Facilitating Access to PET Probes and Advanced Biofuels

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Nucleophilic aromatic substitution ($S_N$Ar) has long been the predominant method to introduce $^{18}$F into aromatic molecules in the synthesis of tracer molecules for $^{18}$F PET, a non-invasive medical imaging technique. $S_N$Ar is limited in its scope to arenes bearing electron-withdrawing substituents as a direct consequence of the reaction mechanism; the negatively charged ‘Meisenheimer’ intermediate formed through nucleophilic attack ipso to the leaving group is only energetically accessible when the arene substrate bears electron-withdrawing substituents. The first part of this talk will showcase an alternative: concerted nucleophilic aromatic substitution (CS$N$Ar), which is not restricted to electron-deficient arenes. CS$N$Ar is shown to be the preferred mechanism of nucleophilic displacement for aromatic deoxyfluorination with the reagent ‘PhenoFluor’, even with substrates for which an $S_N$Ar pathway would be energetically accessible. Detailed mechanistic analysis permitted the adaptation of PhenoFluor-mediated deoxyfluorination, which requires both a fluoride-containing reagent and extraneous fluoride, for $^{18}$F-chemistry, where fluoride is, by necessity, the limiting reagent. The resulting radiodeoxyfluorination is operationally convenient, and tolerates a wide range of functional groups. Stabilization of a crucial reaction intermediate through η⁶-coordination to ruthenium resulted in a substantial extension of the scope to yield a practical and general $^{18}$F-labeling method.

The second part of my talk will focus on the use of metal-organic frameworks (MOFs) in the development of catalysts for the synthesis of biofuels. While ethanol can be sustainably sourced in large quantities, its properties as a fuel additive are sub-optimal. 1-Butanol, on the other hand, can serve as a drop-in replacement for gasoline, but it is currently made from petrochemicals. We have shown that MOF-supported RuNi alloy nanoparticles can catalyze the Guerbet reaction of ethanol to form 1-butanol with turnover numbers over 725,000. Catalytically active RuNi nanoparticles are formed under the reaction conditions from commercially available ruthenium(II) precursors heterogenized in a nickel-based MOF. 1-Butanol is formed with 99.9% selectivity among liquid products at 21% ethanol conversion, despite 1-butanol being itself a competent substrate for the Guerbet reaction.