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Effects of the dose-rate on the radiolysis of water and small protein biomolecules

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Ionizing radiations are known to have important effects on living organisms, as their energy deposition causes a lot of damages. Studying fundamental chemical mechanisms of the effects of ionizing radiations on biomolecules is crucial to have a better understanding of their radiobiological effects. These ionizing radiations can come from radioactive isotopes, or be used in a therapeutical context in radiotherapy to treat cancers by damaging tumoral tissues. Particle therapy, using accelerated ions, is very interesting for its better targetting of tumors compared to classical X-Rays. FLASH radiotherapy, which has been attracting a lot of interest recently, could have a preserving effect towards healthy tissues, using very high dose rates (>40Gy/s) [1]. At this moment, the molecular mechanisms of the FLASH effect are still far from being completely understood.
Our team is developing a systematic study of the chemical effects of water radiolysis species on protein biomolecules, especially under ion irradiation. For this purpose, we compare yields of water radiolysis species (esp. HO•, e-aq, H2O2) to that of amino acids, peptides and proteins, in order to study the mechanisms of degradation of the biomolecules. Experiments are performed with ions and low-LET ionizing radiations (X-rays, γ, electrons) for comparison, to identify eventual ion specific mechanisms [2]. The effect of dose-rate on the radiolysis mechanisms are also scrutinized.
Hydroxyle radical (HO•) is the most potent chemical species towards biomolecules degradation. It has been quantified using scavenging probes at various dose-rates, from 0.1 to about 2000 Gy/s, under irradiation by 1MeV electrons, showing a significant dose-rate effect. Radiolysis of amino acids and of a small peptide, aspartame, was studied in the very same conditions and correlated to the dose-rate effect on HO• , as shown in Figure 1 with the example of the 2,5-dopa, one of the radiolysis products of phenylalanine.

[1] de Kruijff, R.M., FLASH radiotherapy: ultra-high dose rates to spare healthy tissue. International Journal of Radiation Biology, 2019, 1–5.
[2] Ludwig, N et al, Radiolysis of Phenylalanine in Solution with Bragg-Peak Energy Protons. Radiation Measurements 2018, 116, 55–59.

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