UMONS
Université de Mons

Faculté des Sciences

Design and synthesis of an artificial catalyst inspired by carbonic anhydrase

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SRC
SOCIÉTÉ ROYALE DE CHIMIE

S²MOs

Carbon Capture, Utilization and Storage - CCUS

Global warming :

- A global temperature rise prevision of 1.5 °C between 2021 and 2040
- Excessive anthropogenic greenhouse gases (GHG)
- CO_2 contributes to 72% of GHG
- Urgent need to **reduce atmospheric CO_2 rate**

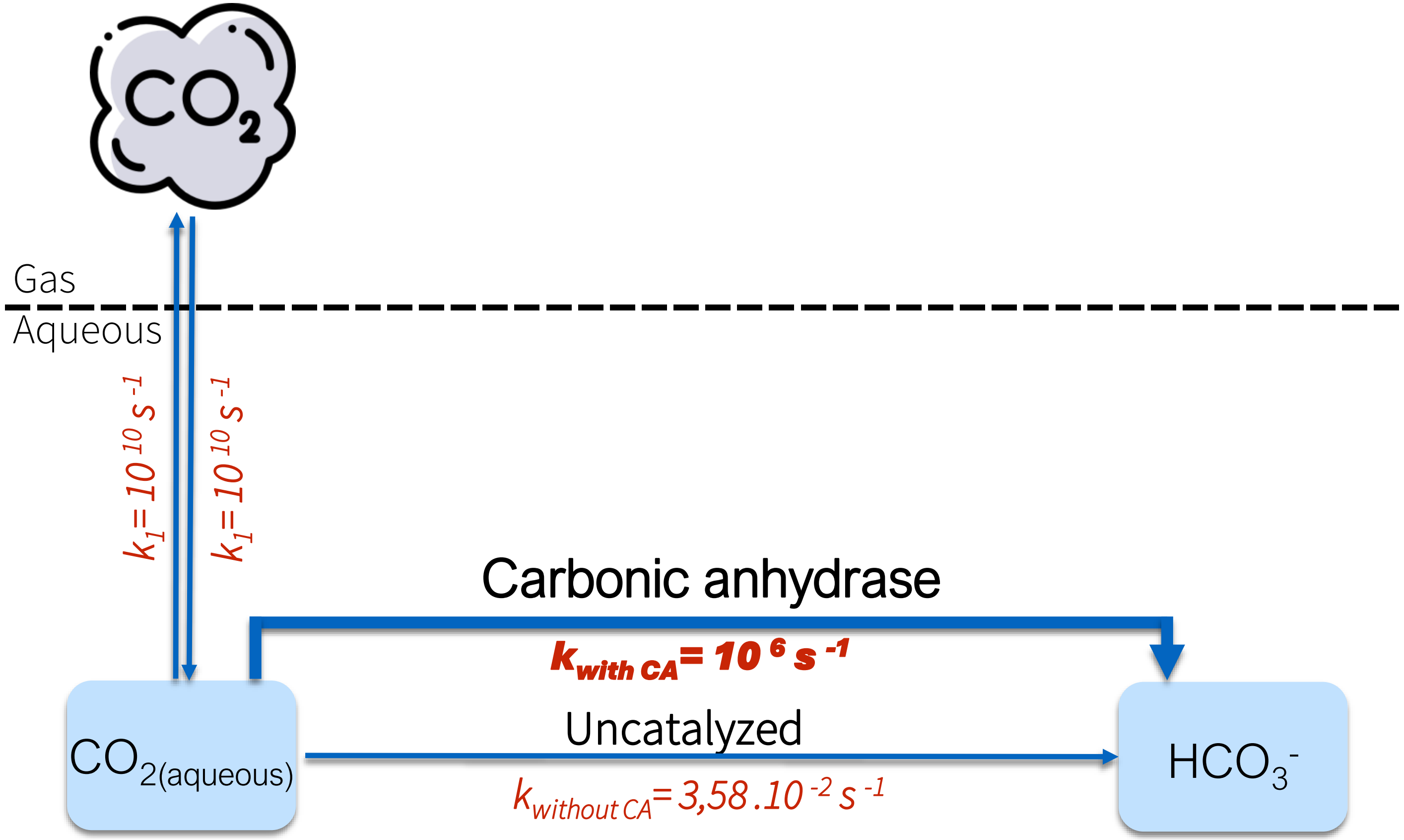
CCUS : $\boxed{\text{Capture}}$ & **Utilization** (new chemicals including fuels) or **storage** (underground & offshore)

→ Chemical absorption

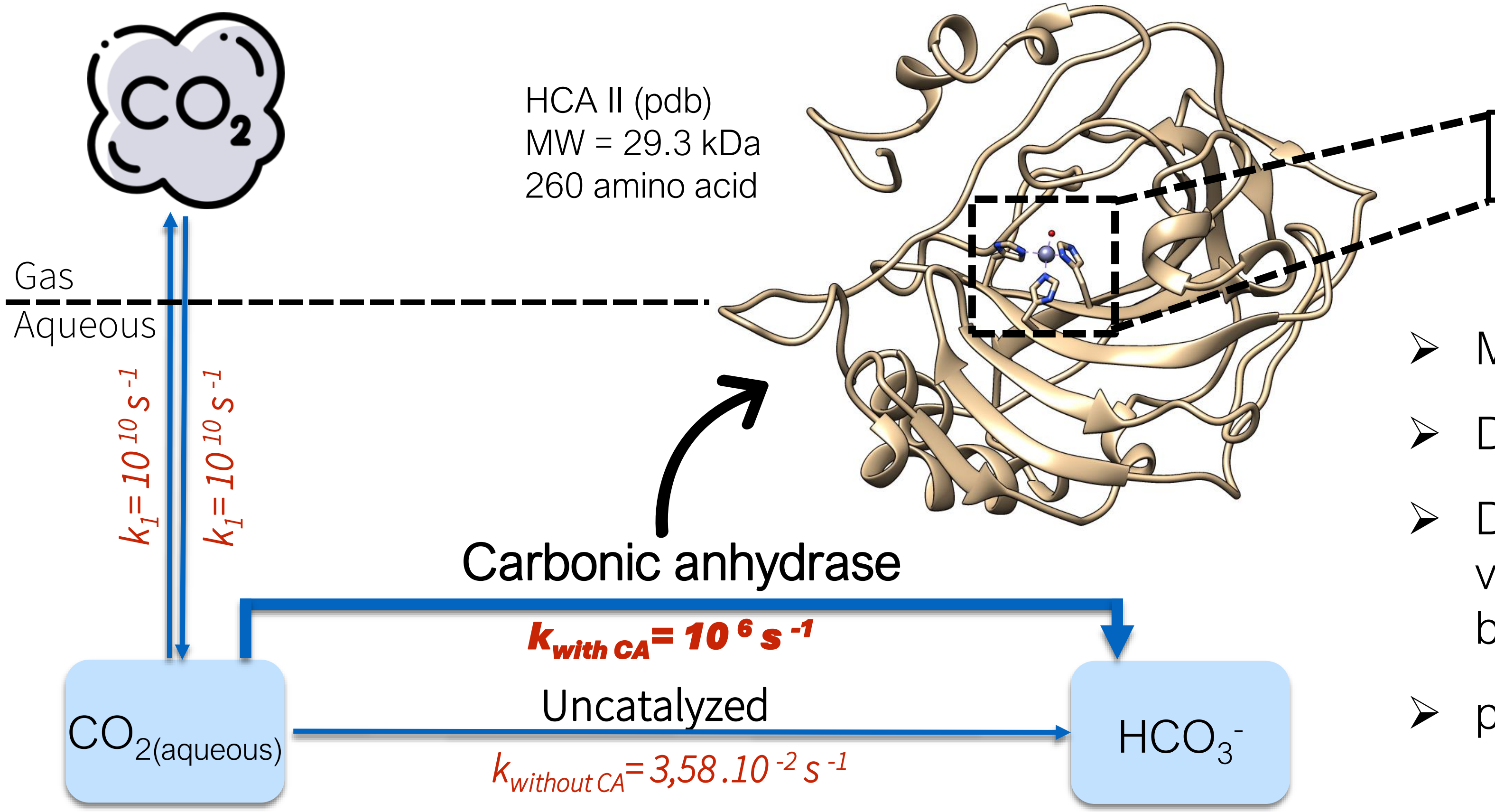
*Biocatalysts – **enzymes** – to reduce energy consumption*

