High School Chemistry Curricular Redesign: The Spiral Curriculum

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High School Chemistry Curricular Redesign: The Spiral Curriculum

By

John Posillico

A thesis submitted to the

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in partial fulfillment of the requirements for the degree of

Master of Science in Education
High School Chemistry Curricular Redesign: The Spiral Curriculum

APPROVED BY:

_________________________________________              ___________
Advisor

_________________________________________              ___________
Director, Graduate Programs

Date
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Chapter I: Introduction

Statement of the Problem

Traditional approaches to learning in science classrooms have been predicated on the concept of repetitive, or blocked practice (Blasiman, 2017). This approach is readily taken up by many science teachers, especially chemistry. The reason this practice is ubiquitous across high school chemistry classrooms is because it makes intuitive sense to teach things in repetition until mastery is observed before moving on to the next concept, or problem. However, the major obstacle that nearly all chemistry teachers face is that their students forget concepts over time and do not retain them in their long term memory (Taylor & Rohrer, 2009; Miller, Watson, & Strayer, 2012). This has proved to influence exam scores and there have been a myriad of approaches to address the underperformance seen in the current cohort of students (Blasiman, 2017). Currently there has been a large allocation of resources investigating an innovative teaching strategy called interleaved practice (Brown, 2014). Interleaved practice can be observed in many classrooms throughout America. Teachers have begun to create curriculum built on the foundation of interleaving and spacing concepts. This has been traditionally referred to as the Spiral Curriculum.

Interleaving and spacing concepts happen concomitantly and their effects on student performance has proven to be positively synergistic (Blasiman, 2017; Guzman-Munoz, 2017; Rau, Aleven, & Rummel, 2013). Interleaving and spacing content requires the following: the students are provided an exemplar and get an attempt to try a similar but distinct problem, the problem that the students attempted gets reviewed and then they move on to a new, but distinguishable problem. Students will repeat this process for multiple concepts, the foundational idea behind this practice is that the students will be allotted time to forget the minutia of each concept addressed and when they revisit after a particular period of time, they will make a stronger mental effort to relearn the
distinct underlying principles behind each concept (Brown, 2014; Eglington & Kang, 2017; Taylor & Rohrer, 2009). The period where forgetting occurs is integral to this type of practice.

Allowing sufficient time to forget distinguishable characteristics between similar concepts requires more resources to reactivate the necessary neural networks (Lin, Chiang, Wu, Iacoboni, Udompholkul, Yazfanshenas, & Knowlton, 2012; Van Leeuwen, Manalo, & Van Der Meij, 2015; Vlach, Sandhoefer, & Bjork, 2014; Zulkiply, 2013). The reactivation of the neural networks is what makes the stronger connections and embeds learning into an individual’s long term memory (Brown, 2014). It is unambiguous that interleaved and spaced curricular design is a superior pedagogical approach towards creating robust learning within our students, compared to the current blocked practice model that is observed in a vast majority of classrooms.

The spiral curriculum has proven to be a more effective approach than current models that are implements today in a majority of classrooms. There are two major reasons that this model is not being accepted by many teachers. The first is that it requires much more work on the end of the teacher than the traditional blocked model does. Teachers already have a very large workload and it is not an easy task to encourage teachers to take on an even larger workload without any incentive that they don’t currently have. If you will not pay them more for doing much more work, most teachers will be reluctant to do so. The other major reason is that the struggle students experience during the spiral is perceived as a negative thing. Students motivation is supported through their successes and interest, and there is a claim that students do not enjoy struggle which will result in them disengaging in (Patall, Pituch, Steingut, Vasquez, Yates, & Kennedy, 2019). Keeping students engaged is critical and may be considered more difficult once you encourage struggling. Being perceptive of students’ emotions while they experience struggles in learning is not something all teachers are equipped to do and results in teachers being even more
reluctant in instituting the spiral into their classrooms. Currently, there are not many reliable and free resources for teachers to go to for facilitating the creation of a unique spiral curriculum.

**Project Design**
- The following is a project design outline, and example(s). This capstone project will produce a curricular outline, all associated lesson plans, activities, and interleaved assignments and assessments that are robustly supported by literature.

- The scope of this capstone project will display the connections between content within the spiral over six (6) units in chemistry. The assertions made in the literature pertaining to learning benefits attributed to interleaving and spacing practices will be the foundation for the design of this spiral curriculum. Each unit will provide a complete set of lesson plans, learning activities, assessments, and all materials needed for instruction. This capstone project will ensure that these lessons are readily implemented into any chemistry classroom for the first six (6) units of an academic year.

- Lesson Plans will provide the following: title of lesson, length of the lesson, unit of study, essential unit vocabulary, lesson objective, essential question for the unit, materials, learning standards for the lesson, strategies for differentiation and supports for diverse learning needs, assessments and evaluation criteria, relevant theories and references, and a lesson timeline, and direct connections to the literature that supports the methodologies and theories.

- Learning activities will provide the following: title, source, standards, materials, learning objective(s), narrative summary, rationale for the activity, potential misconceptions, and instructional/preparational recommendations, and direct connections to the literature that supports the methodologies and theories.
- Curricular outline will show a progression of concepts over the course of six (6) units in chemistry

**Example Lesson Plan:**

<table>
<thead>
<tr>
<th>Lesson Time: 60 Minutes</th>
<th>Grade Level: High School</th>
<th>Content Area: Chemistry</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unit of Study: Nuclear Chemistry</td>
<td>Lesson Title: Half Life Introduction</td>
<td></td>
</tr>
</tbody>
</table>

**Essential Question:**
What is half-life and why is it significant?

**Content Standard(s):**
*Next Generation Science Standards:*
HS-PS1-8: Develop models to illustrate changes in the composition of the nucleus of the atom and the energy released during the process of fission, fusion, and radioactive decay.

**Learning Objectives** associated with the content standards:
**Students will be able to (SWBAT):**
- SWBAT understand half-life
- SWBAT determine the length of the half-life for a radioisotope
- SWBAT calculate the number of half-lives passed for a radioisotope

**Instructional Resources and Materials** to engage students in learning: PowerPoint, laptop, calculator, Promethean ActivBoard, math and vocabulary review sheet, and activity packet

**Lesson Timeline, Instructional Strategies and Learning Tasks** that support diverse student needs:

<table>
<thead>
<tr>
<th>Time</th>
<th>Teacher will...</th>
<th>Students will...</th>
</tr>
</thead>
<tbody>
<tr>
<td>0:00-7:00</td>
<td>• Welcome the students into the class</td>
<td>• Enter the class, grab a note sheet and get into their seats</td>
</tr>
<tr>
<td></td>
<td>• Encourage them to write down the learning objective and work on the Do Now</td>
<td>• Begin writing down the Learning Objective for the day and start working on the Do Now</td>
</tr>
<tr>
<td></td>
<td>• Collect any work that has not been turned in yet</td>
<td>• Turn in any completed assignments</td>
</tr>
<tr>
<td></td>
<td>• Go over the Do Now with the students and address any misconceptions if they arise</td>
<td>• As a class, provide steps/answers for the Do Now questions</td>
</tr>
<tr>
<td>7:00-13:00</td>
<td>• Introduce the topic of half-life to the students through a video</td>
<td>• Watch a video that introduces half-life</td>
</tr>
<tr>
<td></td>
<td>• Instruct the students to write down two things they learned from the video on the top of their note sheet, in the designated area.</td>
<td>• Write down two things that they learned from the video in the designated area on their notes sheet</td>
</tr>
<tr>
<td></td>
<td>• Take four to six volunteers to write on the board one thing that they learned from the video</td>
<td>• Participate in the class discussion by either writing their newly learned information on the board or sharing it aloud with the class</td>
</tr>
<tr>
<td>Time</td>
<td>Activity</td>
<td></td>
</tr>
<tr>
<td>--------</td>
<td>--------------------------------------------------------------------------</td>
<td></td>
</tr>
</tbody>
</table>
| 13:00-25:00 | • Start going through the guided notes  
• Throughout the guided notes, calls on students to provide suggestions for what should go into the blanks  
  o Ask students: “How much would be left after one half-life?”  
• Discuss how to read the graph for the radioactive decay of a radioisotope and explain what changes, or remains the same for different radioisotopes  
  o Ask students: “How much is left after one half-life?”  
  “How much decays from the first half-life to the second half-life?”  
  “How much time does it take to go through two half-lives, according to the graph?”  
  “How many times do we cut our radioactive sample in half?”  
• Model how to solve a problem involving radioactive decay  
  o Ask students: “according to our formula, how many half-lives passed?”  
  “How many times do I cut my radioactive sample in half?”  
  “If I cut in half two times then what percent of our original sample remains radioactive?”  
  “If I wanted to go backwards and figure out how much we started with, instead of cutting in half what would I do?”  |
| 25:00-50:00 | • Instruct the students to break up into their usual groups  
• Walk around the room assisting students who appear to be struggling. Reinforcing the students who are doing well with the material  |
|         | • Fill in their guided notes  
• Provide suggestions as to what they think will go in the blanks  
• Annotate the graphs at the bottom of their note sheet  
• Follow along as a problem is modeled for them  |
|         | • Get into their groups that they have been working in since the beginning of the year  
• Working together in groups on the problem set  
• Ask questions with their partners before asking the teacher  
• If they finish early, they will help their classmates |
| 50:00-60:00 | Encourage those who finish to help their classmates who are not done yet |
| 50:00-60:00 | Address misconceptions and student questions about the problem set |
| 50:00-60:00 | Collect student work |
| 50:00-60:00 | Ask questions about the problem set |
| 50:00-60:00 | Turn in completed problem set |

**Differentiation and planned universal supports:**

*Learning Disability (LD):* In group activities these students will be placed with other student(s) that does not have a disability or learning need or any kind. Students with a LD will be given a supplemental vocabulary sheet that defines all academic vocabulary that is present throughout the lesson. There will be guided notes that require the students to fill in the key academic vocabulary. Students have benefitted from this method of grouping throughout the year. An additional modification a scaffolded problem set that is to be administered to all students when they break into groups.

*Students with other learning needs, struggling readers and struggling public speakers:* Students will be provided a vocabulary sheet with definitions of all academic vocabulary. These students will also be paired up with another student in the class who does not have a learning need or disability. The one student who struggles with public speaking will be grouped up with at least of the two students that they are comfortable working with. These two students have continually displayed through previous group work to be a strong support for the struggling public speaker.

The teacher will model the group work for the students before directing them into their groups. Students are also permitted additional time, in accordance with their 504 plans. A separate location is available for them to complete their work outside of class. Students can work here during their lunch period and after school. All students will also all have access to a *Supplemental Review Sheet* that covers math skills needed for the learning segment as well as the academic vocabulary that will be encountered throughout. Math skills include converting fractions to a percentage, calculating percentages, and division and multiplication.

**Type of Student Assessments and what is being assessed:**

- **Informal Assessment:** While students are working, the teacher will be walking around the room listening and observing student conversations and work. The Do Now question, at the beginning of the lesson, will address concepts from the day before as a check for retention of student understanding and it will reactivate the necessary neural networks associated with learning (Huelser, 2012).

- **Formal Assessment:** The problem sets are to be turned in after they are completed at the end of class or at a later date. This problem set requires students to recall previous atomic structure unit. Practicing this recall will help assess retention of previously learned material (Brown, 2014).

- **Modifications to the Assessments:** Students will be given a supplemental vocabulary and math skills sheet for the entire unit. The vocabulary will contain academic and non-academic vocabulary that students may struggle with. The problem set will also have every question scaffolded. Students will also be given a calculator to help perform the required math necessary to solve the problems in the set.
### Evaluation Criteria:
Students will be evaluated on their understanding through answering the activity questions. There are seven questions that students will be assessed on. Each question will be worth one point each, for a total of seven (7) points on the assessment.

### Relevant theories and/or research best practices:

### Example Learning Activity:

<table>
<thead>
<tr>
<th>Title of Activity</th>
<th>Flame Test</th>
</tr>
</thead>
<tbody>
<tr>
<td>Source(s)</td>
<td>Created by John Posillico, Dr. Carleton Gaupp, and Ethel Khanis</td>
</tr>
</tbody>
</table>
| NYS Standard(s)   | 3.1i Each electron in an atom has its own distinct amount of energy.  
|                   | 3.1j When an electron in an atom gains a specific amount of energy, the electron is at a higher energy state (excited state).  
|                   | 3.1k When an electron returns from a higher energy state to a lower energy state, a specific amount of energy is emitted. This emitted energy can be used to identify an element.  
|                   | 3.11 The outermost electrons in an atom are called the valence electrons. In general, the number of valence electrons affects the chemical properties of an element. |
| NGSS Standard(s)  | **HS-PS1-1**: Use the periodic table as a model to predict the relative properties of elements based on the patters of electrons in the outermost energy level of atoms |
| Supplies          | Popsicle Sticks, Bunsen Burner, Beakers, Sparker, Ionic Metal Solutions, Fire Extinguisher, Fire Blanket, Eye Wash Station, Gloves, Goggles, Erlenmeyer Flasks |
| Key Questions     | What are the observable differences between the different ionic metal solutions?  
|                   | What is the unknown ionic metal solution?  
|                   | Why do we see different colors for different ionic metal solutions?  
|                   | How can we predict general trends in the colors of metal ion solutions? |
| Narrative Summary | Students love to see brilliant colors produced in person. Seeing fireworks during the summer is always a fun attraction for kids and adults. This lab will address misconceptions associated with the colors that fireworks produce, making real-world phenomena less abstract (Erman, 2017). Students will be given stock |
solutions of various metal ion solutions that will all be labeled except one. Students will work with partners and record their data in a lab packet (heterogenous grouping is used relative to students’ academic performance) (Brown, 2014). Students will have to use their data and knowledge about electron configuration of metal ions to conclude what the unknown metal ion solution will be. This activity will address multiple concepts that have been previously addressed through the spiral curriculum and will reappear throughout the remainder of the year.

