Equitable Chemistry Education for Language Learners: An Exploration of Light and Matter

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This curriculum unit is recommended for:
Personalized Academic Command of English (PACE) Grades 9-12
Chemistry I (as a supplemental toolkit)

Keywords: glow, luminescence, light, matter, electrons, chemistry, fluorescence, molecules, bilingualism, English learners

Teaching Standards: See Appendix 1 for teaching standards addressed in this unit.

Synopsis: This CU is built for English Learner (EL) students. The unit will be modeled after pre-existing PACE units with a large emphasis on scaffolds and language development for Newcomers (students who have been in the United States for one year or less and are at beginning levels of English). The unit will begin with foundational scientific vocabulary terms in English. The words will be chosen by considering which vocabulary is integral for a basic understanding of chemistry and photoluminescence. At several points during the unit students will engage in simple hands-on experiments in order to benefit kinesthetic learners and maintain focus and interest in the curriculum. These experiments will have a speaking and listening linguistic focus. Additionally, grammar instruction and practice will be embedded into the unit through practical applications. Finally, the unit will include resources that can be utilized by Chemistry I teachers. There are frequent requests from content teachers for methods and materials to help EL students understand their content and to succeed in their classes. This unit will provide scaffolds that can be utilized by these content teachers who may not have training or experience with EL students.

I plan to teach this unit during the coming year to 40 students in Personalized Academic Command of English (PACE). The unit will be provided to science and chemistry teachers to incorporate into their classrooms.

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Sarah Wallace

Introduction

Objects that glow attract our attention. This is why highlighters are used to draw attention to important facts, why glowsticks are included in emergency kits, why rave goers adorn themselves with bright necklaces and bracelets. The same is true for students. They are often attracted to flashy things and typically pay more attention (at least at the onset) to things with a robust visual or audio quality. Therefore, introducing a unit that centers around things that glow, something that is both exciting visually and practically, can serve as a hook to persuade learners of all academic levels. Additionally, the topic of photoluminescence is one that encompasses multiple domains. Students who are interested in history can explore the beginnings of the field, students who are inclined towards social issues can look at practical applications, art students can look at new mediums, and so on. In sum, photoluminescence interests students because of its wide berth and can help sustain their attention on the topic in the long run. This leads directly into a successful curriculum for EL (English Learner) students because it gives the teacher a large range of vocabulary and content from which to choose.

Rationale

EL students come from richly diverse cultural backgrounds and have varying levels of academic experience. Some students come from privileged backgrounds and strong schools. Others are having their first educational experience in the United States. However, in the American school system they are unified through their English language ability. Many times, teachers assume ELs have a low understanding of content areas *because* of their English language ability when in reality their present English language ability sometimes precludes them from actively engaging in grade-level curriculum. Therefore, a chemistry unit written specifically for these students can be helpful to both engage students in the curriculum and present it in an understandable way and to assist content teachers in supporting students who are not yet proficient in English. For use in the Personalized Academic Command of English (PACE) class, this unit can serve as an introduction to scientific, and more specifically, chemistry, vocabulary in English. In a Chemistry course, the toolkit portion of this unit can be used to support students in equitable access to the curriculum.

More often than not, EL students in the United States do not have the opportunity to engage in higher level scientific courses, “most ESOL students never get the opportunity to enroll in a science course such as physics, biology, or chemistry” (Hademenos, Heires, Young 2004, 27). Students who complete their English as a second language courses are often enrolled in lower-level sciences despite prior courses or experience they may have in their home country.

Equally important, some students are never given the opportunity to take these courses because their schedule is padded with English development classes which, while currently important for success in most public schools, do not provide students with the opportunity to develop higher level academic skills in other content areas. However, curriculum designed with ELs in mind rather than ELs as an afterthought has the potential to provide these students with an academic experience that is on par with students who are without the English Learner designation. The rationale behind this unit is to provide an equitable scientific curriculum to these students. However, it should be noted that this curriculum unit is only that, a single unit, and for students to gain real equitable access to higher level academic classes, nothing short of systemic change is acceptable.

School and Student Demographics

Hopewell High School's current enrollment sits at 1,787 students with 90 direct ELs (5.036% of the total school population). However, there is a high level of transience within the EL population so this number is in constant flux during the school year. Direct ELs are English Learners who are currently enrolled in the district's EL program because they have not reached the required English proficiency as measured by the WIDA (World-class Instructional Design and Assessment) Consortium's ACCESS test. This test is the English-language proficiency test given to students in Kindergarten to 12th grade in participating WIDA states. These 90 Direct ELs at Hopewell are from 20 different countries and speak 12 different languages. Spanish is the dominant language with 73 speakers (81.11% of the Direct EL students).

While these statistics are accurate, this number is an underrepresentation of the number of bilingual students at Hopewell. These statistics only account for students with an English Learner designation, and do not include students whose bilingualism does not condemn them to systemic entrenchment as second-class students. Class rosters are determined by student proficiency, so within any class it is possible to have speakers of multiple languages. Additionally, even though the goal is to divide students by similar proficiency levels, often due to time and budget constraints, students of multiple levels have to be in the same class, requiring teacher flexibility and curriculum modifications; options for the latter will be addressed in this unit.

Unit Goals

The goal of this unit is to provide students with general academic words in the content area of science, and specifically, chemistry. As has been stated before, students often have strong scientific academic backgrounds in their home languages; they simply lack the equivalent discourse to be able to demonstrate their knowledge in English. Additionally, given the theme of the unit, students will understand the basics of luminescence and the different types of luminescence: chemiluminescence, bioluminescence, electroluminescence, and photoluminescence. This focus will also provide a hook in which to engage students as well as a basis for in class experiments that can benefit all learners but that will specifically benefit kinesthetic and visual learners.

Finally, students will be given opportunities to engage in the four domains of English language learning: listening, speaking, reading, and writing. They will be given

opportunities throughout the unit to engage in activities that allow for productive input and output. Some speaking and writing lessons will include direct grammar instruction to build on students' metalinguistic knowledge. The grammar instruction will include foundational structure such as parts of speech, beginning verb structures, and antecedent use. Finally, the curriculum unit will address polysemy for common scientific vocabulary. See Appendix 1 for details of specific WIDA standards that will be addressed in the PACE unit.

Content Areas

The content area for this CU will be divided up into two parts. While the CTI seminar and content area is chemistry, the majority of this material will be used in an English Learner class with a specific demographic of students. Therefore, in order to properly understand the context in which chemistry is being taught, the content area of teaching English as a Second Language must first be considered.

Teaching English as a Second Language (ESL)

The field of ESL, specifically in terms of ESL in public schools, is incredibly diverse. There is variation in standards, models of instruction, and instructional programs in every school district in every U.S. state. This diversity is a product of a lack of cohesive federal and state standards and directions. Until the passage of the *No Child Left Behind* Act in 2001, there was little to no focus on linguistically diverse learners. Regular content area standards existed; however, "academic content-area standards mandate high levels of achievement in content learning for all students, they do not provide educators strategies needed to assist English language learners because they assume student proficiency in and ability to use English to engage with content" (Fenner and Segota). When this act was passed it was the first time any type of standards were mandated for English Learners. However, each state was given the option to develop their own standards and programs. Some (including North Carolina) joined the WIDA Consortium and others created independent models. Thus, ESL education has more variety of instruction than any other content area (Fenner and Segota).

Despite the 2001 act and previous Supreme Court rulings revolving around the education of immigrants and English Learners, there are many different models in schools for instruction of ELs with some schools showing great programs that meet the needs of diverse language speakers. Other schools have programs that are nonexistent. However, even more effective programs are often based in assimilationist and deficit perspectives of education policies of the early twentieth centuries. Those approaches looked at student success by gauging how well they assimilated into U.S. society. Foundationally this has created programs with focuses:

> A single-minded focus on the acquisition of English as a set of discrete skills, structures, and vocabulary items that must be mastered in a prescribed order, persists as a dominant pedagogical approaches used to teach English language learners, including many newcomers. This approach can result in students being tracked into a never-ending cycle of remedial classes that focus on the mastery of these skills and structures and very little else. This is particularly unfortunate when it prevents English learners from a) gaining opportunities to learn content and build on and

further develop their linguistic and cultural resources and b) segregates them from their English-speaking peers (Samway, Pease-Alvarez, and Alvarez 2020, 7).

