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Kinetics of Corrosion Inhibition of Aluminum in Alkaline Solutions by Water-Soluble Poly (Vinyl Alcohol) as Synthetic Polymer

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Keywords: Corrosion, alkaline inhibition, poly (vinyl alcohol), aluminum, adsorption

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1. Introduction

Development of inhibitors for aluminum corrosion in aqueous media in particularly the alkaline solutions has been the subject of numerous investigators. Many organic [1-7], inorganic [8,9], natural polymers [10-14] and synthetic polymers [15-17] were used as inhibitors for the corrosion inhibition of aluminum in aqueous solutions. However, a little attention has been focused to the role of the inhibitor in terms of its nature and geometrical structure on the kinetics and mechanistic of the corrosion process. Indeed, Hassan and coworkers investigated the corrosion inhibition of Al by using some water-soluble anionic

polyelectrolytes containing secondary alcoholic groups such as pectates [17] in acidic media and both pectates and alginates [10] in alkaline media. They found that nature and geometrical structure of the inhibitor have an effective role on the kinetics and mechanisms of the corrosion inhibition processes for the tested solutions.

Preliminary experiments showed that poly (vinyl alcohol) as a synthetic polymer carrying secondary alcoholic groups has a remarkable inhibition effect on the rates of dissolution of Al in alkaline solutions.

In view of the above aspects, the present work of the corrosion inhibition of Al in alkali by using poly (vinyl alcohol) has been undertaken with the aim

of shedding more light on the nature and geometrical structure of the inhibitor on the corrosion mechanism. In addition, it is of interest to extend our work as a part of series of physicochemical investigations on water-soluble macromolecules such as the kinetics of oxidation [18,19], kinetics of sol-gel transformation [20], electrical properties [21,22], degradation [23] and synthesis [24] in particularly the poly (vinyl alcohol) macromolecule [25].

2. Experimental

2.1. Materials

All materials used were of analytical grade. Doubly distilled water was used in all preparations. The temperature was controlled within $\pm 0.1^\circ\text{C}$.

Poly (vinyl alcohol) (Merck grade powder 72000) was used without further purification. The degree of hydrolysis is 98.2%. The measured inherent viscosity was found to be 1.97 dl/g for a 4% w/w solution in water at 20°C (the reduced viscosity is 6.88 dl/g measured under the same condition).

Aluminum metal used was 99.98% purity (Ventron Corp, Osaka, Japan).

2.2. Preparation of Poly (Vinyl Alcohol) Sols

Poly (vinyl alcohol) sol was prepared as described elsewhere [25]. This process was performed by stepwise addition of the powder reagent to doubly distilled water whilst vigorously stirring the solution to avoid the formation of lumpy precipitates, which swell with difficulty.

2.3. Hydrogen Evolution Measurements

This technique provides a rapid and reliable means of assessing the inhibitive performance of corrosion inhibition of aluminum in alkaline solutions at short term immersion periods. The

rates of corrosion were determined volumetrically. This process was performed by measuring the evolved hydrogen produced from the dissolution of aluminum in NaOH. Rectangular specimen of metal aluminum of around 3 cm long and 2 cm in diameter were used without further polishing to ensure reproducible surface. However, they were washed with carbon tetrachloride, absolute ethyl alcohol and then dried in acetone and stored in moisture-free desiccators prior to be used in the corrosion testing. The specimen were suspended by means of glass hooks in the tested solutions of NaOH which were previously placed into conical flasks fitted with graded side-arm burette filled with doubly-distilled water as described elsewhere [10]. The conical flasks were thermostated in a controlled water-bath at the desired temperature within $\pm 0.1^\circ\text{C}$. When the NaOH solution had attained the temperature of the thermostat, the Al specimen was immersed into the alkali solution. The course of reaction was followed gasometrically by recording the volume of evolved hydrogen as a function of time. The volume of active hydrogen was evaluated in accordance to the dimensions of Al specimens plates used.

Some kinetic measurements were performed using the classical weight-loss method [26, 27] in order to check the reproducibility of the gasometric data obtained. The analyses of the results obtained were found to be in a good agreement with each other within the experimental errors ($\pm 5\%$). This fact may indicate the reproducibility of the results obtained, by gasometric method. No stirring of the corrosion medium was employed.

All experiments were repeated using different concentrations of NaOH and inhibitor at various temperatures. The results used were at least an average of five experimental runs.

