

## **ELECTRONIC SUPPORTING INFORMATION FOR:**

### **DFT characterization of the reaction pathways for terminal- to $\mu$ -hydride isomerization in synthetic models of the [FeFe]-hydrogenase active site.**

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#### **General notes**

Even if experimental results suggest that isomerization at the protonated iron atom can be in some cases be accompanied by isomerisation of the other iron centre, the overall computed energy profile for the hydride-bond iron atom isomerisation, which is the focus of this work, is only slightly changed, not affecting the general conclusions (data not shown).

#### **Computational methods**

Density functional theory (DFT) calculations have been carried out with the TURBOMOLE 5.7 suite.<sup>1</sup> Geometry optimizations and transition state searches have been carried out using the pure functional B-P86,<sup>2,3</sup> in conjunction with a valence triple- $\zeta$  basis set with polarization on all atoms, a level of theory which has been shown to be suited to reliably investigate [FeFe] hydrogenase models.<sup>4-6</sup>

Stationary points of the energy hypersurface have been located by means of energy gradient techniques and a full vibrational analysis has been carried out to further characterize each stationary point.

The optimization of transition state structures has been carried out according to a procedure based on a pseudo Newton-Raphson method. Initially, geometry optimization of a guessed transition state structure is carried out constraining the distance corresponding to the reaction coordinate. Vibrational analysis at BP86/TZVP level of the constrained minimum energy structures is then carried out and, if one negative eigenmode corresponding to the reaction coordinate is found, the

curvature determined at such point is used as starting point in the transition state search. The location of the transition state structure is carried out using an eigenvector-following search: the eigenvectors in the hessian are sorted in ascending order, the first one being that associated to the negative eigenvalue. After the first step, however, the search is performed by choosing the critical eigenvector with a maximum overlap criterion, which is based on the dot product with the eigenvector followed at the previous step.