<table>
<thead>
<tr>
<th>Rationale</th>
<th>This lab is designed to assess student understanding on multiple concepts that were covered previously as well as current concepts being addressed in class. It helps enlighten electron excitation by making the abstract concepts more explicit and observable through a kinesthetic and visual experience. This activity also helps elaborate why fireworks produce a variety of colors. This is something most students are familiar with, but have misconceptions about (Stein, Larrabee, &amp; Barman, 2008). Students will be exposed to an analytical technique that relies upon atomic structure, thus highlighting the relevance of understanding atomic structure beyond chemical reactions.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Potential Misconceptions</td>
<td>Electrons stay in the excited state and therefore the energy that is used to excite the compound is what we are seeing during the flame test. Fireworks use dyes in their explosive parts to produce different colors. Only heat can excite an electron out of the ground state. The color that is emitted is the same wavelength as the color that is absorbed. All metals in the same group will emit the same color and have the same wavelength.</td>
</tr>
<tr>
<td>Recommendations</td>
<td><strong>Pre-Lab:</strong> Create large volumes of stock metal ion solutions for each metal ion and the unknown. This will avoid running out of solutions in the instance of spills. Also soak the popsicle sticks overnight so the solution works up into the popsicle stick and will produce a more concentrated colored flame during the flame test. <strong>During Lab:</strong> Do not allow students to work without the water running at a controlled rate while their Bunsen burner is on. This will help prevent fires from getting out of control because students will be able to drop popsicle sticks into the sink when needed. Also, do not let students hold popsicle sticks without using gloves. <strong>Post Lab:</strong> Have separate waste beakers for each metal ion solution. Some metals need to be disposed of differently than others and therefore it makes clean up safer and more efficient.</td>
</tr>
</tbody>
</table>
Significance of Project

The insistence of a spiral curricular design is pertinent towards success in the chemistry classroom for our students. Pursuit of STEM education and occupations is below 25% because of students disinterested in the content. This is derived from students not being able to conceptualize abstract concepts therefore finding the content too difficult. This curricular design will allow educators to circumvent this problem through embracing the struggle and facilitating student learning through a mentally stimulating environment.

The spiral curriculum has begun to increase in popularity as teachers across New York state have started to understand the benefits and observe them in their own classrooms. Teachers understand that the profession they’re in is predicated on the betterment of the next generation. Teachers take on a responsibility to provide the best quality of education to their students and that is regardless of the means it takes to get there. As educators, we must take our responsibility to educate the current cohort of future STEM professionals to the best of our abilities. Preparing each day as a new day with the mindset that we will have to work harder than our students in order to adequately prepare them to enter the world outside of our classrooms is not a job that should be taken lightly. The spiral curriculum is far more rewarding than it is time consuming. If teacher candidates wish to pursue careers in education, then it is pertinent that they take the aforementioned statements serious in order to understand their role in society. Teacher are responsible for helping students fulfill their potential and the spiral curriculum is the tool that can facilitate student development.

Chapter II: Literature Review

Neurological Foundations of Learning

The amount of grey matter in an individual brain is widely accepted to be representative of the cognitive function. Grey matter is composed of neurons that are myelinated which is
associated with quicker propagation of action potentials. The quicker the propagation of action potentials, the quicker the stimulus is received and responded to within the brain. Thus, it is concluded that more grey matter in one’s brain positively correlates to the cognitive load that the individual can efficiently process. Understanding the influence of grey matter and brain function as a whole is of primary concern for neurologists as well as educational researchers. To elucidate the pathways in which learning takes place will ultimately allow education practitioners to stimulate those pathways through innovative pedagogical strategies. Clarifying which pathways are stimulated during learning and to which degree provides a more resounding understanding of how we can effective create better, more enriching learning environments for our students.

Changes in the grey matter volume must occur over time and therefore it must be the accumulation of multiple structural changes that occur instantaneously throughout the learning process. Keller and Just (2016) investigated short term structural and functional changes to enlighten which short term changes over time are consolidating into the macroscopic changes observed in the brain as a result from learning. Keller and Just (2016) use diffusion-based metrics to assess how structural changes are related to changes in brain function. They measure how water is being diffused throughout the brain regions that are associated with learning, mainly the hippocampus. They hypothesized that changes in diffusion in the hippocampus is representative of short term neuroplasticity. This region of the brain is related to long term potentiation (LTP) which is the solidification of learning and memory.

The Keller and Just (2016) experiment utilized fMRI to measure brain diffusion during a driving simulation. Participants were divided into two groups; the experimental group was given only one driving route to learn and the control group was given multiple different routes to drive.
The idea was that more robust learning and memory would occur within the experimental group because after each 45 minute trial they would have increased their knowledge of the route and the control group would not display this type of mastery. As the experimental group develops a stronger mastery for the route, their short term neuroplasticity changes in the brain would accumulate and display stronger readings on the fMRI. Participants showing a decreased diffusivity in the brain would lead to greater functional connectivity, which means changes in the brain function (Keller & Just, 2016). Functional connectivity is a measure of changes in the levels of activation of separate regions of the brain.

Keller and Just (2016) found that functional connectivity increased in the experimental group. The experimental group showed decreased diffusivity which meant that multiple regions of the brain were interconnected and created multiple short term memories through neuroplasticity mechanisms. These short term learning moments showed functional changes in the brain, as detected by the fMRI, and resulted in more robust learning. Also, Keller and Just (2016) found that functional changes during learning are detectable in time frames as short as 45 minutes. These functional changes can lead to structural changes in the hippocampus and thus grey matter volume. Future studies may be able to detect the lower limit of time required to create functional and structure changes in the hippocampus during learning. The time frame here is of significant importance because the typical class in high school is at the very least 40 minutes, therefore emphasizing the importance of each class in the development and restructuring of students’ brains. Educators should make value of every minute in their class with the current knowledge that 45 minutes in sufficient time to create structural and functional changes in the brain.
The findings by Keller and Just (2016) help highlight the importance of how critical short term processes are in the context of brain reconfiguration. Students need to be actively engaged and motivated in order to make the most of each class because of how influential it is on the development of their cognitive functioning. The Keller and Just (2016) focused on a driving simulation and therefore their findings cannot be confidently applied to education. The driving simulation used many other areas of the brain that may or may not be activated during a traditional learning process. The interconnectivity of regions of the brain may have been greater during their simulation and provided data that may not be representative of classroom based learning. Future studies need to apply the methodology used by Keller and Just (2016) in the classroom in order to extrapolate their findings from the current study.

It has been well documented in the literature that interleaved practice has led to a stronger retention of learning material when compared to repetitive, blocked practice. Interleaved practice encourages the reactivation of neural networks in the brain which in turn induces more cognitive demand than blocked practice. This significant increase in cognitive demand is often referred to as desirable difficulties (Lin, Chiang, Wu, Iacoboni, Udompholkul, Yazfanshenas, O, & Knowlton, 2012). It is common that results during practice are less impressive for interleaved practice, by comparison to blocked. However, retention is far superior for those who utilize interleaved practice. Lin et al. (2012) investigated the physiological responses in the brain for subjects who use interleaved and blocked practice and whether age affects which areas of the brain are activated during practice.

Neural plasticity is the ability to reform neural networks in order to create new memories, skills, etc. Learning is not crystallized after a certain age; adults are able to learn new skills and
content through the *rewiring* of the brain. Lin et al. (2012) used fMRI to map the brain in young, college-aged adults, and senior citizens (65+ years old). This study sought to map out brain activity while subjects performed a series of learning tasks. They were tested three times a day for five days, and each test lasted for 3 minutes and 48 seconds. Subjects wore electrodes that would map electrical activity of neural networks within the brain, creating a map showing the regions of the brain that were active during the process. Lin et al. (2012) hypothesized that different brain regions would be active when comparing the brain regions, thus highlighting the biomarkers used to uncover the age-related changes in neuroplasticity. All participants in the study were cleared through background checks assessing their mental health. Subjects were dismissed from the study if they had previous health records indicating any personality disorders, or any other disorder that is derived from neurological misfunction (Lin et al., 2012). This ensured that the data would be representative of healthy functioning brain and that age would be the primary influencer in differences in brain activity.

Major findings of this study support the idea that in order to overcome the age-related degradation of the brain, more neural networks are activated than the young adult brain. Older participants showed greater recruitment of the motor and bilateral parietal cortex; two regions that are associated with spatial and sensorimotor mapping. Older adults also show more medial frontal cortex activation than the young adult group (Lin et al., 2012). These results held true for both blocked and interleaved practice. During the interleaved practice, young adults showed more neural activation in the dorsolateral prefrontal cortex, area of the brain associated with critical thinking, in comparison to the repetitive practice brain map. Older adults showed greater recruitment of the rostral prefrontal and sensorimotor regions of the brain during interleaved practice (Lin et al., 2012).
The findings by Lin et al. (2012) directly challenge the idea that additional recruitment of neural networks causes an overload that actually hinders learning. Mapping brain activity during both types of practice, interleaved and blocked, showed that there was much greater brain activity in both groups during interleaved practice. Since interleaved practice is widely acknowledged as a superior form of practice that leads to more robust learning, this refutes the claim that more brain activity causes cognitive overload. A key finding in this study from the young adult group is that during interleaved practice, the dorsolateral prefrontal cortex, DLPFC, region showed a much greater recruitment of neural networks than blocked practice (Lin et al., 2012). While this result was expected, it should be highlighted due to the nature of this region. The DLPFC is associated with higher order critical thinking and therefore stimulating more of this region will result in greater learning and superior retention of memories. Lin et al (2012) provided strong evidence for the superiority of interleaved practice in comparison to traditional blocked practice. This study should be taken into strong consideration when creating curricula due to the irrefutable fMRI results comparing brain activity during the investigation by Lin et al. (2012).

The major weakness in this study was the assessments used on the subjects. These assessments required subjects to memorize patterns using blocked and interleaved representation of the material. The practice time for the sessions were also very brief and therefore the patterns were most likely made very simple in order to allow for maximal retention. Although it may be strange and very difficult, a potential remedy for making the assessments too simple would be to have subjects who pass the mental screening enroll in a course that utilizes the practices. During their attendance in the course, brain mapping would be recorded while in class. These results
could afford a more accurate portrayal of true brain activity during more realistic scenarios and further clarify the comparison of two practices.

Current classrooms are littered with distractions. Teachers are encouraged to create learning environments that are enriching to students and directly motivate them to want to be there. However, the problem associated with attempting to create these engaging environments is that they amplify the magnitude of distractions for students. Students have the greatest distraction of all at their fingertips; cell phones. Cell phones create a large distraction because of the instantaneous connection to the world outside of the classroom. Students can feasibly check out of the class discourse and not actively engage in their learning. This leads to many gaps in their learning and therefore an insufficient base of knowledge that is required to succeed in the classroom. However, many students are able to overcome this insatiable interconnectivity with the outside world and actively engage with their learning. Detecting this out of context behavior is an error processing that actively occurs in the brain. Students who are able to effectively detect this off task behavior (using cell phones) and redirect their impulses (putting them away and paying attention) are utilizing many of the same parts of their brain that they use while learning. Meaning that the error processing parts of the brain for detecting off task behaviors are very similar to the error recognition and behavior modulating centers of the brain that are activated during the learning process. The question now becomes: *how can we detect which students are better able to recognize and modulate this behavior?*

Being able to process errors while continually redirecting mental resources is a job that requires the recruitment of various portions of the brain. The two-process models of attention control in the brain posits that the PFC is the center that maintains focus on the goals of the task
at hand, and the posterior and anterior cingulate cortex (PCC and ACC, respectively) is responsible recognizing distractions or errors that obstruct the goals being maintained by the PFC (Miller, Watson, & Strayer, 2012). These regions of the brain are the primary attention centers of the brain that are utilized during learning and performance. Thus, it is important to measure activity in these portions of the brain the help clarify the neural networks in action during task performance. This would help allow us to better understand how learning and attention modulation occur and create potential ways to mediate discrepancies in students’ abilities to modulate their own attention.

Recognizing errors in thinking and learning is critical towards the success of students, resulting in this area of cognition being under intense investigation. Miller et al (2012) investigated the impact of working memory capacity, WMC, and how that could predict action monitoring (error monitoring) and the error-related negativity, ERN, which is a biomarker that is measured using electroencephalograms, EEG. Elucidating this connection between WMC and error recognition and monitoring could help educators more effectively address discrepancies in student learning by highlighting student errors in thinking.

Miller et al (2012) investigated the connection between WMC and error processing by conducting an experiment that had participants take part in two cognitive tests. The first cognitive test participants had to memorize letters while solving math problems, this helped assess their frontal mediated WMC, or attention control which would bring light to their ability to manage errors. The second session assessed the same thing, but during this session participants had electrodes placed on their heads to record EEGs (Miller et al, 2012). Subjects were encouraged to answer questions with as much speed and precision as possible.
Miller et al (2012) found that there was no substantial difference in ERN in relation to variance of WMC within the sample when there was little or no distraction present. This means that the ACC and PCC did not need to be activated by the PFC because there were no errors made during the task as a result of minimal distractions. However, when distractions were present, Miller et al (2012) found that individuals with a higher WMC were better able to correct their behaviors through stronger activation of the ACC and PCC, as detected by the ERN recordings on the EEG, in comparison to those with lower WMC. These results were consistent with their original hypothesis.

This study helped elucidate the brain pathways that are activated during error processing. Miller et al (2012) provided biological evidence to support theoretical implications about the influence of WMC on error processing. Individuals with higher WMC appear to have an advantage over individuals with a lower WMC when tasks become more complicated, implying that lower WMC individuals need more support during more complicated learning tasks. This is important for science teachers because they can better support the students with lower WMC who are more easily distracted by removing as many distractions in their room as possible. They can also incorporate more supports for these students in their teaching practices to circumvent the discrepancy in abilities between students’ WMC.

The main problem with the experiment by Miller et al (2012) was that they encouraged both speed and precision instead of just having participants answer with speed. By encouraging precision, participants may have slowed themselves down to really think about the questions and thus stimulate the ACC and PCC more than they would have if they were to only focus on speed. Artificially stimulating the ACC and PCC would have given stronger ERN readings on the EEG and inflating the results to provide stronger support for their hypothesis. Future conduction of
this experiment should test the effects of encouraging participant to focus on speed, precision, and both speed and precision.

The human brain is said to be very plastic. Our brains go through the major stages of development through puberty and then reach an anatomical plateau, meaning that the size and invaginations to not change as we age. There are mechanisms in our brain that allow us to continue to learn and acquire skills. Someone at the ripe age of 40 can go learn how to play the guitar or the trombone, for example. Through our neuroplasticity we are able to continue to grow as learners, but there is a point in our lives where our brains aren’t as malleable, in fact they begin to degrade over time. The rate at which our brains vary depending on a lot of things such as our genetics. However, there is one thing that is debated that people can do to in order to prevent cognitive decline: the pursuit of higher education. It has been debated that the more educated one becomes, the less their brain degrades. Intuitively, this makes sense. Pursuing higher degrees will make one think more deeply and this stimulate neurogenesis and angiogenesis in the brain which would provide more nutrients and prevent steep cognitive decline as one grows old (Cassilhas, Tufik, & Trulio de Mello, 2016). If we can stimulate deep interest and robust learning at a young age, this could relieve individuals of the onset of steep neurodegenerative decline as the age. Stimulating interest and deep learning will potentially influence them to pursue higher education. If it is true that this will help remedy or prevent neurodegenerative diseases, then it is of the utmost importance for every educator to positively influence their students to pursue higher education.