The ultimate goal in educating English Learners should be for all teachers to be highly trained in the education of ELs and for them to always have access to high level content regardless of their language ability.

At present there is no one model that has been adopted by most schools to fulfill these purposes. Instead, most schools operate under one of three main structures:

1. Bilingual Education Programs
2. Newcomer Centers or Programs
3. ESL/ELD (English Language Development) Programs

Bilingual Education Programs are not common for immigrant students in the United States. Instead, when these programs do exist, they are usually offered to affluent American pupils trying to learn a foreign language, rather than students who are already gifted with fluency in a language other than English. However, when these programs do exist, they provide instruction in both English and in the students' native language. The ultimate goal is normally a transition into a complete English-speaking classroom rather than a setting that encourages further education and fluence in the students' native language.

Newcomer centers or programs are self-contained schools or sections of buildings where students participate in curriculum that is "designed to help them acclimate to U.S. schools, learn English, and develop their academic skills in English...ELs typically spend no more than one year in newcomer centers and are then mainstreamed into regular classes" (Samway, Pease-Alvarez, and Alvarez 2020, 9).

Finally, the most common program for English Learners in the U.S., and the one used in Charlotte-Mecklenburg Schools (CMS) is the use of ESL and ELD programs and classes. The content of these programs varies from school to school but they usually contain a combination of direct language instruction and content-area learning. Sometimes school administration dictates what is taught in these classes and other times it is up to the individual teacher. There is little oversight in English Language education. As for instruction, "a wide range of people, including specially trained teachers, non-specialist teachers or aides, speech and language teachers, and volunteers, teach ESL/ELD classes" (Samway, Pease-Alvarez, and Alvarez 2020, 8).

However, regular subject content teachers are often the least prepared to teach English Learners. Unless they themselves have actively pursued an additional licensure in teaching ESL, they often have little experience or knowledge of these students which in turn places a great burden on licensed EL teachers to not only provide linguistic support for their students, but also to support them in every content area. Content teachers are not required to participate in courses or programs that prepare them for working with English Learners. Therefore, when regular classroom teachers come into contact with ELs they are under equipped and ill prepared to provide an equitable and academic education to this large demographic of students. Naturally, this often results in ELs being excluded from academic content-area curriculum.

ESL Best Practices

"Students don't need a high level of English to start learning content through English. With support and thoughtfully planned instruction, newcomers can start learning content in English" (Samway, Pease-Alvarez, and Alvarez 2020, 203). Therefore, what are best practices for thoughtfully planned instruction that can support ELs in both their language development and content classes? Samway, Pease-Alvarez, and Alvarez elaborate on several ways that that content instruction can be planned for Newcomers.

1. **Draw on family and community-based funds of knowledge** - To elaborate, this means enabling "teachers to integrate resources that are part of newcomer students' home and community networks into inquiry-based units in their classrooms." Teachers can do this incorporating students' and families' academic and personal background knowledge, life experiences, world views, etc. into the content. Most school practices are based on white, middle class norms and perspectives. "By integrating patterns of learning, knowing, and doing that are familiar to culturally and economically diverse students, academic content becomes easier to connect to their lives and is understood on a deeper level" (Funds of Knowledge). In essence, teachers should consider the areas of expertise, interest, and experience of students' communities.
2. **Connect content to relevant social issues** - As with anyone, students are more likely to focus on content when they can make connections between it and their own lives. English Learners are no exception. However, ELs often "have experienced the kind of oppression that has constrained their voices, rights, and ability to have an impact on their environment." Subsequently, generalized curriculum that is marketed as "culturally relevant" is often only applicable to only white, middle class students, with other perspectives ignored. The following table provides examples of connecting content to relevant social issues in science. However, teachers should be cautioned from the assumption that ELs always come from communities with a lower corpus of resources. Instead, teachers should let the students' own stories and voices shape the social issues that are adapted into the curriculum.

Discipline	**Example Connections to Contemporary Issues That May Be Relevant to Newcomers**
Science	● Climate change and its consequences in different parts of the world ● Access to healthy food in low-income communities ● Water crises due to drought and contamination ● Engineering solutions to issues (e.g., saving energy by creating energy-efficient homes, filtering, or desalinating water) ● Environmental issues in students' communities (e.g., cleaning up local creeks and the watershed, lobbying against companies that pollute the neighborhood)

(Samway, Pease-Alvarez, and Alvarez 2020, 211)

3. **Structure inquiry-based units** - Inquiry based units capture students' interest and curiosity about a topic. This can be done through commonly used classrooms strategies such as See-Think-Wonder, gallery walks, KWL charts, clustering questions, etc.
4. **Use multi-modal resources and experiences** - It is important to remember that the act of reading is not limited to text and prose but rather in many disciplines it is extended to graphs, maps, diagrams, scientific models, etc. Students should be presented with more than just texts in order for them to understand content. Examples include:
    a. Hands-on investigation
    b. Visuals
    c. Computer simulations
    d. Kinesthetic activities
5. **Scaffold reading activities** - Anchor texts can be scaffolded through the use of highlighting main ideas and concepts and demonstrating pictorial representations of key vocabulary. An example can be seen in Appendix 2.
6. **Modify text and videos strategically** - While it *is* important for students to have access to grade level and challenging curriculum, texts should be accessible, particularly for Newcomer students. A guide for modifying texts can be found in Appendix X.
7. **Provide multiple ways for students to demonstrate learning**
    a. Creating visuals, sequencing, sorting, writing, using the native language

This final step, providing multiple ways for students to demonstrate learning, is possibly the most important. As has already been stated, often students have the content knowledge, even before they take the course; however, due to language barriers they are often prevented from being able to demonstrate their knowledge. "Alternative assessments benefit ESOL students by allowing practical and realistic evaluations that concentrate on students' strengths (Hademenos, Heires, Young 2004, 31). Flexible assessment methods by teachers can be pivotal in allowing ELs to show what they know and what they have learned and not being discouraged by low grades which are a product of a language barrier and not academic performance.

Chemistry

Chemistry is the study of the different elements that make up the world. It is an important science with a wide scope that touches on everything from cooking to automobile propulsion to climate change. "Chemistry is sometimes called the 'central science' because it relates to so many areas of human endeavor and curiosity" (Petrucci and Harwood 1993, 2). Therefore, it is important that students have at least an introduction to the field; with this they can have a basic understanding of a central science both for their own edification and as a potential field that they may want to pursue at higher educational levels.

One of the main barriers to an equitable scientific education for English Learners is language. However, in this case the barrier is not just an issue of native language versus a second language; here the linguistic language barrier is heavily offset because of scientific vocabulary and cultural referents in explanations. For example, lack of adequate

understanding of polysemy is a problem not only with English Learners, but with native English speakers. Many words have different meanings across content areas and within everyday vernacular. Words such as “element” or “matter” have precise definitions in chemistry but are simply higher-level academic vocabulary in English and History classes. “Grasping the true meaning of chemical concepts requires a dialogue, between students and between teachers and students” (Visser et al. 2018, 1331).

A lack of understanding of basic vocabulary is not the only obstacle to ELs in a Chemistry classroom. Many ELs are immigrants and therefore have different areas of experience and knowledge from a U.S. based student. This can cause confusion when an instructor or another student attempts to explain a concept in terms of referents that might be common or instinctual to a student from the United States but confusing to a student from another country. In a study on language problems in lectures to non-native English speakers, the conclusion was drawn that the “language of chemistry has a peculiarity it shares with physics, that many of the words describe entities which are invisible” (Arden-Close 1993, 254). When most teachers attempt to describe these concepts, they do so with real world examples and analogies, attempting to make connections for students to conceptually understand difficult concepts. However, there is an added layer of complexity when trying to make an analogy to a person who might have a different frame of reference or world view. For example, in the same study by Arden-Close, the science lecturers noticed confusion and a lack of common ground when giving examples that compared scientific concepts to a game of tug-of-war, growing grass, and the hybridization of goats. The students in these rooms had different frames of reference, making the lecturers’ “explanation” of the scientific concept more confusing (Arden-Close 1993).

