**Learning Goals**

**Students should be able to:**

•Define redox flow batteries

•Outline the design features of a redox flow battery

•Compare and contrast a redox flow battery to traditional battery

•Apply concepts of green chemistry principles to article

•Summarize the key findings in the paper on studying an energy carrier for redox flow batteries

**Polyoxovanadate-alkoxide clusters as multi-electron charge carries for symmetric non-aqueous redox flow batteries**

VanGelder, L. E.; Kosswattaarachchi, A. M.; Forrestel, P. L.; Cook, T. R.; Matson, E. M. *Chem. Sci.* **2018**, *9*, 1692.

Read the article written by Dr. Ellen Matson and coworkers. *Chem. Sci.* **2018**, *9*, 1692. You may need to use outside resources to answer these questions. Please cite those resources near the answer to the question.

1. What is a redox flow battery?
2. What are the key components of a redox flow battery? Include the components that comprise the electrolytes. You should use outside resources to answer this question.
3. Is a redox flow battery a primary or secondary battery? Provide a reason.
4. Name two advantages and two disadvantages of flow batteries.
5. Name two applications that use a flow battery. Be sure to cite the source of your research.
6. What is the main difference between conventional batteries and flow batteries?
7. What was recognized by the Nobel Prize in chemistry in 2019? Describe the invention in a few sentences highlighting the advances of Whittingham, Goodenough and Yoshino.
8. Small molecules can be used as charge carriers in redox flow batteries. One example is the metal(acac) compound seen below. The V(acac)3 species was used as a reference to compare the use of a single molecule charge carrier and multi-metallic charge carrier. Using your notes from the first half of the semester determine the Electron Number (EN), Valence Number (VN), Ligand Bond Number (LBN), dn configuration and the oxidation state of V.



1. What is the difference between aqueous and non-aqueous redox flow batteries?
2. What is a polyoxometalate (POM)? Why is it advantageous to use them in redox flow batteries?
3. What are the key features desired for a good charge carrier in non-aqueous flow battery applications?
4. Draw out the features of the redox flow cell that would possibly be formed using the best electron carrier discovered and reported in this paper. (Don’t worry about drawing the ions formed and passing through the membrane)
5. Large scale energy storage and vehicles may one day be powered using redox flow batteries. What is the difference between hybrid and all electric vehicles?
6. Figure 2 from the paper is presented below. It is a voltammogram, obtained from cyclic voltammetry (CV) showing the results of adding potential to a solution of the **p**oly**o**xyo**v**anadate-alkoxide cluster (POV). The top trace represents the electrochemical behavior for the POV-methoxide while the blue trace is for the POV-ethoxide cluster. The arrow direction shows the application of the potential. How many electron transfers are observed for the POV clusters? Are they reversible? How do you know that?

See figure 2 from the paper

1. What experiments were conducted to assess the stability (chemical and electrochemical) of the POV-alkoxide clusters? HINT: There are two sets of different experiments done. What were the outcomes of these experiments for the POV-methoxide and POV-ethoxide clusters?
2. Describe how the authors concluded that the V6O7(OMe)12 cluster was unstable.
3. Given the V6O7(OMe)12 cluster was unstable the authors proposed a hypothesis. What was it?
4. Summarize in your own words the main 3 findings described in this paper.
5. Write and answer two unique questions that cover the material covered in the crossover and membrane fouling section of the paper.
6. Identify 3 different green chemistry concepts from this work and the green chemistry principles by number and name that are adhered herein.
7. What is sustainability and how do flow batteries the goals of sustainability? What aspects to the UN sustainable development goals do flow batteries address?