Mungas, Gavett, Fletcher, Tomaszewski Farias, Decarli, and Reed (2018) investigated the effects of education on cognitive decline and cognitive reserve. Cognitive reserve is a metric
of brain atrophy which occurs as individuals age. They hypothesized that more educated individuals will show less cognitive decline and higher cognitive reserve. Mungas et al (2018) took a diverse sample size to avoid any demographical biases, and also ensure that the sample size ranged in educational attainment.

Mungas et al (2018) used MRI to assess grey matter volume changes in the brain because grey matter is associated with cognitive functioning. The greater the grey matter, the higher cognitive reserve and less cognitive decline. Their results showed that individuals with higher education attainment showed less cognitive decline than individuals who did not have as high of an educational attainment (someone with a PhD versus someone who has a GED). However, conflicting with their hypothesis, this did not protect them from less decline in cognitive reserves by comparison. Mungas et al (2018) found that individuals with higher education attainment experienced greater rates of decline in grey matter volume after diagnosis with neurodegenerative diseases than those with less educational attainment. Within the cohort, the data suggested that higher educational attainment correlated with delayed onset of neurodegeneration by comparison. This means that there is evidence to support that higher education potentially delays the onset of grey matter atrophy, which is a temporal marker for cognitive decline. It can be inferred that higher education may not protect individuals from grey matter atrophy, but it can increase one’s health-span which is the portion of life where an individual remains healthy and is self-sufficient. This is a promising finding that should be more intensely investigated.

While this may not be directly related to the process of educating students, the findings are important towards motivating students to learn. Mungas et al (2018) found that it is actually better for one’s health-span to attain higher education. The data supports that the quality of
one’s health improves with greater educational achievement and therefore serves as a motivating factor for students to pursue their studies more seriously. A cliché that most teachers use as motivation is that *every profession is made possible because of teachers* and we take our jobs seriously. Mungas et al (2018) adds another layer to the importance of teaching because it was elucidated that we are also influential towards the health-span of our students as well. Teachers must use these findings as motivation to more effectively engage their students and potentially influence them to pursue higher education. This could potentially delay the onset of neurodegeneration and therefore promote the increase of our students’ health-span.

There have been many proposed arguments as to the reason for the benefits in learning through interleaved practice. Many attribute the associated learning gains, when compared to blocked presentation, to the subjects’ minds having to work harder to reactivate long term memories and bring them into their working memory, thus applying them to the current problem. This brings into question the influence ones working memory capacity has in the gained learning benefits from interleaved presentation. Sana, Yan, Kim, Bjork, and Bjork (2018) investigated whether working memory capacity does moderate the documented benefit in interleaving practice.

Sana et al (2018) proposed two questions to address in their research. First, if interleaving presentation benefits those with a high working memory capacity (WMC) then they would be more efficiently able to utilize interleaving in their working memory than individuals with lower WMC. And second, a contrasting hypothesis, was that individuals with a lower WMC are more responsive to interleaving because it compensates for the lack of reactivation of long term memories to distinguish between-category comparisons (Sana et al., 2018). These two
questions are plausible because the nature of interleaving requires individuals to filter through multiple characteristics of concepts simultaneously, thus utilizing one’s working memory.

Understanding the role of working memory in the learning benefits associated with interleaving is essential for educators and researchers to discover. This would provide educators the foresight to tailor education for individual students instead of taking a broad, general approach that may not benefit everyone.

Sana et al (2018) broke down their investigation into three parts, study 1, 2 (a and b), 3, and 4. Study 1 investigated whether the observed increases in inductive learning of perceptual categories were applicable to induction for different statistical tests. This study also addressed whether blocking or interleaving would vary in effectiveness in relation to WMC (Sana et al., 2018). It was observed that interleaving provided general inductive learning benefits across WMC ranges, high to low. High WMC provided to be a good predictor of test performance for individuals, suggesting that these individuals were better able to focus and filter through information more efficiently than those with lower WMC. This provides support in the affirmative for the first question addressed by Sana et al (2018): individuals with high WMC receive greater learning benefits from interleaving than those with a low WMC.

Study 2 had parts a and b, which were the exact same study just performed with two different groups. This aim of this study was to address whether scheduling by WMC had an effect on learning. The results were consistent with Study 1, where participants showed greater performance when using an interleaved schedule in comparison to a blocked schedule and WMC was a significant predictor of performance (Sana et al., 2018). Participants also reported that blocked practice was more effective than interleaved practice, even though their results suggested the contrary. This observation is consistent with the literature.
Study 3 was an extension of Studies 1 and 2, in that the previous studies only required 3 to-be-learned categories. Study 3 incorporated 12 categories and assessed whether increasing the number of categories would change the effectiveness of interleaved practice in relation to WMC. Sana et al (2018) found that the interleaving provided the same general inductive effects across the WMC range. This finding seemed to be underpowered and therefore Sana et al (2018) performed another study using a more diverse applicant pool. In Study 4, they aimed to investigate the same concepts that were investigated in Study 3, and the results of Study 4 were consistent with Studies 1 and 2.

However, Sana et al (2018) concluded that any seen benefit indicated by the results that a high WMC was a strong predictor for performance was due to baseline differences between cognitive abilities. They concluded that either question proposed in their research could not be confidently answered because of the null interaction of the data (Sana et al., 2018). It cannot be confidently claimed that interleaving benefits individuals with a high WMC or a low WMC, but rather it has a general applicability that benefits all learners. The main concern that this research addressed is that interleaved practice will not leave behind the low learners of the classroom because they reap the same benefits that the high learners do, as well. The medium that is used by both types of learners is yet to be illuminated.

Individualizing education has been a daunting task imposed on teachers more in recent years than ever before. Teachers are responsible for the progression of a student’s learning throughout an academic year. If the teacher is hitting a wall with a particular child and unable to progress the child at the same rate as the rest of the class, that teacher consults with school administration and psychologists to perform a series of tests. These tests assess the child’s
current understanding of previously learned topics and therefore they are set up for failure. If you test a child on previously learned knowledge that you’ve already seen them struggle with, they will only perpetuate that failure during the assessments. Stad, Wiedl, Vogelaar, Bakker, and Resing (2019) investigated whether the role of cognitive flexibility within a student could serve as a predictor of a student’s potential to learn. Cognitive flexibility can be defined as the ability to effectively switch between concepts and adjust to the changing cognitive demands between different tasks. This would enlighten school professionals in a way that would help them better supplement the teacher in providing the need of each student to effectively access the content.

Stad et al (2019) investigated cognitive flexibility through the use of dynamic testing. This type of testing requires that students are trained during the task, which provides an accurate assessment of real time progression on how well the student processes the material. This is an innovative strategy used to assess problem solving and track student thinking, ultimately providing further insight as to what the student’s real needs may be. Traditional approaches measure crystallized thought processes, such as an IQ test, which do not provide a reliable portrayal of the student’s actual abilities. Dynamic testing has also been documented to be a good predictor of future student achievement in academia (Stad et al., 2019). Dynamic testing assesses inductive reasoning, which is the ability to understand case specific information and create generalizations or inferences about similar concepts (Stad et al., 2019). A student’s ability to effectively practice inductive reasoning, especially in science, is critical to success in the classroom. If a student can display that they are able to correctly make inferences about concepts that are derived from exposures to a few exemplars, that student will create a robust foundation of knowledge.
The investigation by Stad et al (2019) utilized dynamic testing by having students, aged 6 to 7 years old, observe a series of pictures and make inferences about them. The series of pictures had repeating elements such as the shapes, colors, etc. To circumvent the influence of working memory, students were given feedback in real time, thus facilitating the children and promoting their potential for learning to be more accurately observed. Children were assessed on two things: 1) their performance during the card sorting test which would provide a metric of how well they respond to feedback, and 2) a verbal fluency test measuring their ability to efficiently switch between verbal cognitive clusters (Stad et al., 2019). These two tests would provide an accurate portrayal of the cognitive flexibility of the child and therefore provide an assessment on the child’s potential for learning.

The findings by Stad et al (2019) showed that the real time feedback provided a positive influence on students who had low cognitive flexibility. This positive influence showed that with coaching in the moment students displayed a potential for learning. Students of varying cognitive flexibilities showed equal benefits from higher level prompts (metacognitive prompts), but the students with weaker cognitive flexibilities more frequently needed step by step prompts, in comparison to the higher cognitively flexible students (Stad et al., 2019). The most likely reason that students showed a high degree of benefit from the prompts was because it promoted metacognition. Students were more effectively able to process their thinking in the moment and approach the tasks more analytically than they were without the prompts. These results were observed in both testing phases, concluding that students with weaker cognitive flexibilities require more individualized prompting than students with a high degree of cognitive flexibility (Stad et al., 2019). This study highlights the practical incorporation of dynamic testing and how it can effectively assess student needs based on objective assessments. This study allows
educators to gain the foresight necessary in addressing students’ learning needs and their potential to learn effectively in the general education classroom.

This study has one major flaw that encourages further investigation: the test subjects were very young. Developmentally, 6 and 7 year old children can have a great degree of differences in their cognitive development. Academic learning is very primitive in this stage of life, even the smallest developmental differences can have a profound effect in results. Therefore, tests should be done on children who are more cognitively developed and can be administered more cognitively demanding tests. This would provide more reliable data because of the more physically mature brains of the students. Stad et al (2019) provided a good foundation to build upon for analyzing the role of cognitive flexibility in determining the potential for learning.

Understanding the foundations of learning is under constant objection. There are many thoroughly researched practices and theories, however the debate lies within the subjective interpretations of the researchers. Educational research is predominately founded upon utilizing data collected from experiments and the researchers’ interpretations of what they are observing. There aren’t many studies that use objective data, where the data collected isn’t contingent upon subjects verbalizing their knowledge or perceptions but lies within human neurophysiology. Van Leeuwen, Manalo, and Van Der Meji (2015) conducted an experiment in which they measured brain activity using an electroencephalogram, EEG. This device detects brain activity in real time, providing an accurate assessment of neural activity during learning activities.

Van Leeuwen et al (2015) sought to uncover whether more mental resources were recruited during learning activities that required more abstract thinking. Previous research has
extensively documented that students’ graphic literacy has been an area of struggle. Students appear to possess this extraneous difficult when it comes to processing and inferring information from diagrammatic representations of concepts. The hypothesis behind this idea is that there is a greater cognitive demand on the brain to recruit more neural networks, or resources, to process the diagrammatic representations. This therefore hinders organic synthesis of original ideas, ultimately having students then become curators of what they read or are told by teachers, professors, etc. (Van Leeuwen et al., 2015). The job of every educator should be to promote students to create their own understanding of material presented to them. This has been little success with the incorporation of diagrammatic representations because of the innate complexity to them.

Van Leeuwen et al (2015) used EEG and measured the P3b in subjects. P3b is an attention modulated cognitive component that has been shown to be proportional to the cognitive demand and allotment of mental resources; the greater the P3b, the greater the cognitive demand. This group tested the recruitment of resources when subjects observed different types of visual representations: equation, picture, data table, and graph. They hypothesized that the equation and picture would stimulate the least amount of cognitive recruitment of neural networks, then the table would require more cognitive activity, and the graph would create the most cognitive demand (Van Leeuwen et al., 2015). The data was consistent with their hypothesis, except there was an insignificant advantage in cognitive demand when subjects were exposed to the graph, in comparison to the data table. This supports the claim that more cognitive strain is present when students encounter more abstract representations of concepts.

Diagrammatic representations of concepts are frequently encountered in science. Students need to have a sufficient graphic literacy in order to successfully process information in
class, as well as many aspects of life outside of science. In physics students are constantly using free body diagrams to study forces, and in chemistry students will interpret graphs while investigating reaction rates. It is very common for students to be assessed on graphical literacy on standardized exams in primary and secondary education. Therefore, this study sets the foundation for beginning to learn how to address the discrepancy in student proficiency in diagrammatic literacy. By uncovering the cognitive demands associated with the processing of abstract concepts, educators can remedy student behavior prior to student exposure. Student behavior towards tasks that stimulate cognitive strain is lackluster and this causes them to opt out of the mental challenge for a task, or practice that is more feasible (Van Leeuwen et al., 2015). Students do not generally welcome challenge and understand it to positively influence their learning because their practice seems to be contradictory of that. Struggling during practice discourages them and inadvertently persuades them to pursue the avenue that is the least cognitively demanding, giving them a false sense of mastery. This is typically seen as them parroting what they read or listen to, which does not help them understand how to apply the information since they do not genuinely understand it.

The findings by Van Leeuwen et al (2015) are significant but do cause some concerns. The content used to promote abstract thinking in the tables and graphs may have been differing in complexity. The graph that displayed the relationship between the variables being represented may have been more explicit to the subjects than the data listed in the table. This may have simply been a formatting issue with the table that made it appear more complex than intended. This would have inflated the cognitive demand on the subjects, resulting in higher P3b measurements. Future studies should normalize the difficulty in all visual representations and test on the same exact concept to ensure consistency. If the concepts were varied during the
experiment, this would have also given unreliable data due to subjects having greater proficiency in one area in comparison to another.

**Interleaved and Spaced Practice**

Blasiman (2017) designed a study to analyze the effects of spaced and interleaved practice on an introductory undergraduate psychology course. Previously, studies of this type of practice had only been done in smaller settings analyzing much simpler and less cognitively demanding topics. Many researchers incorporated spaced and interleaved practice into curricula that were much more flexible than an introductory undergraduate course. Blasiman (2017) found that the effects seen on simpler topics in previous studies can transcend into collegiate level coursework with great success.