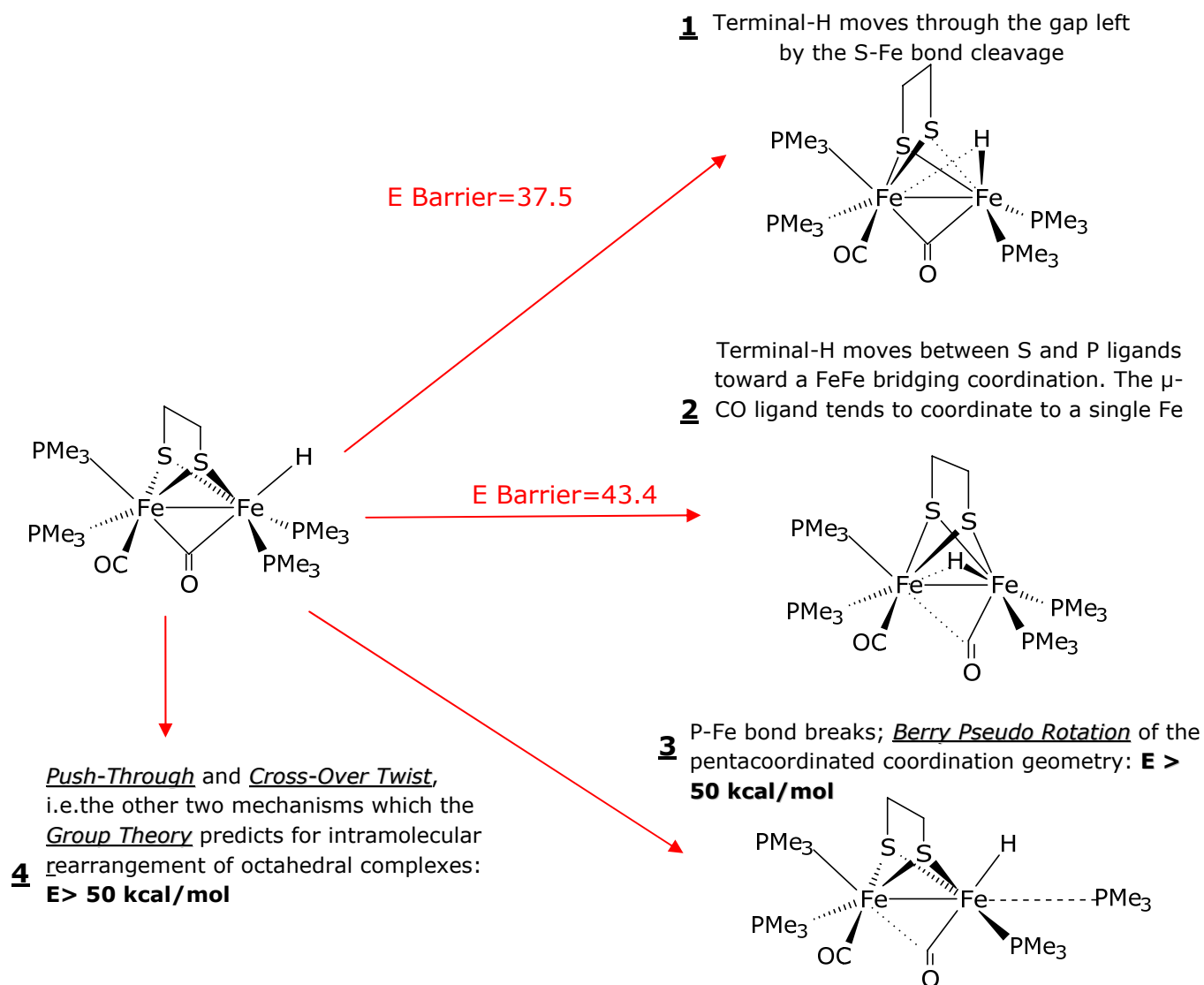
Gibbs free energy (G) values have been obtained from the electronic SCF energy considering three contributions to the total partition function (Q), namely  $q_{\text{translational}}$ ,  $q_{\text{rotational}}$ ,  $q_{\text{vibrational}}$ , under the assumption that Q may be written as the product of such terms. In order to evaluate enthalpy and entropy contributions, the values of temperature and pressure have been set to 273.15 K and 1 bar, respectively, to reproduce as closely as possible experimental conditions. Rotations have been treated classically and vibrational modes described according to the harmonic approximation.

All Gibbs free energy differences have been computed by correcting gas phase data with the inclusion of an implicit treatment of solvent effect (COSMO).<sup>7</sup> The  $\epsilon$  value has been set to 37.5 (corresponding to acetonitrile).

