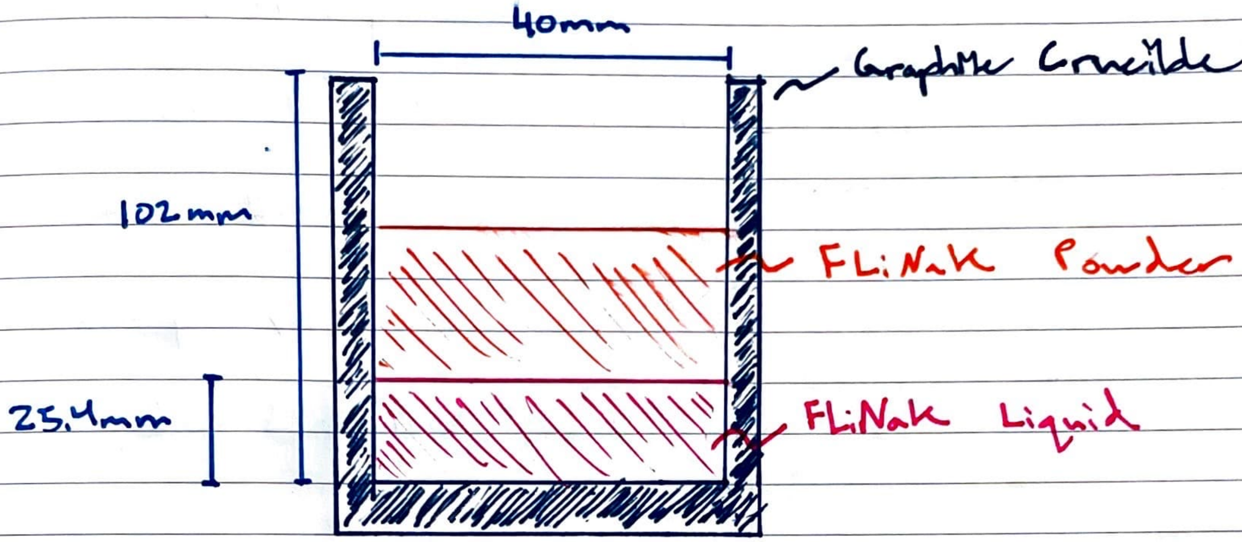
Day 67 10/4/22

- Ask barrett what time is your operator
- Graphite FLiNak fill calculations



Volume Required for Liquid FLiNak:

$V = \pi (20mm)^2 (25.4mm)$

$V = 31{,}918.58 mm^3 = 3.191858 \times 10^{-5} m^3$

Density of FLiNak at 650°C ~ 2,050 kg/m³

Amount of FLiNak powder required:

$\frac{3.191858 \times 10^{-5} \cancel{m^3}}{1} \cdot \frac{2{,}050 kg}{1 \cancel{m^3}} = 0.065433089 kg$

$\boxed{65.43 \text{ g FLiNak}}$

Day 67 (Continued) 10/4/22

- In order to make 65.43 g FLiNak we need to measure out our constituents...

Eutectic FLiNak has a molar mass of 41.291 g/mol

$$\frac{65.43\,g\,\cancel{FLiNak}}{1} \cdot \frac{1\,mol\,FLiNak}{41.291\,g\,\cancel{FLiNak}} = 1.5846\,mol\,FLiNak$$

For 1.5846 mol FLiNak we need... (Eutectic)

$$1.5846\,mol\,FLiNak \times 0.465 = 0.736839\,mol\,LiF$$

$$\frac{0.736839\,\cancel{mol\,LiF}\,\cancel{\times}}{1} \cdot \frac{25.939\,g\,LiF}{1\,\cancel{mol\,LiF}} = \boxed{19.11\,g\,LiF}$$

$$1.5846\,mol\,FLiNak \times 0.115 = 0.18223015\,mol\,NaF$$

$$\frac{0.18223015\,\cancel{mol\,NaF}}{1} \cdot \frac{41.988\,g\,NaF}{1\,\cancel{mol\,NaF}} = \boxed{7.65\,g\,NaF}$$

$$1.5486\,mol\,FLiNak \times 0.420 = 0.665532\,mol\,KF$$

$$\frac{0.665532\,\cancel{mol\,KF}}{1} \cdot \frac{58.096\,g\,KF}{1\,\cancel{mol\,KF}} = \boxed{38.66\,g\,KF}$$

To check my work...

$$19.11\,g\,LiF + 7.65\,g\,NaF + 38.66\,g\,KF = 65.42\,g\,FLiNak$$

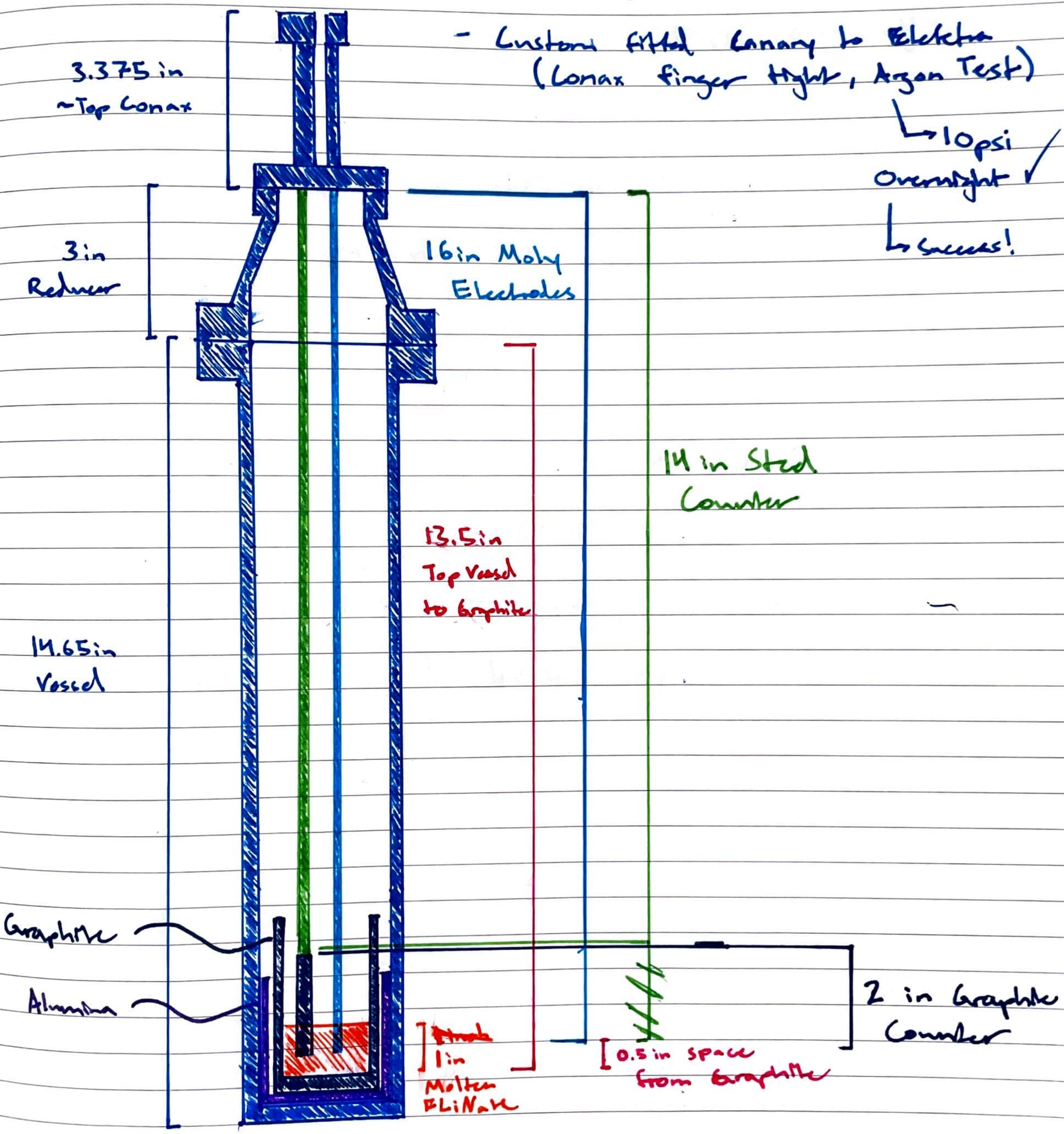
=> ~~65.46~~

$$65.42\,g\,FLiNak \approx 65.43\,g\,FLiNak$$ ✓

Day 70 (continued) 10/10/22

- Elektra / Canary Electrode Heights 1:1/3 Scale

- Custom fitted Canary to Elektra (Conax finger tight, Argon Test)
  - ↳ 10psi Overnight ✓
    - ↳ Success!



- 1/2 in submersion (electrodes in FLiNaK)