Blasiman (2017) designed a methodology that consisted of analyzing two groups, each comprised of roughly 50 students. She used the first exam as a baseline assessment to confirm that there were no significant statistical differences between the two groups. She then carried out regular lecture format with the control group. Students in the experimental group received a 5-10 minute *debrief* at the beginning of each lecture that covered concepts from previous classes. There was no particular order in which they were covered. Some concepts were covered one to three times while other concepts were not reviewed at all. During the review sessions Blasiman (2017) found that having students hear the concept one time then be tasked to rephrase the concept was an effective approach towards incorporating the interleaved practice into the course. The data from the remaining two exams supported this; students in the experimental group outscores the students in the control group by a half-letter grade, on average (Blasiman, 2017).

Another interesting and even more promising finding was that students in the experimental group showed a stronger performance on questions that were on the concepts that
had they had repeated exposure to during the 5-10 minutes *debrief* sessions. Students performed better on concepts that were reviewed just once compared to the concepts that were not reviewed at all. The same trend was observed for concepts that were reviewed two and three times; concepts reviewed three times showed the strongest performance in the experimental group in comparison to the control (Blasiman, 2017). This is distinctly different from the concept of blocked practice in that these concepts were not practiced in succession. Students were re-exposed to them randomly throughout the duration of the semester. These findings support the idea that interleaved and spaced practice can be incorporated into higher education, thus addressing more complex concepts.

Though this work was insightful, there were some weaknesses within in it that could have provided an inaccurate assessment of the data. Blasiman (2017) used multiple choice questions in her assessments. Multiple choice questions test students’ recognition abilities which is less cognitively demanding than recall. Interleaved practice strengthens subjects’ recall memory and therefore more assessments of recall should have been incorporated into the assessments. Another implication that must be considered is that students in the experimental group may have felt an inclination to study the concepts that were covered in the pre-class *debrief* sessions more intently than other concepts. This would mean that the conclusion of multiple exposures in an interleaved format may not correlate with stronger retention of the concepts, but actually increased students’ motivation to study those particular concepts. Repeated exposure through an interleaved format needs to be more closely monitored in order to assess the veracity of the claim made by Blasiman (2017). Perhaps, creating an experiment ensuring that the students are not receiving supplemental support, or studying content outside of the classroom would help prove the accuracy of this claim.
The major implications from Blasiman (2017) was that interleaved practices can be readily incorporated into more complex content areas. Chemistry is a broad and complex content area that students struggle with because of the scaffolding nature of it. Success in chemistry classrooms is contingent upon mastery of the very rudimentary concepts that are covered in the beginning of the year. If a student does not display mastery or is close to mastery, they will become overwhelmed by the enormity of content that will be covered in succession. Blasiman (2017) provided a format in which teachers will be able to incorporate review and informal assessments of present levels of student understanding. The cost of implementing this interleaved strategy is time, but she proved that would only require a small allotment of time at the beginning of the class. Teachers can restructure their class and utilize the very beginning of each class to serve as a rough metric of student understanding. This will require more work from the teacher as well as being more cognitively demanding on the students, but these costs are negligible in comparison to the documented benefits by Blasiman (2017).

Eglington and Kang (2017) investigated the effectiveness of interleaved practice on more complex content, organic chemistry. Typically research in this area has been done with simple concepts extending the claims that interleaved practice promotes robust learning through text and visual domains. These studies have been carried out in small classrooms that typically address recognizing artwork, or simple mathematical operations. No study has been conducted that addresses more complex content, such as recognizing and categorizing chemical compounds that are either structurally simple or complex.

Eglington and Kang (2017) cite the discriminative-contrast hypothesis that states that juxtaposing salient categories highlights the differences between them and aids in category
discrimination. This is not present in blocked practice because each successive presentation is categorically identical to the previous one. This means that interleaving practice may be more practical in STEM classrooms than what has been traditionally studied: differences in paintings and calculating the number of edges in three dimensional shapes. In STEM concepts, concepts are more discernable in concrete ways, such as functional groups in organic compounds. There are small differences in bonding arrangements between amines and amides, and thus interleaving practice would be a more beneficial mode of instruction than blocked practice (Eglington & Kang, 2017).

Eglington and Kang (2017) investigated whether there is a significant difference between blocked and interleaved presentation for learning organic chemistry categories that are unique, and whether illuminating the differences between the categories would modulate its effect. The idea behind the second part of the investigation is that if the differences between the unique categorical features were highlighted, then the benefit from interleaving presentation would be lessened. The benefits from interleaving the mode of presentation is derived from noticing the subtle differences between categories. Thus, if those differences are made apparent to the learner, they would not have to reactivate the mental networks necessary to discern between categories and therefore learning wouldn’t be nearly as robust.

A series of four experiments were run by Eglington and Kang (2017). The first two addressed whether interleaved practice was more effective for inductive learning than blocked practice. Experiment 1 was conducted using simple organic molecules that were easily discernable and provided results that were consistent with the literature: interleaved practice was more effective towards promoting inductive learning than blocked presentation. Experiment 2 built upon Experiment 1 by utilizing more structurally complex molecules, testing whether or not...
the level of complexity would have an influence on the effect on inductive learning in either mode of presentation. The results of Experiment 2 mimicked Experiment 1 (Eglington and Kang, 2017). The findings of Experiment 2 brought out the second half of the research question: if the categorical differences are highlighted: *would this modulate the effectiveness of either mode of presentation?*

In Experiment 3, Eglington and Kang (2017) highlighted the differences, thus making the effects of interleaving more obvious and less hard to work for. This, however, did not affect the comparative results between interleaving and blocking presentation. Interleaved practice still outperformed blocking, but there was an observed ceiling effect. The same categories were being tested and therefore to circumvent this problem, in Experiment 4 Eglington and Kang (2017) incorporated four new categories and performed the same experiment with them. This increased the task difficulty and therefore would eliminate the ceiling effect. This did not change the results. Participants in the interleaved group outperformed those in the blocked group. Concluding that interleaved practice was more effective for inductive learning than blocked practice, regardless of highlighting the distinct differences between the categories (Eglington and Kang, 2017).

Eglington and Kang (2017) argue that highlighting the categorical differences may have benefitted both groups, but the higher performance of the interleaved group may be due to the inherent spacing incorporated in this presentation method. This allows subjects to practice reactivating neural networks that then strengthen them each time they become reactivated, entrenching them in their long term memory. This argument is consistent with the literature.

The experiment by Eglington and Kang (2017) was significant because it illuminated the possibility for incorporating interleaved practice into STEM classrooms in higher education.
This is a promising finding because traditional research has only proven interleaving presentation to be effective in simpler scenarios that assess recognition of artwork, or simple math procedures. STEM educators should take this research into serious consideration when creating content.

There is a robust body of research supporting the conception that interleaving presentation of exemplars is superior, in terms of retention of memory and skills, than massed practice. Guzman-Munoz (2017) investigated three commonly stated hypotheses that state the reasons for success of interleaved practice. This research used previously studied approaches and incorporated a few modifications that helped highlight, or disprove certain claims made in the literature while also testing the influence of working memory capacity (WMC).

The first of the three claims that Guzman-Munoz (2017) tested was the discrimination hypothesis which states that if the degree of similarity between concepts is very high then subjects would benefit from interleaved practice more because it promotes inductive learning more efficiently than massed practice. If the concepts are easily discernable, then massed practice is favored (Guzman-Munoz, 2017). The second hypothesis was the study-phase retrieval hypothesis which discusses WMC. It states that the advantage of interleaved practice is related to the consistent practice in retrieval of long term memories, and not the capacity of holding multiple representations in the working memory. This suggests that the act of retrieving memories is more influential towards retention of memory than the capacity of one’s working memory. The final hypothesis that was tested by Guzman-Munoz (2017) was the attention-attenuation hypothesis. This hypothesis states that massed practice promotes a disinterest among subjects during the practice phase. Subjects gain a false sense of fluency during practice and
therefore do not pay full attention and do not become aware of the subtleties of the concepts they are practicing. Therefore, when they are tested, they do not perform as well. Whereas during interleaved practice they do not have an opportunity to check out during practice because each successive exposure is distinctly different from the previous one. There were three total experiments conducted by Guzman-Munoz (2017) that tested all three hypotheses stated above.

The first experiment manipulated presentation style, massed versus interleaved, and induction was tested immediately. Guzman-Munoz (2017) found results that were consistent with the predictions and previous literature. Subjects performed better, meaning faster and more accurate, under interleaved conditions in comparison to blocked conditions. Subjects’ perceptions of the efficacy of presentation styles aligned with the ideology that massed practice was more efficient. This is contrary to the results of the immediate tests because interleaved practice proved to improve test performance.

The second experiment was run similar to the first experiment but added a spaced component to test the influence of temporal gaps in the learning process. Subjects experienced a short and long gap, this would help assess the influence of WMC. Results were similar when comparison massed and interleaved practice in accuracy, speed, and perceptions of efficacy of presentation. The temporal gap showed a noticeable increase for both subjects with low WMC and high WMC. There was a larger profit for the subjects with a high WMC, suggesting that there is a potential influence of WMC within interleaving (Guzman-Munoz, 2017). The higher the WMC within an individual, the potential for a greater benefit from interleaving presentation.

The final experiment of the investigation performed by Guzman-Munoz (2017) was similar to the second experiment, but the temporal gap was filled with subjects performing a distractor mathematical task. In addition to the immediate test, a one-day testing delay was
incorporated to assess the effect of a more meaningful delay. The results showed that the temporal gap did not have a significant increase in the interleaved group, but did have an influence on the massed group. The negligible impact that the temporal gap had on the interleaved group suggests that interleaved presentation is more influential towards learning than spacing (Guzman-Munoz, 2017). This is significant from both a practical and theoretical standpoint because it suggests that spacing, while it does positively impact learning, does not promote as many benefits as interleaved presentation does. Therefore, incorporating interleaved presentation should be of higher concern than spacing.

Guzman-Munoz (2017) highlights a potential influence that WMC may have on interleaving. The research suggests that individuals with a higher WMC can benefit more from interleaved presentation than massed practice. The data also showed that individuals with low WMC benefitted from the same methodology. However, the higher WMC group showed a greater benefit, by comparison. This finding should influence future research as to how influential, if at all, WMC is in interleaving learning processes.

The claim made about WMC having a potential influence in interleaved learning, while it may appear intuitive, should be taken with caution. There were some severe limitations in this study that could have conflated the data. The sample size in this experiment was very small, which is common for similar studies. There were a varying number of students in each of the three experiments and therefore subjects were not the same in all three. This is a double-edged sword because it allows for generalizations to be made based on average performance but does not allow for consistency within the sample. Also, to extend claims like the one being proposed by Guzman-Munoz (2017), sample size should be larger in order to be more generalizable and
the data to be more representative. The data in this experiment wasn’t explicit of what was being assessed. Future studies need to be conducted on a larger scale.

A serious concern in American education that is under constant is student engagement. Student engagement is critical to the success of every student; there are strong correlations between positive active student engagement and academic performance (Patall, Pituch, Steingut, Vasquez, Yates, & Kennedy, 2019). The flaw in the expectations of our students to be constantly engaged is that it is unrealistic for adolescent students to be completely invested into every word and item being presented to them during lessons. Students have a myriad of things to worry about in their lives and therefore are not always going to view certain concepts as the most important or interesting thing in their lives at every moment of the day. There has been a paradigm shift in the way people are connected in modern society, by comparison to 15 years ago. There has been an exponential increase in the access to instant communication within that time, and students are the primary group being adversely affected by it. Student engagement has been dwindling over the years because of the increase in the potential number of distractions, resulting in much poorer academic performance (Patall et al., 2019).

Patall et al. (2019) investigated student engagement as it corresponded to the academic environment: how does the learning environment influence student engagement and motivation to learn? The motivation within the students will ultimately dictate their engagement, thus influencing their cognitive development. Patall et al. (2019) assert that students who are actively engaged will display practices within the classroom that help them enrich their learning; actively annotating the texts, taking detailed notes, making eye contact with the speaker, etc. There are four main types of engagement: agentic engagement, emotional, behavioral, and cognitive.
Agentic engagement is achieved when student needs are satisfied by the teacher. The teacher must support students’ autonomy in the learning process and not force feed them information. Preparing the students to become creators of their own knowledge is the foundation for this type of engagement (Patall et al., 2019). Positively influencing agentic engagement is essential for the other three types of engagement to occur. Students will be motivated if they feel responsible for their own learning, thus influencing the other three dimensions of student engagement. 208 high school students were surveyed assessing their teachers’ influence on their motivation based on how supported they felt within the classroom. Assessing student interpretations of teachers’ classroom facilitation and environment is essential because of how strongly related academic performance is to motivation and engagement.

Patall et al (2019) found that students who perceived their teachers to be active supporters, positively influencing their agentic engagement, felt more in control of the classroom learning process which resulted in higher student engagement. Students felt that the teachers who best supported their practices within the classroom learning environment allowed for them to shape their own learning which made the process more engaging. Rather than being told what to think and how to think about it, teachers acted as facilitators that support and modify student thinking and actions as needed in order to ensure that main concepts were correctly understood. This avoided the consolidation of misconceptions without spoon feeding the information to the students. Teachers who create classroom environments where students are the creators while the teacher is the guide, positively influence student engagement. This, in turn, meets the needs of the students to achieve agentic engagements (Patall et al., 2019).

Patall et al. (2019) didn’t address a major point within their research and specify which content areas students felt that their teachers were able to sufficiently support agentic
engagement. Certain science subdisciplines are more feasible to allow for student autonomy, thus encouraging agentic engagement. Biological science courses are more conceptually based than the physical sciences which rely heavily on math fluency. Physical science courses are more difficult for students to be autonomous due to the complexity of the material. Ensuring that students are mathematically competent while also understanding concepts adds more to the complexity, by comparison to biological science where math does not appear nearly as frequently. Potential further research into student perception of teacher support in an autonomous learning environment could distinguish between content areas. It seems plausible to assume that students would have a negative perception of teacher support for physical courses because of the traditionally non-autonomous nature of those classes derived from the added mathematical component.

Interleaved practice is acknowledged by educational researchers as an efficient mode of strengthening robust learning in students. However, previous studies do not discuss the format in which interleaved practice is incorporated into curricula. Rau, Aleven, and Rummel (2013) investigated whether interleaving the mode of representation or the task type would be the more effective form of interleaved practice leading to stronger student learning.

