

BioLogic Software & Instrumentation Guide

Chemistry 248 – Electrochemistry

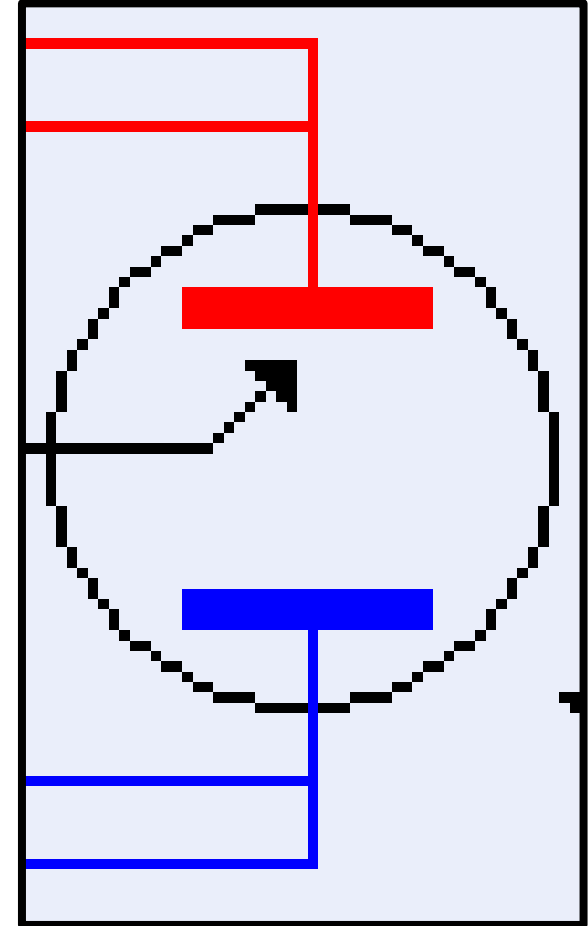
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BioLogic Software

Install the BioLogic software (EC-Lab) onto your compatible PC. Sorry Mac/Linux users, this software is only available on Windows.

Double-click the icon shown at the right to execute the program.