The ionic strength was maintained constant at 4.0 mol dm^{-3} by adding NaClO_4 as an inert electrolyte.

3. Results

3.1. Evolved-Hydrogen (and Weight-Loss) – Time Curves

Corrosion inhibition performance of organic compounds as corrosion inhibitors can be evaluated using electrochemical and chemical techniques [14]. For the chemical methods, weight-loss measurements are ideally suited for long term immersion tests, whereas the gasometric technique is more suitable for the short term immersion tests. The volume of the evolved hydrogen (or weight loss of Al metal) was measured as a function of time and can be defined as the rate of dissolution of aluminum in sodium hydroxide and can be expressed by Equations. <1> and <2>, respectively:

$$R_c = \frac{V_{H_2}}{S \cdot t} \quad <1>$$

$$R_c = \frac{\Delta W}{S \cdot t} \quad <2>$$

where R_c is the rate of corrosion, S is the surface area of Al metal (cm^2), t is the time (min), V_{H_2} is the volume of evolved hydrogen (ml) and ΔW is the loss in mass (mg) of Al metal in the corrosive medium.

3.2. Dependence of Corrosion Rate on [PVA]

Plots of the evolved-hydrogen or weight-loss against the time gave good straight lines. Typical plots are shown in *Figures 1 and 2*, respectively. The rate of corrosion (R_c) was obtained from the slopes of such plots. The values of R_c were calculated by using the least-squares method and are summarized in *Table 1*. Increasing the concentration of PVA, keeping the concentrations of all other reagents constant resulted in decreasing the corrosion rate as shown in *Table 1*.

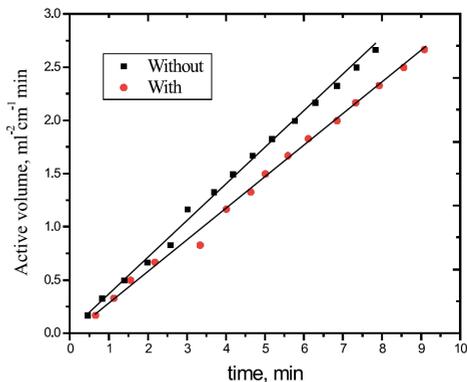


Fig. 1: Plots of hydrogen evolved vs. time in the corrosion of aluminum in sodium hydroxide in the absence and presence of 0.02 mol dm^{-3} (0.4 %) PVA inhibitor. $[\text{OH}^-] = 4.0 \text{ mol dm}^{-3}$, $I = 4.0 \text{ mol dm}^{-3}$ and 25°C .

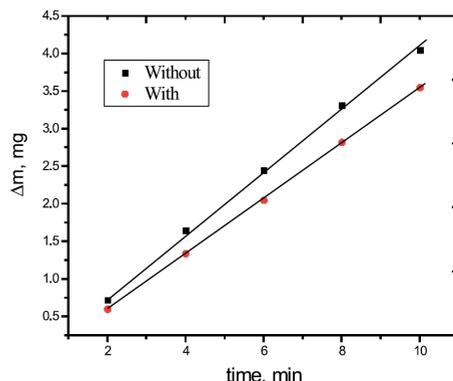


Fig. 2: Plots of weight-loss vs. time in the corrosion of aluminum in sodium hydroxide in the absence and presence of 0.02 mol dm^{-3} (0.4 %) PVA inhibitor.

$[\text{OH}^-] = 4.0 \text{ mol dm}^{-3}$, $I = 4.0 \text{ mol dm}^{-3}$ and 25°C .

It was found that the experimental runs which performed by weight – loss or H_2 gas evolution methods gave values of R_c in good agreement with each other within experimental errors ($\pm 5\%$) (*Table 1*).

3.3. Dependence of Corrosion Rate on [OH-]

In order to examine the influence of alkali concentration on the corrosion rates, some exper-

imental runs were performed at various initial concentrations of the alkali at constants for all other reagents. The corrosion rate was found to increase with increasing the alkali concentration. The results are summarized in *Table 2*.

The percentage of inhibition efficiency (I.E %) of PVA inhibitor was calculated using the following equation

$$\% I.E = \frac{R_c^o - R_c'}{R_c^o} \times 100 \quad <3>$$

where R_c^o and R_c' are the corrosion rates of Al metal in the absence and presence of PVA inhibitor. The results are listed in *Table 3*.

