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## Research of Water Catholyte of Presence of Nascent (Atomic) Hydrogen (H<sup>\*</sup>). Hydrogen and Nascent Hydrogen of the Reactions for Origin of Life in Hot Mineral Water

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### Abstract

A reaction is published for forming of nascent (atomic) hydrogen (H<sup>\*</sup>) from hydronium ions (H<sub>3</sub>O<sup>+</sup>) in catholyte (Ignatov et al., 2015). It is also observed the production of nascent hydrogen in electrolysis in the transition to H<sub>2</sub> (Mehandjiev et al., 2017a, b). For checking of the theoretical suggestion experiments with potassium permanganate (KMnO<sub>4</sub>) are conducted. Potassium permanganate is a strong oxidizing agent. In this compound, manganese is in the +7 oxidation state (Mn<sup>7+</sup>). In reduction process the color of the aqueous solution of KMnO<sub>4</sub> is changed and thus the process could be examined spectrophotometrically. Described is a reaction that proves the presence of nascent hydrogen in catholyte using potassium permanganate (Parn et al., 2012). In order to avoid the influence of salts contained in water from other sources, deionized water is used for production of catholyte/anolyte.

There is possibility nascent hydrogen to have been part of reaction for origin of life in hot mineral water in primary hydrosphere as result of contact with hydrogen from primary atmosphere with hydrogen and gas discharge (Ignatov, 2019).

**Keywords:** electrolysis, catholyte, anolyte, nascent hydrogen, reduction.

### 1. Introduction

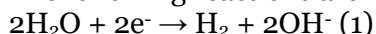
The interest towards electrochemically activated water (ECAW) increases due to its applications. It is gained from electrolysis with direct current where the electrodes are separated with semipermeable membrane. The liquid surrounding the cathode is called catholyte, and the liquid surrounding the anode is called anolyte. It is observed a higher pH in catholyte (> 7.0) in comparison with the water before activation. Lower pH is observed in the anolyte (< 7.0) compared to the water before activation. The catholyte has reduction properties, and the anolyte oxidative. The catholyte has beneficial effect over the human health. The strong oxidative action of anolyte enables its use as an antibacterial tool for disinfection, in agriculture, and for purifying contaminated water.

For the science however, still remains open the question what determines these specific properties of ECAW. A large number of scientific investigations are conducted in this field, and certain physical properties of ECAW are established.

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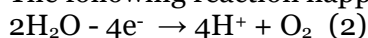
E-mail addresses: [mbioph@dir.bg](mailto:mbioph@dir.bg) (I. Ignatov)

The following reactions are known:



The hydrogen gas is separated and the water acquires alkaline reactivity. The catholyte has reduction properties, and it has increase in number of the electrons compared to the control sample, and a negative ORP.

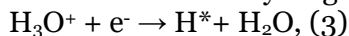
The following reaction happens in the anode section



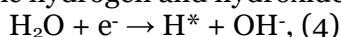
The anolyte has oxidative properties and there is reduction in number of the electrons in it, and a positive ORP, compared to the control sample.

The following is valid (Ignatov, Mosin et al., 2015).

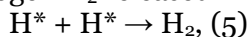
The gaseous hydrogen is generated at the cathode while the oxygen is produced at the anode. Water also contains a certain amount of hydronium ions ( $\text{H}_3\text{O}^+$ ) depolarizing at the cathode with formation of the atomic hydrogen:



In an alkaline environment a disruption of  $\text{H}_2\text{O}$  molecules, accompanied by formation of atomic hydrogen and hydroxide ion ( $\text{OH}^-$ ) occurs:

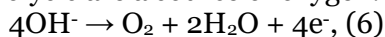


The reactive hydrogen atoms are adsorbed on the surface of the cathode, and molecular hydrogen  $\text{H}_2$  released in the gaseous form after recombination is formed:



At the same time atomic oxygen is released at the anode. In an acidic environment this process is accompanied by the destruction of  $\text{H}_2\text{O}$  molecules according to formula (2).

In an alkaline environment the  $\text{OH}^-$  ions moving from the cathode to the anode during the electrolysis are a source of oxygen:



In a previous article (Mehandjiev et al., 2017a, b) was shown that the mechanism of activation in ECAW can occur with the following intermediate reaction taking place:



In ECAW the mechanism includes two stages as it is for cathode and anode. At the first stage nascent hydrogen and nascent oxygen are released according to reactions (7) and (9). The gained products react with each other and produce a hydrogen molecule and an oxygen molecule respectively – reactions (8) and (10). Certain quantities of the nascent forms of hydrogen in catholyte, and oxygen in anolyte can be kept. Due to the strong reduction properties of the nascent hydrogen and the oxidative properties of the nascent oxygen, the obtained catholyte and anolyte have stronger reduction and oxidative abilities respectively. The experimental check of this statement defined the aim of the current scientific research.

