

Ph.D. Candidate

Fahad Alkhayri

Graduate Academic Unit

Chemistry

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**July 6, 2021**

**2:00 p.m. (Atlantic)**

**Virtual Defence**

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Examining Board:

Dr. John J. Neville (Chemistry)

Dr. Anna Ignaszak (Chemistry)

Dr. Allison Enright (Earth Sciences)

Dr. C. Adam Dyker (Chemistry) Supervisor

External Examiner: Dr. David E. Herbert
Department of Chemistry
University of Manitoba

The Oral Examination will be chaired by:

Dr. Kevin Englehart, Associate Dean of Graduate Studies

BIOGRAPHY

Universities attended (with dates & degrees obtained):

2015 – present Ph.D. candidate, University of New Brunswick
2013 MSc in Chemistry, University of New Brunswick
2008 Bachelor of Chemistry, Umm Al Qura University

Publications:

A Two-Electron Bispyridinylidene Anolyte for Non-Aqueous Organic Redox Flow Batteries, **F. Alkhayri** and C. A. Dyker, *J. Electrochem. Soc.*, 167, 160548 (2020).
Evaluation of Two-electron Bispyridinylidene Anolytes and a TEMPO Catholyte for Non-Aqueous Redox Flow Batteries, **F. Alkhayri** and C. A. Dyker, *J. Electrochem. Soc.*, Manuscript ID JES-103888, Submitted February 25, 2021.
A Parallel-plate RF Probe and Battery Cartridge for 7Li ion Battery Studies, A. R. Aguilera, B. MacMillan, S. Krachkovskiy, K. J. Sanders, **F. Alkhayri**, C. A. Dyker, G. R. Goward, and B. J. Balcom, *J. Magn. Reson.*, 325, 106943 (2021).

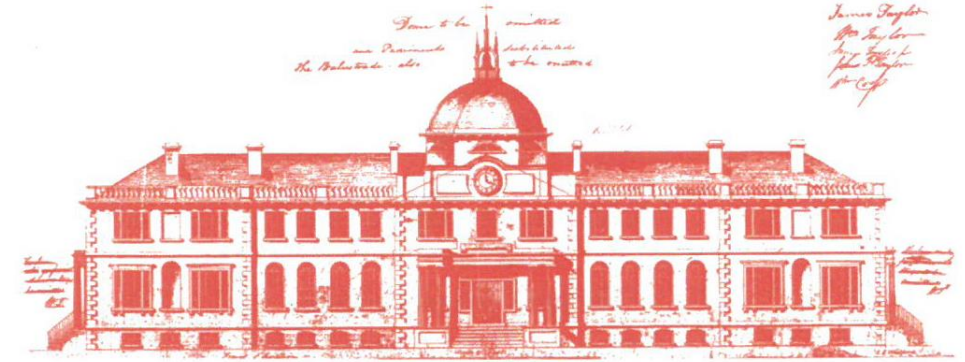
Conference Presentations:

‘Organic Redox Flow Batteries’, (Oral presentation), **F. Alkhayri** and C. A. Dyker, Atlantic Inorganic Discussion Weekend (AIDW), Moncton, March 21-23, 2013.
‘Toward An All-Organic Redox Flow Battery Based on TEMPO and a Bispyridinylidene’, (Oral presentation), **F. Alkhayri** and C. A. Dyker, 2017 100th Canadian Chemistry Conference (CSC), Toronto, May 28 – June 1, 2017.
‘An Organic Anode Enabling High Concentration and Cell Potential of An All-Organic Redox Flow Battery’, (Poster), **F. Alkhayri** and C. A. Dyker, 2018 Canadian Association of Physicists Congress (CAP), Halifax, Dalhousie University, June 10-16, 2018.
‘Strategies in Electrolyte Design for Organic Redox Flow Batteries’, (Oral presentation), G. Charlton, **F. Alkhayri**, S. Barbon, J. B. Gilroy, and C. A. Dyker, in Spring 2019 ACS National Meeting, Orlando, FL, March, 2019.
‘Bispyridinylidenes: Tunable Anolytes for Organic Redox Flow Batteries’, (Oral presentation), **F. Alkhayri** and C. A. Dyker, in 236th ECS Meeting, Atlanta, GA, October, 2019.

Investigation of Low-Potential Organic Bispyridinylidene-Based Anolytes with Simultaneous Two-Electron Utilization for Non-Aqueous Flow Battery Applications

Abstract

Redox flow batteries (RFBs) have attracted a lot of attention recently as promising systems for energy storage from intermittent renewable resources and to allow integration with the power grid. Most RFBs are based on metallic active species in aqueous media, however there is a growing interest around the use of soluble organic redox couples in non-aqueous solvents to achieve higher energy density. Organic compounds with high redox potentials (catholyte) are available, but new organic compounds with low redox potentials (anolyte) that undergo multi-electron reduction at the same redox potential are needed to boost the energy density of RFBs. This thesis will outline efforts to develop a new bispyridinylidene (BPY)-based anolyte that undergoes a reversible two-electron oxidation (-1.69 V vs. ferrocene), and assess its applicability in a RFB. In a dimethylformamide (DMF)-based electrolyte, both bridged bispyridinylidene (bBPY) charge states (0/2+) exhibited complete compatibility, long lifetime, and excellent solubility (1.18 M, corresponding to a high theoretical capacity of 63 Ah L⁻¹ and energy density of 61 Wh L⁻¹) in DMF. Symmetric cell testing of bBPY achieved capacities of up to 100% of the theoretical value and coulombic efficiencies above 98%, though cell lifetimes with cycling were less than those of the individual bBPY redox partners alone in the electrolyte. This work was also extended to design the first full cell studies using BPYs as anolytes vs. 2,2,6,6-tetramethyl-1-piperidinyloxy (TEMPO) catholyte. The cells delivered a cell voltage of ~1.9 V. However, in comparing two different BPYs, one featuring a propylene bridge between the pyridyl rings (bBPY) and another featuring two N-propyl groups (prBPY), it was found that the bridge led to improved stability of the BPY. Furthermore, the instability of oxidized TEMPO⁺ in the supporting electrolyte as well as parasitic side reactions caused by cross-contaminations of active materials through the ion exchange membrane are believed to be the main cause for the cell's rapid capacity loss. Further studies will be required to understand the capacity decay over cycling. ferroan dolomite, indicate anoxic phreatic conditions during shallow burial. The deep burial mesodiagenetic realm reflects only minor alterations including dickite and illitization of kaolinite.



Home of the School of Graduate Studies, Sir Howard Douglas Hall was designed by J.E. Woolford in 1825 and is the oldest university building in Canada still in use.

The University of New Brunswick recognizes that the university sits on traditional Wolastoqey territory. The river that runs right by our university – the St. John River – is also known as Wolastoq, along which live the Wolastoqiyik -- the people of the beautiful and bountiful river.

UNIVERSITY OF NEW BRUNSWICK SCHOOL OF GRADUATE STUDIES

ORAL EXAMINATION

Fahad Alkhayri

IN PARTIAL FULFILMENT
OF THE REQUIREMENTS FOR THE DEGREE OF

DOCTOR OF PHILOSOPHY