UV-Vis Spectroscopy and Cyclic Voltammetry of Quinones in Buffered Aqueous Solution

Abstract:

Our laboratory studied both the electrochemical properties and the time-dependent stabilities of selected quinones using Cyclic Voltammetry (CV) and UV-Vis Spectroscopy, respectively. In CV, each quinone was solubilized at varying concentrations in an aqueous solvent of phosphate buffer (pH 7) using tetrabutylammonium tetrafluoroborate as an electrolyte. We focused on documenting both the formal reduction potential values and the ratio between peak current values. When subjected to a potential, TCBQ was calculated to have the lowest formal reduction potential under our experimental conditions. HNQ exhibited the highest calculated formal reduction potential value. A 1:1 ratio between the peak current values, as seen with HNQ, indicated a fully reversible system, whereas non 1:1 ratio, as in MBQ indicated a less than reversible reaction. These results signified that quinones with a lower formal reduction potential value exhibit higher electrochemical reactivity than those with higher formal reduction potential values. Additionally in UV-Vis analysis, either 10% ethanol or methanol was added to phosphate buffer (pH 7) in order to increase solubility. Each quinone was solubilized in this buffer solution at a 0.1mM concentration, and the absorbance values were analyzed for 24 hours. Similarly, it was found that HNQ had the least variation in peak absorption value over 24 hours, while MBQ had the greatest peak absorption fluctuation. Therefore, our findings correlated to previous documentation of quinone biological reactivity in inducing protein modifications.

Introduction:

Previous experimentation by this laboratory and others has indicated that quinones have the ability to detrimentally affect biological functioning \cite{1,4,9,12,15,19,20}. Therefore, the purpose of these experiments was to expand upon previous findings by looking at the stability of individual isolated quinones, both their immediate electrochemical properties and their time-dependent characteristics, through the utilization of Cyclic Voltammetry and UV-Vis Spectroscopy, respectively.

Prior studies suggest that quinones have the ability to illicit cytotoxic effects when introduced into a biological system – the effects of which are propagated by certain principal mechanisms. As evidenced through the utilization of Cyclic Voltammetry, quinones have varying reduction potentials, the varying values of which give insights into how readily the quinone will be reduced when a negative potential is applied to the system \cite{2,5,7}. In general, the more readily a quinone can be reduced, the higher the quinone’s comparative reactivity. In a biological system, more reactive quinones are also likely to be reduced to a semi-quinone radical form.
This can lead to effects such as oxidative damage to a living cell and interference in the electron transport chain, the results of which can be catastrophic to cellular function [11,15,20]. Additionally, quinones can bond to the body’s proteins through nucleophilic addition reactions, forming a compound known as an adduct. This adduct formation disrupts the structure of proteins, thereby inhibiting their biological functioning [4]. Thirdly, the presence of quinones can induce protein oligomerization, in which the misfolding of proteins leads to the formation of protein aggregates, the result of which also greatly inhibits the protein’s proper function [4,19].

Due to the ubiquitous nature of quinones in our daily lives, the experimentation performed by our laboratory is focused on understanding why these particular biological mechanisms of cytotoxicity occur by analyzing the comparative reactivities and stabilities of two quinone families, benzoquinones and naphthoquinones. Through the use of Cyclic Voltammetry and UV-VIS Spectroscopy, we are able to describe the electrochemical reactivities and time-dependent stabilities of individual quinones in order to gain insight into their reactions within a biological environment.

Cyclic Voltammetry

The Cyclic Voltammetry (CV) apparatus allows us a method of comparatively studying the reactivity of a quinone species in isolation, to further address the mechanisms by which individual quinones illicit their biological reactions. CV is a method of electrochemistry that allows us to experimentally determine the formal reduction potential of a species [5,7,8]. The CV apparatus consists of multiple electrodes, including a working electrode, a reference electrode, and an external reference electrode encapsulated in a KCL solution, all of which are submersed in the sample quinone solution [2,3,6,7,16].

