Synthesis of Cyclodextrin Precursors for the Generation of Novel Crystalline Materials for Environmental Remediation

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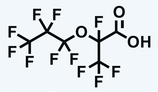
Introduction

What is PFAS?

Per/polyfluoroalkyl substances, or PFAS, are highly persistent environmental contaminants, frequently called "forever chemicals" due to a half-life spanning 2–15 years. These compounds are primarily utilized for hydrophobic enhancement, a property derived from their exceptionally strong carbon to fluorine bonds. This specific chemical structure renders PFAS remarkably resistant to both chemical and biological degradation, especially in aqueous solutions, causing various issues in public water and ecological systems. Although the Environmental Protection Agency(EPA) has linked PFAS exposure to various potential adverse health effects—including increased risks of cancer and infertility—the comprehensive scope of these risks is still being investigated. Due to the existing remediation systems being inaccessible, mostly characterized by high costs and operational inefficiencies, there is an urgent demand for the development of a new class of high-capacity sorbents.

a)

Perfluorooctanoic acid (PFOA)



Hexafluoropropylene oxide dimer acid (GenX)

Perfluorooctane Sulfonic acid (PFOS)

Perfluorooctanesulfonamide (PFOSA)

b)

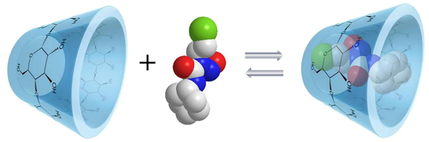


Figure 1. a) Chemical structures representing per- and polyfluoroalkyl substances (PFAS), including PFOA, GenX, PFOS, and PFOSA **b)** Schematic illustration of host–guest inclusion complex formation, where a guest molecule is encapsulated within a host cavity (Inclusion Complexes, T. Sohajda, 2023)

Introduction

What is Cyclodextrin's purpose?

Produced through the enzymatic degradation of starch, these cyclic oligosaccharides are classified as a-, b-, or y-CD depending on whether they contain six, seven, or eight glucose sub-units. Cyclodextrins function as versatile host molecules due to their unique molecular structure, which can be characterized by a hydrophobic internal cavity and a hydrophilic external surface. With these properties, Cyclodextrin is able to participate in "host guest chemistry".

CD (n)	Diameter Å
α (6)	4.7 – 5.3
β (7)	6.0 – 6.5
γ (8)	7.5 – 8.3

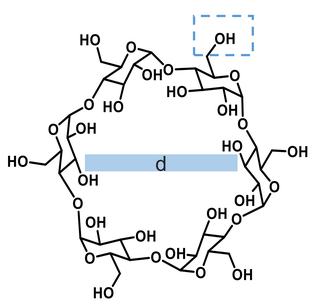


Figure 2: Structures and cavity diameters of α-, β-, and γ-cyclodextrin, showing how ring size (n = 6–8) influences the internal cavity width.

Experimental Technique- Soxhlet Extraction Apparatus

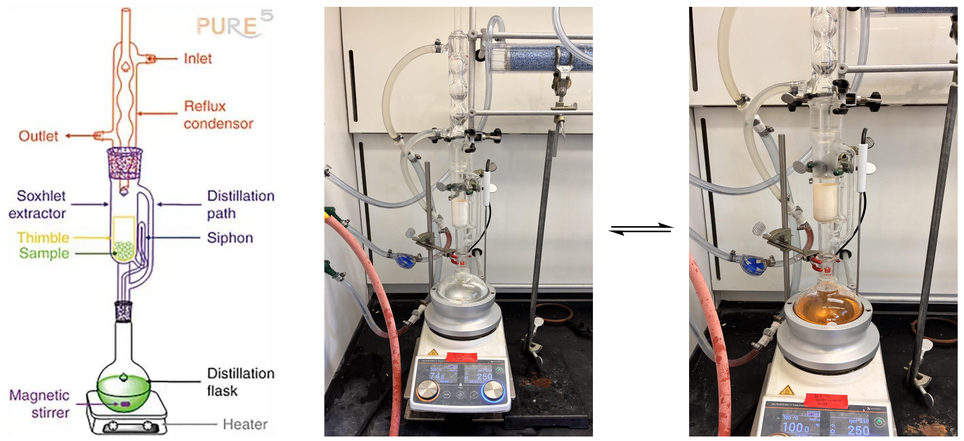
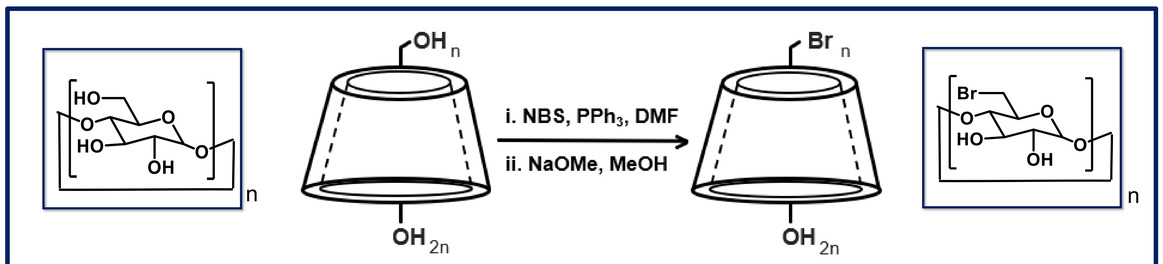


Figure 3: Soxhlet extraction setup and process, showing the apparatus schematic alongside experimental images before and after extraction (STANTCHEV G, PURE[5] , 2023)

The synthesis starts out with a set ratio of β-CD, PPh_3 , and NBS being dried under inert N_2 gas and heated to 50˚ C overnight. The solids were then dissolved in DMF and combined into one round bottom flask via canula transfer(NBS added to PPh_3 (on ice), then transferred to β-CD solution) which was then heated to 80 °C. The reaction is then diluted MeOH and allowed to react for 30 minutes. After this step, the pH of the solution is adjusted to ~9 using 3M NaOMe, still under N_2 gas. This Br7-CD solution is then precipitated out in cold DI water and filtered and washed with EtOAc and MeOH. The solids filtered are then added to a **thimble** and added to the **soxhlet apparatus** (MeOH, 100˚ C, 1-2 days).