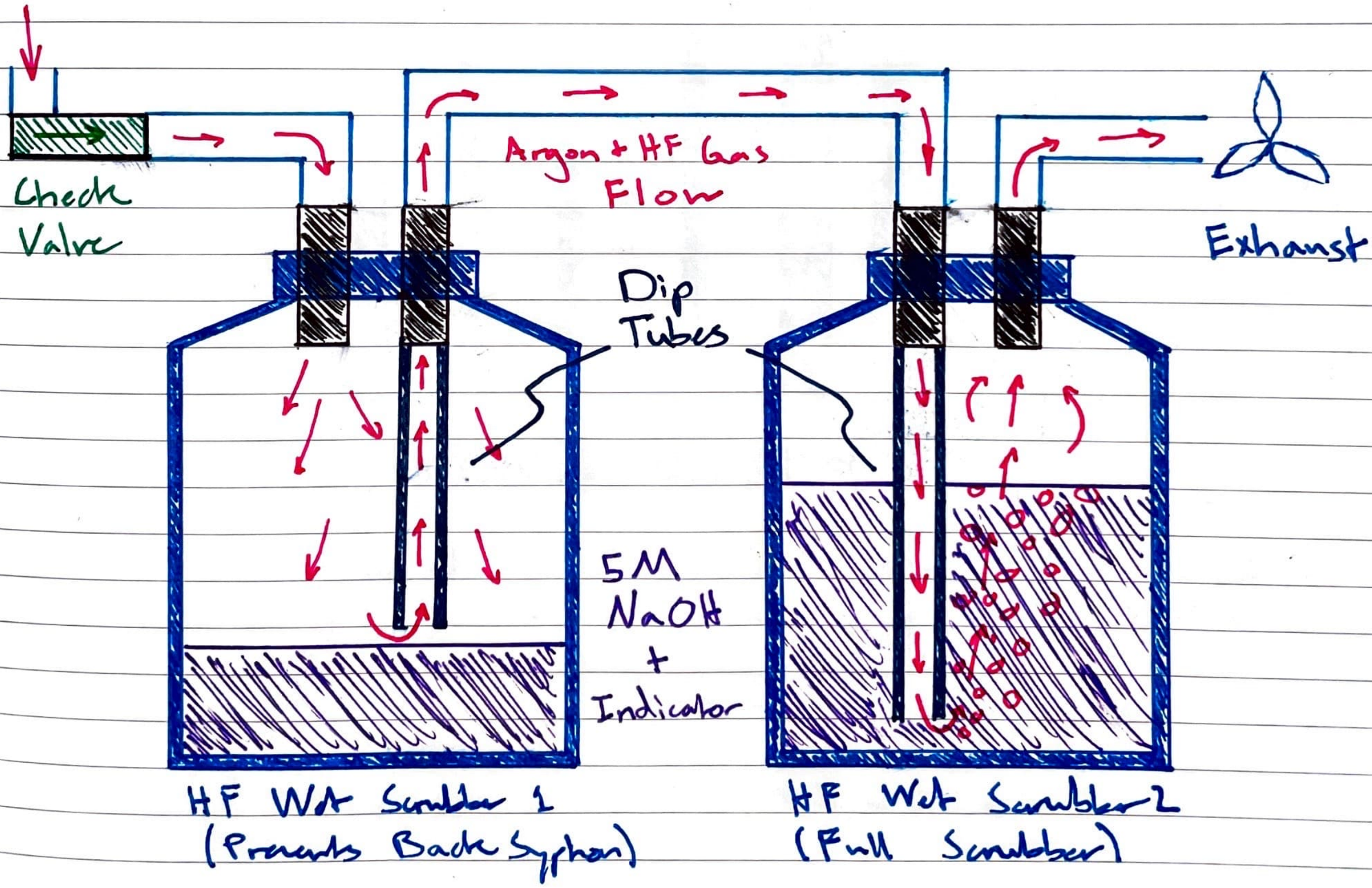
Day 72 10/12/22

- Elektra turned on 10:00 A.M., ramp 5°C/m to 650°C
- Yesterday, I purposefully left the system unpressurized to test the back syphon phenomenon

  5M NaOH + Indicator was pulled into the capture scrubber (only a small amount).

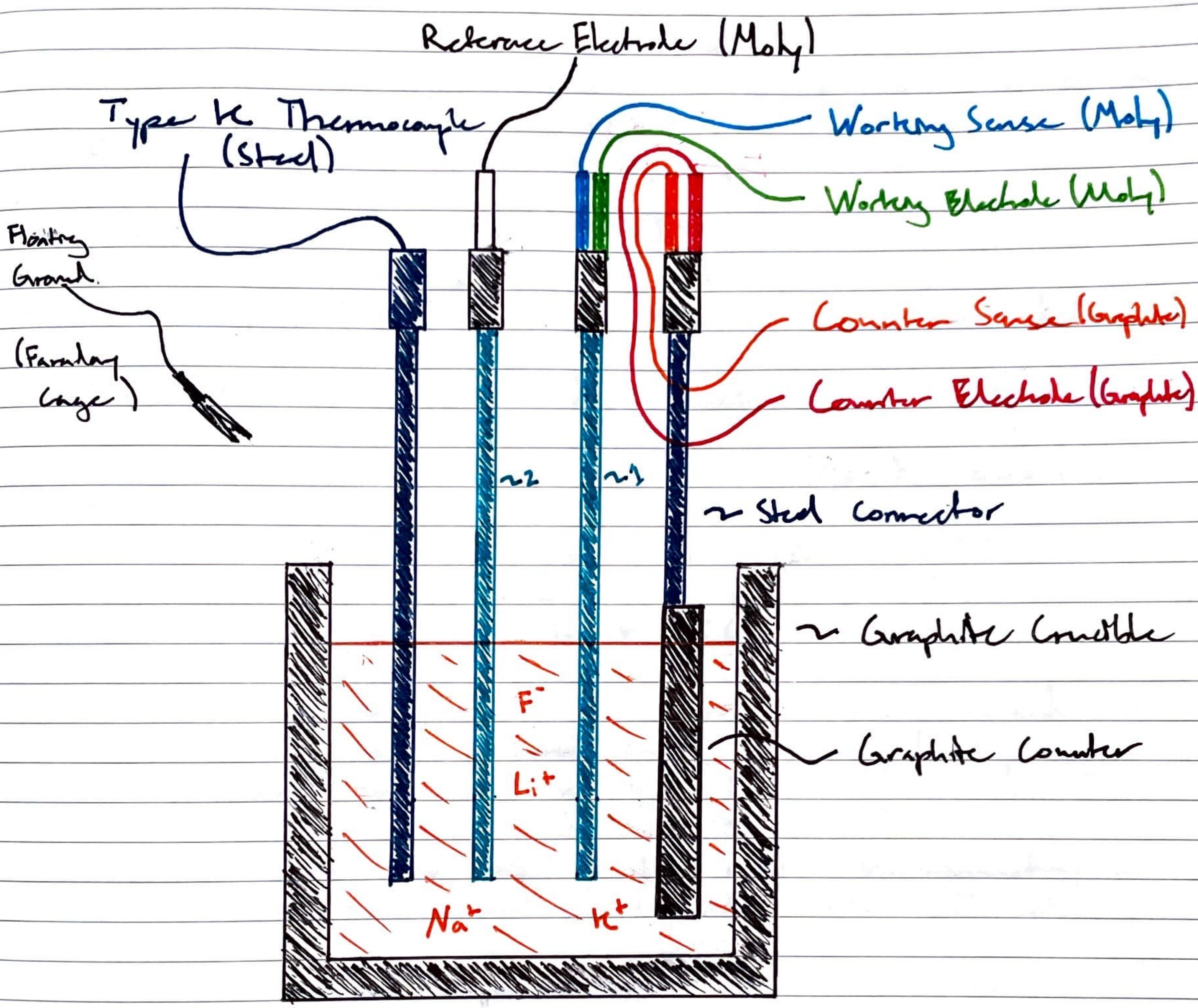
  I am curious the pre-requisites for total scrubber pull... infinite vacuum?

  I repressurized the system before major transfer, hopefully my salt is not contaminated...
- Possible Syphon Control Scrubber System Redesign



Day 72 (Continued) 10/12/22

- Gamry Electrochemical Setup FLiNaK



- This electrochemical setup was utilized to isolate the redox potential window of Moly / FLiNaK

-1.725 V
Reducing
Potassium

+0.350 V
Oxidizing
Molybdenum

Day 72 (Continued) 10/12/22

- OKR Completed (not really) / Historic Moment!!! (kinda)

Develop reliable oxide measurments techniques for FLiBe by finishing Elektra setup and successfully running 10 CV SWV runs with gold electrodes in FLiNak by 9/30/22.

🟥 Unfinished 🟩 Finished

- I collected first set of FLiNak electrochemical data

2:00 P.M., PAPR up + dip electrodes in salt

Hand held TC reader for salt showed 626.4°C

Furnace set point TC 650°C

Furnace limit TC 700°C

- Electrode heights seem to be perfect based off TC reading and electrochemical testing (perhaps single short or counter short... will verify in the future)

- Open circuit potential + 10 cyclic voltammetry runs with chronoamperometry cleaning after 5th CV

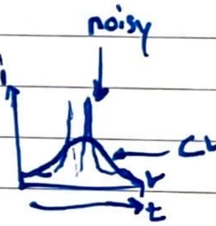
- Better electrode connectors could be made, custom aligator clips for gold standard

- Many processes can be optimized to run Elektra

- Electrochemical parameters to be discovered like operating voltage window, scan rate prime, oxidation + reduction potentials

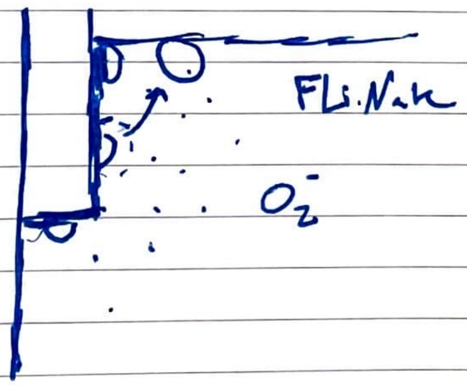
Day 78 10/20/22

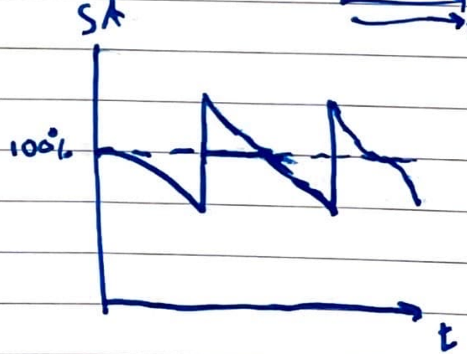
- Formal procedure
  - Adding lithium oxide, does not change trend
  - New batch for each lithium oxide
  - Calculate based on mass of for lithium oxide
  - Lithium oxide melting point
  - Avoid carrying over error
  - Baseline already contaminated
  - Solubility delay, dissolving problem
  - Calculate oxygen atoms bubbled
  - Explore square wave in any case
  - Bubbles change surface area



ⓥ → Bubbles Free Energy

$O_2^- \rightarrow O_2 + 2e^-$
↳ gas





Bubbles also agitate surface, enhances O_2^- diffusion, plays with convection

Day 78 10/20/22

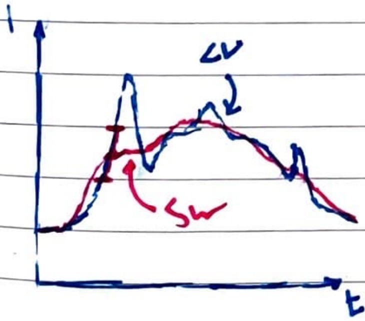
- Eventually measure surface area, gold electrode
- Impose concentration, calculate diffusion, measure oxide
- CV Randles Sevcik equation

  [C][D][SA][TP][Constants]

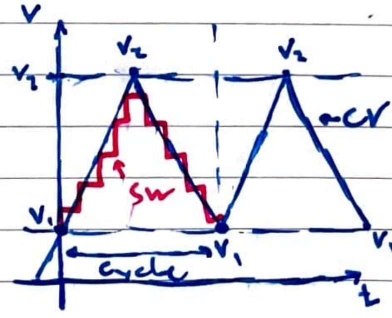
- Current densities ↑ rate of electrochemical reaction

  (- current density makes independent from surface area
  → the current itself ~~is~~ is dependent on surface area (overall magnitude))

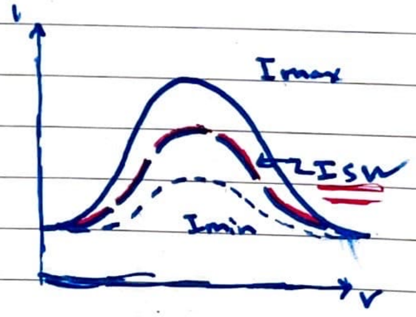
- Reference electrode little current running through it
- Counter electrode ideally infinite
- Two weeks goal for ETU-ET (apply for aides)
  ↓ ask Sam
- S-Lab ingot prep
- S-Lab graphite pellet



