I = weight loss of metal in inhibited solution.

W_u = weight loss of metal in uninhibited solution.

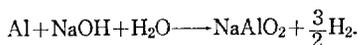
According to Straumanis and Brakss⁷⁾ the initial corrosion reactions of aluminium in aqueous solutions of sodium hydroxide may be represented as



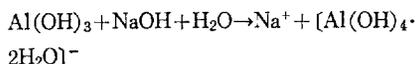
This is then followed by the reaction



the net reaction thus being



And according to Putilova⁷⁾ et al,



Aluminium hydroxide begins to precipitate in a pH interval 3~9 with maximum precipitation taking place between 6.5 and 7.⁷⁾ Thermodynamically aluminium is an unstable metal and reacts spontaneously with oxygen to give aluminium oxide



However, in spite of this, aluminium shows quite a high resistance to water, most neutral solutions, and

many weakly acidic solutions. This resistance to corrosion may be ascribed to the formation of an extremely thin, but remarkably tight and adherent, oxide film on the metal surface.

Although aluminium hydroxide begins to precipitate in a pH interval of 3~9, the oxide film is generally stable in solutions of pH 4.5~8.5.

However, due to its amphoteric nature, the film will dissolve and aluminium is active in strongly acidic, and particularly alkaline, media. Namely there is no possibility of deceleration of attack due to an oxide film formation beyond these pH values.^{7,8)}

That is why the corrosion of aluminium proceeds unabated in alkaline solutions.

According to Evans⁷⁾, the inhibition of corrosion of aluminium in alkaline solutions is a difficult problem, possibly because of the specific adsorption of OH^- on the metal surface.

1. Effect of inhibitor concentration.

Figure 2. Shows the effect of inhibitor concentration on inhibitive efficiency of various p-substituted phenols in 0.1M NaOH. From the figure it is that at higher concentrations of the inhibitor (0.5% and above) the efficiency increases with increase in inhibitor concentration in the case of all the compounds studied. At lower concentrations of the inhibitor (0.1% and below) the efficiency decreases (with increase in inhibitor concentration) to minus values. It means there is an acceleration of attack probably because of the depolarizing action of the inhibitor.²⁾ At 2.0% concentration of inhibitors, the inhibitive efficiencies of various inhibitors increases in the order (Fig 2), p-aminophenol (85.6%) < p-cresol < hydroquinone < phenol < p-nitrophenol < p-chlorophenol (98.6%)

According to Machu⁷⁾, the inhibitors are believed to be generally molecularly absorbed on the active centers of the metal surface. Thus an absorbed layer characterised by a high electrical resistance is formed on the metal surface which may also be responsible for the reduction in the rate of diffusion of ions necessary for the corrosion process.

2. Effect of alkali concentration on the inhibitor efficiency.

During pickling for one hour, aluminium surfaces generally came in contact with aqueous solutions of

