Studies of Solution Paramagnetic-Substrate Nuclear and Electron Intermolecular Interactions

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A dissertation submitted to the faculty of
Virginia Polytechnic Institute and State University
in partial fulfillment of the requirements for the degree of

Doctor of Philosophy

in

Chemistry

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April 17, 2006
Blacksburg, Virginia

Keywords: Hyperfine Coupling Constant, TEMPO, Magnetic Resonance Imaging, Relaxivity, Endohedral Metallofullerene, and Contrast Agent.

Abstract

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Advanced nuclear and electron magnetic resonance techniques (i.e. nuclear magnetic resonance (NMR), dynamic nuclear polarization (DNP), and magnetic resonance imaging (MRI)) were used to study the attitude and dynamics of TEMPO (2,2,6,6-tetramethylpiperidinyloxy)-substrate systems and the relaxivity properties of water-soluble trimetallic nitride template functionalized endohedral metallofullerenes (TNT-fMF). The attitude and average distance of interaction for each TEMPO-substrate system was determined from comparing density functional theory (DFT) calculation results with experimental hyperfine coupling constants leading to an improved understanding of solution dynamics. The short-lived solvent-solute interactions of the TEMPO-substrate molecules, such as transient complex formation, are governed by weak hydrogen-bonding interactions. The collisions in solution were explained by determining the favored orientations of the two molecules interacting using calculated relative energy minima and reproducibility of the experimental results by the calculated coupling constants.

Water-soluble TNT-fMFs are studied as candidates for the next generation MRI contrast agents as diagnostic agents and also as possible therapeutic agents to kill cancer cells and decrease tumors. The TNT-fMFs are being studied as part of a multi-modal platform dependent upon which metal atoms are encapsulated inside: Gd – MRI contrast agent (diagnostic), Lu and Ho – radio labeled for use as a therapeutic agent, Tb – fluorescence, and Lu – x-ray contrast. The current commercial MRI contrast agent, Omniscan^{TM}, contains one gadolinium atom; however, the metal is complexed to, not encapsulated in, the molecule. TNT-fMFs fully encapsulate three metal atoms to ensure the patient does not run the risk of metal poisoning. The r_1 and r_2 relaxivities of TNT-

fMFs containing either Gd, Lu, Ho, or Sc metals were measured at 0.35T. The data for the Gd containing TNT-fMFs indicated the metallofullerene has significantly higher relaxivities than Omniscan^{TM}, and can be the next generation MRI contrast agent. The Ho containing species has a high R_2/R_1 ratio compared to the other samples showing it is a potential T_2 agent, and has therapeutic capabilities.

Acknowledgements

First, I would like to thank Dr. Harry Dorn for his direction throughout the many courses of this project. I have learned so much from your invaluable discussions and guidance. Thank you for everything!

Many thanks to my husband, Nick, for his love, support, and prayers. It has been an interesting last five years, many times not easy, but you stuck with me. I could not have done it with out you. I love and appreciate you. Thank you so much!

I would also like to thank Dr. Jim Duchamp for his insight and discussions. You are always able to explain complex topics in a way that I can understand, and you always have a unique twist on explanations, figure design, or anything really, that no one else had considered. Also, thanks for being a good friend!

Thank you to Dr. Jimmy Ritter for his instruction on the 15MHz NMR instrument. Thanks so much for taking the time to teach me and troubleshoot problems. I am grateful for your training and the sharing of your expertise in this area.

I thank all of my committee members: Dr. Merola, Dr. Tanko, Dr. Ritter, and Dr. Crawford, and group members: Xuelei Wang, Tianming Zuo, Ting Cai, Liaosa Xu, and Wujun Fu, as well as, Dr. Ge and Jon Reid for their helpful comments and suggestions throughout the last several years. I especially thank Xuelei Wang and Dr. Ge for performing all of the preparation steps for the metallofullerene samples that I measured. I really appreciate everything!

I would like to acknowledge our collaborators at VCU, Frank Corwin and Dr. Panos Fatouros for performing the 2.4 T relaxivity measurements, and Juan Gu, Ziqi Sun, and Li Song for performing the DNP experiments and determining the experimental data referenced in this project.

Many thanks to my parents, Roger and Tammy Kile, and my sister Jessica Mick. I cherish all the love, support, and prayers that you have given to me throughout the many, many years. You have truly blessed me. I am so loved!

Finally, I thank all of my family and friends. I am richly blessed!

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