$\boxed{\textit{Carbonic anhydrase as a promising candidate}}$

CO_2 dissolution and hydration



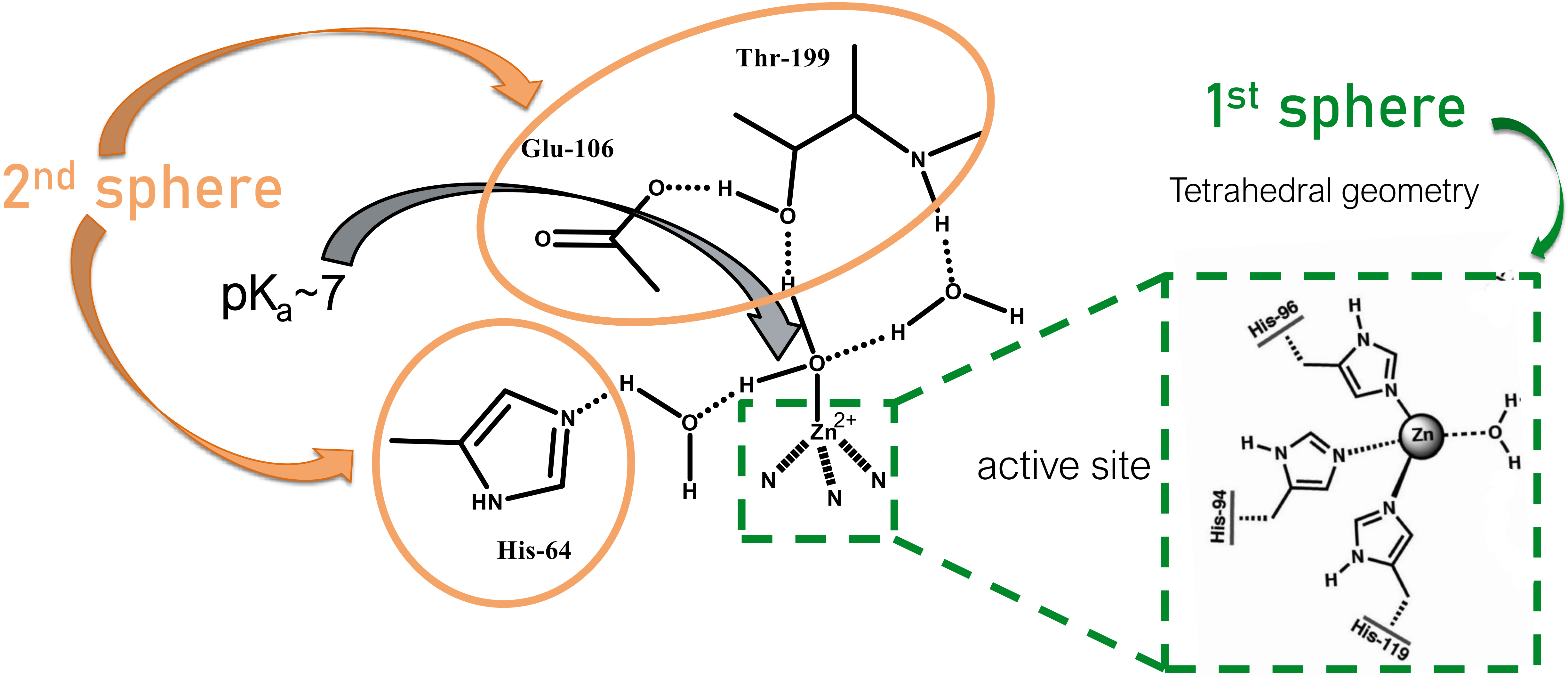
CO_2 dissolution and hydration



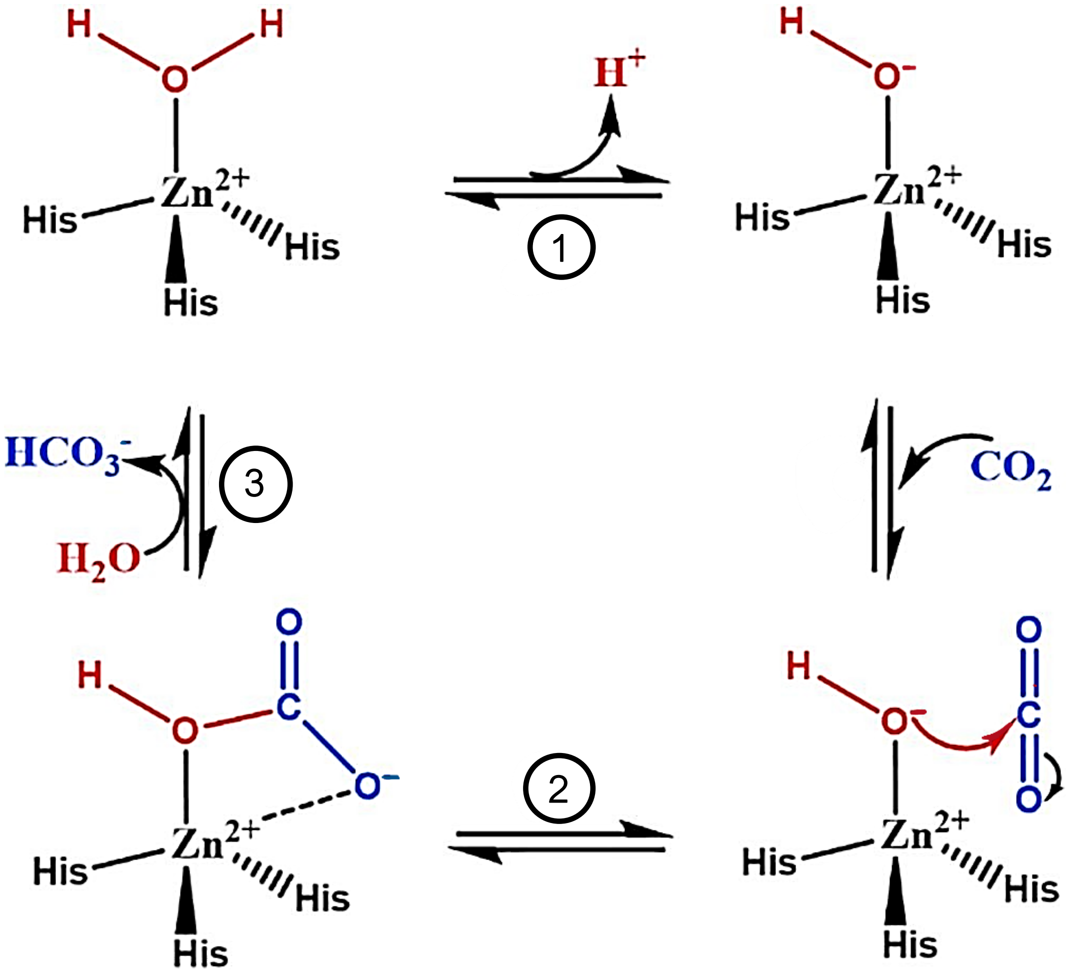
$$CO_2 + H_2O \rightleftharpoons HCO_3^- + H^+$$