The chemical mechanism of CV is classified as “surface chemistry,” meaning that all oxidation-reduction reactions occurring in the experiment take place at the interface between the surface of the electrode and the solution directly around the electrode, rather than throughout the bulk solution [2,3,5,6,13,18]. The CV experimentation functions by first reducing a species, then in turn, re-oxidizing it. Initially, the quinone exists in solution as a fully oxidized species. Through the CV’s cathodic electrode, an increasingly negative potential is applied to the sample solution in order to reduce the species, until the point at which all of the quinone species at the solution-electrode interface has been fully reduced [6,13,21]. Graphically, a peak is seen at this point, representing both the peak cathodic current value and the peak cathodic potential value – the voltage value at which all species are reduced and the resulting current. Once the species has
been fully reduced, an increasingly positive potential is applied at the CV’s anode to re-oxidize
the species, producing a similar graphical peak potential and peak current.

This graphical representation of resulting peak values, in particular the peak reduction
potential values, are the means by which we compare the quinones’ reactivities to one another
[2,5,13]. Potential, or voltage (E), is the driving force of an electrochemical system in that it
causes the movement of electrons that either reduces or oxidizes the system of interest. When a
positive voltage is applied, the system is oxidized at the anode of the electrode; when a negative
potential is applied, the system is reduced at the electrode’s cathode [3,6,7]. For this reason, it is
important to always measure the supplied potential from the working electrode versus the
external reference electrode [3].

Of particular interest is the reduction potential of a half-cell (the cathode or anode), or the
half-cell’s tendency to acquire electrons, or be reduced. Therefore the formal reduction potential
of a redox-coupled reaction can be calculated using the Randles-Sevcik equation:

\[ i_p = (2.69 \times 10^5)n^3A^2CD^2v^{1/2} \]

in which we see that the peak current value \((i_p)\) is directly proportional to the surface area of the
electrode \((A)\), the concentration of the solution \((C)\) and the square root value of the sweep rate
\((v^{1/2})\) [5,7,13]. The current is a measured value of the flow of electrons as a result of the redox
reaction, and therefore the current value gives us a measurement of the rate of the reaction. In a
theoretically reversible reaction, we expect the cathodic and anodic peak currents to exist in a
relatively 1:1 ratio [13]. Therefore, the formal reduction potential gives insight into the relative
reactivity of each quinone species, while the ratio between peak current values shows whether the
system of interest is fully reversible, quasi-reversible, or perhaps irreversible when a potential is
applied.

**UV-Vis Spectroscopy**

The UV-Vis Spectroscopy instrumentation functions by breaking apart a beam of light
from a UV or visible light source into its component wavelengths. This single source wavelength
is subsequently split into two light beams of equal intensity – one beam passes through a cuvette
containing the quinone sample of interest, and the second beam passes through a cuvette
containing only the solvent of use (the standard reference) [10]. The UV-Vis Spectrometer
measures and compares the intensity of these light beams in reference to the absorption \((A)\) of
each beam [10]. The reference beam experiences no absorption, so the absorption value of each
studied sample is compared to this \(I_0\) value [10]. If the studied sample absorbs light, then the
sample’s intensity value (I) will be less than $I_0$ – this difference is then represented graphically, as absorbance vs. wavelength [10].

Furthermore, the presence of chromophores in the quinone sample molecule greatly affects the absorbance spectra. A chromophore is a part of the molecule responsible for the molecule’s color, in that it absorbs certain wavelengths of light and reflects others [17]. Even small variations (or time-dependent changes) in the structure of the molecule, such as the reductive addition of a hydrogen to a previously double-bonded oxygen, can result in noticeable differences in the resulting UV-Vis Spectra.

The Beer-Lambert Law is used to analyze the data seen in the UV-Vis spectra. The equation, which states $A = e \times b \times c$, implies that the reported absorbance ($A$) is directly proportional to the absorptivity coefficient ($e$), the path length of the light through the cuvette ($b$), and the concentration of the solution ($c$) [10].