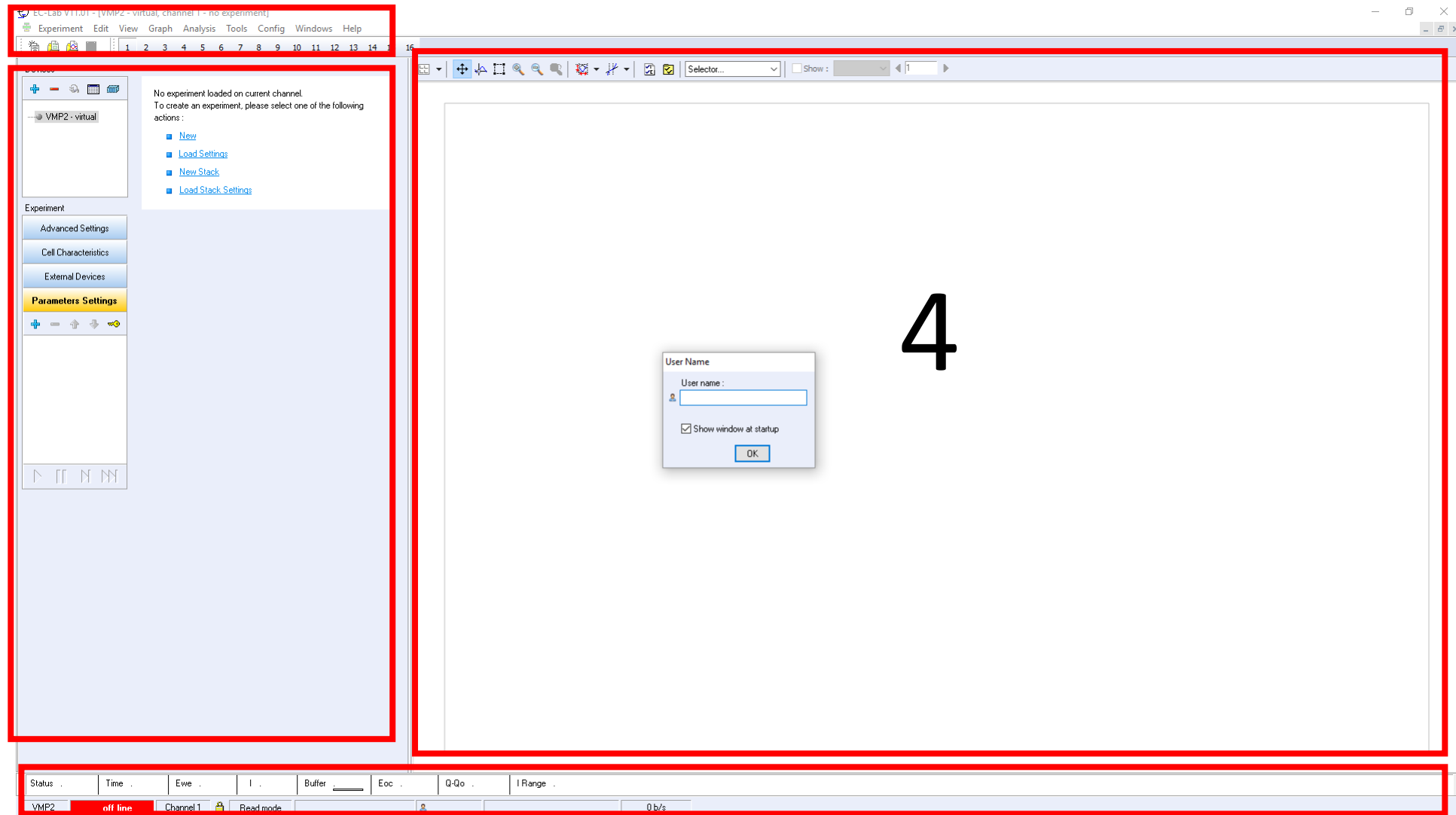


There are four main sections to pay attention to in EC-Lab... each one provides the scientist with a variety of information.

1

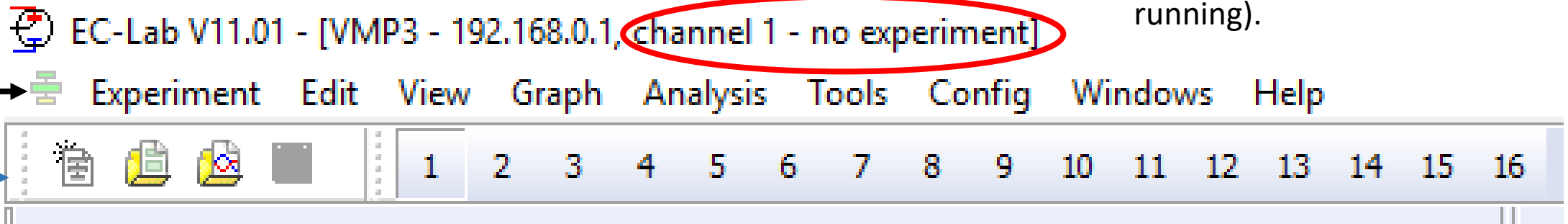
3

2



Section 1 – Top Toolbar

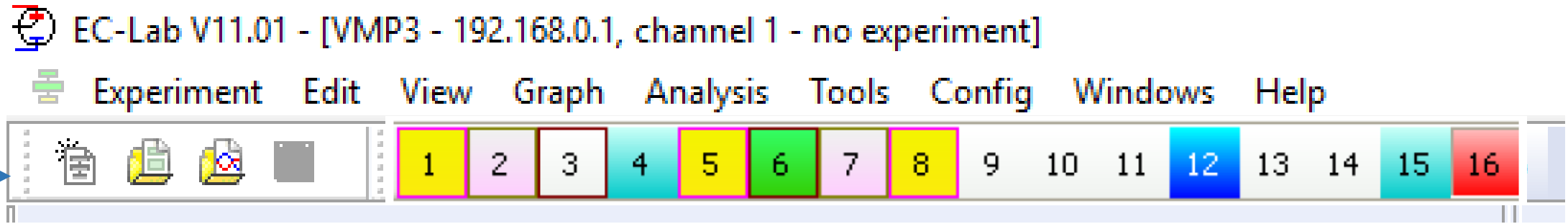
Information on the current channel # (which is the potentiostat #): status (running/non-running), which technique is active, and the file name that is currently being written (if running).



Toolbar – categories will be described as appropriate later

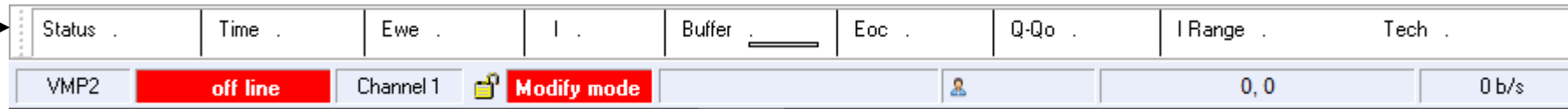
Sub-Toolbar – The left-hand side contains, in order, buttons for “a new experiment,” “load settings,” “load data,” and “save file.” The right-hand side contains numbers and provides information on the status of all channels connected to the potentiostat (the toolbar shown here is for a potentiostat with 16 channels; ours has 5 channels). A “depressed” button indicates that the channel is currently in use and clicking on it opens its settings/techniques (see [Section 3](#)).

Section 1 – Sub-Toolbar, Right Side



status - the running sequence of an experiment is in progress: **Oxidation/Charge**, **Reduction/Discharge**, or either oxidation or reduction in **impedance** technique, **Relax** for open circuit potential, **Paused** for a paused experiment and **stopped** for channel where an error happened.

Section 2 – Bottom Toolbar



Current channel's values panel – provides important information on the status of the current channel including

Status: informs user if experiment is currently under oxidation, reduction, paused, etc.

