Accumulator Analysis: A Comparison of Storage Capacity and Long Term Consistency Between Lithium and Sodium Anodes within Tungsten Vanadium/Niobium Batteries

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Introduction:

In a rapidly changing world, finding new sources of energy is among the highest priorities of modern societies. We believe that retrieving efficient energy sources is greatly important. However, equal emphasis should be placed on its storage and usage. One of the primary factors influencing and driving the global energy crisis we face today is the limited capability and long-term inconsistency of batteries. In our experiment, we aimed to measure the long-term consistency of lithium ion batteries in order to better our understanding of their long term feasibility and analyze their role in our future.

Abstract:

The purpose of this experiment was to critically analyze the charging capacity, speed, and reliability of lithium ion Vanadium and Niobium batteries after several hundred charges. Furthermore, comparing "fast-charging" to normal charging was examined. We studied this by using Extended X-ray absorption fine structure (EXAFS).

- Our research confirmed the difficulty Niobium has with discharging electrons when compared to Vanadium

1. Niobium Lithium/Sodium Cycling Comparison:

As shown in Graph 1, data was taken from the Niobium metal, uncycled anode and 1st lithiation/delithiation, and 1st sodiation and desodiation. We can derive two conclusions from the graph:

1. The Sodiation of the Niobium Metal is failing to properly react. And the edge does not noticeably change from the cycling.

2. The 1st lithiation does not show a noticeable shift towards lower energy levels, and the delithiation does not return the state of the niobium to the uncycled value.

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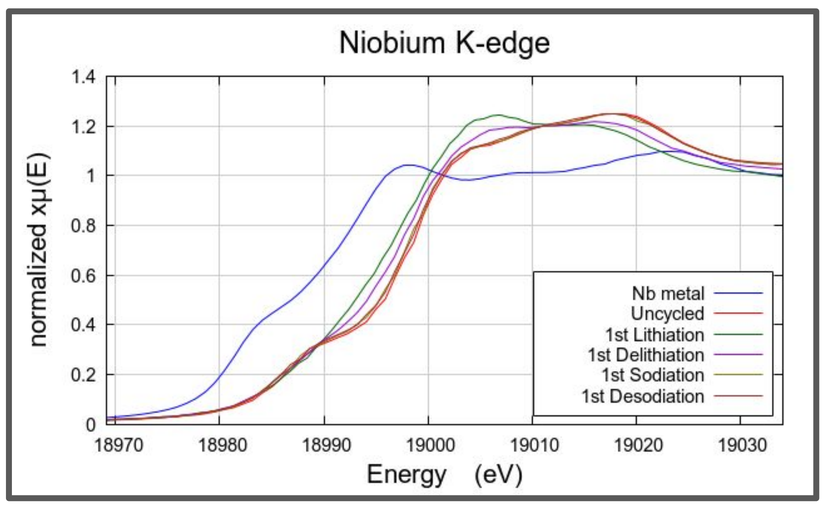

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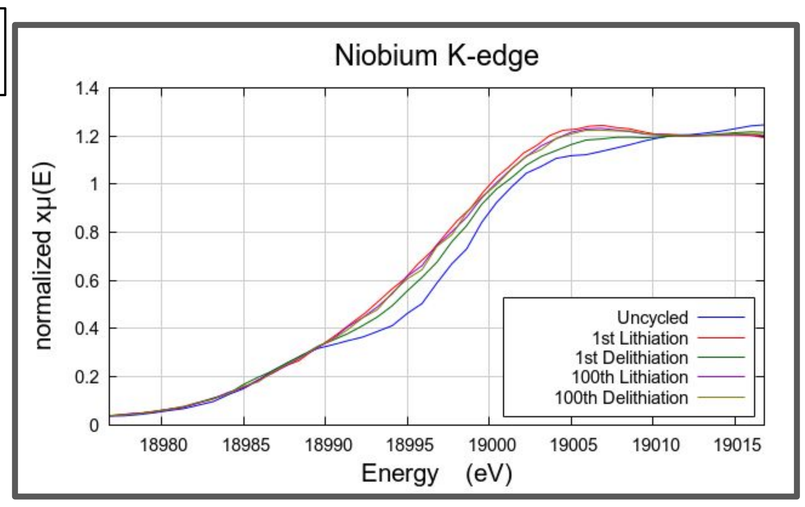

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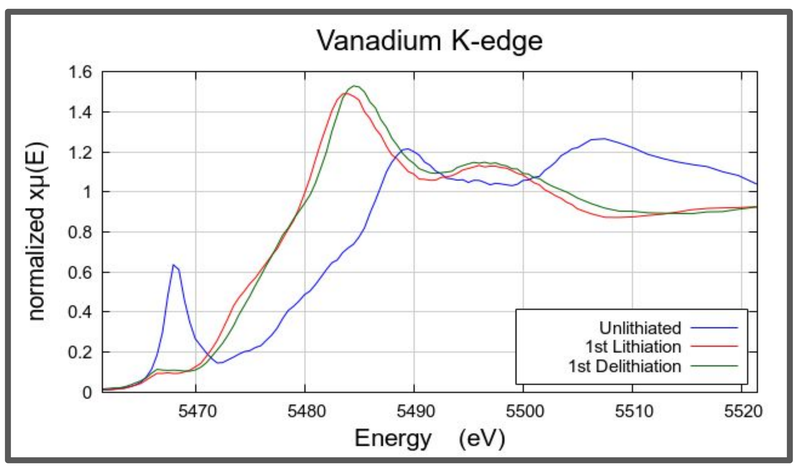

2. Niobium and Vanadium Cycling Comparison:

Graph 2 showcases the 1st and 100th cycles of lithiation and delithiation for Vanadium.

