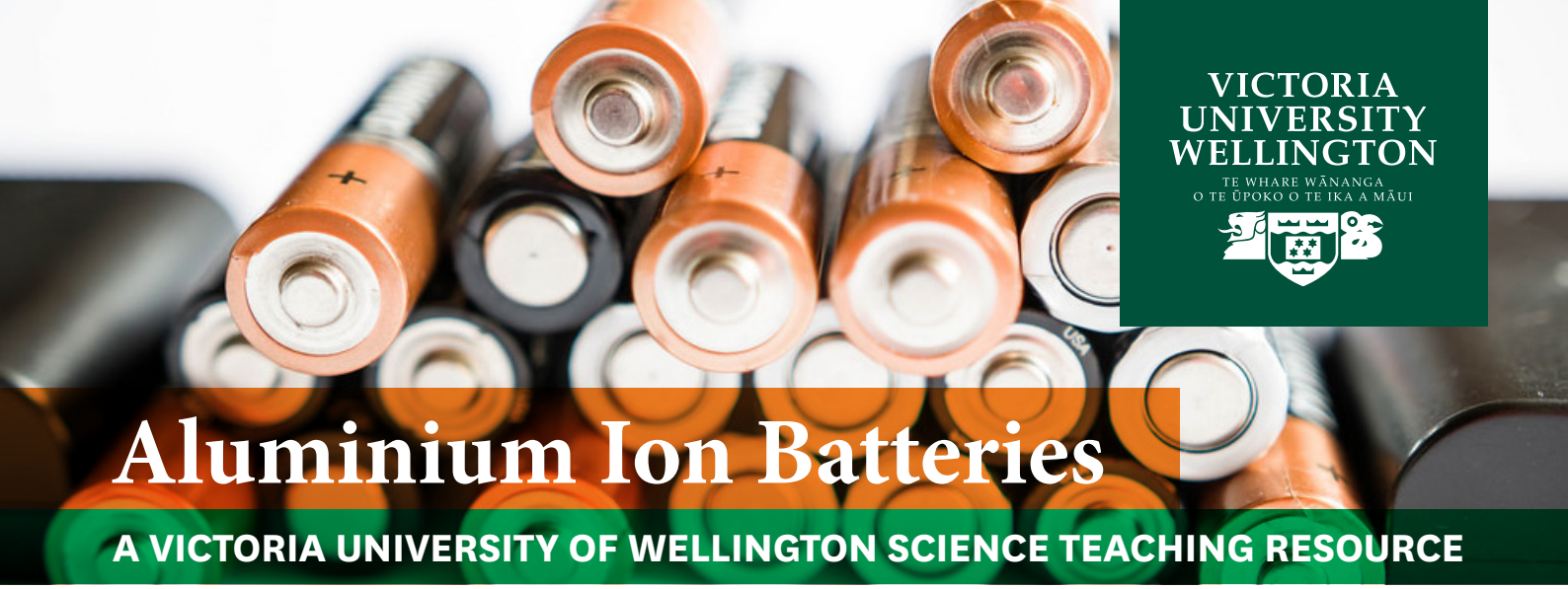


Aluminium Ion Batteries

A VICTORIA UNIVERSITY OF WELLINGTON SCIENCE TEACHING RESOURCE

WHO?

Dr Thomas Nann, an electrochemist at Victoria University of Wellington.

WHAT'S HE DOING?

Developing a new type of battery based on aluminium.

WHY DO WE NEED MORE BATTERIES?

As we make the transition to using more renewable energy sources, a number of challenges need to be overcome. Many of the renewable energy generation methods are not consistent, such as wind or solar, so we need a reliable way to store, and later access, energy when there is an excess.

- *What are some ways we could store energy for use at a later date?*

Batteries are one of the most obvious forms of energy storage. At the moment, the most widely used rechargeable batteries are lithium-ion batteries (LIB).

The three key components of most rechargeable batteries

1. The anode.
2. A 2D layered cathode.
3. An electrolyte solution, to transfer charge between the two.

An 2D layered cathode has another molecule being 'hosted' within its different layers. In the case of batteries, the cathode contains the product of the reaction between the electrolyte ions and the ions formed as the anode oxidises.