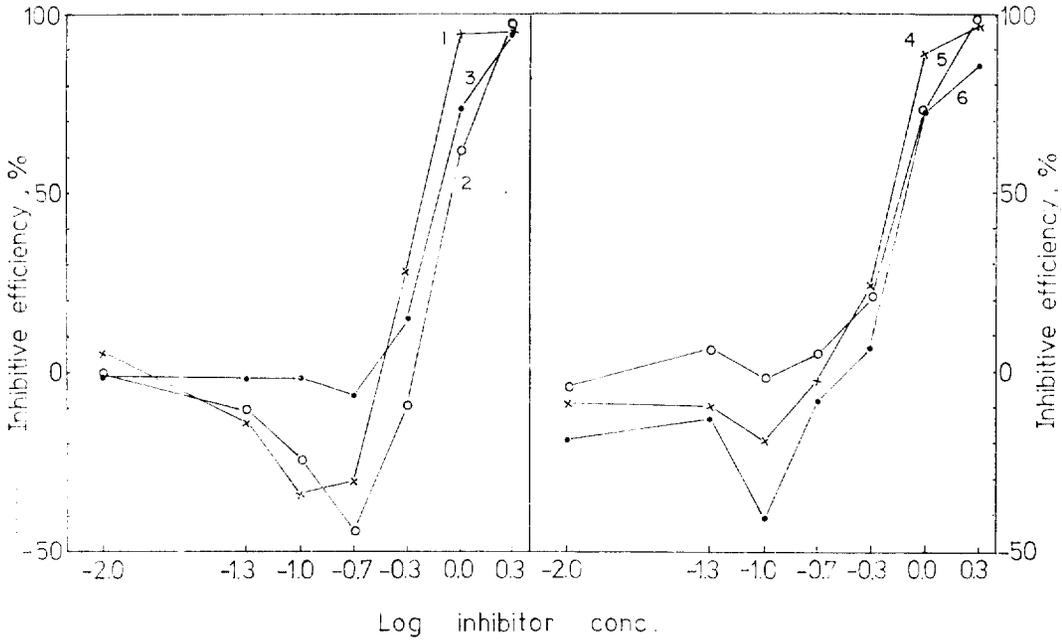


Fig. 2. The effect of inhibitor concentration on inhibitive efficiency of *p*-substituted phenols for aluminium sheet in 0.1M NaOH.
 1. hydroquinone, 2. *p*-nitrophenol, 3. *p*-cresol 4. phenol, 5. *p*-chlorophenol, 6. *p*-aminophenol.

sodium hydroxide of concentrations 0.1~1.0M at three different inhibitor concentrations (2%, 1% and 0.1%).

The efficiencies of the inhibitors at three different inhibitor concentrations are shown in Fig 3. It is observed that the efficiency decreases with increase in the concentration of the alkali. But hydroquinone (0.1%) is an exception

Probably it is due to the solubility of hydroquinone.

The decrease in inhibitive efficiency with increase in concentration of the alkali may be due to the formation of the complex aluminate ion, which keeps the concentration of the Al^{+3} ion in solution very low, and may be attributed to the high rate of evolution of hydrogen in concentrated alkalis which may interfere with the absorption of the inhibitor on the metal surface.^{1,7)}

3. Effect of immersion period

In order to determine the effect of exposure period on inhibitor efficiency, the extent of corrosion was

measured in 0.1M NaOH containing 1.0% inhibitor for exposure periods of 15, 30, 45 and 60 minutes. The results are given in Fig 4.

It shows that the efficiency of hydroquinone, phenol and *p*-chlorophenol decreases till 30 minutes. After that the efficiency increases slightly.

The inhibitors studied shows a slight change of efficiency with time. It is probable that these effects are due to depletion of alkali in the solution by corrosion process, or by absorption of CO_2 from the air, the most dilute solutions being the most affected.

4. Effect of temperature on inhibitor efficiency.

In practice, the pickling of aluminium was carried out in 0.1M NaOH solution at 1.0% inhibitor concentration for one hour at temperatures ranging between 20 and 50°C.

The results indicate in Fig. 5 and table 1 that the extent of corrosion increases with a rise in temperature, but the efficiency of each of the inhibitors rema-

