Mapping Host-Guest Chemistry: ITC, ^{19}F NMR, and Molecular Dynamics Characterization of Cyclodextrin-PFAS Binding

Rebecca Lahousse, Elise Hanley, Tristan Hart-Bonville, Dr. Aylin Aykanat
Chemistry, University of New Hampshire, Durham, NH 03824

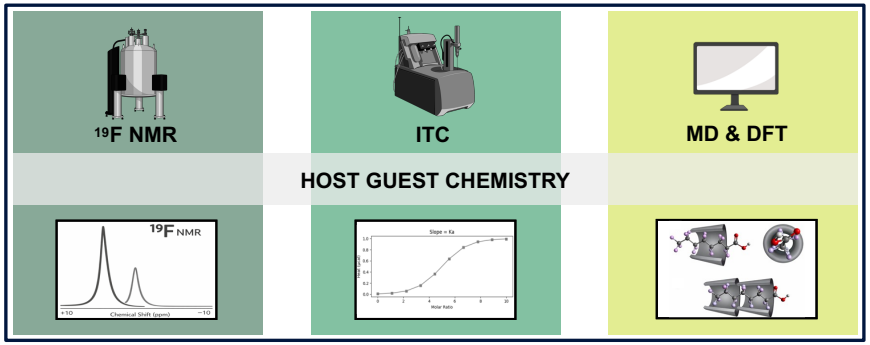
Introduction

What Is PFAS?

Per- and polyfluoroalkyl substances (PFAS) are persistent environmental contaminants widely used due to the exceptional stability of the carbon–fluorine bond, leading to environmental accumulation, structural diversity, and significant remediation challenges.(1) Although cyclodextrin-based host–guest systems show promise for PFAS capture, the fundamental thermodynamic and kinetic mechanisms governing binding remain poorly understood. This study investigates β-cyclodextrin–PFAS interactions using ITC, ^{19}F NMR spectroscopy, and molecular dynamics to quantify binding affinities and thermodynamic parameters, providing molecular-level insight to guide the rational design of next-generation PFAS remediation materials.

Figure 1. Everyday products containing PFAS. (2)

Methods



^{19}F NMR

PFOA

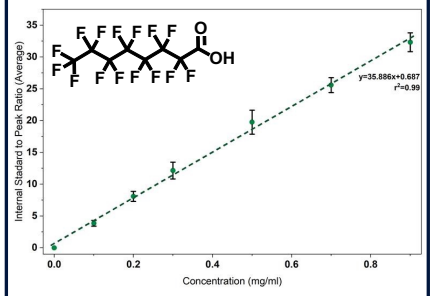


Figure 3. ^{19}F NMR calibration curve for PFOA (R^2=0.99).

PFVA

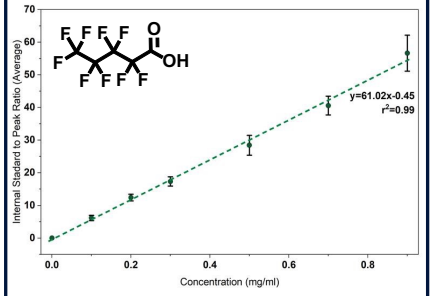


Figure 4. ^{19}F NMR calibration curve for PFVA (R^2=0.99).

Results and Future Work

Table 1. Future Work: pH-dependent PFAS binding investigations.

	β-Cyclodextrin (OH)			Per-6-Amino-β-Cyclodextrin (NH2·HCl)		
pH	4	7	9	4	7	9
PFOA						
PFOS						
Gen X						

Molecular Dynamics & DFT Calculations:

Molecular dynamics simulations address a fundamental knowledge gap by resolving β-cyclodextrin–PFAS binding geometries and dynamics, linking experimental thermodynamics (ITC, ^{19}F NMR) to structure–binding relationships. Density functional theory (DFT) calculations complement these results by quantifying interaction energetics and electronic contributions, informing the design of next-generation PFAS sorbents.

