CHEM 116 Final Course Project Option 1
Prof. Sevian, Fall 2020

For each numbered part, write out your observations or answers to questions. For example, in part 1, write down your observations as you dissect the battery, and include photos. You will turn in one project report that includes your answers, observations, data, photos, etc., that is collaboratively written by both of you. It may be easiest to create your report in a shared Google doc or OneDrive doc, so that you both can add to it simultaneously as you work together. Remember to include both of your names on the document that you will submit. There are no formatting requirements other than to organize your project report into numbered parts. If you use resources from the internet, cite them using any citation style you prefer. Since you are digital natives, you will be able to find ways to label the diagrams that occur in this document when you add those parts to your shared project report that you will submit. You will upload your project report in Blackboard. Decide which one of you will upload the project report for you both, and make sure to give the other person evidence as assurance that it was successfully submitted. There are two appendices to help you with dissection and cleanup, and the third appendix is the rubric.

A Battery is an Electrochemical Cell

1. Take apart a common battery (AA, AAA, C, D, or 9-volt) and figure out how it works.

Both partners must take apart batteries and do these experiments. Make sure you have an "alkaline" battery. Before you dissect your battery, write down all of the information that is on the battery case. If you have the packaging, also write down information that you think is relevant from the packaging.

Dissect the battery using needle-nose pliers (if you have those), otherwise using regular pliers. If you have a second pair of pliers, you can use those to hold the battery. If you don't have a second pair of pliers, use an oven hot mitt to hold the battery because it might become hot. Or you can wrap it in paper towels to hold it.

See Appendix 1 that is at the end of this document for a detailed guide with a picture to help you dissect the battery.

Be extremely careful to open the battery away from your face or skin, the battery contains a highly concentrated base solution that may leak out. Wear clothing that covers your arms and keep your face away from the battery. To start dissecting the battery, it is easier to start with the negative end.

When you dissect the battery, a black material can be found on the outer edge of the battery, closest to the cylinder exterior. A grey material can be found in the center of the battery. A divider keeps the two materials separated. Make sure to separate these components (the black and grey materials on either side of the divider) onto two different plates (do not mix them) for a later part of the experiment.

Take photos of the components of your battery. One of your photos must be a selfie or a photo that someone else takes of you with your dissected battery components. This is to prove that you did this work yourself. The photo will not be seen by anyone other than a TA or Dr. Sevian and will not be shared beyond this group unless you give permission.

2. Identify the components in the battery and map them to the components of the electrochemical cell model that we study in CHEM 116.

After these instructions are two diagrams for you to label. Identify the following parts that you dissected in the first diagram (you can use the internet to help you figure this out), and then map those to the standard electrochemical cell diagram (the second diagram).

There are five blue lines to label for each diagram. For each blue line in both diagrams, you will write one item from the left column in the table below AND one item from the right column. In this way, you will map the alkaline battery to the traditional representation of an electrochemical cell.

The ordering of the items in these table columns is not matched. You will have to figure out what the correct matches are.

Description of parts of the dissected battery	Electrochemical cell in CHEM 116
• The black material • The grey material • The stick-like object • The divider (separator between black and grey material) • The other end of the battery (opposite the stick-like object)	• Anode cell • Cathode cell • Anode • Cathode • Salt bridge

