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Communication

Nucleotide coordination with 14 lanthanides studied by isothermal titration calorimetry

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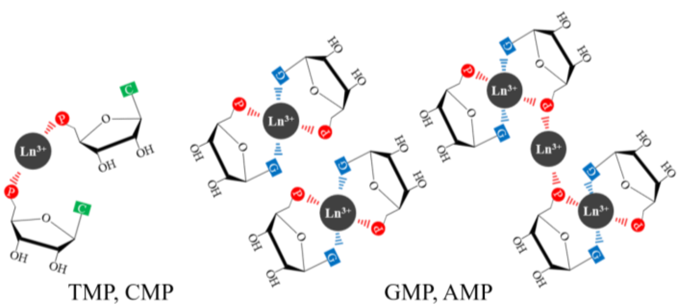
Graphical Abstract



ITC reveals the increasingly importance of entropy for heavier lanthanides binding to nucleotides. The phosphate group forming chelating effect with purine bases but not with pyrimidines.

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ABSTRACT

With their hydrolytic, optical and magnetic properties, lanthanide ions (Ln^{3+}) are versatile probes for nucleic acids. In addition, nucleotide-coordinated Ln^{3+} ions form useful nanoparticles. However, the thermodynamic basis of their interaction is still lacking. In this work, isothermal titration calorimetry (ITC) is used to study the binding between nucleotides and 14 different Ln^{3+} ions. Ln^{3+} interacts mainly with the phosphate of cytidine and thymidine monophosphate (CMP and TMP), while the nucleobases in adenosine and guanosine monophosphate (AMP and GMP) are also involved. Phosphate binding is fully entropy driven since the reactions absorb heat. Nucleosides alone do not bind Ln^{3+} and the purines need the phosphate for chelation. With increasing atomic number of Ln^{3+}, the binding reaction with GMP goes from exothermic to endothermic. The entropy contribution starts to increase from Gd^{3+}, explaining the 'gadolinium break' observed in many Ln^{3+}-mediated RNA cleavage reactions. This study provides fundamental insights into the Ln^{3+}/nucleotide interactions, and it is useful for understanding related biosensors, nanomaterials, catalysts, and for lanthanide separation.

Lanthanides refer to a group of 15 elements from La to Lu. While they have been researched mostly for electronic, optical, and magnetic applications [1], lanthanide ions (Ln^{3+}) are also useful tools in biochemistry. For example, nucleic acids enhance the luminescence of Tb^{3+} [2-4], which has been used for probing metal binding and designing biosensors [5]. Ln^{3+} can cleave RNA at high metal concentrations [6,7]. Since cleavage activity is sensitive to RNA secondary structure, this is also useful for structural probing [8]. In addition, Ln^{3+} ions were used as metal cofactors in ribozymes and DNAzymes [3,9-17]. DNAzymes are DNA-based catalysts with promising applications in biosensor