Designing Solar Cells using Reaction Rates

(Estimated Time: 180 minutes, 2 class periods)

Authors

Linda Crossno

Sergio Narez

SUBJECT/GRADE LEVEL

Subject Area:
Science
(Integrated Science, Chemistry, Physical Science)

Grade Level:
High School

Folder Link of Resources

Materials

- Engage Demos: Mg ribbon, Flame Test Salts (KCl, NaCl, SrCl, $CuCl_2$)
- Engage Activity:
  - Station 1: Alka seltzer tablets, mortar-pestle, film canisters with lid, timer, meter stick
  - Station 2: Beaker, cold water, hot water, sugar cubes, timer (optional: stirrer)
  - Station 3: Catalase (yeast, potato juice, liver), water, hole punch, coffee filter, 3 test tubes + rack, 3% hydrogen peroxide, tweezer
  - Station 4: vitamin C capsule, providence iodine (from the grocery store), corn starch, dI water, stirring rod
- Explore Activity: Semiconductor glass plates, titanium dioxide, berries, cheese cloth, iodine, multimeters, graphite, candle, space heater, lab sieve of different sizes, graphite (specific sizes can also be purchased directly)
- Elaborate: Modeling - poster paper, markers, scissors and glue if using the scaffolded modeling activity.
- Evaluate: Device to watch presentation

STANDARDS

Next Generation Science Standards

- HS-PS3-2. Develop and use models to illustrate that energy at the macroscopic scale can be accounted for as a combination of energy associated with the motions of particles (objects) and

energy associated with the relative position of particles (objects).
- HS-PS1-5. Apply scientific principles and evidence to provide an explanation about the effects of changing the temperature or concentration of the reacting particles on the rate at which a reaction occurs.
- HS-PS3-3. Design, build, and refine a device that works within given constraints to convert one form of energy into another form of energy.*
- HS-ETS1-2. Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering.
- HS-ESS3-1 Obtain and combine information to describe that energy and fuels are derived from natural resources and their uses affect the environment.

Mathematics Standards | Common Core State Standards

- Optional: Can have students calculate the rate of a reaction
- Standard: CCSS.MATH.CONTENT.8.F.B.4: Construct a function to model a linear relationship between two quantities. Determine the rate of change and initial value of the function from a description of a relationship or from two (x, y) values

English Language Arts Standards | Common Core State

- ELA9-10.6 Reading closely literary and informational texts and viewing multimedia to determine how meaning is conveyed explicitly and implicitly through language
- ELA9-10.9 Expressing information and ideas in formal oral presentations on academic topics
- ELA9-10.12 Selecting and applying varied and precise vocabulary and other language resources to effectively convey ideas

LESSON OBJECTIVE(S)

- Students will be able to manipulate variables to determine its effect on reaction rates using qualitative and quantitative data.
- Students will design a solar cell prototype to determine the rate of energy output. This includes modeling findings and identifying limitations.

CAREER CONNECTION(S)

Mentor Background: Dr. Katherine Ferguson received her PhD in Electrical and Computer Engineering at Duke University where she studied different methods to grow ultrathin dielectrics onto 2D materials for use in transistors. At ARL, she is currently working on optimizing nano-explosive ink by encapsulating materials to protect from environmental factors and increasing the reliability of igniters.

STEM Careers: Electrical Engineering, Chemical Engineering, Pyrotechnics, Renewable Energy Engineer, Nanoscientist

ENGAGEMENT

Brief Description: The teacher will demo a flame test using various salts and of various concentrations. The teacher can also burn a 3mm magnesium ribbon and 6mm magnesium ribbon and have students jot down their observations of each (worksheet & slides)

Following this, students will get into groups of 3-4. They will move from one station to another to gather observations from various mini-labs that will make reaction rates meaningful, interesting, and engaging to them. Each station should take approximately 30 minutes. To ensure the success of each

station, the teacher should model each station for the student or show an example video of how the procedure may look like. Some example links are provided below.

Overview of each station:

- Station 1 will ask students about the effects of changing particle size and surface area on the rate of reaction using alka seltzers and film canisters. (video example: seltzer rockets)
- Station 2 will ask students about the effects of changing temperature on the rate of reaction using sugar cubes and in hot versus cold water. It is suggested to use a stirrer at a constant speed if possible. If cost is an issue, ice cubes or same size can be used in place of sugar cubes.
- Station 3 will ask students about the effects of catalyst (catalase) on the rate of reaction. The catalase can be a yeast solution, liver solution, or potato juice. (video example: using liver)
- Station 4: will ask students about the effects of concentration on the rate of reaction using an iodine clock reaction. (video example: iodine clock)

Procedures:

- Students will use the following handout for the Engage piece of the lesson.
- Students will follow the instructions found at each station.
- Teachers will walk around, ask probing questions, ensuring observations include quantitative and qualitative observations and are using adjectives, color changes, state of matter in their writing. The teacher will ensure safety protocols are in place.
- The teacher supports English language learners by providing sentence frames on the white board. Example sentence frames:
    a. "I notice _____. This is because _____"

Other optional demo:

- In a Biology class, the teacher can demo "Fantastic Flourescening Chlorophyll" and relate it to photosynthesis photosystem II.
- Elephant Toothpaste can be used as an additional demonstration to show the effect of catalyst.