- Metalloenzyme
- Discovered in red blood cells in 1933
- Distributed in the cytoplasm of vertebrates, green plants, algae, and bacteria
- pH regulation, breathing …

Active site environment of CA



Catalytic mechanism



1) Deprotonation

$$Zn^{2+} - H_2O \rightleftarrows [Zn^{2+} - OH^-] + H^+$$

2) Nucleophilic addition

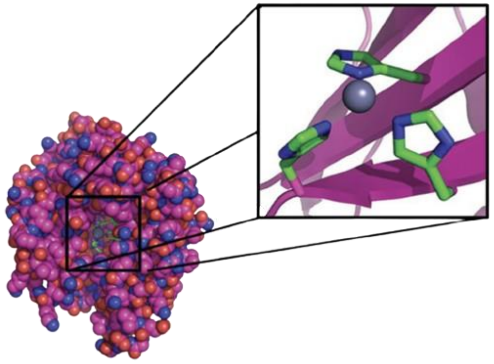
$$[Zn^{2+} - OH^-] + CO_2 \rightleftarrows [Zn^{2+} - HCO_3^-]$$

3) Substitution

$$[Zn^{2+} - HCO_3^-] + H_2O \rightleftarrows [Zn^{2+} - H_2O] + HCO_3^-$$

Context and objective

Context :



Carbonic anhydrase for CO_2 capture in industrial research

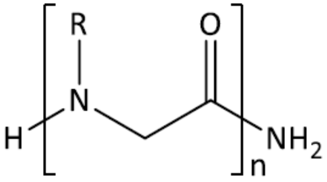
Drawback : thermal stability → loss of enzyme activity

➔ *New cost-effective materials with simple preparation conditions, high substrate affinity …*

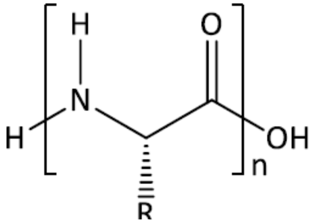
Objective :

Design and synthesis of a peptoid-based artificial catalyst inspired by carbonic anhydrase