Rau et al. (2013) sought out to analyze whether more robust student learning would occur when interleaving the mode of representation while blocking the task type, or when interleaving the task type while blocking the mode of representation. No studies have been conducted previous to this one and therefore this novel approach towards analyzing interleaved practice is essential for both practical and theoretical purposes. Multiple representations of concepts has been well documented to support student progression and creation of robust learning (Rau et al.,
2013). This practice allows for multiple channels for students to connect their prerequisite knowledge to new concepts. Rau et al. (2013) investigated this approach while incorporating interleaved practice, with the assumption that there would be a synergistic effect. The hypothesis behind this research is that interleaving the task type while blocking the mode of representation will have a stronger effect on student learning than interleaving the mode of representation while blocking the task type (Rau et al., 2013).

Interleaving task type requires students to reactivate prior knowledge more consistently and frequently than interleaving the mode of representation (Rau et al., 2013). By encountering different types of tasks, students will experience an intense cognitive demand to recall the necessary information to solve the task at hand. This circumvents the possibility for autopilot to occur while solving problems because each one is distinctive from the previous one, thus requiring a new and potentially more challenging approach. In fact, the more distinguishable each successive task, the better it is for promoting students to reactivate prior learning (Rau et al., 2013). This is not as prominent when interleaving the mode of representation while also blocking the task type. Although changing the mode of representation would still provide benefits towards strengthening student learning, it allows to students to transpose their current thought process between similar tasks. The concept of the task remains the same, the way in which it is being represented is changing. Students do not need to reactivate a new base of knowledge for the successive task (Rau et al., 2013). Interleaving task type while blocking mode of representation led to increased effectiveness (accuracy) of learning and efficiency (time to complete) by comparison. It is argued that this was the case because interleaving across the most variable domain encourages the most reactivation in memory, by comparison, resulting in more robust learning (Rau et al., 2013).
The findings by Rau et al. (2013) are practical and should be considered when designing curriculum. However, there are some areas of concern that should be taken into consideration prior to committing to this form of interleaved practice. One must recognize that they do not need to fully commit to one or the other but could, and should, incorporated both. The work done in this experiment involved an online learning platform that incorporated interactive manipulatives. The students who had interleaved modes of representation via the online learning platform may have experienced stronger motivation to participate and engage with the concepts than students who may not have access to the interactive learning manipulatives (Rau et al., 2013). Thus, if incorporating this practice into the classroom, one should be wary of student engagement with non-interactive modes of representation. Also, the modes of representation in this particular study may have been too easy, meaning that they required only perceptual navigation of the model rather than both perceptual and conceptual. Diagrams and graphs can be intuitively navigated without having a strong conceptual understanding the data in the graph/diagram/etc. Thus, it may be worthwhile to do future research on the incorporation of diagrams and graphs that require a strong conceptual understanding of what is being represented. Rau et al. (2013) highlighted the effectiveness of interleaving task type in comparison to mode of representation, but they should not be mutually exclusive because both showed progression of student learning.

The practice and benefits of interleaving concepts has been well documented by many researchers. Rohrer (2012) is one of the pioneering researchers in the field of interleaving practice. Interleaving is considered to be a more effective way to learn and has been well documented to have participants outperform those who learn through traditional methodology.
However, Rohrer (2012) acknowledges that not all content should be interleaved. It is asserted that the interleaving benefit is best observed through incorporating it when the degree of similarity between concepts is very high. The idea is that when students are exposed to multiple similar concepts utilizing blocked, or repetitive practice they are easily mixed up. Students are not made aware of the distinctions between concepts and therefore easily mix them up with the similar concepts. Rohrer (2012) reports that this is not observed in interleaved practice. Through interleaved practice is it observed that students are better able to distinguish between similar concepts than students who receive blocked instruction.

Rohrer (2012) refers to this as discrimination learning. The example in biology is provided during the genetics unit; a very large majority of the biology curriculum. Students are tasked with differentiating between transcription, translation, and other replication processes. Students who are able to effectively navigate these terms and apply them to their learning are effectively practicing discrimination learning (Rohrer, 2012). Being fluent in the academic vocabulary for the unit is necessary for success in the class because those terms are frequently encountered. Rohrer (2012) states that discrimination learning is essential in not only biological sciences, but also in physical sciences as well where multiple concepts are similar but discernable if students possess an adequately knowledge of the distinctions.

Interleaving and spacing are two practices that are commonly coupled together because of their observed synergistic effect on student learning. Interleaving has spacing incorporated within it, but it has been studied to be a positive influencer of the development of robust student learning (Rohrer, 2012). In the investigation by Rohrer (2012), students were introduced to two trials. The first trial was involved with discerning between artists based on the style of the paintings. Participants were separated into two groups where one group was exposed to only
interleaving and the other was repetitive practice. Both groups experienced spacing because Rohrer (2012) wanted to study the influence of interleaving and therefore incorporated spacing to fix the influence spacing had on learning across both groups. The paintings were very similar, but the styles varied slightly; enough for participants to distinguish the paintings by artists. Aligned with the aforementioned benefits seen with interleaving representation of material, participants in the experimental group outperformed the control group in identifying which artist painted which picture.

Rohrer (2012) expanded this experiment to math learning. Mathematical proficiency is critical for students in physical science classes because these science courses are very math intensive. If students struggle distinguishing similar mathematical concepts, then they are more likely to struggle with applying them to physical science concepts. Rohrer (2012) used ratio problems to assess the influence of interleaving, while using the same experimental design as used in the painting experiment. The results of the mathematical experiment supported the findings seen in the painting experiment. These findings provide further support for the effectiveness of incorporating interleaving into curriculum.

Rohrer (2012) states that a teacher should not solely depend on interleaving for curricular design, as there are benefits to blocked practice. Blocked practice allows for familiarity with the content and helps develop a sense of confidence within students, whereas interleaving practice is more difficult and therefore more discouraging for students. Students do not perform as well during the practice portion of interleaving, but retain the material much longer than students who receive blocked instruction. Rohrer (2012) also asserts that the best time to incorporate interleaving into curricular design is during parts of the units where concepts become increasingly similar and difficult to differentiate.
Interleaving helps elucidate distinctions and give students the opportunity to become more fluent with the concepts being taught. Rohrer (2012) also acknowledges that incorporating interleaving is not an easy feat. The difficulties associated with mastering the teaching style that aligns with this practice is difficult. It is also very difficult to convince students that they need to struggle during practice in order to learn more effectively. This runs counter to our intuition and makes students feel incompetent when they struggle more than they do during blocked practice. Teachers must use trial and error when incorporating interleaved practice into their curriculum to find the methodology that best suits their specific classroom.

The prior research has consisted of testing interleaved and spaced practice concomitantly, thus any benefits found couldn’t be attributed to either spaced or interleaved practice individually. Any claims that interleaved practice was primary reason for the promotion of stronger learning must be viewed ostensibly due to the nature of previous experiments testing these effects (Taylor & Rohrer, 2009). Spaced practice has been well documented as an effective approach towards enhancing recall in mental performance tests, as well as physical tests. The goal of this research was to test the effectiveness of interleaved practice in comparison to blocked practice.

Taylor and Rohrer (2009) conducted the experiment in a way that fixed the amount of spaced practice ensuring that data analysis would be concentrated on whether interleaved practice was a more effective learning strategy than blocked practice. They did this by ensuring that both approaches, interleaved and blocked, had the same amount of spaced practice incorporated into them on average. Thus, any benefit received from spaced practice is included in both practices (Taylor & Rohrer, 2009).
Before moving any further, we must differentiate between interleaved and blocked practice. Interleaved practice is applicable to many facets of life outside of education. It is an approach to learning that requires the subject to have a first exposure to multiple concepts, then perform a randomized practice set of all concepts in no particular order. The contingency for interleaved practice is that the subject cannot perform the same task in succession, each task/problem/concept is allotted one attempt/exposure before addressing another concept. The premise to this practice is that subjects have to work harder to recall the information needed to solve the task they are addressing. Interleaved practice is the far more difficult of the two strategies and thus less desirable for subjects to incorporate into their own practice (Taylor & Rohrer, 2009). Whereas blocked practice is a much more feasible approach for subjects to utilize. However, blocked practice allows for the subject to become more automatic during their practice and not force them to truly process the task they are completing (Taylor & Rohrer, 2009). Blocked practice is the traditional approach to learning that is implemented into classrooms. Students are given an exemplar to follow and then complete multiple problems of the same type, in succession, until they master the approach before moving on to a new concept. While this seems practical, it doesn’t promote retention of the concepts needed by allowing for autopilot to take over during the task.

Taylor and Rohrer (2009) uncovered that interleaved practice was more beneficial than blocked practice. Subjects in the interleaved practice group showed more struggles during the practice sessions but displayed stronger retention of the concepts during the testing phase of the experiment. The difference between subjects’ retention of concepts was more than twice as much in the interleaved group compared to the blocked practice group. And more interestingly, during the testing phase there were two common errors that occurred. There were fabrication
errors, where subjects made up procedures that they were not taught, and discrimination errors, where subjects did not correctly discern between concepts.

The differences between the two groups in fabrication errors were negligible, while there was a stark difference between the discrimination errors between them (Taylor & Rohrer, 2009). The blocked practice group had more than four times the amount of discrimination errors than the interleaved group. It can be inferred that the *autopilot* phenomenon discussed earlier was responsible for this difference. Students in the blocked group were unable to distinguish between concepts, while the students in the interleaved group proved to be more successful. They were able to make stronger connections to the concepts during practice even though their practice data was far less impressive than the blocked practice group.

The authors mentioned that the *ceiling effect* could have been responsible for the discrepancy in performance for the blocked practice group. Taylor and Rohrer (2009) stated that there wasn’t much room for them to grow because their practice data was nearly perfect, whereas the interleaved practice group had much more room to grow. I do not ascribe to this claim because the practice and assessments were separated by one day and therefore there was not a sufficient amount of time for the subjects in the interleaved group to grow such a substantial amount, by comparison.

There were two substantial limitations in this study. The first being sample size; there were 24 fourth grade children in this study. The second limitation being the concepts that were tested were very rudimentary and therefore promoted the *autopilot* phenomenon for the blocked practice group. The first limitation is very difficult to overcome because data acquisition and experimental methodology is a more feasible task in smaller groups; presenting less opportunity for the inclusion of outliers in the data is optimal when conducting any experiment. The second
limitation is inherent to the uniqueness of this particular study. Creating an experiment presents many challenges, thus distilling what you are testing the subjects on in the primitive phases of the research into the benefits of interleaved practice is pragmatic. Researchers must be wary of being too audacious in their goals for their research because incorporating too many aspects can conflate data and not be an accurate portrayal of what is intended to be analyzed.

The most basic and important mental process students need in order to be successful is to effectively exercise their inductive learning. Students who can successfully do this are more likely to experience success in academia. This ability is mediated through a variety of neural mechanisms. Creating these generalizations of categories is positively influenced by distributed and spaced exposures to the representations. The Spacing Effect has been extensively investigated and proven to enhance robust learning. Vlach, Sandhofer, and Bjork (2014) investigated the role of spaced learning in categorizations and generalizations made by students. These two types of tasks are different from memorization tasks because they require students to hone in on important details while actively ignoring the irrelevant information. They then have to process that information and create new categories or generalizations, this is often referred to as inductive reasoning. Determining the influence of variable spacing schedules has both practical and theoretical implications that will better serve educators once they are uncovered.

Vlach et al (2014) investigated the effect that expanding the spacing schedule would have on inductive learning. The hypotheses that expanding the schedule would positively influence learning are 1) memory is enhance through reactivation of neural networks, 2) individuals who are susceptible to rapid forgetting benefit most from expanding the spaced schedule (young children and older adults), and 3) reactivating memory along a forgetting curve fosters a stronger
retention of that memory (Vlach et al., 2014). The third hypothesis is the most interesting and sets the foundation for distributed and spaced practice. Each time the subject is exposed to the concept, it fosters a strengthened connection in the neural network needed to reactivate the memory. Therefore, more time is needed to promote forgetting for each successive exposure which would ultimately result in long term entrenchment into long term memory. This means that the memory would become innate to one’s foundational knowledge and need little cognitive effort to reactivate.

The results from the investigation by Vlach et al (2014) were largely consistent with the body of research pertaining to the effectiveness of distributed and spaced practice. Students tested on their abilities to make generalizations 24 hours after their initial exposure showed a greater degree of success than the students who were assessed immediately after. Students showed that the more time allotted for the to forget, the better they did in comparison to those who tested immediately after learning (Vlach et al., 2014). Being given that time to forget is essential because it makes reactivation more difficult each successive exposure. However, over time it gets easier and an expanded schedule is needed to further promote forgetting until mastery is attained. The work by Vlach et al (2014) is significant because it begins to uncover that the same cognitive processes that work in memory consolidation, derived from spaced practice, are at the very least similar to the cognitive processes required for inductive learning. Thus, expanding the learning schedules not only positively influences memory, but also positively influences inductive reasoning within students. This type of expanded schedule that was conducted by Vlach et al (2014) mimics a *Spiral Curriculum*. This type of curriculum has a shorter spaced schedule in the introductory phase of each new concept, and over time the schedule for exposure to the concept expands as reactivation of the required neural networks
becomes more feasible for the student. The *Spiral Curriculum* has been gaining popularity over the past few years, as more teachers continue to adopt it.

The findings of this study are significant in that they highlight a potential neurological connection between memory and inductive reasoning. However, some concerns arise while analyzing this study that may conflate the data. Vlach et al (2014) experimented using young children who are more susceptible to forgetting than teenagers and young adults. In future experiments, the new subject group should be different to check the validity of their conclusions to groups that are far less susceptible to forgetting.

It has been widely established through multiple experiments that spaced practice, experienced concomitantly with interleaved content has led to improved and more robust memory in comparison to traditional learning styles. Supplementing spaced practice with interleaving the content has shown to have strong effects on memory retention in the context of inductive learning (Zulkiply, 2013). Traditionally, the effects of this type of practice have been assessed on visually presented texts, and pictures. Prior to the work of Zulkiply (2013), no experiments have been conducted that assessed the effects of interleaved practice on aurally presented exemplars and the influence it has on inductive learning.

Inductive learning is assessed by the subject’s ability to correctly make inferences from an incomplete data set. The subject makes these inferences based on commonalities among the data within the set and applies it to the incomplete portions, assuming that all data are related. Zulkiply (2013) investigated the effectiveness on aurally presented exemplars because of the prominence of aural presentation in education; lectures, videos, discourse, etc. Participants were exposed to four different phases in the experiment. The first phase was the practice phase where
the participants experienced either massed or interleaved practice. All participants experienced both types of practice at different times. Zulkiply (2013) presented six different psychopathological disorders on a screen and subjects were to listen to about a 40 second explanation of the disorder. Immediately after the 40 seconds were up, subjects performed the next phase of the experiment referred to as the distractor task. This was 15 seconds long. Then the subjects were divided into two separate groups; short term and long term. The short term group took the test immediately after the distractor task, whereas the long term group took the test a week later. After the test, participants answered a questionnaire that assessed their opinion on which, if any, practice type was better when comparing the massed and interleaved.