Once a foundation of common scientific vocabulary terms are understood, students can begin exploration of more specific topics in science and chemistry. This is an important step to get to and it is important for EL students to not stay at the level of simply memorizing and regurgitating word definitions because “chemistry education is not about memorizing facts; it is about analyzing and understanding phenomena around us” (Visser et al. 2018, 1331). Students, both in ESL classes and in content classes, must first be given opportunities to understand content specific vocabulary with culturally relevant referents. Only then can they move on to scientific interactions in English with more advanced concepts.

Fluorescence: The Interaction of Light and Matter

One such concept in which students can grasp a higher level of knowledge is that of fluorescence. Fluorescence is “the term used to describe the emission of light by a material when it is struck by energetic radiation” (Petrucci and Harwood 1993, 37). More specifically, fluorescence is the emission of light due to an electron relaxing from an excited state and moving into a ground state by one of several different processes. Radiation is absorbed, electrons are excited then relaxed, and finally light his emitted causing a glow. To fully understand this process, it must be understood what an electron is and why it reacts the way it does.

When they were first discovered, electrons were known as cathode rays because they were observed travelling through an evacuated tube from the negative terminal (cathode) to the positive terminal (anode) after being charged by a high voltage source (Petrucci and Harwood 1993, 37). Because the rays were invisible, this process was only observed because light was emitted by the materials the ray was striking, an evacuated tube coated in neon. The neon was excited by the energy passing through which caused an atomic emission, namely, fluorescence. The fact that light was first absorbed and *then* emitted rather than being reflected demonstrates the distinction between fluorescence and light reflection, the former relying on electrons as the vehicle for light. Due to this observation, in the late 1800s it was concluded that "cathode rays are negatively charged fundamental particles of matter found in all atoms [and] subsequently became known as electrons" (Petrucci and Harwood 1993, 37). Eventually, electrons were seen as fundamental particles of matter and their presence in atoms was soon understood to influence a majority of science. Therefore, electrons and fluorescence are inextricably tied.

A cursory look at the period table shows many different elements (atoms with different numbers of electrons, protons, and neutrons). Putting these atoms together in different arrangements forms a molecule. Molecules are the building blocks for different natural and synthetic structures such as chlorophyll, caffeine, and ibuprofen. There are many practical applications for molecules and scientists are constantly working on creating new molecules and finding applications for them as well as finding new uses for long discovered molecules. A molecule's propensity to emit light is dependent on three factors: the number of electronic states in the molecule, the positions of electrons in the molecule, and the energy source that is exciting the molecule.

For example, a commonly taught molecule is chlorophyll. Chlorophyll's construction makes it more likely to glow given the clustering and quantity of double bonds (when two pairs of electrons are shared by bonded atoms). Chlorophyll operates under the same principle of luminescence. Light excites the electrons in the chlorophyll which allows plants to grow and make their food. Furthermore, chlorophyll *will* glow under the right conditions--when it is removed from the chloroplast with alcohol it can be viewed under ultra violet (UV) light. When this happens the chlorophyll glows red--an example of photoluminescence.

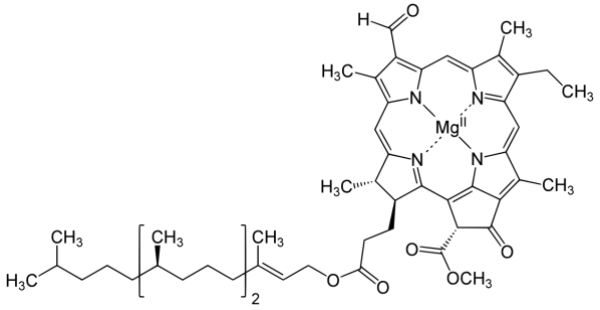


Image 1. Chlorophyll

Photoluminescence is a type of luminescence and one of the four principal ways in which electrons can become excited, relaxed, and subsequently glow. Included in the banner of luminescence is photoluminescence, chemiluminescence, electroluminescence, and bioluminescence. Each of these different processes has the same result: the emission of light.

This process has been the basis for many different types of technology, toys, and household items over the years. The most common glowing household object being the glowstick, an item that produces its glow through chemiluminescence. Another common glowing object include cell phone screens.

Instructional Implementation

The PACE class is meant to be an introduction to academic vocabulary in each content area. Students are exposed to core concepts in an abbreviated manner to help prepare them for interaction with the content in their core classes. This PACE unit will teach students very foundational chemistry terms through the lens of the interaction with matter and light. The unit will begin with an introduction to molecules and electrons and the concept of glowing and then move to the different types of luminescence: photo, electro, chemi, and bio. Embedded into the unit will be grammar concepts and common vocabulary constructions.

<table>
<tr><td colspan="4">PACE Unit: Scope and Sequence</td></tr>
<tr><td>Title: Things That Glow</td><td>Timeframe: 6 Weeks</td><td>Topics: Fluorescence, Luminescence, Molecules</td><td>Content Focus: Chemistry, Technology</td></tr>
<tr><td colspan="4">Essential Question: What are the processes that cause something to glow?</td></tr>
<tr><td colspan="2">Anchor Literacy Standard:
Literacy.RI.9-10.2 Determine a central idea of a text and analyze its development over the course of the text, including how it emerges and is shaped and refined by specific details; provide an objective summary of the text.</td><td colspan="2">Anchor Content Standard:
Chm.1.1.3 Describe the concepts of excited and ground state of electrons in the atom:
1. Gaining energy results in the electron moving from its ground state to a higher energy level.
2. When the electron moves to a lower energy level, it releases the energy difference in the two levels as electromagnetic radiation (emissions spectrum).

Articulate that this electromagnetic radiation is given off as photons.</td></tr>
<tr><td colspan="4">See Appendix I for supplemental literacy and content standards.</td></tr>
<tr><td colspan="4">WIDA ELD Standard
ELD Standard 4 English language learners communicate information, ideas and concepts necessary for academic success in the content area of Science.</td></tr>
</table>

Anchor Text	**Supplemental Texts**
"Things that Glow" Types of Luminescence Jigsaw Texts 1. Photoluminescence 2. Electroluminescence 3. Chemiluminescence 4. Bioluminescence	"Glow sticks' glimmer caused by cool" "Lured by the bright lights" "Let Them Glow" "Baruch Professor discovers the reason behind glowing sea pickles"

Power Sentence Fluency Protocols

"If you look around at night you will see many different things that glow. From your cell phone to televisions to glowsticks at parties, things are glowing. We are able to see in the dark better than ever before; however, we often take this for granted! So how do things glow? What are the scientific processes that cause light to be emitted?"

"Everything in the world is made up of things called molecules. Inside of a molecule are elements such as carbon, hydrogen, nitrogen, oxygen. Different combinations of these elements along with electrons create different molecules. Scientists are trying new combinations of elements all the time to create new molecules, like a chef creating a new recipe!"

"When an electron is in a molecule it usually exists in what is called "the ground state." This means the electron has very little energy. However, sometimes an electron becomes excited. After the electron is excited, it starts to relax again and goes back to its ground state. When the electron returns to its ground state it causes certain molecules to glow."

"Electrons can be excited in four main ways, causing molecules to glow. The process of glowing is called luminescence. The common ways a molecule glows are photoluminescence, electroluminescence, bioluminescence, and chemiluminescence."

Language Focus	**Grammar in Context**	**Assessments**	**Culminating Project**
Cause and Effect Prediction Interpreting Data Polysemy	Present Tense Verbs Present Progressive Verbs Antecedents	Exit Ticket Present Tense Practice FlipGrid Explanation	Why Does It Glow? Research Project

The preceding table provides a general overview of the unit. The following will provide detail for each lesson within the unit. The unit is designed to be accessible to beginning ELs; however; students who are at the very beginning of their language proficiency should be encouraged to translate the readings into their L1.

Lesson 1 - Chemistry Foundations

Essential Question: What are molecules and electrons?
Language Target: I can define vocabulary words and represent them with pictures using a graphic organizer.