Time: displays the total elapsed time for all experiments performed on the channel

Ewe: displays the potential of the working electrode

I: displays the current being passed

Buffer: displays the buffer status of information flow from the potentiostat to the computer; *low numbers (single or double digit) are ideal and large numbers (thousands) are bad. If you fill up the buffer before the data can be written to your hard drive, any information exceeding the buffer limit will be lost; buffers fill when a lot of data is taken over a short amount of time.*

Status bar – provides a variety of information of lesser importance to the user including

VMP2: displays the model of potentiostat you are connected to

offline: displays the status of the connection to the potentiostat and of the currently selected channel

Channel 1: displays the current channel

person: displays the name of the user

etc.: ignore the rest of the information on the bar

Section 3

Device information. Provides information on connection to the potentiostat. →

Green: connected

Red: disconnect/unavailable

“+”: add a potentiostat

“-”: remove a potentiostat

On occasion to clear a software issue you will need to remove and then re-add the potentiostat to the **Devices** sub-section.

The screenshot displays a software interface for a potentiostat. The main window is titled "Devices" and contains a list of devices. A red box highlights the "VMP2 - virtual" device, which is currently connected (indicated by a green status icon). Below the device list, there are several buttons for "Experiment" settings: "Advanced Settings", "Cell Characteristics", "External Devices", and "Parameters Settings". The "Parameters Settings" section is currently active and shows various experimental parameters:

- Turn to OCV between techniques
- Rest for t_R = 0 h 0 mn 30.000 0 s
- Limit $|dE_{we}/dt| < dE_R/dt$ = 1.0 mV/h
- Record every dE_R = 1.0 mV
- or dt_R = 0.500 0 s
- E Range = -10 V; 10 V
- Resolution = 305.18 μV

At the bottom of the interface, there are control buttons for starting, pausing, and stopping the experiment.

Section 3

Experiment information. Provides tabs to control various parts of the experiment and to add techniques (+).

“+”: add a technique

“-”: remove a technique

Arrows: moves a highlighted technique up or down in the ordered sequence

“The Key Image” – allows one to enter “Modify mode” and modify most of the properties (settings, techniques, parameters, etc.). Some properties can be edited while the technique is running. If you click the key and update a property while the technique is running, you MUST click the key again to immediately implement the property change.

Devices

Turn to OCV between techniques

Rest for t_R = 0 h 0 mn 30.000 0 s

Limit $|dE_{we}/dt| < dE_R/dt$ = 1.0 mV/h

Record every dE_R = 1.0 mV

or dt_R = 0.500 0 s

E Range = -10 V; 10 V

Resolution = 305.18 μ V

Experiment

Advanced Settings

Cell Characteristics

External Devices

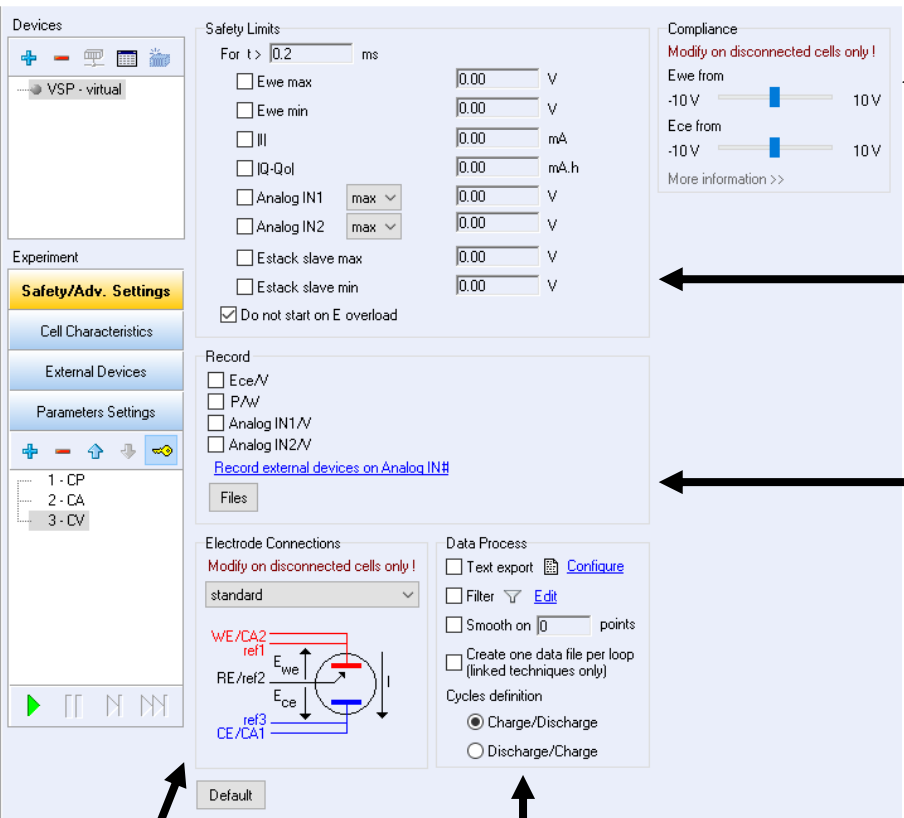
Parameters Settings

1 - OCV

2 - CV

3 - OCV

Section 3 – Sub A – Advanced Settings



Ignore this section for now

Compliance. Depending on the sensitivity of your experiment, too large of a potential can damage your materials, etc. Set as appropriate. Most users ignore this; we will ignore this for the hands-on discussion activities, but be aware that the compliance voltage is 10 V.

