Abstract:

A weak polyampholyte is a polymer that consists of both acid and base groups along the chain. In aqueous solutions, these groups dissociate in a certain pH range, leading to a dramatic change in the overall charge of the polyampholyte from positive to negative as the pH increases. The ability of weak ampholytes to switch their charge in response to changes in pH makes them useful in various applications. Despite the considerable research on weak polyampholytes, the understanding of some aspects is still insufficient.

To address this, I systematically investigated the charge regulation of weak polyampholytes, specifically peptides, both in solution and during their interaction with polyelectrolytes. Furthermore, I also looked at the charge regulation of polyzwitterions. All these studies were carried out using a simple coarse-grained bead-spring model in Langevin dynamics simulations. In addition, I used the constant-pH ensemble to account for the ionization reactions of acid and base groups in the implicit solvent.

Through our simulations, we made significant advancements in understanding how charges and the ionization states of acid and base groups in various peptides and polyzwitterions respond to pH changes. By comparing simulation results with the ideal results predicted by the Henderson-Hasselbalch equation, we showed that simulation results deviated from ideal behaviour due to electrostatic interactions between charged groups. Furthermore, by comparing simulations with experiments, we successfully predicted charge regulation in different peptide sequences and one polyzwitterion. However, our model encountered difficulties in accurately capturing the behaviour of another polyzwitterion due to a specific interaction contribution that was not considered in our model. Moreover, in the context of peptides interacting with polyelectrolytes, our simulations shed light on the phenomenon of proteins adsorbing to polyelectrolytes on the "wrong" side of the isoelectric point. This occurs when the overall charge of the proteins has the same sign as that of the polyelectrolyte. By using our simulation approach, we provided an explanation for this phenomenon.

Ultimately, our models could be used to understand the complex coupling between the ionization and conformation of flexible polyampholytes, including synthetic polymers, biomimetic materials, and biological molecules, such as intrinsically disordered proteins, whose charges can be regulated by changes in the pH.