

## Abstract

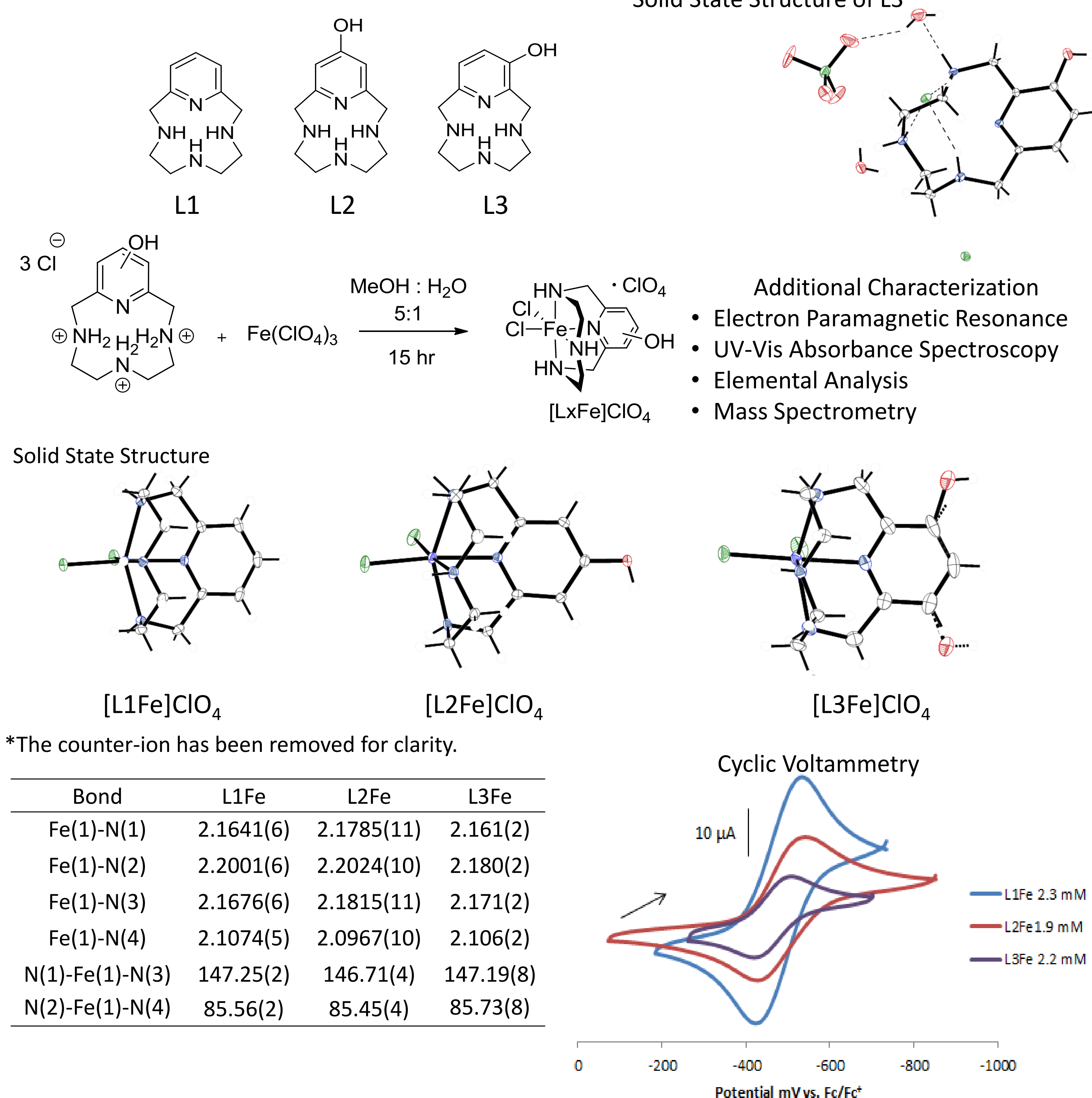
Iron plays a pivotal role in metabolism and transport processes in nature but can also be used to accomplish important chemical transformations on the bench top; recently, iron(II) salts have been shown to catalyze direct Suzuki – Miyaura coupling of N-heterocyclic compounds and arylboronic acid derivatives in the presence of oxygen. Presented herein are three tetra-aza macrocyclic iron(III) complexes [L1Fe(III)(Cl)<sub>2</sub>]<sup>+</sup> (**L1Fe**), [L2Fe(III)(Cl)<sub>2</sub>]<sup>+</sup> (**L2Fe**), and [L3Fe(III)(Cl)<sub>2</sub>]<sup>+</sup> (**L3Fe**) [L1 (Pyclen)=1,4,7,10-tetra-aza-2,6-pyridinophane; L2 =3,6,9,15-tetraazabicyclo[9.3.1]penta-deca-1(15),11,13-trien-13-ol; L3 =3,6,9,15-tetraazabicyclo[9.3.1]penta-deca-1(15),11,13-trien-12-ol] that catalyze the coupling of pyrrole and phenylboronic acid. Following the synthesis and reactivity studies, investigation into the oxidation state of the iron center throughout the catalytic cycle was explored. The results of this work to date will be presented, and will facilitate the understanding of the challenging chemical reactions catalyzed using inexpensive earth abundant metals such as iron.