Safety limits. Depending on the sensitivity of your experiment, too large of a potential, current, and/or charge can damage your materials, etc. Most users ignore this; we will ignore this for the Discussion activities. But, **make sure to check the “Do not start on E overload” box.**

Record information. BioLogic is one of few, if not the only, potentiostat manufacturer that allows you to simultaneously record potential information at the working and counter electrodes! **Check the box for “Ece/V” to record the potential of the counter electrode. You should treat this as an essential step when setting up a measurement.** While it is technically not necessary to do so, recording the potential of the counter electrode can be a helpful diagnostic when issues arise. *It is not a matter of if issues will arise, but of when issues will arise!* You can ignore everything else under “Record”.

Electrode connections. This section allows you to adjust the internal connections of the potentiostat for greater customization of electronic configuration(s). Keep it in “**standard**” mode, unless otherwise directed. Also, the diagram below the drop-down box shows how to configure your electronic connections and what cables should go to your working, counter, and reference electrodes.

Section 3 – Sub B – Cell Characteristics

Devices

Cell Description

Electrode material

Initial state

Electrolyte

Comments

Electrode surface area 0.001 cm²

Characteristic mass 0.001 g

Battery Corrosion

Equivalent Weight 0.000 g/eq.

Density 0.000 g/cm³

Reference Electrode

Ag/AgCl / KCl (sat'd)

Offset potential vs. Normal Hydrogen Electrode: 0.197 V

Experiment

Safety/Adv. Settings

Cell Characteristics

External Devices

Parameters Settings

1 - CP

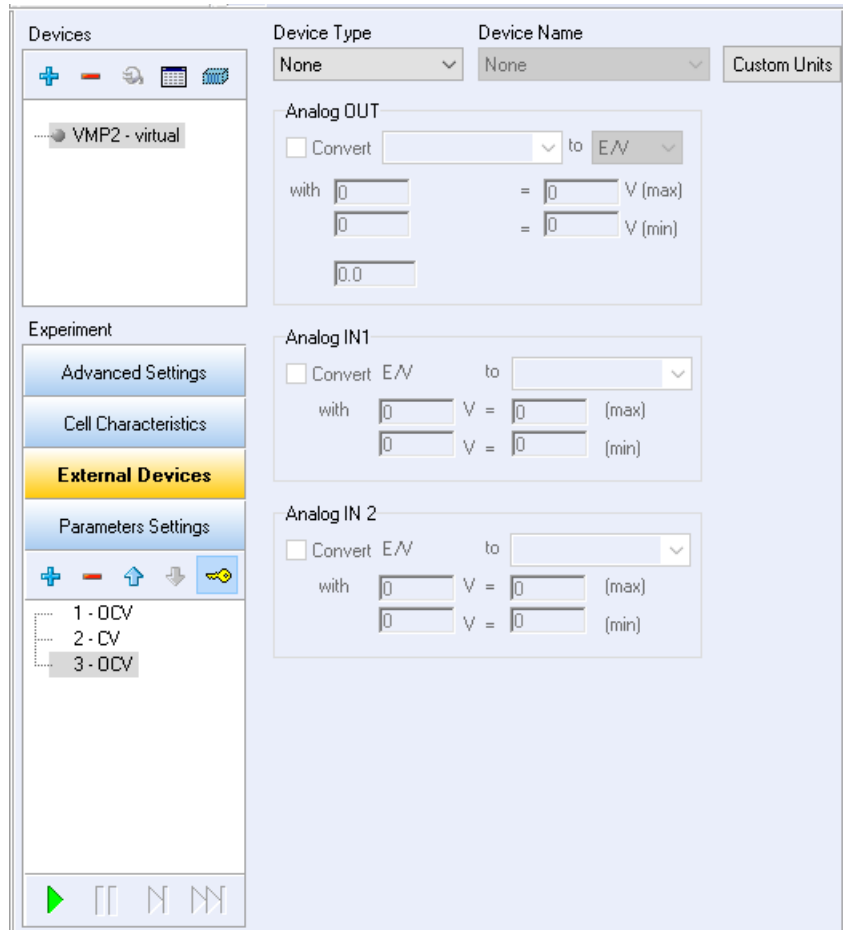
2 - CA

3 - CV

← **Cell description.** You can ignore this section, unless you plan to use a more specific feature in EC-Lab. As an example, you can use EC-Lab to calculate values like current density provided that you enter information about the surface area of your electrode.

← **Reference electrode information.** You can set the type of reference electrode you are using here. Its potential *versus* NHE will be displayed and each of your plots will have this reference noted on its potential axis.