3.4. Dependence of Corrosion Rate on Temperature

In order to evaluate the kinetic parameters of the corrosion process, experimental measurements

Tab. 1: Dependence of the corrosion rate on [PVA] in the corrosion of Aluminum in alkaline medium. [OH⁻] = 4.0, I = 4.0 mol dm⁻³ and various temperatures.

[PVA] %	10 ² mol dm ⁻³	R _c , ml cm ⁻² min ⁻¹	
		25°C	30°C
0	0	0.38 (0.36*)	0.6 (0.51*)
0.1	2	0.34	0.49
0.6	3	0.31	0.44
0.8	4	0.28	0.39
1.2	6	0.25	0.35

Experimental errors ± 5%

*Calculated from the weight - loss method

Tab. 2: Dependence of the corrosion rate on [OH⁻] in the corrosion of Aluminum in alkaline medium. [PVA] = 0.02 mol dm⁻³ (0.4 %) and various [OH⁻] at 25°C

[OH ⁻], mol dm ⁻³	2.0	3.0	4.0	5.0	6.0
R _c , ml cm ⁻² min ⁻¹	0.25	0.30	0.34	0.38	0.42

Tab. 3: Percentage inhibition efficiency (% I.E.) in the corrosion of Aluminum in alkaline medium. [OH⁻] = 4.0 mol dm⁻³, I = 4.0 mol dm⁻³ and various temperatures.

10 ² [PVA], mol dm ⁻³ (%)	2.0	3.0	4.0	6.0
	(0.4)	(0.6)	(0.8)	(1.2)
25°C	11.8	18.95	26.31	34.21
30°C	19.16	26.67	35.17	41.17

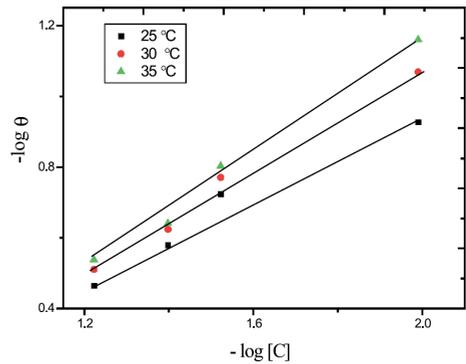


Fig. 3: Freundlich isotherm in the corrosion of aluminum in sodium hydroxide. [OH⁻] = 4.0 mol dm⁻³, I = 4.0 mol dm⁻³ and various temperatures.

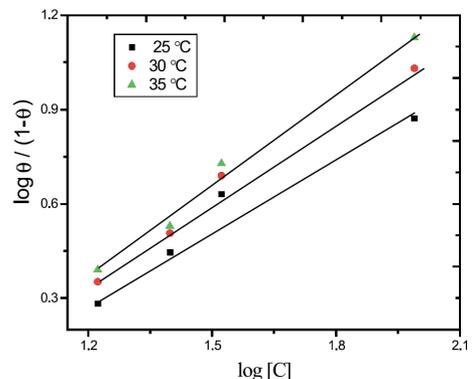


Fig. 4: Plots of Modified-Freundlich isotherm (El-Wady and coworkers) in the corrosion of aluminum in sodium hydroxide. [OH⁻] = 4.0 mol dm⁻³, I = 4.0 mol dm⁻³ and various temperatures.

Tab. 4: Thermodynamic parameters in the corrosion of Aluminum in alkaline medium (Freundlich and El-Wady isotherms). $[\text{OH}^-] = 4.0 \text{ mol dm}^{-3}$ and $l = 4.0 \text{ mol dm}^{-3}$ at 25°C .

Model \ Parameter	n	$10^2 K$, $\text{dm}^{-3} \text{ mol}^{-1}$	$-\Delta G^\circ$, kJ mol^{-1}	$-\Delta H^\circ$, kJ mol^{-1}	$-\Delta S^\circ$, $\text{J mol}^{-1} \text{ K}^{-1}$	R^2
Freundlich isotherm	0.59	0.55	8.46	38.29	100.15	> 0.99
El-Wady isotherm	0.75	0.26	3.39	34.92	105.8	~ 0.99

Experimental Errors $\pm 3\%$

were performed at various temperatures and constants of all other reagents. The corrosion rates were found to increase with increasing the temperature. The kinetic data were found to fit both the Arrhenius and Eyring equations as shown in *Figures 3 and 4*. The kinetic parameters were evaluated from the temperature dependence of the corrosion rates using the method of least-squares. The results are listed in *Table 4*.