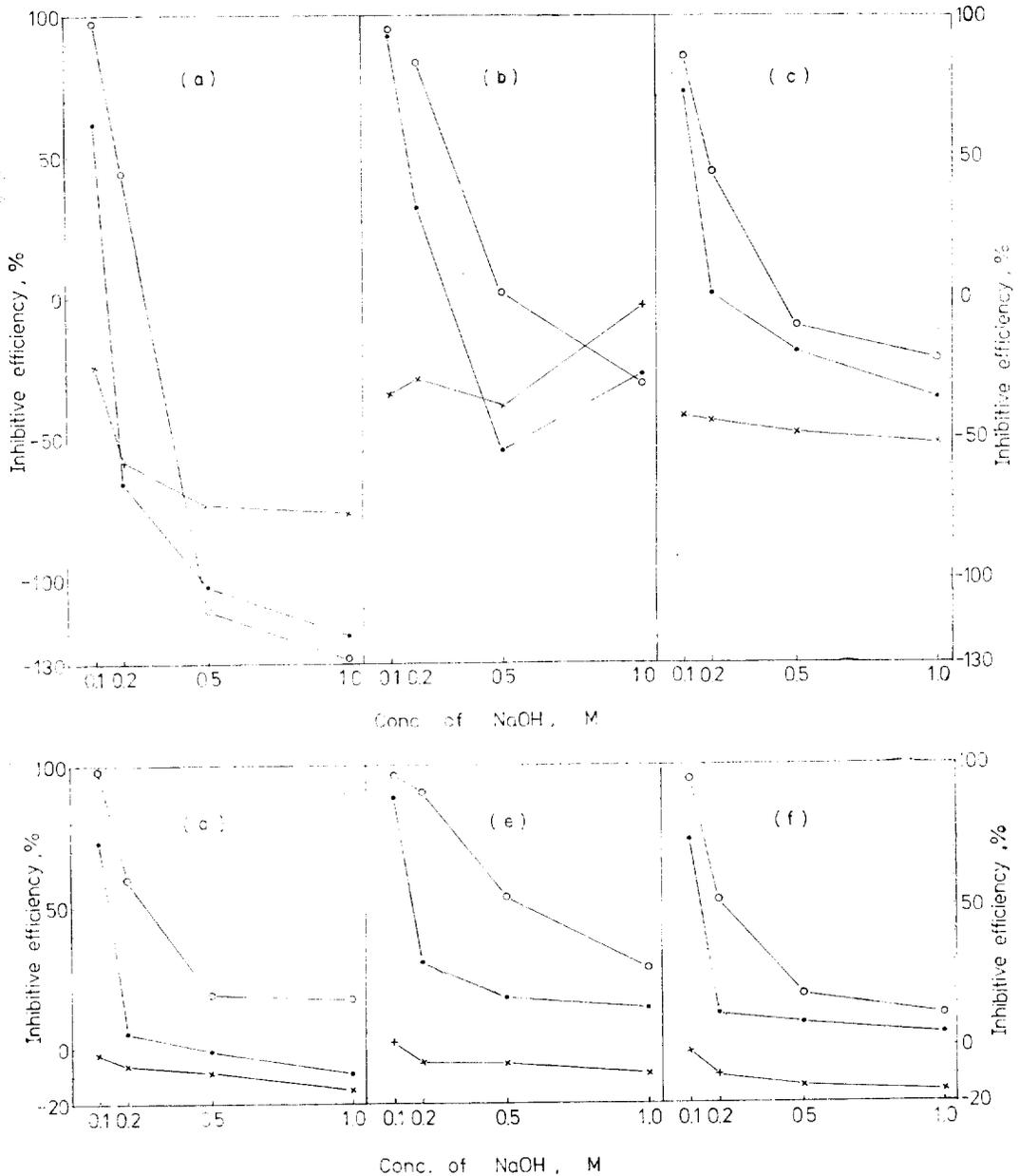


Fig. 3. The effect of concentration of NaOH on inhibitive efficiency of p-substituted phenols for aluminium sheet.

○—○ 2% Inhibitor ●—● 1% Inhibitor ×—× 0.1% Inhibitor

(a) p-nitrophenol (b) hydroquinone (c) p-aminophenol (d) p-chloropheno (e) phenol (f) p-cresol

