Electron emission from water and neucleobases with radio-sensitizer

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Synopsis We report a comprehensive study of the double differential e-emission cross sections from water, adenine, uracil and bromouracil in collisions with fast highly charged C, O and Si ions ~MeV/u i.e. at the Bragg peak. A large enhancement in e-DDCS for bromouracil (a radiosensitizer) over adenine and uracil has been observed which can not be explained by electron statistics, rather in terms of collective shape resonance or Auger cascade in Br. Large set of TCS data provides a scaling law in terms of v_p and q_p, The agreement with the QM model calculations (CDW-EIS, CB1) for such large molecules is encouraging. We have also measured the K-ionization and K-K e-transfer TCS for adenine.

The secondary electron emission from nucleobases and water is an important parameter to estimate the radiation damage caused by the fast ions, at the Bragg peak of energy loss, in the context of hadron-therapy. However, a realistic estimation of collision cross sections, the energy loss in such a solid or liquid medium needs much more input. The angular distribution of electron double differential cross sections (DDCS) and total ionization cross section (TCS) as well as the recoil-ion fragmentation spectrum provide crucial inputs towards the mechanism of such ionization process. The presence of a radio-sensitizer, which enhances the e-emission, helps to reduce the radiation dosage. Therefore the study of the influence of such sensitizers in a nucleobase has been a topic of current study. But there is no quantitative study of the exact enhancement so far.

A recently installed ECR based ion-accelerator on 400 kV deck and the existing 14 MV Pelletron tandem accelerator in TIFR, Mumbai are being used to investigate many body effects on collisions C_{60}, PAH, water and nucleobases [1-8]. The collision energy of C, O and Si ions vary between ~100 keV-100 MeV. A series of experiments are carried out with for uracil, adenine and bromouracil targets from a hot-oven vapor source. The experiment with water target involves a vapor target. An electron spectrometer is used for the measurement of low energy electron DDCS whereas the recoil-ion TOF setup is used for TCS measurement and fragmentation. Low energy electrons in the range of 1-600 eV are detected which also include the C, N and O K-LL Auger e-emission. The dramatically large forward backward asymmetry in electron emission for uracil [4,6,7] and adenine indicates a size and multi-center effect. An unusually large enhancement in e-emission from, the radio-sensitizing molecule, bromouracil has been quantitatively measured which goes beyond the electron statistics. Different mechanisms in terms of collective shape resonance and Auger cascade decay are possible candidates for an explanation. The K-K electron transfer and the K-ionization for nucleobase molecule are reported for the Ist time.

The CDW-EIS model provides an excellent agreement in contrast to earlier observed deviation for uracil molecule. The TCS data for water, uracil and adenine are found to follow a scaling behavior which is different from q^2-law (q=charge state) which will provide an useful input for the model calculation for radiation damage. Some relevant examples will be presented, based on our recent work.

References

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