Tailor-made sequence-defined macromolecules as peptidomimetics



Peptoid

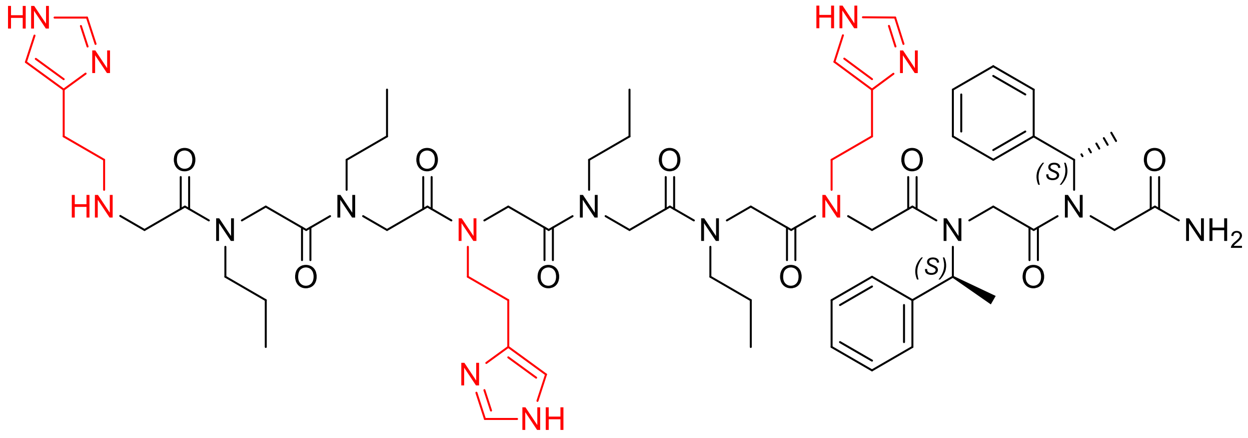


Peptide

Peptoid design

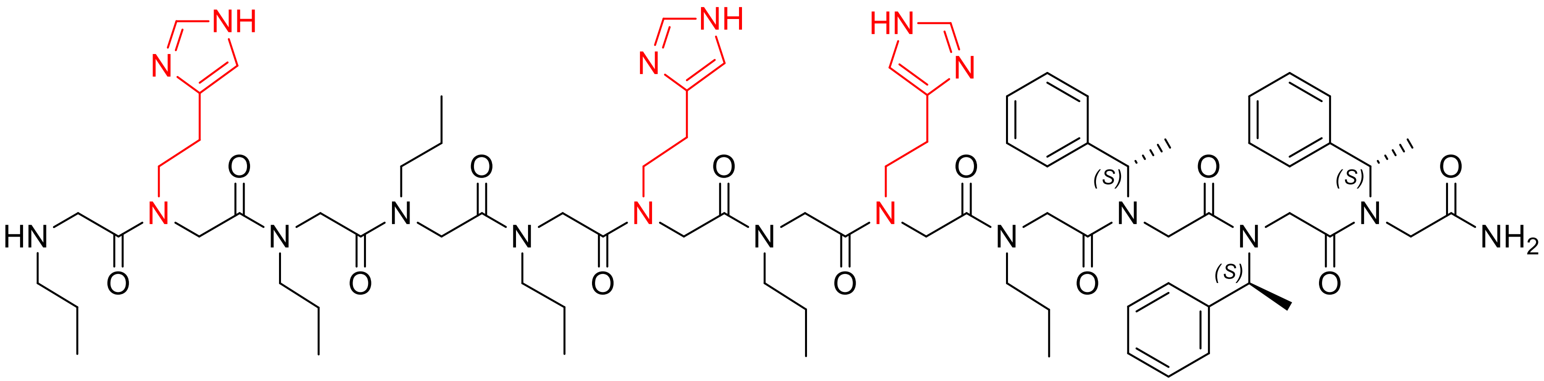
Peptoid A

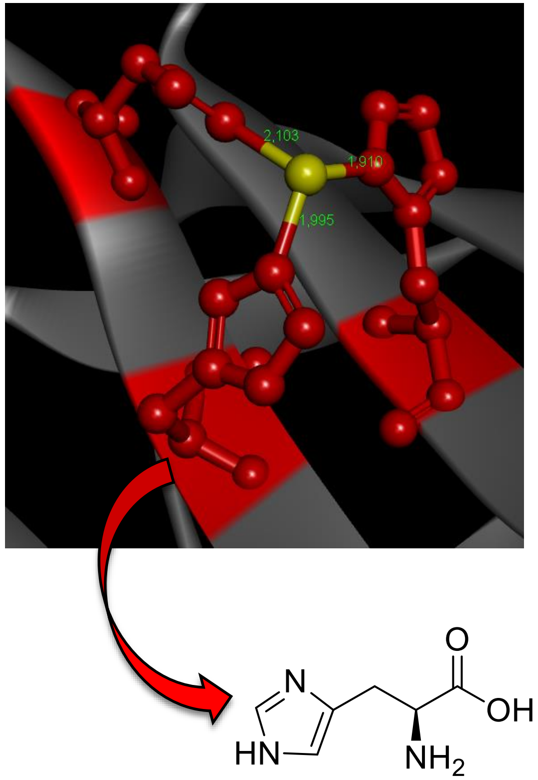
9 units



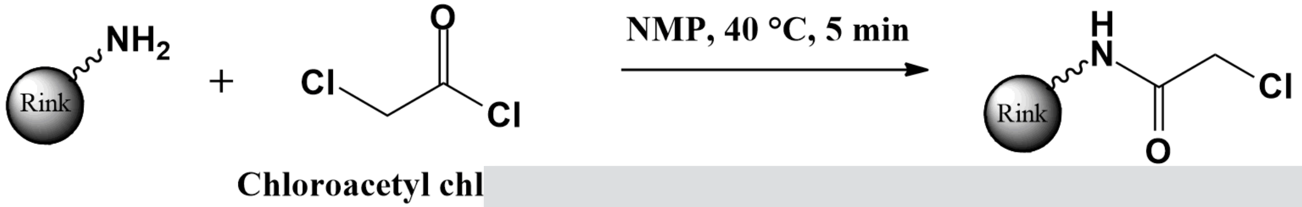
Peptoid B

12 units



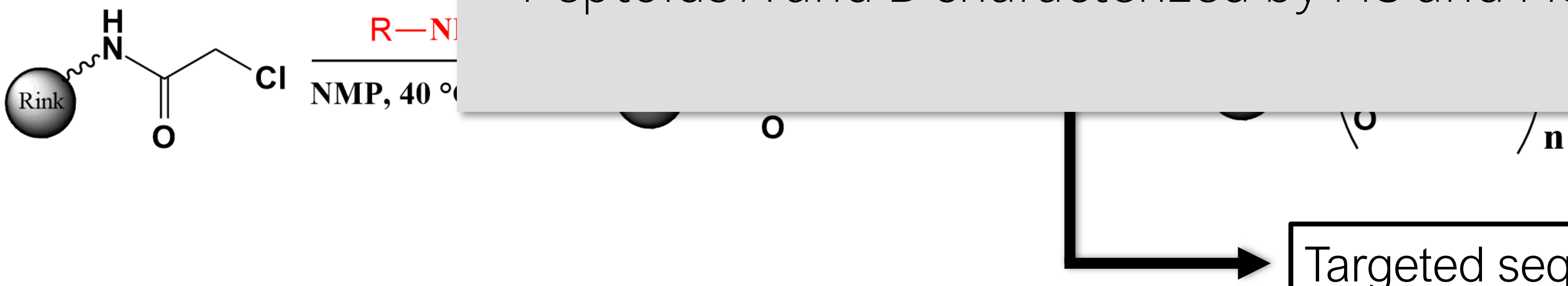


Solid phase synthesis



→Chloroacetylation

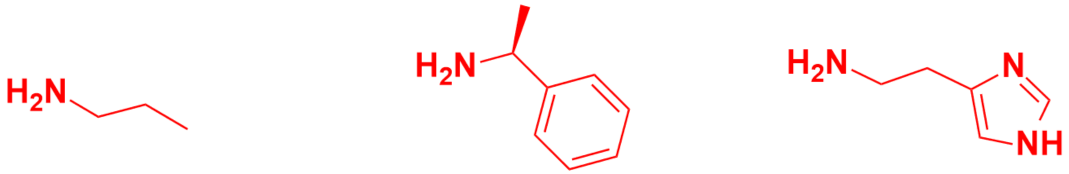
Peptoids A and B characterized by MS and MS/MS



…cleophilic substitution

Targeted sequence and length

R-NH_2 =

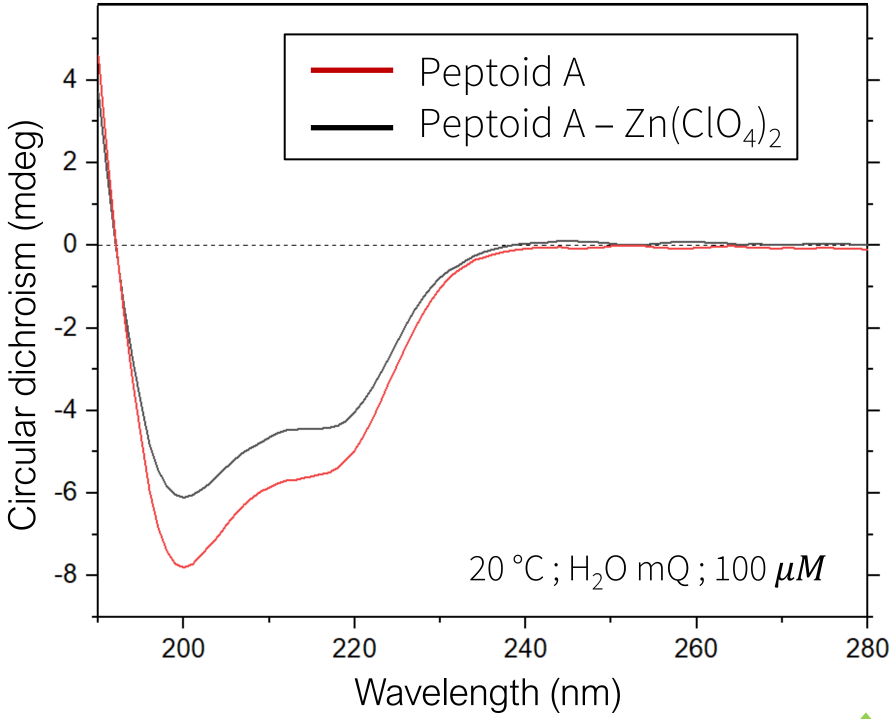


Propylamine (*S*)-phenylethylamine Histamine

Flash chromatography purification (C18)