Cyclic Voltammetry Averaged by Square Wave



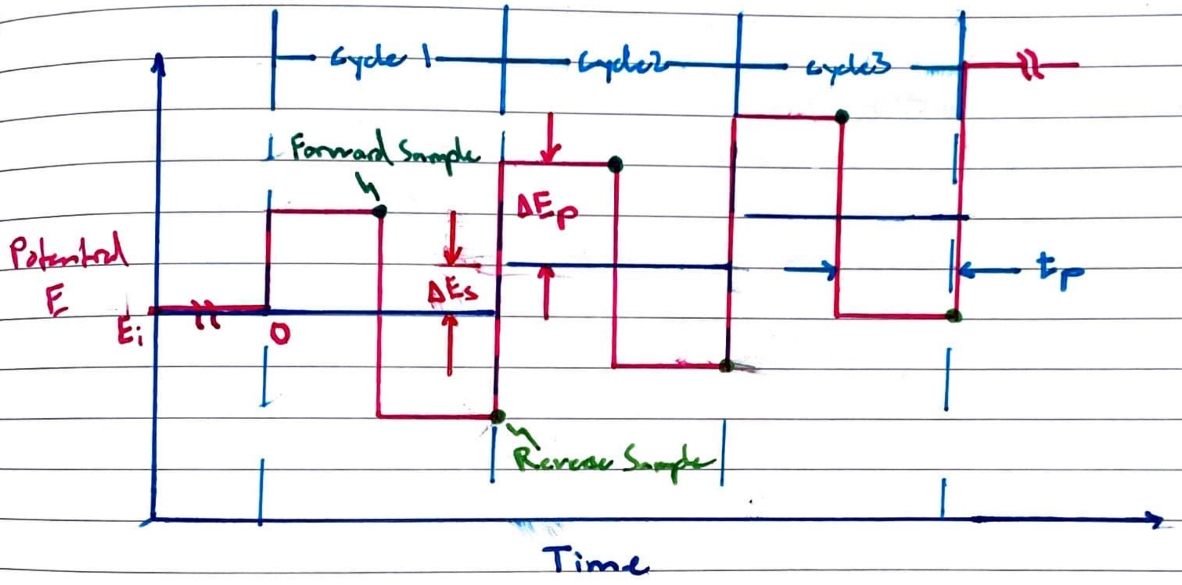
Potential Applications Cyclic Voltammetry Square Wave



Square Wave Current Return

Day 83 10/27/22

- Electrochemistry notes
  - Square wave voltammetry invented by Ramaley and Krause
    Further developed by Osteryoungs
    - Combines the best part about pulse techniques
    - Symmetrical double pulse, one forward one reverse

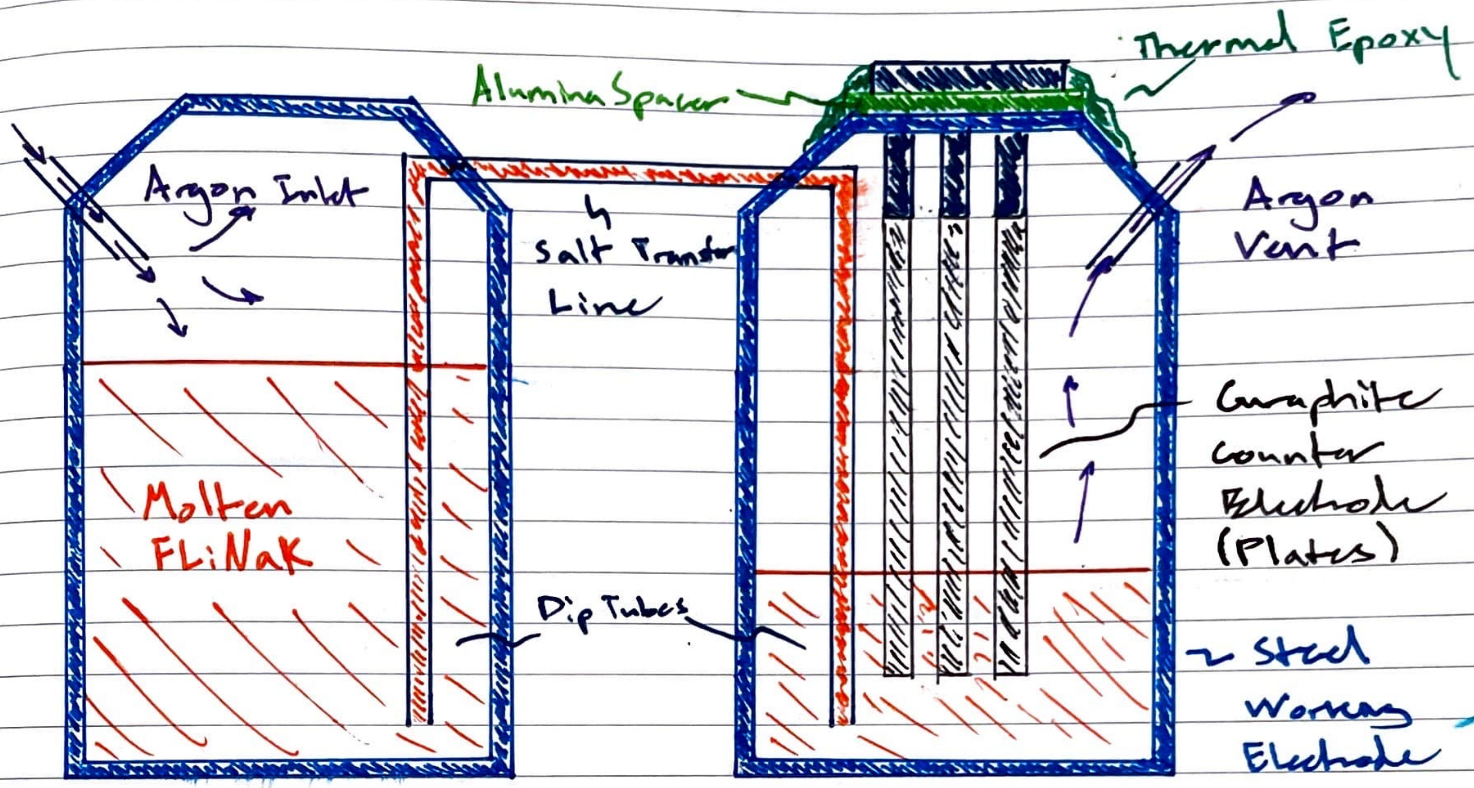


Square Wave Voltammetry Waveform

- No true polarization, forward + reverse currents applied
  - ↳ not sure about this (nomenclature forward + reverse based on direction from staircase)
- ΔE_p, pulse height (mV)
- t_p, pulse width, frequency (Hz)
  ... specifically $f = 1/2 t_p$
- ΔE_s, stair-case shift beginning of each cycle
- Scan rate $v = \Delta E_s / 2t_p = f \Delta E_s$

Day 89 11/7/22

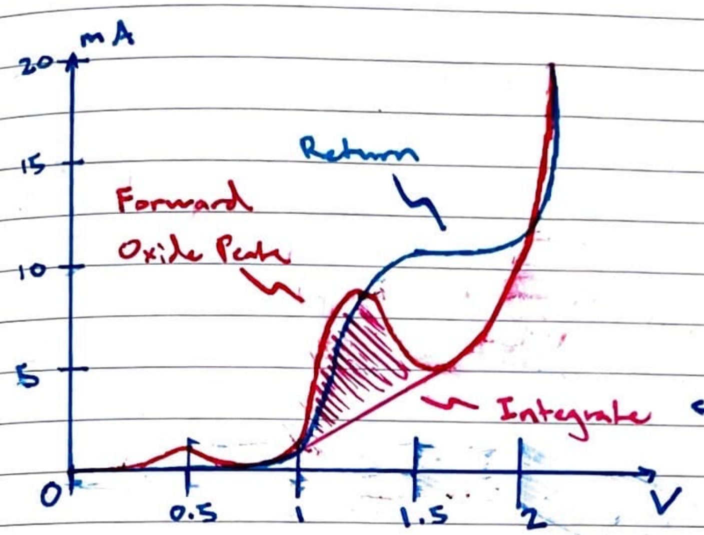
- FLiNaK Purification Design (PRET V2)



- An empty salt tank can be converted into a giant electrochemical cell
- Working electrode can plate out impurities
- Counter electrode will generate flouride gas
- This would require massive amounts of power
- Once the salt is pure, it can be transferred back to the storage tank
- Raw sodium or potassium is highly explosive
- Alumina spacer ring isolates electrodes
- This is a difficult process to navigate

Day 89 11/7/22

· The Amount of Charge Passed From Cyclic Voltammetry



- From an integration of the oxide peak based off an arbitrary baseline, we discover charge passed...

⟷ 4.09 mili Coloumbs

1 mC has the equivalent charge of...

6.2415×10^{15} electrons

$$\Rightarrow 4.09\,\cancel{mC} \cdot \frac{6.2415\times10^{15}\,e^-}{1\,\cancel{mC}} = 2.52718\times10^{16}\,e^- \text{ passed...}$$

To convert to mols utilize Avogadro's number...

$$2.52718\times10^{16}\,e^- \cdot \frac{1\text{ mol}}{6.022\times10^{23}\text{ units}} = 4.19658\times10^{-8}\text{ mol } e^- \text{ passed...}$$

To find mols of O^{2-} consumed and $O_{2(g)}$ generated...

... From Massot... $O^{2-} \rightarrow \frac{1}{2} O_{2(g)} + 2e^-$

$$4.19658\times10^{-8}\,\cancel{\text{mol } e^-} \cdot \frac{1\text{ mol } O_{2(g)}}{4\,\cancel{\text{mol } e^-}} = 1.04915\times10^{-8}\text{ mol } O_{2(g)}$$

$$4.19658\times10^{-8}\text{ mol } e^- \cdot \frac{1\text{ mol } O^{2-}}{2\text{ mol } e^-} = 2.09829\times10^{-8}\text{ mol } O^{2-}\text{ ions}$$

↳ Free Oxide Ions!!!

Day 10 11/8/22

- Identifying + Confirming Oxygen Peaks Gold Electrode

Mol ratios for oxygen from Massot...

$O^{2-} \rightarrow \frac{1}{2} O_{2(g)} + \boxed{2e^-}$ → Identifying feature of oxide peak

From Massot as well...

