Structural and Reactivity Studies of a Synthetic Model System for a Rare-Earth Containing Enzyme

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https://youtu.be/-Gc9t8NR4iY

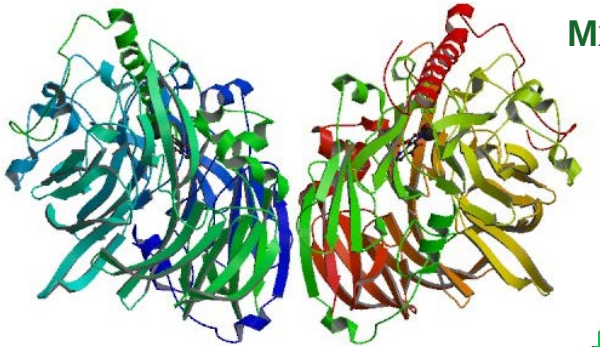
For attendees: during review of the presentation, please direct comments to Alison by using "@AlisonKnasin". This will ensure she receive your comments and questions directly.

Clean Energy Education & Empowerment (C3E)

Methanol Dehydrogenase (MDH)

$CH_4 \xrightarrow[\textit{pMMO}]{} CH_3OH \xrightarrow[\textit{MDH}]{} CH_2CO \Longrightarrow CO_2$, biomass

First instance of lanthanides in an essential biochemical role!

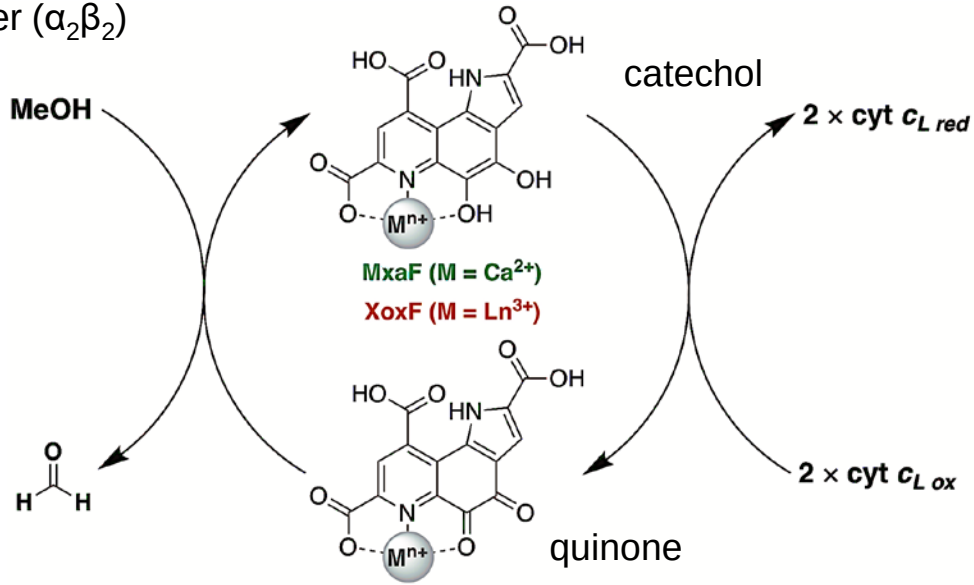


MxaF-type PDB: 2AD8

Heterotetramer ($\alpha_2\beta_2$)

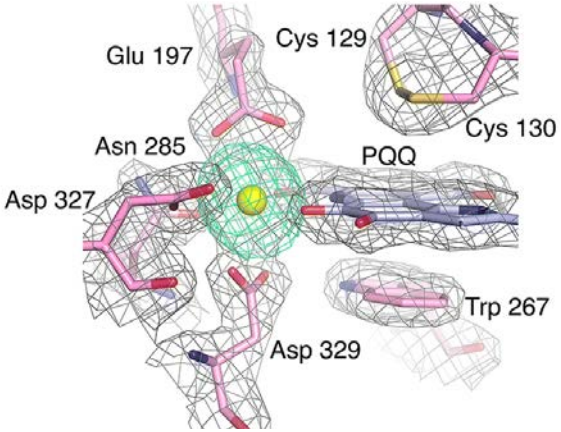
XoxF-type PDB: 4MAE

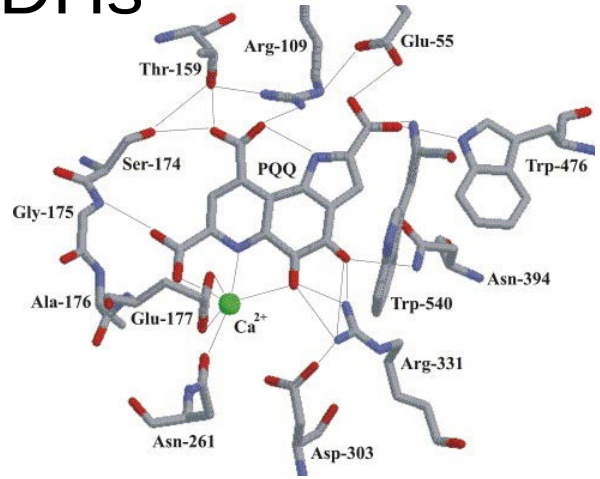
Homodimer (α_2)