There our laboratory chose to additionally utilize the methodology of UV-Vis spectroscopy in analyzing the time-dependent reactivity of these selected quinones because we could view the quinone’s changing structure over time in the phosphate buffer solution by looking to the varying absorbance values as reported in the comparative spectra.

**Safety Concerns:**

Throughout the research, it was critical to take several precautions both to ensure the validity of the investigation and the safety of the researchers. All experiments were carried out with safety goggles and gloves on the researcher, since various quinones are known biological toxins and protein modifiers. Furthermore, all glassware, laboratory equipment, and experimental surfaces were thoroughly cleaned with ethanol before and after each procedure to prevent cross-experiment contamination. All chemical waste were collected and properly handled according to the Safety Rules of the Department of Chemistry and MSDS information. In specific regards to CV experiments, to avoid any electric shock, the potentiostat was used in accordance with the manufacturer's instructions. Additionally, great care was taken when cleaning the electrodes with diluted solution of $\text{H}_2\text{SO}_4$ since it is an acid and a skin irritant.

**Experimental Procedure/Materials:**

For these experiments, all chemical materials such as quinones, ethanol, methanol, materials for phosphate buffer solution, argon gas, and materials for cleaning solution of the CV apparatus were purchased from Fisher. The deionized water used in this study was purified using a Millipore system. In order to gather data using Cyclic Voltammetry, we placed samples in an
approximately 50 mL glass vial and utilized Potentiostat software. To obtain data on UV-Vis Spectroscopy, we placed the samples in a 1 cm x 1 cm quartz cuvette and used a Shimadzu Biospec-1601 spectrophotometer.

_Cyclic Voltammetry Analysis of Quinones in Solution_

In order to prepare each quinone sample, a standard procedure was used to ensure uniformity through the experimentation process and is described as follows. The appropriate amount of quinone needed to make a stock solution was weighed (see table below) and transferred directly to a volumetric flask of appropriate volume (see table below). Each quinone sample was diluted to the volumetric flask fill line using a phosphate buffer (50.0 mM, pH 7) and then sonicated until dissolved. The appropriate aliquots of stock solution (see table below) was transferred to a plastic vial with a blue cap, and diluted further to the 15 mL line with phosphate buffer. The following table specifies the appropriate measurements, concentrations, and volumes for each experiment:

**Table 1**

<table>
<thead>
<tr>
<th>Quinone</th>
<th>Volumetric flask size</th>
<th>Sample weighed</th>
<th>Stock solution concentration</th>
<th>Final Concentration</th>
<th>Aliquot of quinone stock</th>
</tr>
</thead>
<tbody>
<tr>
<td>CBQ</td>
<td>10 mL</td>
<td>0.0143 g</td>
<td>10.0 mM</td>
<td>3.0 mM</td>
<td>4500 µL</td>
</tr>
<tr>
<td>FBQ</td>
<td>50 mL</td>
<td>0.0092 g</td>
<td>1.0 mM</td>
<td>1.0 mM</td>
<td>To 15 mL line, not diluted</td>
</tr>
<tr>
<td>MBQ</td>
<td>10 mL</td>
<td>0.0122 g</td>
<td>10.0 mM</td>
<td>3.0 mM</td>
<td>4500 µL</td>
</tr>
<tr>
<td>PBQ</td>
<td>10 mL</td>
<td>0.0108 g</td>
<td>10.0 mM</td>
<td>3.0 mM</td>
<td>4500 µL</td>
</tr>
<tr>
<td>TCBQ</td>
<td>50 mL</td>
<td>0.0123 g</td>
<td>1.0 mM</td>
<td>1.0 mM</td>
<td>To 15 mL line, not diluted</td>
</tr>
<tr>
<td>HNQ</td>
<td>10 mL</td>
<td>0.0174 g</td>
<td>10.0 mM</td>
<td>3.0 mM</td>
<td>4500 µL</td>
</tr>
<tr>
<td>ONQ</td>
<td>50 mL</td>
<td>0.0079 g</td>
<td>1.0 mM</td>
<td>1.0 mM</td>
<td>To 15 mL line, not diluted</td>
</tr>
<tr>
<td>PNQ</td>
<td>25 mL</td>
<td>0.0158 g</td>
<td>10.0 mM</td>
<td>3.0 mM</td>
<td>4500 µL</td>
</tr>
</tbody>
</table>

The prepared solution was then transferred to a CV sample glass vial with black cap in order to be utilized by the CV apparatus.