$W_{1/2}$ (Descent Peak Half Width) = RT/nF = Volts or J/C

$\Rightarrow n = RT/W_{1/2}F$

For Cyclic Voltammetry...

$$n_{CV} = \frac{\overset{(3.52)}{\wedge}(8.314\ \cancel{J}/\cancel{K}\,\cancel{mol})(923.15\ \cancel{K})}{(0.159\ \cancel{J}/\cancel{C})(96{,}485\ \cancel{C}/\cancel{mol})} = 1.761 \rightarrow \text{Close to } 2e^-$$

For Square Wave Voltammetry...

$$n_{SWV} = \frac{(3.52)(8.314\ \cancel{J}/\cancel{K}\,\cancel{mol})(923.15\ \cancel{K})}{(0.217\ \cancel{J}/\cancel{C})(96{,}485\ \cancel{C}/\cancel{mol})} = 1.290 \rightarrow \text{Not so close}$$

- Heavy differences between calculated and predicted values come from arbitrary half peak widths...
  - Specifically, the descent point is relatively unstable compared to the center, also functioning as maximum peak height.
- Further itterations and identical methods will most likely improve precision, accuracy, and a closer result ✓

Day 91 11/9/22

- Calculating Free Oxide Concentration Cyclic Voltammetry

Randles Sevcik utilizes the curve peak...

$$i_p = 0.4463\,nFAC\sqrt{\frac{nFvD}{RT}} \Rightarrow C = \frac{i_p}{0.4463\,nFA\sqrt{\frac{nFvD}{RT}}}$$

Variables...

i_p = Current Maximum (Amps)	0.004513
n = Number electrons transferred redox event	2
A = Electrode Surface Area (cm^2)	0.406834
F = Faraday Constant (C/mol)	96,485
D = Diffusion Coefficient (cm^2/s)	4.74×10^5
C = Concentration (mol/cm^3)	unknown
v = Scan Rate (V/s)	0.25
R = Ideal Gas Constant (J/Kmol)	8.314
T = Temperature (K)	923.15

$$\Rightarrow C = \frac{(0.004513\,\cancel{C}/s)}{0.4463\,(2)(96{,}485\,\cancel{C}/mol)(0.406834\,cm^2)\sqrt{\frac{(2)(96{,}485\,\cancel{C}/\cancel{mol})(0.25\,\cancel{J}/\cancel{Cs})(4.745\times10^5\,cm^2/\cancel{s})}{(8.314\,\cancel{J}/\cancel{Kmol})(923.15\,\cancel{K})}}}$$

$$= 7.46212 \times 10^{-11}\ mol\ O^{2-}\ ions\ /cm^3$$

Convert to mols + grams in 65.43 g FLiNaK ($31.917\ cm^3$)...

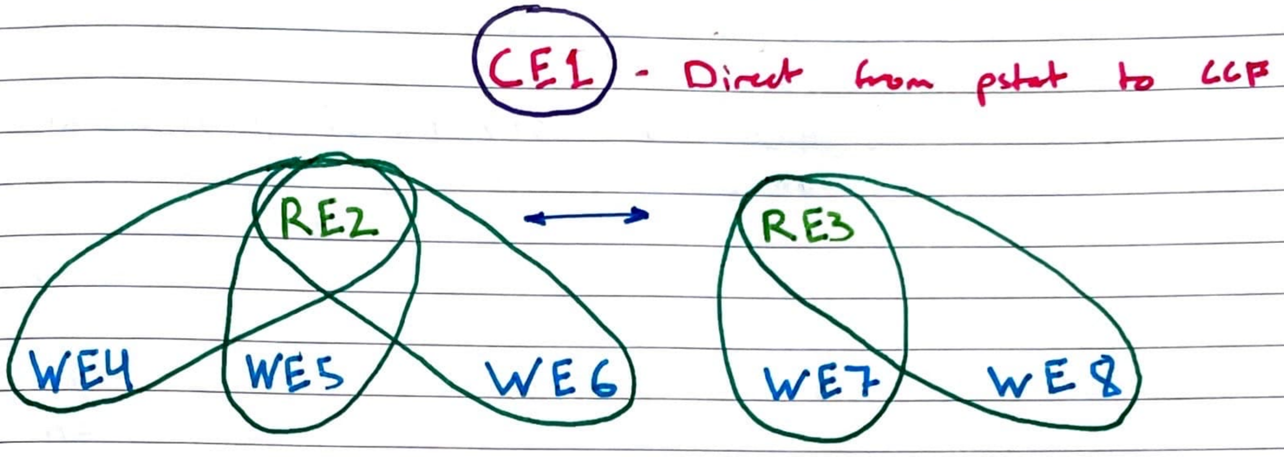
$$\frac{7.46212\times10^{-11}\ mol\ O^{2-}\ ions}{1\ \cancel{cm^3}} \cdot 31.917\ \cancel{cm^3} = 2.38\times10^{-9}\ mol\ O^{2-}\ ions$$ ✓

$$2.38\times10^{-9}\ \cancel{mol\ O^{2-}}\ ions \cdot \frac{16\ g\ Oxygen}{1\ \cancel{mol\ Oxygen}} = 3.81\times10^{-8}\ grams\ O^{2-}\ ions$$ ✓

$$ppm = \frac{Mass\ of\ Solute\ \cancel{(g)}}{Mass\ of\ Solution\ \cancel{(g)}} \times 10^6 = \frac{3.81\times10^{-8}\ g\ \cancel{O^{2-}}\ ions}{65.43\ g\ \cancel{FLiNaK}} \times 10^6 = 0.000582\ ppm$$ ✓

Day 22 11/10/22

- ETU 1.0 CCF Multiplexer Meeting with Rebecca



- Using only 1 potentiostat, for 2 CCFs
  ... requires hardware switch for CE1

Option 1: Run wire from each counter to potentiostat, manually switch

Option 2: Figure out how to do it through MLTX

Option 3: Second multiplexer, switch between two channels

Can the counter sense follow the counter...

High positive, low negative, guard shielding
↳ under use

Test connecting channels on different slot cards, enable us to copy Argon NL (National Lab)

Touch base with Sam, about ANL

Try to have a plan by end of next week, to finish wiring... check connections to multiplexer from pstat + electrodes

Day 93 11/14/22

- Free Oxide Concentration Square Wave Voltammetry

Faulkner utilizes the current peak...

$$\Delta i_p = \frac{nFAC\sqrt{D}}{\sqrt{\pi t_p}}\Delta\Psi \Rightarrow C = \frac{\Delta i_p\sqrt{\pi t_p}}{nFA\Delta\Psi\sqrt{D}}$$

Variables...

Δi_p = Differential Current Peak (Amps)	0.004912
n = Number electrons transferred redox event	2
A = Electrode Surface Area (cm^2)	0.40684
F = Faraday Constant (C/mol)	96,485
D = Diffusion Coefficient (~~x~~ cm^2/s)	4.74×10^5
C = Concentration (mol/cm^3)	unknown
t_p = Pulse Width (s) ~ Inverse Frequency	0.02778
$\Delta\Psi$ = Dimensionless Peak Limiter (Size : Resolution)	0.4531

$$\Rightarrow C = \frac{(0.004912\,\cancel{C}/\cancel{s})\sqrt{(3.14159)(1/36\,\cancel{s})}}{(2)(96{,}485\,\cancel{C}/mol)(0.40684\,cm^2)(0.4531)\sqrt{(4.74\times10^5\,cm^2/\cancel{s})}}$$

$= 5.92501\times10^{-11}$ mol O^{2-} ions $/cm^3$

Convert to mols + grams in 65.43 g FLiNaK (31.917 cm^3)...

$$\frac{5.92501\times10^{-11}\text{ mol } O^{2-}\text{ ions}}{1\,\cancel{cm^3}}\cdot 31.917\,\cancel{cm^3} = 1.89109\times10^{-9}\text{ mol } O^{2-}\text{ ions}$$ ✓

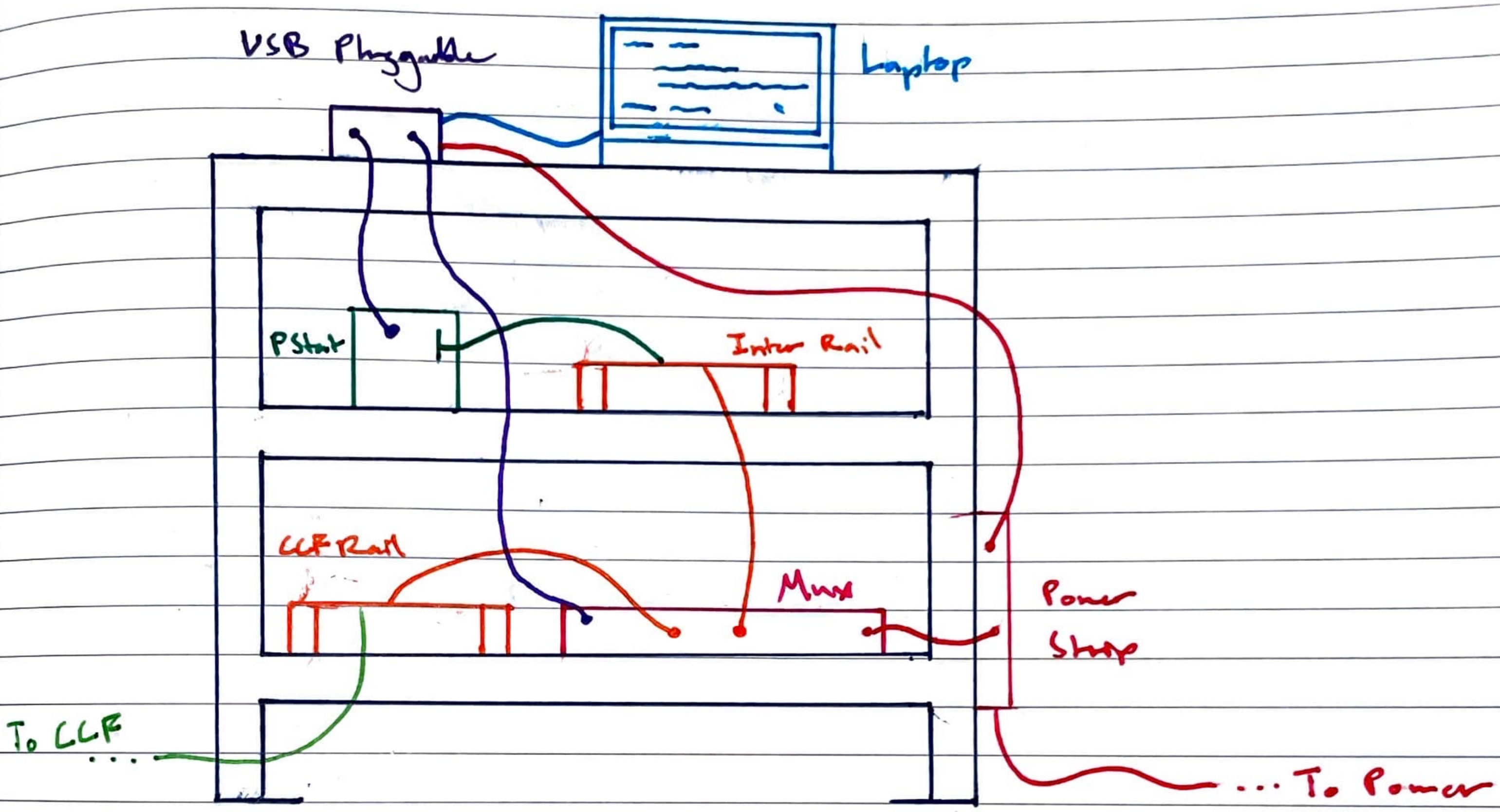
$$1.89109\times10^{-9}\,\cancel{\text{mol } O^{2-}}\text{ ions}\cdot\frac{16\text{ g Oxygen}}{1\,\cancel{\text{mol Oxygen}}} = 3.02575\times10^{-8}\text{ grams } O^{2-}\text{ ions}$$ ✓

$$ppm = \frac{\text{Mass of Solute (g)}}{\text{Mass of Solution (g)}}\times10^6 = \frac{3.02575\times10^{-8}\text{ g } O^{2-}\text{ ions}}{65.43\text{ g FLiNaK}}\times10^6 = 0.00046244\text{ ppm}$$ ✓