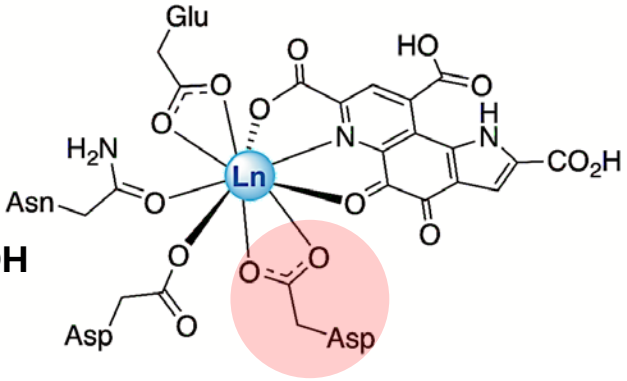


Anthony, C. and coworkers. *Arch. Biochem. Biophys.* **2004**, *428*, 2-9.
Rosenzweig, A. C. and coworkers. *JBIC, J. Biol. Inorg. Chem.* **2018**, *23*, 1037-1047.

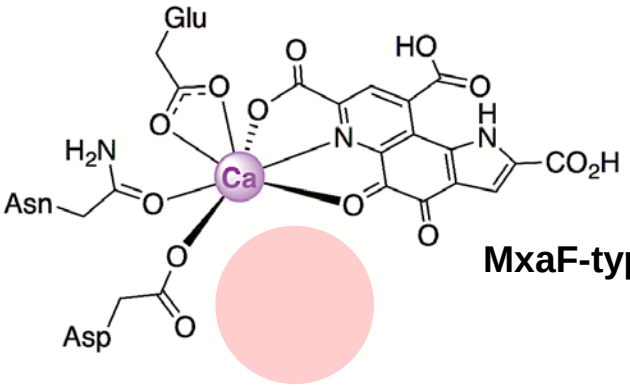
XoxF–Type vs MxaF–Type MDHs







XoxF-type MDH



MxaF-type MDH

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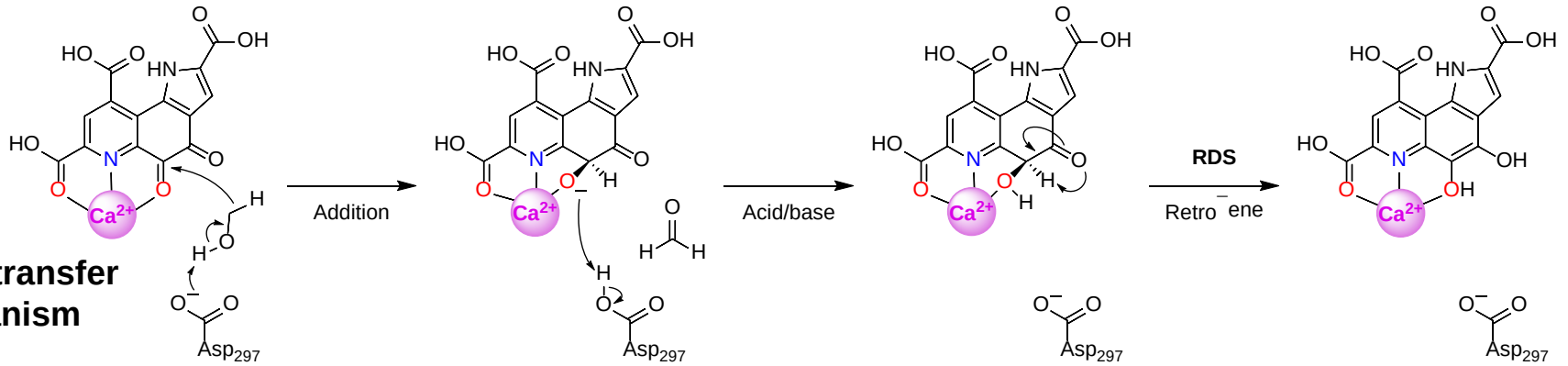
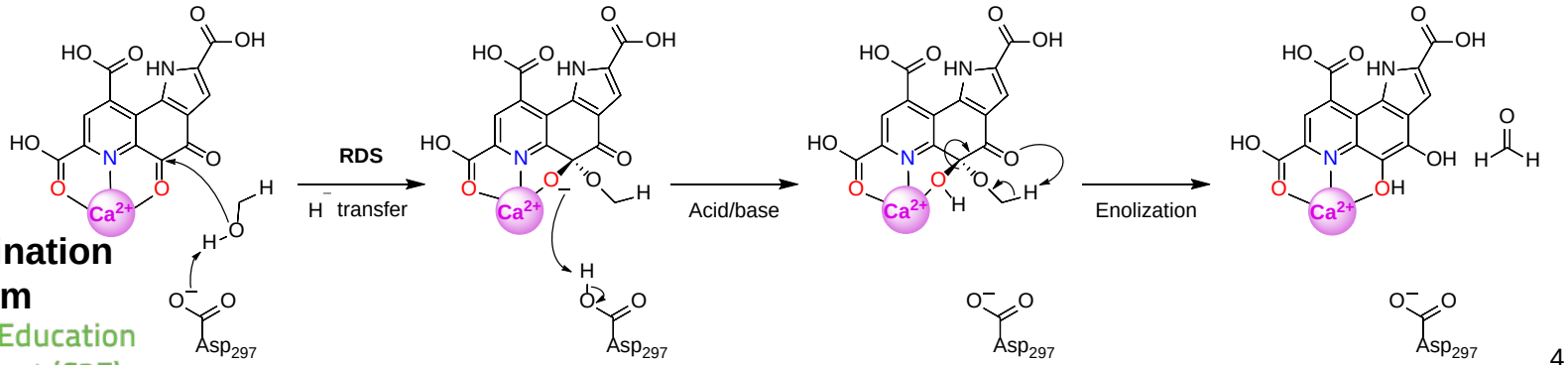
Debated Mechanisms (Hydride Transfer vs Addition Elimination)