Students will begin with a Quickwrite. It is recommended that students have a writing journal to use throughout *all* PACE units in order to track their writing progress; however, this is optional. Students will preview the topic by listing things that glow. Students who are not familiar with the word "glow" are encouraged to translate the word into their L1. Teachers are encouraged to give examples by showing pictures. Students will answer the questions "What are some examples of things that glow? How can things that glow be helpful? What do you think causes things to glow?" Optional sentence frames will be provided for beginning students.

Next, students will engage in the Power Sentence Protocol. Power Sentences are a variation on the "Juicy Sentence" structure developed by Lily Wong Fillmore. The teacher will start by modeling the reading with a read-aloud. They will then highlight key words and structures. Next, students listen and repeat key words and structures. Students and teacher then choral read as a class followed by a partner read with pairs of students. The protocol ends with another class choral read.

After the Power Sentence Protocol the teacher will show 1-2 videos to use as a hook for students to be engaged in the content. The unit will include several videos that the teacher can choose from; teachers can also show multiple videos, time depending. After the video students will complete a "See, Think, Wonder" chart. In a graphic organizer students will respond to the following questions:

1. What do you observe/see?
2. What is an opinion you have?
3. What is a question you have?

Students at a beginning level should respond with individual words either in English or their L1. Intermediate students can be expected to produce phrases or complete sentences.

The next part of the lesson is direct instruction. It introduces students to the critical vocabulary words "molecule" and "electron." Teachers should read the definitions in the Google Slides that are provided. Students will add these words to a vocabulary journal that they will update throughout the unit. Students will be required to include the following in their vocabulary journal: word, translation, definition, example, picture. Supplemental reading will be provided for teachers who wish to have a deeper understanding of each of these terms. At this point it is critical for teachers to have a general understanding of the effects that electrons have on molecules.

After discussion the double bond structure of electrons in molecules students will look at the molecular structure of rhodamine B, chlorophyll, and vitamin C. They will examine the prevalence and clustering of double bonds in these molecules and predict which they think will have a higher propensity to glow. Students should predict that rhodamine B and chlorophyll have a higher likelihood to glow given the higher number of double bonds.

Finally, students will complete an exit ticket that makes a prediction about what will be learned in this unit. They should use as many of the vocabulary words taught in lesson 1 as possible. A sentence starter will be provided for students who need the support.

Lesson 2 - The Basics of Glowing

Essential Question: What causes something to glow?
Language Target: I can read a text, annotate important details, and identify the main idea.

Students will begin with their second Power Sentence Protocol. The protocol will introduce two new vocabulary words, “excited” and “state.” Teachers should highlight the polysemy of the words by distinguishing between the everyday usage of these words and their specific definitions in Chemistry (provided in the Google Slide presentation).

Next, students will begin conceptualizing the different types of luminescence through a “Sort, Order, Label” activity. Provided in the lesson is a document with 21 pictures of different things that glow. Teachers can print the document and cut the document up into cards or use the photos to allow students interact with the cards in digital form. Students will then be required to work in groups. Students will take turns describing each photo; after they have done that, they will work together to arrange the cards into different categories. They can divide the photos into any category--the focus being students’ abilities to describe the cards and conceptualize differences between them. Some examples of categories that students might choose are color, living things, shape, or usage. However, these are by no means the limit to what students can use to categorize. Sentence frames will be provided for students to articulate complete sentences.

Before reading the anchor text for the unit, the first language dive of the unit will be taught. Students will explore simple present tense verbs. The teacher should focus on regular present tense verbs, standard conjugations, negative construction, and common irregular verbs (including be and have). It should be stressed that the simple present tense is used to talk about facts and things that are true all of time. Students will demonstrate their understanding of direct language instruction by writing novel sentence in the present tense without the use of a translator. Novice students can combine words from three separate word banks (subjects, verbs, objects) while conjugating and considering reasonable meaning of the sentences.

Students will now read the anchor text, “Things That Glow” that was created for the unit. The text will be read twice. The text first should be read with the teacher as a guide (students will have an opportunity for group and independent reading in the next lesson). The teacher should do a guided reading of the text. While the teacher (or student volunteers) are reading aloud, students should highlight 1-3 lines in the text that look like a central idea. They should also highlight important vocabulary words and identify examples of present tense verbs. Students should be encouraged to use different colors of highlight in order to distinguish between the different types of annotation. The second read of the text will allow students to comprehend more specific details. While reading a second time they should complete a double entry journal to summarize central ideas and provide evidence of the central ideas. Teachers should model the double entry journal for the students.

The final step of lesson 2 is for students to write a summary of the anchor text. Novice students should only be required to write a one sentence summary. Intermediate students should be expected to write three sentences: one sentence that demonstrates the main idea and two sentences that demonstrate supporting detail. A successful summary will explain that there are four main ways to make something glow.

Lesson 3 - Photoluminescence

Essential Question: What is photoluminescence?

Language Target: I can use the present progressive to talk about what is currently happening.

The third lesson will introduce the concept of photoluminescence. This lesson and the subsequent three lessons will break down each type of luminescence, giving students a general understanding of why and how things glow. Students will begin by making a prediction through a Quickwrite (again, utilizing a writing journal if they have it) and make a prediction of why some things glow under a blacklight and others do not. If teachers have a blacklight or a UV flashlight, they should use it to demonstrate how some things around the classroom glow under the light and others do not. If a blacklight is not available, a supplemental video can be shown demonstrating the same thing.

Here, the second language dive will take place. The present progressive will be taught in order for students to be able to talk about what light *is doing*. It should be stressed that the present progressive is used to talk about things that are currently happening. Teachers should also review (or teach) standard present tense conjugations of "be" so that students can conjugate in the present progressive. Teachers should gauge comprehension of present progressive conjugation through the assessment worksheet, found in Appendix V.

In the next part of the lesson students will practice orally using the present progressive. The teacher will shine a UV light on different things in the classroom and students will respond by stating whether the object glows or not. For example, if the teacher shines the UV light on a highlighter, students should respond "The highlighter is glowing," demonstrating both their observation of photoluminescence and usage of the present progressive verb tense. Without a UV light, another video can be used and students can call out their observations.

Finally, students will read the supplemental text "Photoluminescence" to gain a deeper understanding of photoluminescence. Intermediate students can be expected to read and annotate the entire text. Novice students can be put into groups in order to lessen the workload. Students can participate in a text jigsaw if necessary. Comprehension of the article should be demonstrated through an exit ticket where students are able to articulate that photoluminescence is caused when light excites electrons in a molecule causing it to glow.

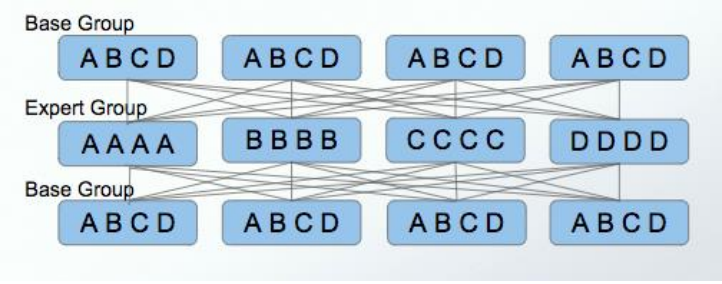


Image 2. Jigsaw Read Structure

Lesson 4 - Chemiluminescence

Essential Question: What is chemiluminescence?
Language Target: I can use ordinals and transitional phrases to explain a process.

Students will begin by reviewing what they learned from the prior class using a "Trading Cards" activity. On an index card they should write everything they remember about photoluminescence. Students will then read their card to a partner and swap cards. They should then find a new partner, read their new card to the partner, and then continue until they have read all cards or until time is up.

Next the teacher will prepare introduce sequencing and transition words. This type of vocabulary is helpful in chemistry and other science classes as it allows individuals to communicate time and directions. Words that can be taught include basic ordinals (first, second, third) as well as next, then, last, finally, etc.. Teachers can introduce the concept by ordering common daily actions. For example, "First, I wake up. Second, I eat breakfast. Next, I take a shower." This also provides an extension to review the simple present (repeated actions) and daily routine verbs.