The check of the reduction property of catholyte was performed through a chemical reaction with potassium permanganate as a reagent, and a strong oxidant. It is well known that potassium permanganate dissolves in water to give intensely pink or purple solutions. Therefore the content of manganese ions ( $\text{Mn}^{7+}$ ) in the permanganate anion ( $\text{MnO}_4^-$ ) can be controlled spectrophotometrically.

## 2. Materials and methods

The production of catholyte is performed by the means of device called “Activator 2”, developed in the Institute of Information and Communication Technologies, BAS. The electrochemical treatment of water is processed in a glass container inside of which two electrodes from platinized titanium are put. These are cathode and anode at a distance 3 cm of each other. The electrodes of size 17/3 cm and thickness of 0.5 mm are separated by a semipermeable membrane. Direct current of 220 V is used. The anode space contains 400 ml of water, and the cathode one 1500 ml. Time for activation is 6 minutes, which is sufficient to reach the saturation point of the pH curve.

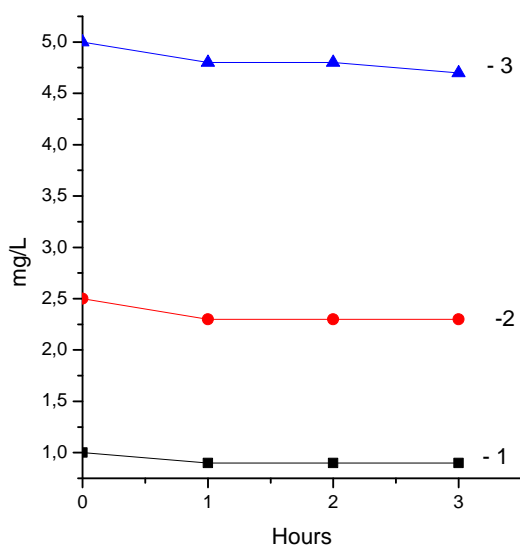
Methodology is based on defining the concentration of potassium permanganate in the catholyte. For this purpose potassium permanganate ( $\text{KMnO}_4$ ) from Merck (Germany) is used. Initial solution of  $\text{KMnO}_4$  is prepared with a concentration of 1000 mg/L through dissolving the necessary amount of salt into the deionized water. In volumetric flasks of 50 ml solutions of  $\text{KMnO}_4$  of concentrations 1, 2.5 and 5 mg/L are prepared through dilution of the starting solution with deionized water or catholyte.

The concentrations of solutions are measured spectrophotometrically using the apparatus Spekol 11 (Carl Zeiss Industrielle Messtechnik GmbH) via admeasurement of absorbance at  $\lambda_{\text{max}}$  of 560 nm. The width of cuvettes is 1 cm. Standard line is built within the interval of concentrations of  $\text{KMnO}_4$  from 0.2 to 50 mg/L ( $R^2 = 0.9988$ ). The concentrations of the working solutions are measured at different intervals of time – 1, 2, 3, 24 hours.

### 3. Experimental results and discussion

#### 3.1. Experiments with potassium permanganate for presence of nascent hydrogen

On Fig. 1 are presented the results from the potassium permanganate concentration measurements at three initial concentrations of 1.0 mg/L; 2.5 mg/L; 5.0 mg/L, depending on the time. Over the course of time the concentration of potassium permanganate in the catholyte slightly decreases. This supports the supposition that active reduction forms are built in the catholyte, which reduce the manganese ions. In control study with the same deionized water but without electrolysis the concentration of potassium permanganate remains unchanged over a time period of 24 hours.



**Fig. 1.** Change of concentration of potassium permanganate in the catholyte over time depending on the initial concentration of 1.0 mg/L; 2.5 mg/L; 5.0 mg/L

From the conducted experiments we can conclude that during the electrolysis atoms of nascent hydrogen are created in the catholyte, according to the equations (3) and (7). Figure 1 shows that the activity of cations lasts for 24 hours with regards to the reduction process. We need to take into consideration that as per reaction (8) hydrogen molecules are also released into the solution, as they saturate it. In order to exclude the possibility that the observed reduction of concentration of permanganate ions is due to this hydrogen, trials were conducted under the same conditions using deionized water saturated with hydrogen at 20°C for a period of 30 minutes without electrochemical activation. The analysis of the contents of permanganate ions shows that their concentration is not diminished as a result of saturation of water with hydrogen. This proves that the observed reduction of concentration of these ions is due to the formation of nascent hydrogen during the electrochemical activation of deionized water.