## Introduction

Nature is capable of transforming unreactive alkanes and alkenes under mild conditions, but comparable laboratory transformations require multiple steps that include expensive and/or toxic metals such as palladium, protecting groups, and strong oxidants.<sup>1</sup> The development of highly efficient, catalytic reactions to modify organic bonds continues to be a formidable synthetic challenge to chemists.<sup>2</sup> Due to the large abundance and low toxicity of iron, it has received attention as a catalyst for the synthesis of fine organic materials. Many studies have focused on developing mononuclear iron catalysts based on chelating motifs seen in nature.<sup>3</sup> These complexes are then studied to determine their catalytic profile, based on the modification of directing groups, steric effects, and electronic characteristics of the substrates.<sup>4</sup> In many cases less emphasis is given to the spin state of the iron center. Although it is necessary to identify the limitations of the catalyst based on substrate scope, it is also important to determine the properties of the metal center that allow catalytic processes to occur. Identification of necessary metal properties will allow for rational design of future iron catalysts.

## Catalyst Design and Properties

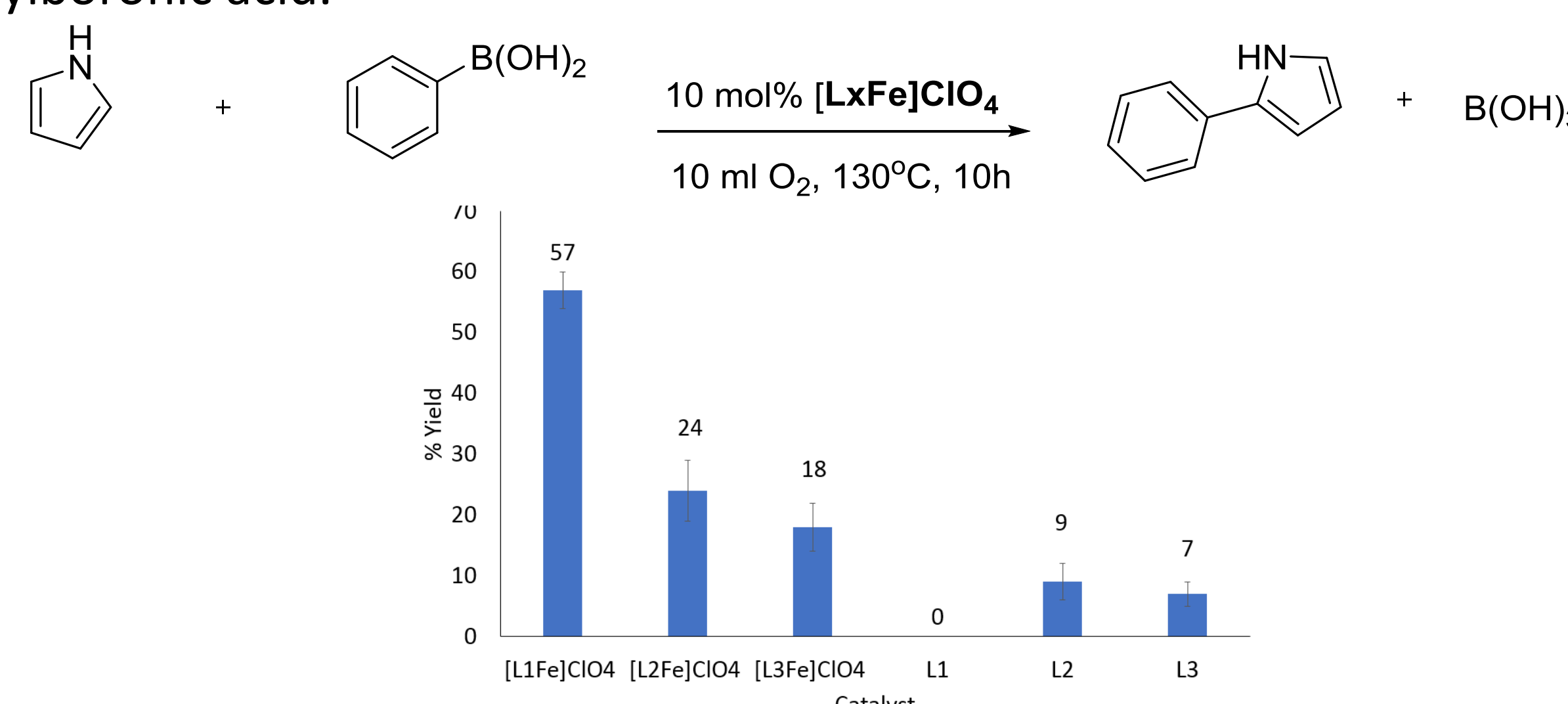
**Hypothesis:** Structural changes to ligands will impact the donor ability and iron coordination chemistry.