To prepare for the lesson on chemiluminescence the teacher should hold up a glowstick, crack it to activate the reaction and then ask students to predict why the glowstick begins to glow when you crack it. Students will write a "Quickwrite" explaining their predictions. When they are finished the teacher will distribute the "Chemiluminescence" text and perform a guided reading with the class. At the end of the text the teacher will explain and demonstrate chemiluminescence by opening up a glowstick and showing the chemical reaction. The teacher will cut the end of the end of a glowstick, pour the hydrogen peroxide into a glass, then crack the tube of dye into the hydrogen peroxide showing the process of chemiluminescence. Again, the role of electrons in the process should be highlighted. See detailed instructions for the experiment in Appendix VI.

To demonstrate their understanding of both chemiluminescence and ordinals students should write a short paragraph detailing the steps taken in the experiment. The retelling should include a correct ordering of steps in addition to the use of the key words molecule and electrons. A paragraph that lacks the words molecule and electrons does not demonstrate complete knowledge of the chemiluminescent process. Beginning students can be given a graphic organizer and/or word bank to help them complete their paragraph. The graphic organizer is located in Appendix VII.

Lesson 5 - Electroluminescence

Essential Question - What is electroluminescence?
Language Target - I can use correct nouns and subsequent pronouns in which to reference the nouns.

The teacher should begin the lesson by asking students to get out their phone. Students will be asked to examine their phone screen. What does it look like up close? What does it look like far away? What happens when they touch it? Students will then make predictions on how the touchscreen works and how the phone lights up, or glows. Students who predict that it electrons are involved in the process are understanding the main idea of the unit. Students will write their predictions on the board or in a Google Jamboard. Students and teachers will then watch an eight

minute video on how touchscreens work. If the teacher wants to shorten the video for the sake of time, they can start at timestamp 3:14 (the first part of the video explains chemically toughened glass and while interesting, is not necessary for the understanding of the unit). Teachers should draw attention to the video at around 3:45 as the video begins to explain the role of electrons in phone screens.

Next, the teacher should engage in a lesson on antecedents. Students often begin sentences with pronouns without first using the noun to which the pronoun will refer (the antecedent). This can be detrimental to students during formal scientific assessment. They might be asked a question about the reaction between "hydrogen peroxide and rhodamine B" and respond that "it glows." However, this pronoun use is unclear as it does not first clarify *what* glows. The hydrogen peroxide? The rhodamine B? The combination of the two? Students should be able to accurately identify what they are talking about. First, the teacher should explain the difference between singularity and plurality. Next, he or she should teach English pronouns with a focus on "it." For a more in depth lesson on antecedents teachers can also opt to teach relative pronouns like "this" and "that." See Appendix VIII for a worksheet in which students can practice pronouns and antecedents.

To demonstrate their understanding of electroluminescence students should record a FlipGrid video in which they explain how phones and other electronic devices glow. Students should focus on simple and progressive present tense verbs and correct use of antecedents. A successful video will also describe how a screen is made up of different layers and that electrons are excited by an electrical charge. Novice students can be provided with sentence frames to assist them; however, they should complete the correct sentence frame on their own.

Lesson 6 - Bioluminescence

Essential Question - What is bioluminescence?
Language Target - I can identify and use basic adjectives in a sentence.

Students will begin by watching a short video that demonstrates bioluminescence and then complete a brainstorming activity. Students should write down as many words as they can while watching that describe what they see. Novice students should be free to write their observations in their L1. The goal of this activity is for students to describe what they see with adjectives which will lead into the grammar activity.

Teachers should explain that adjectives are a part of speech that describes another word. He or she can give examples of common adjectives (hot, fast, tall, angry, blue, etc.). Teachers should also note that in English adjectives go before a noun. Students will then build their own adjective lists by describing different pictures of bioluminescent animals. Teachers should show thes students the bioluminescent animals and organisms in Appendix IX one at a time. For each picture students will list words that describe the picture. Students should be free to articulate the word in their L1 and then look up a translation of the word. Students will then place the words in an adjective vocabulary journal (using the same vocabulary journal from Appendix III). These words can then be turned into anchor charts to be used in the classroom to enrich student vocabulary. Students should practice writing sentences using these adjectives.

After students have a grasp of appropriate adjectives the teacher should move on to talk about bioluminescence. Students and teacher should revisit the unit anchor text (Appendix II) and discuss different reasons that animals might be bioluminescent (to attract mates, to scare away predators, etc). Students will then engage in a Viewing with a Focus activity. They will watch a TedTalk entitled "The weird, wonderful world of bioluminescence." Transcripts of the video are available in 34 languages and students should be encouraged to read the transcript during and/or after the video facilitate understanding. Students should check their understanding of the video by writing a short summary (main idea plus three supporting details). Novice students can use the video to build vocabulary picking out five novel vocabulary words to define and learn. After the video the teacher should have students share their summaries and reiterate that bioluminescence is also reliant on organisms containing molecules that are excited with certain external stimuli.

Students will demonstrate their understanding of bioluminescence by creating a Google Slides Presentation or a Jamboard which researches one animal or organism that glows. The presentation should include an image, three facts, 5 adjectives that describe the organism, an explanation of how it glows (answer should include the words electrons and molecules), and the reason for why it glows. Teachers can also choose to have the students present their research to the class either through a presentation or a FlipGrid.

Final Assessment

At the culmination of the unit students will be required to combine what they have learned about luminescence and create a research project. They will research a single object that glows. For example, they can choose a specific bioluminescent animal, a molecule, glow in the dark paint, luminol, etc. Students will complete a project that describes the object, explains what kind of luminescence activates the glow, and practical applications for the object (how it is used or how it could be used). Students will be expected to use both the present and present progressive in their writing as well as correct use of antecedents. Students should cite one article and one video in their research (demonstrating both listening and reading comprehension) and should demonstrate their understanding of the material both with writing and speaking. Students can link to a FlipGrid or embed a video in their presentation. The complexity of student output should be assessed based on student language level. The final product should be organized, colorful, and include visuals.

Appendix I: Teaching Standards

Literacy Standards	**RI.9-10.2** Determine a central idea of a text and analyze its development over the course of the text, including how it emerges and is shaped and refined by specific details; provide an objective summary of the text.	Production of a main idea and summaries of texts are skills that students will need to demonstrate in every content area. Therefore, it is important that this skill is taught and reinforced for ELs. Additionally, this standard focuses on students' reading and comprehension skills.
	W. 9-10:2 Write informative/explanatory texts to examine and convey complex ideas, concepts, and information clearly and accurately through the effective selection, organization, and analysis of content.	Students will be able to write sentences or paragraphs (depending on proficiency) that explains concepts in a clear and organized manner. Grammar lessons on pronouns and ordinals will contribute to this.
	SL.9-10.1 Initiate and participate effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on grades 9–10 topics, texts, and issues, building on others' ideas and expressing their own clearly and persuasively.	Student discussion is important because it helps students to develop their ideas among peers and consistently practice their speaking and listening abilities. Students can also demonstrate skill in this standard by the use of digital tools such as Flipgrid.
	SL.9-10.5 Make strategic use of digital media in presentations to enhance understanding of findings, reasoning, and evidence and to add interest.	It is important that students receive language input from a variety of sources. They should be able to disseminate information and incorporate it into their work.
Content Standards	**Chm.1.1.3** Describe the concepts of excited and ground state of electrons in the atom: 1. Gaining energy results in the electron moving from its ground state to a higher energy level. 2. When the electron moves to a lower energy level, it releases the energy difference in the two levels as electromagnetic radiation (emissions spectrum).	While this unit is, at its core, an English Language unit, it is structured around a scientific topic. The hope is that, in addition to language skills, students will also understand critically important scientific terms and concepts such as electrons, excited and ground states, and the electromagnetic spectrum.

Appendix II: Anchor Text

https://docs.google.com/document/d/1WKPPPbF7RgJehH0qPiIRPTBp8g038DiSygt_5MyW4T0/edit?usp=sharing

The Science of Glow

by Sarah Wallace

If you look around at night you will see many different things that **glow**[1]. From your cell phone to televisions to glowsticks at parties, things are glowing. We are able to see in the dark better than ever before; however, we often take this for granted! **So how do things glow? What are the scientific processes that cause light to be emitted[2]?**

What other things glow? Write some examples here.