Hydride transfer mechanism



RDS = rate–determining step

Addition–elimination mechanism



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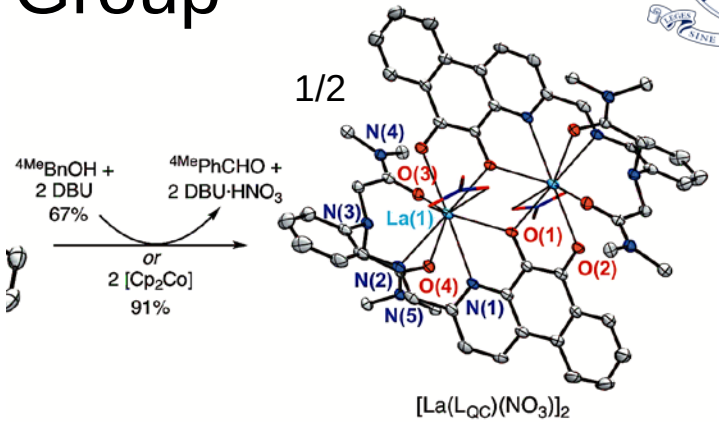
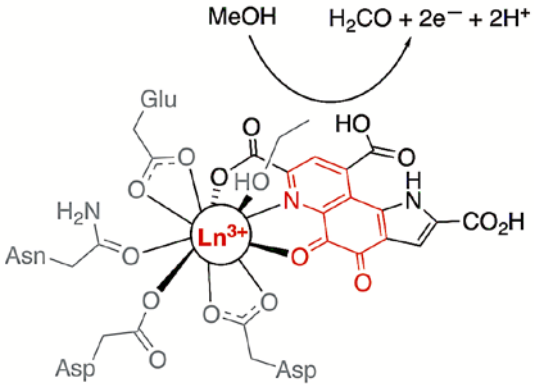
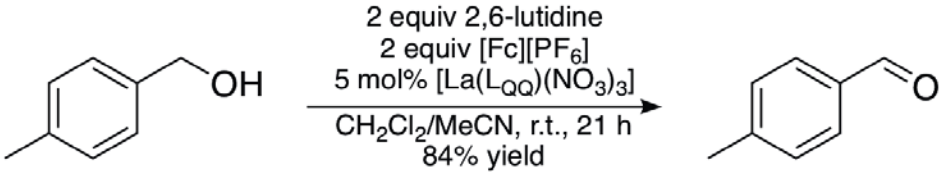
Prior Research in the Schelter Group



quinone

catechol





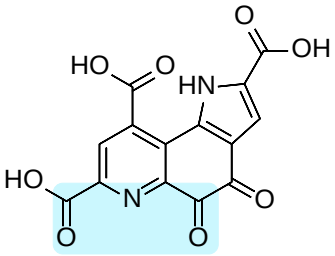
This is the first synthetic lanthanide–containing enzymatic model system.

