DOI: 10.46991/JISEES.2025.SI1.193

A Molecular-Level Understanding of the Thermodynamic Efficiency of Photosynthetic Phosphorylation

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ABSTRACT

Photosynthesis is a fundamental molecular-level process in biology that has a profound influence on the entire Biosphere. Hence an in-depth understanding of the photosynthetic process at the molecular level is central to the biological and environmental sciences for fostering transformation to a more sustainable future of our planet. Estimations of efficiencies of these processes is a necessary first step towards this goal. Here, the thermodynamic efficiency of the overall photosynthesis process and its component sub-steps are calculated from first principles. An overall efficiency of ~31.5 % is obtained for photosynthesis in C3 plants using flashes of red light. The mechanistic $P/2e^-$ stoichiometric ratios have been estimated, and the resulting efficiencies of the linear and cyclic pathways have been quantified. These calculations are then related to the functioning of the Photosystem I, Photosystem II, and ATP synthase at the molecular level. Such studies not only help in better understanding of the thermodynamic efficiency of photosynthesis but also in an enhancement of the photosynthetic process, leading to diverse applications in biology and sustainability science.

Keywords: photosynthetic phosphorylation, ATP synthesis, thermodynamic efficiency, molecular mechanism, P by $2e^-$ ratio, cyclic and non-cyclic phosphorylation, oxygen evolution

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