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Analysis of the radiation-chemical yield of molecular hydrogen formed during the radiolysis of pure water and an aqueous solution of NaOH

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The effect of the concentration of aqueous solution NaOH (C_M = 0.025 ÷ 8 mol / l) on the radiation-chemical output of molecular hydrogen was studied in the process of radiolytic conversion under the action of γ-quanta ((^{60}Co, P = 26,1 rad/l). It has been established that the radiation-chemical yield of molecular hydrogen decreases depending on the concentration of the solution. This is due to the fact that thermal electrons formed by the action of emissions with Na^+ ions form excited intermediate complexes. And it reduces the emission of free electrons, which play an indirect role in the formation of molecular hydrogen.

Keywords: molecular hydrogen, aqueous solution NaOH, γ-quantum

Introduction

Recently, related with the rapidly growth of industry, the demand for natural energy oil and gas reserves is constantly growing. But in turn of their use becomes the cause of intensive pollution of the environment - the lithosphere, atmosphere and hydrosphere. For this purpose, it is necessary to create a large supply of environmental friendly energy sources. In recent years, new-found interest in the hydrogen economy from both industry and academia has helped to shed light on its potential. Hydrogen can enable an energy revolution by providing much needed flexibility in renewable energy systems. As a clean energy carrier, hydrogen offers a range of benefits for simultaneously decarbonizing the transport, residential, commercial and industrial sectors. Hydrogen is shown here to have synergies with other low-carbon alternatives, and can enable a more cost-effective transition to de-carbonized and cleaner energy systems [1].

In nuclear reactors of the fourth generation (PWR, BWR, SCWR, etc.), light water is used as an energy carrier and a cooling system [2-9]. Various energetic particles (heavy ions, protons, neutrons, electrons, γ-quanta, etc.) formed during fission of nuclei in the core inside the reactor, during elastic and inelastic collisions with water molecules, while passing through water and water vapor, gradually lose their kinetic energy. The processes occurring at the physical stage can be described by the expressions:

$$H_2O \xrightarrow{ionizing\ \ radiation} H_2O_j^+, H_2O_i^*, H_2O^{**}, e_{sub}^- \qquad (1)$$

$$e^- \rightarrow e_{aq}^- \qquad (2)$$

$$e^- + Na^+ \rightarrow (Na^+ \cdots e^-)^* \qquad (3)$$

$$(Na^+ \cdots e^-)^* \rightarrow \begin{cases} Na + aq & (4) \\ Na^+ + e_{aq}^- & (5) \end{cases}$$

$$H_2O^+ + H_2O \rightarrow H_3O^+ + OH \qquad (6)$$

The products of the physicochemical phase, formed under the action of ionizing radiation on water, can be conditionally described as follows. (7):

$$H_2O \xrightarrow{ionizing\ \ radiation} H, OH, H_2, H_2O_2, e_{aq}^-, H_3O^+, OH^-, HO_2 \qquad (7)$$

EXPERIMENTAL PART

In the experiment, we used an aqueous solution of NaOH of high purity (99.9%), with a concentration of CM = 0.025 ÷ 8 mol / l. After a glass ampoule with a volume of 20 ml was cleaned in a special mode, treated at 500 ° C for 48 hours in air, then reheated to 400 ° C in a vacuum (p = 10-3 mm Hg), the required concentrated NaOH was added. After degassing the dissolved air several times, the solution is hermetically closed under vacuum condition. The ampoule was irradiated with γ-rays (60Co, P = 26.1 rad / sec). The amount of molecular hydrogen obtained by radiolytic decomposition (accuracy 8%) was determined by the chromatographic method. In a chromatograph with a column length of 1 m and an inner diameter of 3 mm, activated carbon with a size of d = 0.25–0.6 mm was used. High purity argon (99.9%) was used as a gas carrier.

RESULTS AND DISCUSSIONS

As in the physical, as well as in the physicochemical stages of the radiolytic process by the action of γ-quanta on the aqueous solution of NaOH, such intermediate products are formed (H, OH, H2, H2O2, HO2, H3O + and OH). Some of these products cause corrosion of reactor materials. Because of their elimination is one of the main problems. For this purpose, was prepared different molar concentration of NaOH in solution with water used as an energy carrier and a cooler material. These solutions were exposed with γ-quanta and was determined the amount of molecular hydrogen obtained by the radiolytic pathway on chromatographic methods.

From the fig. 1 represents the dosage dependence of molecular hydrogen formed in 5 ml of solution. We show from the figure, with an increase in the concentration of the solution, after certain values, the radiation-chemical output of molecular hydrogen. This is explained by the fact that with increasing concentration in the solution of Na + ions, the concentration of thermolyzed electrons decreases.

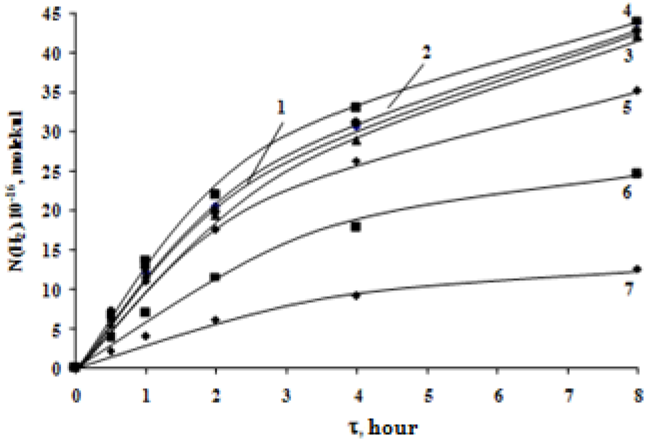

Fig. 1. Dependence of the yield of molecular hydrogen formed by the action of qamma-quanta (P = 26.1 rad / sec) on the aqueous solution of NaOH in a volume of 5 ml, different concentration (C_M = 0 (1); 0.025 (2); 0.05) . (3); 0.1 (4); 1 (5); 5 (6); 8 (7) mol / l)

Table

Speed of formation (w (H_2)) and radiation-chemical yield of molecular hydrogen, formed during radiolysis (P = 26.1 rad / sec) of water solution NaOH with different concentration.

	concentration NaOH, *mol/l*								
	0	0,025	0,05	0,1	0,5	1	2	5	8
$w(H_2)\cdot 10^{-13}$, molecule/q·sec	0,724	0,791	0,746	0,71	0,694	0,6	0,473	0,322	0,222
$G(H_2)$, molecule/100eV	0,443	0,464	0,457	0,435	0,42	0.368	0,29	0,198	0,136

Conclusion. As can be seen from the data obtained, the radiation-chemical output of molecular hydrogen in pure water is G (H_2) = 0.443 molecules / (100 eV). And the radiation-chemical yield of molecular hydrogen obtained by radiolysis of aqueous solution of NaOH with a concentration of C_M = 0 ÷ 0.5 mol/l can be said that it does not change, and at values of C_M> 0.5 mol/l depends on the concentration.

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