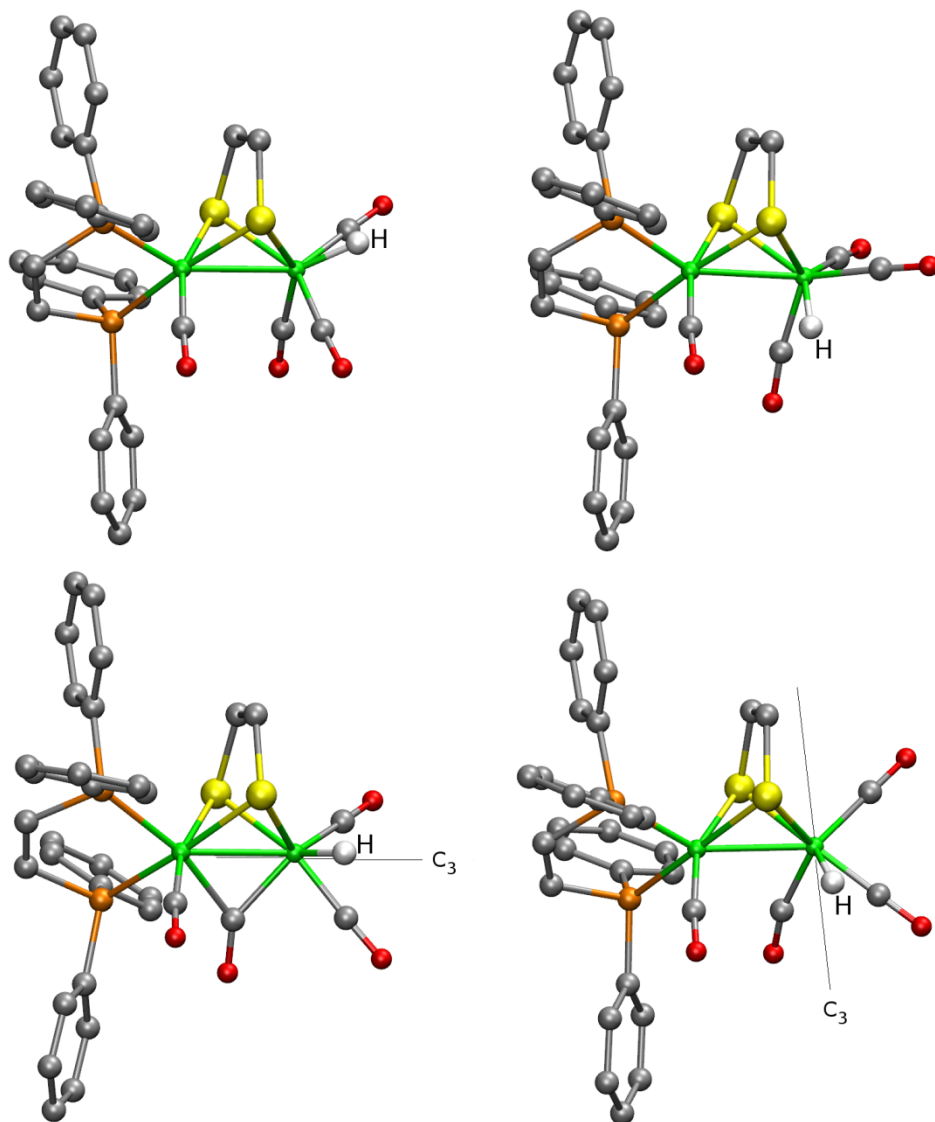
In light of available experimental data and considering the chemical nature of the ligands, only low-spin species have been investigated.

