This problem set was created in February 2021 by Mayukh Bhadra (Massachusetts Institute of Technology, mbhadra@mit.edu), and posted on VIPEr on March 16, 2021, Copyright 2021. This work is licensed under the Creative Commons Attribution-NonCommercial-ShareAlike License. To view a copy of this license visit [https://creativecommons.org/licenses/by-nc-sa/4.0/](http://creativecommons.org/about/license/)

**Effect of Intramolecular Hydrogen Bonding on Cupric Superoxide Complexes**

In August 2020, Professor Kenneth D. Karlin from The Johns Hopkins University was awarded the *ACS Award for Distinguished Service in the Advancement of Inorganic Chemistry*, sponsored by Strem Chemicals. This award is given “to recognize individuals who advanced Inorganic chemistry by significant service in addition to performance of outstanding research.” In this assignment you will learn about his lab’s seminal work on understanding structural/electronic properties of primary Cu/O2 intermediates called cupric superoxides when you examine his recent paper “Intramolecular Hydrogen Bonding Enhances Stability and Reactivity of Mononuclear Cupric Superoxide Complexes” *J. Am. Chem. Soc.* **2018**, *140*, 9042−9045. You will apply a variety of inorganic concepts to understand what is so exciting about his work.

You will not have to read all sections of this paper in equal detail.  Be sure to refer to your textbook or other resources to answer any questions that arise as you read.  \* Indicates more challenging questions that will require additional reading and thought.

**Background**.

1. In the context of Cu-containing enzymes, can you rationalize the reason for our interest in understanding dioxygen reduction at copper? (Exercise: Read about the specific roles of the two ‘magnetically non-coupled’ CuH and CuM (CuB) sites in the functions of essential enzymes such as Peptidylglycine-a-hydroxylating monooxygenase (PHM), and Dopamine-b-Monooxygenase).
2. Summarize the sequential steps for the reduction of O2 to H2O involving protons and electrons. (Hint: Add H+ and/or e- in individual steps to break the O-O bond)
3. Revise the MO diagram of O2 to construct that of O2-and O22-. Calculate the Bond orders of the superoxide and peroxide anions and arrange O2, O2-and O22-in order of their relative bond lengths.
4. Pick one of the authors and try to find out what their current position is.  Using SciFinder Scholar, how many journal articles has that person published?

Read the **Introduction**.

1. In your own words, describe the purpose of this study.
2. What is meant by “primary” and “secondary” dioxygen-adducts of copper?

Examine **Figure 1**.

1. Read in brief about the spectroscopic technique used to semi-quantitate the trend in O-O stretch in the H-bonded cupric superoxide complexes. Why did the authors use 18O2 along with 16O2 for their experiments? \* [A good preliminary reading can be obtained at https://en.wikipedia.org/wiki/Resonance\_Raman\_spectroscopy]
2. What do you think might be causing the differences in the O-O stretches across the series **A-D?** (Hint: How are the O-O and N-H dipoles aligned, in terms of spatial directions?)

Examine **Figure 2**.

1. Look at Equations 1 and 2 at the Top of Page 1, above Figure 1. Write down the equilibrium constants in terms of the reactants and product concentrations.
2. From this equation, can you think what might happen to the magnitude of k-1 for superoxide complexes **A-D** (qualitatively)?
3. Explain what might be happening to the equilibrium constants as a function of H-bonding strength of the secondary sphere residues across the series **A-D** and the relative amounts of superoxide and peroxide in solution.

Examine **Table 1**.

* 1. Draw the Lewis structures and show the resonances of the azide moiety in the Cu(II)-N3- unit and explain the trend in IR stretches across series **A-D**.
  2. Read the Supporting Information (Page S23, Resonance Raman summary) and explain the trend in the Charge Transfer bands (~ 420 nm region) for the series **A-D** observed in UV-Vis spectroscopy for both the superoxide and azide complexes (the values are summarized in **Table 1**). \*

Examine **Figure 4**.

1. Write down the products of the low-temperature hydrogen atom abstraction (HAA) reaction between the copper superoxide and an hypothetical O-H or C-H bond. Can you come up with some experiments to detect the products of a (Hint: how do you detect a radical species in solution?) \*
2. What do you expect for the reactivity of **A-D** towards hydrogen atom abstraction reaction? (Hint: What effect does H-bonding have on the overall electron density on the end-on bound O2- moiety of the superoxide complexes across **A-D**?)
3. In simple words, explain the anomaly observed for the HAA (hydrogen atom abstraction) reaction between **C** and **D** when subjected to 2,6-di-tert-butyl-4-methoxyphenol.
4. What can you tell about the geometry around the copper center in the cupric hydroperoxide product from the EPR spectrum (See figure S45 on Page S56 in the Supporting Information)?  (Hint: Read the following text material: Pages 1231 and 1232 from <https://pubs.acs.org/doi/10.1021/ed083p1229> ) \*