4-3 Why Do Heavy Ions Have Great Effect on a Cell? Chemistry Elucidates the Reason

–Quantitative Analysis of Reactive Species Which Induce DNA Damage–

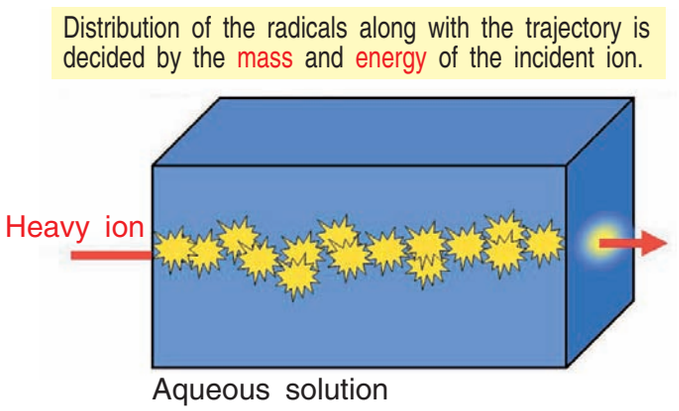

Fig.4-7 Radicals generated along heavy ion trajectory in water
A heavy ion deposits its kinetic energy densely along its trajectory to produce reactive species. Their distributions are decided by the mass and specific energy of the incident ion. Moreover, reactive species react and diffuse with time.

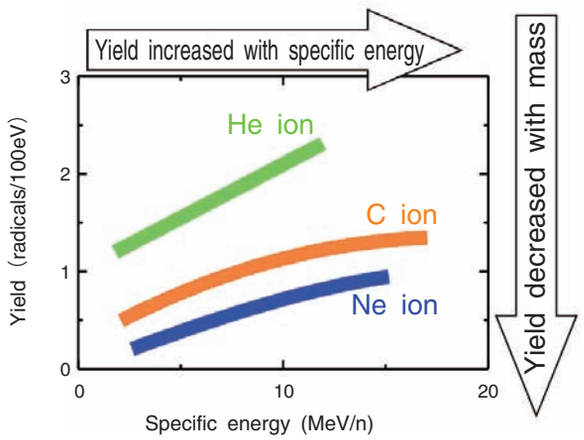

Fig.4-8 Dependence of yield of hydroxyl radicals on specific energy and mass of incident ion
Yields of hydroxyl radicals increased with the specific energy for each ion, but decreased with the mass of each ion at the same specific energy.

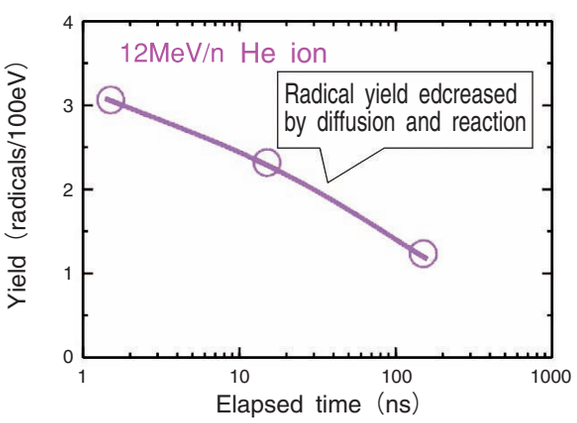

Fig.4-9 Yield of hydroxyl radicals decreased with elapsed time just after helium ion irradiation
Yield of hydroxyl radicals decreased in ns time scale, with diffusion and reaction of the radicals. The same tendency was observed in other energies and ions.

High energy heavy ions are used for plant breeding and cancer treatment. The heavy ion can produce highly reactive species (e.g. hydroxyl (OH) radical) with a different distribution from that of conventionally used radiation, such as γ-rays, in a cellular tissue, i.e. an aqueous solution, as shown in Fig.4-7. Although the characteristics of the heavy ion irradiation effects can be explained in terms of LET (linear energy transfer) in many cases, one cannot explain the spatial distribution of the reactive species using LET. Moreover, the reactive species diffuse and react with time. Since the OH is considered the most important basic radical for radiation chemistry research, we estimated the yield of the OH radicals based on the mass and energy of the incident ion, and the elapsed time.

We irradiated aqueous phenol solution with heavy ions, changing the mass and energy systematically, and estimated the OH radical yield from the yield of reaction products of phenol. As a result, the yield of the OH radicals increased with the specific energy in the case of each ion, but decreased with the mass of the ion at the same specific energy as shown in Fig.4-8. The yield decreased with elapsed time (Fig.4-9). These results can be derived from the initial distribution of the reactive species around the heavy ion trajectory, and subsequent diffusion and reaction of the radicals.

Presently, we are constructing a time resolved optical measurement system. We will thereby increase the reliability of data about the radical yield, and observe directly reactions of radials with biomolecules.

Reference

Taguchi, M. et al., Yield of OH Radicals in Water under Heavy Ion Irradiation. Dependence on Mass, Specific Energy and Elapsed Time, Nuclear Science and Techniques, vol.18, issue 1, 2007, p.35-38.