The results of the Zulkiply (2013) experiment showed a common theme with interleaved practice. Participants reported that massed practice helped more than interleaved practice, but the results from interleaved practice showed participants had a better performance in comparison to massed practice. As expected, this trend was present in both the short term and long term groups. Zulkiply (2013) proposes three potential reasons for the interleaving effect seen in the literature. First, subjects are more effectively able to discriminate the differences between different categories because of the uncertainty in point of contrast. This causes the differences to be more salient, which is not apparent in massed practice. Second, massed practice promotes subjects to check out while experiencing the material. The subjects make generalizations about the material and do not pay full attention because of the persistent patterns. Interleaved practice avoids this because each successive exemplar is a different category, thus is inherently different from the previous. Lastly, retrieval in interleaved practice is more difficult and therefore enhances learning, in comparison to massed practice where learning is not made nearly as difficult (Zulkiply, 2013). The results of this study were consistent with previous studies.
asserting that there are significant benefits in the memory retention when combining spaced and interleaved practice, by comparison to massed practice.

Zulkiply (2013) designed the experiment to assess memory retention from aurally presented exemplars but used text assessments. The assessments were multiple choice and did not test the participants’ recall memory, a more accurate indicator of robust memory retention compared to recognition. Although one could extrapolate the findings from this study to have the same effects on recall memory, it cannot be confidently asserted. Future studies assessing benefits of this type of practice should no longer be concerned with recognition memory, rather they should investigate the effects on recall memory. The underlying concept for interleaving practice is that it creates a greater cognitive demand than other forms of practice. Therefore, it experiments should follow the idea that a more challenging form of memory be assessed as well to further determine the effectiveness of this type of practice on memory retention. It eventually becomes redundant to utilize the same form of assessment, especially when the results are consistent with many other studies investigating the same practice method.

Zulkiply (2013) highlighted an important concept in this experiment. Aural presentation of material is the most prominent form of presentation in education. Most of learning occurs through aural presentation of content, whether it be from video, discourse, lecture, etc. Understanding that this type of practice extends from visual presentation is a critical discovery and should be thoroughly investigated by educators in order to effectively incorporate it into their own practice.

**Misconceptions**

The overview of this research addresses student misconceptions involving the dissolution process between ionic compounds and water. Students were assessed on their understanding on
endothermic and exothermic processes. Data analysis of student responses uncovered four groups of common misconceptions. All but two students in the sample size (n=34) were unable to correctly identify and articulate the two major conceptual underpinnings that occur during endothermic or exothermic processes (Abell & Bretz, 2018).

The two theoretical foundations of this research were Novak’s Theory of Meaningful Learning and Johnstone’s Triangle (Abell & Bretz, 2018). Novak’s Theory of Meaningful Learning (NTML) states that for meaningful learning to take place students must have sufficient and relevant prior knowledge to serve as a foundation for the creation of new learning (Abell & Bretz, 2018). This is a common claim made throughout educational research and is not only pertinent to this study and science education as a whole, it applies to all realms of learning. Johnstone’s Triangle asserts that knowledge in chemistry exists in three domains: symbolic (models and diagrams), particulate (atomic level), and macroscopic (tangible, or easily observable). Students who are unable to fluently maneuver between the three domains are presented with a larger challenge to access learning than those students who are able to maneuver through the domains in Johnstone’s Triangle (Abell & Bretz, 2018). It is common that students are able to master one or two of these domains, but not typical that all three are mastered. This study showed how students can understand the symbolic domain, typically lecture material, but not successfully transition that understanding into the other two domains. This gap between lecture material and lab work is very common in undergraduate students as well as K-12. Being able to successfully articulate understanding of all three domains is representative of conceptual mastery.

Addressing student misconceptions is critical to improving pedagogical strategies implemented in the classroom. The students in this study did not possess the knowledge in the
three domains specified by Johnstone’s Triangle and thus were unable to successfully make the necessary connections to the content (Abell & Bretz, 2018). The disconnect between lab and lecture is apparent in this study, although it is not explicitly discussed in great depth. Students showed that they understood chemical processes such as bond breaking and bond forming. They also displayed an understanding of the temperature changes associated with exothermic and endothermic processes (Abell & Bretz, 2018). Student disconnect lied within their application of that understanding to what they were observing because that material was not made relevant to the applications they were being assessed on. Although this study directly deals with temperature changes while dissolving salt, the underlying problem is apparent in all areas of education. Students are unable to attribute what they were observing in the macroscopic domain to what they understood in the symbolic domain due to the inability to successfully navigate their knowledge into the particulate domain.

This paper addresses a problem that encompasses all content areas in education, most prominently science. The disconnect with the material is derived through the inability for students to master the three domains of Johnstone’s Triangle, as well as NTML. Without the ability to create fortified connections to the content, students will check-out. This will perpetuate the current problem in science education; students are becoming increasingly disinterested in science. Addressing the misconceptions in the class is critical; whether it be temperature changes or quantum mechanics. Creating interest in the content is pertinent for student conceptual understanding in all domains of learning that were assessed in this study.

The main weakness in this study was the actual topic they were studying. The researchers appeared to have a specific answer in mind for their three research questions that they believed assessed student understanding of the concept (Abell & Bretz, 2018). These three
questions could be answered in a variety of ways, especially since this study included upperclassmen who had exposure to the content in greater depth than the freshmen chemistry students. Entropy plays a very large role in temperature changes of solution formation and therefore an upperclassman would have a better understanding of the chemical processes that occur, by comparison. However, this was not the case due to the fact that only 32 students were examined and 13 of which were upperclassman. With this small sample size and lack of a strong incentive for multiple participants, the data could also be greatly influenced by the quality of student in the study. We were not informed of how well these students performed academically. This could have been the lower quartile of chemistry students, which would make the data unreliable and mold to the narrative presented by the researchers that students lack the ability to connect all three domains of learning in science.

Compiling a list of common misconceptions within chemistry is difficult for researchers to do because every chemistry classroom is contingent upon the competence of the teacher. Therefore, some chemistry classrooms with an exemplary teacher could have very minimal development of misconceptions, whereas a classroom with a chemistry teacher that lacks proficiency in the content can develop a myriad of misconceptions resulting in minimal success. Al-Balushi, Ambusaidi, Al-Shuaili, and Taylor (2012) investigated the most common misconceptions that were observed in chemistry classrooms in Oman. The curriculum is similar and therefore teachers are expected to know the same material as teachers in preparatory programs in American schools.

Al-Balushi et al (2012) investigated student misconceptions using a test called the Chemistry Misconceptions Diagnostic Test (CMDT). This test incorporated many visual
representations and tested student understanding on them. Al-Balushi et al (2012) found seven common misconceptions among the 786 participants: atomic structure, compound structure, bonding, equilibrium, electrochemistry, combustion, and oxidation and reduction reactions. These concepts make up a vast majority of the chemistry curriculum in American schools. These seven aforementioned concepts were further assessed by Al-Balushi et al (2012) using the CMDT. The CMDT was given to the 786 participants and they were granted 90 minutes to complete it. To be considered a common misconception, during the data analysis more than 20% of students had to believe in the alternative conception. The 20% cutoff was used because it had been seen in other studies that Al-Balushi et al (2012) predicated their research design on. These strict parameters make sense because a misconception held by one out of every five students is a serious concern for all teachers to take instructional time to address it.

The misconceptions associated with atomic structure were tied with combustion for the lowest in quantity. Students possessed misconceptions about the orbit of electrons being in a fixed path, as depicted by the planetary model. This model helps create misconceptions because it shows electrons in fixed orbits around the nucleus, however this model is only used because it is convenient to help show electronic structure of an atom. Over 60% of students failed to have the correct conception about electron location in atomic structure, which is an area of large concern that teachers need to address (Al-Balushi et al., 2012).

The most concerning misconception in compound structure concepts was that water vapor consists of individual atoms that have no bonds between them. Students conceptualize water vapor to be comprised of hydrogen and oxygen atoms that have no bond, instead of the water vapor just being intact water molecules in the gas phase. Almost 40% of students perceived this to be an accurate description of evaporated water (Al-Balushi et al., 2012). Not
being able to understand that water vapor is still water molecules is a serious misconception that will influence many concepts in the future curriculum after phase changes.

The concept with the most alternative conceptions was chemical bonding. This is a unit where students struggle to make distinctions between bonding types because the minute details that distinguish between bond type are very similar and easily overlooked. Students believed that breaking a stick of wood is the same as breaking bonds between the molecules within the piece of wood. They do not understand that molecules are being separated physically and not chemically. This immature understanding of chemical bonding was possessed by more than 40% of students. This is the most concerning finding by Al-Balushi et al (2012) because not understanding the difference between physical and chemical changes is essential to successful learning throughout this unit. Another serious misconception that was found when analyzing the results from the CMDT was that nearly 70% of students did not recognize that the bond between sulfur and oxygen was a covalent bond between two non-metals (Al-Balushi et al, 2012).

The other concepts tested by Al-Balushi et al (2012) showed similar trends where essential concepts to the unit were misunderstood by students. Their findings are concerning because it suggests that students are not paying close enough attention to the concepts when they are being taught them. Many of the observed misconceptions are easily addressed and contradicted by teachers. The problem must be with the mode of representation for the concepts. Students are more than likely not paying full attention to instruction because many of the misconceptions are not even taught to students, in fact the complete opposite is taught to students. The example where nearly 70% of students couldn’t identify that a covalent bond is the type of bond between oxygen and sulfur is a result of not paying full attention (Al-Balushi et al., 2012). Covalent bonds are taught to all high school students to be a bond between two non-
metals without exception. Perhaps Al-Balushi et al (2012) unintentionally made an argument for interleaving curriculum because it forces students to be fully engaged with the content by making each successive presentation/concept distinct from the previous. I firmly believe that interleaving bond types would help address the aforementioned misconception.

There is a vast amount of resources dedicated towards investigating student misconceptions. This is an incredibly important body of research because it is a teacher’s job to identify them and do everything within their power to elucidate and replace these alternative conceptions with the accurate conceptions. Burgoon, Heddle, and Duran (2011) took note of the large body of research for student misconceptions, but did not see the same amount of attention directed towards identifying teacher alternative conceptions. Through an extensive literature review of the shallow body of research dedicated towards the aforementioned, Burgoon et al (2011) took note that teachers and students possessed many of the same misconceptions. This suggests that misconceptions permeate throughout all levels of education.

Teachers possess these alternative conceptions and perpetuate them into the current cohort of future leaders; our students. In order to address this problem, Burgoon et al (2011) sought to identify the misconceptions that are shared between students and teachers. The idea is that if we can identify the alternative conceptions that teachers possess, then we can remedy them and potentially thwart the perpetuation of them through the current cohort of students.

Burgoon et al (2011) investigated this problem by enrolling 103 science teachers into a grant funded teacher development program. Teachers were assessed using traditional methodology; multiple choice tests, multiple answer questions, and open ended written response questions. The questions involved content that there was observed common misconceptions with
teachers and their students: gravity, magnetism, gases, and temperature. These concepts are among the more abstract concepts in physical science courses and therefore are prone to having students and teachers developing misconceptions with. Examples of each misconception depict the problem that is unintentionally instilled into our students. Teachers stated that gravity increases as the object’s height increases above the ground (Burgoon et al., 2011). This assertion is inherently false, and the opposite of observable data. A troubling misconception with magnetism was that teachers believed that all metals were magnetic; again, inherently false and easily tested. Some teachers even contradicted themselves by saying that stainless steel isn’t magnetic. Misconceptions for gases were that gases were always lighter than liquids or solids. This is based on alternative conceptions of density; teachers didn’t think about the fact that some gases are more dense than some liquids and solids which would make them lighter given the same volumes of each sample. The final concept in the study by Burgoon et al (2011) was temperature. Teachers stated that some objects are colder than others because of intrinsic properties of the particular object. They completely disregard that temperature is not an intrinsic property of an object or material, and that it is a direct measure of energy. The stated misconceptions are extremely disappointing because they are easily dispelled through content preparation in pre-service teaching programs. Teachers shouldn’t be allowed to progress through their programs if they possess such rudimentary misconceptions about simple concepts.

Burgoon et al (2011) recognize this as a serious problem and the consequences of teachers possessing these alternative conceptions are not to be taken lightly. Teachers should be sufficiently prepared for progressing through preparatory programs before gaining certifications to teach. Teachers are the most influential figures in student learning and parents need to feel that their children are receiving an education from competent professionals. Burgoon et al
(2011) assert that it should be the goal of all teacher candidate preparation programs to improve teacher candidate quality. Teachers should go through rigorous preparation through their programs and ensure that only qualified candidates are passing through. This is a difficult feat to accomplish because class sizes are increasing and the number of teachers entering into the applicant pool is not increasing at the same rate. In order to address this discrepancy in teacher preparedness, effective training must be implemented (Burgoon et al., 2011). Teachers are in high demand (except on Long Island!) and therefore this problem does not seem to be easily resolved in the near future. Teacher preparation programs should begin to hold their candidates to a higher standard while also providing sufficient support for development. In order for students to learn effectively, they need to have teachers who are prepared and well versed in the content that they are teaching.

The foundation of success in chemistry lies within the student’s understanding of how electrons are transferred or shared. This process is involved in every single facet of chemistry. Electron configurations determine the properties of elements and therefore the reactivity and necessity of each element. If we do not have sufficient understanding of the relevance of electron sharing and transfers, then we would not be living with the current state of society as it is today. It would resemble something more like ancient times, where this base of knowledge was a mere nanoparticle of what it is today. To understand bonding is to understand chemistry.

Erman (2017) analyzed the common misconceptions amongst his students at a small undergraduate university. There were four main questions of this investigation: (1) do students possess misconceptions about covalent bonding? (2) Is there a pattern in student misconceptions? (3) What factors influence these misconceptions? (4) Are these new misconceptions from what
has been previously recognized and addressed in the literature? The roots of all misconceptions are founded within the students’ immature knowledge base of the given chemistry concept, in this case covalent bonding (Erman, 2017). Having an immature foundation of knowledge about covalent bonding makes thinking abstractly much more difficult than it would be if a student were to have a more robust understanding of the chemical principles associated with covalent bonds.