Before CV testing, the solution was flushed with argon for 5 minutes, using two hypodermic needles both to deliver the gas and allow excess oxygen to escape inserted in the septum, and then parafilmed to create an air-tight seal to prevent re-oxygenation. The sample was then immediately capped, and taken to the CV-apparatus for testing.
Lengthy conditional optimization experiments were performed in order to determine the appropriate potential windows and sweep rates (measured in mV/s) used for testing, the significance of both are expressed in the Randles-Sevcik equation. In general, the following sweep rates were applied to each quinone sample, with 3-5 trials of each being performed to maximize data accuracy: 10, 25, 50, 75, 100 mV/s. The optimal potential window parameters were specific to each quinone, but were consistently between the values of -1 to 1 mV.

**UV-Vis Spectroscopy Analysis of Quinones in Solution**

For the preparation of each quinone sample, a standard procedure was also used to ensure uniformity through the experimentation process and is described as follows. The appropriate amount of quinone needed to make a stock solution was weighed (see table below) and transferred directly to a volumetric flask of appropriate volume (see table below). Each quinone sample was diluted to the volumetric flask fill line using a solvent of either 10% ethanol or methanol phosphate buffer (50.0 mM, pH 7) and then sonicated for 30 seconds to maximize solubility. The quinone stock solution was transferred to a beaker, and the appropriate aliquots were pipetted into the sample cuvette for a total of 1.0 mL (1000 µL) of solution in each cuvette to result in a 0.1 mM concentration. The following table specifies the appropriate measurements, concentrations, and volumes for each quinone experiment:

**Table 2**

<table>
<thead>
<tr>
<th>Quinone</th>
<th>Volumetric flask size</th>
<th>Sample weighed</th>
<th>Stock solution concentration</th>
<th>Aliquot of quinone stock</th>
<th>Aliquot of buffer (pH 7)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CBQ</td>
<td>25 mL</td>
<td>0.0071 g</td>
<td>2.0 mM</td>
<td>50 µL</td>
<td>950 µL</td>
</tr>
<tr>
<td>FBQ</td>
<td>25 mL</td>
<td>0.0092 g</td>
<td>2.0 mM</td>
<td>50 µL</td>
<td>950 µL</td>
</tr>
<tr>
<td>MBQ</td>
<td>25 mL</td>
<td>0.0061 g</td>
<td>2.0 mM</td>
<td>50 µL</td>
<td>950 µL</td>
</tr>
<tr>
<td>PBQ</td>
<td>25 mL</td>
<td>0.0081 g</td>
<td>3.0 mM</td>
<td>33 µL</td>
<td>967 µL</td>
</tr>
<tr>
<td>TCBQ</td>
<td>200 mL</td>
<td>0.0049 g</td>
<td>0.1 mM</td>
<td>1000 µL</td>
<td>0 µL</td>
</tr>
<tr>
<td>HNQ</td>
<td>25 mL</td>
<td>0.0087 g</td>
<td>2.0 mM</td>
<td>50 µL</td>
<td>950 µL</td>
</tr>
<tr>
<td>ONQ</td>
<td>25 mL</td>
<td>0.0079 g</td>
<td>2.0 mM</td>
<td>50 µL</td>
<td>950 µL</td>
</tr>
<tr>
<td>PNQ</td>
<td>25 mL</td>
<td>0.0079 g</td>
<td>2.0 mM</td>
<td>50 µL</td>
<td>950 µL</td>
</tr>
</tbody>
</table>

Three cuvettes were prepared for each trial in order to triplicate the data, and the standard reference cuvette was prepared by pipetting into it 1000 µL of the utilized solvent. 

