1

SYNTHESIS OF DIAMINE

Sarah Al Karawi, Senior, Chemistry, University of Kentucky
Robert Grossman, Chemistry, University of Kentucky

Abstract:

Diamines have multiple utilities in pharmaceuticals, natural product synthesis. Effort was put with the aim to synthesize chiral diamine. The synthetic approach starts with deprotonating the alpha carbon of diethyl malonate using Sodium Ethoxide followed by adding crotyl chloride in room temperature. Time was of the essence, to avoid double deprotonation, hence prevent the formation of dimer. The resultant product was subject to further deprotonation of the alpha carbon using the stronger smaller base, NaH in this case, was achieved then ethylene dibromide was added in anhydrous THF in reflux. After purifying the compound, a substitution reaction was performed to substitute Bromine with Azide in DMSO. Cycloaddition occurs at high temperatures between the prochiral alkene and the dipolar Azide ion generating a pyridine with two chiral centers.

Further steps including alkylating the terminal secondary amine and reducing the double bond and releasing nitrogen gas, would yield the desired diamine.

2

COMPARISON OF THE PLANT PROTEIN ANALOG "BEYOND MEAT" HAMBURGER TO A TRADITIONAL MEAT BASED HAMBURGER

Nathan Britt, Senior, Psychology, Eastern Kentucky University
Li Li Zyzak, Chemistry, Eastern Kentucky University

Abstract:

Global concerns related to the continued availability of animal-based protein sources, in addition to the awareness of consumers for healthier and less-global climate impact food sources, have driven the introduction of plant-based meat products in the marketplace. Some of the challenges in winning over more consumers relates to the taste of these non-animal based products. Can companies really make a plant-based chicken or beef product taste as good as the animal-based version? In our lab, we investigate the chemical compounds in foods and beverages that are responsible for the taste and aroma. By leveraging the technique of Gas Chromatography – Olfactometry (GC-O), we can identify the volatile compounds which are strongly contributing to the aroma of a food product. This approach enables us to focus on the most relevant compounds in our Gas Chromatography – Mass Spectrometry (GC-MS) analysis while not ignoring the non-odor impactful volatiles which can sometimes give additional information about a food product. During our work, we used GC-O and GC-MS to identify and differentiate the volatiles of various plant-based hamburgers compared to a traditional beef hamburger. In addition, we performed sensory analysis of the hamburgers prior to analysis. Next, we used Principal Component Analysis (PCA) to help us identify differentiating volatiles between these various hamburgers. PCA was a valuable tool in accessing the volatile profile and could easily distinguish the five different products. The observation plot within the PCA data showed that Beyond Meat hamburger was closest to the traditional beef hamburger. This data supported our sensory analysis. In addition, the PCA biplot was beneficial with identifying compounds which correlated with each of the four plant-based hamburgers. This data provides an explanation of the sensory differences between the products and also provides a roadmap for making the plant-based hamburgers closer to a traditional beef hamburger.

3

THE FATE OF AMMONIUM IN SOILS

Matthew Burton, Senior, Chemistry, University of Kentucky
Chris Matocha, Plant and Soil Science, University of Kentucky

Abstract:

Nitrogen is a highly important plant nutrient, necessary to the production of chlorophyll, enzymes, and protein. Much of a plant's nitrogen supply is taken in from the soil. However, only certain nitrogen forms are available for plant use, namely, ammonium and nitrate. This research looks at the extent and kinetics of the reaction between ammonium and montmorillonite, a 2:1 expanding clay mineral commonly found in many soils. Reaction kinetics were evaluated by plotting remaining ammonium in solution over time. The reaction was found to have fast kinetics, as most the ammonium was removed in the first several seconds of the reaction. To evaluate the extent of the reaction, isotherms were made for the reaction at different temperatures. A higher K* value was observed for the reaction at the warmer temperature, suggesting the reaction is endothermic. More research will be needed to further understand the reaction proceedings, as well as the ammonium retention mechanisms.

