2021_SSP Faculty Projects

Row 1

Research Group	Venable
Project Title	**The Synthesis & Characterization of [(arene)Ru]$C_2H_2B_9H_9$ Ruthenacarborane Clusters as Potential Boron Neutron Capture Therapy (BNCT) Agents**
Research Question, Hypothesis, or Conjecture	Are we able to prepare molecules with the general formula [(arene)Ru]C2H2B9H9 in which we systematically vary the identity of the arene moiety to tailor site-specific absorption in targeted cells?
Project Description	Our long-term goal is to prepare a boron-rich molecule in which the identity of the arene offers the opportunity for tissue specific absorption, ideally targeting a specific tumor type. These molecules offer a unique approach to a cancer treatment known as boron neutron capture therapy, which has been successfully used clinically to treat both skin cancer and glioblastoma multiform, one of the most insidious of all brain cancers. The boron-containing pharmaceuticals are irradiated with neutrons after being administered to the patient. This absorption of neutrons yields a metastable B atom which rapidly undergoes a fission reaction to release an alpha particle, which only irradiates and destroys those cells immediately surrounding the absorbed RuC2B9 molecule. Our summer focus is to explore two potential routes to varying the arene portion, which controls absorption selectivity, of the ruthenacarborane. One route is to vary the identity of the [(arene)RuCl2]2 reagent in the reaction. My lab has previously prepared a variety of reagents varying the arene to explore the effect of changing arene size and polarity on the stability of the [(arene)RuCl2]2. A second route is to explore the possibility of arene exchange reactions in which [(p-cymene)Ru]C2H2B9H9, a known molecule, is heated in the presence of a second arene in the hopes the second arene will displace the p-cymene. After synthesizing what we anticipate is a new (arene)ruthenacarborane, we will purify it using standard chromatography techniques and characterize it using infrared (IR) spectroscopy, ultraviolet-visible (UV-vis) spectroscopy, nuclear magnetic resonance (NMR) spectroscopy, and finally single crystal x-ray diffraction (XRD) to determine the detailed structure, including bond distances and angles, of the new molecule. These are standard tools for the structural determination of any new molecule. Of these, we will focus on NMR and XRD. The information they provide is complementary; NMR data is used to determine the structure of a molecule in solution while XRD is used to determine the structure of a molecule in the solid state. As part of our structural studies, we will use computational software, SPARTAN, to explore the reactivity and stability of the target (arene)ruthenacarboranes. Will our observations in lab match the predictions provided by the software? Will the computations allow us to predict the route of a chemical reaction? Students will learn how to build molecules in this software and perform computations to determine the electronic structure of the final product. The work described here represents speculative research in which students will have to develop the protocols for preparing these new molecules. In contrast to the lab work associated with courses, there are no existing protocols insuring a successful synthesis. This is why my research groups meet daily to use results from one day to plan the work for the next day. These molecules have never been made before.
Introductory	1) Barth, R. F., et al. “Boron Neutron Capture Therapy of Cancer.”

References	Cancer Research, 1990, 50, 1061. 2) Gozzi, M., et al. “Quinoline-Conjugated Ruthenacarboranes: Toward Hybrid Drugs with a Dual Mode of Action,” ChemMedChem, 2019, 14, 2061-2074. 3) Kellert, M., et al. “Ruthenacarborane-Phenanthroline Derivatives as Potential Metallodrugs,” Molecules, 2020, 25, 2322-2333.
Project Timeline (weekly), during June 1 - July 31	Wk1: Introduction of research topics in the literature (BNCT, cluster chemistry, use of SciFinder) Wk2: Introduction to synthesis techniques in the lab Wk3: Synthesis of [(p-cymene)RuCl2]2 and H2C2B9H10- (SPARTAN use to predict reactivity) Wk4: Synthesis of [(p-cymene)Ru]H2C2B9H9 and attempted thermal exchange with a new arene Wk5: Synthesis of [(C6H4CH3COOH)RuCl2]2 and reaction with H2C2B9H10- Wk6: Purification and characterization of new (arene)ruthenacarboranes (IR, UV-vis, NMR) Wk7: Final characterization of new compounds; preparation of crystals for XRD Wk8: Evaluation of reaction schemes and project evaluation
Expected Learning Outcomes	In addition to the anticipated, successful synthesis of a new (arene)ruthenacarborane students will gain extensive, hands-on experience with several key techniques for the characterization of any new substance. •NMR Spectroscopy is considered the powerful tool for the solution characterization of any molecule. These students will move beyond the one-dimensional spectra 1H and 13C spectra for organic molecules and will be taught to analyze two-dimensional, multi-nuclear NMR spectra. •If we successfully synthesize any of the target molecules, students will gain experience in single crystal x-ray diffraction, the standard technique for determining detailed (bond lengths and angles) images of new molecules. This opportunity is available through a collaboration with Prof. Gary Guillet of Georgia Southern University, a collaboration that has already produced two new x-ray structures from previous summer work. •SciFinder is the most powerful search engine for chemistry literature and one we will use routinely during the summer to follow the work of other researchers. •SPARTAN computational software is one of the foremost programs used to introduce students to the capabilities of high-level, computational work on molecules. We will use this software to study both the energetics and the potential chemical reactivity of molecules, both starting materials and products. •Techniques such as UV-visible spectroscopy and IR spectroscopy are tools for chemical analysis of molecules and although not as powerful as those techniques mentioned above, these are standard tools for molecular analysis. All the techniques listed here represent skills which should be listed on a student resume.
Research Team & Environment	My research team is to be made up of two ASC undergraduate students and myself as mentor.
Department	Chemistry
4 or 8 Week Project	8 weeks
# of full-time student positions requested (1-3)	2
Minimum Requirements (for research novices)	Chemistry 150/150L. Should have own transportation or live near campus in order to access ASC labs and computer rooms.
Requirements for Advanced students	NA
Recommended Preparation	

(but not required)	
Modification for Remote Research (IF needed)	If students are unable to access the lab, we would plan to run the lab work as a remote class in which students would see the lab work either synchronously or asynchronously, depending on wifi availability, and after viewing the lab skills portion of the project, students would be provided with the lab results (IR, NMR, UV-vis) to analyze remotely. This analysis would require students to compare the lab results to the same spectra collected on the starting materials. This is the same process students would pursue if on-campus.