Section 3 – Sub C – External Devices



← **External devices subsection.** You can ignore this section, unless you plan to use and control an external device(s), either alone or in tandem with your electrochemical experiments (e.g. rotating electrodes, pH meters, thermocouples, etc.).

Section 3 – Sub D – Parameter Settings

The screenshot displays the software interface for parameter settings. On the left, the 'Devices' panel shows 'VMP2 - virtual'. Below it, the 'Experiment' panel lists '1 - OCV', '2 - CV', and '3 - OCV', with '3 - OCV' selected. The main area shows a settings window for the selected technique. At the top, a checkbox 'Turn to OCV between techniques' is checked. The settings include: 'Rest for t_R ' set to 0 h 0 mn 30.000 0 s; 'Limit $|dE_{we}/dt| < dE_R/dt$ ' set to 1.0 mV/h; 'Record every dE_R ' set to 1.0 mV; 'or dt_R ' set to 0.500 0 s; and 'E Range' set to -10 V; 10 V. A resolution of 305.18 μV is noted at the bottom.

← You will need to pay attention to this subsection as it controls all the parameters that dictate your experiment! Available parameters are dependent on the electrochemical technique currently selected. Details are provided for specific electrochemical techniques (see Section 3, Sub E).

Section 3 – Sub E – Techniques

Devices

Turn to OCV between techniques

Rest for t_R = 0 h 0 mn 30.000 0 s

Limit $I_{dE_{we}}/dt < dE_R/dt$ = 1.0 mV/h

Record every dE_R = 1.0 mV

dt_R = 0.500 0 s

E Range = -10 V; 10 V

Resolution = 305.18 μ V

Experiment

Advanced Settings

Cell Characteristics

External Devices

Parameters Settings

1 - OCV

2 - CV

3 - OCV

Insert Techniques

Electrochemical Techniques

- Voltamperometric Techniques
 - Open Circuit Voltage - OCV
 - Special Open Circuit Voltage - SOCV
 - Cyclic Voltammetry - CV
 - Cyclic Voltammetry Advanced - CVA
 - Linear Sweep Voltammetry - LSV
 - Chronoamperometry / Chronocoulometry - CA
 - Chronopotentiometry - CP
 - Staircase Voltammetry - SV
 - Large Amplitude Sinusoidal Voltammetry - LASV
 - AC Voltammetry - ACV
 - Levich plot
- Impedance Spectroscopy
- Pulsed Techniques
- Technique Builder
- Ohmic Drop Determination

Electrochemical Applications

- Batteries Testing
- Supercapacitor
- Photovoltaic/Fuel Cells
- Corrosion
- Custom Applications

Insert Technique

Before

After

Load from default

Advanced setting

Cell characteristics

External devices

Custom Applications

Rename Add Remove Stack

OK Cancel

Voltamperometric Techniques. For our hands-on discussion activities, we will use techniques under this drop-down list almost exclusively, namely OCV, CP, CA, and CV. Moreover, you are likely to need these techniques if you perform electrochemistry in your own labs. Feel free to peruse the other sections.

Section 3 – Sub E' – Techniques

OCV – Open-Circuit Voltage

◆ *Cannot be changed while the experiment is running*

((Galvanostatic) Chronopotentiometry at $I_s = 0$)

Set a limit to the change in potential over time (dE_R/dt). Setting a limit here can often result in experiments ending prematurely. Thus, it is common to eliminate this limit by setting it to 0.

Set the potential range of an experiment and by doing this, control and display the potential *Resolution*.

The screenshot shows a software window with the following settings:

- Turn to OCV between techniques
- Rest for t_R = 0 h 0 mn 30.000 0 s
- Limit $|dE_{we}/dt| < dE_R/dt$ = 1.0 mV/h
- Record every dE_R = 1.0 mV
- or dt_R = 0.500 0 s
- E Range = -2.5V; 2.5V
- Resolution = 100 μ V

Set the length of time the experiment is performed

Set how often the potential is recorded. **Only record based on time (dt_R) and thus, leave dE_R blank.** (If dE_R is too small and the data has rapid fluctuations, e.g. noise, potential will be recorded very often.) **Recording data too quickly/often can fill the buffer.**

Section 3 – Sub E' – Techniques

CP – (Galvanostatic) Chronopotentiometry ◆ *Cannot be changed while the experiment is running*

Advanced sequencing option to link a sequence of multiple runs ◆

Set limitations to prevent damage or safety issues as appropriate; “pass” means to skip it. ◆

Set the potential and current ranges. ◆

In a “quick and dirty” experiment usually use “Auto” (I Range) or the default setting (E Range). However, when the ranges are known, set them in order to maximize the resolution of your signals (signal-to-noise).