4

THE EFFECTS OF C8-SUBSTITUENTS ON ELECTRONIC STRUCTURES OF FLAVINS

Samuel Chasen, Senior, Chemistry, University of Kentucky
Rajiv K. Kar, Chemistry, Technische Universität Berlin

Abstract:

Flavins are versatile molecules that have an absorption maxima at 447 nm to 374 nm, giving off a yellow color. These molecules have been shown to exhibit significant oxidation and reduction activities that are imperative to life. Recent studies at the Miller Lab have shown that changing the C8 position of the simplest flavin, lumiflavin, has significant effects on the absorption maxima and its electronic properties. To understand these transitions, numerous quantum chemical methods were used to simulate seven lumiflavin derivatives to identify changes in the flavin's electronic structure that corresponds with its changing spectra. Using computational methods to simulate these flavins, it was found that the optical spectra from the calculated values of the simulated flavin are in a good agreement of the derivatives and follow a consistent trend of the experimental spectra.

5

UNDERSTANDING WHICH ELEMENTS ARE HARDER TO MEMORIZE AND EASIER TO FORGET

Hunter Filley, Senior, Chemistry, University of Kentucky
Stephen Testa, Chemistry, University of Kentucky

Abstract:

Objective: This project is based on the biochemical characterization of a putative Glucan Water Dikinase (GWD) orthologue that has been identified in a unicellular, thermophilic red alga, Cyanidioschyzon merolae (Cm). The goal of this experiment is to study the functioning of three carbohydrate binding modules (CBM) of family 45 contained in the sequence of CmGWD.
Significance: Glucan water dikinase is involved in starch metabolism through phosphorylation. The carbohydrate binding modules are thought to be critical for the enzyme's ability to efficiently phosphorylate starch. The role of CmGWD in starch metabolism is of interest because of potential industrial applications.
Methods: Bioinformatics to design primers to mutate certain tryptophan, tyrosine, or phenylalanine residues to alanine in three CBM45s. Polymerase chain reaction (PCR) to amplify the mutations. Transformation into chemically competent E. coli cells to grow cultures containing a large number of cells. A two-step purification scheme using affinity chromatography and fast protein liquid chromatography (FLPC). Carbohydrate binding and differential scanning fluorimetry (DSF) assays to test the ability of the CBMs to bind substrate.
Results: We were not able to purify some mutations of CmGWD. The assays that were performed showed reduced binding ability. We observed that mutations of critical amino acid residues did affect the overall binding ability of the CBMs.
Conclusion: On the CAZY server, the family CBM45 consists of 89 eukaryotic members, and all are found in GWDs. This project focused on the three CBM45s found in CmGWD. Knowing which amino acids alter the binding ability of CBM45s can help us determine the amino acids that are essential for the phosphorylation of starch by CmGWD.

6

SOLIDAGO AS A FETAL ALCOHOL SYNDROME PREVENTION METHOD

Camryn Kennemore, Senior, Chemistry, University of Kentucky
Allan Butterfield, Chemistry, University of Kentucky

Abstract:

Fetal Alcohol Spectrum Disorders is a worldwide issue that results in a child after prenatal alcohol consumption. These disorders are incurable, which is why there is such a focus on preventing FASDs. New research suggests that alcohol related birth defects can be lessened or reversed using antioxidants. Because ethanol from alcohol creates oxidative stress in a fetus, scientists hope that a supplement of antioxidants could neutralize the radical oxidative species and prevent the damage caused by them. My intended project was to determine if the solidago has antioxidant properties that could do this.

7

THE ROLE OF POLYCOMB REPRESSIVE COMPLEX 2 AND CYSTATHIONINE BETA SYNTHASE IN LUNG CANCER AND COPD

Alexsdandr Lukyanchuk, Senior, Chemistry, University of Kentucky
Christine Fillmore Brainson, Toxicology and Cancer Biology, University of Kentucky
Allan Butterfield, Chemistry, University of Kentucky

Abstract:

Studying the epigenetics and cellular microenvironment of lung cancer and COPD could lead to a better understanding of the nature and vulnerabilities of these diseases. This project focuses on how methionine metabolism affects the histone methylation and epigenetic state of lung cancer cells, and on how histone methylation affects lung cell differentiation in COPD. An important epigenetic regulator is Polycomb Repressive Complex 2 (PRC2), an enzymatic complex that methylates histones. The activity of PRC2 is potentially affected by Cystathionine Beta Synthase (CBS, an enzyme involved in the production of antioxidants) via a divergence in the methionine cycle favoring the transulfuration conducted by CBS instead of the methylation conducted by PRC2. The first hypothesis is that low methionine levels limit CBS activity which in turn stabilizes PRC2's methylating capabilities and increases therapy response. Lung cancer cells from three cell lines (A549, H2009, and H2030) were grown in variable methionine media and then analyzed with qPCR, western blotting, and Carboplatin dose-response studies. The results were that a low methionine restriction leads to a noticeable and reproducible decrease in CBS protein levels and also results in a higher susceptibility to chemotherapy treatment when compared to a high methionine medium, but the link to histone methylation is unclear. The second hypothesis is that decreased PRC2 activity in COPD patients drives the dysregulated differentiation of the lung epithelial cells. Lung epithelial tissue derived from normal and COPD- diagnosed patients was stained with various lung cell markers (MUC5ac, KRT5, and CCSP) and then analyzed with immunofluorescences. The results were that there is a significant correlation between low PRC2 activity and cell lineage shifts towards basal and goblet cell types as seen in COPD lung histology and that there is significant CBS overexpression in COPD lung tissue.

8

THE RATE OF FORGETFULLNESS FOR PERIODIC TABLE ELEMENTS

Maggie McGoldrick, Senior, Chemistry, University of Kentucky
Stephen Testa, Chemistry, University of Kentucky

Abstract:

The most known periodic table elements (noble gases, nonmetals, alkali, etc) are often introduced in introductory level chemistry courses, but as students near upper level courses, less common elements begin to be incorporated into the curriculum. When new elements are introduced that students have not yet covered, they are not only learning the new curriculum, but they are also trying to learn and remember an element. This creates more work for the student and can potentially lead to underperformance. The purpose of this research is to determine which periodic table elements are already known, easily remembered, or easily forgotten. With this data, chemistry curriculum could be more focused towards elements that are more easily remembered by students after being introduced, versus elements that were found to be forgotten easily.

9

THE ELEMENTS: ENCODING, RETAINING, AND FORGETTING

Richard Murt, Senior, Chemistry, University of Kentucky
Stephen Testa, Chemistry, University of Kentucky

Abstract:

Time is a finite resource that shouldn't be wasted by inefficient methods or procedures, thus students who are pursuing degrees and taking upon themselves a firehose worth of material should pursue the most efficient methods possible to retain the material for success in their exams and futures. The goal of this experiment was to determine if a spaced repetition model was sufficient for retaining concrete material given a limited amount of preparation time. COVID-19 regulations limited the scope of the sample pool but results initially point to success in retaining material over a period of several months with an additional increase in retention once another period of material exposure occurred. Implications of this research could influence students, professionals, anyone that needs to retain knowledge to adopt a method that may be more efficient for their retention and success.

10

THE PERIODIC TABLE

Danielle Peterson, Senior, Chemistry, University of Kentucky
Stephen Testa, Chemistry, University of Kentucky

Abstract:

This study investigates memorization, retention, and my familiarity with the periodic table. Over a 63 day period, I took 10 tests to examine my retention of the periodic table elements. These tests were taken on day 1, 15, 16, 17, 19, 23, 31, 39, 47, and 63. The abbreviations were provided and I was tested on my ability to identify and correctly spell the elements. A baseline test was taken on day 1 of this study and acted as a point of reference for any progress throughout the study. For two weeks I studied the periodic table in whatever manner I found fit and took no tests. On day 15, I improved from 59 correct elements to 113. From day 17 - 23 only 3 elements that were learned from the study period were forgotten. A total of only 6 elements were never learned and 3 elements were hard to define throughout the study because they were forgotten, mixed up, or misspelled occassionally. The general trends for 12 elements that were either never known, hard to define, or forgotten were elements that resided in periods 5, 6, and 7. It is concluded that the chemistry of elements has not been explicitly discussed or mentioned throughout my undergraduate career and this made memorization difficult. I can conclude that familiarity with elements is crucial and aids in the retention of element abbreviations and names.