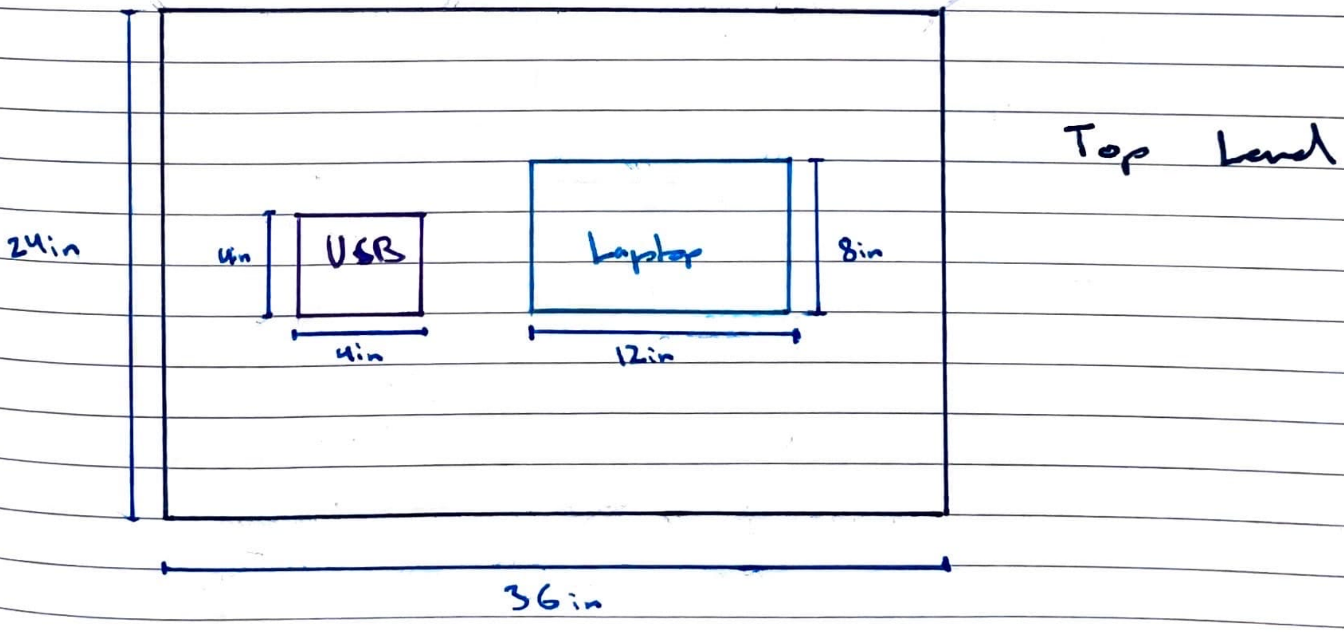
CV → 0.000582 ppm SWV → 0.00046244 ppm (Similar) ✓

Day 100 11/23/22

- Multiplexer Arrangement for ETU LO CCFs 4:1 Scale

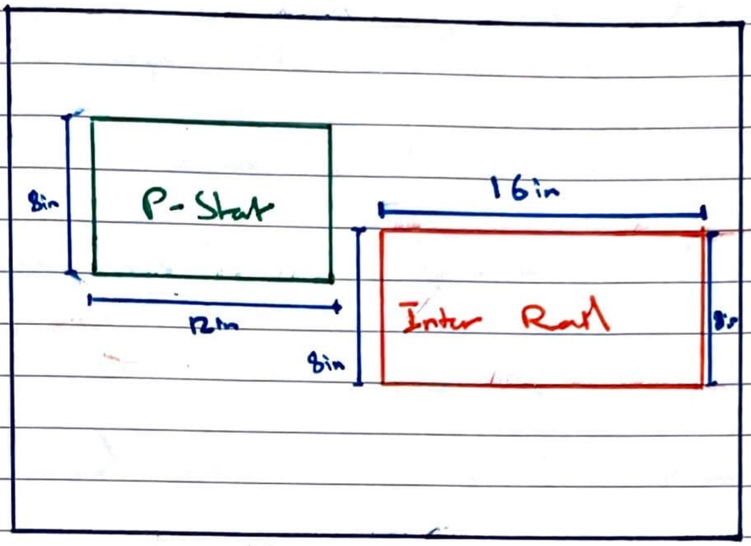


- Pathway Circuitry



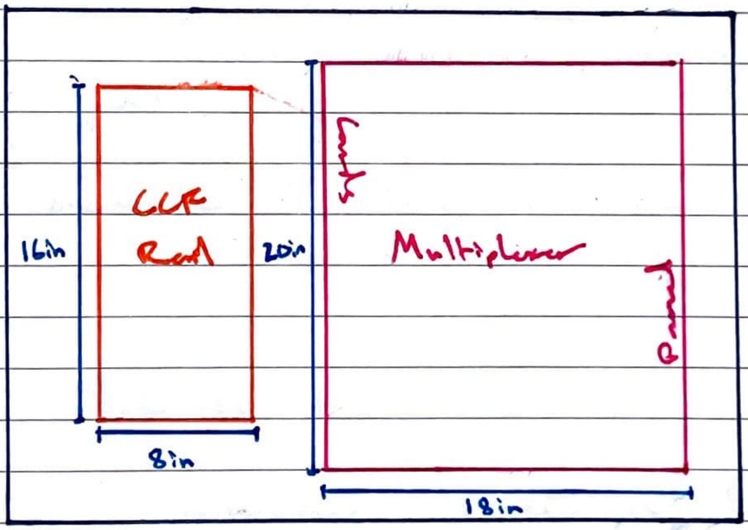
Day 101 11/28/22

- ETU CCF Physical Setup Pstat /Mux 4:1 Scale



Middle Level

- Connectors + Positions can be reoriented



Lower Level

Day 103 11/30/22

- Multiplexer terminal cable connection resistances

	Channel	High	Ω	Low	Ω
- Card 1: (30 ft) ETU	1	WE4	~~RE2~~ 0.4	RE2	0.4
	2	WE5	~~R~~0.4	RE2	0.3
	3	WE6	0.3	RE2	0.4
	4	WE~~8~~7	0.5	RE3	0.4
	5	WE8	0.4	RE3	0.4
	6	RE3	0.5	RE2	0.4
	7	RE2	0.3	RE3	0.3
- Card 3: (30/40) ETU/IMS	1	CE1	0.4	~	~
	2	CE9	2.4	~	~
- Card 2: (40 ft) IMS	1	WE12	0.7	RE10	0.4
	2	WE13	11.7	RE10	0.4
	3	WE14	0.5	RE10	✗
	4	WE15	0.5	RE11	0.4
	5	WE16	0.9	RE11	0.4
	6	RE11	0.4	RE10	0.3
	7	RE10	0.5	RE11	0.4

Measurements for the ETU CCF are pristine ✓

Low resistances encountered...

Stabalized around 0.4 Ω

Linear sweep voltammetry calibrations are successful!

Some measurements for the IMS CCF are out of range... ??

The low for channel 3 (RE10) is a failure ☹

The entire card was sabotaged by CE9 resistance drift. ;-;

Day 105 12/5/22

- Spent the weekend troubleshooting multiplexer
  - Rechecked connectors, ferrules increase quality
  - Card 3, channel 2, high CE9, measured high resistance
    ↳ moved to channel 3, fixed problem ✓
    (perhaps broken relay)
  - Card 2, channel 1+2^{+5}, highs WE12+13^{+16}, measured high resistance
    ↳ tightened connections^{x}, might have to move channels
    (be careful when sliding in card)
  - Card 2, channel 3, low RE 10, no connection
    ↳ found loose jumper on inter rail, fixed problem ✓
  - Card 2, channel 1+2+5, high W12+13+16, high resistance
    ↳ moved to channel 8+9+10 (switching card slots did not fix)
    ... compared to previous

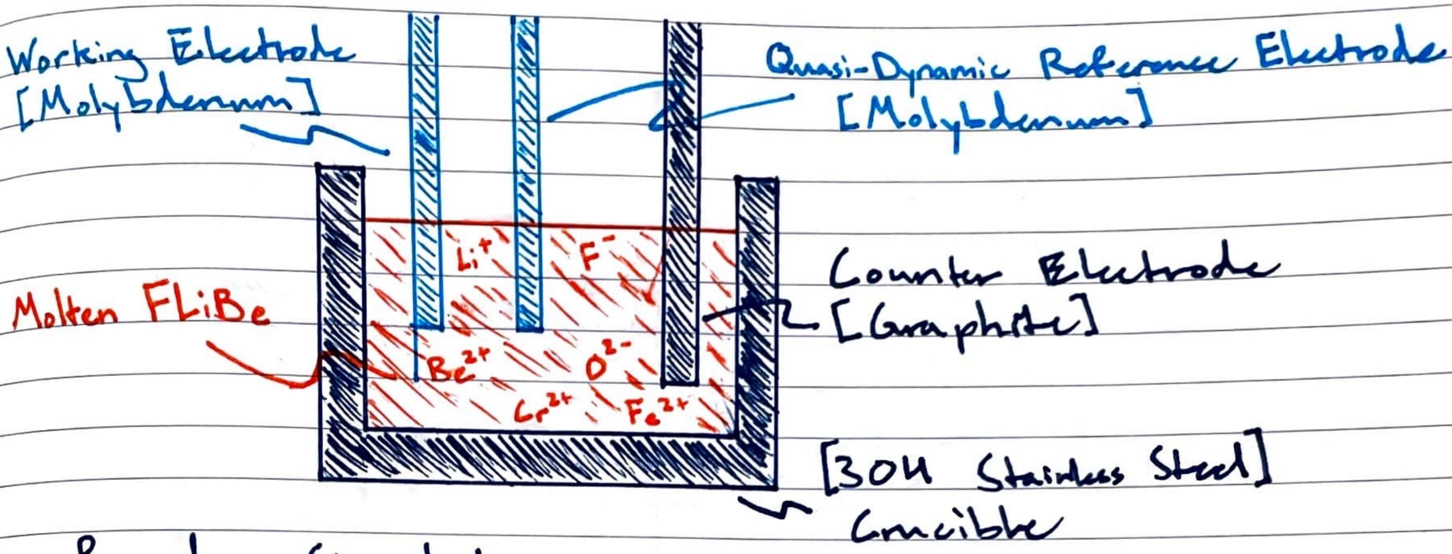
Channel	High	Ω	Low	Ω
1 → 8	WE12	0.3	RE10	0.3
2 → 9	WE13	0.4	RE10	0.2
5 → 10	WE16	0.3	RE11	0.3

