XUV Induced Ultrafast Dynamics of 5-Halouracils

R. Cireasa*[1], D. Dowek[1], P. Çarçabal[1], J.-P. Champeaux[2], P. Moretto-Capelle[2], D. Descamps[3], S. Petit[3], V. Blanchet[3], Y. Mairesse[3], M. Castrovilli[4], A. Trabattoni[4], M. Nisoli[4], F. Calegari[4], P. O'Keeffe[5], P. Bolognesi[5], L. Avaldi[5]

[1] Institut des Sciences Moléculaires d'Orsay, Université Paris Sud, Orsay, France
[2] Laboratoire Collisions Agrégats et Réactivité, Université Paul Sabatier, Toulouse, France
[3] Centre Lasers Intenses et Applications, Université de Bordeaux, Talence, France
[4] Department of Physics, Politecnico di Milano,CNR-IFN, I-20133 Milan, Italy
[5] Istituto di Struttura della Materia, Area della Ricerca Roma 1, 00016, Monterotondo Scalo, Italy
Corresponding author: raluca.cireasa@u-psud.fr

Abstract

We have studied the interaction between a particular class of biomolecules called radiosensitisers (5-Halouracils) and XUV radiation. Energy-resolved experiments employing XUV synchrotron radiation were performed in order to identify the cation states accessed in the ionisation and the fragmentations steps. Some ultrafast dynamics on timescales shorter than 30 fs occur for both steps as revealed by pump-probe measurements where high order harmonics were used as source of femtosecond or attosecond XUV radiation. For both FU and BrU, fs proton migration dynamics was measured for the time dependences of two couples of fragments separated by one mass unit.

Exposing biomolecules to high energy photons in the XUV domain leads to radiation damage. There is a particular class of biomolecules called radiosensitisers that enable the use of the radiation damage for therapeutic purposes. 5-Halouracils (5XU) belong to this class because when utilised in combined chemo- and radio-therapy treatments to replace the Thymine in the DNA of the tumour cells, they enhance the lethal effects of the UV, X-ray, proton and γ radiation on these cells.

In order to understand at the molecular level, the 5XU interaction with XUV radiation, we have investigated the ionisation and fragmentation of 5FU and 5BrU induced by high order harmonics, HH, (9-35 eV) and synchrotron radiation (9-26 eV). The ensuing dynamics was detected by recording Time-of-Flight (TOF) spectra of the photofragments as a function of the delay between the XUV pump pulse (fs or attosecond) and the probe pulse (4 fs IR or ~40 fs UV) and as a function of the excitation energy. For the time-resolved measurements, the kinetic energy of the main fragments was recorded by velocity map imaging, while for the energy-resolved ones, both the fragment and the (correlated) photoelectron kinetic energies were measured by using the photoelectron-photoion coincidence 3D momentum imaging.

The mass spectra can be explained only by considering that the parent ionisation is followed by complex dynamics involving ring opening reactions, proton/hydrogen transfer, multichannel and sequential dissociations. Measuring at various photon energies in 9-26 eV range, the mass spectra and the photoemission spectra of the electrons coincident with the parent ion and with different fragment ions enabled us to identify the parent cation states involved in the fragmentation. In addition, the energy-resolved measurements reveal that most of the energy is taken by the photoelectron. All fragments bear very little kinetic energy, maximum 1 eV and typically, less than 0.5 eV. These results are consistent with those obtained in the fragmentation induced by HH. For both, FU and BrU, we have recorded ultrafast dynamics (<10 fs) manifested as delayed signal appearances and sharp rising/decaying signals. An ultrafast decay of about 40 fs was observed for the signal from the fragment 43 (HNCO or FCCH) and the complementary rising behaviour on the same timescale was observed for fragment 44, which can be only formed by H/H^+ transfer, most probably via tautomerisation. Similar behaviours, although slower, were measured for the fragments 31 (FC) and 32 and for the equivalent BrU fragments. These dynamics may be associated with H or proton transfer processes where the difference in timescale is determined by the initial and final sites of the H/proton transfer and, in particular, to the involvement of the halogen atom.

Since 5XU are routinely used as radiosensitisers in radiotherapy treatments, the present work provides new insights in the XUV induced structural changes (tautomerisation) that may be responsible for DNA mutagenesis and the DNA breaking that occur when these molecules are embedded in the DNA of the tumour cells.

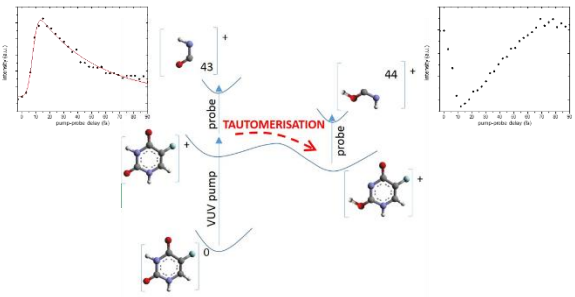

Fig.1 Tautomerisation dynamics for 5FU from di-keto isomer to keto-enol isomer