Review of OCV test steps

- In this lesson, you will learn how to process the OCV test data to compute coulombic efficiency and total capacity
- Recall the test steps for OCV testing:
  1–2. Soak cell at test temperature; discharge from 100 $\%$ SOC to $v_{\min}$ (note: this is not the same thing as 0 $\%$ SOC)
  3–4. Soak cell at 25 °C; dis/charge cell to 0 $\%$ SOC (now equivalent to $v_{\min}$)
  5–6. Soak cell at test temperature; charge from 0 $\%$ SOC to $v_{\max}$ (not 100 $\%$ SOC)
  7–8. Soak cell at 25 °C; dis/charge cell to 100 $\%$ SOC (now equivalent to $v_{\max}$)
- With careful consideration of the meaning of each of these steps, we can compute coulombic efficiency and total capacity

Processing data for 25 °C

- Easiest case because all steps are executed at 25 °C—no other temperatures are involved
- One method to compute SOC uses $z[k] = z[0] - \dfrac{1}{Q}\sum_{j=0}^{k-1} \eta[j]i[j]$ where, in our case, $z[k] = z[0] = 1$ (cancels out)
- Multiply by $-Q$, split summation into discharging and charging sets

$$0 = \sum_{\text{discharge}} i[j] + \sum_{\text{charge}} \eta[k]i[j]$$

- Since $\eta[k] = \eta(25\,°\text{C})$ in all steps, compute the coulombic efficiency at 25 °C as

$$\eta(25\,°\text{C}) = \frac{\text{total absolute ampere-hours discharged in all steps at 25 °C}}{\text{total absolute ampere-hours charged in all steps at 25 °C}}$$

Processing data for other temperatures

- Tests collect data at temperature T *and* at 25 °C
- Still have $z[k] = z[0] = 1$, but now have

$$\begin{aligned} 0 &= \sum_{\text{discharge}} i[j] + \sum_{\text{charge at } T} \eta[k]i[j] + \sum_{\text{charge at 25 °C}} \eta[k]i[j] \\ &= \sum_{\text{discharge}} i[j] + \eta(T)\sum_{\text{charge at } T} i[j] + \eta(25\,°\text{C})\sum_{\text{charge at 25 °C}} i[j] \end{aligned}$$

- Compute coulombic efficiency at test temperature T:

$$\begin{aligned} \eta(T) = &\frac{\text{total absolute ampere-hours discharged}}{\text{total absolute ampere-hours charged at temperature } T} \\ &- \eta(25\,°\text{C})\frac{\text{total absolute ampere-hours charged at 25 °C}}{\text{total absolute ampere-hours charged at temperature } T} \end{aligned}$$

Capacity estimation for 25 °C

- Theoretically, total capacity Q is not a function of temperature
- But, can verify this experimentally as well
- Note that SOC is 100 % at start of test and 0 % at end of step 4
- Again, use SOC relationship where, now, $z[k] = 0$ and $z[0] = 1$

$$z[k] = z[0] - \sum_{j=0}^{k-1} \frac{\eta[j]i[j]}{Q}$$

- Summing over all data in steps 1–4 gives Q in ampere-seconds

$$Q(25\,°\text{C}) = \sum_{j=0}^{k-1} \eta[j]i[j]$$

Capacity estimation for other temperatures

- SOC is still 100 % at start of test and 0 % at end of step 4
- Again, use SOC relationship where $z[k] = 0$ and $z[0] = 1$

$$z[k] = z[0] - \sum_{j=0}^{k-1} \frac{\eta[j]i[j]}{Q}$$

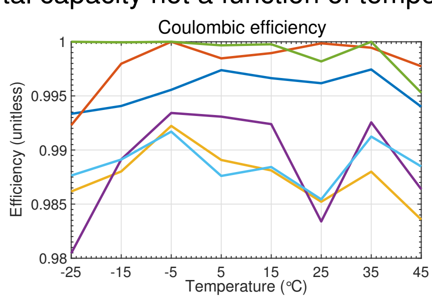
- Summing over all data in steps 1–4 gives Q in ampere-seconds

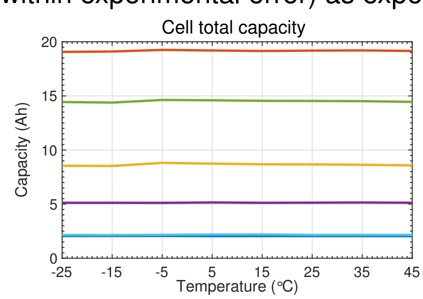
$$1 = \sum_{\text{data at } 25\,°\text{C}} \frac{\eta(25\,°\text{C})i[j]}{Q(25\,°\text{C})} + \sum_{\text{data at } T} \frac{\eta(T)i[j]}{Q(T)}$$

- Note: Assumed $Q(25\,°\text{C}) = Q(T)$ when computing $\eta(T)$, but can solve simultaneous equations for $Q(T)$ and $\eta(T)$ if not convinced this is true

Sample results

- Coulombic efficiency *should* always be less than one, but experimental accuracy of accumulated ampere hours inexact
- Also function of rate: different tests could be implemented to extract this information
- Total capacity not a function of temperature (within experimental error) as expected





Summary

- Calculate absolute sum of ampere-hours discharged
- Calculate absolute sum of ampere-hours charged at 25 °C
- Calculate absolute sum of ampere-hours charged at all other temperatures
- Compute $\eta(25\,°\text{C})$, $\eta(T)$ for other temperatures of interest
- Compute $Q(25\,°\text{C})$, $Q(T)$ for other temperatures of interest
- While *total capacity* is not a function of temperature, there is a strong temperature dependence on *discharge capacity* and *charge capacity*