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ELECTROCHEMICAL RULES OF FERRUM-ALUMINIUM ELECTRODES PAIR DISSOLVING WHEN POLIRIZED WITH ALTERNATING CURRENT

Abstract. The purpose of this work is to research electrochemical rules of dissolution of a pair of ferrum-alluminium electrodes when polarized with 50 Hz industrial alternating current. The process of dissolution of ferrous and aluminium electrodes was researched (Fe-Al) in water solution of chlorohydric acid with electrolysis method. It was established, that when current density is alternated within interval of 100–300 A/m^2, dissolving current output of aluminium electrode increases from 62 to 90,4 %, and for ferrous electrode increases from 12 to 34 %. It is established that along with increase of chlorohydric acid concentration, dissolving current output for ferrous electrode is not changing. At the same time dissolving current output for aluminium electrode is increasing. Results of research as regards impact of electrolysis time upon the process showed that together with increase of time, ferrum dissolving current output with creation of ferrum ions remains stable. At the same time aluminium dissolving current output with time decreases. It is established, that within the temperatures range 25–70 °C, together with its increase the processes of ferrum and aluminium dissolution intensify. Possibility to synthesize mixed salts of researched metals by ferrum and alluminium polarization with alternating current in chlorohydric acid is demonstrated.

Key words: electrochemistry, electrolysis, aluminum, ferrum, coagulant, current density, concentration, electrode, alternating current, temperature.

Electrochemical method is one of environmentally friendly technologies [1-6]. Therefore application of industrial alternating current for the purposes of synthesis of metal compounds from water medium, that are significant for national economy, gives opportunity for resolving a range of problems connected with purification of natural water bodies and making coagulant for these purposes [7].

Suspended dispersed and colloidal particles in water in the majority of cases have equal charges, that preconditions appearing of intermolecular repulsion powers and aggregate stability. Since water purification technology envisages partial or complete removal of impurities, they try to destroy particles' stability, removing their charge or decreasing it to very small values. This effect is obtained by adding to the water sulfates of aluminium, ferrum (II) and ferrum (III), aluminium chloride, ferrum chloride (III), aluminate of soda, aluminium oxychloride and other substances that being coagulants either violate aggregate stability or create hydrolysis-caused colloids absorbing alloys from water [8-16].

Dissolving of ferrous electrode together with aluminium electrode when polarized with alternating current was researched (table 1). This type of experiment was intended for electrochemical synthesis of ferrous-aluminium coagulant in acid solutions. The experiment showed that within interval of current densities 100–300 A/m^2 dissolving current output for aluminium electrode comprised not more than from 62 to 90,4 %, and for ferrous electrode increased from 12 to 34 %. Dissolving current output for ferrous electrode compared to aluminium electrode is less. In anodic half period the increase of electrode chemical dissolution happens due to substantial hydrogen disengagement speed up on the surface of electrode, which gives alkaline characteristics to the solution.

Table 1 – Impact of current density upon mixed ions creating current output when aluminium ferrous electrodes pair is polarized with alternating current

i, A/m^2	100	150	200	250	300
BT (Fe), %	12,0	13,1	16,2	25,0	34,0
BT (Al), %	62,0	62,4	87,0	89,3	90,4
Note: HCl – 1M; τ = 1,5 hour; t = 25ºC.					

Emergence of aluminium ions (III) when polarized with alternating current is explained by the fact that aluminium electrode dissolves in anodic half period and aluminium ions (III) disengage in the process, while in cathodal half period hydrogen ions discharge on the surface of the metal.

$$Al^0 + 3\,e \rightarrow Al^{+3} \quad (1)$$

$$2H^+ + 2e \rightarrow H_2 \quad (2)$$

Standard electrode potential of ferrum transfer into ions has negative values:

$$Fe - 2e \rightarrow Fe^{2+}\ E^0 = -0{,}44\ V \quad (3)$$

$$Fe - 3e \rightarrow Fe^{3+}\ E^0 = -0{,}04\ V \quad (4)$$

However, the oxide layer emerging on its surface in atmospheric conditions does not allow the metal to dissolve in the water, but ferrum is slightly dissolvable in acids, for example, in chlorohydric acid, however, the speed of dissolution is not high.

$$Fe + 3HCl \rightarrow FeCl_3 + H_2 \quad (5)$$

Main reaction going on during anodic oxidation of ferrum in chlorohydric acid – dissolving of metal with creation of two- and trivalent ions, and creation of oxide layer on it if current density is high.

Process of depassivation of certain part of metal in presence of chloride ions is shown in the literature [17-20]. With adsorption method, it pushes out from the metal surface passivating oxygen, which in the end increases speed of dissolving process.