Clean Energy Education & Empowerment (C3E)

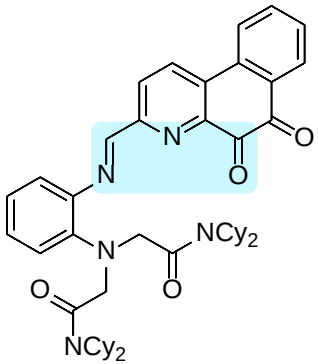
Schelter, E. J. and coworkers. *J. Am. Chem. Soc.* **2018**, *140*, 1223-1226.

Objectives of Study

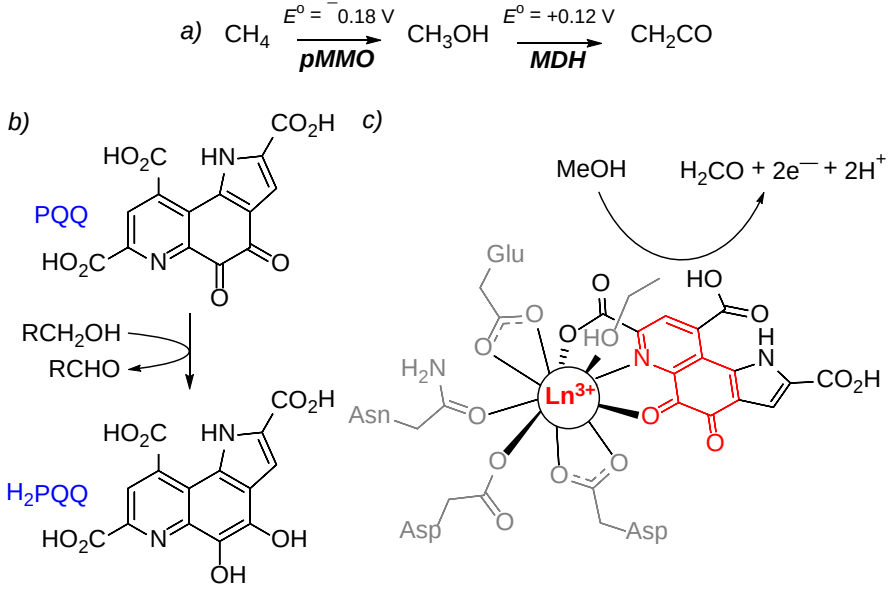
- Compare affinities of La^{3+} and Ca^{2+} in the L_{QQ} binding pocket
- Collect kinetic data for alcohol oxidation reactions with La/Ca(L_{QQ}) complexes