The Foundations of Chemistry

Everything in the world is made up of things called **molecules**[3]. Inside of a molecule are **elements**[4] such as carbon, hydrogen, nitrogen, oxygen. Different combinations of these elements along with **electrons**[5] create different molecules. Scientists are trying new combinations of elements all the time to create new molecules, like a chef creating a new recipe!

Molecules can be used for many different things. Some molecules, like chlorophyll, are used to allow plants to grow. Other molecules, like caffeine, are used to keep people awake. Each molecule has different characteristics that cause it to do different things. For example, some molecules can glow!

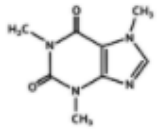
How do electrons make things glow?

When an electron is in a molecule it usually exists in what is called "the ground state." This means the electron has very little energy. However, sometimes an electron becomes **excited**[6]. After the electron is excited, it starts to relax again and goes back to its ground state. **When the electron returns to its ground state it causes certain molecules to glow**.

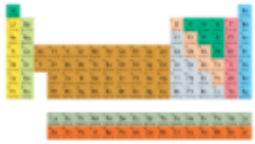
[1] **glow** - to emit light

[2] **emit** - to send something out

[3] **molecule** - a combination of atoms. A molecule is the smallest amount of a substance

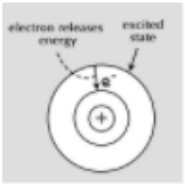


[4] **element** - In science, an element is a substance of a a single atom



[5] **electron** - a particle (small part) with a negative charge.

[6] **excite** - to cause something to move



What causes an electron to get excited?

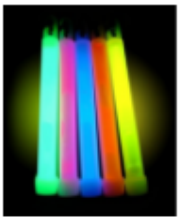
Electrons can be excited in four main ways[7], causing molecules to glow. The process of glowing is called luminescence. The common ways a molecule glows are **photo**luminescence[8], **electro**luminescence[9], **bio**luminescence[10], and **chemi**luminescence[11].

Photoluminescence occurs when light is absorbed by the electrons and then released, causing a glow. If something is photoluminescing, light is causing the glow. However, there are many different types of light! The most common types of light are ultraviolet (UV) light and fluorescent light. Examples of things that use photoluminescence to glow are highlighter colors under a UV light. The dyes in the highlighters contain molecules that get excited when they are hit by UV light.

Electroluminescence is what causes our phones to light up. It happens when electricity excites the electrons in our phone screens. Electroluminescence is also how we see images on a TV screen.

Bioluminescence is usually caused by a biological **reaction**[12] with a living being. Some bioluminescence is caused by chemical reactions within an animal. Other bioluminescence is caused by physical reaction like touch. Many animals emit light to find food, attract mates, and defend against predators.

Chemiluminescence is caused by electrons being excited when different chemicals mix together in a reaction. Glowsticks emit light using chemiluminescence. When you crack a glowstick, an inner glass tube released a dye that combines with hydrogen peroxide. The reaction of the two molecules create a glow!



At the beginning of the reading you listed examples of things that glow. Which **category**[13] of luminescence do you think each of the those things belong in?

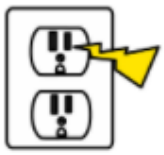
Why is luminescence important?

Luminescence is important because it can give us ways to emit light that use less energy and heat. It is more cost effective and doesn't hurt the

[7] **way** - method or process

[8] **photo** - light

[9] **electro** - electricity



[10] **bio** - life or living things

[11] **chemi** - chemical

[12] **reaction** - a change that happens when two or more things combine

[13] **category** - a group of things that are similar

environment like traditional light sources (like a light bulb which uses a lot of energy and heat). Luminescence is also used in **cinematic**[14] technology like the large LED screens used in TV shows like "The Mandalorian." Finally, luminescence is even used in COVID-19 testing to identity the presence of the virus.

What do you think are other applications for this technology?

What is the main idea of the text?	Which quote from the text proves that this is the main idea?

[14] **cinematic** - relating to movies

Appendix III: Vocabulary Journal

https://docs.google.com/document/d/1fTFpNi_aT0q9FZsQYTfGfAMEywUHG-pUU4UwY5YBznk/edit?usp=sharing

Vocabulary Journal

Word	Translation	Definition	Example	Picture

Appendix IV: Sort, Order, Label Activity
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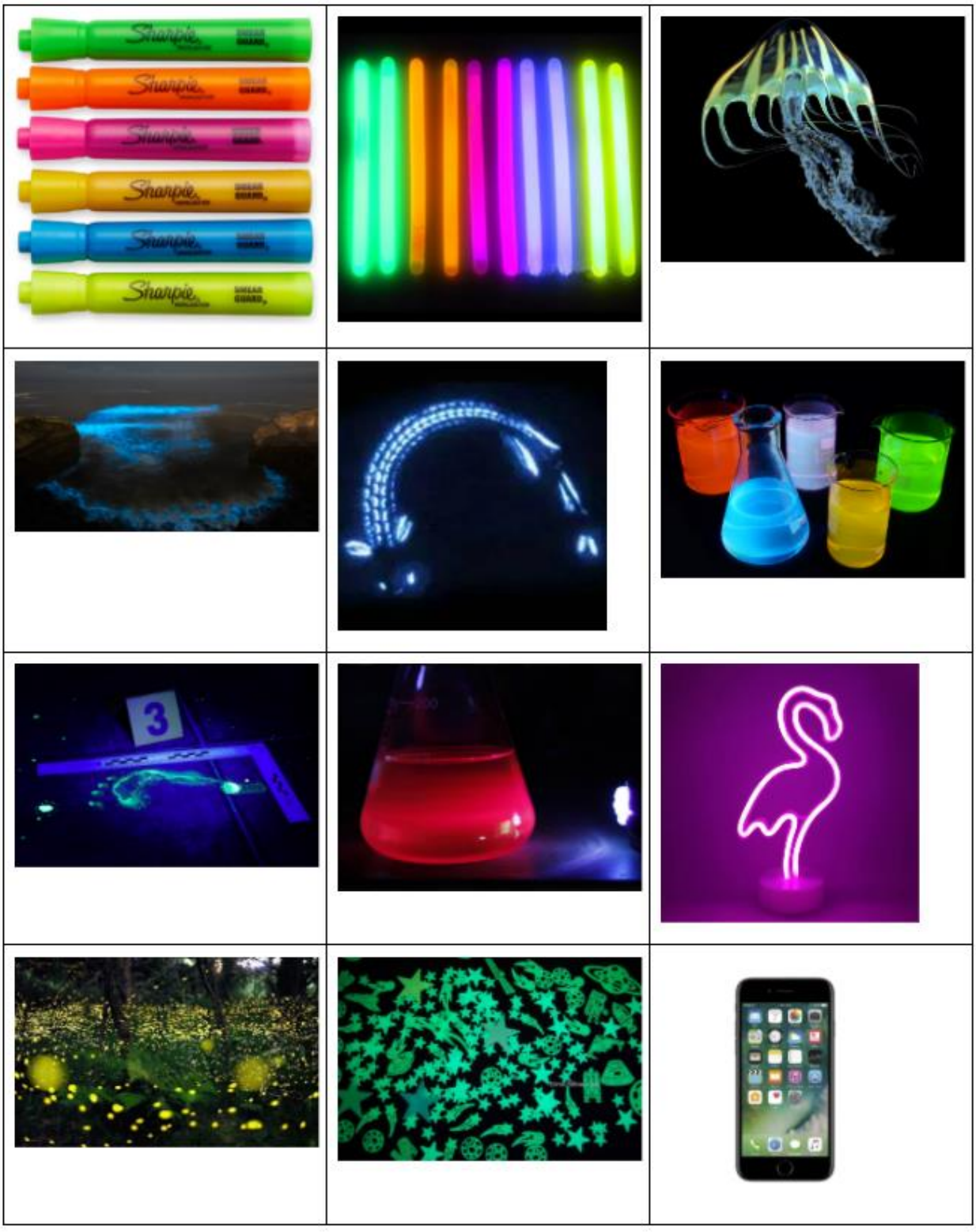
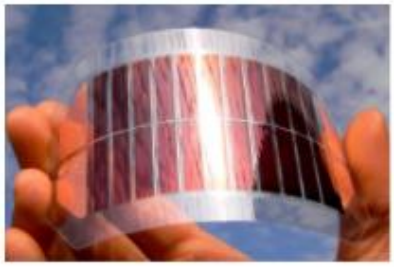
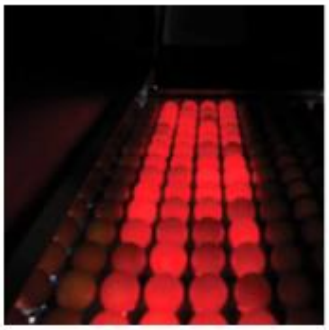







POLA
TONIC
WATER


12
1
2
3
4
5
6
7
8
9
10
11

Appendix V: Simple Present vs. Present Progressive Worksheet
https://docs.google.com/document/d/104h7O9gMvX2HeL2daAg3kHIk93qwOYXsvmMgh4DyF-I/edit?usp=sharing

Name:
Date:

The Present Progressive

"Be" Conjugation: Write the correct present tense form of "be" next to each pronoun.