For card 2...
... switching faulty relay channels fixed high resistances ✓
↳ Unfortunately, this means some relays within MUX might be broken :(

- I highly recommend purchasing additional cards for future repairs, modifications, or troubleshooting (broken pathways)
  - This will also increase the capabilities of the overall system ✓

Day 110 12/12/22

- ETU-ET Canary Representation



Render Simulation

- Direct Current Electrochemical Test Methods

Chronoamperometry: Cleans working electrode by forcing exterior layers to dissolve

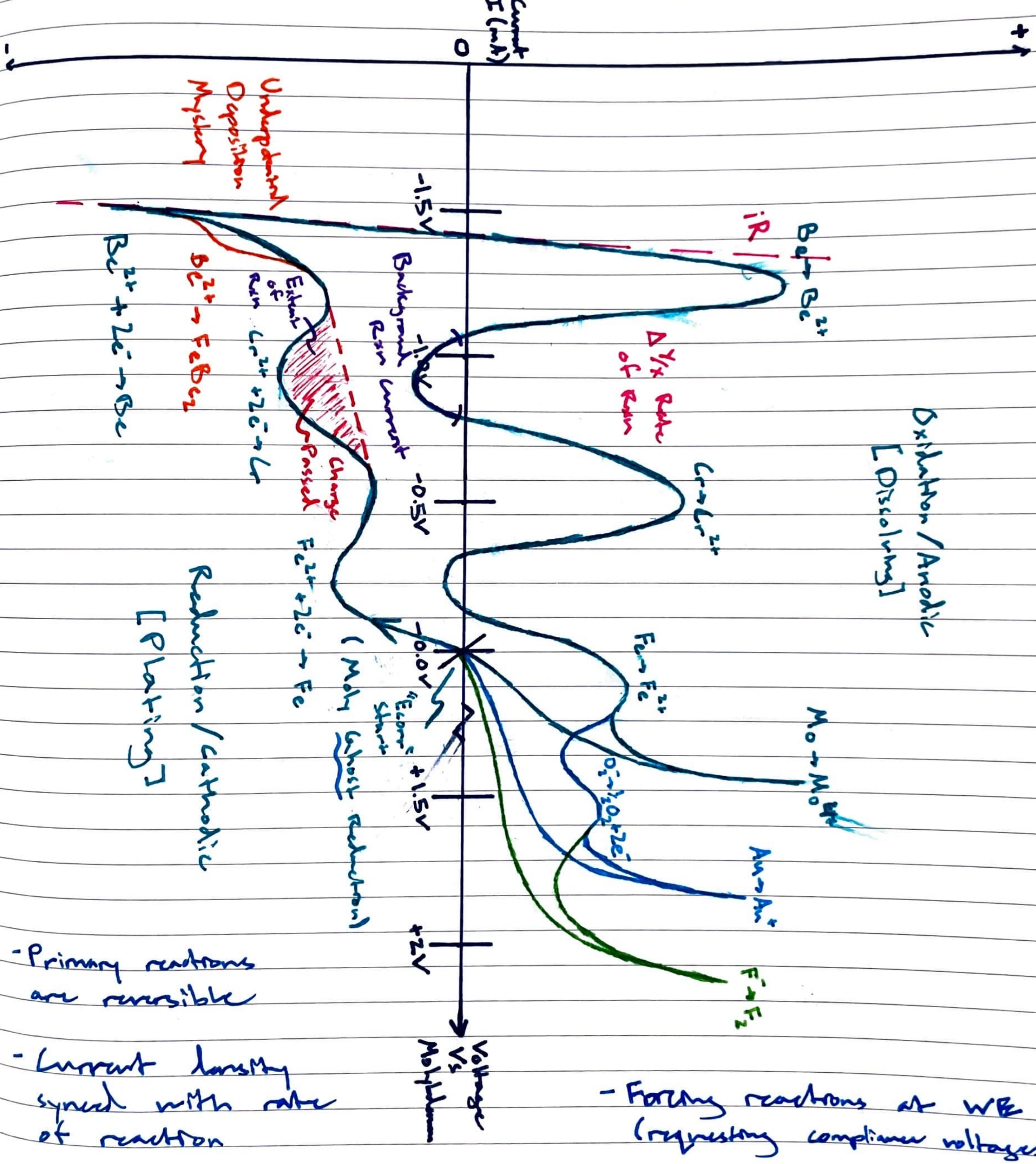
Chronopotentiometry: Plates working electrode with beryllium, then redissolves naturally, measuring redox potential

Cyclic Voltammetry: Plates multiple layers on the working electrode, then redissolves, establishing stability windows, extent of reactions, and rate of reactions

- Essentially forcing chemical reactions at the working electrode

Day 110 12/12/22

- FLiBe Electro Chemistry Visualized Cyclic Voltammetry



- Primary reactions are reversible

- Current density synced with rate of reaction

- Forcing reactions at WE (requesting compliance voltages)

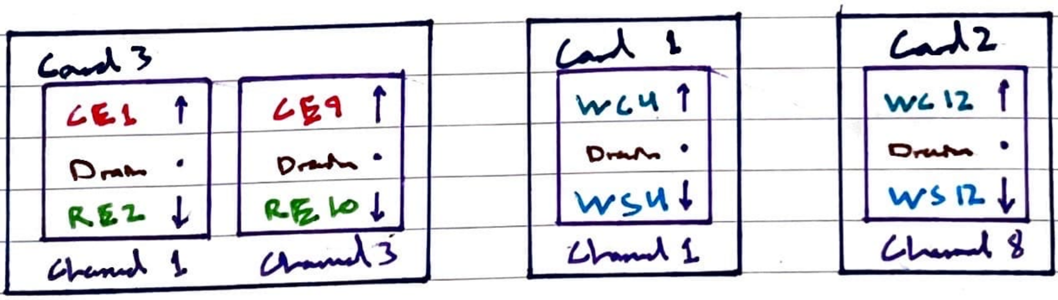
Day 111 12/13/22

- The objective for today is to test splitting the working wires and sense signals
- The momentary wired setup:

  C1c1 C3c1

  C2c8 C3c3

- Action required to convert system
  - Add RE2 to low of C3c1 ✓
  - Add RE10 to low of C3c3 ✓
  - Split WE4 on C1c1 to ↑WC4 and ↓WS4
  - Split WE12 on C2c8 to ↑WC12 and ↓WS12
  - Adapt wiring + connectors as needed
- Simplified card schematic + labeled diagram



- Electrochemical testing through multiplexer conducted
  ↳ similar to format as before
- Sequencing : OCP → Oxidation → Reduction → Chronoamp → CV (window)

Day 112. 12/11/22

- ETU 1.0 CCF Multiplexer Redesign ~~Shopping~~ Wish List

Wires + Cables: Long shielded cable 40 ft
(x15 x2 +5) x 40 ft = 1,400 ft

Intermediate shielded wire 4 ft
(x20 x2 +5) x 4 ft = 180 ft

Rail Terminals: Black for shield
(x30 x2 +5) = 65 terminals or units

Blue for WE designators
(x5 x2 +5) = 15 units

Green for RE designators
(x2 x2 +5) = 9 units

Red for CE designators
(x1 x2 +5) = 7 units

Grey for signal splitters
(x10 x2 +5) = 25 units

Connectors: Terminal Jumpers 10 long
(x5 x2 + 5) = 15 units

Ferrules for Rail Connectors
(x200 x2 +100) = 500 units

Keithley High Current Cards
(x3 x1 +3) = 6 units

Electrode Connector Rings
(x8 x2 +10) = 26 units

Day 113 — 12/15/22.

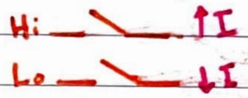
- Today some interesting ideas were covered and discovered regarding ETU LO LCF multiplexer design
- Specifically, it seems optimal to setup the Mux like so...

Card 1: ETU + IMS Counter / Reference

Card 2: ETU Working Current / Sense

Card 3: IMS Working Current / Sense

- The above design is...
  - The most efficient setup ✓
  - Allows card space for backups ✓
  - Enables the maximum maneuverability / adaptability ✓
  - Requires the least amount of physical wiring ✓ (reduces opportunities for failure)
  - High current applications still need to be tested through double relays



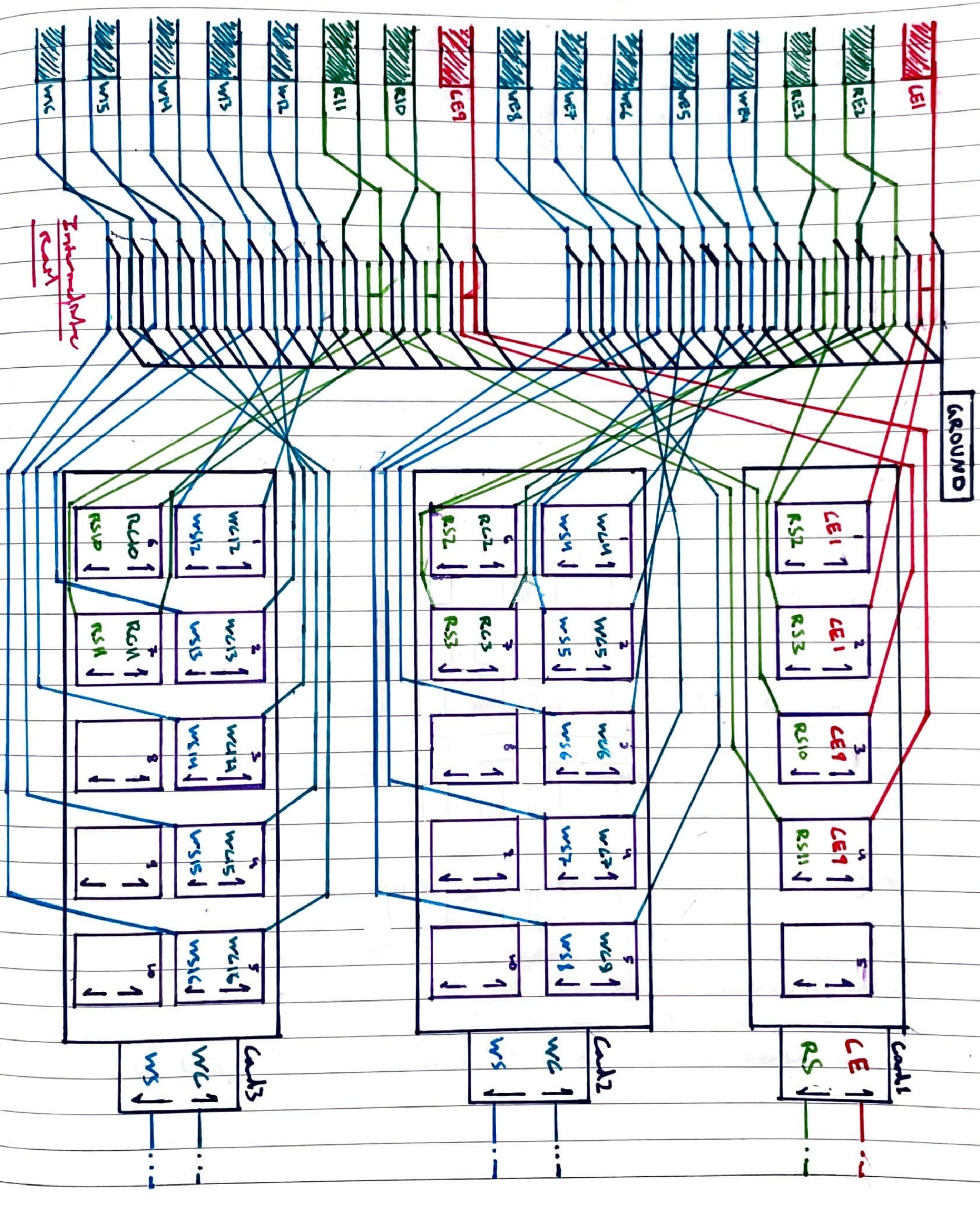
✗ or ✓ ?

