THE EFFECT OF LOW AND EXTREMELY LOW DOSES OF RADIATION ON AQUEOUS SOLUTIONS IN CONDUCTOMETRIC MEASUREMENTS

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Aqueous solutions of bioorganic compounds are sensitive to ionizing radiation even at low and ultra-low doses, due to changes in their microstructure and ionic composition. The primary acts of water radiolysis are accompanied by the formation of active species (•OH, e^-_{aq}, H•), which initiate further physicochemical transformations. In aqueous-organic systems, these processes are complicated by additional interaction channels with the organic component, leading to the formation of new charged and polar structures.

In the low-dose range, the decisive role is played not so much by deep destructive processes as by a shift in the equilibrium between radiolysis products, the restructuring of the hydrogen-bonded network, and a change in the effective mobility of ions, which is directly reflected in the system's electrical conductivity. In this regard, conductometric and impedance methods are highly sensitive tools for detecting such effects.

This work aims to establish the patterns of changes in the electrical conductivity of aqueous ethanol solutions under the influence of ionizing radiation over a wide range of energies and doses, with an emphasis on the manifestations of low-dose effects.

Experimental Conditions

The study subjects were 10% aqueous ethyl alcohol solutions, which were treated as model bioorganic systems.

Irradiation was performed using accelerated electrons under various energy and dose conditions, enabling a wide range of radiation effects to be studied.

High-energy irradiation was performed on an M-30 electron microtron at energies of 12.5 and 18 MeV. The bremsstrahlung doses were 17, 33, 44, and 67 Gy, which ensured that the samples were exposed to different radiation doses.

Additionally, radiation treatment was performed using a clinical accelerator (regional clinical oncology center) at an electron energy of 6 MeV and doses of 25, 50, and 100 Gy. The use of two sources with different energy characteristics allowed for varying the linear energy transfer and the spatial distribution of ionization.

This approach enabled comparison of the effects of different irradiation regimes on the formation of electrophysical properties of solutions and to detect even weak dose effects against the background of more intense radiation effects.

The electrophysical parameters were investigated using impedance spectroscopy in the frequency range from 1 kHz to hundreds of kilohertz. The measurements were performed at room temperature in a measuring cell with metal electrodes. The frequency dependencies of the active resistance, capacitance, and electrical conductivity were analyzed, allowing separation of contributions from volume conductivity and polarization processes.

It was established that irradiation of aqueous ethanol solutions alters their electrical conductivity, with the nature of these changes determined by both the dose and the energy of irradiation [1]. Even at low doses, reproducible deviations in conductivity from control values are observed, indicating the system's high sensitivity to weak radiation effects.

It has been shown that irradiation leads to the formation of a non-equilibrium ion-radical state, which alters the concentrations of charge carriers and their mobilities. In water-ethanol systems, reactions involving organic radicals additionally occur, leading to the formation of stabilized charged complexes and, consequently, more prolonged changes in electrical conductivity.

Frequency analysis of the impedance characteristics showed that the low- and mid-frequency regions are most sensitive to irradiation, where interphase polarization and relaxation processes are significant. This indicates a change in the solution's structure at the mesoscopic level, specifically the rearrangement of clusters and hydrogen-bonded ensembles.

A comparison of results for different electron energies (6, 12.5, and 18 MeV) showed that the nature of ionization losses changes with increasing energy, thereby affecting the efficiency of active particle formation and, consequently, the magnitude of the changes in conductivity. This confirms the importance of considering radiation's energy parameters when analyzing the effects of low doses.

The results obtained demonstrate that impedance spectroscopy and conductometric measurements are effective tools for detecting subtle changes in aqueous-organic systems under the influence of ionizing radiation. The identified patterns can be used further to investigate the mechanisms of radiation effects on bioorganic media and to develop methods for monitoring their physicochemical state.

1. 1. V. T. Maslyuk, N. I. Svatiuk, N. V. Boiko et al. Nuclear Physics and Energy 25 (2024) 72.