4. Discussion

It has been reported [28] that increasing the alkali concentration is usually accompanied by an increase in the dissolution of Al metal as was experimentally observed. The observed fractional first-order in $[\text{OH}^-]$ for the corrosion process means that at least one of the corrosion-paths of Al in NaOH should be involved a hydroxide ion in the rate-determining step. The inhibition efficiency (% I.E) was found to increase with increasing the concentration of the added inhibitor (*Table 3*). It may be affected by many factors such as the adsorption of the additives on Al metal surface which depends on some physicochemical properties such as the nature of the medium, the position of the functional groups, steric effects and geometrical configurations of the inhibitor [13,14].

4.1. Corrosion Mechanism

In view of the above interpretations and the experimental observations, a suitable mechanism for corrosion may be suggested. It involves the electrochemical process resulting from dissolution of Al metal by the alkali [29]. This process can be expressed by the following anodic and cathodic processes, Equations <4> and <5>, respectively,



The overall electrochemical process is



The cathodic reaction produced $\text{H}_{\text{chemisorbed}}$ by picking up an electron that released in the anodic reaction ($\text{H}^+ + \text{e} = \text{H}_{\text{chemisorbed}}$) for corrosion of Al in NaOH. In such alkaline solutions, the $\text{H}_{\text{chemisorbed}}$ on the metal surface reacts by combining with other adsorbed $\text{H}_{\text{chemisorbed}}$ to form a molecule of H_2 gas, which bubbles from the metal surface. Of course, a very small amount of the uncombined $\text{H}_{\text{chemisorbed}}$ will remain; however, this amount does not affect the whole process. Therefore, the rate of combination and adsorption of $\text{H}_{\text{chemisorbed}}$ are nearly the same for all inhibitor levels. This fact is confirmed

by the identical results obtained for the corrosion rates calculated from the gasometric and weight-loss techniques in *Table 1*.

Generally, the inhibitor can affect the corrosion rate of metals in the corrosive media if it is able to affect the kinetics of dissolution or alter the position of electrochemical behavior [30]. This effect takes place when a thin film of the inhibitor is formed on the surface of metal by either the interaction or adsorption processes. The protective coating of the thin film will isolate the metal from the corrosive medium.

As shown in *Table 1*, addition of small amounts of poly (vinyl alcohol) to Al in NaOH leads to a remarkable decrease in the corrosion rate of aluminum metal in alkali. This means that the corrosion rate is a function of the concentration of alkali. The net result may be explained by adsorption of a thin film of the inhibitor on Al surface. The formed film will prevent more aluminum atoms from leaving the metal surface to dissolve into the corrosive medium and, hence, the corrosion rate is decreased. Therefore, the anodic reaction may be suggested to be the rate-determining step in the present corrosion process.

Again, Khairou and El-Sayed [31] reported that the functional hydroxyl groups of the macromolecules could be bridged between the polymer and the metal surface which leading to the observed inhibition effect. The formation of alkoxide form of the inhibitor in the alkaline solutions as well as the presence of lone pairs of electrons on the oxygen atoms of the hydroxyl groups of the inhibitor may enhance the adsorption between the inhibitor and the positive sites which are formed on Al surface (as a result of liberation of electrons in the anodic process).

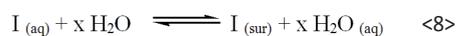
4.2. Adsorption Isotherms

In aqueous solutions, the metal surface is always covered with the adsorbed water molecules.

Therefore, the adsorption of inhibitor molecules from aqueous solutions is a quasi substituted process [32]. Hence, the inhibitors that have the ability to be adsorbed strongly on the metal surface will hinder the dissolution reaction of the immersed metal in the corrosive medium. Here, the degree of the surface coverage (θ) is considered as the determining factor that plays the main role for the adsorption process phenomenon [17]. The value of (θ) can be evaluated from the relationship

$$\theta = 1 - (R'_c)_{inh} / (R^{\circ}_c)_{free} \quad <7>$$

where $(R'_c)_{inh}$ and $(R^{\circ}_c)_{free}$ the corrosion rates in the presence and absence of inhibitor. It was noticed that θ values decreased with increase in temperature as a result of increased the adsorption of inhibitor molecules. Again, the θ values increased with increase in inhibitor concentration as a result of decrease in the corrosion rates (R'_c) . Theoretically, the adsorption process can be regarded as a single substitution of (X) molecule from the water molecules adsorbed on the metal surface by the following equation



where x is the size ratio and equals the number of adsorbed water molecules replaced by a single inhibitor molecule (I). The extent of adsorption is mainly dependent on many factors, such as the condition of the metal surface, chemical structure of the inhibitor, the nature and position of the functional groups, pH and type of corrosion medium and temperature [14, 16, 33].

