Equilibrium Studies of the Iron Exchange Reaction of Ferrioxamine B with 8-hydroxyquinoline-5-sulfonate

Kelei Glover, Edwin G. Olmstead, Jr.
Chemistry Department, Fort Hays State University, Hays, KS, United States

Introduction

Iron is an essential nutrient for almost all forms of life, however most of the iron in the environment exists in insoluble forms. In order to acquire iron from the environment, many organisms will produce high affinity iron(II) chelators called siderophores. However, once the very stable iron-siderophore complex is formed, it becomes thermodynamically challenging for the iron to be released so that the organism can use it. In order to overcome this challenge, it has been proposed that some organisms may utilize competing ligands to assist in the release of iron through the formation of ternary complexes. These ternary complexes can enhance the release of iron by shifting the reduction potential of the iron complex and facilitating the reduction of iron by physiologically reducing agents.[1-3] After reduction the siderophore, which has a much lower binding affinity for iron(II) than iron(III), readily dissociates.

In this study, we will be investigating the ligand exchange reaction between a model siderophore, ferrioxamine B (FeDFB, B) and a model competing ligand, 8-hydroxyquinoline-5-sulfonate (HQS, H). Upon deprotonation, 8-hydroxyquinoline-5-sulfonate forms a stable iron(II) complex (FeQ5, III) via the aromatic N and hydroxyl O donor atoms. The 8-hydroxyquinoline-5-sulfonate ligand is also biologically relevant as the quinoline functional group is present in flavin mononucleotide, a physiological retardant which has been shown to be capable of reducing ferrioxamine B to iron(II) and in the siderophore quinolobacitrol.[5] In order to study this reaction and determine the stability constants of the products formed, we performed a series of spectrophotometric measurements in which the pH and HQS ligand concentrations were varied. We also determined the stability constants associated with the H+ + HQS and Fe3+ + HQS reactions in order to obtain values for these parameters under our experimental conditions. A generalized chemical equation and stability constant expression for the reactions we studied is shown below.

Experimental

Spectrophotometric and potentiometric measurements were collected for all reactions studied. Reaction mixtures were allowed to come to equilibrium at 25°C in a thermostated flask. A background electrolyte concentration of 0.1 M NaNO3 was added in order to maintain a constant ionic strength. Absorbance measurements were collected using a Shimadzu UV-1601PC spectrophotometer. The pH was monitored using a general purpose Accumet combination electrode with Ag/AgCl reference and an Oakton pH 1100 meter. The pH meter and electrode were calibrated using the GLOBE calibration method.[6] The potentiometric and spectrophotometric data was analyzed using pHAB 2003 software.[7]

Results

Figure 1 shows the absorbance of the species that are present under the conditions of the FeDFB + Q5 equilibrium reactions.

- Data in the 425-700 nm range is the useful range for ternary complex analysis.
- Under 425 nm, the absorbance is dominated by the QS ligand species.
- Absorbance in the 525-700 nm range is diagnostic for FeQ5 complexes.

Table 1 shows the stability constants determined in this work. β[Fe3+], K[H][HQS] and K[H] are determined from separate spectrophotometric titration experiments (not shown).

- β[Fe3+] for the formation of FeDFB(HQs)(H) was determined using conditions of 1.26–4.92 mM QS ligand and pH 4.5–8.0 assuming FeDFB and FeQ5 were also present. For conditions outside this range, an other light absorbing complex, presumably FeDFB(Q5)(H), was present and caused poor fitting results.
- Addition of the FeDFB(Q5)(H) to the model resulted in ill-defined and unstable β[Fe3+] and molar absorptivity parameters. In order to determine β[H][HQS], additional experiments would need to be performed under conditions where this complex is present in greater quantities.
- Based upon previous ternary complex studies, the protons in the ternary complex are added to the deprotonated B ligand to give FeDFB(Q5).QS.

Figure 4 shows a comparison of the fraction of FeDFB converted into ternary complex for the QS ligand and previously reported ternary complexes. FeDFB(Q5)(H) clearly has much greater stability than the other ternary complexes at neutral pH values.

Conclusions

8-hydroxyquinoline-5-sulfonate (QS) forms a ternary complex with ferrioxamine B (FeDFB) with the stoichiometry of FeDFB(Q5)(QS).

At pH 6.0–8.0, the Fe(HQ5)(Q5)(QS) ternary complex is more stable than any of the previous ferrioxamine B ternary complexes reported.

References