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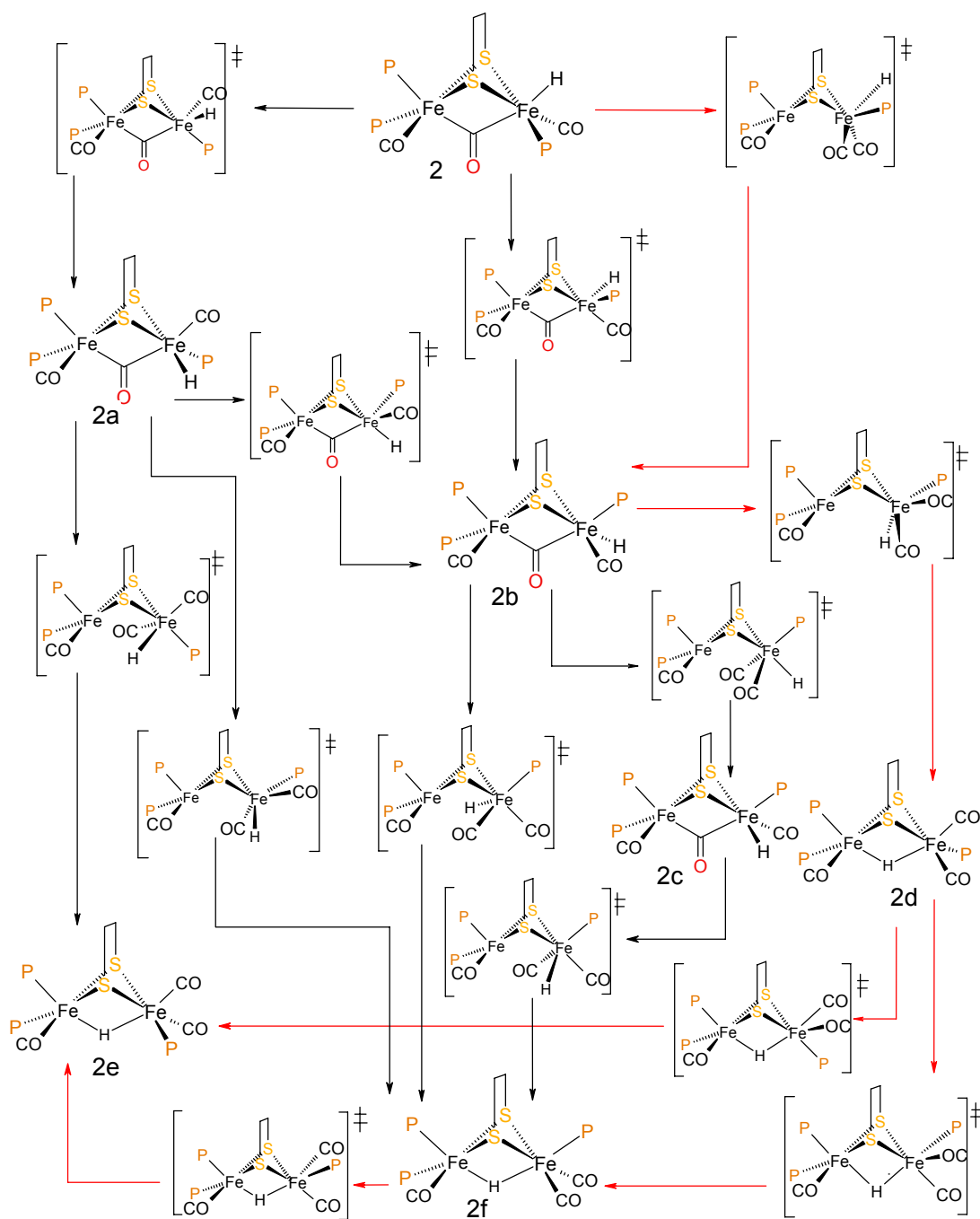
**Scheme 1S.** Other reaction pathways tested by DFT calculations. Structures are schematically shown only for complex **3** for the sake of clarity. Energies in kcal/mol.