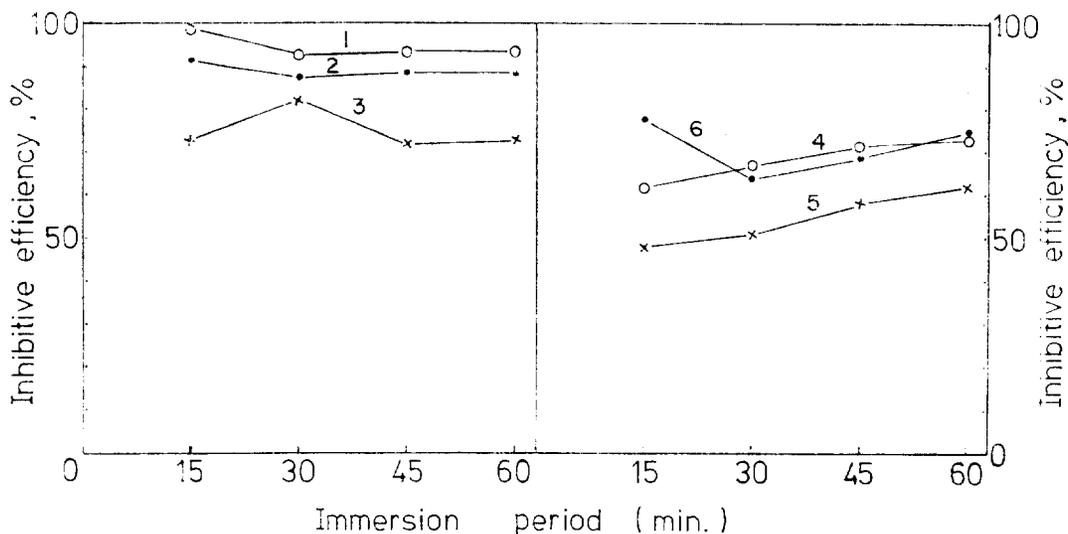


Fig 4. Effect of immersion period on inhibitor efficiency of *p*-substituted phenols for aluminium sheet in 0.1M NaOH.
 1. hydroquinone 2. phenol 3. *p*-cresol 4. *p*-aminophenol 5. *p*-nitrophenol 6. *p*-chlorophenol

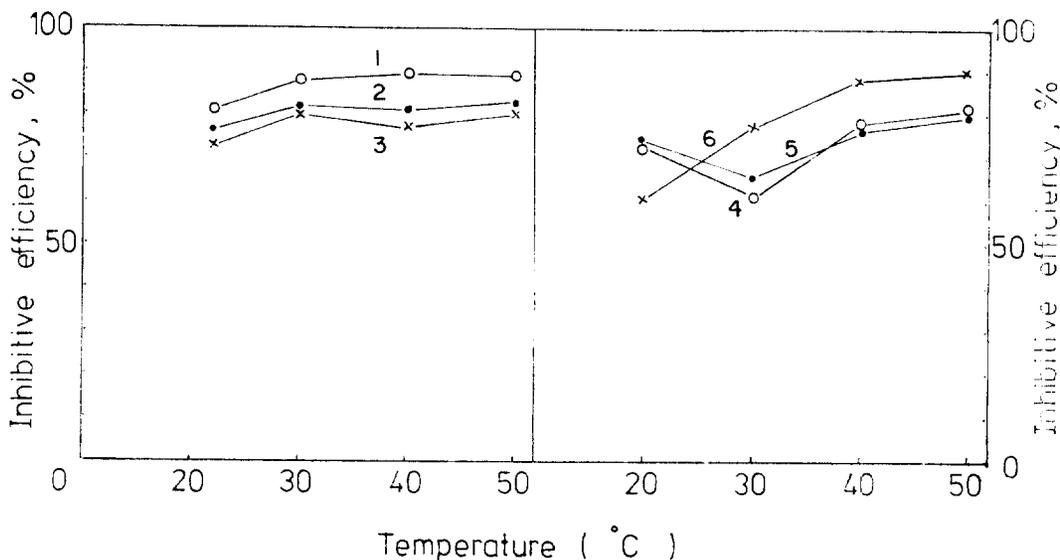


Fig 5. The influence of temperature on inhibitive efficiency of 1.0% *p*-substituted phenols for aluminium sheet in 0.1M NaOH
 1. hydroquinone 2. phenol 3. *p*-cresol 4. *p*-aminophenol 5. *p*-chlorophenol 6. *p*-nitrophenol

ines almost constant or change to a slight extent.

5. Effect of substituent groups.

In order to determine the effect of substituent groups and molecular structure on the inhibitive properties, different *p*-substituted phenols were added at 0.1M concentration to 0.1M NaOH and their inhibitive effect was measured as in table 2. At an inhibitor concentr-

ation of 0.1M, i.e. when an equal number of molecules of each of the compounds was present in the alkali, the efficiency of different para-compounds increases in the order: *p*-aminophenol (77.8%) < phenol < hydroquinone < *p*-chlorophenol < *p*-cresol < *p*-nitrophenol (96.1%)

The order of efficiency is different from that observed

Table 1. The influence of temperature on the weight loss (gr.) of aluminium sheet in 0.1M NaOH containing 1.0% *p*-substituted phenols.

