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Oxygen sensing ability of positronium

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Positronium (Ps) is an exotic atom consisting of a positron and an electron, and around 10¹¹ Ps atoms form in the human body during a PET scan. We have discussed little Ps in PET because its formation does not change the spatial information obtained by PET; Most Ps annihilates into back-to-back gamma-ray photons. However, Ps can provide other unique information due to the delay of the gamma-ray emission as long as its lifetime. The lifetime varies according to the chemical and physical environment for Ps. For example, the lower dissolved oxygen concentration (pO₂), the longer a Ps atom survives in solutions. This is because of the unpaired electrons in the O₂ molecule that enhance Ps annihilation via the electron exchange interaction. Knowing pO₂ distribution is important for cancer patients because hypoxic cells are often resistant to radiotherapy as well as chemotherapy.

Moskal *et al.* named the new concept of PET as "Ps imaging [1]," and they also found that the Ps lifetime differs between healthy and cancer cells [2]. The difference may come from a combination of several chemical and physical conditions, but how each factor changes the Ps lifetime is a challenging matter to be understood. Some efforts have revealed how O₂ molecules reduce Ps lifetime. Stepanov [3] found a positive correlation between the pO₂ and Ps annihilation rate (the inverse of the lifetime) in water. Furthermore, we found good linearity between them by accumulating 50 times larger number of counts, as shown in Fig. 1 [4]. This line is namely calibration line for Ps as an oxygen sensor, and this result indicates a possibility of Ps as a hypoxia biomarker candidate. In other words, during a PET scan, 10¹¹ nanosized sensors for O₂ are spontaneously created in vivo, and it is worth trying to read the indicator for improving cancer treatments.

Fig. 1 pO₂ vs Ps decay rate: squares (Lee [5]), triangles (Stepanov [3]), and circles (Shibuya [4]). (see at *https://www.nature.com/articles/s42005-020-00440-z/figures/3*)

References

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