DFT Calculations of a Catalytic Reaction Cycle linking Proton Transfer with Proton Pumping in a Bacterial Cytochrome c Oxidase

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The electron transport chain in mitochondria and aerobic bacteria contain three integral membrane protein complexes which link electron transport to chemical proton transfer and proton pumping across the mitochondrial membrane in eukaryotic cells and similarly across the periplasmic membrane in aerobic bacteria. The terminal electron acceptor complex (Complex IV) accepts electrons from the mobile protein carrier cytochrome c, and uses these electrons, and "chemical protons" to reduce O2 to 2H2O. In this process, protons are pumped across the membrane, creating an electrical potential for energy storage. We present DFT calculations for the catalytic center, a dinuclear heme Fe---Cu Complex, that performs the catalytic chemistry. Structures and energies of intermediate states of this Complex are evaluated. Vibrational frequencies of Fe-O bonds are calculated for these intermediates and compared with results from Resonance Raman spectroscopy. We show the surprising role of water molecules in activating a proton pumping pathway.