This investigation consisted of 77 participants, and the 10 students that showed the most misconceptions were interviewed. Erman (2017) had the participants engage in a multiple choice assessment, diagnosing the severity of their misconceptions about covalent bonds. There were three parts of data collecting: (1) the assessment, or the multiple choice test, (2) the interview with the 10 students who displayed the most misconceptions, and (3) a review of the students resources. The assessment was comprised of 42 multiple choice questions with four answer choices. The interviews and analysis of students resources was conducted after the completion of the first part of the investigation.

The results showed that there were eight common misconceptions amongst the cohort in this investigation (Erman, 2017). They found that students who also got the correct answers, during the interviews, were unable to adequately explain how they arrived at that answer. A common misconception was synthesizing Lewis Diagrams. The main concept behind these diagrams is primitive and covered very early in high school curricula. Students need to understand how to construct these because the Lewis Diagram is a pictorial representation of a particular element’s bonding properties. Accurately showing the valence electron configurations for atoms and molecules will elucidate bonding characteristics between atoms or within molecules. Erman (2017) found that a lot of the misconceptions are derived from not
understanding that electronegativity between two atoms within a covalent bond are similar so the electrons are shared and not more strongly attracted to one atom within the bond. These misconceptions are examples of the immature base of knowledge that students have when entering undergraduate studies.

Erman (2017) then dove further into the problem by analyzing the resources that are available to students. It was discovered that the textbooks within high school classrooms were a major source of misleading information. Textbooks that were analyzed were the resources that were available to the 10 students that were interviewed during this study. There were four different textbooks, but they had the same misconceptions littered throughout them regarding covalent bonding. An example of one was that all atoms follow the octet rule (Erman, 2017). This is one of the grossest over statements about electron configuration that can be relayed to students learning chemistry for the first time. Some of the most important chemistry is done with atoms that do not obey this rule (i.e. boron and phosphorus) and students should be made aware of this from the very beginning. This will allow such misconceptions to not be fostered so early on in their exposure to chemistry content and potentially not at all.

This study points out important problems with student learning. Currently, the myriad of resources that are deemed appropriate for high school chemistry are too simplified and they are littered with misleading information that fosters the development of misconceptions (Erman, 2017). Teachers need to take a more careful look at what they make available for their students to supplement their learning in the classroom and ensure that the content is not misleading. The data collected by Erman (2017) showed that misleading information about covalent bonding from chemistry textbooks permeated into college chemistry courses. If teachers recognize that there are bits of misleading information within their resources, they must address them prior to
Creating curriculum has been made very easy for chemistry teachers over the past years, prior to the Next Generation Science Standards. The Common Core Learning Standards provided an outline for what students will be responsible to know for each concept, broken down to pretty much each lesson objective. The incorporation of the Common Core Learning Standards into classrooms was to ensure that teachers were held responsible for teaching the same content to all students, guaranteeing that every chemistry student was provided the same foundational knowledge before progressing into post-secondary education. This left teachers in somewhat of a rush because they had so much to cover in a fixed amount of time. Thus, the same types of experiments and lessons began to be incorporated into classrooms. This vanilla approach to teaching chemistry had not proven to be successful. This vanilla approach, while judicious in the attempt to provide quality education to students, had proven to be unsuccessful in nearly all classrooms that had the Common Core Learning Standards. The data that was being recorded was anything but promising. This left teachers and educational researchers to find research-based designs for curricula that addresses this problem.

Kaanklao and Suwanthanpornkul (2018) investigated the problem of designing an organic chemistry unit using a research-based design. Organic chemistry is the unit that most students appear to struggle with during high school chemistry. Organic chemistry is a very difficult unit to teach due to the fact that it is much more abstract than other units. Students need to be able to differentiate between functional groups, understand elementary reactions, and various other concepts. These concepts are difficult for students to understand because they are
very abstract (Kaanklao and Suwanthanpornkul, 2018). Therefore, the need to design a curriculum that helps teachers elucidate the aforementioned concepts within the unit is a necessity.

Kaanklao and Suwanthanpornkul (2018) created an approach towards designing the organic chemistry unit referred to in the literature as Posner’s approach. Posner’s approach is divided into four parts. The first part of Posner’s approach is to provide sufficient time for students to struggle with solving problems. The struggle will help them realize that their current conception of the content is inherently flawed and not helping them solve the problems they are faced with. The second condition is that a new concept that is to replace the old conception is to be intelligible. If the students cannot understand the vernacular of the concept, they will not be able to replace alternative conceptions that caused them their initial struggles. The third component is that the new conception must have practical use to address the problems that the students struggled with initially, or at least some of the problems they struggled with. The last condition is that the new concept must have some sort of aspect to it that students can inquire about further through a designed research project (Kaanklao and Suwanthanpornkul, 2018). Giving students new ways to work with the new concept and apply it to different contexts will create a more viable and robust conception that will lead to greater success in the classroom.

Kaanklao and Suwanthanpornkul (2018) found that designing and adjusting the classroom to adhere to Posner’s approach was positively influencing student learning, relative to organic chemistry. Comparing the data of the resolution of misconceptions between the control and experimental groups, it showed that the experimental group greatly benefitted from Posner’s approach in unit design than the control group did with the traditional approach. They also found that creating a friendly and competitive environment was positively influencing on
engaging students in the lessons. The competition incentivized students to participate and created a sense of community within the classroom (Kaanklao and Suwanthanpornkul, 2018). The data supports the claim that a research based approach utilizing the principles within Posner’s approach would be much more effective in teaching abstract concepts than current methodologies.

The relevance of this investigation by Kaanklao and Suwanthanpornkul (2018) to the concept of spaced and interleaved practice is that they both incorporate the emphasis of struggle. The main idea with struggling while learning is that it is a more significant learning experience than being able to easily access new concepts without much mental effort. Posner’s approach towards reducing the quantity of misconceptions is similar to interleaved in that they both utilize struggles to help students become more aware of the learning process. Both approaches do not have to be mutually exclusive and can be intertwined. One can design a spiral curriculum utilizing Posner’s approach because many aspects of it are incorporated into spiral curriculums already.

In order for teachers to address student misconceptions, teachers must understand where the misconceptions are derived from. Experienced teachers are more prepared for addressing misconceptions within their students’ foundational knowledge because of the generalization student misconceptions. Typically, students have similar misconceptions year after year (Naah, 2015). Pre-service teachers, or teachers in formal training programs, do not have the experience necessary to make them aware of the common student misconceptions. Naah (2015) investigated this problem within a midwestern university teacher education program.
Naah (2015) found that pre-service teachers were unaware of many misconceptions that arise in learning chemistry. Teacher candidates tend to be unable to adequately explain concepts in chemistry, in accordance with accepted scientific principles. Pre-service teachers are not cognizant of effective ways to address student misconceptions (Naah, 2015). There are two common methodologies utilized by experienced teachers to address student misconceptions; generating cognitive conflict and immediate refutation of the misconception. Generating cognitive conflict requires carefully designed labs that present two distinctly different results, where one of the results is the conceptually correct one. Immediate refutation requires the teacher to present the misconception and then articulate exactly why it is wrong through thoroughly explaining the correct concept of interest (Naah, 2015). Pre-service teachers are unable to effectively do this because they are uncertain about the role of students’ prior knowledge and where exactly the misconceptions are derived from.

Understanding the role of students’ prior knowledge in the development of robust learning, or misconceptions, is integral towards providing effective education that reaches all students. The inexperience of pre-service teachers has been noted by Naah (2015) and was circumvented by having designed an assignment that encouraged the pre-service teachers to explore common misconceptions that occur while learning chemistry. Students were tasked with teaching a lesson to their peers that addressed a specific misconception in chemistry, such as the solubility of sugar, and was founded on peer-reviewed research. This not only provided students further insight as to how they should address problems that will arise in their careers, but also gave them a chance to practice and troubleshoot problems they did not foresee (Naah, 2015). The assignment prepared pre-service teachers to be more able to address student misconceptions responsibly through the accumulation of peer-reviewed literature. The pre-service teachers were
more effectively able to recognize the origins of student misconceptions through assessing the prior knowledge and uncovering novel strategies to address it that they may not have recognized otherwise (Naah, 2015).

There were a couple of major weaknesses in this study that may have construed the data. The most prominent weakness in the study by Naah (2015) was that it was conducted with other pre-service teachers playing the role of students during the lessons. It is safe to assume that these teacher candidates are more fluent in chemistry than the average student encountering the curriculum for the first time. They have a greater foundational knowledge which would result in an inaccurate assessment of the role of prior knowledge in the development of misconceptions, on the end of the pre-service teacher teaching the lesson. The assumption can be made that because they were unable to effectively portray student misconceptions within the lesson, the teacher candidates were not effectively engaging in their teaching in a way that would efficiently address the common student misconceptions. This is a major problem in this study that could have brought the integrity of the data into question, had there been claims about specific strategies being more effective than others. However, this does not refute the claims made by Naah (2015) that increasing the awareness of pre-service teachers of the misconceptions that arise in chemistry is an effective preparation tool. This approach does help address the inexperience of pre-service teachers and equips them with a foundational toolset to better suit them for their initial years.

Ultimately, Naah (2015) found that enlightening pre-service teachers on the role of students’ prior knowledge in the development of learning proved to be beneficial in strengthening teacher confidence. Teachers developing the confidence within their practice allows them to fearlessly and seamlessly integrate effective pedagogy that benefits the students.
Being prepared for what the most frequent obstacle students will run into will allow the ebb and flow of the classroom to be smoother, had the teacher not received this type of training during their pre-service years. Successful teachers, regardless of experience, will be able to effectively address student misconceptions through preparation derived from understanding students’ prerequisite knowledge.

One of the more complicated units in chemistry is the ideal-gases unit. Students struggle with concepts within this unit because of how abstract the concepts are. It is difficult for students to visualize the movement of gaseous particles and simultaneously make sense of all the concepts being addressed within the unit. Theories taught in this unit are able to be applied to both liquid and gas mixtures which is a major source of confusion for students. Gases and liquids behave in distinct manners, while also possessing similar properties. It also does not help that perfect-gas and ideal-gas are used as interchangeable terms by students because they misinterpret the words *perfect* and *ideal* to be synonyms, when in this context they are not. The misconceptions associated with gas and liquid mixtures stretch across high school chemistry classrooms into undergraduate chemistry classrooms. Teachers in all levels of education struggle to elucidate the distinctions between concepts for their students.

Privat, Jaubert, and Moine (2016) investigated this issue that they observed in their undergraduate chemistry classrooms. They saw that the multiplicity of definitions used for perfect/ideal-gas mixtures and gas ideal solutions. Thus, it is necessary to accurately and adequately define the terms and explicate the distinctions between them. A perfect gas is defined as a theoretical fluid that obeys the law PV=nRT; all energies within the atoms of the fluid are equal to zero, meaning there are no attractive forces between molecules, and they can pass
through one another without any repulsive forces. An ideal solution is defined as the mol fractions of the gas multiplied by the vapor pressure equaled to the vapor pressure of the liquid multiplied by the mol fraction. Thus, the energies of the mixtures should be equal to the average energies of each pure substance within the mixture (Privat et al., 2016). Consequently, an ideal gas abides by these laws as well, making it also an ideal solution. This is where the confusion is derived from for most students. Not understanding the distinction that ideal gases are also ideal solutions, but not all ideal solutions are ideal gases causes a lot of struggle for students. There is a lot of emphasis on ideal gases in chemistry curricula, resulting in a major reason that students develop misconceptions about gas laws.

Privat et al (2016) used mathematical derivations of the equations used to represent gas laws to clarify misconceptions and create more robust student understanding of the behaviors of fluids. The mathematical derivations used addressed three conditions: (1) the mole fraction of one component of the fluid tends towards zero, as the same rate as the reciprocal component tends towards 1. (2) The interaction between particles within the fluid is zero. (3) As the pressure tends towards zero, any real fluid will behave as a gas (Privat et al., 2016). Using mathematical derivations, supplemented by pictorial representations of each case, students exhibited a stronger and more resounding understanding the gas laws compared to traditional methods. Privat et al (2016) saw that 80% of students were able to adequately explain and use gas laws to solve problems using this method of teaching, compared to the 20% from the year before. Privat et al (2016) found that this approach was preferred by the students as well.

This approach towards teaching gas laws can be expanded to other concepts in physical science classrooms as well. The main idea to the investigation by Privat et al (2016) was that articulating the intricacies and derivations to their students helped them better understand the
concepts at an in-depth level. Diving deeper into the concepts allows educators to really hash out what students are really learning. Consistently throughout educational upbringings students are lied to. These lies are convenient because it allows us to quickly go over concepts without getting too focused on details that they’re not required to know. Privat et al (2016) showed that by diving deeper into the concepts that students have misconceptions with, it elucidated the areas of confusion.

Providing clarity on similar ideas is difficult given that teaching time is very constrained. Teachers do not have the fortune of ample time to thoroughly cover content because of standardized examinations of student learning. If less content was required of students, perhaps this would be a more feasible feat for teachers to accomplish. The investigation by Privat et al (2016) provided little amounts of data to support their approach towards addressing student misconceptions. While their claims make sense intuitively, more data is needed to support the veracity of them. Perhaps next time they could provide two groups within the same student cohorts: same academic year, majors, gender, etc. This evidence would allow to point out discrepancies across multiple categories and not assert that this approach is a one-size fits all. While promising and logical, this specific approach needs further investigation for addressing gas law misconceptions.

One of the most ubiquitous concepts in chemistry is the formation of salts. Salts are traditionally taught during the unit of acids and bases. Students are taught that salts are formed through a neutralization reaction between an acid and a base from the Bronstead-Lowery perspective. The problem with this is that students are usually not made aware of the fact that
this is not the only way to form acids and bases. This causes students to form many misconceptions pertaining to the formation of salts.

Secken (2010) identified five categories that misconceptions can be derived from: preconceived notions, non-scientific beliefs, conceptual misunderstandings, vernacular origins, and factually incorrect knowledge. Each of the five listed foundations for misconceptions to build on are present in the chemistry classroom, especially involving the concept of salts. Salt is something that all students are familiar with (Secken, 2010). Therefore, there will be a lot of previous knowledge that students have with respect to salts, whether it is correct or not. It is the job of the teacher to assess students prerequisite knowledge of the concept to elucidate misconceptions and effectively incorporate pedagogical strategies to address them.

