The Building Blocks of Battery Technology:

Using modified tower block game sets to explain and aid the understanding of rechargeable Li-ion batteries

Activity Sheet: A-Level Chemistry and Scottish Highers Qualifications

Introduction

Lithium ion (Li-ion) batteries are a rechargeable-type of battery which have become a staple in modern-day life and are used in mobile phones, laptops and, in more recent times, electric vehicles. As these batteries are rechargeable they have to be charged, used (discharged) and then recharged. The majority of electrode materials currently used in Li-ion batteries have a layered structure, and so Jenga can be used to help demonstrate charging and discharging processes, in addition to exploring why batteries fail over time and why the rate of charge is important. The original Li-ion batteries used $LiCoO_2$ and graphite as the electrodes. In newer cells, some of the cobalt is typically replaced by nickel and manganese in order to reduce the cost (cobalt is a less abundant element).

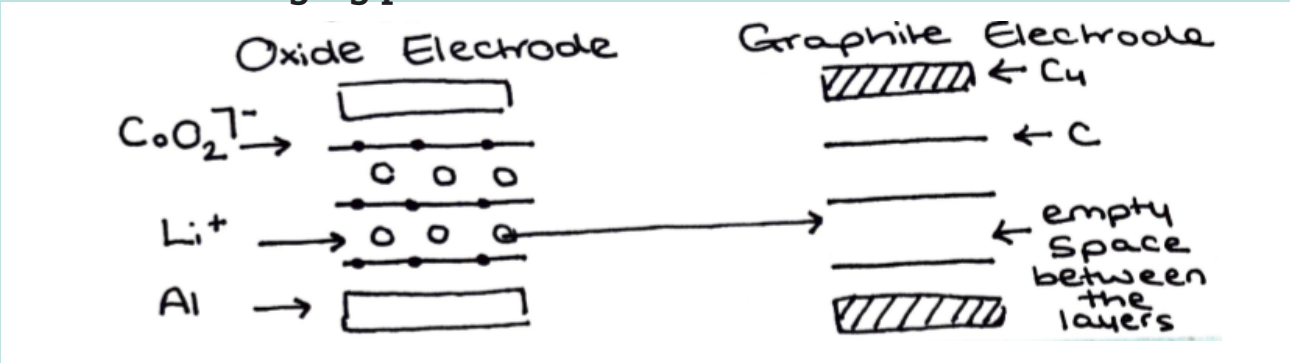
What to investigate:

1) Charging-Discharging

When batteries are charging, Li-ions move from the oxide electrode to the graphite electrode. The reverse process occurs on discharge.

- Have a go at charging your battery Jenga by removing the Li-ion blocks from the oxide electrode and inserting them between the layers of the graphite sheets on the graphite electrode (i.e. in place of the white blank blocks).
- Do the reverse process to reset the battery Jenga to show discharge.

Draw a diagram of the two electrodes you have sent up. Then draw arrows of where you have moved the Li-ions from one electrode to the other on a charging process.



Both on charging and discharging, a redox reaction is occurring. Write both half cell equations which would describe the reduction process occurring at the oxide electrode ($LiCoO_2$) and the oxidation process on the graphite electrode (C).

Oxidation Is Loss
Reduction Is Gain

Oxide Electrode

$Li^+ + e^- + CoO_2 \rightarrow Li^+[CoO_2]^-$ or $LiCoO_2$

Graphite Electrode

$CLi \rightarrow C + Li^+ + e^-$

In the oxide electrode, write a half equation which explains the change in oxidation state of the cobalt ion upon discharge.

Referring to the previous question, where we're focusing on discharge

$\therefore \quad Co^{4+} + e^- \rightarrow Co^{3+}$

2) Rate of Charge

Think about how long mobile phones take to charge - do you think electric cars take the same time to charge?

- Focusing on the oxide electrode, time yourself removing a Li-ion block every 10 seconds.
- How many Li-ions are you able to remove in the space of 30 seconds?
- How many could you remove in total, without collapsing the structure?

↳ Not possible to remove all as tower will collapse. Possible to remove 2 Li-ion blocks from each row of 3 Li-ion blocks.

Place all the Li-ion blocks back into the oxide electrode, so we have reset the structure.

Again, focusing on the oxide electrode, how many Li-ions can you remove in 30 seconds, if you remove the blocks every couple of seconds?

(Don't worry if the structure collapses on this fast charge).

Faster and more haphazard process which leads to the structure collapse.

Relate to battery safety.

In your own words, describe what you have observed from this demonstration and why it is important to have a high charge rate for applications, but how this can impact safety.

Why
High charge rate allows for devices to be charged quickly before use. However, too fast will result in structure collapse and an unfunctional battery.

3) Degradation

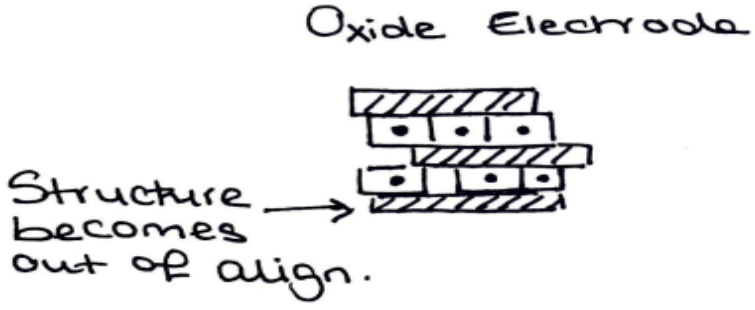
In the next demonstration we're going to think about the lifetime of the batteries.

- In the first demonstration where we showed charging and discharging (known as cycling our battery), did you find it tricky to remove the blocks?
- Did any of the electrodes collapse or were knocked quite easily?

Cycle (charge and discharge) your battery Jenga set multiple times.

- Can it help you work out why batteries fail over time?

Draw a diagram of how the oxide electrode looks after you've repeatedly cycled the battery Jenga.



Write 5 take-home points for the whole of this activity.