**Conclusion:** 1) The complexes take on a cis-folded octahedral geometry, in which the iron center is high-spin. 2) The donor ability of the ligands does not effect the stability of the iron (III) center.

## Comparison of Catalytic Reactivity

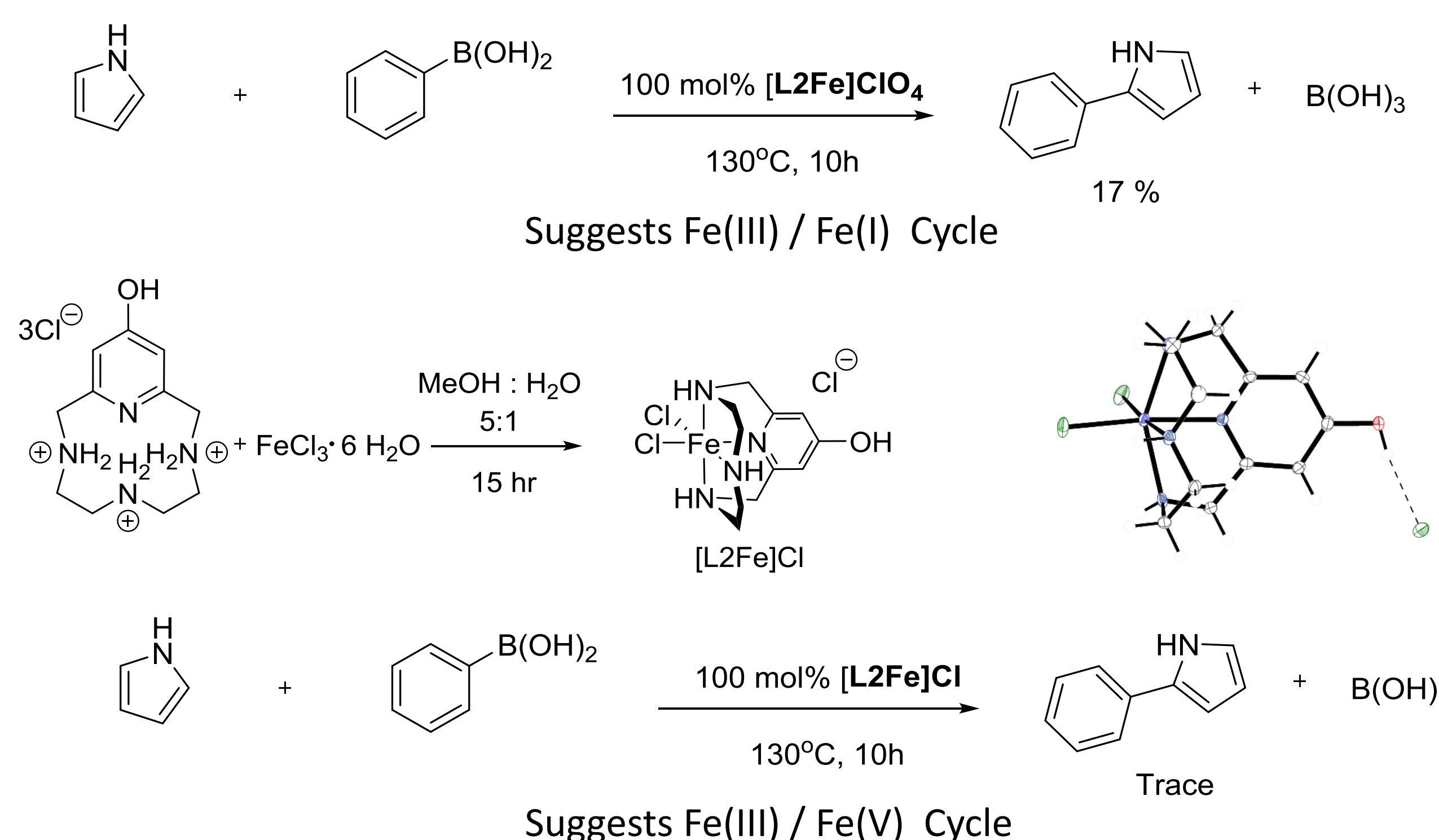
**Hypothesis:** The high-spin iron(III) complexes are capable of coupling pyrrole and phenylboronic acid.



