

Quantifying water ionization by soft X-rays using a microfluidic device

L.Huart^{1;2;3}, C.Chevallard¹, C.Nicolas², J.Kaddissy¹, A.Touati³, J.-M.Guigner³, M.-F.Politis⁴, P.Mercere², J.-P.Renault¹, M.-A.Hervé du Penhoat³

¹NIMBE UMR CEA-CNRS 3685, Saclay, France,

²Synchrotron SOLEIL, Saint Aubin, France,

³IMPMC, Sorbonne Université, UMR CNRS 7590, MNHN, 75005 Paris, France

⁴LAMBE UMR 8587, Université d'Evry val d'Essonne & Université Paris-Saclay, 91025 Evry, France

Abstract

The description of the biological effects of ionizing radiation requires a good knowledge of the dose deposition processes at both the cellular and molecular scales. However, the specific behavior of subkeV electrons which deposit their energy in nanometric volumes, remains poorly described [1]. Moreover, theoretical calculations have shown that ionizing the K-shell electrons of metal ions in solution can lead to large local production of radical and slow electron species [2]. Irradiating solutions containing metal ions, such as Mg²⁺, with monochromatic X-rays around their K edges could thus allow to investigate this process.

Hydroxyl radical quantification was conducted through OH scavenging by benzoate to form the fluorescent hydroxybenzoate [3]. Liquid water samples were first irradiated in a static cell with monochromatic soft X-rays (0.2-1.4 keV) at the Metrologie beamline (SOLEIL synchrotron, France). Yields of OH radicals exhibit a minimum around 1.5 keV, in good agreement with the literature [4, 5]. This minimum may be attributed to an increased ionization density in the photo- and Auger electrons tracks. Moreover, OH yields are found relatively independent of the benzoate concentration in the investigated range, which correspond to scavenging times from 170 ns to 170 ps.

Implementation of a new microfluidic cell in the setup has permitted to drastically increase the signal/noise ratio and our detection sensitivity. Therefore, the OH scavenging method was also applied to solutions containing Mg or Na ions. By varying the X-ray energy below and above the K-shell of these atoms (1317 eV for Mg and 1071 for Na), the OH radicals production was measured in order to probe a threshold effect. Our results will be compared with standard gamma-rays expositions and differences will be highlighted.

Keywords— SOFT X-RAYS, HYDROXYL RADICAL SCAVENGING, WATER RADIOLYSIS

References

- [1] D.T. Goodhead and J. Thacker. *Int. J. Radiat. Biol. Relat. Stud. Phys. Chem. Med.* 31: 541 (1977).
- [2] V. Stumpf, K. Gokhberg, L. S. Cederbaum, *Nature Chemistry* 8: 237 (2016).
- [3] G. Louit, S. Foley, J. Cabillic, H. Coffigny, F. Taran, A. Valleix, J.-P. Renault, S. Pin. *Radiat. Phys. Chem.* 72: 119 (2005).
- [4] J. Fulford, P. Bonner, D. T. Goodhead, M.A. Hill, P. O'Neill. *J. Phys. Chem. A* 103: 11345 (1999).
- [5] J.A. LaVerne and S.M. Pimblott, *J. Phys. Chem.* 95: 3196 (1991).