CURRICULUM VITAE

Asmita Singha, Ph.D.

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Current Affiliation: Assistant professor in the Department of Chemistry and Chemical Biology at IIT ISM), Dhanbad

Education & Research Experience:

Jan 2024 – present	Assistant Professor (Grade –I)	Department of Chemistry and Chemical Biology, IIT (ISM), Dhanbad
March 2020 – April 2023	Postdoctoral research fellow Supervisor: Prof. Edward I Solomon	Department of Chemistry, Stanford University, USA
August 2014 – December 2019	Ph.D. Supervisor: Prof. Abhishek Dey	School of Chemical Science, Indian Association for the Cultivation of Science, Kolkata
July 2012 – July 2014	M.Sc. Master's project supervisor: Prof. Gopalan Rajaraman	Department of Chemistry, IIT Bombay
July 2009 – June 2012	B.Sc.	Presidency College, University of Calcutta

Academic Achievement:

- All India 1st in Joint Admission Test for M. Sc (JAM) in 2012

- All India 17th in National Eligibility Test (CSIR NET) in 2013

Scholarship Achieved:

- CSIR-SRF and CSIR-JRF in 2014 and 2016, respectively from CSIR

- Government of India scholarship from the Ministry of Human Resource Development (MHRD) Department of Higher Education

- JAI PRAKASH BOOK AWARD from the Department of Chemistry, IIT Bombay

Research Experience:

- Postdoctoral Research experience| Tuning the Type 1 Reduction Potential of Multicopper Oxidases: Uncoupling the Effects of Electrostatics and H-Bonding to Histidine Ligands

Supervisor: Prof. Edward I Solomon

In multicopper oxidases (MCOs), type 1 (T1) Cu accepts electrons from the substrate and transfers these to the trinuclear Cu cluster (TNC) where O_2 is reduced to H_2O. The T1 potential in MCOs varies from 340 to 780 mV, a range not explained by the existing literature. This study focused on the ∼350 mV difference in potential of the T1 center in Fet3p and Trametes versicolor laccase (TvL) that have the same 2His1Cys ligand set. A range of spectroscopies performed on the oxidized and reduced T1 sites in these MCOs shows that they have equivalent geometric and electronic structures. However, the two His ligands of the T1 Cu in Fet3p are H-bonded to carboxylate residues, while in TvL they are H-bonded to noncharged groups. Electron spin echo envelope modulation spectroscopy shows that there are significant differences in the second-sphere H-bonding interactions in the two T1 centers. Redox titrations on type 2-depleted derivatives of Fet3p and its D409A and E185A variants reveal that the two carboxylates (D409 and E185) lower the T1 potential by 110 and 255−285 mV, respectively. Density functional theory calculations uncouple the effects of the charge of the carboxylates and their difference in H-bonding interactions with the His ligands on the T1 potential, indicating 90−150 mV for anionic charge and ∼100 mV for a strong H-bond. Finally, this study provides an explanation for the generally low potentials of metallooxidases relative to the wide range of potentials of the organic oxidases in terms of different oxidized states of their TNCs involved in catalytic turnover. [*J. Am. Chem. Soc.*, **2023**, *145*, 13284−13301]

- Ph.D. Dissertation| Spectroscopic characterization and theoretical investigation of electronic structures and reactivities of Fe containing metalloporphyrins

Supervisor: Prof. Abhishek Dey

The $4e^-/4H^+$ reduction of O_2 to water is a fundamental process in biology as well as in the industry. The doctoral thesis is focused on understanding the details of the mechanism of oxygen activation by iron porphyrins via trapping and characterization of reaction intermediates.