**Conclusion:** [L1Fe]ClO<sub>4</sub> catalyzes the reaction to the greatest extent followed by [L2Fe]ClO<sub>4</sub> then [L3Fe]ClO<sub>4</sub>.

## The Role of Oxygen

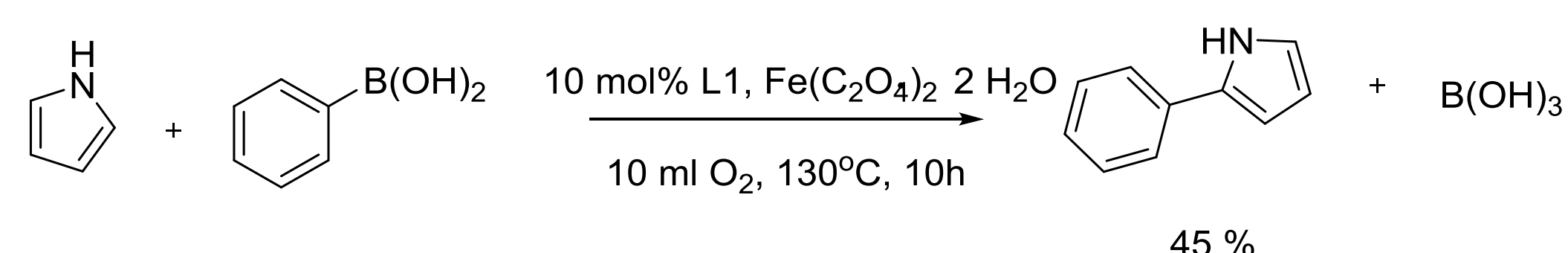
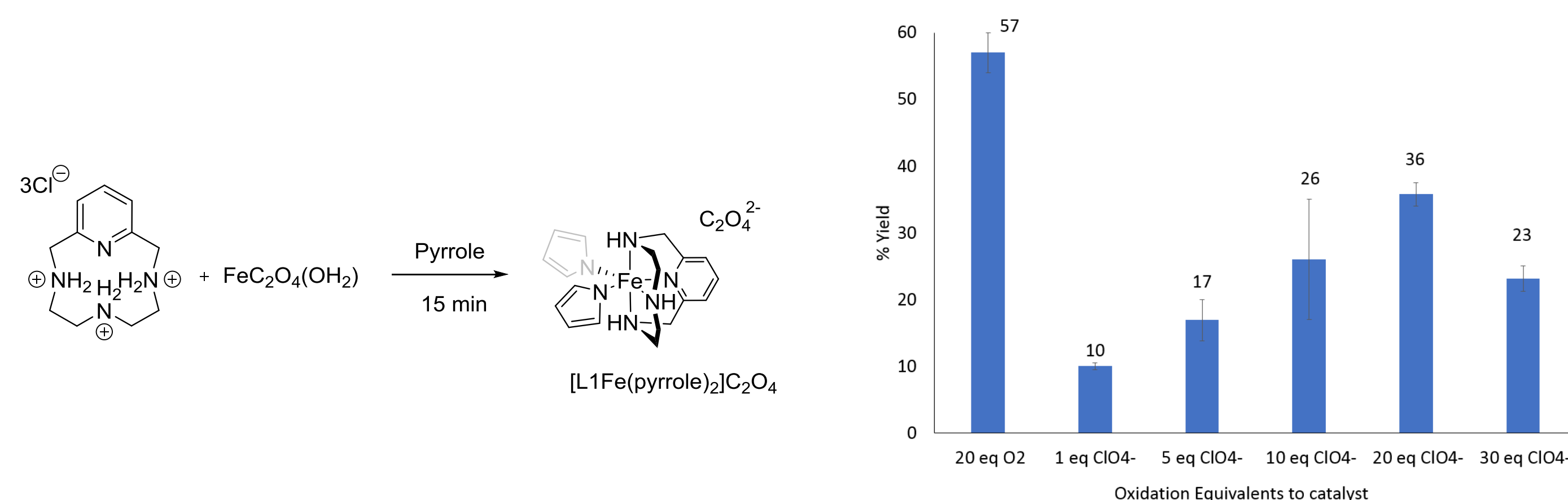
**Hypothesis:** Oxygen is not required for a catalytic turnover.