Turn to OCV between techniques

0

Apply $I_s = 50.000 \mu\text{A}$ vs. $\langle \text{None} \rangle$
for $t_s = 0$ h 0 mn 10.0000 s

Limits $E_{we} > E_M = \text{pass}$ V
 $\Delta QI > \Delta Q_M = 138.889$ nA.h

Record $\langle E_{we} \rangle$
every $dE_s = 0.0$ mV
or $dt_s = 1.0000$ s *average on 5000 points*

E Range = -2.5 V; 2.5 V \dots
Resolution = 100 μV

I Range = $100 \mu\text{A}$

Bandwidth = 5 - medium

Go back to sequence $N_s = 0$ *(9999 ends technique)*
for $n_c = 0$ time(s) *(0 for next sequence)*

Set the current (I_s); perform the experiment for a given amount of time (t_s).

◆ Record the **average potential** ($\langle E_{we} \rangle$) every time period (dt_s). **Never record raw potential (E_{we})**, because each data point is only measured over $200 \mu\text{s}$, and thus is very noisy.

◆ Advanced sequencing option to link a sequence of multiple runs

Section 3 – Sub E' – Techniques

CA – (Potentiostatic) Chronoamperometry / Chronocoulometry

Advanced sequencing option to link a sequence of multiple runs



Turn to OCV between techniques

+ 0 -

Apply E_i = 0.350 V vs. Ref

for t_i = 0 h 0 mn 10.0000 s

Limits I_{max} = pass mA

I_{min} = pass mA

$|\Delta Q| > \Delta Q_M$ = 0.000 mA.h

Record <I>

every dt_a = 0.1000 s

E Range = -2.5V; 2.5V Resolution = 100 μ V

I Range = Auto

Bandwidth = 5 - medium

Go back to sequence N_s = 0 (9999 ends technique)

for n_c = 0 time(s) (0 for next seq.)

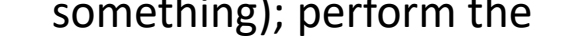
Cannot be changed while the experiment is running



Set the potential (E_i) (versus something); perform the experiment for a given amount of time (t_i).



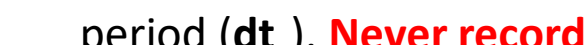
Record the **average current** (<I>) every time period (dt_a). **Never record raw current (I)**, because each data point is only measured over 200 μ s, and thus is very noisy.



Advanced sequencing option to link a sequence of multiple runs



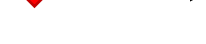
Set the potential and current ranges.



Set limitations to prevent damage or safety issues as appropriate; "pass" means to skip it.



Set the potential and current ranges.



In a "quick and dirty" experiment usually use "Auto" (I Range) or the default setting (E Range). However, when the ranges are known, set them in order to maximize the resolution of your signals (signal-to-noise).

Section 3 – Sub E' – Techniques

CV – Cyclic Voltammetry

◆ *Cannot be changed while the experiment is running*

Set initial potential (E_i) ◆

Turn to OCV between techniques

Set E_{we} to E_i = V vs.

◆ E versus reference (Ref) or measured open-circuit potential (E_{oc}) (or previous controlled potential (E_{ctrl}) or measured potential (E_{meas}))

Set scan rate (dE/dt)

Scan E_{we} with dE/dt = mV/s

Set E_1 , to scan from E_i to E_1

to vertex potential E_1 = V vs.

Set E_2 , to scan back from E_1 to E_2

Reverse scan to vertex E_2 = V vs.

Repeat n_c = time(s)

Repeat n_c times and thus, scan a total of $(n_c + 1)$ times, e.g. $n_c = 5$ would scan 6 times

Measure average current at the end of the potential step (50% is standard.) Repeat ($N - 1$) more times and average them; value affected by RC.

Measure $\langle I \rangle$ over the last % of the step duration

Record $\langle I \rangle$ averaged over N = voltage steps

E Range =

Resolution = 100 μ V

I Range =

Bandwidth =

◆ Set the potential and current ranges.

Bandwidth performs a sort of hardware filtering that removes noise associated with RC of your circuit. **Keep it at 8 unless you know what you are doing!** Set final, ending potential (E_f)

End scan to E_f = V vs.

Force E_1 / E_2 (dE/dt ~ 100 μ V / 5 ms)
(dEN ~ 1.0 mV)
(4000 points per cycle)

In a "quick and dirty" experiment usually use "Auto" (I Range) or the default setting (E Range). However, when the ranges are known, set them in order to maximize the resolution of your signals (signal-to-noise).⁷

Section 3 – Sub E' – Techniques

PEIS: Potentio(static) Electrochemical Impedance Spectroscopy

Cannot be changed while the experiment is running

Set initial potential (E_i)
Time before measurement, needed for current to stabilize at the given potential (t_E)

Range of highest (f_i) to lowest (f_f) frequency
Number of points per decade of frequencies (N_d). Determines the total length of experiment and resolution of data obtained

Delay before each frequency (p_w)
Repeat measurement at same frequency (N_a). Set to 1

Bandwidth performs a sort of hardware filtering that removes noise associated with RC of your circuit. **Keep it at 8 unless you know what you are doing!**

Turn to OCV between techniques

Excitation signal mode: Single sine

Set E_{we} to $E = 0.0000$ V vs. E_{oc}
for $t_E = 0$ h 0 mn 0.000 s
 Record every $dI = 0.000$ mA
or $dt = 0.000$ s