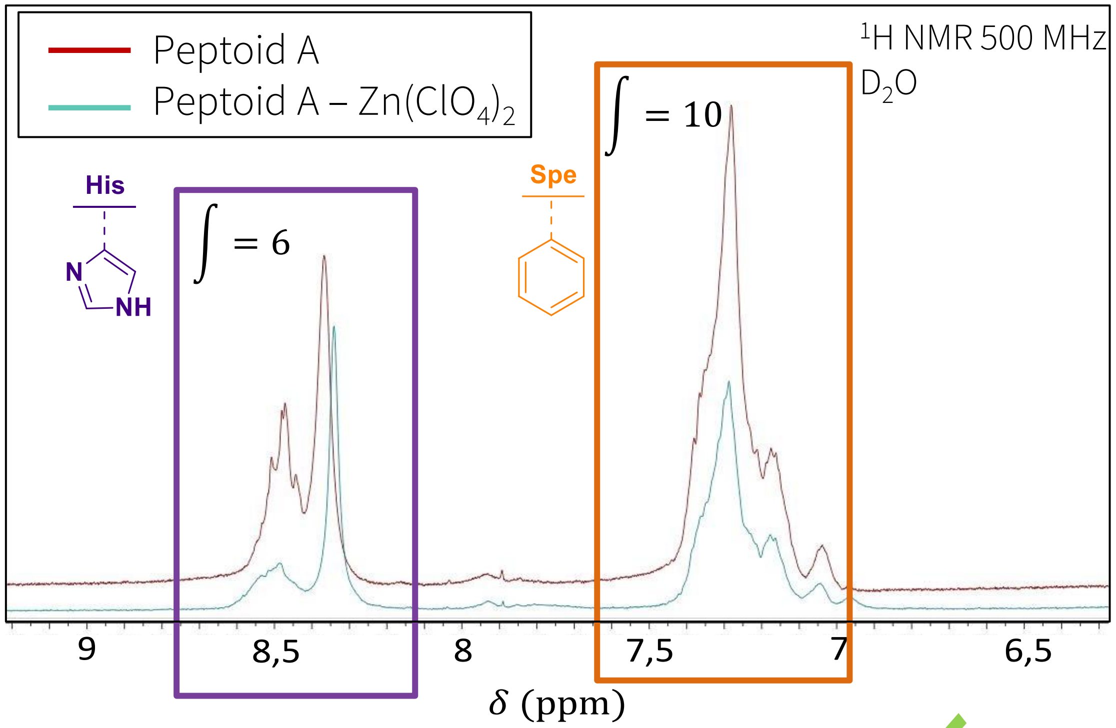
Complexation in solution

Circular dichroism



Interaction between Zn^{2+} and peptoid

^1H NMR



Specific interaction to imidazole groups

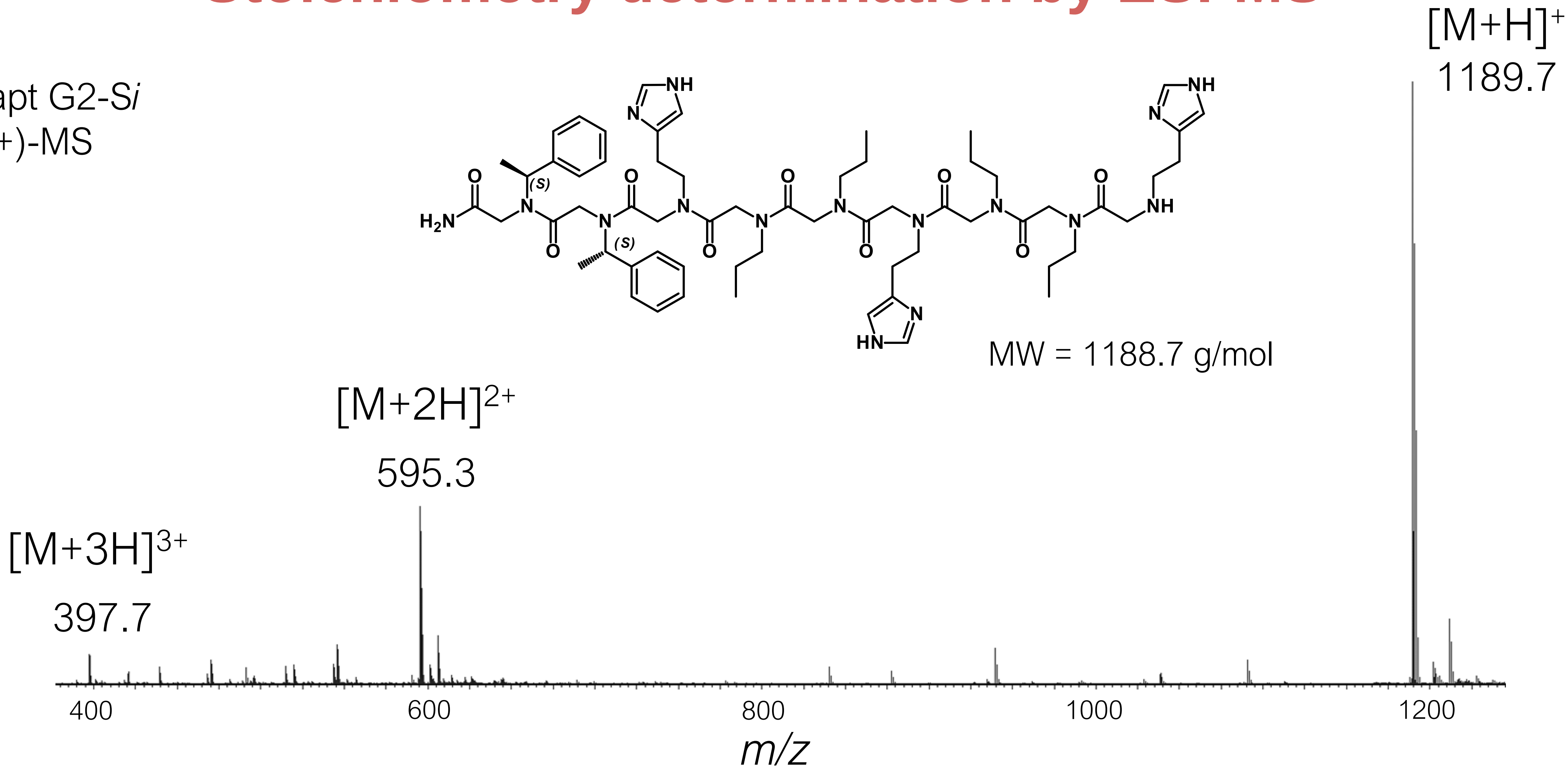
CD & NMR

Specific interaction between imidazoles and Zn^{2+}

Several characterization techniques needed to understand how the metal complexes form