1. The 1st lithiation does not show a noticeable shift towards lower energy levels, and the delithiation does not return the state of the niobium to the uncycled value.
2. Furthermore, by the 100th cycle the Niobium fails to undergoing anymore noticeable oxidation and reduction
   a. This is likely because the capacity of the anode is close to zero by this point
3. We can conclude through this graph that Sodium performed poorly compared to its Lithium counterpart

Graph 3 showcases the 1st cycle of vanadium's lithiation and delithiation. Already the differences are evident.

1. Unlike Niobium, Vanadium demonstrates very clear and noticeable peaks within its first cycles.
   a. The most predominant being at around 5485 eV

2. The ending behavior is also something to note. Notice the large shift to lower a oxidation state of the vanadium that seems to be nonreversible upon delithiation.
   a. This implies the existence of a large irreversible capacity in the first lithiation cycle. Making vanadium a weak long term option.

3. Conclusion:

- We found the Sodium samples to be noticeably worse than their Lithium alternatives.
- The Niobium samples remained relatively consistent from cycle to cycle, and serves as a consistent, long term material for comparison.
  - The process of the Niobium experiencing lithiation and delithiation did not affect the long term capacity as much.
- As shown in Graph 3, because the Vanadium edge is a "K-Edge"/S-Orbital compound, we can see the D-State electrons are highly localized for a brief period of time only to "delocalize" after.
  - Moreover, the Vanadium seems to be composed in a "non-octahedral" formation and becomes more octahedral as cycles and electrons pass.

4. Possible Next Steps:

Although our research showcased a considerable difference between Sodium and Lithium, we would like to further study Sodium and see if it has any other practical or feasible applications with regards to energy management. Additionally, we believe studying the battery performance given temperature changes (both externally and internally) would be crucial in order to conclude our research.

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Cho, A. Science, 2010, 329, 786-7; Lewis, N.; Nocera, D. Proc. Nat. Acad. Sci. USA. 2006, 103, 15729-35; Utschig, L. et. al. J. Phys. Chem. Lett. 2011, 2, 236-41; Utschig, L. et. al. J. Am. Chem. Soc. 2011, 133, 16334-7; Silver, S. et. al. J. Am. Chem. Soc. 2013, 135, 13246-9

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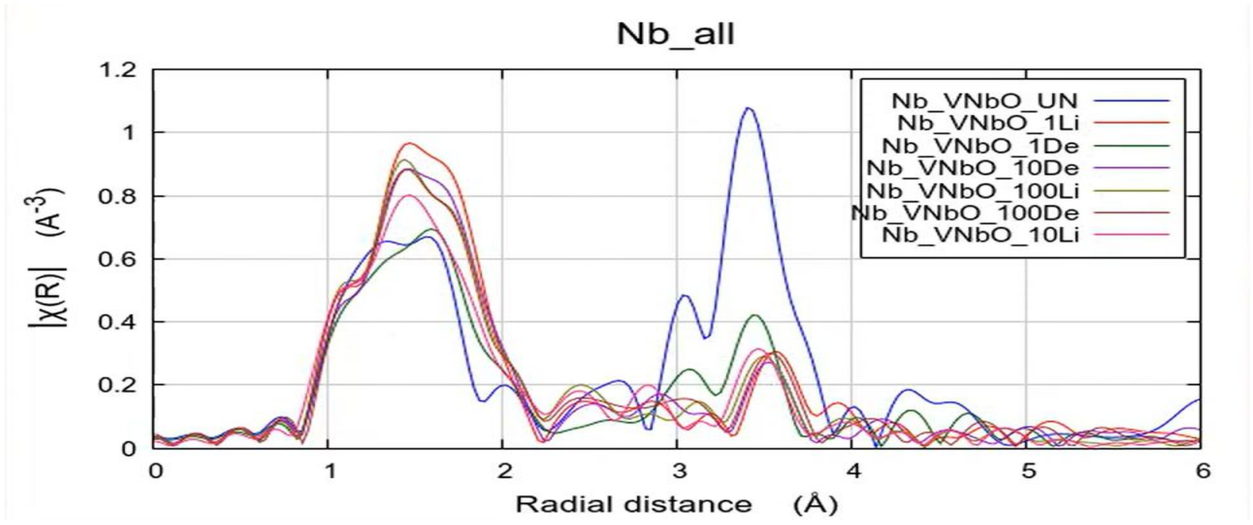