I _____ You _____ He _____

She _____ It _____ We _____

They _____

Simple Present or Present Progressive? Write simple or progressive next to each sentence to identity the tense.

Ex. He is talking. → Progressive

1. They eat dinner. _____
2. It is glowing. _____
3. The electron is moving. _____
4. We are learning. _____
5. I study every day. _____

Change the time. Change each sentence from the simple present to the present progressive.

Ex. He talks. → He is talking.

1. She teaches. _____
2. We listen. _____

Write your own sentences! Write your own sentences using the present progressive tense.

1. _____
2. _____

Appendix VI: Chemiluminescence Experiment
https://docs.google.com/document/d/106fuSXGHCNrSKw4w5GRPq5oGh8IdJECtrTRk4KdjF78/edit?usp=sharing

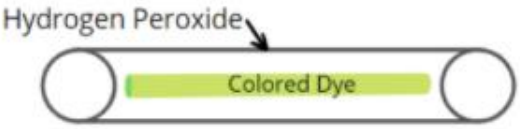
Exploring Chemiluminescence with Glowsticks

Materials Needed

- Glowstick (medium size)
- 2 small beakers or glasses
- Cutting board
- Knife
- Pliers
- Paper towel

Directions

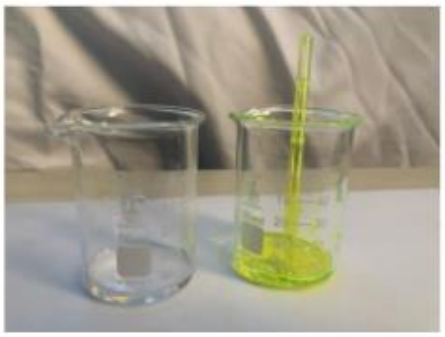
1. Look closely at one end of the glowstick and notice the smaller tube inside the outer plastic tube.



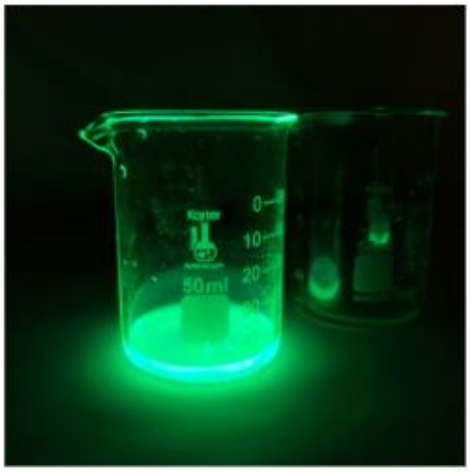
2. Using the knife and the cutting board, cut the tip off of one end of the outer plastic tube.

3. Pour the hydrogen peroxide into one of the glass beakers (the glass inner tube will also fall out).
4. Carefully pick up the glass tube and wipe it dry with the paper towel.

5. Place the glass tube into the other glass beaker. Break the bottom of the glass tube with the pliers. Be careful of small glass shards. Pour the dye out of the glass tube into the glass beaker.



6. Dim the lights of your room.
7. Pour the dye into the hydrogen peroxide. Swirl the beaker to combine the solutions and watch it glow!



Appendix VII: Graphic Organizer
https://docs.google.com/document/d/1q_M1Kli_j7ut2uD9NwNM9l8vvSUUfDRhhOYaA0fwxHc/edit?usp=sharing

Chemiluminescence and Ordinals Graphic Organizer

Word Bank

Nouns		Verbs	
glowstick	tube	turn off	break
plastic	glass	cut	pour
beaker	liquid	combine	dry

Graphic Organizer - Write a different step inside each box.

1.	
2.	
3.	
4.	
5.	
6.	
7.	
8.	

Appendix VIII: Pronoun Practice
https://docs.google.com/document/d/1yoj0adgYJ-l2E0Lt8qu1ZIH43YBlCSb7touDuCTzBeU/edit?usp=sharing

Pronoun and Antecedent Practice

Write the correct pronoun for each noun.

1. Ms. Whelan → _____
2. The students and I → _____
3. The employees → _____
4. Pedro → _____
5. My phone → _____
6. His books → _____

Write 2 sentences about each topic. The first sentence should use a noun. The second sentence should use a pronoun that refers to your noun. Highlight the noun and the pronoun that refers to it.

Ex. **TV Show**

The Mandalorian is a great TV show. It is very interesting.

1. A teacher

   _____

2. Food

   _____

3. A sport

   _____

4. Your friends

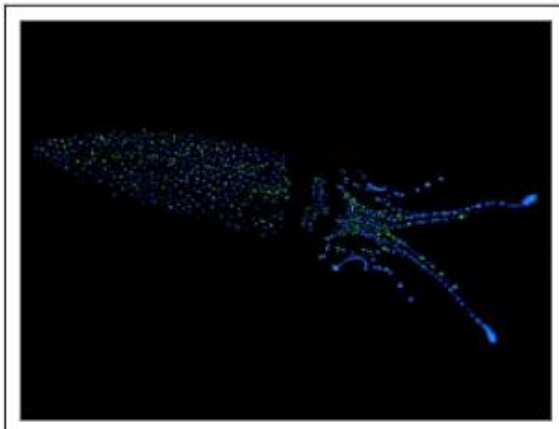
   _____

5. A song

   _____

Appendix IX: Bioluminescent Organism Adjective Activity
https://docs.google.com/document/d/1LMg_oHim7RSZ-ZJ6694wrtekqXbH6WZ45990Ghyh48I/edit?usp=sharing

Bioluminescent Organisms



Appendix X: Engaging Newcomers in Content Classes

The purpose of this article is to provide a **guideline** for helping you integrate Newcomers with little to no English into your classrooms during their **first days** and **weeks** of school. Some of these tips/tools will be things that you naturally do with your students already. Some will be specific to ELLs and their unique situation as minority speakers in an English classroom.

Here is some important information about Newcomer situations and educational backgrounds.

1. Newcomer ELLs come from a variety of educational backgrounds; however, **some have never had access to formal education**. This can contribute to a high level of culture shock.

2. Students come from a variety of linguistic backgrounds. Some students are proficient and gifted learners in their first language (L1). **Some students have never had the opportunity for literacy and education in their L1.**

3. It is important to note that **a Newcomer's language ability is not reflective of their grasp of the content**. Conversely, their grasp of the content is not reflective of their language ability.

4. ELLs often go through a "silent period." This is an indefinite period of time when English learners choose not to communicate productively through speech. This is normal and **teachers should not force ELLs to talk if they are not ready**. Respect the silent period (Clark-Gareca and Olsen 120). However, this does not mean that teachers must ignore the Newcomers.
    - Greet students every day, even if they do not respond to you
    - If natural, offer friendly compliments--students will often develop the confidence to say "thank you" within a few days or weeks (Clark-Gareca and Olsen 122).
    - Be animated with your facial expressions and use gestures to communicate; however, **DO NOT** increase the volume of your voice or significantly slow your speech down in an attempt to communicate.

So how can you create an environment that is both respectful of Newcomers' situations *and* encourages them to want to learn and absorb the class content?