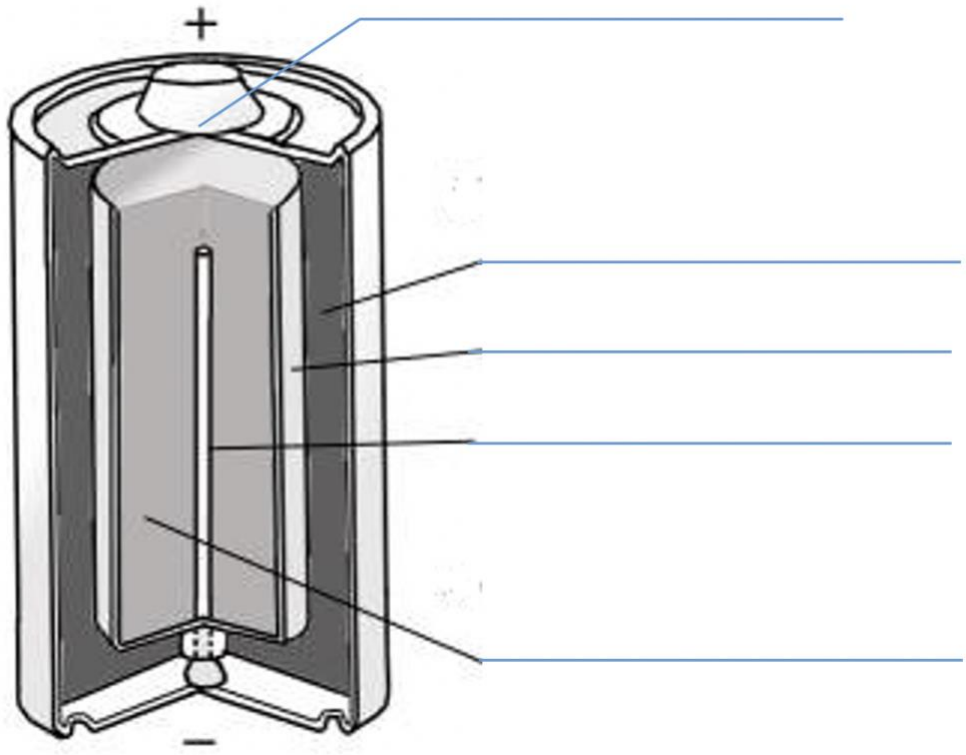
AFTER YOU LABEL YOUR DIAGRAMS, ADD ONE MORE PIECE OF INFORMATION TO EACH DIAGRAM:

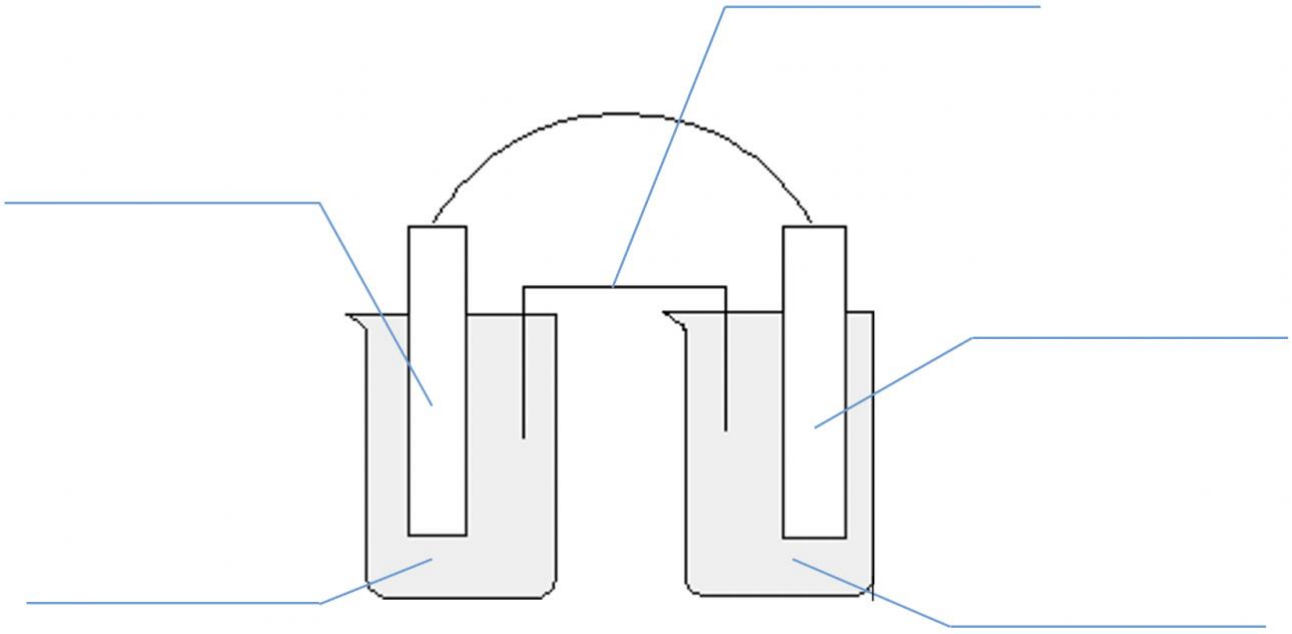
On both diagrams, draw arrows to show the direction of flow of negative charges through the battery.