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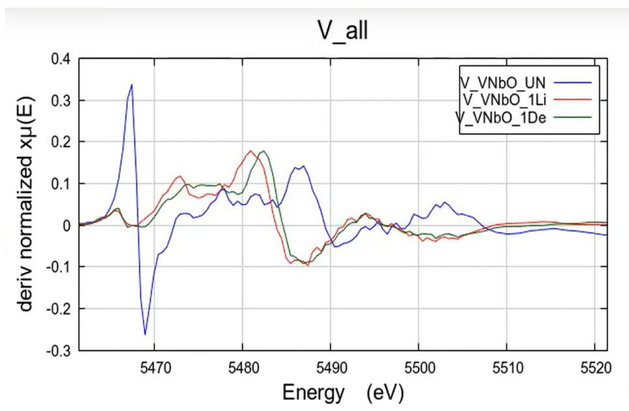

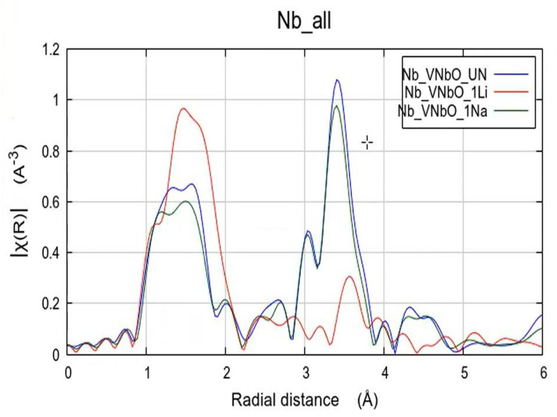

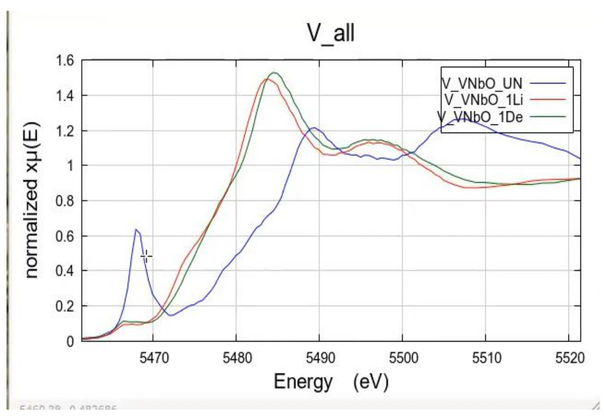

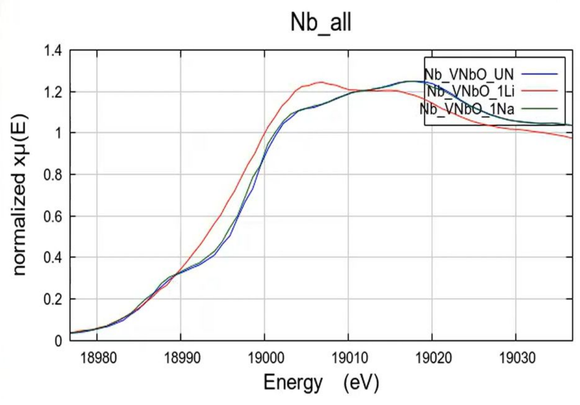

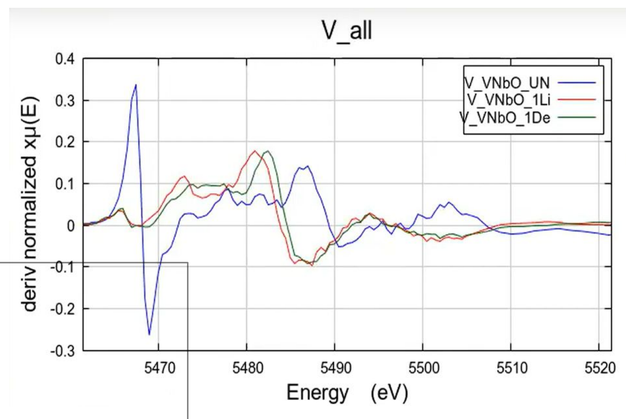

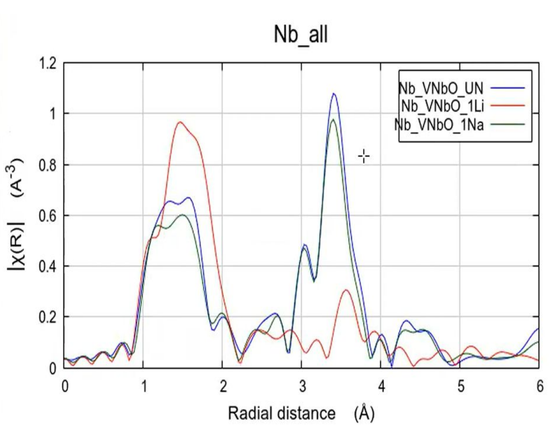

Future Direction:

- Test the anode short and long term capabilities given a dramatic change in temperature
- Find feasible ways to use the lithium-vanadium batteries even with a supposed unideal quality
- Further research on how the sodium samples were significantly more limited in terms of electron movement capability