Written Report – Laidlaw Scholars 21-22

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1. Brief description summarizing the purpose of the project, hypothesis, methodology, procedures, principal results, and conclusion

This research project aimed at developing an electrocatalytic method to upcycle chloride ions (Cl^-) derived from polyvinyl chloride (PVC), a commonly used plastic product for making water pipes, into hypochlorite ions (OCl^-), which is a bleach that we use for cleaning. Electrocatalytic means using electricity and catalyst, and a catalyst is a substance that can lower the energy required for a reaction. People over the world dispose of over 200 million tons of plastics annually, for example, PVC[1,2]. To utilize the PVC wastes as much as possible, it is hypothesized by the scholar that Cl^- can be extracted from PVC and converted into OCl^- with the help of a platinum metal catalyst.

Figure 1. The electrochemical set-up used in the research project

[1] Gibb, BC. Nature Chem. 2019;11:394. Schneiderman, D. K.

[2] Nichols, W., & Smith, N. (2019, June). Waste Generation and Recycling Indices 2019: Overview and findings. Retrieved from https://www.circularonline.co.uk/wp-content/uploads/2019/07/Verisk_Maplecroft_Waste_Generation_Index_Overview_2019.pdf

For the methodology, 0.5 M of sodium chloride solution (NaCl) was used as the electrolyte. From Figure 1, the red and green wires were platinum metal, which was my catalyst, and the white wire was silver/silver chloride, which was the reference electrode. Also, a direct current with ±2.7 volts (V) of applied electrical potential was used. The majority of the results were based on UV-visible spectroscopy (UV-vis) and cyclic voltammetry (CV).