In [Table 1](#) the measurement results done 24 hours later are presented. The initial and residual concentration of permanganate ions, % of reduction, reduced  $Mn^{7+}$ - ions, and the quantity of nascent hydrogen for this reduction are also shown.

The content of nascent hydrogen remains the same for 24 hours even in the presence of a strong oxidizer such as the manganese ion ( $Mn^{7+}$ ) in the permanganate anion ( $MnO_4^-$ ). It can be concluded that the action of ECAW continues for at least 24 hours. From the [Table 1](#) is also evident that with the increase of the initial concentration of potassium permanganate the quantity of reduced manganese ions increases. The explanation for this is that the probability for reacting in such low concentrations gets higher with the increase of the initial concentration of manganese ions.

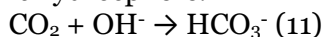
**Table 1.** Initial and residual concentration of permanganate ions, % of reduction, reduced  $Mn^{7+}$ -ions, and the quantity of nascent hydrogen for this reduction

Initial concentration mg/L	Residual concentration mg/L	% of reduction	Reduced $Mn^{7+}$ - ions mg/L	Nascent hydrogen mg/L $10^2$
1.0	$0.8 \pm 0.2$	20.0	0.2	1.85
2.5	$2.1 \pm 0.2$	16.0	0.4	3.65
5.0	$4.5 \pm 0.1$	10.0	0.5	4.65

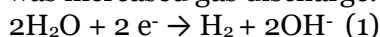
In the [Table 1](#) is also calculated the quantity of nascent hydrogen contained in ECAW for up to 24 hours and acted as antioxidant agent. The amount of stabilized nascent hydrogen is low, in a range of  $0.9 \cdot 10^{-2}$  mg/L, but it has to be taken into account that these are only the kept after reactions (5) (8) and forming of molecular hydrogen quantities.

### 3.2. Reactions with hydrogen and nascent hydrogen in ancient hydrosphere and atmosphere

There were the following reactions for structuring of stromatolites in hot mineral water in ancient hydrosphere.

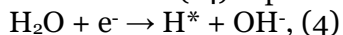


The following reaction (1) is valid in electrolysis. In the ancient atmosphere and hydrosphere there was increased gas discharge.

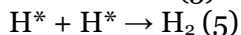


The same reaction contributed for the formation of stromatolites as result of negative oxidation reduction potential in hot mineral water ([Ignatov. 2019](#)). Nowadays it is observed in electrolyzer devices for waters catholyte and anolyte. In the ancient hydrosphere and land the charge had been negative and in the atmosphere positive. The conditions had been optimal for "nature" electrolysis. In these direction had been the experiments of Miller ([Miller, 1953](#)).

The reaction (14) is possible to structure nascent hydrogen  $H^*$  ([Mehandjiev et al., 2019](#)).



The reaction (5) released in the gaseous form after recombination is formed:



The nascent hydrogen is very active for chemical reactions in primary hydrosphere for origin of life and additional formation of  $H_2$  makes alkalizing effect.

The allocation of  $H_2O$  molecule when a peptide chain is formed is important factor in reaction of condensation of two amino acid molecules into dipeptide. As reaction of polycondensation of amino acids is accompanied by dehydration, the  $H_2O$  removal from reaction mixture speeds up the reaction rate. This testifies that formation of early organic forms may have occurred nearby active volcanoes, because at early periods of geological history volcanic activity occurred more actively than during subsequent geological times.

However, dehydration accompanies not only amino acid polymerization, but also association of other small blocks into larger organic molecules, and also polymerization of nucleotides into nucleic acids. Such association is connected with the reaction of condensation, at which from one block a proton is removed, and from another – a hydroxyl group with the formation of  $H_2O$  molecule ([Ignatov. Mosin, 2012](#))

#### 4. Conclusion

The achieved results show that ECAW creates strong reducing agents in catholyte. The availability of free electrons contributes to the reduction properties of catholyte. Deionized water is used, as the reducing components in this case can be also based on hydrogen. These are atoms from nascent hydrogen ( $H^*$ ), which can be achieved from hydronium ions ( $H_3O^+$ ) and from the electrolysis itself, as an intermediate reaction of  $2H^* \rightarrow H_2$ . The atoms of nascent hydrogen ( $H^*$ ) get stabilized within certain amounts in the catholyte, and by having strong reducing activity they define its antioxidant activity. The obtained results reveal that the mechanism of activation is also determined by nascent hydrogen in ECAW.

There has been possibility the nascent hydrogen to have took part of reaction for origin of life in hot mineral water in primary hydrosphere as result of contact with hydrogen from primary atmosphere with hydrogen and gas discharge (Ignatov, 2019).

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