Quantum Chemical Investigations of Reaction Paths of Metalloenzymes and Biomimetic Models – The Hydrogenase Example

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Abstract Quantum chemical methods allow one to investigate chemical aspects that are often difficult to evaluate using only experimental approaches. In particular, the continuous increase in reliability and speed of quantum chemical methods has recently allowed...
the investigation of very complex molecular systems, such as biological macromolecules. In this contribution, we present applications of quantum chemical methods to the investigation of reaction paths of metalloenzymes and related biomimetic models, using hydrogenase models as a reference case. In particular, we discuss several examples from the literature, emphasizing the possibilities (and limitations) offered by present theoretical approaches to study structures, electronic properties and reactivity of metalloenzyme models. Some relevant aspects which have not yet been fully explored using theoretical methods, such as the role of antiferromagnetic coupling and photochemical reactions in [Fe] hydrogenases, are treated in more detail, with presentation and discussion of original data recently obtained in our laboratory.

**Keywords**  Coordination compounds · DFT · Hydrogenases · Metalloenzymes · Quantum chemistry

**Abbreviations**

B3LYP  Becke3-Lee-Yang-Parr DFT functional
BP86  Becke-Perdew 1986 DFT functional
CI  Configuration interaction
CIS  Configuration interaction singles
DFT  Density functional theory
dppe  1,2-bis(diphenylphosphino)ethane
DTMA  Di(thiomethyl)amine
EDT  1,2 Ethanedithiolate
EPR  Electron paramagnetic resonance
Feₚ  Iron atom of the binuclear cluster proximal to the [Fe₄S₄] cluster in [Fe] hydrogenases
Fe₄  Iron atom of the binuclear cluster distal to the [Fe₄S₄] cluster in [Fe] hydrogenases
G2  Gaussian-2 molecules set
GGA  Generalized gradient approximation
HF  Hartree–Fock
HOMO  Highest occupied molecular orbital
LUMO  Lowest unoccupied molecular orbital
KS  Kohn–Sham
LDA  Local density approximation
MP2  Möller–Plesset second order perturbation method
MOs  Molecular orbitals
CT  Charge transfer
o-xyldt  Orto-xylenedithiolate
PBE  Perdew–Burke–Ernzerhof DFT functional
PDT  1,3-Propanedithiolate
RI  Resolution of identity
TDA  Tamm–Dancoff approximation
TDDFT  Time-Dependent density functional theory
TDHF  Time-dependent Hartree–Fock
TZVP  A triple-zeta basis set
VWN  Vosko–Wilk–Nusair DFT functional
ZORA  Zero-order regular approximation
BS  Broken symmetry