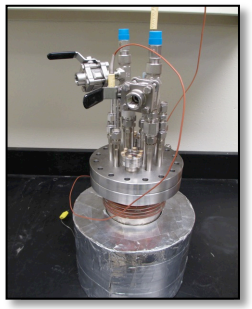

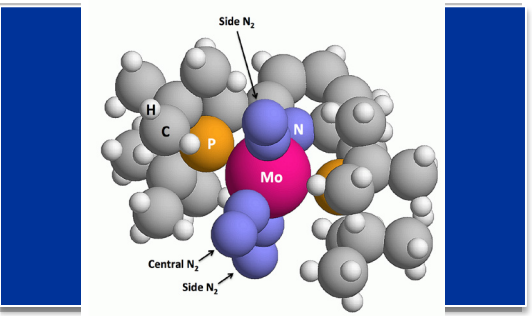

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Nitrogen/Oxygen Battery

A Transformational Architecture for Large Scale Energy Storage

US DOE Energy Storage Systems Research Program
Peer Review, Washington, DC Sept. 26-28, 2012

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N_2/O_2 Battery Project Overview

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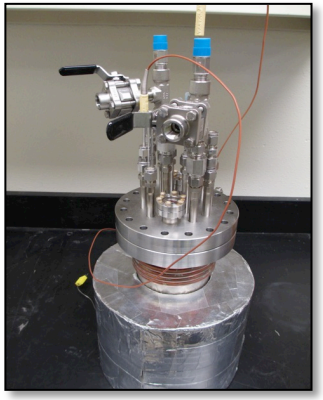
- Air/Air battery.
- N_2 electrochemistry enables the redefinition of a gas (diffusion) electrode and the three phase interface.
- Operated as redox flow battery.
- Provide a very high energy density, very low cost, environmentally benign electrochemical platform for load leveling and for grid-integrated storage of energy generated by wind, solar and other sustainable but intermittent sources.
- Project requires a reversible N_2 electrode.

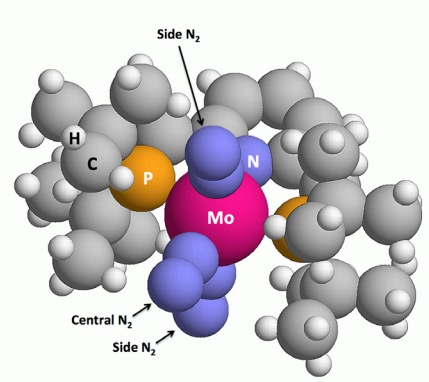
Anode requires the reversible electrochemical reduction/oxidation of N_2.

Three approaches to achieve N_2 reduction (nitrogen fixation).

1) Direct reversible reduction/oxidation of N_2 to $2N^{-3}$ in molten salt at + 400°C.



2) Mediated and catalyzed reduction of N_2 to NH_3 and subsequent utilization of the NH_3 as the anode in an NH_3/air fuel cell.



3) Indirect reversible reduction/oxidation of N_2 to $2N^{-3}$ at ambient temperature.

Indirect Reduction of N_2 at Ambient Temperature.

At ambient temperature N_2 is not directly reduced on any electrode in any electrolyte.

Some researchers have achieved Li mediated reduction of N_2 by the exposure of N_2 to electrodeposited Li metal.

$$Li^+ + e^- \rightarrow \underline{Li}$$

$$3\underline{Li} + 1/2N_2 \rightarrow Li_3N \qquad \text{electrode passivates}$$