inhibitor	temperature	weight loss (gr.)			
		20°C	30°C	40°C	50°C
hydroquinone		0.0142	0.0210	0.0381	0.0502
<i>p</i> -nitrophenol		0.0295	0.0358	0.0415	0.0459
<i>p</i> -cresol		0.0202	0.0320	0.0874	0.0914
phenol		0.0174	0.0291	0.0704	0.0822
<i>p</i> -chlorophenol		0.0203	0.0565	0.0837	0.0918
<i>p</i> -aminophenol		0.0205	0.0742	0.0801	0.0895
nil		0.0750	0.1650	0.3836	0.4806

Table 2. Effect of substituent groups on inhibitor efficiency of some *p*-substituted phenols for aluminium sheet in 0.1M NaOH. (inhibitor conc. : 0.1M; temperature: 20±0.5°C; immersion period: 1 hour)

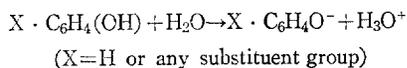
inhibitor	<i>p</i> -substituent	pKa ¹⁰⁾	pH of 0.1 MNaOH +0.1M inhibitor	weight loss(mg)	inhibition, %
phenol	—	9.99	10.3	11.1	85.6
<i>p</i> -cresol	—CH ₃	10.22	10.6	4.01	94.8
<i>p</i> -aminophenol	—NH ₂	8.16	10.6	17.1	77.8
hydroquinone	—OH	10.35	11.0	8.34	89.2
<i>p</i> -chlorophenol	—Cl	9.18	12.4	6.72	91.3
<i>p</i> -nitrophenol	—NO ₂	7.15	12.3	3.01	96.1
nil			12.3	77.2	

earlier when the results with the same quantity (% by weight) of the inhibitor were compared.

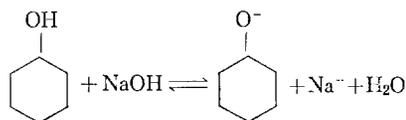
The results show that the introduction of substituent groups like—NH₂ in the para-position decreases the inhibitive efficiency of phenol whereas introduction of groups like —Cl, —OH, —CH₃ and —NO₂ increases the efficiency of the resultant compound.

The *p*K_a values of phenol and *p*-substituted phenols range between 7.15 and 10.35.

They dissociate in aqueous solution as follows:



Further, compared to the undissociated molecule, the phenoxide ion is more stable as there is no charge separation and the negative charge on the phenolate ion is distributed throughout the aromatic ring. Hence the equilibrium in above equation is displaced to the right when phenol is added to caustic alkalis⁹⁾.



The phenolate ion, because of the net negative charge, preferably on the oxygen atom, because of the lone pair of unshared electrons on the oxygen atom, may get attached to a point which would suffer anodic attack, through the (negative) oxygen atom. This will increase the electron atmosphere at such a point and thus render the detachment of (positive) metallic ions more difficult.²⁾

By introducing different substituent groups at suitable positions in the benzene ring, the negative character of the region can be enhanced and inhibition made more effective. Introduction of a negative group could do this.

In the para-substituted phenols studied, both the functional groups are in para-position to each other and therefore, the inductive effects are small due to the

great distance that separates the substituent from the reaction center.

The functional groups have both resonance and inductive effects on the electron atmosphere thus the negative character of the region can be more enhanced or less enhanced than phenol.²⁾

Therefore the order of efficiency may be obtained.

6. The Variation of pH in the corrosion

solution.

The variation of pH during the operation was detected by a pH meter (corning model-5). The results are shown in table 3.

It is observed that the extent of the variation of the variation of pH is small. Namely, the value of pH is almost constant or shows a slight tendency to decrease.