Scan from $f_i = 200.000$ kHz to $f_f = 100.000$ mHz
with $N_d = 6$ points per decade
in Logarithmic spacing
sinus amplitude $V_a = 10.0$ mV ($V_{rms} \sim 7.07$ mV)
wait for $p_w = 0.10$ period before each frequency
average $N_a = 2$ measure(s) per frequency
drift correction
Repeat $n_c = 0$ time(s)

E Range = -10 V; 10 V
Resolution = 305.18 μ V
I Range = Auto
Bandwidth = 5 - medium (~ 1mn32s / scan)

Go back to seq. $N_s = 0$ (9999 ends technique)
for $n_r = 0$ time(s) (0 for next sequence)
 increment cycle number

E versus reference (Ref) or measured open-circuit potential (E_{oc}) (or previous controlled potential (E_{ctrl}) or measured potential (E_{meas}))

Click here to get the list of frequencies used

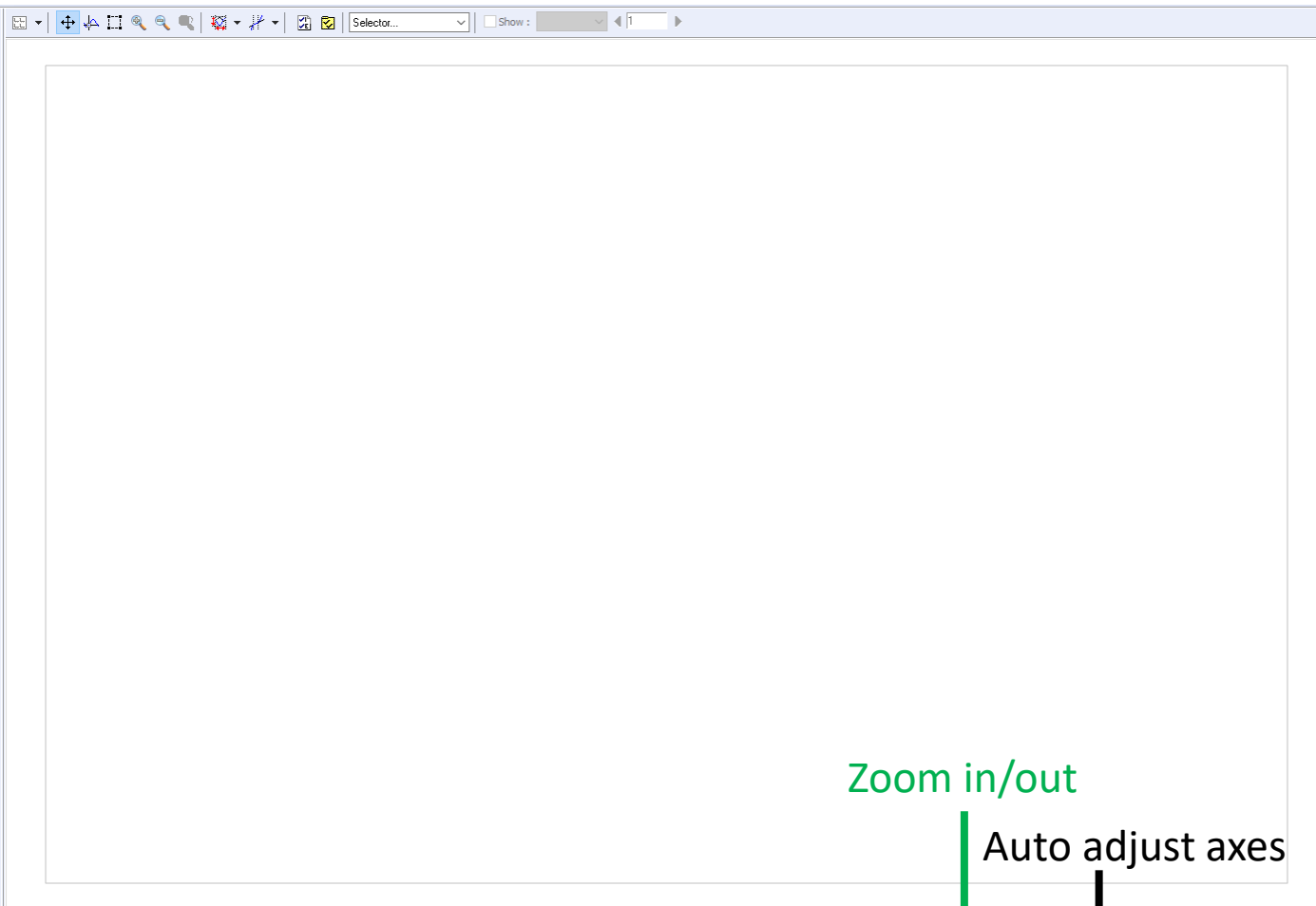
Amplitude of sine wave (V_a). 10 mV is a good amplitude as it will not perturb the system significantly, and that is desired

Repeat n_c times and thus, scan a total of ($n_c + 1$) times

Set the potential and current ranges.