Such an adsorption provides some information about the interaction among the inhibitor molecules themselves as well as on their interaction with the metal surface. Actually, the adsorbed molecules may cause some difficulty for the surface to adsorb some further molecules from

neighboring sites and, hence, a multilayer-adsorption may take place. The net result, is that the various surface sites could be had varying degrees of activation. For this reason, a number of mathematical adsorption expression models have been developed to fit the degree of surface coverage through adsorption isotherms, graphically, in order to provide some knowledge on the nature of interaction of the adsorbed molecules. The correlation coefficient (R^2) obtained through those isotherms can be used to determine the best fit model.

Langmuir isotherm suggests that each site holds one adsorbed species [33, 34, 35]. This isotherm can be represented by the following relationship

$$\frac{C}{\theta} = \frac{1}{K_{ads}} + C \quad <9>$$

where C is the molar concentration of the inhibitor and K_{ads} is the equilibrium constant of adsorption process. Equation <9> required that a plot of C/θ against C should be linear with unity slope. The experimental data were found to satisfy this requirement with good correlation coefficients, but the slopes were deviated from unity. The deviation from unity may indicate that the model of Langmuir isotherm not be strictly applied.

On the other hand, the experimental results of the present work were found to follow the Freundlich adsorption isotherm [16, 36] which obeys the following relationship

$$\log \theta = \log K_{ads} + n \log [C] \quad (0 < n < 1) \quad <10>$$

According to Equation <11>, Plots of $\log \theta$ against $\log [C]$ should be linear with intercepts on $\log \theta$ axis as was experimentally observed in *Figure 3*. The values of n and K_{ads} can be evaluated from the slopes and intercepts of such linear plots. These values were calculated by the method of least - squares and are summarized in *Table 4*.

Furthermore, it was surprising to find the kinetic results obtained in the present work were verified the adsorption model of El-Wady [33].

$$\log (\theta / 1 - \theta) = \log K' - n \log C \quad <11>$$

The results are shown in *Figure 4*. The equilibrium constant of adsorption $K = K'^{(1/n)}$, where $1/n$ is the number of surface sites occupied by one inhibitor molecule. The results are summarized along with that obtained in the data of Freundlich adsorption isotherm model (*Table 4*).

The standard adsorption free energy (ΔG°) which is associated with the water adsorption / desorption equilibrium can be calculated from the well-known relationship [33, 36] that relates the adsorption equilibrium constant to the adsorption free-energy by the equation

$$\log K_{ads} = - \log C_{H_2O} - (\Delta G^\circ)_{ads} / 2.303 RT \quad <12>$$

where C_{H_2O} is the molal concentration of water (55.5), R is the gas constant and T is the absolute temperature (*Table 4*). The negative values obtained for ΔG°_{ads} indicates that the adsorption process of PVA inhibitor on Al surface is consistent with the spontaneity of such adsorption process as well as the stability of the adsorbed layer of PVA inhibitor on Al surface.

Thermodynamically, ΔG°_{ads} is related to the enthalpy (ΔH°_{ads}) and entropy (ΔS°_{ads}) of adsorption process by the famous Gibbs- Helmholtz equation

$$\Delta G^\circ_{ads} = \Delta H^\circ_{ads} - T \Delta S^\circ_{ads} \quad <13>$$

From equations <12> and <13>, the following equation may be obtained [35],

$$\log K_{ads} = \left(- \log C_{H_2O} + \frac{\Delta S^\circ_{ads}}{2.303R} \right) - \frac{\Delta H^\circ_{ads}}{2.303RT} \quad <14>$$

Plots of $\log K_{\text{ads}}$ vs. $1/T$ gave good straight lines from whose slopes and intercepts the values $\Delta H^{\circ}_{\text{ads}}$ and $\Delta S^{\circ}_{\text{ads}}$ can be evaluated. These values were calculated by using the least-squares method and are summarized in *Table 4*.