Stoichiometry determination by ESI-MS

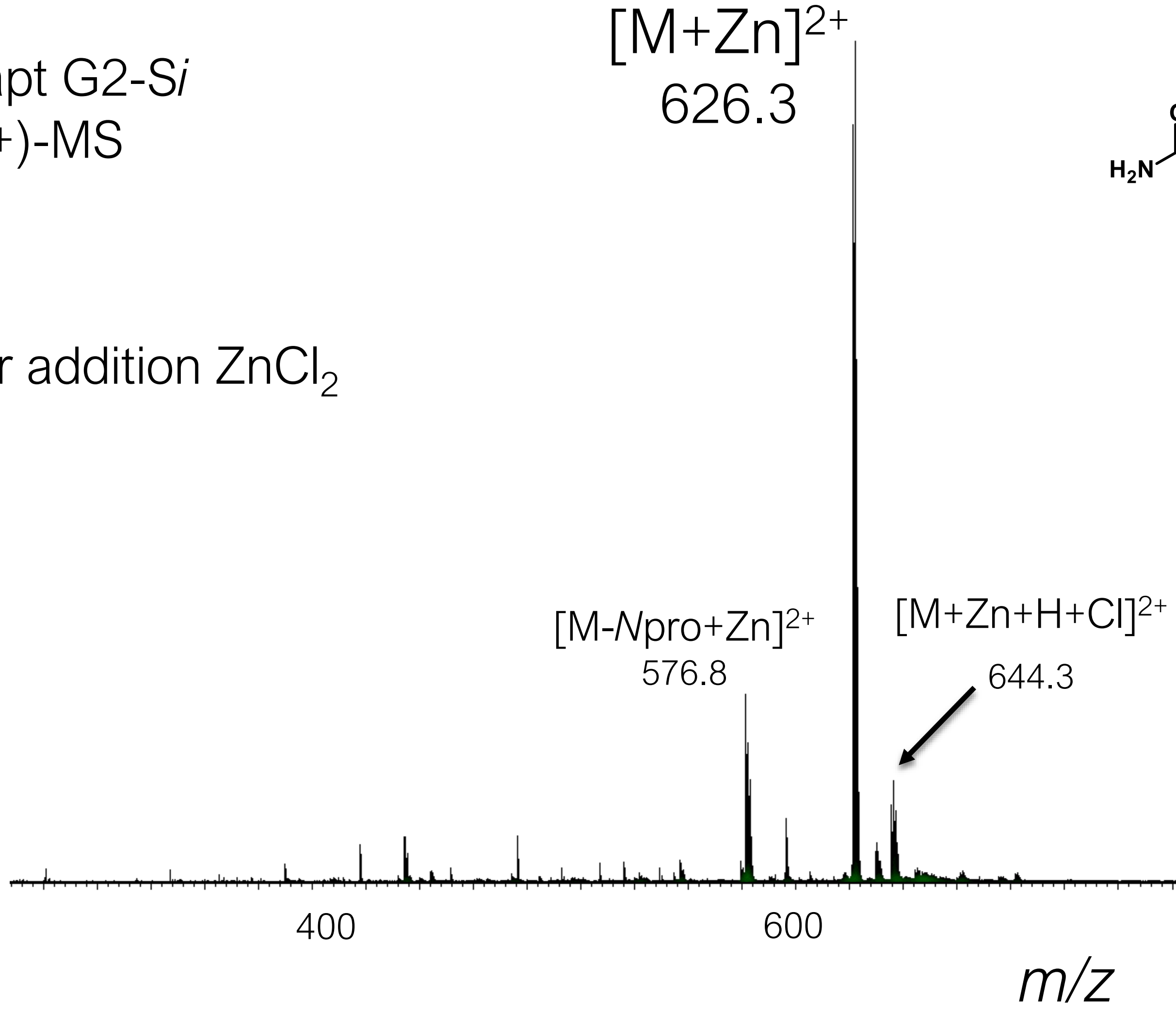
Synapt G2-S*i*
ESI(+)-MS
H_2O

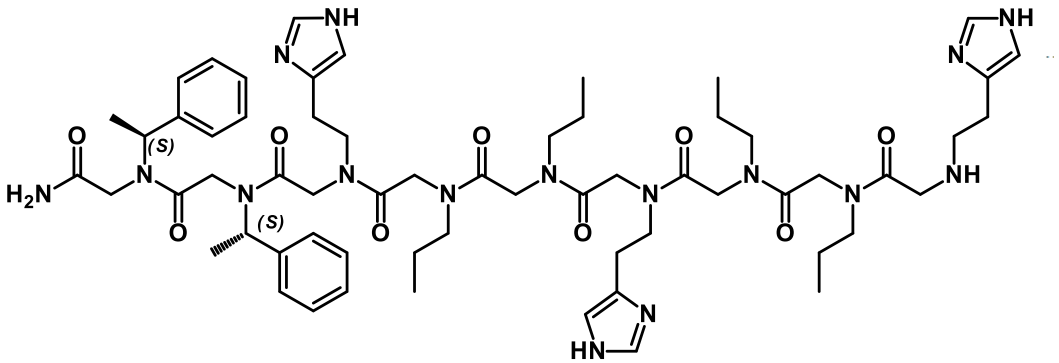


Stoichiometry determination by ESI-MS

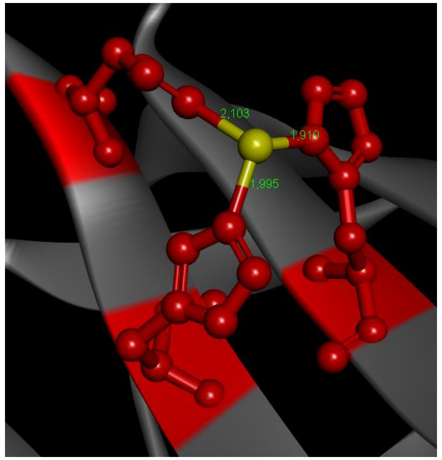
Synapt G2-*Si*
ESI(+)-MS
H_2O

After addition $ZnCl_2$





MW = 1188.7 g/mol



CD & NMR

Specific interaction between imidazoles and Zn^{2+}

MS

1:1 complexes $[peptoid+Zn]^{2+}$

CD & NMR

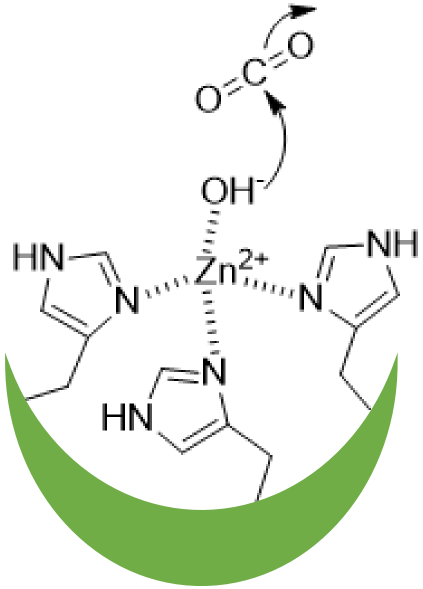
Specific interaction between imidazoles and Zn^{2+}