Table 3. The variation of pH in the corrosion solution.

conditions	time (min.)	pH				
		0	15	30	45	60
sample+0.1M NaOH+0.01% hydroquinone		12.3	12.4	12.3	12.0	11.6
" " +0.05% "		12.3	12.4	12.2	12.0	11.8
" " +0.1% "		12.2	12.3	12.1	12.0	11.9
" " +0.2% "		12.1	12.2	12.0	11.9	11.9
" " +0.5% "		11.5	11.6	11.5	11.35	11.35
" " +1% "		10.7	10.5	10.4	10.3	10.3
" " +2% "		9.9	9.8	9.8	9.6	9.7
sample+0.1M NaOH+0.01% p-nitrophenol		12.4	12.4	12.3	12.1	12.1
" " +0.95% "		12.3	12.3	12.2	12.1	12.2
" " +0.1% "		12.3	12.3	12.3	12.1	12.2
" " +0.2% "		12.2	12.2	12.2	12.1	12.2
" " +0.5% "		12.0	12.1	12.1	12.1	12.1
" " +1% "		11.7	11.7	11.7	11.7	11.6
" " +2% "		7.4	7.4	7.4	7.4	7.4
sample+0.1M NaOH+0.01% p-cresol		12.35	12.3	12.3	12.1	12.1
" " +0.05% "		12.35	12.2	12.2	12.1	12.1
" " +0.1% "		12.35	12.1	12.2	12.0	12.0
" " +0.2% "		12.3	12.0	12.1	12.0	11.95
" " +0.5% "		12.2	12.0	12.0	12.1	12.0
" " +1% "		11.1	11.25	11.0	11.2	11.15
" " +2% "		10.0	10.3	10.1	10.4	10.35
sample+0.1M NaOH+0.01% phenol		12.35	12.4	12.3	12.2	12.25
" " +0.05% "		12.35	12.35	12.3	12.2	12.25
" " +0.1% "		12.3	12.3	12.2	12.1	12.2
" " +0.2% "		12.3	12.3	12.2	12.1	12.2
sample+0.1M NaOH+0.5% "		12.05	12.0	12.0	11.9	11.9
" " +1% "		10.4	10.4	10.4	10.5	10.5
" " +2% "		9.65	9.65	9.7	9.8	9.8
sample+0.1M NaOH+0.01% p-chlorophenol		12.35	12.4	12.0	11.8	11.8
" " +0.05% "		12.35	12.35	12.0	11.7	11.7
" " +0.1% "		12.3	12.3	12.0	11.65	11.85
" " +0.2% "		12.3	12.3	11.9	11.6	11.7
" " +0.5% "		12.1	12.1	11.9	11.55	11.7
" " +1% "		11.35	11.4	11.2	11.0	11.0
" " +2% "		9.3	9.4	9.3	9.2	9.2