Each cuvette was scanned once every hour, for 24 hours, in order to analyze the quinone’s stability over a 24-hour timeframe.
Results:

Cyclic Voltammetry Analysis of Quinone Species

Figure 1.1a

Figure 1.1b

Figure 1.2a

Figure 1.2b

Figure 1.3a

Figure 1.3b

The above figures represent data collected from the Cyclic Voltammetry analysis of naphthoquinones, HNQ, ONQ, and PNQ respectively, at varying concentrations dissolved in phosphate buffer (pH 7) and flushed with argon gas for 5 minutes. Figures 1.1a, 1.2a, and 1.3a illustrate the reversibility of the system by graphing the peak current values, both cathodic and anodic, to the square root value of the sweep rate, in order to analyze whether or not a 1:1 ratio...
exists. Figures 1.1b, 1.2b, and 1.3b illustrate the peak potential values and the peak currents values, both upon reduction and oxidation, as produced by the Potentiostat.

**Figure 2.1a**

![Sweep Rate vs. Peak Current 3.0 mM CBQ](image)

**Figure 2.1b**

![All Sweep Rates 3.0 mM CBQ](image)

**Figure 2.2a**

![Sweep Rate vs. Peak Current 1.0 mM FBQ Time 0 5 min Ar (septum)](image)

**Figure 2.2b**

![meb-2-59 1.0 mM FBQ, 5 min Argon (septum) All Sweep Rates](image)

**Figure 2.3a**

![Sweep Rate vs. Peak Current 3.0 mM MBQ](image)

**Figure 2.3b**

![Sweep Rate Comparison 3.0 mM MBQ](image)

**Figure 2.4a**

![Sweep Rate vs. Peak Current 3.0 mM PBQ](image)

**Figure 2.4b**

![Sweep Rate Comparison 3.0 mM PBQ](image)
The above figures represent data collected from the Cyclic Voltammetry analysis of benzoquinones, CBQ, FBQ, MBQ, PBQ, and TCBQ respectively, at varying concentrations dissolved in phosphate buffer (pH 7) and flushed with argon gas for 5 minutes. Figures 2.1a, 2.2a, 2.3a, 2.4a, and 2.5a illustrate the reversibility of the system by graphing the peak current values, both cathodic and anodic, to the square root value of the sweep rate, in order to analyze whether or not a 1:1 ratio exists. Of note, Figure 2.5a does not contain a graphical representation of Peak Cathodic Current values because there were no discernable cathodic peak current values, as seen in Figure 2.5b. Figures 2.1b, 2.2b, 2.3b, 2.4b, and 2.5b illustrate the peak potential values and the peak currents values, both upon reduction and oxidation, as produced by the Potentiostat.

Figures 3.1 and 3.2 are graphical overlays of quinones at 1.0 mM and 3.0 mM respectively, at a sweep rate of 50 mV/s, in order to visually compare the relative peak potential (anodic and cathodic) values of each quinone species. The following table is a tabular representation of the graphical data, ordered from most negative formal reduction potential to most positive formal reduction potential:
Table 3