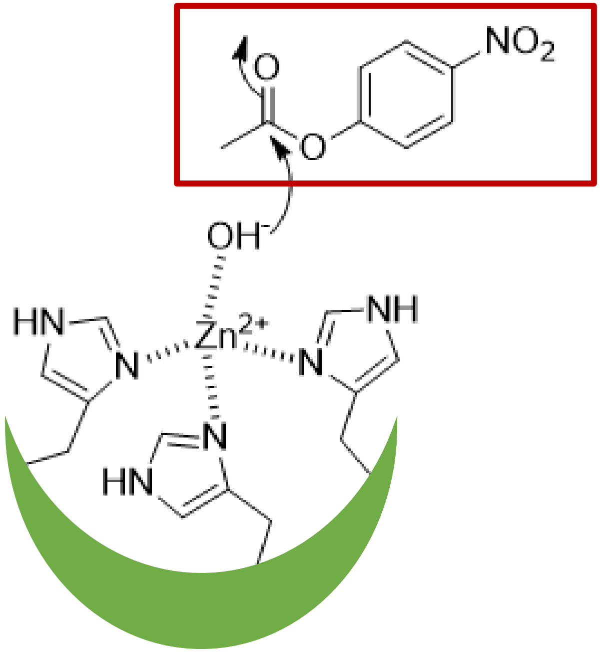
MS

1:1 complexes $[peptoid+Zn]^{2+}$

Catalytic activity

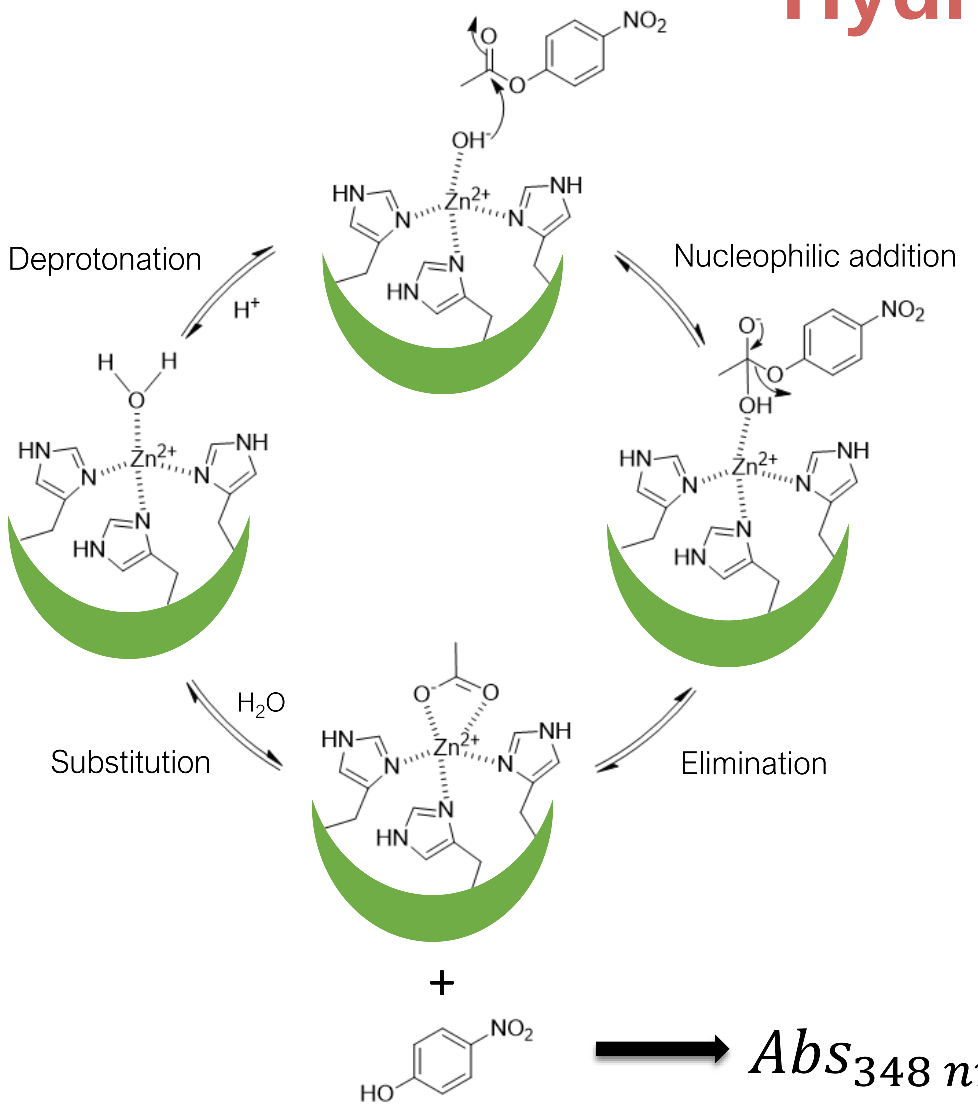
4-Nitrophenyl acetate (4-NPA)