The resting ferric heme porphyrin is first reduced to its ferrous form, which can bind dioxygen molecules. This reaction can be achieved by sulfide. A 6 coordinated (6C) low spin (LS) HS-bound ferric heme intermediate is trapped and characterized to establish that this reaction is inner-sphere and results in colloidal sulfur (S_6) and ferrous porphyrin as its product. [*Inorg. Chem.* **2017**, *56*, 3916-3925]

The ferric heme superoxide complex is ubiquitous in nature. Several enzymes involved in oxygen transport and storage (Hb, Mb), oxygen activation (cytochrome P450, heme dioxygenases), oxygen reduction (cytochrome C oxidase), etc. utilize ferric heme superoxide complex. There is a long-standing debate on the electronic structure of ferric heme superoxide complexes. Using a combination of vibrational spectroscopy and electronic structure calculations, the Fe-O and O-O stretching frequency of 6C ferric heme superoxide complexes are found to correlate positively with each other both in the protein system as well as in the model system unlike ferrous carbonyl complexes (synergistic effect). DFT calculations provide the ground state wave function of these species and indicate three major bonding interactions. Using the GS wave function these different bonding interactions are shown to determine the vibrational frequencies and geometries of the Fe-O_2 unit. In fact, the correlations with the bonding parameters are so strong, that one can extract the GS wave function from experimentally available vibrational data. [*Inorg. Chem.*, **2019**, *58*, 10704−10715.]

There are several instances, where stability and reactivity of ferric heme superoxide complexes are controlled by distal H-bonding. Using a series of synthetic iron porphyrin complexes, the role of hydrogen bonding in tuning the electronic structure of the oxy complexes is elucidated. The data and calculations show that hydrogen bonding can weaken or strengthen the Fe-O_2 bonding depending on the acidity of the hydrogen bonding proton. [*Dalton Trans.*, **2019**, *48*, 7179-7186]

To mimic the electron and proton transfer sites in nature, iron porphyrin molecules with covalently attached quinol and phenol groups are synthesized. Upon reaction with ferrous porphyrin with a dioxygen molecule, the hydroquinone ring is found to transfer one H atom to metal-bound superoxide to generate a ferric-hydroperoxide-semiquinone complex, which is found to transfer another H atom from semiquinone to metal-bound hydroperoxide ligand to form ferryl-oxo species with quinone ring attached to it. All of these intermediates have been characterized using resonance Raman and EPR spectroscopy. This is the first evidence, where heme superoxide and hydroperoxide complexes in the synthetic model system are shown to abstract H atom from a pendant hydroquinone ring similar to their non-heme analogs [*Chem. Commun.*, **2019**, *55*, 5591-5594]. Electrochemical oxygen reduction reaction under heterogeneous conditions in an aqueous medium by this porphyrin having hydroquinone ring in the distal site follows the same mechanism involving 2 successive HAT from hydroquinone ring, which makes the catalyst very selective towards 4 electron reduction minimizing the amount of partially reduced product during ORR even when the catalyst is physiadsorbed on an electrode having very slow electron flux. Alternatively, when the phenol group is attached to the distal site of iron porphyrins unlike $FeQH_2$ the ferric superoxide complex takes one proton from pendant phenol but an electron from another ferrous porphyrin following a proton-coupled electron transfer (PCET) mechanism instead of HAT. Furthermore, when the two hydroxyl groups of hydroquinone are replaced with two methoxy groups the reaction is stopped at the ferric superoxide stage in the organic medium, and it follows an ETPT mechanism to reduce oxygen to water in an aqueous medium. Thus, just by modifying the distal residue the mechanism of oxygen reduction switches from HAT to PCET to ETPT. [*J. Am. Chem. Soc.*, **2020**, *142*, 21810−21828]

- MASTER’S DEGREE DISSERTATION| Probing the mechanism of C-H bond activation by diiron (IV) complexes

