Energy Storage Density in the All-Aqueous Copper Thermally-Regenerative Ammonia Battery

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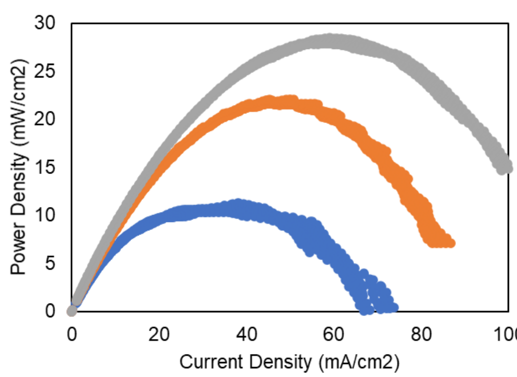
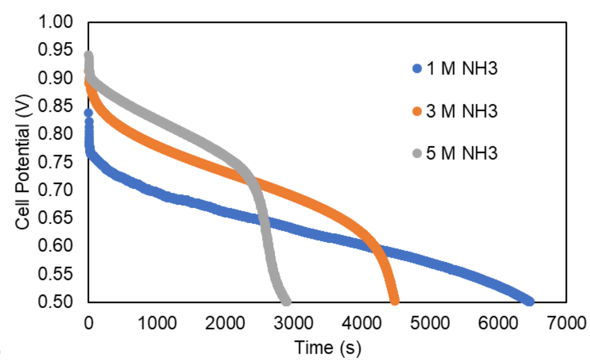
There is a significant amount of low-grade waste heat (<130 °C) available at sources such as thermal power plants and factories that is dissipated into the environment because the amount of energy stored in the fluid is too low to be captured by traditional heat engines. As a result, many researchers are investigating electrochemical methods to use the low-grade waste heat, including thermally-regenerative ammonia batteries (TRABs). TRABs are a technology that were invented at Penn State University as a method to capture this abundant energy source as a method to produce power and store energy using abundant transition metals. The system is designed with two unit operations: a flow battery to produce power, and a distillation column to regenerate the electrolytes and recharge the battery back to 100%. The all-aqueous copper TRAB (Cu_{aq}-TRAB) uses weak and strong field ligands to stabilize both Cu(I) and Cu(II) oxidation states in water, and these two oxidation states are what undergo redox reactions during the discharge of the battery. In this work, the maximum theoretical energy density of this chemistry is determined to be 12 Wh L^{-1} through theoretical equilibrium calculations and experimental solubility limits. It was found that while increasing the ammonia concentration roughly doubles the power density, the energy density decreases by 90% due to parasitic crossover of ammonia through the membrane. Increasing copper concentration is shown to have little effect on the power density and increases experimental energy density relative to the theoretical energy density due to more complexing of the copper with ammonia resulting in less free ammonia in the anolyte.



a)



b)

Figure 1: a) Power curves for increasing NH_3 concentration. b) Discharge curves for increasing NH_3 concentration