sample+0.1M NaOH+0.01% <i>p</i> -aminophenol	12. 3	12. 4	12. 2	11. 9	11. 8
+0.05% "	12. 3	12. 4	12. 2	11. 9	11. 8
+0.1 % "	12. 3	12.35	12. 1	11. 9	11. 8
+0.2 % "	12. 2	12. 3	12. 0	11. 7	11. 8
+0.5 % "	12. 2	12.25	11. 9	11.65	11. 8
+1 % "	11.05	11.05	10.85	10. 6	10. 7
+2 % "	10. 2	10. 3	10. 3	10. 2	10. 2
sample+2% <i>p</i> -nitrophenol+0.1M NaOH	4. 1	4. 3	4. 3	4. 3	4.3
+0.2M "	11. 8	11.85	11. 8	12. 0	12. 0
+0.5M "	12. 7	12. 7	12. 6	12. 6	12. 6
+1 M "	13. 0	12. 9	12. 9	12. 8	12. 7
sample+1% <i>p</i> -nitrophenol+0.1M NaOH	4. 2	4. 4	4. 4	4. 5	4. 4
+0.2M "	12. 3	12. 3	12. 3	12. 3	12. 4
+0.5M "	12. 8	12. 7	12. 8	12. 7	12. 7
+1 M "	13. 0	13. 0	12.9	12. 8	12. 8
+0.1M "	4. 8	5. 0	5. 0	5. 0	4. 9
+0.2M "	12. 5	12. 5	12. 5	12. 5	12. 5
+0.5M "	12. 8	12. 8	12. 8	12. 7	12. 8
+1 M "	13. 0	13. 0	12. 9	12. 8	12. 9
sample+2% hydroquinone+0.1M NaOH	5. 1	5. 2	5. 3	4. 9	5. 4
+0.2M "	10. 1	10. 1	10. 1	10. 3	10. 0
+0.5M "	12. 2	12. 3	12. 4	12. 1	12. 1
+1 M "	12. 8	12. 8	12. 6	12. 6	12. 6
sample+1% hydroquinone%+0.1M NaOH	5. 3	5. 5	5. 6	5. 0	5. 5
+0.2M "	11. 6	11. 5	11. 6	11. 6	11. 3
+0.5M "	12. 6	12. 6	12. 6	12. 4	12. 4
+1 M "	12. 7	13. 0	12. 7	12. 7	12. 6
sample+0.1% hydroquinone+0.1M NaOH	5. 8	6. 1	6. 2	5. 3	5. 9
+0.2M "	12. 5	12. 5	12. 5	12. 2	12. 2
+0.5M "	12. 8	12. 8	12. 7	12. 5	12. 5
+1 M "	13. 0	13. 1	12. 7	12. 8	12. 6
sample+2% <i>p</i> -chlorophenol+0.1M NaOH	5. 4	5. 7	5. 8	5. 7	5. 7
+0.2M "	11. 7	11. 7	12. 1	12. 0	11. 7
+0.5M "	12. 7	12. 8	12. 6	12. 4	12. 5
+1 M "	13. 0	13. 0	12. 5	12. 9	12. 6
sample+1% <i>p</i> -chlorophenol+0.1M NaOH	5. 7	5. 5	5. 2	5. 3	5. 2
+0.2M "	12.35	12.35	12. 2	12. 3	12. 2
+0.5M "	12. 8		12. 4	12. 4	12. 5
+1 M "	13. 1	13. 0	12. 9	12. 9	12. 7
sample+0.1% <i>p</i> -chlorophenol+0.1M NaOH	5. 8	5. 6	6. 1	5. 4	5. 7
+0.2M "	12. 5	12. 5	12. 3	12. 3	12. 4
+0.5M "	12. 9	12. 9	12. 7	12. 6	12. 6
+1 M NaOH	13. 1	13. 1	12. 9	13. 0	12. 7
sample+2% phenol+0.1M NaOH	5. 6	5. 4	5. 4	5. 1	5. 4
+0.2M "	10. 4	10. 3	10. 4	10. 6	10. 5
+0.5M "	12. 6	12. 7	12. 7	12. 6	12. 5
+1 M "	13. 0	12. 9	12. 9	12. 9	12. 8
sample+1% phenol+0.1M NaOH	5. 7	5. 5	5. 6	5. 3	5. 6
+0.2M "	12. 3	12. 2	12. 3	12. 2	12. 2

