Characterizing Monovalent Cation Hydration Effects on Water Uptake of Ion Exchange Membranes

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Background

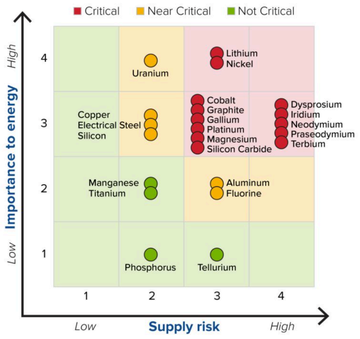


Figure 1: Supply risk vs. importance to energy of critical minerals.

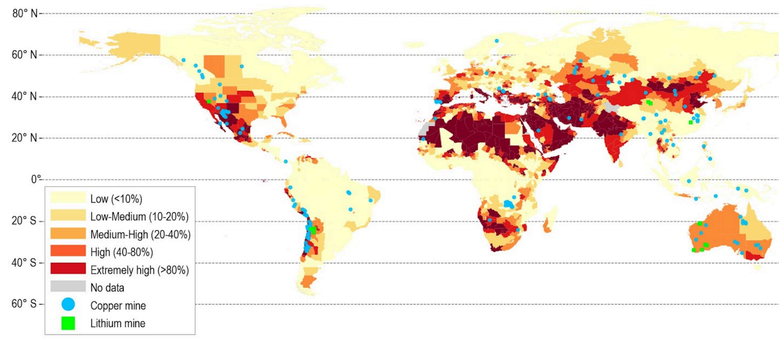


Figure 2: Global map of risk to drought events and prevalence of copper and lithium mines.

- **Clean energy technologies are highly mineral-intensive.**
- **Lithium demand is growing fastest among critical minerals but faces high supply risk (Fig. 1).**
- **Risk to drought events in major lithium-producing regions, combined with water-intensive processing, highlights the need for sustainable water sourcing (Fig 2).**

Introduction

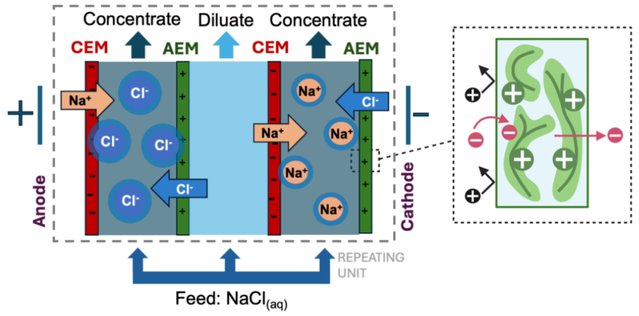


Figure 3: Schematic diagram of electrodialysis. Ion transport begins with sorption into the membrane, then subsequent transport through.

- **Ion exchange membranes (IEMs) and electrodialysis (ED) are used in various water, energy, and environmental applications.**
- **Membranes can be engineered for selective ion transport, enabling resource recovery.**

Problem Statement

Models describing ion exchange membranes do not distinguish between monovalent ions, although experiments demonstratediffering selectivity.

Hypothesis

Li^+, Na^+, and K^+ have drastically different hydration energies, which could influence ion selectivity when entering the membrane.

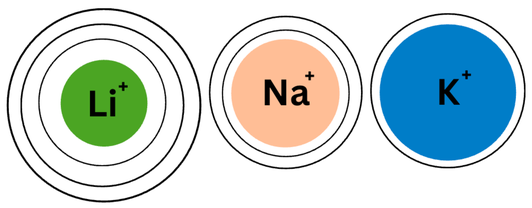
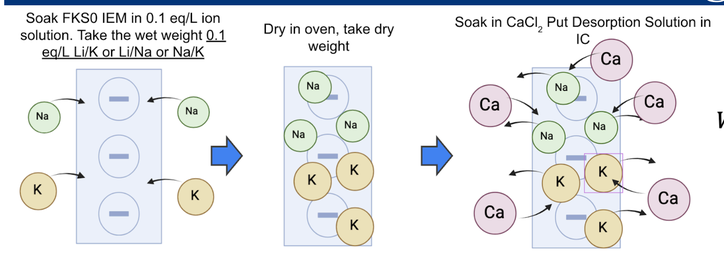


Figure 4: Hydration energies of Li, Na, and K.