$$Li_3N + 3EtOH \rightarrow NH_3 + 3LiOEt \qquad \text{low efficiency}$$

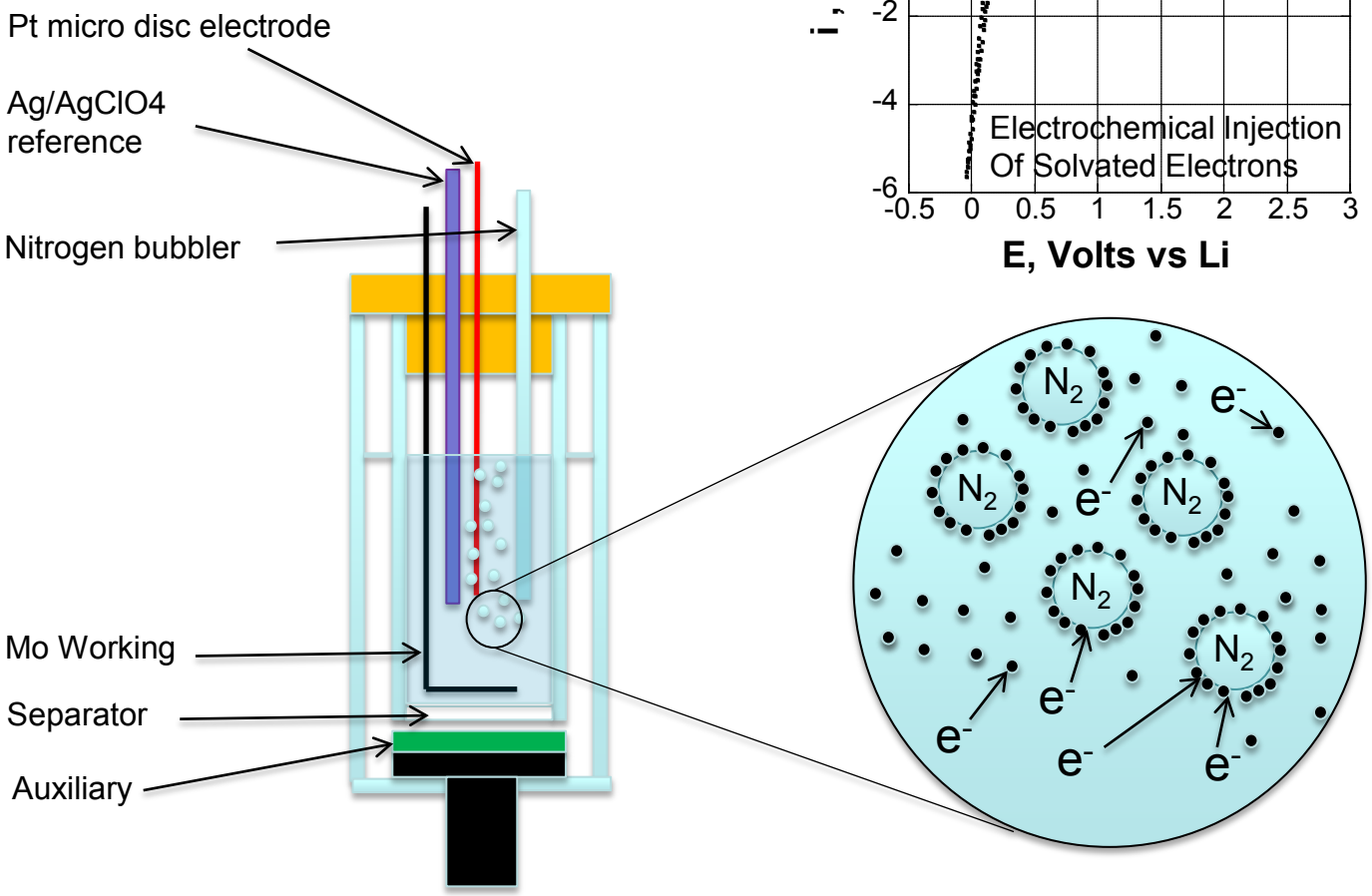
Our approach: Reduce N_2 in a solution of solvated electrons [e_s^-].

