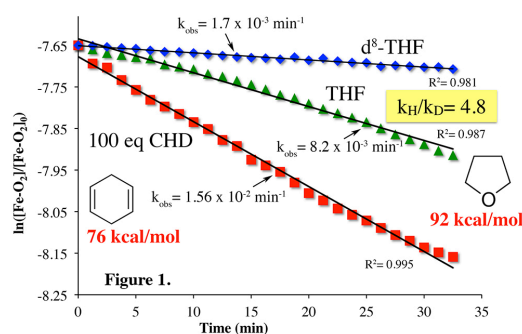


Mechanism of Formation of a Reactive, Alkyl Thiolate-Ligated Fe^{III}-Superoxo Intermediate Derived from Dioxygen

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Thiolate (RS⁻) ligands have been shown to lower the activation barrier to O₂ binding, and facilitate peroxy O-O bond cleavage, and HAT reactions. A new structurally characterized alkyl thiolate-ligated Fe(II) complex will be described, which reacts with dioxygen (O₂) to form an unprecedented example of a reactive iron superoxo (RS-Fe(III)-O₂) intermediate that is capable of cleaving strong C-H bonds.[1] A thiolate-ligated iron superoxo is proposed to play a key role in the biosynthesis of β -lactam antibiotics, as well as tumor suppression. The former is catalyzed by the iron enzyme isopenicillin N-Synthase (IPNS),[2] while the latter by the iron enzyme cysteine dioxygenase (CDO).[3] Very few iron superoxo compounds have been reported, and none are capable of cleaving strong C-H bonds. Spectroscopic characterization, and formation of RS-Fe(III)-O₂ via an alternate pathway, will be discussed, as well as calibrated DFT and TD-DFT calculations, which show that the frontier orbitals consist of two strongly coupled unpaired electrons of opposite spin, one in a superoxo $\pi^*(\text{O-O})$ orbital, and the other in an Fe(d_{xy}) orbital. Unpaired spin on the superoxo likely contributes to the ability of our RS-Fe(III)-O₂ to abstract H-atoms. Both the calculated and experimental electronic absorption spectrum of our RS-Fe-O₂ are similar to that of the putative IPNS superoxo intermediate, as well as CDO. The rate at which our superoxo converts to a second observable intermediate, proposed to be an iron hydroperoxo (Fe(III)-OOH), is shown to depend on the C-H bond strength of the solvent or sacrificial H-atom donor, and a deuterium isotope effect ($k_{\text{H}}/k_{\text{D}} = 4.8$), comparable to that of IPNS ($k_{\text{H}}/k_{\text{D}} = 5.6$), is observed (Figure 1). As demonstrated by the presence of a low energy thiolate \rightarrow Fe-O₂ charge transfer transition, the electron-rich alkyl thiolate likely plays a role in increasing reactivity by creating a more basic superoxo. The bond dissociation energy (BDE) of the C-H bonds cleaved by our RS-Fe-O₂ superoxo compound (92 kcal/mol) are comparable to those cleaved by the enzyme IPNS (93 kcal/mol).



References

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