Research Question

Do monovalent ions exhibit different hydrations within the membrane as they do in bulk solutions, and how does this variance affect selectivity?

Methodology



$$Water\ Uptake\ (WU, \%) = \frac{m_{wet} - m_{dry}}{m_{dry}} \times 100\%$$

m_{wet}: mass of polymer, counterions, and water
m_{dry}: mass of polymer and counterions

3 Combinations of Ions: Li only, Na only, K only, Li/K, Li/Na, Na/K
5 different ratios for each combination of concentrations: 1:1, 3:1, 1:3, 9:1, 1:9

Figure 5: Schematic of water uptake procedure demonstrating the sorption and desorption process.

- **A methodology was developed in which membranes were soaked, dried, and desorbed via soaking in $CaCl_2$ (Fig. 5).**
- **The first step accounts for m_{wet} value, the second step accounts for m_{dry} value, and final step accounts for Ion Exchange Capacity.**

IEC of the membrane (meq/g membrane):

$$IEC = \frac{10\times10^{-3}\times c_d \times V_d}{m_{dry}}$$

C_d: concentration (mmol/L)
V_d: desorption solution volume (mL)

Results

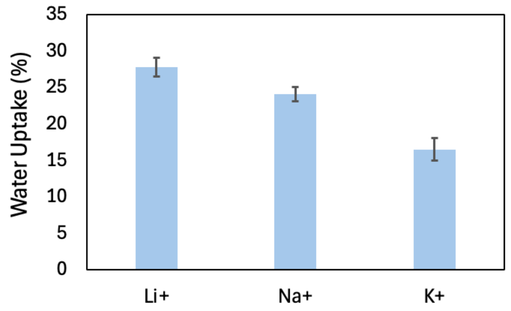


Figure 6: Water Uptake % of Li+, Na+, and K+.

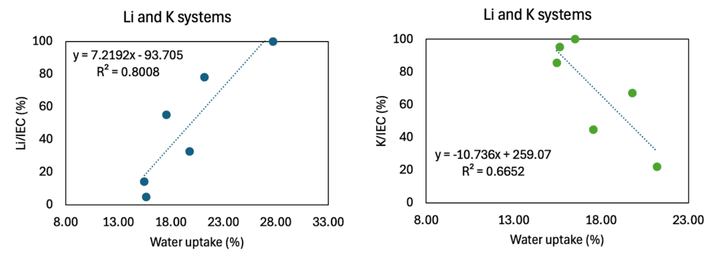


Figure 7: IEC variations in Li/K systems.

- **The water uptake of the membrane (i.e., water content) differs based on the type of ion within single salt systems, following the same trend as hydration energy.**
- **Li^+ presence strongly correlates with water uptake of membranes in binary systems.**

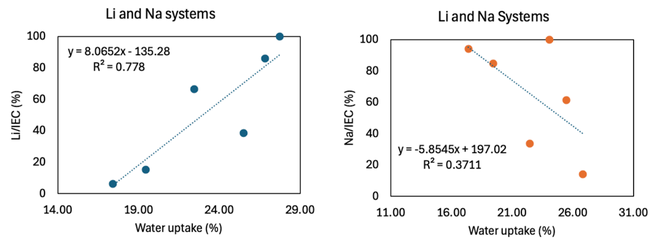


Figure 8: IEC variations in Li/Na systems.

Discussions

There is a correlation between hydration energy and sorption selectivity that influences water uptake into the membrane.

Future Work

Determine the quantity of water that is brought into the membrane with each type of ion, utilizing water uptake and sorption data from mixed salt systems.

References

IEA (2021), The Role of Critical Minerals in Clean Energy Transitions, IEA, Paris https://www.iea.org/reports/the-role-of-critical-minerals-in-clean-energy-transitions, Licence: CC BY 4.0