Experimental Synthetic Mechanism



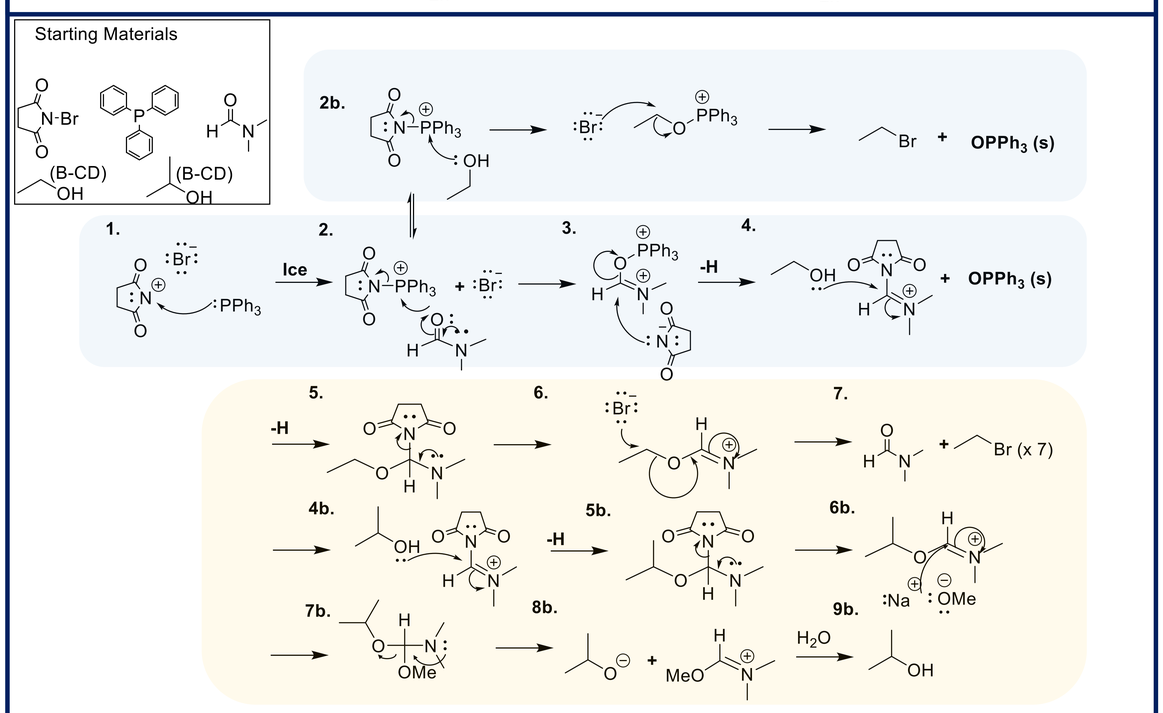
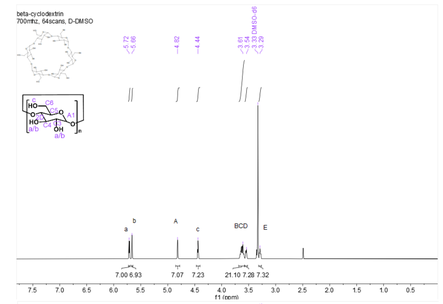


Figure 4: The overall synthetic process for bromination of the primary alcohol on Beta-Cyclodextrin.

Characterization and Future Work

How can we determine the site of Bromination?

a)



b)

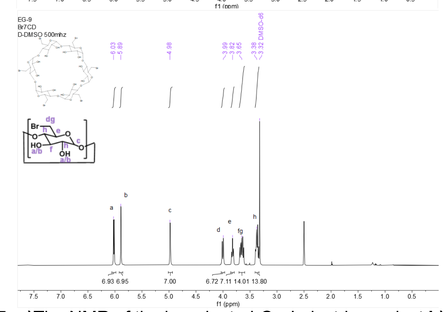


Figure 5: a) The NMR of the brominated-Cyclodextrin product **b)** The NMR of β-Cyclodextrin

Future work

Future work for this project will involve the addition of sodium azide to convert Br7-CD into functionalized N_3-CD, followed by ammonization of the cyclodextrin to complete the synthesis; with the ultimate goal of employing this material for PFAS sorption.

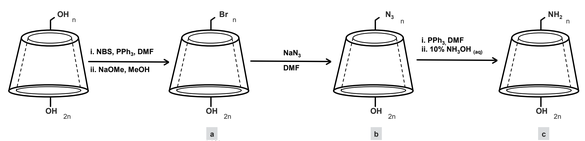


Figure 6: Overall synthetic scheme for the functionalization of β-cyclodextrin, showing the future stepwise reaction conditions and intermediates leading to the ammonization product.

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References

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