The two diagrams are on the next page.

Appendix 2 that is at the end of this document has information on how to safely dispose of the battery.

Diagrams for labeling:





3. **Use the mathematical model of an electrochemical cell (standard reduction potentials, Nernst equation), the information printed on the package or on the battery (before you took it apart), and your observations about the battery components after you took them apart, to figure out what the anode cell, cathode cell, anode, and cathode in your battery are made of.**

   Figure out the identities of the two goopy materials in the battery (the grey material and the black material). The internet will be helpful for this (cite your sources). There are at least two possible correct answers to this. Make sure you search for "alkaline battery". Don't forget to cite your sources. Write the chemical formula for the important substance (species that has the element whose oxidation state changes) in the grey material and the important substance (species that has the element whose oxidation state changes) in the black material.

   Identify what your anode and cathode could be made of. Get the chemical formulas for these. Again, the internet will be helpful for this. Don't forget to cite your sources.

   Write the oxidation half reaction and the reduction half reaction (these should correspond to the questions in the previous two paragraphs).

   Figure out how many electrons are exchanged in this redox reaction, and then sum the half reactions in a way that eliminates the exchanged electrons (i.e., all of the electrons that are lost in the oxidation get gained in the reduction). Show your work.

   Use the Nernst equation with concentrations in an alkaline battery of the anode and cathode substances that you can find on the internet. The concentrations of the solids can be entered as 1.0 M. Show how the Nernst equation gives you the voltage that you wrote down from the battery case or the package. If you dissected a 9-volt battery, clarify what you have found and how it relates to 9 volts.

4. **Use a kinetic or thermodynamic argument to predict what should happen to the voltage (related to directionality and extent of reaction) for three proposed modifications to the battery.**

   Propose three modifications that would change the voltage of your battery and state whether the modification would increase or decrease the voltage. Whatever you propose will change something in the Nernst equation. Choose one of your modifications and reason through the logic, using the Nernst equation, of how your proposed change would change the voltage. After you and your partner convince each other that it makes sense, then write down your explanation in the report.

   Next, choose one of your proposed modifications and make either a thermodynamic (using Q and K) or a kinetic (using forward and reverse rates) argument to explain how the modification you proposed would cause the voltage to be different. If you are not changing the temperature, you will make an argument about forward and reverse rates, or about Q vs. K and how to move toward equilibrium. If your modification involves changing the temperature, you will need to figure out the signs of ΔH and/or ΔS. You should already have enough evidence in your observations to know what the sign of ΔH is, but you need to state your observation and explain it.

5. **What did you learn from the experience of doing this project?**

   Each of you should write a brief paragraph to answer this question. Include your name with your paragraph.

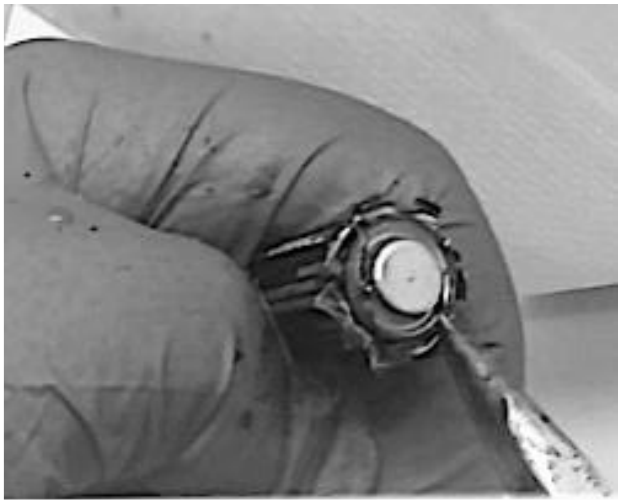
The two appendices begin on the next page.

Appendix 1: To dissect the battery

To dissect a battery, it works best to start at the negative end (flat end of the battery). A good strategy is to fold back the outer ridge to expose the edge of flat end of the battery.