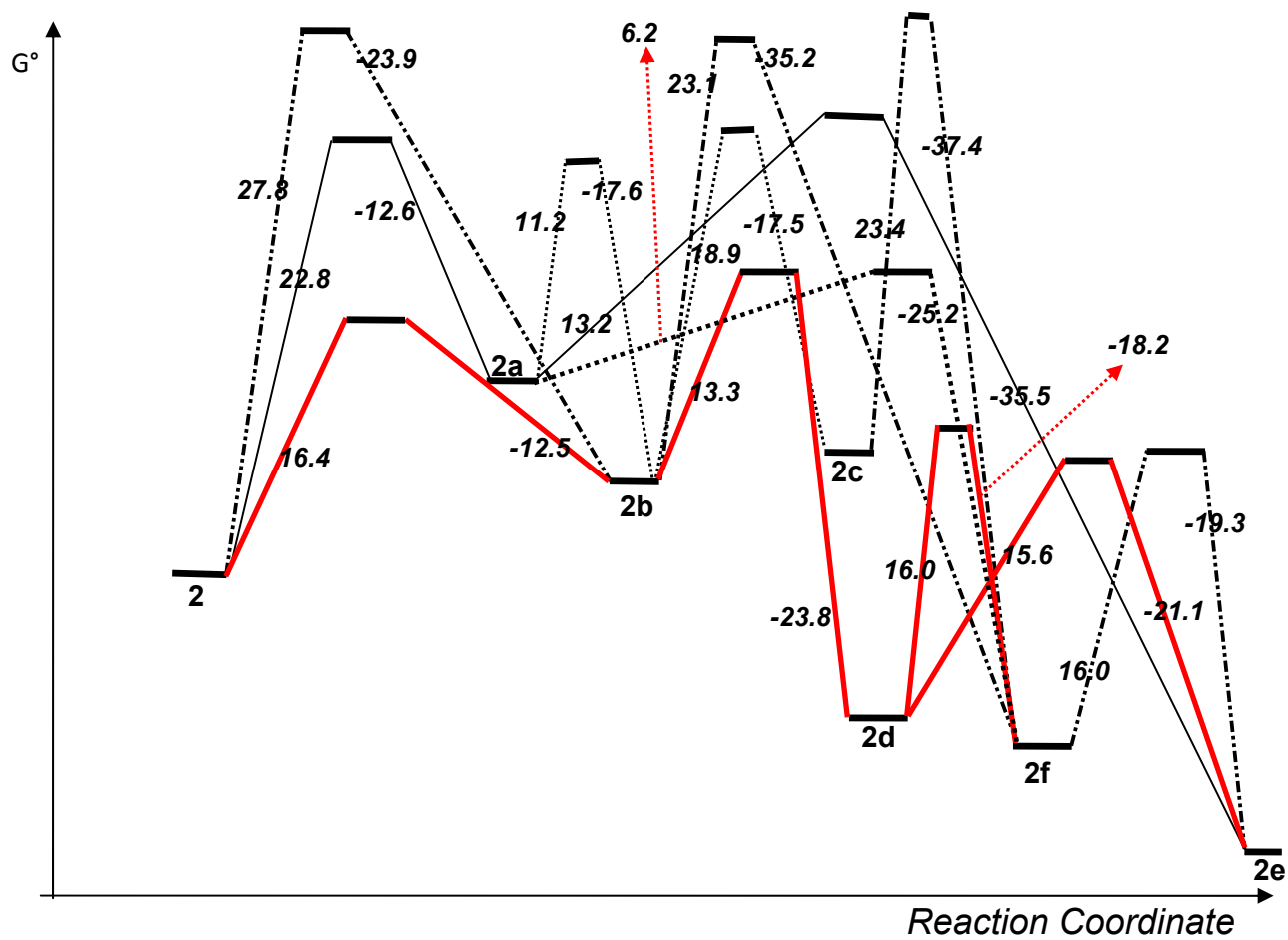
**Figure 1S.** Schematic representation of transition states for terminal-hydride isomerization in complex **1**, according to Ray-Dutt (top) and Bailar (bottom) twist reaction pathways.



