# Freshman Chemical Engineering Experiment: Charged up on Electrophoresis

*Adrienne R. Minerick*[1] *and Kirk H. Schulz*[2]

**Abstract** – A freshman "Introduction to Chemical Engineering" class can be a useful part of the undergraduate curriculum. Goals for such a course range from gaining an appreciation for chemical engineering manufacturing processes and safety, to an overview of the subject areas students will become proficient in by the time they graduate. This article discusses an experiment, Charged Up on Electrophoresis, which is used to enhance the chemical engineering introductory experience. Electrophoretic processes are brought to life via an introductory lecture, assignments, and a simple desktop experiment that utilizes inexpensive supplies to demonstrate electrophoretic motion in an aqueous media. Advantages of this hands-on experience include that it is not dependent on the availability of lab space, and students have a unique experience to link into their evolving understanding of chemical engineering concepts. A complete supply list, pre-assignment exercises, experimental procedure and "lab mats" are discussed and available for instructor use.

*Keywords:* Freshman course, Electrophoresis, Experiment, Inexpensive equipment

## INTRODUCTION

At Mississippi State University, our 1-credit hour freshman seminar course is designed to introduce students to the Chemical Engineering field. The class meets once a week for 50 minutes with about 15 contact sessions in the fall semester. The objectives of the course are multifaceted and include having the students

- gain an appreciation and knowledge of chemical engineering as a career,
- perform laboratory activities that illustrate key chemical engineering concepts,
- gain experience in oral and written communication skills,
- gain an appreciation for chemical manufacturing processes,
- be introduced to MSU chemical engineering faculty and the curriculum.

Laboratory activities are valuable instrumental tools that tie these objectives together. Activities associated with the Charged Up On Electrophoresis experiment span four contact sessions, but only two need to be dedicated solely to this topic. The first is an introductory lecture that reviews basic knowledge and teaches the students important equations and procedures. At this first contact meeting, a preassignment and experimental procedure is handed out; the preassignment is due the following week, just prior to the start of the experiment. The experiment is conducted in teams of two with each team assigned to one of four salt solution concentrations. The procedure can be

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completed within about 30 minutes leaving plenty of time for explanations, corrections, and clean up. The students leave the lab with the data they've collected and are asked to work with their lab mate to calculate mobility of the ions in solution. They turn these results in at the beginning of the third contact session. The instructor compiles the ion mobility results for each of the four groups and distributes this to the entire class. The lab mates once again work in teams to write a two page report complete with tables and graphs discussing their results and how they compared to the trend in the class. These reports are turned in during the fourth contact session. The experiment and each stage of the learning experience are discussed in the following sections. For clarity, this paper discusses each contact session in chronological order: discussions of the lectures, supplies & setting up, experimental procedure, and student work & assignments.

## LECTURE

During the first contact session, we conduct an introductory classroom lecture where the students review basic chemical knowledge and learn important ionic and electrophoretic equations. The specific topics covered in the lecture period include:

- Highlight on Dr. Meredith C. Gourdine, an athlete, physicist, and engineer who pioneered research on electrogasdynamics (EGD) [1]
- Ions, cations, anions [2]
- The formation of ionic compounds
  - Example / Class Activity
- Ionic Radii
  - Example
- Ionic Strength [3]
  - Coulomb's Law
  - Lewis & Randall
  - Example / Class Activity
- Electrolysis Reactions
  - Balance an equation
- pH changes and indicators [2]
  - Additional handout
- Electrophoretic mobility
  - Example / Class Activity

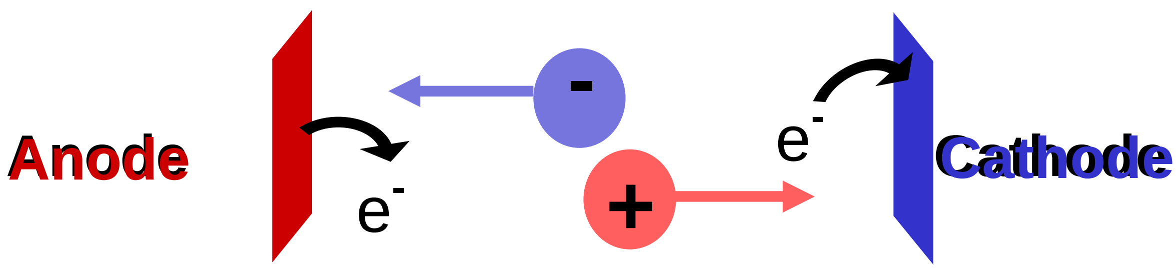
The biographical highlight of Meredith Gourdine is an effective way to draw attention to a renowned and accomplished minority in an area related to their experiment [3]. It also is a transition into talking about the possible paths one takes to success in life. The instructors introduce concepts, work examples, then challenge the students with slightly more advanced problems in the form of a class activity (worked in groups of two). These interactive problems solving sessions with the instructor during the class time is received well by the new college students. They enjoy being engaged in a topic that relates to their chemistry classes, but has an entirely different twist. Over the past two years, Minerick has been unable to finish the lecture up to calculating the electrophoretic mobility. However, this works out just fine because the pre-assignment and the experimental procedure reading assignment reinforce these ideas. These assignments are handed out in class and due at the start of the experiment in the following contact session. Students are asked familiarize themselves with the experimental procedure and required to wear proper dress in the "laboratory."