IMPORTANT: ABOUT SAFETY
If you get any of the battery goop on your skin, wash the affected area with cold water. Make sure you angle the battery away from your face as you open it. Try not to let the black material come into contact with the grey material, but a little bit of contact of these materials may be unavoidable and that will be ok.

It is a lot easier to use needle-nose pliers to dissect the battery. If you don't have needle-nose pliers, you can also try alternately using a flat head screwdriver or a metal dinner knife (not a sharp knife) to try to pry off the outer wall of the battery and open it up. Put the tip of the pliers (or the screwdriver or dinner knife) where the side edge meets the bottom of the battery. The idea is to curl the metal from the bottom to the top, exposing the insert that is the bottom part of the battery (flat round part on the bottom). Then keep going around the negative end of the battery, pulling the metal back until all the rough edges are exposed and it is possible to pull the metal circle with the needle in the middle of that end of the battery out. Once the ridge is pulled back, larger pliers can be used to peel back more of the outer wall.



If you have wire cutters, it can be helpful to use those to get this part started by cutting outer wall of the battery near the metal part on the negative end of the battery once you get a little bit of it pried up. To do this, work one spot to pull back, this is more effective than trying several locations. Grip strength is more important than number of attempts. Make sure to have a grip on the metal edge of battery with pliers before trying to bend back, otherwise the pliers may wear down, as well as the metal pieces being removed.

The battery will become hot due to causing the part of the innards of the battery that get oxidized and the part that gets reduced to be in direct contact. If the oven hot mitt does not provide sufficient insulation, or if it is too difficult to hold onto the battery that way, wrap dry paper towels around the battery. The smaller the instruments you work with, the more easily you will be able to start opening the battery, since you have to get something to fit into the small space between the outer ridge and the flat part on the negative end of the battery.

If there is someone else at home who can help you, it may be helpful to ask someone to assist you as you start the process.

Pull back about 75% of the outer ridge before trying to pull out the pin. After opening the bottom the battery, when looking from the bottom, a dark ring of material will be visible on the outer edge of the metal cylinder (be

careful not cut your hand on the rough edges). This black stuff contains a mixture of coal dust and one of the two species that is part of the redox reaction. In the middle of the cylinder will be a grey slurry wrapped in a separator. The grey slurry is extremely basic. It is a strong basic (high [OH-] concentration) solution that contains the other species that is part of the redox reaction.

As you continue to work on dissecting the battery, try to limit the extent to which the black stuff with one of the species comes into contact with the grey stuff that contains the other species. The goal is to get them separated without having them react with each other.

Use the (needle-nose) pliers to grab the rough edges and pull the metal cylinder around the battery in order to pull out the separator and the grey slurry out of the middle of the battery. It will be easiest to pull out the inner grey slurry core and the separator together when the outer wall is peeled back at least halfway down the battery.

Put the metal exterior from the battery on a plate. Put the black stuff from the outer dark ring on that same plate but not touching it (or you can put it on a different plate or in a bowl. Put the grey slurry from the middle part of the battery in a different bowl or plate. Place the separator off to the side on the plate with the grey slurry but not touching it (or you can put it on a different plate).

Appendix 2: To clean up and dispose of the dissected battery

To dispose the dissected battery parts, keep the black stuff separated from the grey stuff. You can put each set of stuff into some paper towels and wrap them up, and then put them in different parts of a garbage can, or in different garbage cans, so that they do not come into contact with each other, because that could be very exothermic.

Appendix 3: Rubric (same for both projects)

Points possible	Area of competence	What high quality looks like
10	Experimental work	Photos demonstrating that all aspects of the expected experimental work were carried out and that both individuals participated
10	Mathematical work	Correct usage of the mathematical models related to the project
10	Conceptual work	Accurate, clear, and logical explanations of chemical ideas (either acid-base or redox) with correct usage of chemical terminology (e.g., conjugate acid/base, pH, oxidation numbers, anode & cathode)
10	Application work	Appropriate application of chemistry models to explain how (mechanism) and/or why (causal explanation) the behavior or function of a chemical system can be controlled and/or optimized
10	Collaborative work	Clear evidence that the work was shared between the individuals who collaborated on this project, including evidence that both individuals contributed in substantial ways