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WATER RADIOLYSIS: AN OVERVIEW

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DESCRIPTION

Radiolysis consists of a series of phenomena in which molecules are destabilized by ionizing irradiation particles such as phonons, electrons, and heavy ions, and new chemical species are generated. Radiolysis is basically molecular damage to a substance caused by ionizing radiation. Here, the term is used to refer to unprotected radiochemical treatment equipment and components of the product itself.

Radiolysis in aqueous solution has a completely different effect than radiolysis in solid materials. Water molecules are excited or ionized. Radiolysis of water results in both oxidizing (H_2O_2, O_2, $OH^•$, $O_2^•$, $O_2^{•-}$) and reducing (H_2, $H^•$ radicals) species, some of which are unstable (solvated electrons), others are stable molecules (H_2O_2, O_2, H_2). Stable molecules affect the oxidation or reduction properties of water not only under irradiation, but also in the area where this water is transported.

In connection with this mechanism, the interstitial aqueous phase represents a weakness in concrete, and the induced macroscopic disturbance outweighs microscopic events such as intra crystalline defects, amorphization, or separation by atomic displacement.

Radiolysis of water occurs in many situations (radiation therapy, radiation sterilization, wastewater treatment, food irradiation etc.). This radiolysis of water is often affected by the solid or liquid interface. For example, in a water-cooled nuclear reactor, ionizing radiation causes a reaction at the water and interface between solid (fuel shell) and liquid. When storing the waste and disposal of nuclear waste, the heterogeneous materials used (concrete, mortar etc.) can trap large amounts of water. Radiolysis of these trapped water molecules is caused by the presence of nuclear waste accumulated in these materials. The formation of radiolytic products such as H_2 and H_2O_2 should be evaluated for safety reasons to prevent breakage and corrosion of the surrounding matrix.

APPLICATIONS

Corrosion prediction and prevention in nuclear power plants

When designing a nuclear power plant, it is assumed that it is necessary to take into account the increased concentration of hydroxyl in the irradiated water of the internal coolant loops of the light water reactor to avoid loss of coolant due to corrosion.

Hydrogen production

Although the hydrogen yield from irradiating water with β and γ rays is low (G value=<1 molecule per 100 eV of absorbed energy), this is mainly due to rapid recombination of species formed during the first radiolysis.

Spent nuclear fuel

The generation of gas by radiolysis of hydrogen-containing materials has been a problem area for the transportation and storage of radioactive materials and wastes for several years. Flammable and corrosive gases can be generated, chemical reactions can simultaneously remove hydrogen, and these reactions can be enhanced by the presence of radiation. The balance between these competing reactions is currently poorly known.

Radiation therapy

When radiation enters the body, it interacts with cell's atoms and molecules (mainly made of water) to generate free radicals, molecules that reach the intracellular important target DNA, which is indirectly controlled by a chemical reaction, can be damaged. This is the main mechanism of photon injury used in extracorporeal radiation therapy.