WHY ALUMINIUM?

Why Aluminium?

The table below compares different properties of certain elements. Specific capacity refers to the amount of energy that can be stored per unit of mass or per unit of volume.

Answer the following questions:

- *Why is lithium not a sustainable element to use for future batteries?*
- *What are some other issues we know about with lithium-ion batteries?*
- *Why might have researchers focussed on using aluminium rather than the other elements?*
- *What might be a drawback of aluminium?*

	Li	Na	Mg	Al	K	Ca
Valence	+	+	2+	3+	+	2+
Atomic weight	6.94	22.99	24.31	26.98	39.10	40.08
Specific Capacity [A h kg–1]	3862	1166	2205	2980	685	1340
Specific Capacity [A h–1 l]	2062	1128	3832	8046	591	2060
Standard Potential [V]	–3.04	–2.71	–2.36	–1.68	–2.93	–2.87
Abundance [ppm]	18	22700	23000	82000	18400	41000

Building the Battery

SWITCHING TO ALUMINIUM ANODES

While aluminium has the advantage of being the third most abundant element on the planet, as well as having a relatively high energy storage capacity, wide scale use of batteries using aluminium as the anode has been limited because historically charge has been transferred between the anode and cathode through an aqueous electrolyte solution.

- *What do you think that limitation was?*

In an aqueous solution, aluminium forms a protective oxide layer that slows down oxidation. This drastically reduces the efficiency of the battery as well as producing hydrogen gas. To avoid this, most researchers use an electrolyte solution made from an ionic liquid containing aluminium chloride ($AlCl_3$)

Choosing Cathodes

To be a suitable 2D layered cathode, the material needs:

- Pores big enough to allow the electrolyte to move easily.
- Unreactive with the intercalated ions.
- Relatively abundant or easy to produce.

Graphite is a very promising material for aluminium battery cathodes.

- *Why?*
- *Which other materials might be suitable as aluminium battery cathodes?*

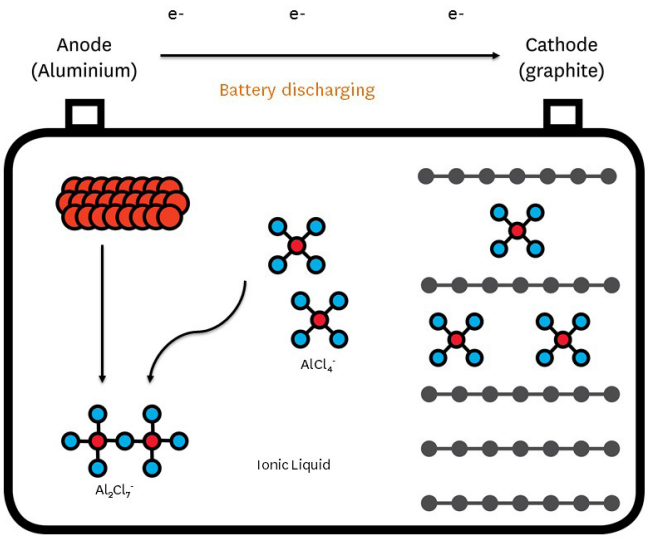
At the anode, the redox reaction when the battery is being used would be:

$Al + 7AlCl_4^- \rightarrow 4Al_2Cl_7^- + [X]e^-$

At the cathode, the redox reaction would be:

$C_n[AlCl_4] + [X]e^- \rightarrow C_n + AlCl_4^-$

- *How many electrons are produced/required by these two reactions?*
- *Can they be balanced?*
- *What do you think the C_n represents and why is it unchanged during the reaction?*
- *Take at the other cathode options in the article. Can you balance the redox reactions associated with them? What other information would you need?*



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F. Ambroz, T. J. Macdonald, T. Nann, Adv. Energy Mater. 2017, 7, 1602093. https://doi.org/10.1002/aenm.201602093