Supervisor: Prof. Gopalan Rajaraman

A computational study has been performed on a model system of sMMO which can react with cyclohexane to form cyclohexene and can also cleave a strong O-H bond of aliphatic alcohol to form the corresponding ketone. The complex has been optimized in different oxidation states of Fe ions to probe the energetics, spin states, and structural details of all species involved in the catalytic pathway that leads to substrate oxidation. The calculation suggested that all three complexes (Fe^{III}-O-Fe^{III}), (Fe^{III}-O-Fe^{IV}), and (Fe^{IV}-O-Fe^{IV}) are stabilized in an antiferromagnetically coupled state and their existence is also confirmed by the calculation of spectroscopic parameters. To assign the ground state electronic configuration of the above three complexes, single-point energy calculations have been performed for each spin state using a higher basis set to get the accurate result. NBO calculations in the ground state of each complex have been done to predict the nature of the bond between Fe atoms and bridged O atom, which helps us to understand the chemical features of the molecule that is responsible for its surprising reactivity towards C-H and O-H bonds. The UV absorption spectrum and Mossbauer parameters have been calculated by employing computational methods to give experimental support to the observed spectral features reported earlier for this model system. The transition state structure for the oxidation cyclohexane and tert-butanol by diiron(IV) complex has been optimized and the energy barrier has been calculated for the oxidation reactions. [*Chem. Eur. J.*, **2017**, *23*, 10110-10125]

Laboratory Experiences	
Spectroscopic Technique	➢ **Vibrational spectroscopy** (resonance Raman and FTIR) ➢ **Chemical Kinetics** ➢ **Resonance Raman and EPR spectroscopy (X-band, liq. N_2 and liq. He).** ➢ **Stopped-flow instrument** (room temperature and low-temperature, aqueous and organic solvents). ➢ **Electrochemistry and electrocatalysis** (homogeneous and heterogeneous) ➢ **Standard characterization tools.**
Synthesis skills	➢ synthesis of small inorganic coordination complexes and elaborate Metallo-porphyrins.
Protein expression and protein purification	➢ yeast cell culture and bacterial (E. coli) cell culture, purification of protein using anion exchange columns
Computational skills	➢ **DFT calculations using Gaussian and ORCA packages.** Electronic structure and reaction co-ordinate analysis. ➢ F77 language programming in performing mathematical operations and transformations.

Research Interest:

- Interested in understanding the (homogeneous and electrocatalytic) reaction mechanism of small molecule activation by various biologically important metalloenzymes and bio-inspired catalysts

- Interested in the characterization of the intermediates involved in various biologically important reactions by employing advanced spectroscopic techniques like absorption, FTIR, Mössbauer, EPR, resonance Raman, etc.

List of Publications:

1. Tuning the Type 1 Reduction Potential of Multicopper Oxidases: Uncoupling the Effects of Electrostatics and H-Bonding to Histidine Ligands
   Asmita Singha, Alina Sekretareva, Lizhi Tao, Hyeongtaek Lim, Yang Ha, Augustin Braun, Stephen M. Jones, Britt Hedman, Keith O. Hodgson, R. David Britt, Daniel J. Kosman*, Edward I. Solomon*
   J. Am. Chem. Soc., **2023**, *145*, 13284−13301
   [https://doi.org/10.1021/jacs.3c03241]

2. Oxygen Reduction by Iron Porphyrins with Covalently Attached Pendent Phenol and Quinol.
   Asmita Singha, Arnab Mondal, Abhijit Nayek, Somdatta Ghosh Dey, and Abhishek Dey*
   J. Am. Chem. Soc., **2020**, *142*, 21810−21828
   [https://doi.org/10.1021/jacs.0c10385]

3. Resonance Raman Spectroscopy and Density Functional Theory Calculations on Ferrous Porphyrin Dioxygen Adducts with Different Axial Ligands: Correlation of Ground State Wave Function and Geometric Parameters with Experimental Vibrational Frequencies
   Asmita Singha, Pradip Kumar Das, and Abhishek Dey*
   Inorg. Chem., **2019**, *58*, 10704−10715
   [https://doi.org/10.1021/acs.inorgchem.9b00656]

4. Mechanism of Reduction of Ferric Porphyrins by Sulfide:Identification of a Low Spin FeIII−SH Intermediate
   Kaustuv Mittra,[#] **Asmita Singha,[#]** and Abhishek Dey* [**# Both authors contributed equally.**]
   Inorg. Chem., **2017**, *56*, 3916−3925
   [https://doi.org/10.1021/acs.inorgchem.6b02878]