The activation parameters of the corrosion inhibition were calculated from the dependence of the corrosion rate on temperature. This dependence was found to fit the Arrhenius and Eyring relationships [37], which are defined by equations <15> and <16>, respectively, as follows

$$\ln R_c = \ln A - \frac{E^{\ddagger}}{RT} \quad <15>$$

where, A is the frequency factor, E^{\ddagger} is the apparent activation energy, R is the gas constant and T is the absolute temperature. And,

$$-\ln \frac{Rh}{NT} R_c = \frac{\Delta H^{\ddagger}}{RT} - \frac{\Delta S^{\ddagger}}{R} \quad <16>$$

where h is the Planck's constant, N is the Avogadro's number, ΔH^{\ddagger} is the enthalpy of activation and ΔS^{\ddagger} is the entropy of activation. The kinetic results were found to fit the Arrhenius and Eyring equations where plots of $1/T$ vs. $-\ln R_c$ or $1/T$ vs. $-\ln (hR_c/k_B T)^*$ gave good straight lines, from whose slopes and intercepts, the activation parameters ΔH^{\ddagger} and ΔS^{\ddagger} can be evaluated (*Figures 5 and 6*). These values were calculated by using the least-squares method and are summarized, along with that reported for the corrosion inhibition of Al in alkaline medium by other natural polymer inhibitors (*Table 5*). The positive values of ΔH^{\ddagger} reflect the endothermic process of adsorption of the inhibitors on Al surface. The negative values of ΔS^{\ddagger} may reflect the association mechanism of corrosion, i.e. the decrease in disorderly takes place on going from reactants to the activated states [13, 14].

* k_B is the Boltzman's constant ($k_B = R / N$)

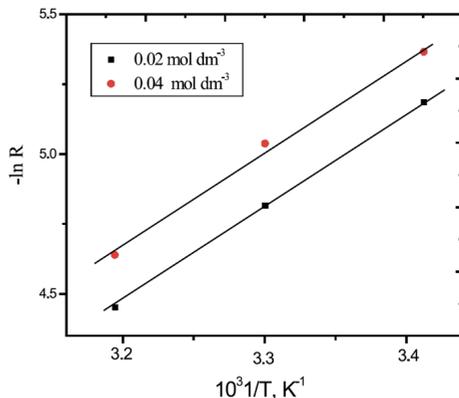


Fig. 5: Arrhenius plots of the temperature-dependence of the corrosion rate in the corrosion of aluminum in sodium hydroxide. $[OH^-] = 4.0 \text{ mol dm}^{-3}$ and $I = 4.0 \text{ mol dm}^{-3}$.

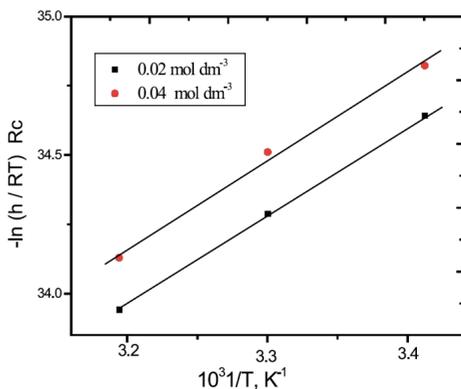


Fig. 6: Eyring plots of the temperature-dependence of the corrosion rate in the corrosion of aluminum in sodium hydroxide. $[OH^-] = 4.0 \text{ mol dm}^{-3}$ and $I = 4.0 \text{ mol dm}^{-3}$.

It was also noticed that addition of small amounts of the inhibitor to the tested solutions alters the values of ΔS^{\ddagger} (in absence of inhibitors) to a less negative values, i.e. inhibits the corrosion rates. This result may be considered as indirect evidence to support the cited proposed mechanism. Furthermore, the E^{\ddagger} values obtained for the inhibited solutions were found to be higher than that of the uninhibited ones indicating the inhibitive action influence of PVA, by increasing the

Tab. 5: Activation parameters of the corrosion of Aluminum in alkaline medium in the presence and absence of added natural and synthetic polymers containing secondary alcoholic groups.