## PREASSIGNMENT & READINGS

The prelaboratory assignment includes a review of ionic charges, ionic bonding rules, and a short exercise where the students are asked to look up definitions and describe the following concepts in their own words. This activity prompts them to begin using terminology necessary for their experiment and lab report.

1. electricity
2. ionic solutions
3. electrophoresis
4. cathode
5. anode
6. electrical potential
7. electrical field
8. mobility

The following is an excerpt from the discussion the students read prior to session two, the experiment. **Electrophoresis** is the migration of charged particles or molecules through a solution under the influence of an applied electric field usually provided by immersed electrodes. Particles with a positive charge go to the cathode (negatively charged electrode) and negative charges go to the anode (positively charged electrode). Electrophoresis is widely known in its role in determining the human genome. This method can separate proteins or nucleic acid chains; by analyzing the rate of movement of each component in a gel, the molecular structure can be deduced.

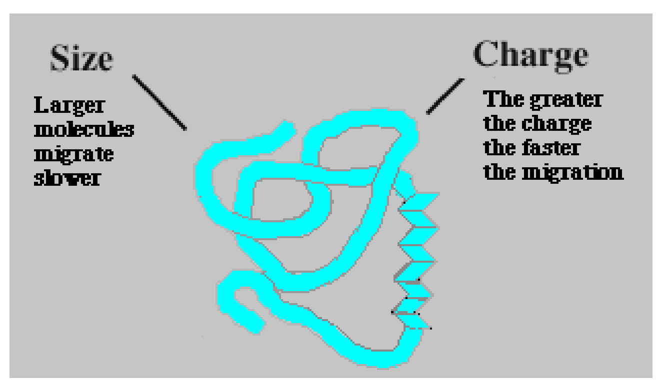



We are going to measure the **mobility, or rate of migration**, of NaCl ions in a water filled tray. Mobility, $\mu$**,** of a charged ion is described by

$$\mu = \frac{q}{6 \cdot \pi \cdot \eta \cdot r} \qquad \left( mobility = \frac{charge}{6 \cdot \pi \cdot viscosity \cdot radius} \right)$$

The electrophoretic mobility, $\mu$, of ions in solution can be obtained from experimental data by taking the **velocity,** $v$**, divided by the electric field, E**.

$$\mu = \frac{v}{E} \qquad \left( mobility = \frac{velocity}{Electric\ \ Field} \right)$$




The electric field is the **voltage divided by the length** between the anode and the cathode.

$$E = \frac{V}{l} \qquad \left( Electric\ \ Field = \frac{Voltage}{length} \right)$$

The students then use these equations to calculate mobility**,** $\mu$, from the data they collect during the experiment.

## SUPPLIES & SETTING UP

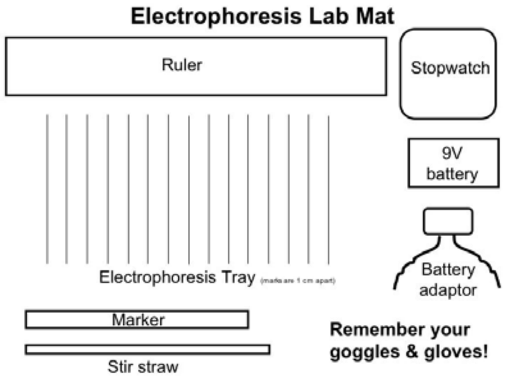
The supplies will need to be ordered a few weeks in advance.

***For each team of students (~2 students per team):***

- Clear sample tray (Heathrow Scientific® Multi-Channel Solution Basin: obtained from Daigger Cat # RX205808AX)
- 9V battery
- 9V battery adapter (RadioShack)
- stopwatch timer
- ruler
- 1 stir straw
- 2 pairs of goggles
- 2 pairs of gloves
- 10 mL graduated cylinder

***For the laboratory:***

- Bromothymol Blue Solution (CAS # 76-59-5)
- Sodium Chloride Solution
- DI water
- Waste containers
- pH paper
- electrical tape
- scissors
- paper towels




Typically, it takes less than an hour before the class to set up stations for 40 to 50 students. Placing all of the equipment on "lab mats" helps facilitate this process. A sample Electrophoresis Lab Mat is shown.

## CHARGED UP ON ELECTROPHORESIS EXPERIMENTAL PROCEDURE

The following is an excerpt from the experimental procedure the students are given.