→ ↳ Use SS CE to produce FeF_x (or perhaps even aqueous chemistry)

- Alternative designs consider housing the current and sense signals on different cards altogether, however those methods constrain us on many other different levels
- Similar problems arise when comparing the approach of Argonne National Laboratory, distinct problem statement altogether
- High current testing could include negative 2 A chronopotentiometry and studying counter electrode reactions... Impurities + Cr + CF_x + F_2 ?? (dangerous)

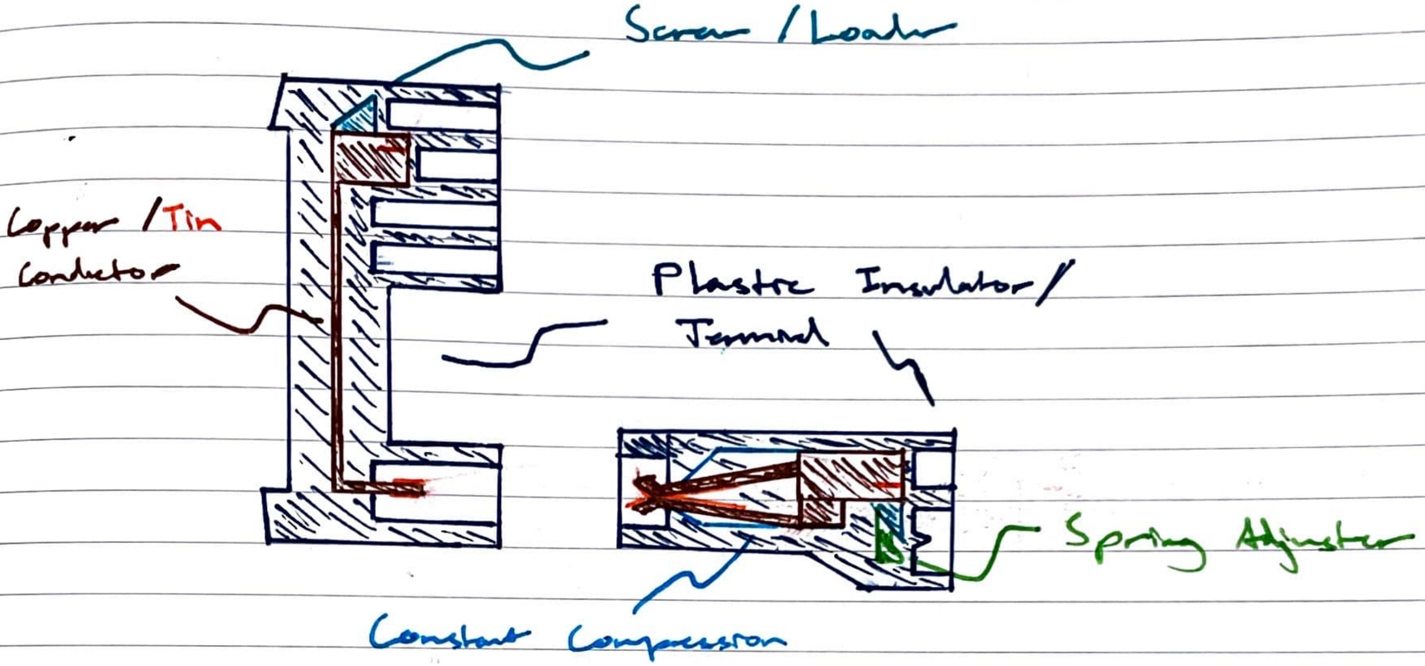
Day 114 12/16/22

- ETU 1.0 CCF Multiplexer Redesign Mk III



Day 116 12/20/22

- Terminal Block Plug & Play Sketch



- A new kind of terminal connection was discovered

- Pluggable terminals can be attached to a din rail
- Incorporating these terminals will...
    - Enable ultimate levels of versitility / adaptability
    - Eliminate the need for operator screws (Simple system to change)
    - Efficiently assemble + dissassemble setup
- Possible failure points increased downside
- Resistance compensated through potentiostat (sense pathway low current, negligable resistance)

Day 117 12/21/22

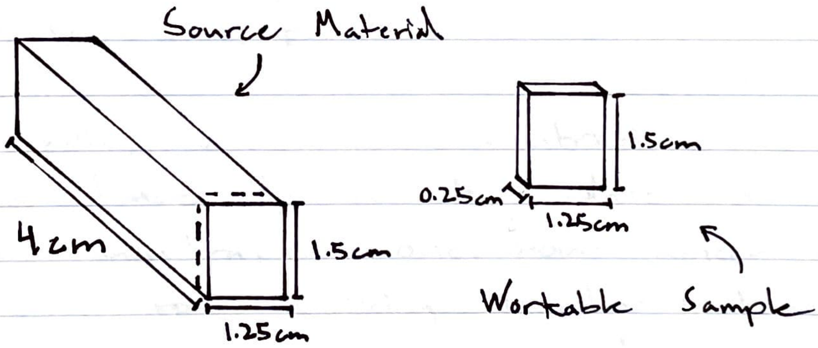
- Multiplexer Relay Precision Resistances

Channel	Highs (Ω)			Lows (Ω)		
	Card 1	Card 2	Card 3	Card 1	Card 2	Card 3
1	0.07	0.14	0.10	0.09	0.14	0.16
2	0.08	0.42	0.43	0.08	0.06	0.15
3	0.07	0.19	0.13	0.15	0.27	0.27
4	0.23	0.15	0.10	0.09	0.16	0.30
5	0.17	0.25	0.15	0.09	0.15	0.09
6	0.18	0.43	0.21	0.03	0.20	0.26
7	0.12	0.04	0.22	0.10	0.06	0.18
8	0.11	0.11	0.15	0.09	0.08	0.17
9	0.21	0.21	0.19	0.16	0.09	0.28
10	0.14	0.08	0.11	0.00	0.11	0.11

- Fluke 1507 insulation tester ~~was~~ utilized alone
- Multimeter had to be rezeroed several times due to potential drift
- Although all ohmage seems fine, previous tests correlate with resistance peaks here, possible scaling
- Applies instrumentational amplifying 5.25 V

Cutting 8/10/21

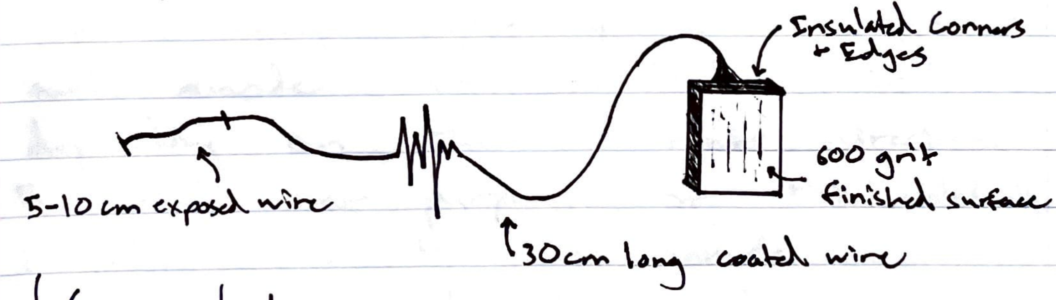
The first step in this electrochemical testing process is cutting raw material into workable sample sizes. Although other materials were already nicely formed into electrode shapes, Nitromax had to be cut. The Nitromax sources were all similarly shaped, 4 ~~cm~~ centimeter by 1.5 cm by 1.25 cm, resulting in a testable area of 1.875 cm^2.



Nitromax is an extremely hard metal alloy. This made the cutting process quite difficult, especially considering that only slow and precise methods could be used in order to avoid altering the heat treatment and destroying the sample.

Mohammad Samir Elassaad 8/15/21

Green liquid electrial tape developed by Gardner Bender was the optimal insulating material for this experiment. It is bright green, which makes it easy to identify and notice on small work areas. It is thick, preventing dripping and drooping, and it dries quickly. However, ~~it can be~~ the fumes that come off it can be nauseating. I reccomend working outside or in a well ventalated area. I covered corners and edges to eliminate electromagnetic field concentrators. A wire coating length of about 30 cm is sufficient, as long as there is some exposed wire at the end to connect to the potentiostat.

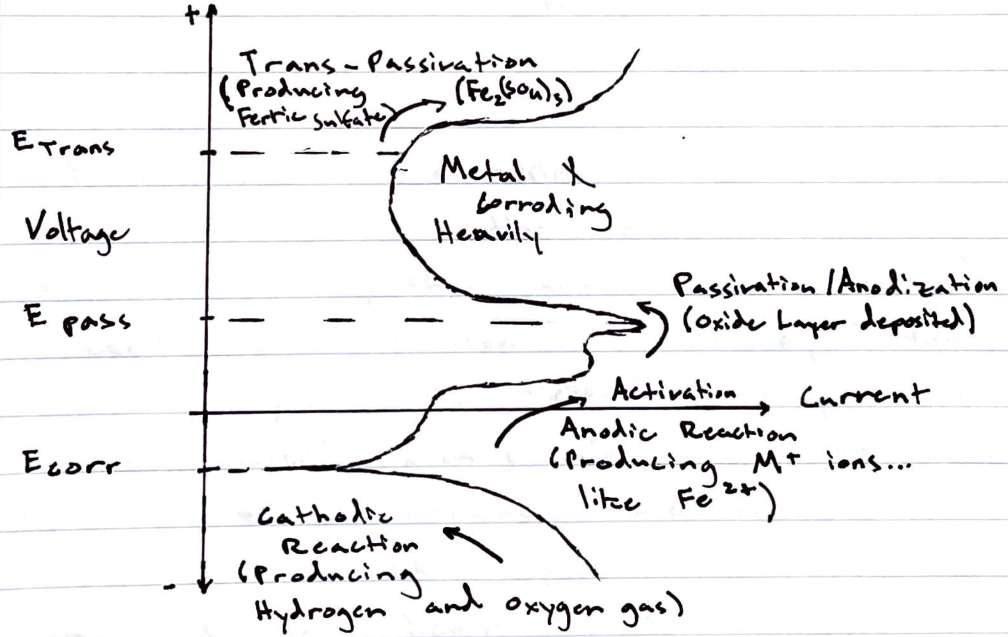


(Complete Electrode)

- M. S. Elassaad

Testing Continued. 8/25/21

I retested the X samples I did yesterday. Visually the data seems to be congruent for Nitromax Base Unknown, Norem 02, and Norem S8. Below is a sketch for a typicall steel current-voltage curve.