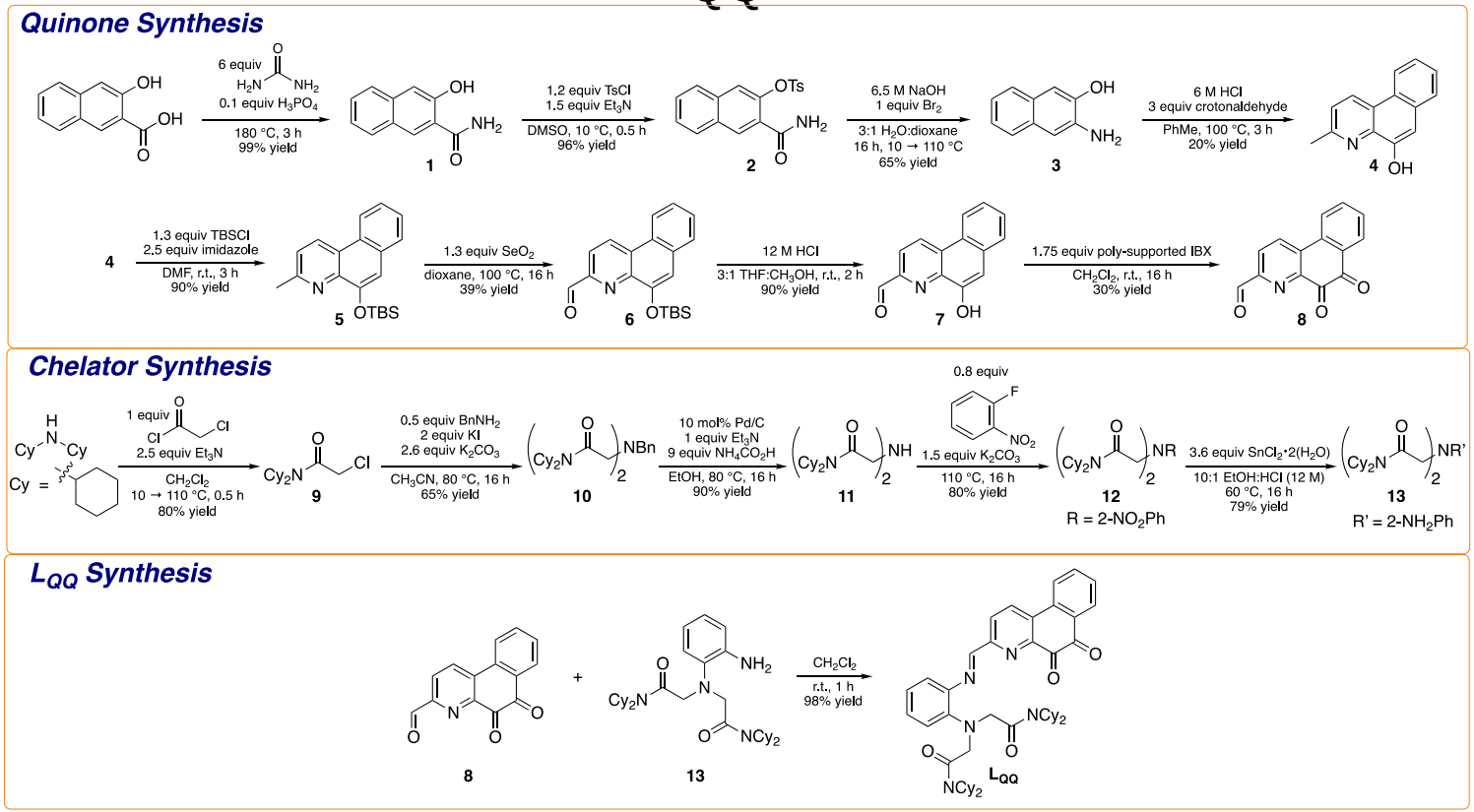
PQQ



L_{QQ}



Optimized Synthesis of L_{QQ}



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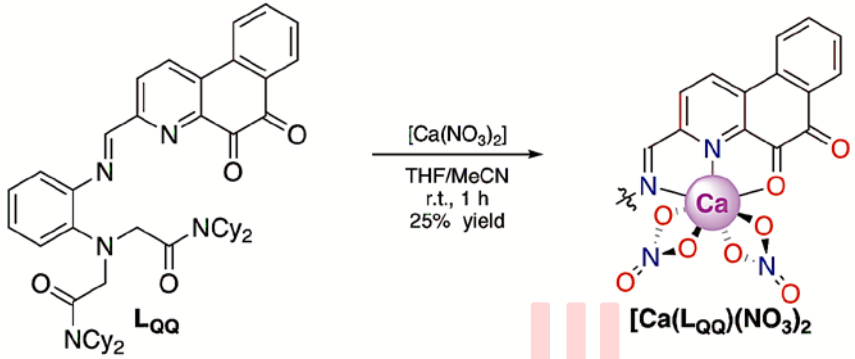
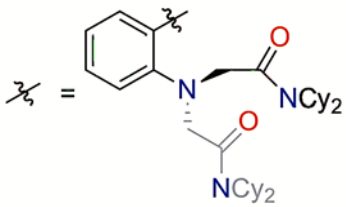
Adapted from Schelter, E. J. and coworkers. *J. Am. Chem. Soc.* **2018**, *140*, 1223-1226.