<table>
<thead>
<tr>
<th>Quinone</th>
<th>Cathodic Peak Current (μA)</th>
<th>Anodic Peak Current (μA)</th>
<th>Cathodic Peak Potential (mV)</th>
<th>Formal Reduction Potential (mV)</th>
</tr>
</thead>
<tbody>
<tr>
<td>HNQ (3.0mM)</td>
<td>-27.0</td>
<td>26.3</td>
<td>-402</td>
<td>-347</td>
</tr>
<tr>
<td>PNQ (3.0mM)</td>
<td>-11.7</td>
<td>9.63</td>
<td>-197</td>
<td>-149</td>
</tr>
<tr>
<td>ONQ (1.0mM)</td>
<td>-5.23</td>
<td>5.51</td>
<td>-81.2</td>
<td>-58.5</td>
</tr>
<tr>
<td>MBQ (3.0mM)</td>
<td>-28.0</td>
<td>15.0</td>
<td>-91.5</td>
<td>53.8</td>
</tr>
<tr>
<td>FBQ (1.0mM)</td>
<td>-2.90</td>
<td>2.77</td>
<td>15.8</td>
<td>70.0</td>
</tr>
<tr>
<td>PBQ (3.0mM)</td>
<td>-31.8</td>
<td>23.5</td>
<td>-5.99</td>
<td>83.7</td>
</tr>
<tr>
<td>CBQ (3.0mM)</td>
<td>-32.8</td>
<td>26.3</td>
<td>38.1</td>
<td>98.4</td>
</tr>
<tr>
<td>TCBQ (1.0mM)</td>
<td>-10.7</td>
<td>Indiscernible</td>
<td>148</td>
<td>Indiscernable</td>
</tr>
</tbody>
</table>

UV-Vis Spectroscopy, 24 Hour Analysis of Quinone Species

For brevity, the reported UV-Vis Spectroscopy data will only include the data obtained using a 10% ethanol phosphate buffer solution, pH 7.

Figure 4

The above figure (Figure 4) illustrates the representative UV-Vis Spectroscopy data at Time 0 hour for a 0.1mM concentration of selected quinone in a 10% ethanol phosphate buffer solution (pH 7).
The above figure (Figure 5) represents the UV-Vis data collected at Time 24 hours for a 0.1 mM concentration of selected quinone in a 10% ethanol phosphate buffer solution.
Figures 6.1, 6.2, and 6.3 represent UV-Vis Spectroscopy data for 0.1 mM solutions of naphthoquinones, HNQ, ONQ, and PNQ respectively, in 10% ethanol phosphate buffer solution (pH 7), as analyzed over 24 hours.
Figures 7.1, 7.2, 7.3, 7.4, and 7.5 represent UV-Vis Spectroscopy data for 0.1 mM solutions of benzoquinones, CBQ, FBQ, MBQ, PBQ, and TCBQ respectively, in 10% ethanol phosphate buffer solution (pH 7), as analyzed over 24 hours.

The values of peak absorbance at Time 0 hour and Time 24 hour are consolidated as follows:

| Table 4 |
|-----------------|------------------|
| **Quinone** | **Peak Absorbance (A) at time 0 hour** | **Peak Absorbance (A) at time 24 hour** |
| CBQ | 1.496 | 0.505 |
| FBQ | 0.886 | 1.000 |
| HNQ | 1.786 | 1.579 |
| MBQ | 2.839 | 1.734 |
| ONQ | 0.019 | 0.110 |
| PBQ | 2.267 | 2.132 |
| PNQ | 2.183 | 1.812 |
| TCBQ | 1.478 | 2.235 |

**Discussion:**

To date, we have gathered evidence that closely supports previous findings on the biological reactivities of quinones when incubated with protein RNase A and analyzed with SDS-PAGE. In the following images, a 0.1mM RNase solution was incubated with a 5.0 mM concentration of the quinone of interest in phosphate buffer (pH7) at 37 degrees Celsius, for varying increments of time:

*Figure 9.1 [14]*  
*Figure 9.2 [14]*  
*Figure 9.3 [4,14]*
Figure 9.3, representing HNQ data, presents a uniform banding pattern at the bottom of the gel, which indicates that no discernable protein modification occurred when HNQ was incubated with the protein under these conditions. Therefore, this data suggests that HNQ is a relatively unreactive species in similar biological conditions. On the other hand, Figures 9.2 and 9.3 represent ONQ and PNQ respectively, incubated under identical conditions, yet varying bands are indeed present throughout the gel. This banding suggests that some protein modification, induced by the quinone was occurring.

