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Excitation and ionisation cross-sections of charged particles in condensed-phase biologically-relevant materials

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The interaction of swift charged particles (either ion beams or energetic electrons) with condensed-phase materials underlies many biomedical applications of radiation. Energetic proton or carbon ion beams are used in the advanced radiotherapy technique of hadrontherapy, and their nanometric track-structure is defined by the ejection and propagation of secondary electrons [1]. Energetic electron beams are also used in radiotherapy, or are ejected by radiopharmaceuticals. Even conventional X-ray radiotherapy produces a large number of photoelectrons. Thus, an accurate modelling (needed to understand and optimise these applications) requires to accurately know the interaction probabilities of charged particles with biologically-relevant materials, particularly for very low energy (< 100 eV) electrons, which represent one of the main inductors for lethal clustered DNA damage [2].

Over the recent years, in our research group we have developed models, based on the dielectric formalism [3,4], for calculating cross sections for inelastic events (the main responsibles for biodamage), both integral and differential (in secondary electron ejection energy and angle), for arbitrary condensed-phase biomaterials (including liquid water and the DNA molecular building blocks). These models were first introduced for the impact of ion beams [5,6], to be more recently extended for electron beams by including the particularities of low energy electrons [7].

Apart from biological materials, current research also requires the knowledge of electronic interaction probabilities of charged particles with transition metals, widely used for enhancing the effects of radiotherapy by means of nanoparticles [8]. Our models are also being applied to obtain accurate energy-loss quantities for these materials [9,10].

The purpose of this contribution is to review these methods, and to show the general good agreement between theory and experiments got for both ions and electrons in a wide energy range and for a large collection of biologically-relevant materials. These models and cross sections will be very useful to advance towards a detailed modelling of nanoscale radiation biodamage.

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