Now lay out your materials for your electrophoresis apparatus. **You should put on your goggles and gloves now.**

Step 1. Using the electrical tape, attach your wire adaptor to your electrophoresis tray. Refer to the example setup at your site. Make sure the exposed wire is close to the bottom of the trough. Do not connect your 9V battery yet.

Step 2. Place the electrophoresis tray on the 1 cm lines on your electrophoresis lab mat. Number the lines starting at 0 on up to 15 cm. This will be used to measure ion movement. **Record the total length of your tray on the Results Page.**

Step 3. Measure out 10 mL of Bromothymol blue pH indicator using your graduated cylinder. Carefully pour this into your electrophoresis tray. **Record this amount on your Results Page.**

Step 4. Using your graduated cylinder, measure out the amount of NaCl solution and E-pure $H_2O$ that corresponds to your group. Carefully pour this into your electrophoresis tray. **Record these amounts on your Results Page.**

| | | |
|---|---|---|
| Group A | 10 mL NaCl | 0 mL E-pure $H_2O$ |
| Group B | 7 mL NaCl | 3 mL E-pure $H_2O$ |
| Group C | 5 mL NaCl | 5 mL E-pure $H_2O$ |
| Group D | 3 mL NaCl | 7 mL E-pure $H_2O$ |

Step 5. Stir with your stir bar until everything in the tray is well mixed. Connect the 9V battery to the wire adapter. Start your timer now.

Step 6. **Record** the time that the blue color reaches each hash mark on the tray.

Step 7. At various times during the experiment, use the pH paper to test the pH along the length of the tray. Just dip one end of the paper into the liquid and compare the color to the scale on the container.

**Example Results Page**

**Step 1**. The voltage that will be applied is ___________________Volts

**Step 2**. The total length of the tray is _____________________cm

The electric field is _________________Volts/cm

**Step 3**. Amount of Bromothymol blue indicator _______________ mL

**Step 4**. Amount of NaCl solution ________________ mL

Amount of E-pure $H_2O$ _________________ mL

**Step 5.** Total liquid in the electrophoresis tray_________________ **mL**

| **Hash mark (cm)** | **Time (min: sec)** | **pH (optional)** |
|---|---|---|
| 1 cm | | |

## FINAL REPORT

With freshman, we have found it is extremely important to clearly communicate what is meant by a lab report and what it should contain. In Fall 2004, we provided the following set of instructions:

> Please write the 2-page lab report with your partner and turn in only one copy with both of your names on it. The report should contain Excel plots of blue color position versus time, pH versus time (optional), and should walk the reader through your calculations of mobility.
> More specifically, the Report should contain:
> 1) a brief description of Electrophoresis,
> 2) a summary of the experimental procedure and data collection methods,
> 3) a summary of results obtained (include plots here),
> 4) a comparison of your results with class results (table format is good),
> 5) a paragraph or two discussing what you think the results mean, and
> 6) draw conclusions from this discussion.

The final reports are turned in during the fourth contact session. The instructors typically read and grade the reports for student understanding of concepts, calculated results, and clarity of writing. The reports with feedback and comments are returned during the fifth contact session.

## CONCLUSIONS

A simple experiment for a freshman "Introduction to Chemical Engineering" class can be a useful part of the undergraduate curriculum. This article discussed an experiment, Charged Up on Electrophoresis, which is used to enhance the chemical engineering introductory experience. A brief discussion of the introductory lecture, assignments, and a simple desktop experiment that utilizes inexpensive supplies demonstrates electrophoretic motion in an aqueous media. Advantages of this hands-on experience include that it is not dependent on the availability of lab space, and students have a unique experience to link into their evolving understanding of chemical engineering concepts. Student feedback has been favorable and the quality of their lab reports has been good. Teaching evaluations have averaged about 4 out of 5 for the past two years, with many students citing the laboratory experiments as what they liked best about the course. A complete supply list, pre-assignment exercises, experimental procedure and "lab mats" were briefly discussed; full versions are available upon request.

## REFERENCES


[1] Meredith C. Gourdine: Physicist, Engineer. Featured in *The Faces of Science: African Americans in the Sciences.* http://www.princeton.edu/~mcbrown/display/gourdine.html. Accessed 2005 16 Feb.

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[3] Noggle, Joseph H., *Physical Chemistry: Third Edition*, Harper Collins College Publishers, New York, 1996, pg. 385-402.


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Adrienne Minerick is an Assistant Professor of Chemical Engineering at Mississippi State University. She received her PhD from the University of Notre Dame in August 2003. Adrienne teaches the main graduate core math class in chemical engineering, the capstone senior process controls class at MSU, and helps out with the freshman level Introduction to Chemical Engineering class. Adrienne's research is in medical microdevices and microfluidics, which she incorporates into her classes via projects and homework problems. She is active in ASEE predominantly in the New Engineering Educators Division and the Chemical Engineering Division.

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