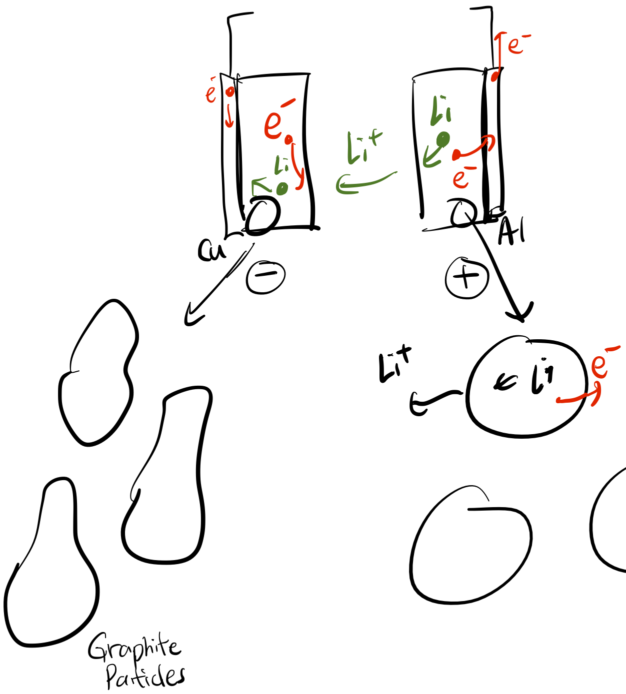
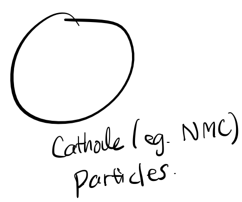
December 6, 2021

Electrochemical Impedance Spectroscopy (EIS)



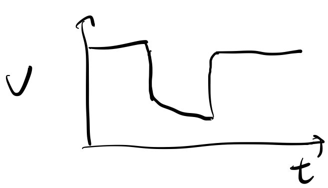
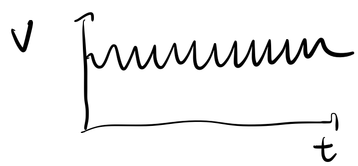
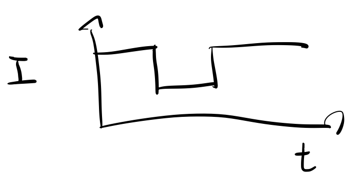
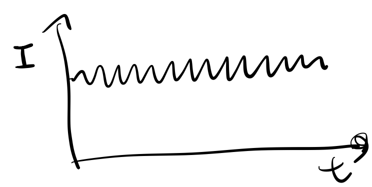


Separation of time-scales

→ diffusion × 2 electrodes → slowest

→ charge-transfer × 2 electrodes → in between

→ electronic resistance → fastest

	DC Analysis (HPPC)	AC Analysis (EIS)
output:		
input:		

$$\rightarrow V = V_0 \sin(\omega t + \phi) = V_0 \exp(j(\omega t + \phi))$$

$$\rightarrow I = I_0 \sin(\omega t) = I_0 \exp(j\omega t)$$

$$R = \frac{V}{I}$$

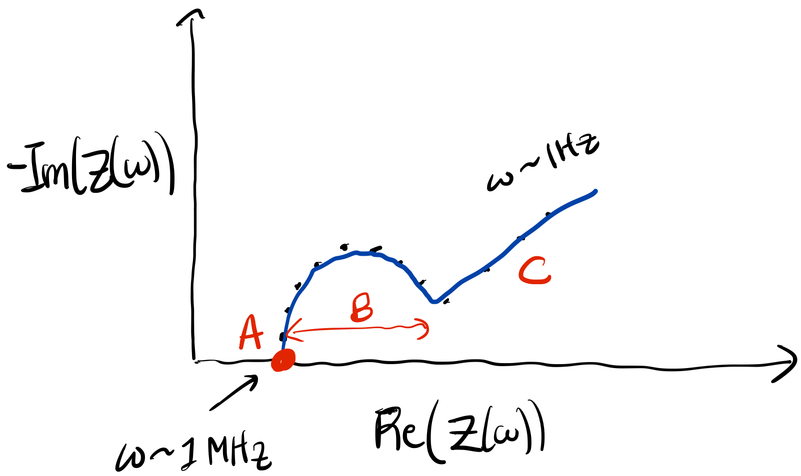
$$Z = \frac{V}{I} = \frac{V_0 \cancel{\exp(j(\omega t)} + \phi)}{I_0 \cancel{\exp(j\omega t)}} = Z_0 \exp(j\phi)$$

$$\left(Z_0 \triangleq V_0 / I_0 \right)$$

$$Z(\omega) = Z_0 \exp(j\phi) \quad \begin{cases} \nearrow \; \mathrm{Re}(Z(\omega)) = Z_0 \cos\phi \\ \searrow \; \mathrm{Im}(Z(\omega)) = Z_0 \sin\phi \end{cases}$$

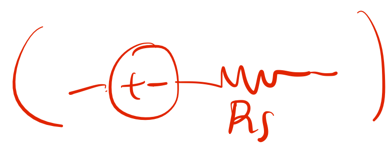
$$\left(e^{j\theta} = \cos\theta + j\sin\theta \right)$$

The EIS experiment



1. Set I_o (usually something small)
2. For a range of ω:
   - Apply $I = I_0 \sin(\omega t)$
   - Measure $V = V_0 \sin(\omega t + \phi)$
   - Calculate $Z(\omega) = I(\omega)/V(\omega)$
   - Put a new point on the plot at $(Re(Z), -Im(Z))$.

Key Features



1. $Re(Z(\omega))$ at A (y intercep) → R_s
2. B is the diameter of the semi-circle → R_{CT}
3. C ~ diffusion

charge transfer resistance

Is this for the cathod or anode? Ans: if measuring a full cell, then it would include both! Sometimes you can see multiple semi-circles that can be attributed to <u>different</u> charge-transfer processes.