Binding free energies will be estimated using a supramolecular approach:

$$\Delta G_{bind} = G_{complex} - (G_{host} + G_{guest})$$

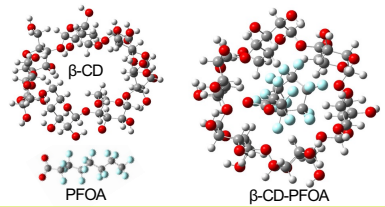


Figure 9. DFT framework for calculating β-CD–PFOA binding free energies.

Experimental Methods

ITC: Instrument performance validated with EDTA–Ca^{2+} QC, followed by a buffer–buffer control to quantify heat of dilution; samples analyzed with the water in the reference cell.

^{19}F NMR: External calibration curves for PFOA and PFVA (0.1–0.9 mg/mL; 100–900 ppm); standards analyzed in triplicate and averaged prior to linear regression. Difluoromethyl benzoic acid was used as the internal standard.

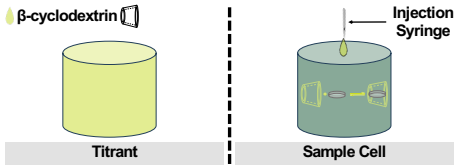


Figure 2. ITC schematic for quantifying PFAS binding thermodynamics.

Isothermal Titration Calorimetry (ITC)

β-cyclodextrin titrated into PFOA

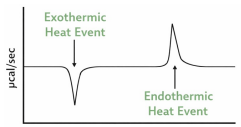


Figure 5. ITC thermogram showing exothermic and endothermic binding events for thermodynamic analysis.(3)

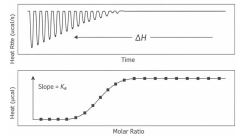


Figure 6. ITC thermogram and binding isotherm for determination of ΔH and Ka.

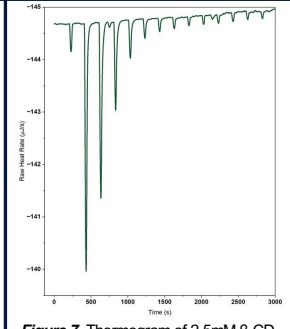


Figure 7. Thermogram of 2.5mM β-CD titrated into 0.25mM PFOA.

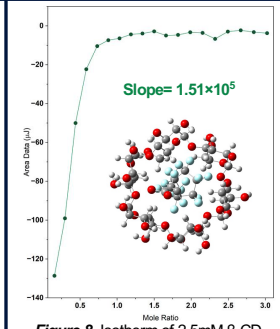


Figure 8. Isotherm of 2.5mM β-CD titrated into 0.25mM PFOA.

Acknowledgements

I would like to thank the UNH chemistry department, Professor Aylin Aykanat, Dr. Priyanshu Chandra, Elise Hanley, Patrick Strobel, Anthony Traficante, Quinton Henoch, Evan Kennedy, Lucas Laventure, Elisabeth Gotschlich, Eddie Gaffny, Tristan Hart-Bonville, and Professor Roy Planalp.

References

(1)Rekik, H.; Arab, H.; Pichon, L.; El Khakani, M. A.; Drogui, P. Per-and Polyfluoroalkyl (PFAS) Eternal Pollutants: Sources, Environmental Impacts and Treatment Processes. *Chemosphere* 2024, *358*, 142044. https://doi.org/10.1016/j.chemosphere.2024.142044.
(2) *What are PFAS? How can I avoid forever chemicals in my home? - King County, Washington.* https://www.kingcounty.gov/en/dept/dnrp/waste-services/hazardous-waste-program/news-events/news/2024-12-12-pfas-explained (accessed 2026-04-04).
(3) *ITC*. Department of Chemistry. https://chemistry.ecu.edu/faculty-staff/spuchesa/itc/ (accessed 2026-04-04).