5. Hydrogen atom abstraction by synthetic heme ferric superoxide and hydroperoxide species
   Asmita Singha and Abhishek Dey*
   Chem. Commun., **2019**, 55, *5591-5594*

[https://doi.org/10.1039/C9CC01423C]

6. Effect of hydrogen bonding on innocent and noninnocent axial ligands bound to iron porphyrins
   Asmita Singha, Kaustuv Mittra and Abhishek Dey*
   Dalton Trans., **2019**, *48*, 7179-7186
   [https://doi.org/10.1039/C8DT03852J]

7. Nitrogen hybridization controls peroxo-oxo equilibrium in ethylenediamine bound binuclear [Cu_2O_2] complexes
   Asmita Singha, Atanu Rana, Abhishek Dey*
   Inorganica Chimica Acta, **2019**, *487*, 63-69
   [https://doi.org/10.1016/j.ica.2018.11.026]

8. Second sphere control of spin state: Differential tuning of axial ligand bonds in ferric porphyrin complexes by hydrogen bonding
   Kaustuv Mittra, Kushal Sengupta, **Asmita Singha**, Sabyasachi Bandyopadhyay, Sudipta Chatterjee, Atanu Rana, Subhra Samanta, Abhishek Dey*
   J. Inorg. Biochem., **2016**, *155*, 82–91
   [https://doi.org/10.1016/j.jinorgbio.2015.11.013]

9. Iron porphyrins with a hydrogen bonding cavity: effect of weak interactions on their electronic structure and reactivity
   Kaustuv Mittra , **Asmita Singha,** and Abhishek Dey *
   Dalton Trans., **2016**, *45*, 18796-18802
   [https://doi.org/10.1039/C6DT03597C]

10. Synthetic heme dioxygen adducts: electronic structure and reactivity
    Asmita Singha, Kaustuv Mittra and Abhishek Dey*
    Trends in Chemistry, **2022**, *4*, 15-31
    [https://doi.org/10.1016/j.trechm.2021.10.008]

11. Tailor made iron porphyrins for investigating axial ligand and distal environment contributions to electronic structure and reactivity
    Sk Amanullah, **Asmita Singha**, Abhishek Dey*
    Coord. Chem. Rev., **2019**, *386*, 183–208
    [https://doi.org/10.1016/j.ccr.2019.01.021]

12. Dey, A.; **Singha, A.** Bioinspired Electrocatalysis for the Oxygen Reduction Reaction. In *Encyclopedia of Interfacial Chemistry*; Wandelt, K., Ed.; Elsevier: Oxford, **2018**; pp 373-383

13. Interplay of Electronic Cooperativity and Exchange Coupling in Regulating the Reactivity of Diiron(IV)-oxo Complexes towards C−H and O−H Bond Activation
    Dr. Azaj Ansari, Mursaleem Ansari, **Asmita Singha**, Prof. Gopalan Rajaraman*
    Chem. Eur. J., **2017**, *23*, 10110 – 10125
    [https://doi.org/10.1002/chem.201701059]

14. Oxygen reduction reaction by metalloporphyrins
    Kaustuv Mittra, Subhra Samanta, **Asmita Singha**, Kushal Sengupta, Sudipta Chatterjee
    Oxygen Reduction Reaction: Fundamentals, Materials, and Applications, **2022**, pp. 45–77

Conference Attended:

1. 3rd International Conference on Proton Coupled Electron Transfer (PCET-2018) held from June 10-14, 2018 in Blowing Rock, North Carolina, US jointly organized by the University of North Carolina at Chapel Hill and Yale University.

2. 5th International Symposium on Advanced Biological Inorganic Chemistry (SABIC-2017) held during January 7-11, 2017 in Kolkata.

3. 6th International Symposium on Advanced Biological Inorganic Chemistry (SABIC-2017) held during January 7-11, 2024 in Kolkata.

4. 6th International Conference on Metal in Genetics, Chemical Biology and Therapeutics (ICMG-2016) held from February 17-20, 2016 in IISc Bangalore.