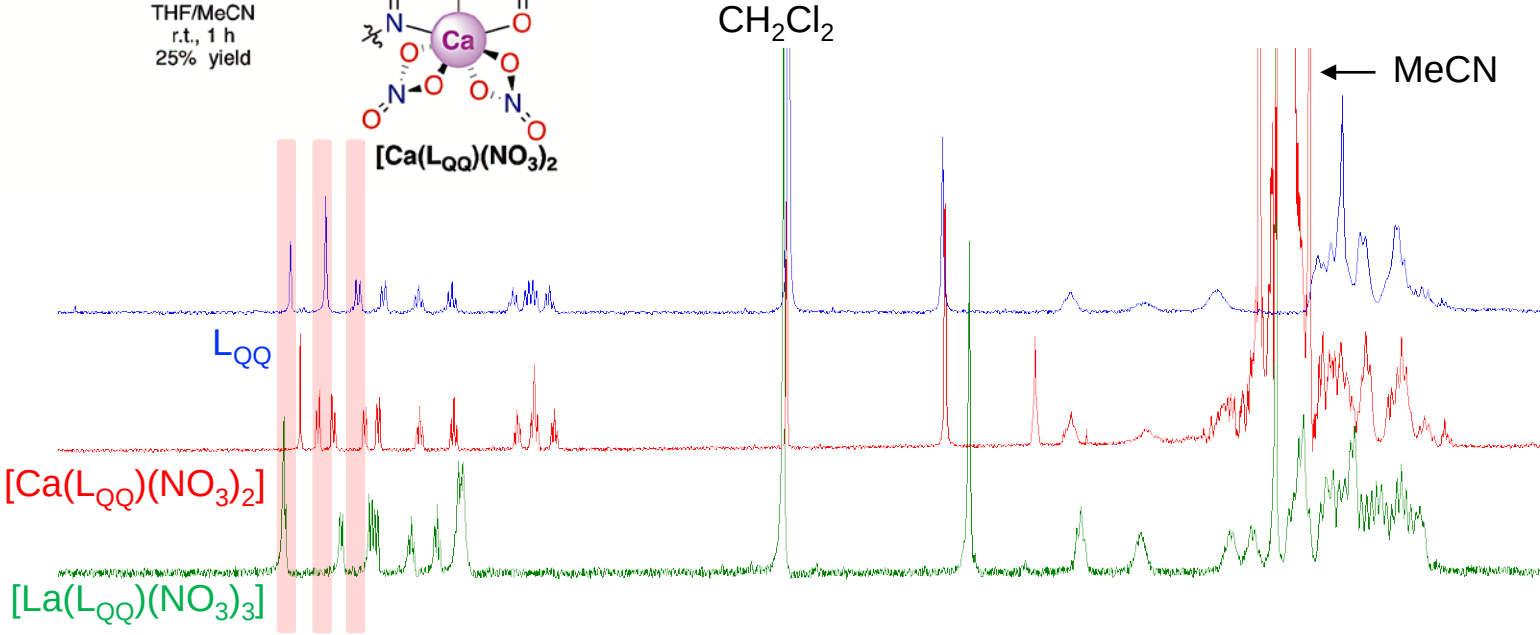
Synthesis of $[Ca(L_{QQ})(NO_3)_2]$



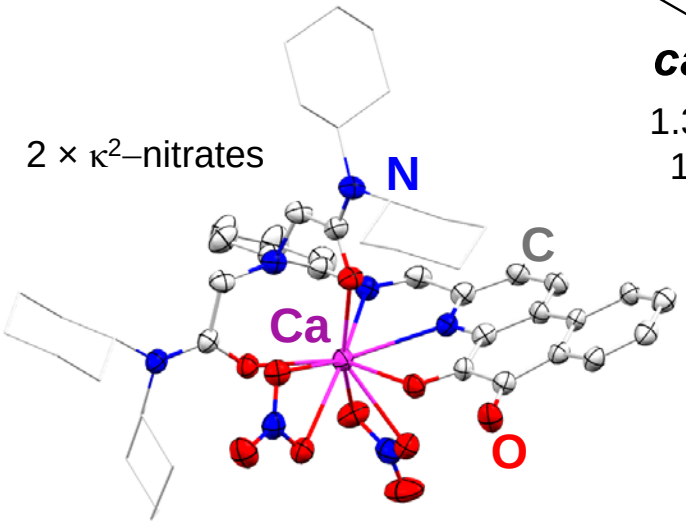
Solvents freshly dried and distilled

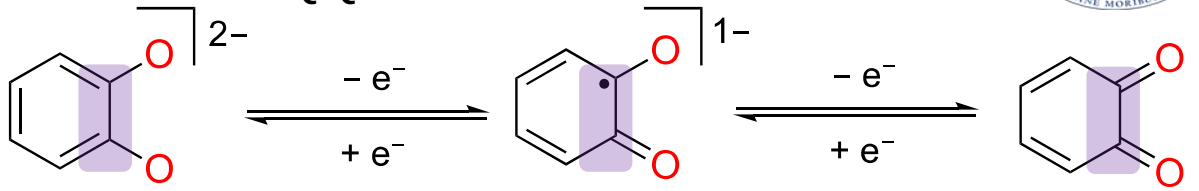
^1H NMR spectra taken in CD_2Cl_2





Structural Analysis of $[Ca(L_{QQ})(NO_3)_3]$





cat

1.348(10)–
1.415(6)

sq

1.42(1)–
1.448(9)

q

1.530(5)

$[La(L_{QQ})(NO_3)_3]$

1.542(5)

$[Ca(L_{QQ})(NO_3)_2]$

1.526(7)

Bonds lengths (in Å) consistent with quinone redox state on L_{QQ} backbone for La and Ca.