As can be seen above, there are three distinct potentials that mark ~~rotat~~ relevant reactions in this linear voltage sweep.

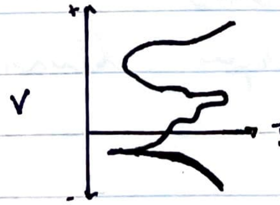
Mohammad Samir Blassaad 9/13/21

Even More Re-Testing 9/13/21

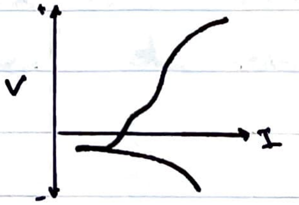
Today I got a large chunk of re-testing done as well as adding another Norem 02 sample to the data set.

I am encountering many problems and am discovering many solutions. First, an uneven polish ruins data. By this I mean, a sample with multiple polishes on its surface (different grits). The difference in depth results in pitting and ruins the sample and data. If a sample is polished, the entire surface needs to be completely polished.

As mentioned before, physical interference can throw off data and even the test itself. Rather than experiencing all parts of the corrosion curve, the sample goes straight from the cathodic reaction to pitting.



Good ✓



Bad X

Solutions & Reflections 9/17/21

I have completed all the necessary testing needed for analysis and reportation. I have completed the majority of the planned testing. In terms of Nitromax, I have collected robust repeatable data for H48 and H52 both at 1050°C and 1200°C. Professor smith will help me with analysis and assembling a report as well as a poster for presentation.

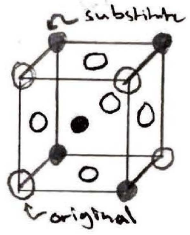
In terms of final notes on test methods, replacing the electrolyte with fresh solution seemed to help with reference overload. The professor suggested the electrolyte may have been contaminated with too many free ions. I deduce this is correct. Voltage start issues still occur(only when the cell is enabled). Tinkering with test settings did not help. Overall, I dedicated much of my life this summer into achieving and learning what I have. I look forward to future projects.

-M. S.

2. a) Solid solution strengthening utilizes a single phase while percipitation strengthening is multiphase.

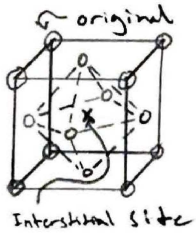
There are two types of solid solution strengthening. These are substitutional and interstitial. Both types involve editing the unit cell of a crystal lattice.

Substitutional replaces individual atoms in a unit cell with an alloying element of similar size. This creates small strains in the unit cell because the alloying element is slightly smaller or larger than the original element.



Here is the FCC unit cell with substitutional solid solution strengthening. The light atoms are the original element and the darke atoms are the slightly larger or smaller alloying elements.

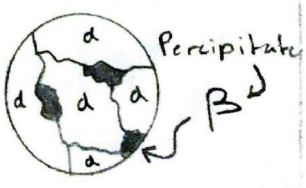
Interstitial inserts individual atoms of the alloying element into interstitial sites between the original atoms of a unit cell. This cramming act creates high strain within the lattice, much higher than substitutional, thus increasing strength.



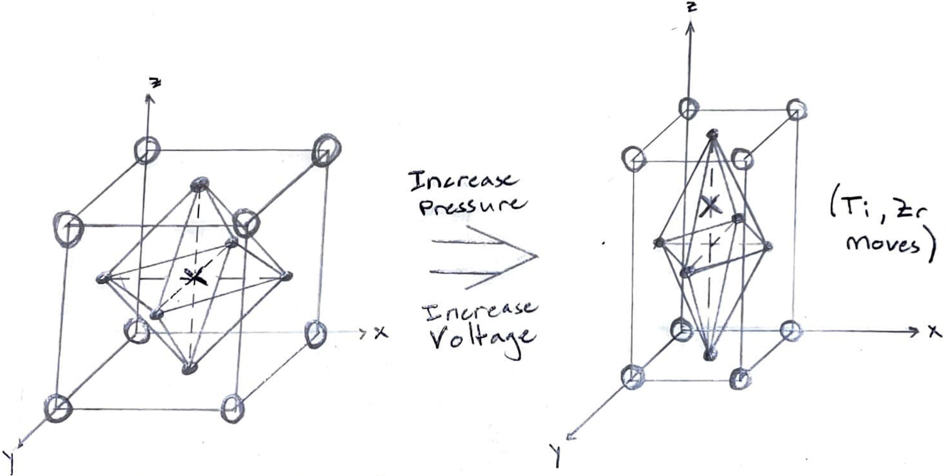
Here is the FCC unit cell displaying an octahedral interstitial site as an X. The original atoms are light circles. The outline of the atoms that touch the interstitial atom forms an octahedron in the FCC unit cell.

Percipitation strengthening occurs on a much larger scale. Now we are talking about different phases in the microstructure. This is a heat treatment. First a sample is heated up to a single phase temperature. Then it is quenched to keep the single phase at room temperature. Last it is naturally aged at room temperature or artificially aged at an elevated temperature. During aging, percipitates nucleate at grain boundaries and vacancies. These percipitates grow over time at certain temperatures which hinders dislocation movement, strengthening the sample.

Here is the microstructure for some generic percipitation strengthened alloy.



Lead Zirconate Titanate



○ = Pb (Lead)

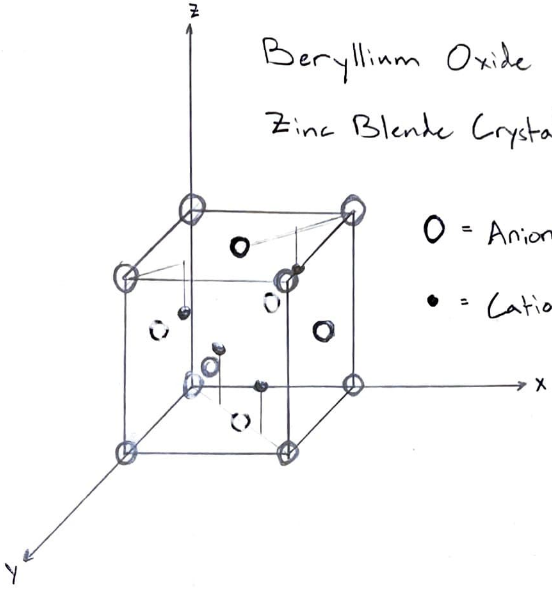
● = O (Oxygen)

X = Ti, Zr (Titanium, Zirconium)

1.

Beryllium Oxide (BeO)

Zinc Blende Crystal Structure



O = Anion - Oxygen

• = Cation - Beryllium

2.

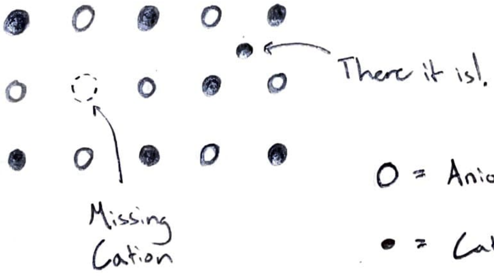
[Lattice] + [Basis]

Cubic F + 2 atoms / Lattice Point

Beryllium cations are $\frac{a_0\sqrt{3}}{4}$ <111> from oxygen anions.

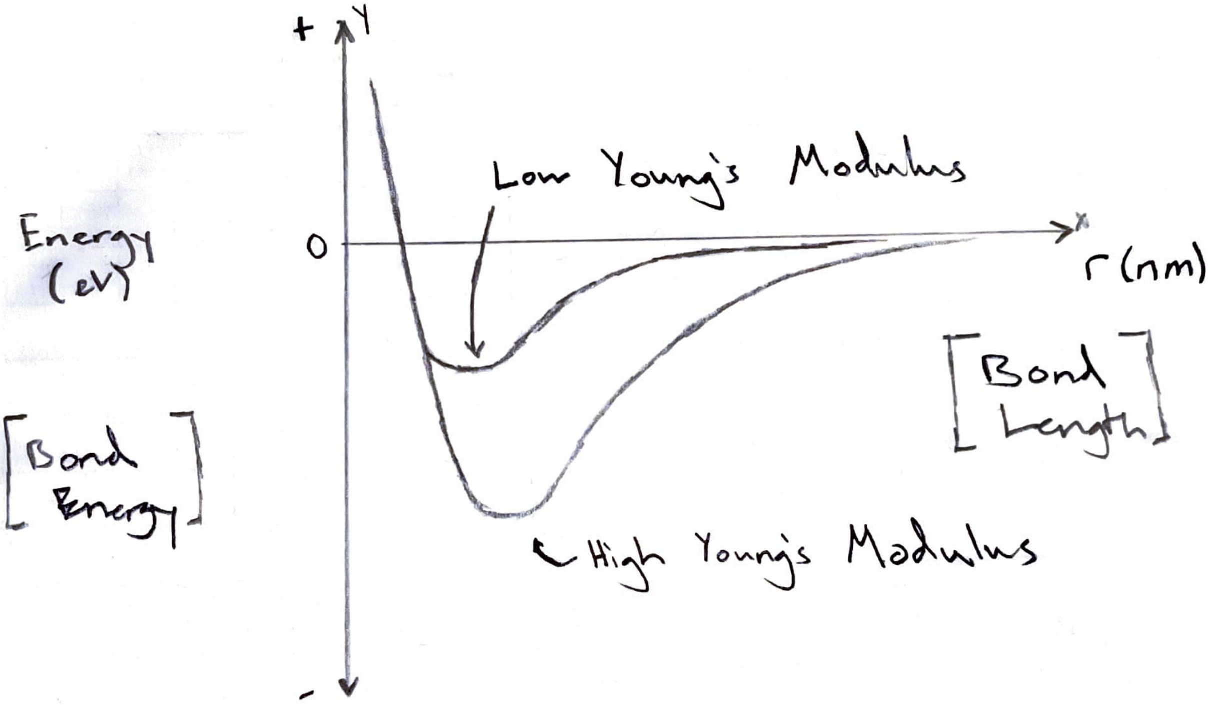
3.

Frenkel Defect



O = Anion - Oxygen

• = Cation - Beryllium



+
Y
Energy (eV)
0
-
[Bond Energy]
Low Young's Modulus
High Young's Modulus
x
r (nm)
[Bond Length]