1. **Encourage students to use their first language.** Obviously the long term goal is for them to be proficient in English; however, their **first few weeks** at school should be focused on building a positive classroom environment and supporting their prior content knowledge. You can do this by…
    - ...allowing students to translate using an iPad, Chromebook, or bilingual dictionary
    - ...assigning a high level ELL to interpret for the Newcomer
    - ...encouraging students to answer questions in their L1 both verbally and in written form on tests, worksheets, quizzes, etc.

2. A picture is worth 1,000 words in any language, so **develop students' vocabulary with visuals.**
    - Add visuals to your PowerPoint presentations.
    - Use a simple Google search to add images to homework, tests, and/or quizzes.
    - **Encourage students to draw pictures of key concepts rather than to copy down definitions.**
    - Allow students to "create digital stories using visual images which they can select for themselves through internet searches or taking their own photos" (Roy-Campbell 4).
    - Emphasize brainstorming and graphic organizers (Roy-Campbell 4).

3. **Be linguistically vulnerable**. Language learning can be very anxiety provoking. Students are almost always more proficient than they demonstrate to us, but they are afraid of making mistakes and therefore do not attempt a more complex sentence. Ask students how to say key terms and phrases in *their* language. This shows them that you are interested in their culture, and shows that it is okay to make mistakes when speaking.

Appendix X: Materials List

- Google Slides Presentation linked here.
- UV Light
- Glowsticks (available at the Dollar Store)
- Cutting Board
- Knife
- Glasses or Glass beakers
- Pliers or Tweezers
- Paper Towel

Appendix XI: Resources for Students

- NYU Steinhardt Bilingual Chemistry Glossary for CMS top 5 languages
    - Spanish
    - Vietnamese
    - Arabic
    - Hindi
    - French
- Students who finish work quickly or need/want extra enrichment in the topic can benefit from the following videos:
    - "Bill Nye The Science Guy Atoms & Molecules" - https://www.youtube.com/watch?v=ogPNZ_MXksM - This video provides students with a general understanding of molecules and how atoms combine to form different molecules
    - "Electroluminescent EL Tape Review" - https://www.youtube.com/watch?v=bSsJgCsrFn8 - This video provides an

explanation for EL Tape and an explanation of another type of electroluminescence.
    - "How do Touchscreens work?" - https://www.youtube.com/watch?v=wKuqNuzM1oM - This video gives an additional explanation of the electroluminescent and engineering process of smartphones.
    - "National Geographic - Bioluminescent Creatures - Documentary 2016" - https://www.youtube.com/watch?v=GfmR8sSy1h8&t=130s - This documentary provides a closer look of bioluminescent creatures.
- The following articles are supplemental texts and news articles that students can use to be better informed on the topic and/or practice text summarization.
    - Hullander, Douglas. "Glow sticks' glimmer caused by cool reaction." Knoxville News-Sentinel, The (TN), October 28, 2002: B4. NewsBank: Access World News.
    - Nickel, Lori. "Lured by the bright lights | Glow-in-dark sticks could help attract more fish." Milwaukee Journal Sentinel (WI), March 1, 2015: 04. NewsBank: Access World News.
    - Batsford, Susan. "Let them glow." Ottawa Sun, The (Ontario, Canada), October 28, 2014: 15. NewsBank: Access World News.
    - Catalan, Israel. "Baruch Professor discovers the reason behind glowing sea pickles." T icker, The; Baruch College (New York, NY), October 30, 2020. NewsBank: Access World News.

Appendix XII: Resources for Teachers

- Maccormac, Aoife, Emma O'Brien, and Richard O'Kennedy. "Classroom Activity Connections: Lessons from Fluorescence." *Journal of Chemical Education* 87, no. 7 (2010): 685–86. https://doi.org/10.1021/ed100262t.
    - This article will provide suggestions for teachers to provide for students for items they can research for their final project.
- https://www.aapt.org/K12/Optics-Collection.cfm - This DigitKit from the American Association of Physics Teachers provides more experiments that teachers and students can do with glowsticks in the classroom in order to extend the learning.
- https://www.scholastic.com/parents/school-success/learning-toolkit-blog/glow-stick-science-experiment-kids.html - This experiment from Scholastic provides teachers and students with an additional experiment that teaches allows students to make scientific predictions about temperature and electrons.
- This Google Slides Presentation can be used as a Pacing Guide to teach the unit. A sample of the slides can be found in the following Appendix (XIII). https://docs.google.com/presentation/d/1EBjUpVFIHwgHIHwlwYX2QyDXBl8yHp_CDK0misJOAh0/edit?usp=sharing

Appendix XIII: Google Slides Presentation

The Science of Glow

Chemistry

Essential Question: What are the processes that cause something to glow?

Standards

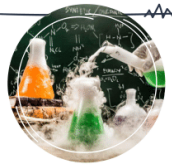
ANCHOR LITERACY STANDARD

Literacy.RI.9-10.2 Determine a central idea of a text and analyze its development over the course of the text, including how it emerges and is shaped and refined by specific details; provide an objective summary of the text.

ANCHOR CONTENT STANDARD

Chm.1.1.3 Describe the concepts of excited and ground state of electrons in the atom:
1. Gaining energy results in the electron moving from its ground state to a higher energy level.
2. When the electron moves to a lower energy level, it releases the energy difference in the two levels as electromagnetic radiation (emissions spectrum).

2



Lesson 1

Chemistry Foundations

3

1

Essential Question

What are molecules and electrons?

Language Target

I can define vocabulary words and represent them with pictures using a graphic organizer.

Quickwrite

- What are some examples of things that glow?
- How can things that glow be helpful?
- What do you think causes things to glow?

5

Quickwrite - Sentence Frames

- Things that glow are _____ and _____.
- Things that glow are helpful because _____.
- I think glowing light is caused by _____.

6

Power Sentence Protocol

If you look around at night you will see many different things that glow. From your cell phone to televisions to glowsticks at parties, things are glowing. We are able to see in the dark better than ever before; however, we often take this for granted! So how do things glow? What are the scientific processes that cause light to be emitted?

glow - light
from...to... - used to give a wide variety of examples
take (it) for granted - to not appreciate something completely
emitted - to send something out

7

See, Think, Wonder

Watch the video and then complete a "See, Think, Wonder" chart.

See - What do you observe/see?

Think - What is an opinion you have?

Wonder - What is a question you have?

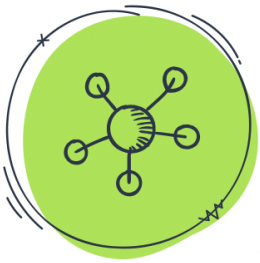
8

Word Study

Molecule

A combination of atoms. A molecule is the smallest amount of a substance.

A molecule is like a recipe. You can combine different atoms and electrons to make different ones.

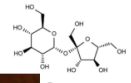


9

Common Molecules

Caffeine

Sugar



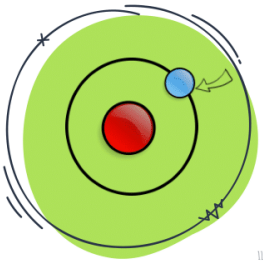
10

Word Study

Electron

A particle (small part) with a negative charge.

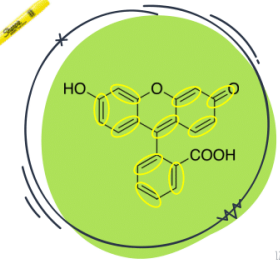
Electrons help to combine different atoms. The more electrons in a molecule, the more likely it will glow!



11

Fluorescein

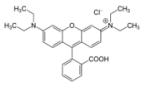
Fluorescein is the molecule that is used in yellow highlighters. There are lots of electrons in fluorescein. That is why it glows! The electrons are located with the double lines (called double bonds).



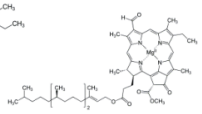
12

Do you think these molecules GLOW? WHY OR WHY NOT?

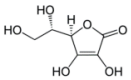
Rhodamine B



Chlorophyll



Vitamin C



Exit Ticket

What do you think we will learn about in this unit? Use as many of your vocabulary words as you can in your answer.

Sentence Starter:

In this unit we will learn about _____.

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