**Conclusion:** 1) An oxidant is required for catalytic reactivity. 2) Perchlorate is a satisfactory oxidant.

## Stoichiometry of the Oxidant

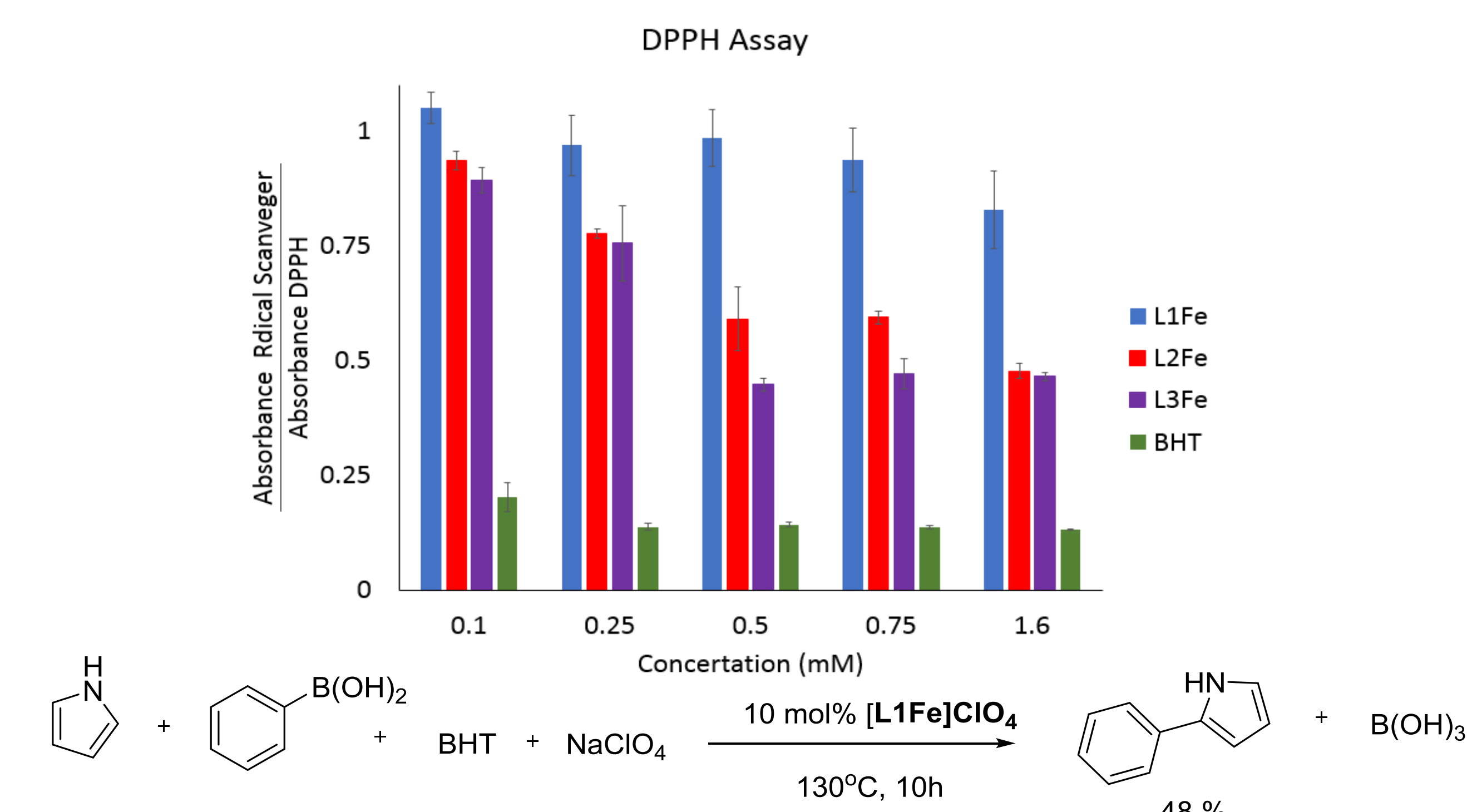
**Hypothesis:** 1) One oxidation events is necessary to generate the active catalyst, therefore, the optimal amount of oxidant is 10 equivalents with respect to pre-catalyst. 2) If an iron(II) salt is used, that salt must first be oxidized to iron(III) before entering the catalytic cycle.