11

DEVELOPING A NEURAL NETWORKS FOR DIHEDRAL DEPENDENT ENERGIES

Andrew Smith, Sophmore, Chemistry, University of Kentucky
Chad Risko, Chemistry, University of Kentucky
Rebekah Duke, Chemistry, University of Kentucky
Vinayak Bhat, Chemistry, University of Kentucky

Abstract:

Computational methods are essential for enhancing the speed of materials development. While these methods are still faster than traditional experimentation many calculations are incredibly time-consuming. Taking, for example, the computational derivation of optical properties interesting in solar cells. To determine these properties, one might use molecular dynamics however this generally requires a dihedral angle vs potential energy surface which must be parametrized using density functional theory (DFT). This is problematic as density functional theory typically runs on an n3 timescale. Thus, leading to calculations of a single conformation taking hours to days for some large molecules. However, some have worked to remedy this by using neural networks such as the ANI model developed at Los Alamos by Smith et. al. in 2016. While this model excels at many simple molecules it struggles with properties key to many organic photovoltaics. In this work, we attempt to expand on the work of Smith et. al. to increase the accuracy of ANI on particularly on molecules with extended pi conjugation and generally larger molecules (greater than 50 atoms). This was done by using active learning as well as in-house generated DFT calculation. Although work is ongoing thus far the accuracy has been improved from an error of ~80kcal/mol to ~32kcal/mol for such molecules.

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DEVELOPING STRUCTURAL DESCRIPTORS FOR Π-CONJUGATED MATERIALS

Parker Sornberger, Junior, Chemistry, University of Kentucky
Chad Risko, Chemistry, University of Kentucky
Vinayak Bhat, Chemistry, University of Kentucky
Alex Ai, Chemistry, University of Kentucky

Abstract:
In organic semiconductors, the chemistries of the π-conjugated backbone and the pendant alkyl side chains can influence the semiconductor's electronic and optical properties by in part controlling how the molecules pack in the solid-state. Unfortunately, a definitive association between molecular structure, solid-state packing, and the resulting properties of the material does not yet exist, and researchers must instead create new organic semiconductors through trial and error. The Organic Crystals in Electronic and Light-Oriented Technologies (OCELOT) database provides researchers with myriad robust chemical and structural descriptors to aid in this process and formats data such that machine learning models can process available data to make predictions about a yet-experimentally uninvestigated material's properties. To provide structural descriptors, the application programming interface (API) of the database utilizes graph-based partitioning methods to rapidly decompose a molecule's structure into a variety of backbones and side-groups. We generate such descriptors by transforming the atoms in molecules rendered via the Python library, Pymatgen to nodes in a graph created with a secondary Python library, NetworkX. From here, we exploit NetworkX's expansive graph manipulation functions to alter our molecules. Through these methods, a researcher can obtain a given molecule's optical chromophore, largest group of fused rings, largest group of rings connected by a single bond, and its Bemis-Murcko scaffold, which contains all rings in a molecule connected by bonds of any length. Likewise, a researcher can also access the side-groups for any structural backbone selected. Furthermore, a machine learning model given this information could use these structural descriptors to make associations with a molecule's experimentally determined properties. Then, the trained model could help a researcher determine the most promising hypothetical materials to experimentally characterize. The OCELOT database can be found at: https://oscar.as.uky.edu/

13

ANALYSIS OF THE ANTIOXIDANTS IN HOMEMADE VS. COMMERCIAL KOMBUCHA

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Bruce Branan, Health and Sciences, Asbury University

Abstract:

Kombucha is tea that is fermented by a symbiotic culture of bacteria and yeast (SCOBY). It has many purported health benefits, partly due to its antioxidant levels. This study contrasted the concentrations of antioxidants in homemade vs. commercial kombucha. High performance liquid chromatography (HPLC-UV) was used to analyze the concentrations of the antioxidants caffeine, catechin, epicatechin, and epigallocatechin gallate (EGCG). UV-Vis spectroscopy was used to analyze the concentrations of total antioxidants in the kombucha samples. The concentrations of caffeine, catechin, epicatechin, EGCG, and total antioxidants were all shown to be statistically higher in homemade kombucha than in commercial kombucha ($p < 5\%$). Of the four, only EGCG concentrations were shown to be higher in homemade fermented kombucha than in the original unfermented tea. There was no significant difference between caffeine, catechin, epicatechin, or EGCG concentrations in the analyzed kombuchas with fruit compared to plain kombucha.