+0.5M "	12. 8	12. 8	12. 7	12. 7	12. 6
+1 M "	13. 3	13. 0	13. 0	13. 0	12. 8
sample+0.1% phenol+0.1M NaOH	5. 9	5. 6	5. 8	5. 3	5. 8
+0.2M "	12. 6	12. 5	12. 4	12. 2	12. 3
+0.5M "	12. 9	12. 9	12. 7	12. 7	12. 7
+1 M "	13. 1	13. 0	13. 0	13. 0	13. 0
sample+2% <i>p</i> -cresol+0.1M NaOH	6. 1	6. 2	6. 3	6. 2	6. 2
+0.2M "	11. 2	11. 0	11. 1	11. 3	10. 9
+0.5M "	12. 7	12. 7	12. 6	12. 6	12. 4
+1 M "	13. 0	13. 0	12. 7	12. 7	12. 5
sample+1% <i>p</i> -cresol+0.1M NaOH	6. 4	6. 2	6. 1	6. 0	5. 9
+0.2M "	12. 2	12. 3	12. 3	12. 2	12. 2
+0.5M "	12. 7	12. 7	12. 5	12. 4	12. 3
+1 M "	13. 0	12. 7	12. 5	12. 3	12. 6
sample+0.1% <i>p</i> -cresol+0.1M NaOH	6. 2	5. 9	6. 1	6. 3	6. 0
+0.2M "	12. 5	12. 4	12. 3	12. 2	12. 3
+0.5M "	12. 8	12. 6	12. 4	12. 3	12. 4
+1 M "	13. 0	12. 7	12. 4	12. 2	12. 5
sample+2% <i>p</i> -aminophenol+0.1M NaOH	7. 4	7. 3	7. 2	7. 3	7. 5
+0.2M "	11. 2	10. 9	11. 3	11. 2	11. 4
+0.5M "	13. 0	12. 6	12. 8	12. 7	12. 8
+1 M "	12. 6	12. 5	12. 7	12. 5	12. 6
sample+1% <i>p</i> -aminophenol+0.1M NaOH	7. 2	7. 6	7. 6	7. 5	7. 7
+0.2M "	12. 1	12. 2	12. 3	12. 2	12. 4
+0.5M "	12. 5	12. 5	12. 7	12. 5	12. 6
+1 M "	13. 0	12. 7	12. 7	12. 5	12. 7
sample+0.1% <i>p</i> -aminophenol+0.1M NaOH	7. 5	7. 4	7. 3	7. 3	7. 7
+0.2M "	12. 4	12. 5	12. 5	12. 4	12. 5
+0.5M "	12. 7	12. 6	12. 6	12. 4	12. 5
+1 M "	13. 0	12. 7	12. 6	12. 5	12. 3
sample+0.1M NaOH+1% <i>p</i> -nitrophenol at 20°C/hr	11. 7				11. 6
at 30°C/hr	11. 7				11. 3
at 40°C/hr	11. 7				11. 0
at 50°C/hr	11. 7				10. 6
sample+0.1M NaOH+1% <i>p</i> -chlorophenol at 20°C/hr	11. 4				11. 0
at 30°C/hr	11. 4				10. 4
at 40°C/hr	11. 4				9. 8
at 50°C/hr	11. 4				9. 6
sample+0.1M NaOH+1% <i>p</i> -aminophenol at 20°C/hr	11. 4				11. 0
at 30°C/hr	11. 2				10. 8
at 40°C/hr	11. 2				10. 3
at 50°C/hr	11. 2				10. 0
sample+0.1M NaOH+1% hydroquinone at 20°C/hr	10. 7				10. 3
at 30°C/hr	10. 5				10. 1
at 40°C/hr	10. 5				9. 8
at 50°C/hr	10. 5				9. 6

sample+0. 1M NaOH+1% phenol at 20°C/hr	10. 4				10. 5
at 30°C/hr	10. 3				10. 1
at 40 C/hr	10. 3				9. 8
at 50°C/hr	10. 3				9. 6
sample+0. 1M NaOH+1% <i>p</i> -cresol at 20°C/hr	11. 1				11. 2
at 30°C/hr	10. 3				10. 0
at 40°C/hr	10. 3				9. 7
at 50°C/hr	10. 3				10. 6
sample+0. 1M NaOH+0. 1M hydroquinone	10. 7	10. 6	10. 4	10. 7	11. 0
+0. 1M <i>p</i> -nitrophenol	12. 0	12. 0	11. 9	12. 0	12. 3
+0. 1M <i>p</i> -cresol	10. 1	10. 2	10. 15	10. 3	10. 6
+0. 1M phenol	9. 9	10. 0	9. 9	9. 8	10. 3
+0. 1M <i>p</i> -chlorophenol	12. 0	12. 3	12. 2	12. 4	12. 4
+0. 1M <i>p</i> -aminophenol	10. 4	10. 3	10. 4	10. 3	10. 6

Conclusions.

Additions of phenol and *p*-substituted phenols to NaOH solutions decreased the corrosion of aluminium sheets.

At 2.0% concentration of inhibitors, the inhibitive efficiencies of various inhibitors increased in the order, *p*-aminophenol (85.6%) < *p*-cresol < hydroquinone < phenol < *p*-nitrophenol < *p*-chlorophenol (98.6%)

But the efficiency decreased with increase in the concentration of the alkali.

The effects of immersion period and temperature on inhibitor efficiency were slight

When an equal number of molecules of each of the compounds was present in the alkali, the efficiency of different para-compounds increased in the order: *p*-aminophenol (77.8%) < phenol < hydroquinone < *p*-chlorophenol < *p*-cresol < *p*-nitrophenol (96.1%) The order of efficiency was different from that observed earlier when the results with the same quantity (% by weight) of the inhibitor.

The pH showed a tendency to decrease slightly during the operation.

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