CO_2 Hydration *vs* Ester Hydrolysis

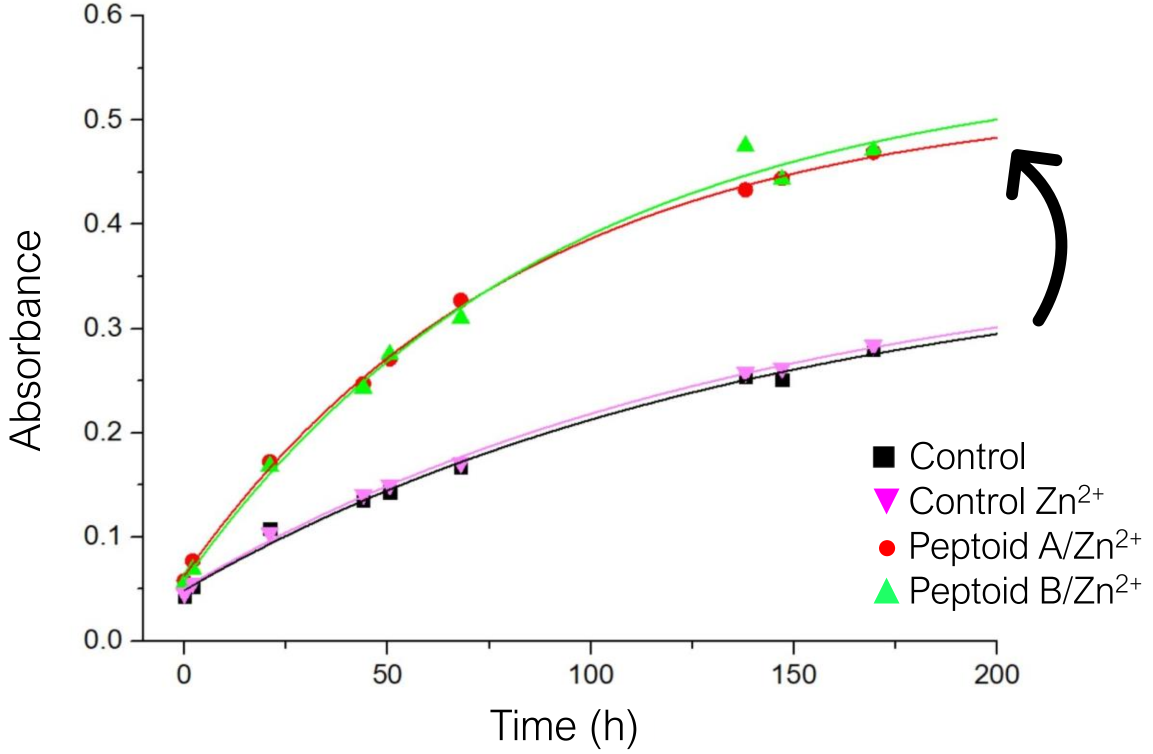
Hydrolysis of 4-NPA

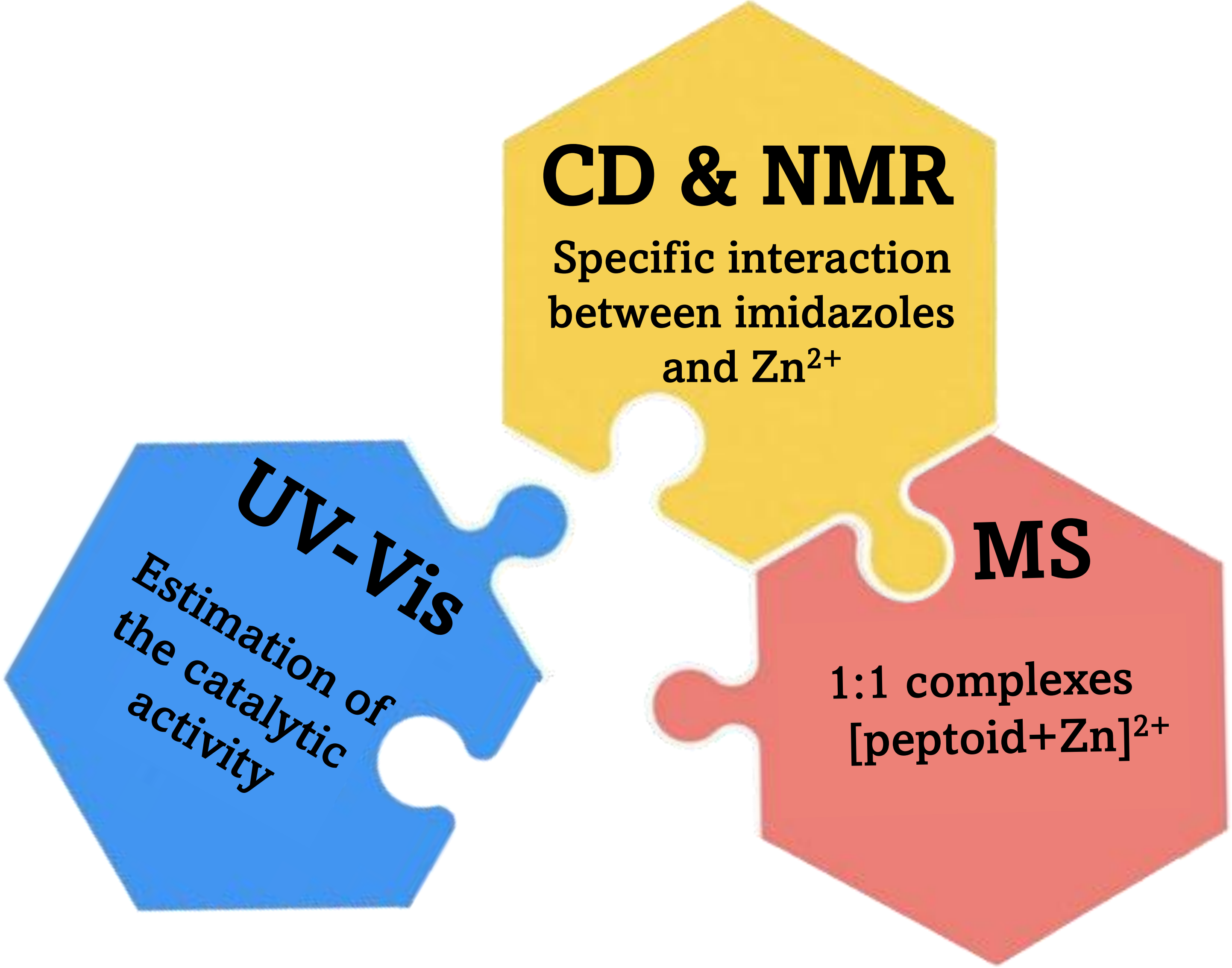


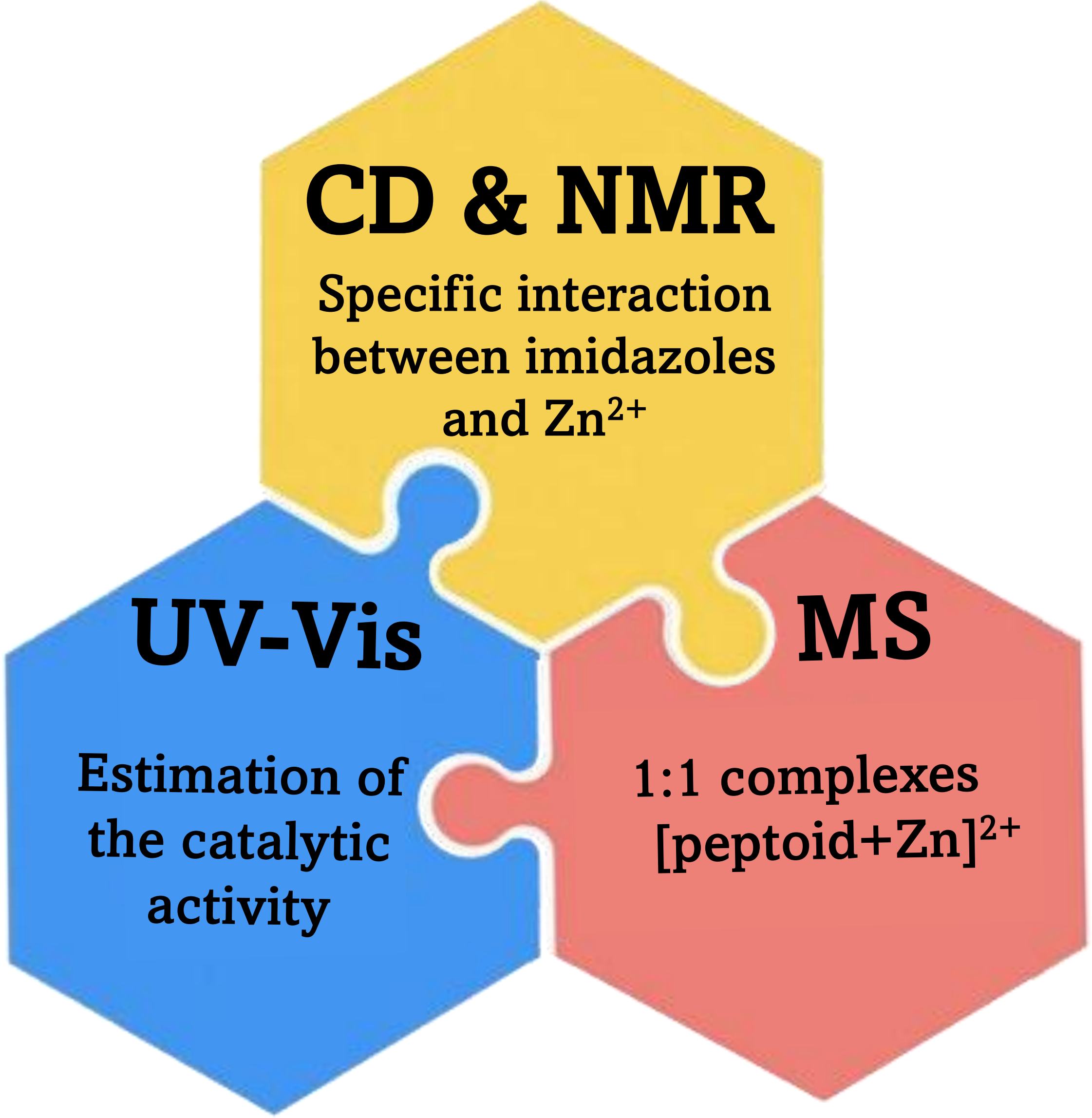
→ $Abs_{348\ nm}$

Reaction conditions :

- Substrate = 4-NPA (10^{-3} M)
- Peptoid/$Zn(ClO_4)_2$ (10^{-4} M)
- 35 °C ; H_2O (2 % acetone) ; pH = 4




CD & NMR
Specific interaction between imidazoles and Zn^{2+}
UV-Vis
Estimation of the catalytic activity
MS
1:1 complexes
$[peptoid+Zn]^{2+}$


CD & NMR
Specific interaction between imidazoles and Zn^{2+}
UV-Vis
Estimation of the catalytic activity
MS
1:1 complexes $[peptoid+Zn]^{2+}$

Conclusions and outlook

Key results :

- Formation of 1:1 complexes (peptoid/Zn^{2+})
- Specific complexation between Zn^{2+} and imidazole groups
- The hydrolysis of 4-NPA is faster in the presence of complexes

How to improve?

- Hydrolysis of 4-NPA under different conditions (pH, counter anion, temperature,…)
- Evaluation of different metal ions (Cu^{2+}, Ni^{2+}, Co^{2+})
- Elaboration of a protocol for CO_2 hydration

Thank you

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Thank you for your attention

S^2MOs