**Conclusion:** 1) The optimal amount of oxidant is 20 equivalents with respect to the catalyst, confirming two oxidative events occur in the catalytic cycle. 2) The iron(II) salt must be oxidized to iron(III) before entering the cycle, seen by a 10% decrease in catalytic yield.

## Radical Scavenging Ability and Its Effect on Catalytic Yield

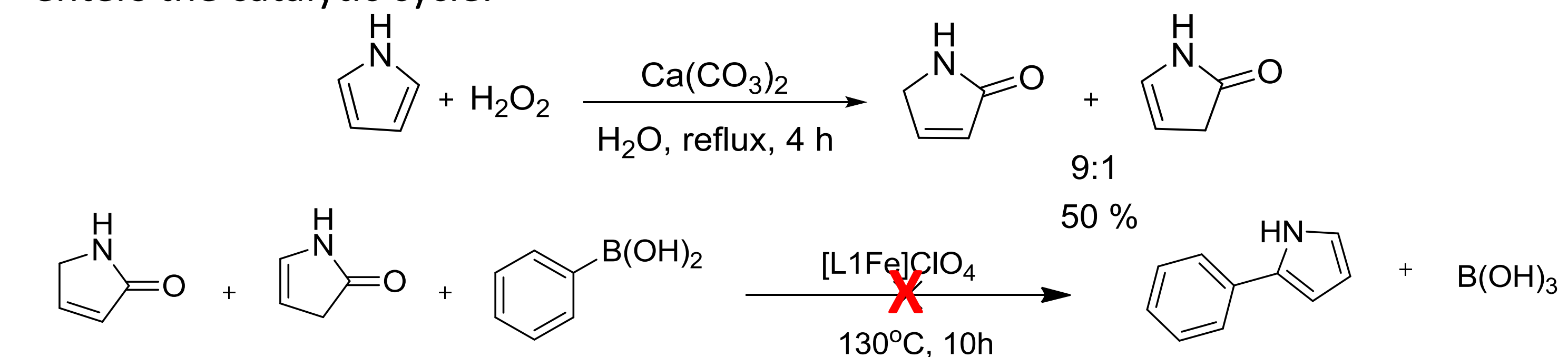
**Hypothesis:** The difference in the catalytic ability of the complexes is caused by the radical scavenging ability of the complexes themselves.