EXPLORATION

Brief Description:

- **Explore 1:** Students will use the inquiry process to manipulate a variable of their choice to determine its effect on the rate of a reaction. Students may manipulate the amount of graphite, the particle size of graphite, the amount of berry juice concentrate, the type of berry, or any variable that may have an effect on the reaction rate. Students will create a DataBlitz to summarize their findings. Background information on Current and Voltage.
- **Explore 2:** Students will gather additional findings using a simulation that allows independent variables to change to determine their effect on reaction rate.

Procedures: (Solar cell intro slides) Reference Video for Instructor (See #2)

1. The teacher would need to frontload what a solar cell is. The following slides can be used to guide the students.
    a. Introduce what a DSSC is.
    b. The schematic of the specific components of the dye-sensitized solar cell is very crucial for them to reference throughout the lesson. The function of each component is found on the slide with notes under the slide that may help clarify the behavior of the electrons.

The students should sketch the schematic so they can internalize it a little better, adding numbers to each com;ponent may help.

c. The cross cutting concepts of the NGSS are introduced as well to further help them understand the purpose of each component of the DSSC.
d. Norms for the lab should be introduced. A quick check for understanding by asking, "What do we wear for safety purposes? What do we do if a chemical spills?"
e. Show students how to use the digital multimeter to determine the conductive side and the non conductive side of the glass plates. This will be presented in the instructional video as well and can be shown to the students if needed. Showing them on a doc camera would be ideal.
f. Cold calling students to read the benefits of a solar cell would be the next step.
g. Before doing the lab, students may do a flow chart of the procedures of this lab. The flow chart is used to help them internalize what they will be doing during the lab, and would encourage students to ask questions before the lab is performed so that the lab runs smoothly.

2. The reference video is 44 minutes long, which should only be used if you are having difficulty with a particular procedure. The reference video goes over:
    a. Materials needed (0:00-4:00)
    b. How to make TiO2 solution (4:00-10:00)
    c. How to use a multimeter (13:30-15:00)
    d. Modeling all the steps of the student handout (15-44:00)
3. The lab handout is found **here** along with the data they are to collect and post lab questions. Providing them with the solar cell intro slides on google classroom (or any platform) will help them revisit what was initially front loaded for them.

EXPLANATION

Brief Description: Students will watch a TedEd video on reaction rates and jot down takeaways on the provided worksheet. Following this, an analogy is used to help diverse learners.

Procedures:

1. Pass out the worksheet and have students watch TedEd Video and complete this worksheet on reaction times.
2. This high five video clip can be shown to engage the students further. It provides an analogy to help explain collision theory in depth. The video clip shows students clapping in a row. The teacher can ask, "what did the students need to physically do to make a synchronous clap a success? Students would respond with: need proper hand orientation, energy to move your hand and proper contact. The idea is to tie this to how particles behave during a chemical reaction where the particles require proper orientation, sufficient energy, and contact to break bonds and form new ones. Students can be asked to complete a quick write in their scientific notebooks using the prompt: What are the requirements for a chemical reaction to occur? Please use collision theory in your response.
3. The following video can be offered as a supplemental video to the TedEd video above.

ELABORATE

Brief Description: Students model on poster paper how energy works in the solar cell device; how their investigation from the explore segment influences the solar cells' activity and output of energy. This

includes any connections to the flame test and simulations involving particles, collision theory, energy conversion, and reaction rate. Students can revise their data blitz on solar cells.

Procedures:

1. The teacher will explain to students that they will create a model of how their solar cells convert energy and how the energy changes depending on the variable they used in the "explore" phase.
2. The teacher may revisit how NGSS modeling in science works. Here is an example google doc task, where students analyze two models and are encouraged to grade each one using the provided generic rubric. The discussion of this encourages consensus building and students are invested in getting to know the rubric/expectations of NGSS modeling. They can use this as a reference each time they need it, especially for EL students or students who need frequent reminders.
3. The teacher provides a word bank/checklist of vocabulary that should be used in the creation of their models. For further guidance, the teacher can print out visuals that students can cut and use in their model. (document)
4. Students should provide feedback to each other by using sticky notes, 2 stars and 1 wish, or any other strategies that are appropriate for peer feedback.
5. Teachers can ask students to briefly present models or to do a gallery walk so students can have an opportunity to verbally communicate their overall learnings and subsequently add new knowledge to their models.
6. A Datablitz and Scientific Modeling is our chosen method for evaluating student learning as shown in the next section of this 5E lesson plan. Handout of Datablitz requirements.

EVALUATION

Brief Description: Students present their DataBlitz and Models.

Procedures:

1. Students will present their DataBlitz slide and Model to the class.
2. Alternative: Students will create and upload their video on LMP such as Google, Padlet, or YouTube channel. The teacher will provide links to all students. Each student will watch at least 2 other presentations and leave constructive feedback. The teacher will provide sentence frames for students who may want to use them:
    a. "Great job on _____"
    b. "I don't understand _____. Can you please clarify _____?"
    c. "Your slides are _____."
    d. "I think your model is _____".

EXTEND

Brief Description: Using the data collected, students will extrapolate how many of the solar cells are needed to turn on a 30W light bulb. This would be an extension to the solar cell design. Furthermore, students can research the pros and cons of solar cells to propose a **solution** to the rise of human induced climate change. This CER is found in the Solar Cell Lab handout. It can be omitted or used as an

extension; depending on the teacher's long term plans.

REFERENCES

- https://www.ccmr.cornell.edu/wp-content/uploads/sites/2/2015/11/Solar-Cells.pdf