INTRA-SPUR POSITRONIC PROCESSES

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Considering that Ps formation in condensed media has to take place in the terminal positron spur which, comprising many positive ions, provides a strong oxidizing environment for Ps, it is suggested that Ps formation via the epithermal process has to be mixed up with that of the spur process. Eventually in condensed media the observable aspect is those involving slowed down electrons and positron. When the size of the terminal positron spur is large, on the other hand, Ps via the epithermal process can survive. It appears to be possible to overcome the apparent inconsistency between the two models in this way. With this assumption admitted, we propose to investigate the intra-spur positronic processes in more detail. The spur process is an evolution of the energy level and the number of excess electrons, and Ps can be formed from various electron states in the course of the evolution: free excess electrons molecular anions, and excited molecular states. Ideas of Ps formation via resonant energy absorption and that involving vacancies are also presented. The importance of the non-exponential decay of o-Ps in the study of the positronic spur processes is also demonstrated with some recent results of scavenger effects.

Although our knowledge about the chemistry of positron and positronium has substantially increased recently, there are still many points that must be clarified. Especially lacking is the knowledge about the mechanism of Ps formation. It is, being not only the matter of fundamental importance, absolutely necessary at this stage when application of positron and positronium to various practices is becoming possible. Without detailed understanding of the Ps formation process the value of PAL has to be substantially diminished. The recent confusing interpretation of o-Ps intensity in polymers is an example.

It is not that there is little data to consider the problem. Since the spur model of Ps formation was published in 1974,1,2 several groups have been trying to evaluate Ps formation data in the light of intra-spur positron reactions,3-6 and many others have reported, even fragmentarily, data favorable for the model. It is unfortunate, however, that normally discussion has not gone beyond judgment of the two alternative models: the ORE model and the spur model. In the following we will show that the inconsistency between the two models disappears by noting that they both must occur in the positron spur. Based on this viewpoint we try to extend our understandings on positronic spur processes.
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Oxidation of Ps in the early stage of positron spur

We will briefly recollect the models of Ps formation. The first model of Ps formation proposed by ORE is the one-step electron abstraction reaction from atoms and molecules

$$M + e^+ \rightarrow M^+ + Ps^* \quad (a)$$

Since the binding energy of Ps is small ($I_{Ps} = 6.8$ eV in vacuum), there is an energy threshold of $e^+$ energy for the reaction: $E_{th} = I_M - 6.8$ eV, where $I_M$ is the ionization potential of $M$. Since $e^+$ with an energy below this threshold cannot form Ps, this is an epithermal reaction and any trivial perturbation near thermal energy is not expected to affect it significantly. The Ps born in Reaction (a) has an energy $E_{Ps} = E_e - E_{th}$. Since this ranges from thermal to several eV, the nascent Ps is mostly a hot-atom and its subsequent reactions are considered to lead to observable changes in the Ps yield. Theoretical treatments based on this viewpoint were extensively given by GOL'DANSKI and others.

In the spur model of Ps formation, radiation chemical aspect of $e^+$ is noted. $e^+$ injected into matter loses energy by repeated ionization and excitation processes by depositing its energy in small space regions (called the radiation spurs) in the form of ion pairs and excited molecules. When the $e^+$ energy becomes as low as about 1 keV the energy deposition becomes more efficient and many ionization events successively take place in a small region of the order of 50 nm in diameter [Reaction (b)]. The yield (G-value) of ion pair production is about 4.5/100 eV, and thus several tens of ion pairs are formed in this small space. $e^+$ should eventually be stopped in this terminal spur, and it has a good chance to combine with one of the excess electrons which otherwise must have recombined with the parent ion $M^+$ [Reaction (c) and (d)]:

$$M \rightarrow M^+ + e^- \quad (b)$$

$$M^+ + e^- \rightarrow M^* \quad (c)$$

$$e^+ + e^- \rightarrow Ps \quad (d)$$

These two models are seemingly inconsistent each other, but it has often been claimed that they can be dealt with in a comprehensive way. Indeed they rather must be regarded as depicting typical different sides of what is taking place in the terminal positron spur, because even Reaction (a), with the energy involved being less than about 10 eV, must occur in it. It was supposed before Reference 13 that hot-Ps produced in the ORE gap will break up in the succeeding collision in dense gases or in condensed