In a "quick and dirty" experiment usually use "Auto" (I Range) or the default setting (E Range). However, when the ranges are known, set them in order to maximize the resolution of your signals (signal-to-noise).

Section 4



← **Graph tool bar.** Provides a variety of tools to manipulate the related graph. More information below.

← **Graph.** Your graph will appear here. You can manipulate your image after you have selected a tool. You can right click your mouse here to get to many advanced options for further customization.

Cycle plot selector. Allows choice in what is plotted in the Graph section. You can choose to plot all cycles or one specific cycle.

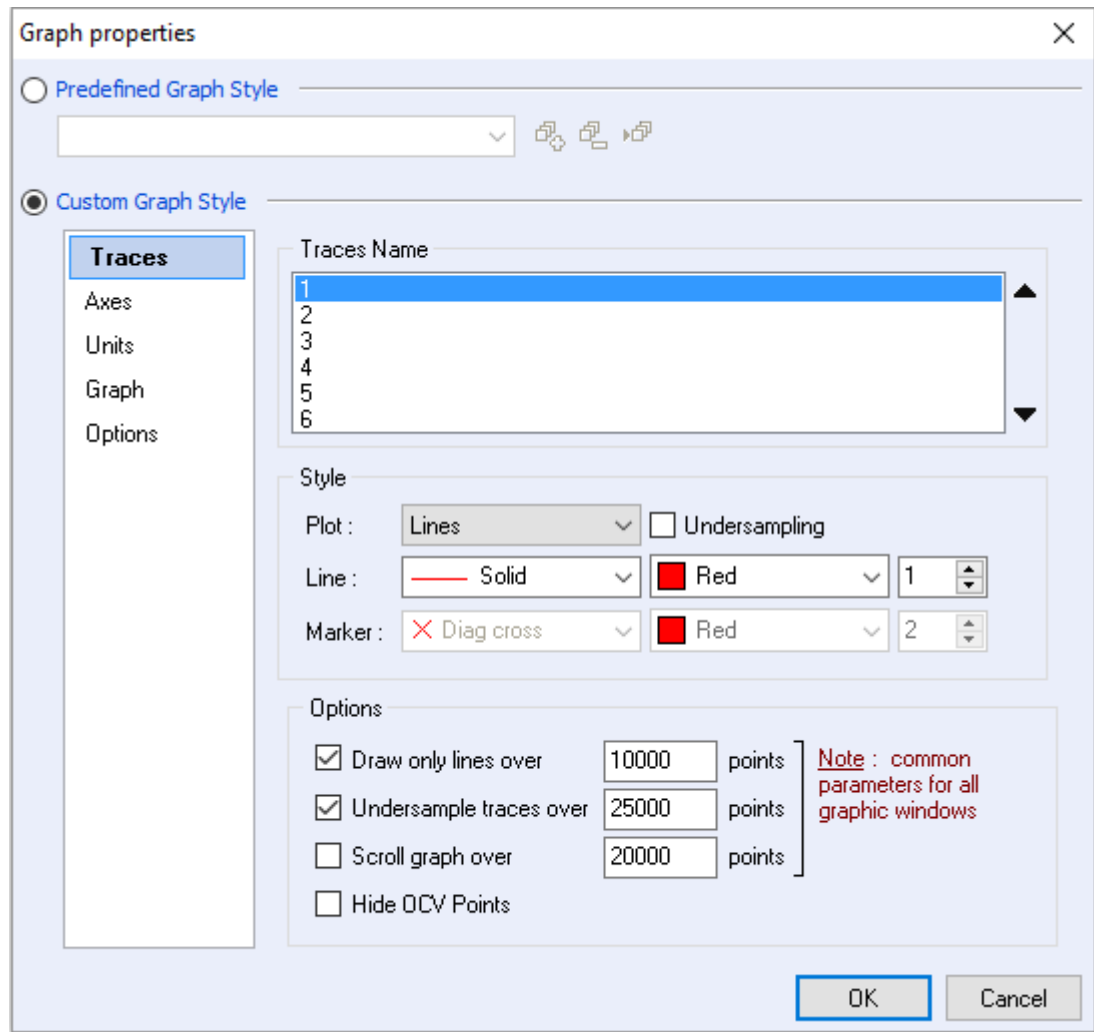
Zoom in/out
Auto adjust axes
Cursor location tool (to get x and y coordinates)
Select points within box



Selector. Allows choice in what variables to plot. Examples: I-V, J-V, I-t, V-t, Q-t, etc.

Section 4 – Graph Properties

Right mouse click on graph or type ALT+P



Traces. Allows one to select and change the line/marker style, color, line thickness, and under-sampling of each trace.

Axes. Allows one to select and change the axes title, scale, range, font, and font size.

Units. Allows one to select and change the size of the unit (e.g. MV or V or mV), reference electrode, mass & surface area of the working electrode, etc.

Graph. Allows one to select and change the legend and title styling.

Options. Allows one to select and change the graphing conventions from IUPAC to a less historically consistent convention that should never be used, unless you are from Texas. **Make sure “Positive oxidation (standard IUPAC convention)” is selected.**