Our laboratory used Cyclic Voltammetry and UV-Vis Spectroscopy to look at both the electrochemical and the time-dependent stabilities of each quinone species, in the effort to formulate conclusions about the various quinones’ stability over time and explain their reactions within a biological system. The significance of using a pH 7 phosphate buffer solvent was to comparatively analyze the quinones in a solution that closely mirrors physiological pH. When used in UV-Vis experiments, the addition of 10% ethanol or 10% methanol to the solvent was to promote quinone solubility in solution.

Our primary goal through quinone analysis using Cyclic Voltammetry was to establish a reactivity profile of the various quinone species in order to declaratively speak to their relative reactivities and stabilities; this information could then be used to make inferences concerning their actions in a biological system. Specifically, we look to the formal reduction potential values for each quinone in order to compare reactivities. The formal reduction potential value gives insight into how much negative potential applied to a species is required in order to reduce that species. Therefore, the more reactive a species is, the less negative potential is required to reduce it – in other words, it reduces more readily than a less reactive species. Therefore from Figures 3.1 and 3.2, we can assume that TCBQ is the most reactive quinone species, while HNQ is the least reactive in terms of applied potentials.

Additionally, we looked at the possible presence of a 1:1 ratio when comparing the peak cathodic and anodic current values, looking specifically at HNQ and MBQ (Figures 1.1a and 2.3a, respectively). HNQ is a relatively unreactive quinone both in isolation and in a biological system; therefore, it is a good example of a quinone that is reversible when it undergoes a redox reaction. This can be said with confidence due to the graphical analysis of looking at both the peak anodic and peak cathodic currents, when graphed against the square root of the sweep rate. Graphically, we see that the linear graphs are in a 1:1 ratio to one another – the absolute values of the slopes would be relatively equal. On the other hand, MBQ gives us an example of a species that is not reduced and oxidized in a 1:1 manner, as seen in the graphical representation, meaning that it is perhaps less than reversible or some unknown product is formed when reoxidized.
Concerning UV-Vis Spectroscopy analysis, this discussion will only analyze the data obtained from 3 quinones species, HNQ, ONQ, and PNQ, for the sake of brevity and in order to compare the data to previous biological findings from SDS-PAGE experimentation. As indicated through the graphical analysis of the UV-Vis spectra, we can see that HNQ displays no fluctuation of peak absorbance over a 24 hour period, while ONQ and PNQ display a significant fluctuation in peak absorbance values while in solution over a 24 hour time period. This data implies that while HNQ is relatively stable in a pH 7 environment over a 24 hour time span, ONQ and PNQ are relatively less stable in that their peak absorbances fluctuate. From this data, we can interpret that the affected quinones are undergoing some change, most likely being reduced in solution, which leads to the observed absorbance decrease. Furthermore, we could also see similar trends in absorbance fluctuations, to varying degrees, in the benzoquinone family species, implying similar differences in the species’ reactivities.

Conclusions:

To date, our experimentation has lead to several further insights on the reactivity and stability of selected quinones, both when analyzed after their being solubilized and in studies of their time-dependent stability. Additionally, the evidential findings of Cyclic Voltammetry and UV-Vis Spectroscopy further corroborate previous findings on quinone reactivities from experiments using SDS-PAGE and other methods. Through these and further investigations into the reactivity and stability of quinones, our laboratory hopes to contribute knowledge to our understanding of quinone reactivity and how this induces protein modification when introduced into a biological system. This avenue of investigation could potentially lead to significant gains in biomedical engineering in the future. For example, our findings collected through CV could contribute to the research and development of certain bioelectric sensors, that when inserted into the brain, could more quickly identify the presence of protein aggregates, which are known contributors to certain neurological degenerative diseases such as Parkinson’s Disease and Alzheimer’s Disease.


14. Smith M. Ribonuclease A Modification Induced by 1,2-Naphthoquinone and 2-Hydroxy-1,4-Naphthoquinone. *Departmental Honors Thesis*. University of Tennessee at Chattanooga. 2015. 1-64.


