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DATA NEEDS FOR THE TRACK STRUCTURE OF ALPHA PARTICLES AND ELECTRONS IN WATER

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We have made calculations of the ionization spectra for alpha particle and electron tracks in water.[1,2] We have also computed the number of ions created per micrometre of track length, the energy distribution of the secondaries, and the energy expended per ion pair created. Our aim is less toward theoretical derivations than to obtain a numerically accurate description of the track structure at all energies in a form suitable for biomedical applications (in our case, the initiation of cancer).

During this work, we have become fully aware of the need for experimental data and painfully aware of the lack of crucial data.

Experimental data are, in principle, needed for three reasons: 1) to check theory where it exists, 2) to fit parameters in the theory, and 3) to find a representation in areas where there is no theory. At very high primary energies, the velocity of the incoming particle is substantially greater than the velocity of the atomic electrons and hence the Born approximation is applicable. Even at these energies, we need good data to find the oscillator strength or the matrix element which is characteristic to the water molecule. At very low energies and especially for small momentum transfers, no quantitative theory exists for these ionization processes and we have to rely almost entirely on the experimental data.

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For electrons, essentially the only data available in the literature are the differential cross section measurements of Opal et al.[3] and the total cross section measurements of Schutten et al.[4] Recently, accurate determinations of the W-values for electrons on water vapor have become available through the measurements of Combecher.[5] Because of the sparseness of data, we had to use the idealization of Kim[6] who proposed to represent the glancing collision cross section as the product of a factor depending on the primary energy and essentially given by the Bethe theory and another factor dependent only on the energy of the secondaries which has to be taken from the data. As the data[3] are at 500 eV only, we have no test for the reliability of this factorization. A repetition of the measurements of single differential cross sections but extended to several energies above and below 500 eV would be highly desirable, as would a careful repetition of the measurements of total cross sections over a large energy range.

For the alpha particles, we were able to use the recent measurements of Toburen et al.[7], at T = 0.3 to 2 MeV, the charge-changing cross sections of Armstrong et al.,[8] the energy loss measurements of Matteson et al.,[9] and of Palmer et al.[10] The slowing down of alpha particles in water involves several processes about which only sparse information is available. Of prime interest are the charge-changing cross sections, pick-up and stripping of atomic electrons, the convoy electrons and absolute measurements of the total cross section covering a wider range of energies than the Toburen data.[7] There are several measurements of the convoy peak, but they are all in an energy range where the convoy contribution is still increasing as the energy decreases.[11] This cannot go on indefinitely and it would be most useful to have a measurement of the differential cross section at an energy below the maximum of the convoy contribution, perhaps at T = 0.1 to 0.5 MeV.

In conclusion, it should be mentioned that any good measurements on water or water vapor will receive almost instantaneous recognition as they are so relevant for many applications. Finally, Rudd[12] reports that double differential cross sections for electrons on water vapor have just been measured[12] and the convoy peak has been observed in protons on water.[13] This is an excellent start!

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