Chlorohydric acid concentration impact upon ferrous-aluminium electrode dissolving current output and upon creation of mixed compounds (table 2) was researched. With current density of 150 A/m^2 and chlorohydric acid concentration increase up to 4M, ferrous electrode dissolving current output does not change, while aluminium electrode dissolving current output increases up to 200 %. In ferrous-aluminium electrodes' pair due to negative value of standard potential of the aluminium electrode, active dissolution of this electrode is observed in anodic half period, while ferrous electrode in this half period is almost not dissolving. It can be explained by the fact that alternating current increases speed of metal oxide film dissolving and chemical dissolution process happens; all these processes result in increase of aluminium electrode current yield.

Table 2 – Impact of chlorohydric acid concentration on ferrum and aluminium dissolving current yield when ferrous-aluminium electrode pair is polarized with alternating current

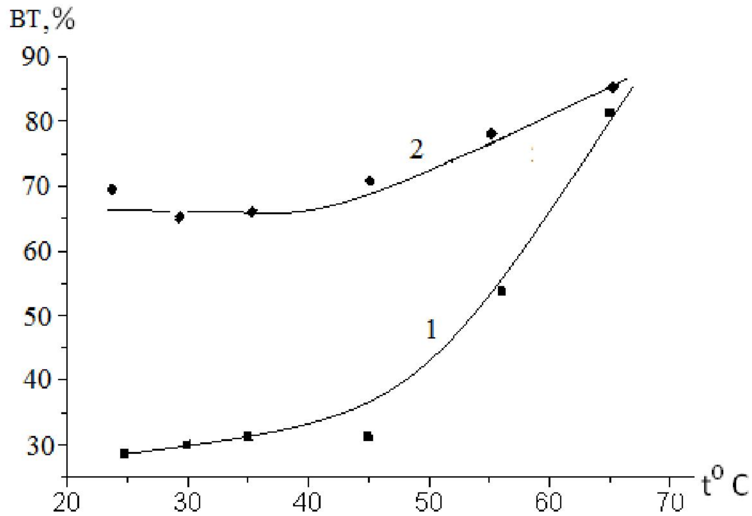
C, H	1,0	2,0	3,0	4,0
BT (Fe), %	18,3	18,3	18,2	18,2
BT (Al), %	72,1	95,1	142,5	200,0
Note: i = 150 A/m^2; τ = 1,5 hour; t = 30ºC.				

As it is obvious from table 3, if electrolysis is extended, ferrous electrode dissolving current output with creation of ferrum ions (II) comprises 20 % and the value stays stable with the flow of time, while aluminium electrode dissolving current output decreases. In galvanic ferrous-aluminium pair of electrodes passivation of ferrous electrode in chlorohydric acid is observed. In galvanic pair of electrodes the process of ferrum chemical dissolution happens when disconnected from electrodes circuit as well. Ferrous-aluminium pair of electrodes, when polarized with alternating current in acid solutions, aluminium ions (III) creating current output decreases if electrolysis process is extended. After a period of time decrease of aluminium dissolving current yield is explained by passivating, which happens due to the fact that electrolysis product covers the electrode surface and concentration polarization occurs.

Table 3 – Impact of electrolysis period on ferrum and aluminium dissolving current output
when ferrous-aluminium pair of electrodes is polarized with alternating current

τ, hour	0,5	1,0	1,5	2,0	3,0
BT (Fe), %	20,0	20,0	20,1	20,1	20
BT (Al), %	79,0	75,0	71,2	60,5	39,1
Notes: HCl – 1M; i = 150 A/m^2; t = 25 °C.					

In further experiments, researches as regards impact of temperature upon dissolving current output for ferrous-aluminium pair of electrodes when polarized with alternating current (figure) were carried out. In the process of polarization with alternating current, if electrolyte temperature is increased up to 70 °C, ferrous electrode dissolving current output increases from 31 to 79,6 %. This phenomenon is explained by the fact that ferrum surface at high temperature partially looses oxide film and together with electro-chemical dissolution ferrous electrode's chemical dissolving is increasing. Aluminium electrode current output increases from 65,5 to 88,2 %.



Impact of temperature upon dissolving current output
for a pair of ferrous (1) - aluminium (2) electrodes when polarized with alternating current:
HCI – 1M; i = 150 А/м^2; τ = 1,5 hour

Increase of current output at high temperatures is connected with speed up of additional reactions of hydrogen disengagement on an electrode, which increases pH alkalinity in the solution around surface of the electrode in this way activating mechanism of electrode chemical dissolving.

Therefore, we have researched process of ferrum and alluminium dissolving with application of 50 Hz industrial alternating current by dissolving a pair of ferrum-aluminium electrodes. Based on the results of researches, absolutely new electrochemical methods of ferrum and aluminium compounds synthesis from metal waste (metal scrap and chips), which are frequently uses as coagulants for waste-water treatment from dispersed pollutants, were developed.