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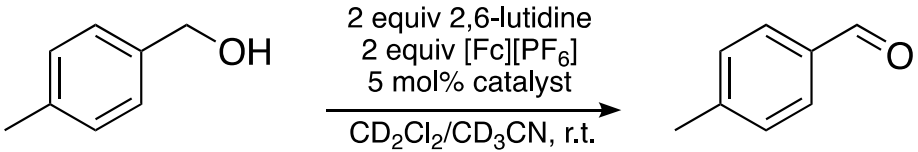
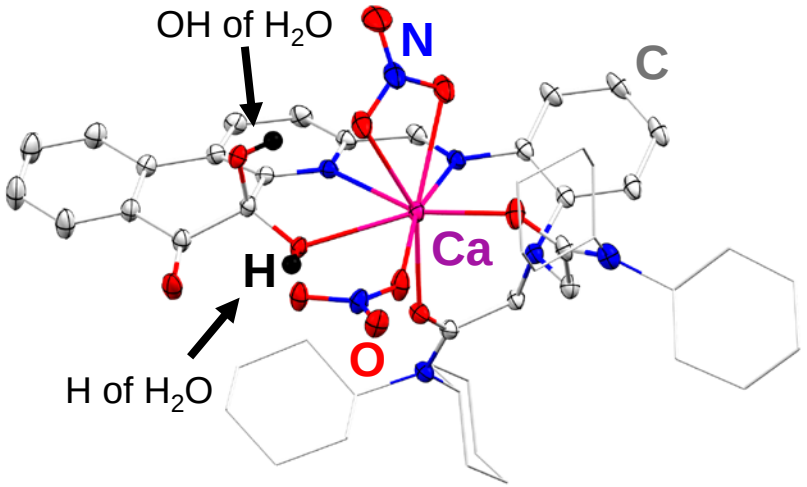
Ellipsoids at 30%. Hydrogen atoms and co-crystallized solvents removed and cyclohexyl groups in wireframe for clarity.

Reactivity of $[Ca(L_{QQ})(NO_3)_2]$ vs $[La(L_{QQ})(NO_3)_3]$



Catalyst	Time (h)	Yield (% ^{4Me}PhCHO)
L_{QQ}	24	14
$[La(L_{QQ})(NO_3)_3]$	21 44	84 96
$[Ca(L_{QQ})(NO_3)_2]$	21 44	2 2

$[La(L_{QQ})(NO_3)_3]$ = hydride transfer



Same structural motif as first intermediate of AE mechanism

Ellipsoids at 30%. Hydrogen atoms and co-crystallized solvents removed and cyclohexyl groups in wireframe for clarity.

Schelter, E. J. and coworkers. *J. Am. Chem. Soc.* **2018**, *140*, 1223-1226.

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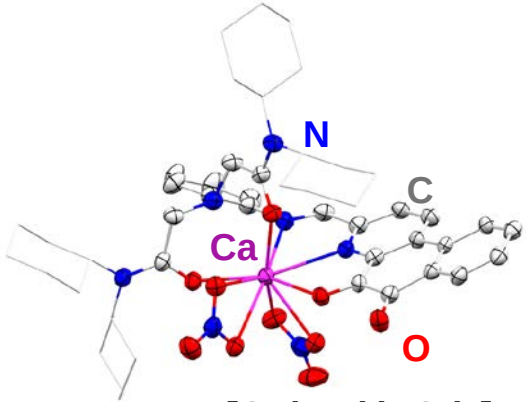
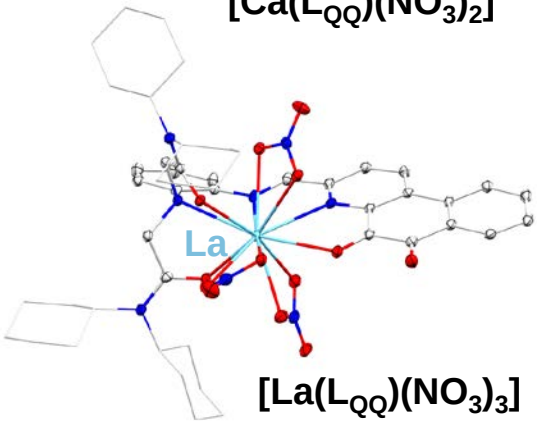
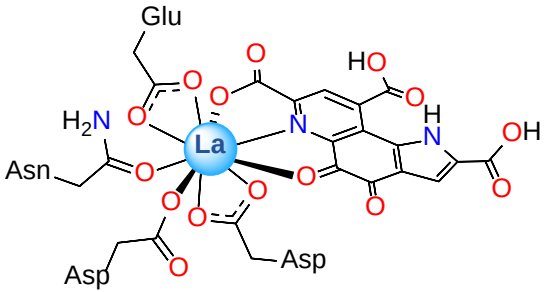
Conclusions



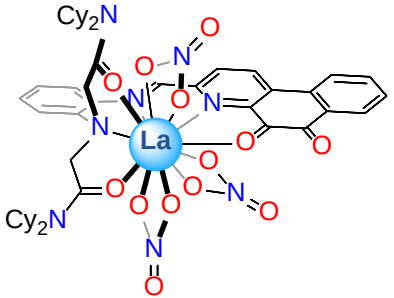
[Ca(L_{QQ})(NO_3)$_2$]