**Conclusion:** The coupling of pyrrole and phenylboronic acid is not a radical process.

## Lactam Pathway

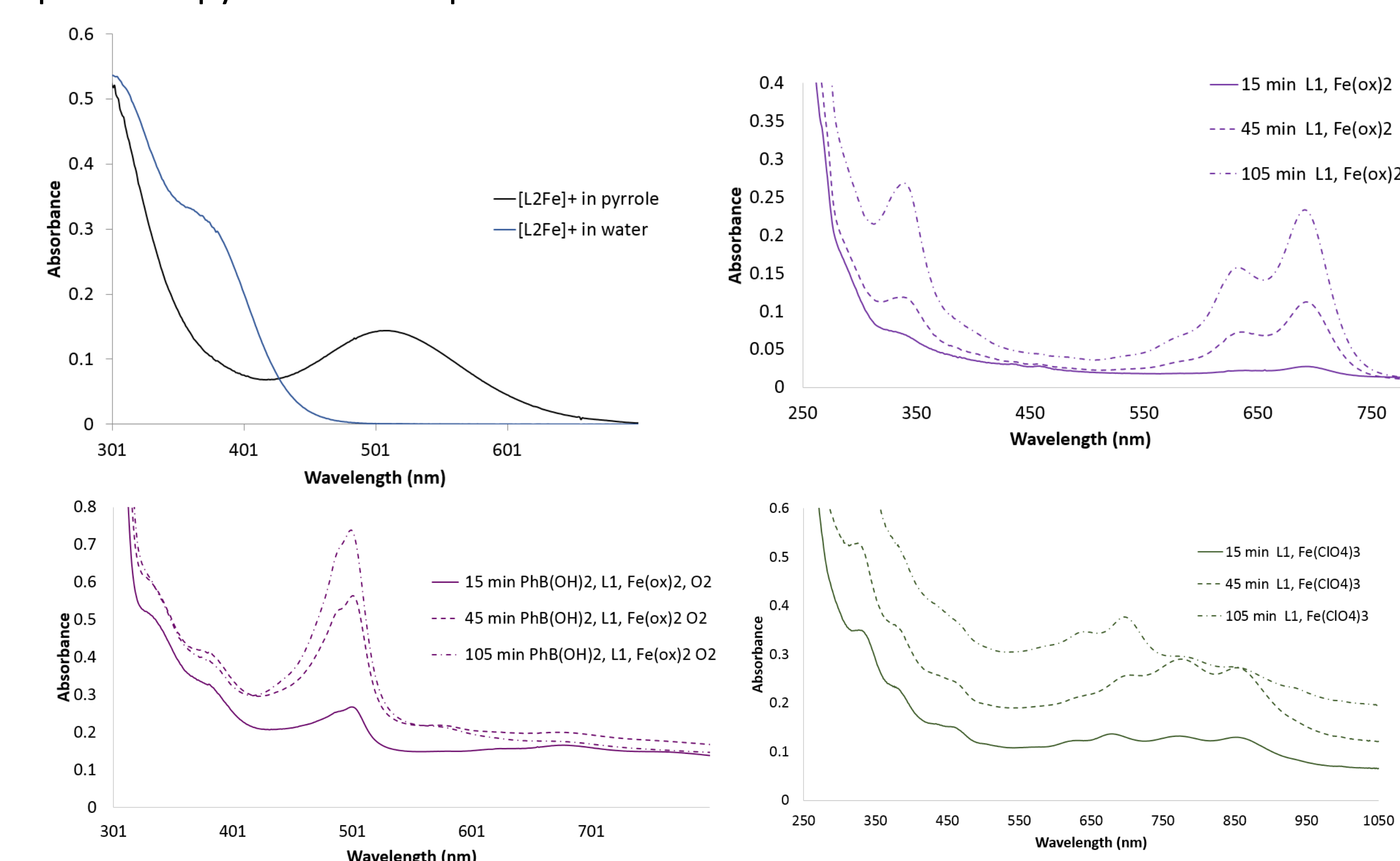
**Hypothesis:** The first oxidation event occurs with pyrrole to form the lactam, which enters the catalytic cycle.



**Conclusion:** The lactam does not react with phenylboronic acid in the presence of the iron catalyst.

## Interaction of Pyrrole and Oxidant with Catalysts

**Hypothesis:** Pyrrole coordinates to catalyst. Active iron species is visible by UV-Vis spectroscopy at room temperature in dichloromethane.



**Conclusion:** 1) Pyrrole coordinates to catalyst. 2) Perchlorate and oxygen interact differently with catalyst. 3) The active iron species needs further investigation.

## References

1. Beck, E. M.; Gaunt, M. J., *Top. Curr. Chem.* **2010**, *292*, 85-121)
2. Sun, C. L.; Li, B. J.; Shi, Z. J. *Chem. Rev.* **2011**, *111*, 1293-314.
3. Costas, M.; Mehn, M. P.; Jensen, M. P.; Que, J., L. *Chem. Rev.* **2004**, *104*, 939-986.
4. (a) Chen, M. S.; White, C. W., *Science* **2007**, *318*, 783-787; (b) Kist, L. T.; Trujillo, M. J. F.; Szpoganicz, B.; Manez, M. A.; Basallote, M. G., *Polyhedron* **1997**, *16*, 3827-3833.