14

EFFECTS OF TREATMENT WITH THE CHEMOTHERAPEUTIC AGENT ABT-199 ON SERUM AND BRAIN LEVELS OF PRO-CASPASE 3 IN WILD-TYPE MICE

Madison Webb, Senior, Chemistry, University of Kentucky
Allan Butterfield, Chemistry, University of Kentucky
Shekinah Alfaro, Chemistry, University of Kentucky

Abstract:

Chemotherapy-induced cognitive impairment (CICI) is a condition occurring during or after chemotherapy treatment that results in memory, learning, concentration, and reasoning impairment, thereby impacting the short-term or long-term quality of life in cancer patients. Certain chemotherapeutic agents, such as the cytotoxic Doxorubicin (DOX), have been shown to induce apoptosis in both tumor and normal models, leading to CICI. ABT-199 is a non-cytotoxic chemotherapeutic agent that functions through inhibition of BCL-2, a protein inhibitor of apoptosis. As such, it is hypothesized that administration of ABT-199 will increase serum and brain levels of pro-caspase 3, a precursor to the downstream apoptotic mediator caspase 3, in wild-type mice. 12 male and 12 female wild-type mice were divided equally into three treatment groups: saline, buffer vehicle, and either acute (one dose of 500 mg/kg) or chronic (escalating daily doses of 25, 50, and 100 mg/kg for 8 days) doses of ABT-199, all given by gavage. Levels of pro-caspase 3 in serum and brain samples post-treatment were determined via Western blot analysis. Compared to the saline control group ($n=4$, 0.85 ± 0.30 a.u.), ABT-199 decreased serum levels of pro-caspase 3 in acutely treated male mice ($n=4$, 0.38 ± 0.21 a.u., $p<0.05$). ABT-199 increased brain levels of pro-caspase 3 in acutely treated male mice ($n=4$, 1.53 ± 0.07 a.u., $p<0.05$) compared to the saline control group ($n=4$, 1.25 ± 0.04 a.u.). No differences were found between groups in acutely treated female mice serum. Similarly, no differences were found between the serum of buffer- treated and chronically treated male or female mice. However, serum pro-caspase 3 levels were increased in female buffer-treated mice ($n=4$, 2.55 ± 0.09 a.u., $p<0.05$) versus male buffer-treated mice ($n=4$, 1.32 ± 0.56 a.u.). ABT-199 decreased brain pro-caspase 3 levels in chronically treated female mice ($n=4$, 0.79 ± 0.10 a.u., $p<0.05$) versus buffer-treated female mice ($n=4$, 0.98 ± 0.06 a.u.). These results indicate that the impact of ABT-199 treatment on pro-caspase 3 levels is dependent upon both sample type and gender. Furthermore, the results suggest that administration of the lipid-heavy buffer itself impacts pro-caspase 3 levels in the brain and serum of wild-type mice. Future research directions include performing Western blot analysis on serum and brain samples to probe for markers of oxidative damage that might precede the observed changes in pro-caspase 3 levels.

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NOVEL SMALL MOLECULE INHIBITORS OF ARID4B

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Samuel Awuah, Chemistry, University of Kentucky

Abstract:

AT-rich interactive domain 4B (ARID4B) is a member of the ARID family. Its upregulation has been shown to promote primary breast tumor growth and metastasis. ARD150, a small molecule that targets the chromo-barrel domain of ARID4B, has been developed by Awuah lab. ARD150 consists of two key structural frameworks, a 3,4- alkoxy substituted aromatic head and a solubilizing tail. This CHE395 project will seek to develop more potent analogs of ARD 150. The design of the new, improved class of ARD-150-like inhibitors - as informed by detailed in-silico studies of the interactions between ARD 150 and key amino acids within the chromo-barrel domain of ARID4B – will seek to modify these two structural parts of ARD150, so to improve therapeutic inhibition of ARID4B. This project will involve rapid optimization and chemical diversification of the lead compound, ARD150 through organic synthesis. This will result in ~20 ARD-150-like inhibitors through the variation and testing of different aromatic heads and solubilizing tails. Using ARD 150 as a scaffold allows for quickly predicting similar compounds without requiring unique in silico design. These modified compounds aim to preserve the target affinity and specificity of ARD 150 while increasing potency.