$$N_2 + 6e_s^- \xrightarrow{Li^+} 2Li_3N$$

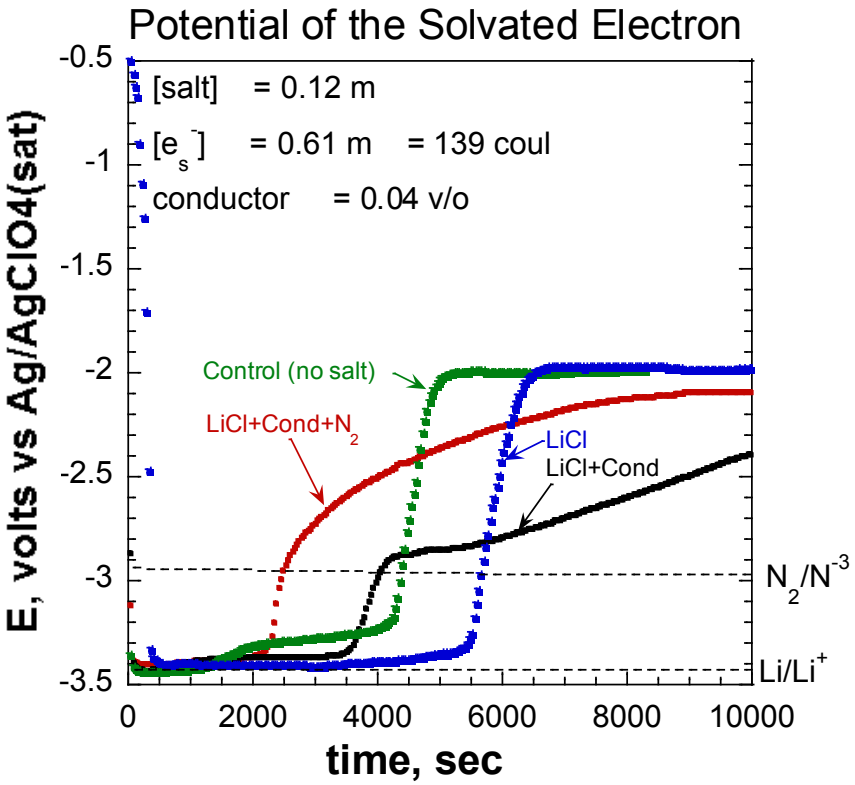
Reduction does not occur at the electrode surface.
Advantage: Gas diffusion electrode not required.

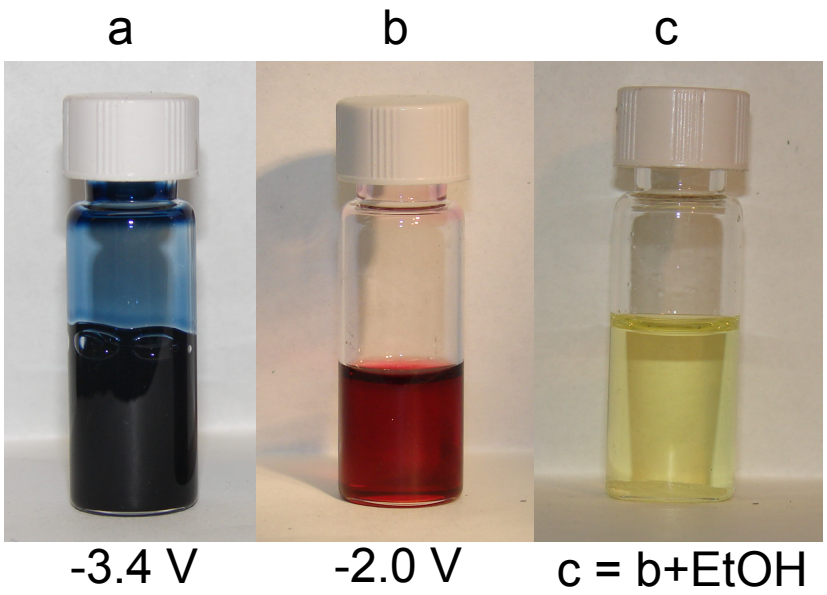
Indirect Reduction of N_2.

Concept Illustration



Stabilization of the Solvated Electron [e_s^-] at High Negative Potential Enables the Reduction of N_2





Summary/Conclusions

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1) Demonstrated reversible redox for N_2/N^{-3} in LiCl-KCl at 450 C

   Developed procedure for large scale purification of LiCl-KCl eutectic.

2) Density Functional Theory (DFT) has been used to analyze the path to NH_3 synthesis on the Arashiba *et. al.* catalyst.

   Paper submitted for publication (Peter Feibelman, J. Phys. Chem.).

3) Developed an electrolyte which stabilizes solvated electrons for the subsequent indirect reduction of N_2.

Future Tasks

- Couple N_2/N^{-3} and O_2/O_2^- reactions in LiCl-KCl electrolytes to produce N_2/O_2 battery prototypes.
- Continue stabilization of solvated electrons at high negative. potential and introduce catalysts to enhance N_2 reduction.
- Identify procedures for chemical analysis of N_2 reduction products.
- Identify appropriate cation to enable the oxidation of N^{-3}.

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Dr. Travis Anderson Advanced Power Sources Dept., SNL
Harry Pratt Advanced Power Sources Dept., SNL

Discussions on electrochemical stability of electrolytes and solvated electrons.
Dr. Chengdu Liang ORNL
Dr. Sheng Dai ORNL
Dr. Loic Baggetto ORNL