Peculiarites of Benzene Decomposition in Cavitation Fields

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Abstract* – It is proposed to carry out treatment of wastewaters, containing of aromatic compounds, in particular benzene, in cavitation fields. The results of studies of the cavitational decomposition of benzene under isothermal conditions (at temperatures 303, 313 and 323 K) are presented. The extremal characterof the dependence of the degree of decomposition of benzene from temperature with a minimum of 313 K is established. An abnormal appearance of the dependence is explained by possibility of occurrence of secondary processes , namely the formation of gas bubbles of nanometer sizes (babstons) and their clusters, which have high mechanical resistance and diffusivityy, and also on the basis of the kinetic theory of Frenkel's fluid.Recommendations for the implementation of the benzene decomposition process in cavitation fields are formulated on the basis of the results of experimental studies.

Keywords – cavitation fields, decomposition, benzene, ultrasonic magnetostrictive emitter, stationary treatment mode.

I. Introduction

Benzene and its derivatives (toluene, phenol, etc.), dispersed and emulsified in aqueous media, are the main pollutants of sewage from chemical enterprises and, in particular, petrochemicals. They suppress the respiratory activity of hydrobionts and lead to changes of kind and trophic structure of biogeocoenoses. Processes of oxidation of aromatic compounds are actively used for the treatment of such wastewaters. The effectiveness of oxidation of inorganic (sodium sulfite) and organic (phenol, cresol, toluene) compounds in cavitation fields has been confirmed by numerous studies [1-3]. As a result of the sonolysis of water molecules in cavitation fields, highly reactive compounds (atomic oxygen, hydroxyl radicals, ozone, etc.) are formed which have properties of oxidants-destructors. Thus, it has been established that benzene, which is contained in an aqueous medium, in the presence of atomic Oxygen decomposes with the disclosure of the benzene ring [3].

The purpose of the research was to study the process of decomposition of benzene in cavitation fields under isothermal conditions.

II. Research results

Investigation of the benzene decomposition in cavitation fields under isothermal conditions was carried out on the example of an imitation system of wastewater containing benzene, mol C6H6 / m3 H2Odistilled: for 303 K – 8.37; for 313 K – 7.26; for 323 K – 6.63. Ultrasonic Magnetostrictive Emitter "Ultrasonic Disintegrator UD-20" was used as a cavitation generator. The mode of cavitation treatment is stationary, that means that process parameters, such as the frequency of ultrasonic oscillations and the specific power of the ultrasound generator, are constant over time and equal respectively 22 kHz and 68 kW / m^3. The duration of cavitation treatment was 1800 sec. The concentration of benzene in the imitation of waste water during cavitation treatment was determined by UV / Viz spectroscopy using a SPECORD M40 Carl Zeiss JENA two-beam spectrophotometer with a 10 mm quartz cuvette in the wavelength range of 200-400 nm.

The dependence of the benzene concentration in the imitation (C, mol /m^3) on the duration of cavitation treatment (t, s) under isothermal conditions is shown in Fig. 1.

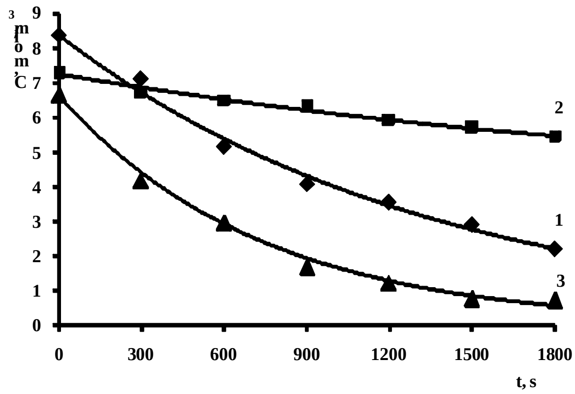

Fig.1. The dependence of the benzene concentration (C, mol / m^3) in the imitation from the duration of cavitation treatment (t, s) under temperature, K: 1 – 303; 2 – 313; 3 – 323

A decrease in the concentration of benzene in the imitation due to cavitation treatment at different temperatures was found, mol / m3: at 303 K – by 6.18 (from 8.37 to 2.19); for 313 K – by 1.8 (from 7.26 to 5.46); for 323 K – by 5.92 (from 6.63 to 0.71). The degree of benzene decomposition is, respectively, %: for 303 K – 73.8; for 313 K – 24.8; for 323 K – 89.3. The nature of the change in the benzene concentration at 303 and 323 K is exponential, and at 313 K − linear.

The minimum degree of benzene decomposition in the cavitation fields and the linear nature of its concentration change at a temperature of 313 K indicate a flow in the system of various secondary processes, which consumes the energy brought to the reaction system. The main process is the formation of babstons – stable gas nano-bubbles. Babstones stability is due to adsorption on their surface of ions with one sign. As a result, there are forces of Coulomb repulsion that act along the surface of babston. They are compensated by the forces of surface tension, which also contributes to the mechanical balance of the babston. The gas pressure inside the separate babston is equal to the pressure of the gas above the surface of the liquid after achievement of mechanical equilibrium. This provides a diffusion (relative to the gas inside the bobston and gas dissolved in the liquid) stability of the babston. The action of frictional forces, which, of course, are present during cavitation treatment, leads to the appearance of an electric charge on the surface of the babston and the formation of a layer of counterions as a result of the Coulomb attraction. Counterions are result of the sonolysis of water molecules in the cavitation fields. The coagulation of babstons with the formation of bubonet clusters in deeply purified water is confirmed by the method of modulation interference microscopy [4]. The presence of new structural entities (babston clusters) in aqueous media is also indicated by a decrease of sound absorption coefficient in 4 times in the temperature range from 273 to 313 K [5]. The diffusion and mechanical resistance of babston and their clusters prevents their growth with forming of cavitation bubbles capable of spraying with high pressure and temperature gradients, and, hence, the proportion of high reactive compounds, in particular oxidative compounds, decreases. This is also reflected by the results of the cavitation destruction of benzene at 313 K. At further rise of temperature to 323 K, cluster structures are destroyed [5], which facilitates the development of cavitation phenomena and contributes to a significant increase in the degree of decomposition of benzene.

The extreme nature of the change in the degree of decomposition of benzene in cavitation fields with a minimum of 313 K can also be explained on the basis of the kinetic theory of Frenkel's fluid. According to this theory, water in a liquid state exists simultaneously in the form of two equilibrium phases – liquid and quasicrystal by analogy with quasicrystals, whose crystal lattice has axes of symmetry of various orders and which is characterized by orderliness in the mutual arrangement of atoms and molecules. In the region of physiological temperatures of 308-314 K, water reaches a state in which the masses of quasicrystalline and liquid water are the same, and the ability of one structure to pass into another (variability) is maximal [6]. With increasing temperature, the proportion of liquid water, which is characterized by thermal fluctuations of the molecules, increases, and, accordingly, the probability of formation of new cavitation nucleus increases.

Conclusions

Consequently, the process of decomposition of benzene in cavitation fields is highly effective (maximum decomposition rate is 89.3%). The extreme nature of the dependence of the degree of benzene decomposition on the temperature of the reaction system indicates the course of the secondary processes, in particular the formation of gas nanobulls (babstons) and their coalescence with the formation of clusters for which mechanical and diffusion stability is characteristic. Therefore, in order to prevent unproductive expenses of energy, the process of cavitation treatment should be carried out at temperatures lower or higher than 313 K (303 and 323 K in the studied range).

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