[La(L_{QQ})(NO_3)$_3$]



XoxF-type MDH active site



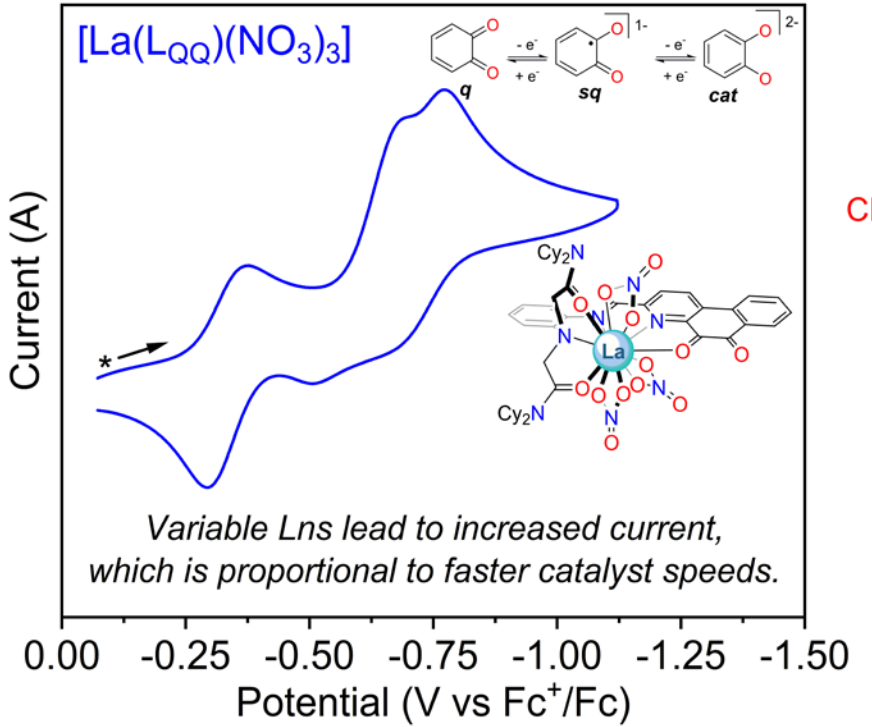
[La(L_{QQ})(NO_3)$_3$]

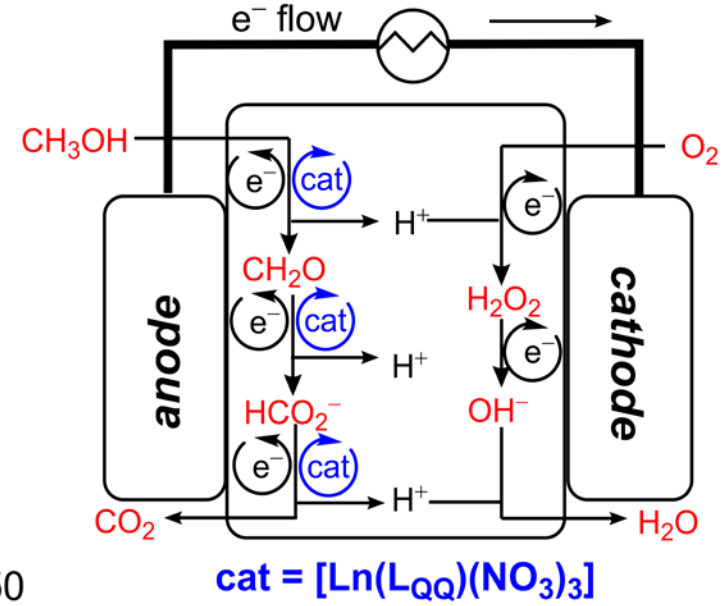
- Isolated [Ca(L_{QQ})(NO_3)$_2$] and showed this species to have an identical binding motif to [La(L_{QQ})(NO_3)$_3$]
- Preliminary data indicates that [Ca(L_{QQ})(NO_3)$_2$] has minimal reactivity compared to [La(L_{QQ})(NO_3)$_3$], which implies a potential shift in mechanism of hydrogenation

Ellipsoids at 30%. Hydrogen atoms and co-crystallized solvents removed and cyclohexyl groups in wireframe for clarity.

Schelter, E. J. and coworkers. *J. Am. Chem. Soc.* **2018**, *140*, 1223-1226.

Future Work and Energy Implications: Fuel Cell Catalysts





Does lanthanide (Ln) identity change reaction rate or selectivity?
Can this be coupled to an fuel cell to release energy efficiently?

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Acknowledgments

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Prof. Karen I. Goldberg

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