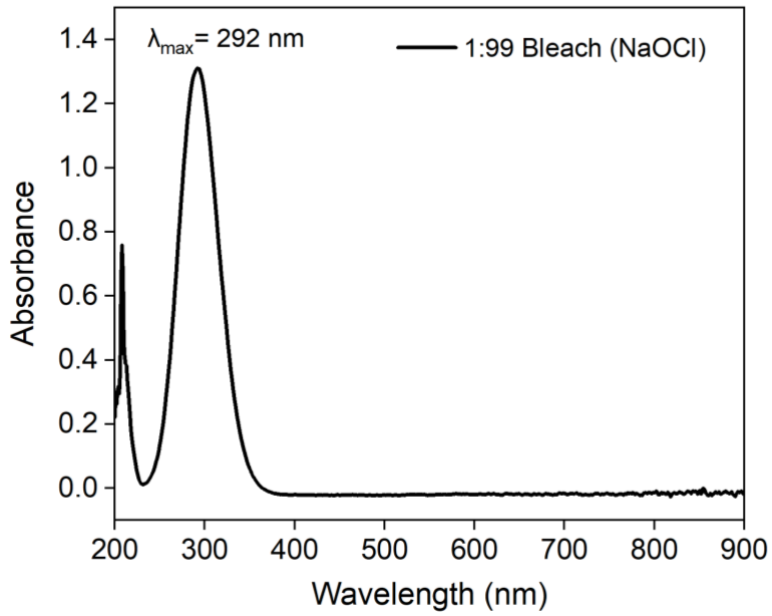

Fig. 2. UV-visible spectroscopy of 1:99 bleach

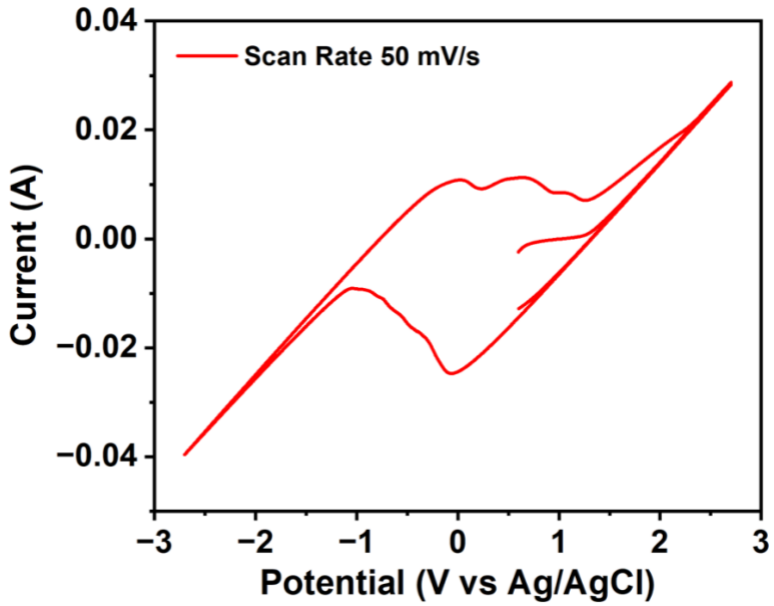

Fig. 3. Cyclic voltammetry curve at 50 mV/s scan rate

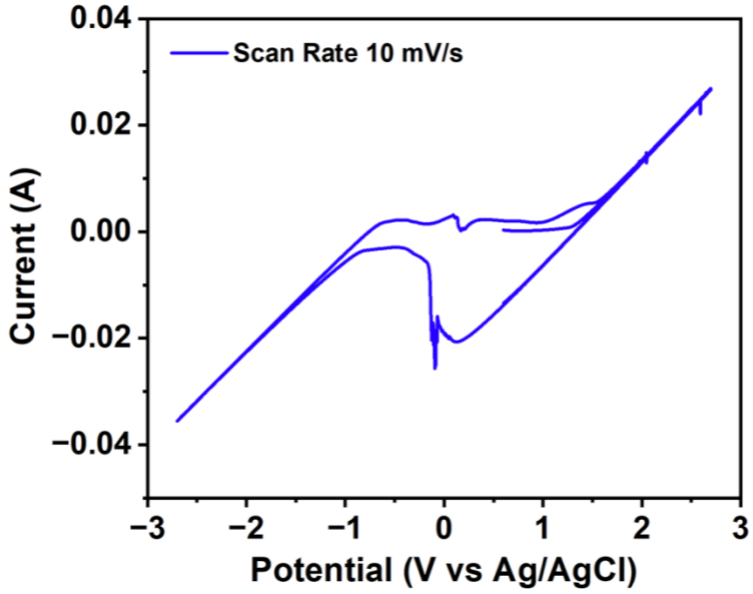

Fig. 4. Cyclic voltammetry curve at 10 mV/s scan rate

The next part is the results of this research. The UV-vis on 1:99 bleach, as shown in figure 2, showed a peak wavelength of 292 nanometres. During CV on the sodium chloride solution, a smell of chlorine was detected. Since chlorine reacts with water in the solution to form OCl^-, the smell of chlorine may indicate hypochlorite ions were present in the solution.

Figures 3 and 4 show two cyclic voltammetry graphs with scan rates of 50 and 10 millivolts per second, respectively. Scan rate means how much the voltage changes per second during the CV. The 2 peaks on each CV curve at -2.7 V and +2.7 V should correspond to the production of oxygen and hydrogen gas bubbles at the electrodes.

To conclude, the above results might suggest the presence of OCl^- in the solution. However, the yield, which means the percentage of Cl^- converted into OCl^- remains unknown and needs to be further investigated.

2. Difficulties encountered and how they were resolved

The research project did not run as smooth as I expected at the beginning, and I encountered several difficulties when I was doing my research project. The first is that when I was doing the cyclic voltammetry experiments using platinum electrodes under direct current, I was concerned that when the oxygen (O_2) and hydrogen (H_2) gas bubbles were mixed, it might cause an explosion. So, I sought help from my mentor at Dr. Edmund Tse's lab on how to tackle this problem. I learned from my mentor's experience that using a two-compartment H-shaped cell with a separator in between the two chambers can prevent the mixing of O_2 and H_2. Hence, the cyclic voltammetry experiments were conducted safely.

Apart from tackling safety concerns, since this is the first time that I had conducted a research project, I lacked experience working in a laboratory. So, I approached my mentor to learn every experimental procedure and took notes of what he said. Also, I read chemistry research publications and watched YouTube videos about different lab skills to get myself familiar before experimenting.

All of the difficulties mentioned were because of my ignorance. From this project, I have learned to be honest about it and there is still a lot of knowledge that has not been taught in class. Therefore, I will ask other people for help and continue to acquire knowledge from outside resources, for example, journal articles.

3. Improvements that could be made if the project were to be repeated

First, I would manage my time better if I could redo this project. Initially, I planned to get the data on a variety of parameters in my set-up, for example, using different applied voltages. However, I was not able to complete this because I spent too much time preparing myself with the experiments beforehand. I would also break down a project into different accomplishable small tasks to boost my confidence. In short, I would assign suitable deadlines for each of the small tasks to make sure I do not overspend the time on one of them.

Furthermore, I would review more related papers when I was writing the proposal for my research project. For example, I first planned to use a direct current during my cyclic voltammetry experiments. However, after I have already started my project, I realized using an alternating current, which is a type of electric current that periodically reverses direction,

would be more efficient for this kind of chloride upcycling reaction. Therefore, I would look for a more comprehensive list of literature before my research project starts.

4. Impacts of the research beyond the classroom

As mentioned in the beginning, this project uses a platinum catalyst that can lower the energy required for a chemical reaction. In 2021, most countries still rely on non-renewable energy as their primary sources of electricity generation.[3] However, the available amount of these non-renewable energy sources, for example, fossil fuels, is limited. So, using a catalyst in this reaction saves energy so that those limited energy sources can last longer before they are used up.

Plastic wastes take many years to break down, and they harm the environment. Since PVC may give out chemicals that damage our health, the chloride ions from PVC may be extracted and turned into something useful in our everyday life[4].

Therefore, I hope my project can make an impact by tackling the long-standing energy shortage and plastic problems, and therefore making our environment more sustainable.

5. Suggestions and extensions for further study

Because of time constraints, I was only able to complete part of my project, and thus more issues can be studied in the future. As mentioned above, the exact yield of OCl^- has yet to be investigated, which can be determined using UV-vis in the future.

The second suggestion is to explore new catalysts, such as titanium, titanium oxide-graphite composite (TiO_2/graphite), and platinized titanium dioxide (Pt/TiO_2). Moreover, the parameters can be changed further by varying the experimental conditions, for example,

[3] Center for Climate and Energy Solutions. (2021, November 10). Renewables 2021 Global Status Report. Retrieved from https://www.c2es.org/content/renewable-energy/#:~:text=Globally%2C%20renewables%20made%20up%2029,was%20added%20globally%20during%202020.

[4] United Nations Environment Programme. (2021, December 22). Plastic planet: How tiny plastic particles are polluting our soil. Retrieved from https://www.unep.org/news-and-stories/story/plastic-planet-how-tiny-plastic-particles-are-polluting-our-soil#:~:text=Chlorinated%20plastic%20can%20release%20harmful,species%20that%20drink%20the%20water.

temperature and the applied voltage. By comparing the yields from the set-ups having the different factors stated above, the optimal conditions of the electrocatalytic upcycling of chloride ions can be studied.

Lastly, as mentioned in section 3, I have explored a new possibility from a journal article to use alternating current instead of direct current, which has proven to boost the yield of OCl^- in a similar reaction as mine. Therefore, the yield of inputting an alternating current to this reaction can be further investigated.