Project 2: Identification and Measurement of Metal Complexes in Solutions for Alternative Energy Development

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Project Summary

Over the last twenty five years, solar panel efficiency has increased from about 14% for crystalline Si cells from RCA to about 44% for multi-junction cells from Scitec. [1]. A lingering problem that limits the economic viability of solar energy is the need to store vast amounts of energy whenever supply exceeds demand so as to balance the energy needs when the sun is not shining. Electrochemical energy conversion (EEC) has the potential meet this need through the use of redox flow battery (RFB) technology that provides volume liquid chemical energy storage [2,3]. However, a key challenge to the implementation of this technology is the low conversion efficiency of existing electrodes. Bi has recently been found to be a promising electro catalyst for the all-vanadium RFB system [2]. The primary goal or *challenge* of this project is to investigate methods to identify and quantify the concentrations of various metal complexes in solution that are essential to optimize the preparation of Bi-based electrodes and monitor their performance. The project will increase the awareness of teachers as regards the numerous job opportunities available in the area of large-scale chemical process control in general and that of ECC processes in particular.

This research will answer the question: Can UV-Vis spectroscopy be used as a means of identifying and quantifying bismuth complexes used in the preparation of electrodes for RFB energy

storage? As shown in **Figure 1 (a)**, Bi can form complexes with a variety of organic ligands to yield intense colors that may be used to monitor concentrations in-situ [4]. The fiber optic-based UV-vis apparatus shown in **Figure 1(b**) will be used to continuously monitor the influence of pH and electrode potential on the formation and reduction of such complexes. Auto-reduction of bismuth in the absence of applied potential is also of interest for electrode preparation. Consequently, the formation of organometallic complexes between Bi and a reducing metal such a Sn will be examined. For example, our laboratory has recently developed a sustainable method to synthesize Bi nanoparticles of well-controlled sizes using Sn [5]. Literature data in this area is lacking and is of broad scientific interest. Teachers will become knowledgeable of key project concepts through hands-on preparation of organometallic complex solutions to be investigated as well as in the operation of a UV-Vis spectrophotometer, a smaller version of which is anticipated to be used by the teachers in their classroom. A field-trip is planned to Mound Technical Solutions in Miamisburg, Ohio. This local company provides outstanding analytical instruments in the area of energy generation and storage.

Possible Ideas for Classroom Implementation

The concepts of color hue and intensity can be readily transmitted to high school students in science through the use of inexpensive spectrophotometers and pH-sensitive dyes. Students in math can examine the proportionality between light intensity and dye concentration and explore linear fitting to the Beer-Lambert Law. Use of white vinegar and city water allows the students to examine how acidity versus alkalinity can change the color of a dye and how this is related to the color that is observed (i.e., that the color observed is opposite the color absorbed). Teachers that pursue this project will gain confidence to explore various engineering design projects. For example, students may be asked to quantify the amount and type of dye required to replicate a “customer sample” of a particular color and intensity. The faculty mentor will encourage periodic visits of teachers and their students to his research laboratory so that they may observe and discuss more complex research and applications related to these concepts than can be covered in the classroom.

References

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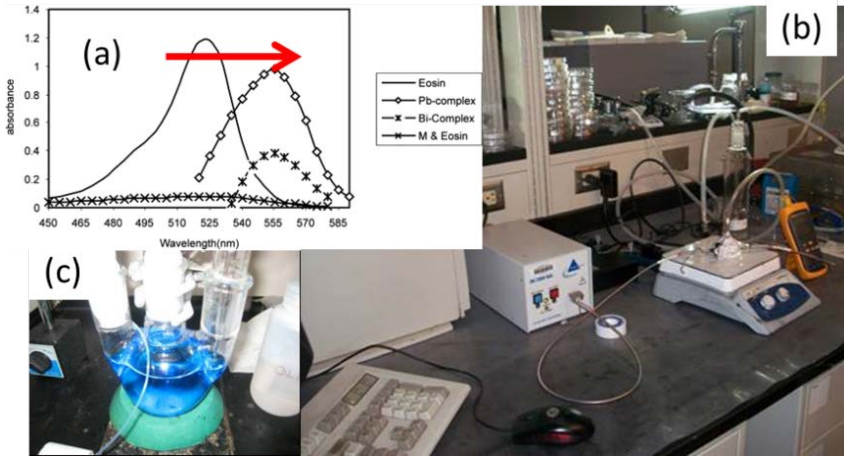

Figure 1: (a) Light absorption spectra with red arrow depicting the transition from a yellow to pink solution due to the formation of an organometallic complex with either Bi or Pb [4]. (b) Fiber optic-based UV-Vis system. (c) Reduced vanadium (IV) solution at the positive electrode