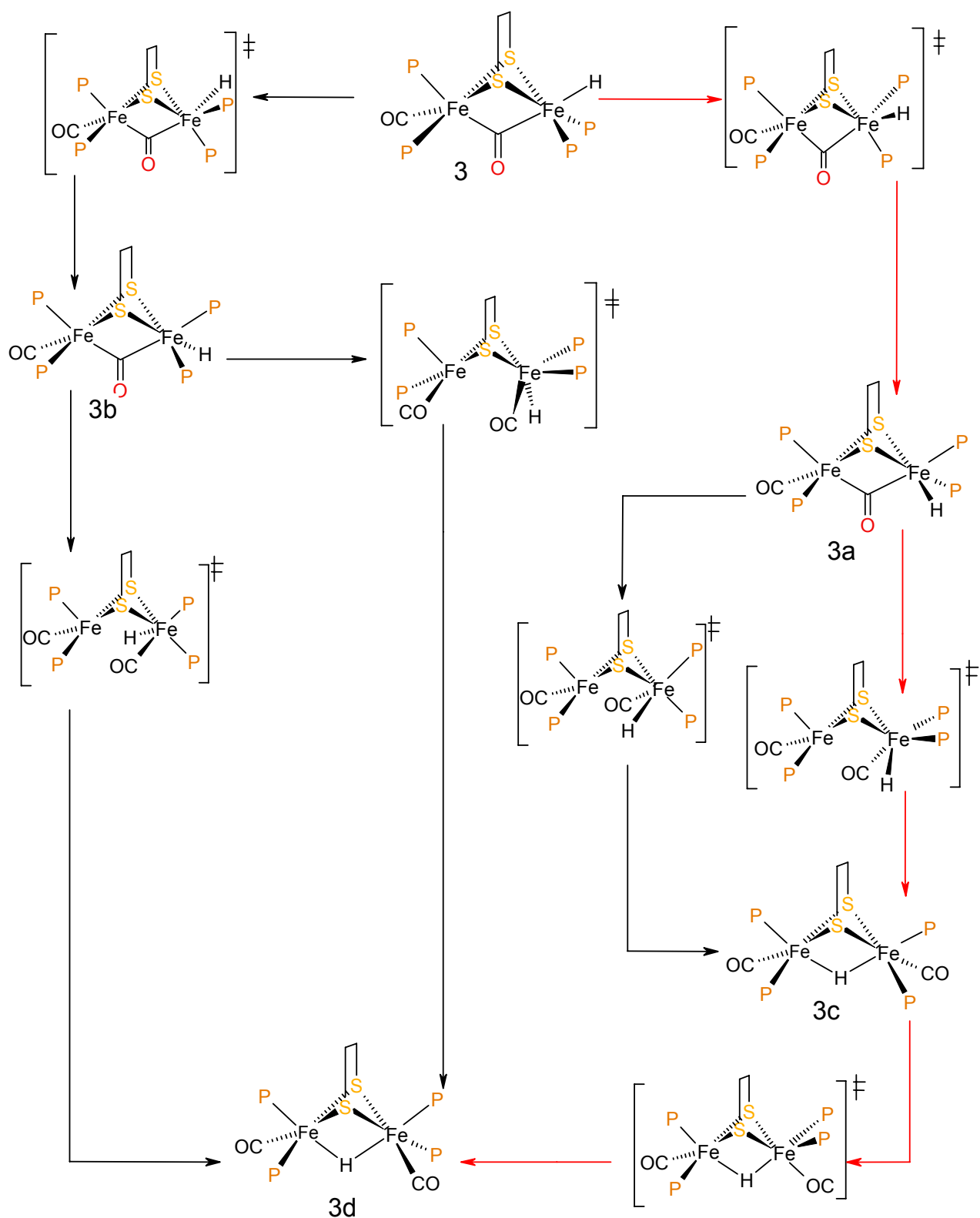
**Scheme 2S.** Intermediate species formed along the isomerization of  $[(\text{dppv})(\text{CO})\text{Fe}(\text{edt})\text{Fe}(\text{CO})_2(\text{PMe}_3)\text{H}]^+$ , (**2**).



**Scheme 3S.** Reaction energy profile for isomerization of  $[(\text{dppv})(\text{CO})\text{Fe}(\text{edt})\text{Fe}(\text{CO})_2(\text{PMe}_3)\text{H}]^+$ , (2).



**Scheme 4S.** Intermediate species formed along the isomerization of  $[(\text{PMe}_3)_2(\text{CO})\text{Fe}(\text{edt})\text{Fe}(\text{CO})(\text{PMe}_3)_2\text{H}]$ , (**3**).



**Scheme 5S.** Reaction energy profile for the isomerization of  $[(\text{PMe}_3)_2(\text{CO})\text{Fe}(\text{edt})\text{Fe}(\text{CO})(\text{PMe}_3)_2\text{H}]$ , (**3**).