Inhibitor	Conc. mol dm ⁻³	*R _c mol cm ⁻² min ⁻¹	*I.E. %	*H [‡] kJ mol ⁻¹	*S [‡] J mol ⁻¹ K ⁻¹	*G [‡] kJ mol ⁻¹	E _a [‡] kJ mol ⁻¹	A mol ⁻¹ s ⁻¹	Ref.
Without	0	0.38	-	58.85	-61.97	77.31	53.75	1.11x10 ¹¹	This work
	0.02	0.34	11.8	53.46	-108.63	85.83	55.98	3.39x10 ⁷	This work
PVA	0.04	0.28	26.3	51.85	-79.88	75.66	55.75	1.99x10 ⁹	This work
	0.06	0.25	34.2	55.39	-104.71	86.59	57.6	5.11 x10 ⁷	This work
Alginate	0.02	0.28	26.5	66.14	-67.69	86.31	68.67	4.98x10 ⁹	10
	0.04	0.16	58.9	69.86	-24.56	76.16	71.98	1.46x10 ¹¹	10
Pectate	0.02	0.17	46.7	88.53	-3.69	89.63	91.06	8.63x10 ¹³	10
	0.04	0.08	72.7	76.93	-2.78	77.21	78.75	1.11 x10 ¹³	10

Experimental errors ± 4 % / *At temperature = 25 °C

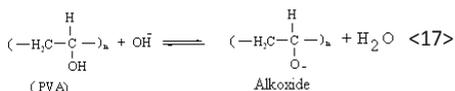
energy barrier for the corrosion process, emphasizing the electrostatic character of the inhibitor's adsorption on Al surface (alkoxide formed by deprotonation of PVA). Again, it was observed that the apparent activation energy, E_a[‡], began to decrease at higher inhibitor concentration. This result may be arising from the shift of the net corrosion reaction from that on the uncovered surface to one involving the adsorbed sites [35, 38]. It noticed that the magnitude of the corrosion rates was decreased in the order PVA > alginate > pectates inhibitors, whereas the inhibition efficiency was increased in the same order, respectively, as shown in *Table 5*. This means that the nature of the inhibitor plays an important role in the behavior of the corrosion inhibition of Al in alkali. This result may be explained on the basis of the properties of the functional hydroxyl groups present on the inhibitor monomers such as the number of OH groups, geometrical positions and the tendency of such groups for deprotonation in alkaline media.

A reported Khairou and coworkers [31] that the hydroxyl groups tend to form bridges between the

inhibitor and the Al metal surface which enhance the inhibitor adsorption on aluminum metal surface. Consequently the number and geometrical position of such OH groups may be considered as the determining factors that play the main role in the magnitude of the inhibitor adsorption efficiency. Alginates (ALG) and pectates (PEC) possessing two hydroxyl functional groups in their monomers, whereas PVA has only one OH group, therefore, we expect that the inhibition efficiency of PEC and ALG would be greater than that of PVA as was experimentally observed (*Table 5*). Again, the structure of pectate is closely related to that of alginates [18]. The principal structural difference between them is the position of the two C-2 and C-3 hydroxyl groups being cis- position in alginates and trans-position in pectates or, if the conformation is considered, axial-equatorial and equatorial-equatorial, respectively. Therefore, the presence of OH group in cis-position in alginates [18] may hinder the adsorption process owing to the steric hindrance, whereas the existence of trans-position of OH groups in pectates [19] will enhance the adsorption process of the

inhibitor as was experimentally observed. This means that the inhibition efficiency of pectates is more effective than that of alginates as shown in *Table 5*.

On the other hand, these inhibitors are water-soluble macromolecules of linear block copolymer structures which have high tendencies for deprotonation by alkali to give the more active alkoxide anions as follows [18, 19, 25]:



The magnitude of the deprotonation constant was found to increase in the order PVA < alginates < pectates [18, 19, 25] and, hence, we can expect that the inhibition efficiency should be increased in the same order as was experimentally observed.

5. Conclusion

1. Poly (vinyl alcohol) as a synthetic polymer is considered to be effective inhibitor for corrosion of aluminum in alkaline medium.
2. The inhibition efficiency of pectates and alginates as inhibitors for Al dissolution in alkaline media was found to be greater than that of poly (vinyl alcohol) which is depending on the number of hydroxyl groups present within the macromolecular chains as well as its geometrical configuration. Therefore, such variable factors will play an important role in the magnitude of the inhibition efficiency.
3. Natural or synthetic polymers containing the same functional groups follow similar mechanisms for corrosion processes.

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