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Theory of Heavy Ion Collision Physics in Hadron Therapy

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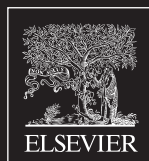
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**Theory of Heavy Ion Collision Physics in Hadron
Therapy**

Edited by

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Preface

This Special Issue is within a wider realm of physical and biological effects of irradiation of tissue and tissue-like targets by energetic heavy ions of high relevance to hadron therapy. The main goal is to review the leading theories describing fast collisions of ions with atoms and molecules by emphasizing the possibilities for improving the existing data bases for energy losses of heavy charged particles during their passage through matter. Ion-atom collisions are included in this topic by presenting those theoretical formalisms that are universally applicable to general targets, including molecules from tissue. Although the main focus is on energy losses due to electromagnetic interactions, also reviewed are the pertinent cross sections and stopping powers for nuclear reactions. Data bases of electronic and nuclear stopping powers coupled with the associated modeling of biological responses of cells to irradiation are essential to hadron therapy.

When determining a treatment plan for a patient with cancer, the radiation oncologist must make a key assumption on the actual amount of dose needed to eradicate all the tumor cells. It is here that the biophysical input is required, accounting for the precise extent of the deposited physical doses, as well as for their biological counterparts that modify the initial impact of radiation by the cell repair processes. The overall success of radiotherapy is contingent upon the dose planning, dose delivery and dose verification systems. To meet with success, radiotherapy must include the most adequate descriptions of energy losses of particle beams in tissue and the cell recovery. Deep-seated tumors are usually treated with energetic hadrons because of the optimal conformity of heavy ions to the targets by way of a very precise local deposition of doses in the vicinity of the Bragg peak.

Versatile biophysical aspects of the topics of this Special Issue are expounded through 14 chapters with the following specific themes:

Chapter 1 (H. Bichsel) examines the stochastic variations of energy losses and biological effects of protons and carbon nuclei in their high-energy collisions with water.

Chapter 2 (H. Paul) performs a comparative analysis of the accuracy of different methods and simulation codes for stopping powers and ion ranges.

Chapter 3 (J.R. Sabin, J. Oddershede and S.P.A. Saue) reviews the theoretical and experimental aspects of determination of the mean excitation energy of water.

Chapter 4 (F. Ziad) studies the molecular scale Monte Carlo simulations of ion tracks using the GEANT4-DNA code with the inclusion of the effects of secondary electrons.

Chapter 5 (J. Beebe-Wang, P. Vaska, F.A. Dilmanian, S.G. Peggs and D.J. Schlyer) investigates the radiation treatment verifications in proton therapy using positron-emission tomographic imaging and Monte Carlo simulations.

Chapter 6 (I. Abril, R. Garcia-Molina, P. de Vera, I. Kyriakou and D. Emfietzoglou) reports on inelastic collisions of energetic protons in tissue-like media using a combination of molecular dynamics and Monte Carlo simulations.

Chapter 7 (C.C. Montanari and J.E. Miraglia) presents a combination of the dielectric formalism with the shell-wise local plasma approximation for inelastic processes in high-energy ion-matter collisions.

Chapter 8 (M.A. Bernal-Rodriguez and J.A. Liendo) assesses the usefulness of the available empirical cross sections relative to the continuum distorted wave theories and experimental data for single ionization of liquid water by protons, alpha particles and carbon nuclei.

Chapter 9 (R.D. Rivarola, M.E. Galassi, P.D. Fainstein and C. Champion) reviews distorted wave methods for electron capture, ionization and excitation processes in high-energy inelastic collisions of ions with water.

Chapter 10 (C. Champion, J. Hanssen and R.D. Rivarola) presents the results of the first Born approximation for ionization and electron transfer in energetic collisions between multiply-charged ions and water.

Chapter 11 (T. Kirchner, M. Murakami, M. Horbatsch and H.J. Lüdde) reports on cross sections for single- and multiple-electron processes in ion-water collisions using the time-dependent density functional theory in the independent electron model.

Chapter 12 (Dž. Belkić, I. Mančev and N. Milojević) deals with the four-body formalism of distorted wave second-order perturbation methods for double electron transitions through simultaneous electron transfer and ionization processes in ion-atom collisions at high impact energies.

Chapter 13 (V.Yu. Lazur and M.V. Khoma) reviews the theoretical concept of the Dodd-Greider integral equations with Coulomb interactions for one- and two-electron capture processes in fast ion-atom collisions.

Chapter 14 (Dž. Belkić and K. Belkić) contributes to a further improvement of the effectiveness of the current radiation treatments of cancer through the amended dose planning systems based on an adequate

description of cell survival valid at all doses as predicted by the new mechanistic repair-based Padé linear-quadratic biophysical model.

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