Secken (2010) investigated the problem of student misconceptions involving salts by analyzing student prerequisite knowledge and the common resources that were made available to the 121 participants in the study. Secken (2010) analyzed the resources prior to investigating the participants’ misconceptions to provide an informal pre-assessment of how participants are expected to perform. It was found that many of the textbooks made available to students did not have a formal, or thorough definition of salts. Many of the resources only defined salts during the acids and bases unit because that is where it is most commonly experienced in everyday life. Many of the examples in the analyzed resources used the same examples: \( \text{NaOH} + \text{HCl} \rightarrow \text{NaCl} + \text{NaOH} \). This shows an acid and base reaction forming the salt NaCl which is the most commonly known salt (Secken, 2010). This helped highlight where students’ misconceptions are derived from because of the lack in diversity of examples of salts and instances where salts are formed.
During the experiment, the 121 participants answered questions involving basic salt concept questions. Participants displayed a strong understanding that group 1 and 2 metals formed salts, as these are the typical products of neutralization reactions. They showed great difficulty in identifying organic salts; incorrectly labeling aniline as a salt through a reaction between phenol and ammonia forming aniline and water. This is a prime example of how misconceptions are formed (Secken, 2010). Having more experience with acid base chemistry that produces salts and an immature foundation knowledge of alternative ways salts can form leads to the entrenchment of these misconceptions.

Secken (2010) makes a few suggestions to address this discrepancy in students’ foundational knowledge of salt concepts. Firstly, teachers need to provide an undisputable definition for what a salt is. Providing the definition without any ambiguity will allow students to be able to apply the concept of salts to different situations where they may encounter them. By creating this definition, students will understand the basic qualifications to consider something a salt and more effectively identify them when they encounter them (Secken, 2010).

Secondly, teachers must provide alternative exposures to salts outside of acid and base chemistry. Students should be made aware of the alternative chemical reactions that produce salts: neutralization reactions (acid and base), synthesis (reaction between metals and nonmetals), metal and acid reactions, metal oxides and acid reactions, nonmetal oxides and base reactions, some decomposition reactions, and substitutions. The plethora of reactions that produce salts outside of acid-base reactions creates the foundation for the argument of interleaving the curriculum.

Without explicitly stating interleaving, Secken (2010) created an argument for its effectiveness in addressing student misconceptions about salts. Salts are a concept that is
frequently encountered throughout high school and undergraduate chemistry courses. Therefore, students will constantly revisit this concept multiple times throughout the academic year. Providing a sound foundation for them to build upon the conceptual framework of what makes a salt a salt will facilitate their academic performance throughout the remainder of the course. Creating a baseline for students to understand what a salt is will help them identify them later on throughout the course when they encounter them. This will help them think more critically about salt concepts and not only have one point of reference as to where salts can be produced.

Class sizes are increasing and the number of teachers entering the field doesn’t seem to be progressing at the same rate. Teachers in the NYC DOE have about 25 to 30 kids in each class. This becomes increasingly more difficult to effectively teach each student in the class and individualize their education. The common perception amongst teachers is that they do not have the resources to adequately address the learning needs of each student. It is common knowledge that all students have different learning preferences and teachers must display content through a variety of mediums to give students an equal opportunity to access the content through their preferred medium. However, there is debate on whether or not students who possess a particular learning style are more likely to possess misconceptions than others and are therefore harder to create channels for them to learn.

Sen and Yilmaz (2012) investigated the veracity of this claim in a science classroom on the concepts associated with melting and dissolving. The four learning modes that were analyzed in this investigation were: concrete experience learners, reflective observational learners, abstract conceptualization learners, and active experimentation learners. The concrete experience learners learn through sensing, such as using manipulatives. Abstract
conceptualization learners learn by thinking about the content. These learners are able to create mental models of concepts and walk through the concepts through deep thought. Reflective observational learners learn by following. An example of how these learners would learn in the classroom is by observing the teacher perform a calculation and then repeating the steps, helping them solidify what they had just seen someone else do. The last type of learner is the active experimentation learners. These learners learn by doing a job or a task; tell a student to go figure out an unknown by giving them a set of materials and they work through the struggle to arrive at a solution (Sen and Yilmaz, 2012). Based on the learner profiles of these learning preferences, one can see how daunting a task it is to bestow upon all teachers to adequately provide a quality education that they all can learn from.

Sen and Yilmaz (2012) investigated how the differences between learning styles affected science learning using the Kolb Learning Style Inventory. This test is administered to students to help reveal misconceptions about melting and dissolving. Student learning style preferences was assessed through the Motivated Strategies for Learning Questionnaire. This was developed to help assess students on which of the four learning styles they preferred to learn best from. The sample size for this study was 118 participants; 55 Assimilator learners (concrete experience learners), 43 Convergence learners (reflective observational learners), 11 Diverger learners (abstract conceptualization learners), and 9 Accommodator learners (active experimentation learners). A majority of the learners in this investigation, 83%, fell under two profiles, the assimilator learners and convergence learners. Because of the discrepancy in sample size, the other two learning profiles couldn’t be adequately analyzed by comparison and therefore their results were excluded from the data analysis.
Sen and Yilmaz (2012) saw that students with the assimilator learning styles had fewer misconceptions about melting and dissolving than the convergence learners. Sen and Yilmaz (2012) assert that the discrepancy in the amount of misconceptions when comparing the two learning styles is because assimilator learners are better suited for chemistry learning than convergence learners. These students may not necessarily be smarter students, but their preferred method is better suited for the chemistry classroom than the students who prefer the convergence learning style. Students with an assimilator learning style rely heavily on instruction from the teacher and therefore benefit most from lectures that are dense with models and diagrams (Sen and Yilmaz, 2012). Although one may infer this, this is not advocacy for a teacher centered learning model. This study supports that students tend to have less misconceptions in chemistry if they have a preference for the assimilator learning style.

One major weakness in this study is that the concept test they used was multiple choice and not short response. Multiple choice creates a fixed set of what possible misconceptions can be identified within our students. Multiple choice tests that are attempting to elucidate misconceptions are inherently flawed because they do not allow students the opportunity to accurately articulate their knowledge, but rather provide students with a response that they may not completely agree with. Future studies attempting to assess student misconceptions and correlate the quantity of those misconceptions with the preferred learning styles should incorporate only free response questions. They can code the responses into subsets that can be further analyzed. Doing this would create a much more accurate picture of what misconceptions are present within our students.
Through informal observations and experiences, it has become more apparent that the quality of content that students are being exposed to is less than sufficient. Students are being taught many concepts in a simplified manner because it makes teaching easier. Kindergarten students in Success Academy Charter Schools are being taught that light travels in a straight line. This is inappropriate to teach such a misleading concept to students who are so young and impressionable because it is inherently false. Light exhibits wave-particle duality meaning that it travels both like a particle and in a wave. This can be observed by taking a flash light and moving it in a straight line backwards and forwards. It will be observed that the area the light covers increases as you pull it back and becomes more concentrated as you bring the light source closer to the object. This is a very tangible experience to refute the concepts being taught to these kindergarteners. If light travels straight, then how would the area it covers increase as you pull it away from an object? There are also many famous experiments, such as the black box experiment that proved this in a more scientific manner. This is just one of the examples of how the current educational system allows for the relay of misconceptions to be taught because it is easier and less time consuming than providing the necessary details to truly and wholly understand concepts at a deep level.

Stojanovska, Petrusevski, and Soptrakovan (2012) noticed that misconceptions were being taught at all levels in science education, specifically high school chemistry. Phase changes is a relatively easy concept for students to conceptualize because the most common phase changes are easily observable. However, there is one phase change that is more abstract; sublimation. Sublimation is a complicated phase change to conceptualize because it is hard to gather enough relevant examples for students to observe (Stojanovska, 2012).
Stojanovska et al. (2012) investigated this problem by analyzing resources made available to students pertaining to the way sublimation was defined. It was observed that the common definition for sublimation was equivocal. The definition allowed for multiple interpretations that are all very broad. The general idea was covered that a substance goes from a solid to a gas without entering the liquid state during the transition. And for high school chemistry this is a decent definition, but the major problem associated with the definitions was the examples they would give. The most obvious example and relevant to many of the students’ lives is carbon dioxide sublimation. However, the next most common example given is iodine (Stojanovska et al., 2012). The only problem is that iodine doesn’t have to sublime under normal laboratory conditions.

The iodine example is usually given because of the scarcity of relevant examples for students to observe. In labs, students can see a solid piece of iodine giving off purple vapors. This shows that it went from a solid to a gas without ever observing a liquid. Stojanovska et al. (2012) refuted that it only sublimes by creating a live demonstration that shows iodine entering a liquid state in normal laboratory conditions. This procedure is observable proof that we have been teaching students a common misconception. Stojanovska et al. (2012) gave an alternative to presenting the concept of sublimation. They proved that iodine can both sublime and melt in normal laboratory conditions. It is dependent on the environment in which the solid iodine is exposed to prior to the phase change. This helps students think more deeply about what is going on during phase changes rather than just remembering them for what they are classically defined as.

While the research by Stojanovska et al. (2012) wasn’t groundbreaking, it was insightful as to how teachers can feasibly teach real content without teaching misconceptions. Teachers
can incorporate live demos in the beginning or end of their lessons to elucidate the real life concepts in real conditions. It is imperative that teachers stop teaching misconceptions to their students in the name of convenience because it does much more harm to the development of a scientifically literate citizenry than we realize. Incorporating live demos provides a tangible experience for students that allows them to more effectively make the proper connections to between content and real life. This can also be done using videos if the materials are readily available to chemistry teachers.

Throughout pre-service teaching coursework for prospective science teachers, science courses are intermixed with teaching theory and methodology course. During this preservice teacher training, science coursework is traditionally completed before the educational theory and methodology courses. This leaves time for teachers to focus more rigorously on their pedagogy because content mastery is considered to be sufficient at that point in time. The problem with this is that teachers are allowed ample time to forget the intricacies of the content. They are not nearly as fluent in their given subfield of science as they were during their years and semesters during their science coursework. Because of this time taken to focus on mastering their practice, they begin to become less proficient in their given content area and therefore misconceptions within their base of knowledge begin to become entrenched. If they are not immediately addressed, the preservice teachers will begin to solidify these misconceptions into their own conceptual framework of their content area and further perpetuate these misconceptions.

There are two questions that arise when discussing misconceptions: (1) where do misconceptions come from? (2) How do we identify them before the perpetuate into further generations of learners? If teachers are the ones who are fostering the educational development
of the current generation of students then intervention should start with them before granting them the responsibility of explicating physical science content to their students (Stein, Larrabee, & Barman, 2008). Teacher misconceptions need to be assessed during each year of their preservice teaching in order to ensure that they are either elucidating science misconceptions that they currently have, and do not further develop any more science misconceptions.

Stein et al (2008) investigated this problem that has been observed in preservice teachers for many years. They sought to find out what is the magnitude of this problem with a cohort of teachers at two different universities. They did this utilizing an online learning software that consisted of 47 true or false questions that required written responses to follow up their answer. This instrument was called the Science Belief Test. Stein et al (2008) had 305 participants use the Science Belief Test to assess their science content knowledge. Most of the participants were elementary education majors. This is important because many of our science misconceptions develop early on before a formal scientific education that is traditionally initially received in middle school (Stein et al., 2008). These will be the teachers responsible for fostering a strong learning environment that creates experiences for students to build their foundations of science knowledge within. Therefore, these teachers must be assessed on their science knowledge.

Results of this investigation were less than promising. Stein et al (2008) found that many respondents had similar common misconceptions. For example, a chemistry based question, 75.2% of respondents said that the main component of the bubbles in boiling water was air. This is inherently false, as the main component of bubbles in water is water vapor because it is water going from the liquid to the gas phase and escaping the solution due to it being much less dense than liquid water. Even more discouraging than the percent of incorrect responses were the written responses. Of those who answered correctly, their written responses were coded into
three categories: (1) correct explanation, (2) incorrect explanation, and (3) guess or incoherent explanation. There were many respondents that got the question right but could not accurately explain why they got it right. This means that they possess alternative conceptions that allowed them to arrive at the same conclusion as those who correctly explained, but they do not truly know why they are right (Stein et al., 2008). This is a major problem, as it is a primary reason for the reoccurrences of the same misconceptions among generations. If teachers cannot rid themselves of these misconceptions and understand the concepts, then it will be impossible to remediate this problem.

Stein et al (2008) sought out to assess the severity of a problem they observed within their teaching candidates. They found the problem to be worse than what they may have anticipated. The concepts addressed in the Science Belief Test were rudimentary and not unreasonable to expect teachers of any level to know. This is a problem that needs to be assessed on a larger scale and addressed very seriously. If we wish to create a scientifically literate citizenry in this country, and the world then we must be able to first address our teachers’ own misconceptions. The next step after that would be to administer this test to our students periodically to assess how they are developing. Because misconceptions arise from experiences that occur prior to formal science education, they must be checked periodically so that we can ensure they are being hashed out.

Addressing misconceptions is a difficult challenge for educators because many of these misconceptions become apparent during the unit. Teachers face the challenge of identifying student misconceptions before allowing further misconceptions to arise. The idea of misconceptions has a strong body of research supporting it. Usta and Ayas (2010) investigated
misconceptions in a chemistry classroom during the nuclear chemistry unit. They implore teacher to successfully identify misconceptions before teaching a unit because it allowed for the entrenchment of new misconceptions to occur.

Usta and Ayas (2010) argue about the perpetuation of student alternative conceptions from the Piagetian point of view. Learning is fostered through creating connections between new concepts with prior experiences. The exceptional challenge that is faced in chemistry classrooms, especially during the nuclear chemistry unit, is that much of the required thinking is very abstract. Therefore, students have a difficult time making explicit connections between the concepts and previous experiences. In order to adequately prepare students for learning new concepts, Usta and Ayas (2010) urge teachers to identify prior knowledge regarding content before moving forward, specifically nuclear chemistry. By addressing student misconceptions, teachers can effectively plan to teach around those talking point and make abstract principles appear clearer than not having planned to explicitly address particular misconceptions.

In their literature review, Usta and Ayas (2010) identified many common misconceptions found in the literature pertaining to nuclear chemistry among students and teacher candidates. A common theme among the literature was misconceptions pertaining to nuclear disasters. Many students have experience with radioactivity concepts from a historical point of view before they experience the concepts from a scientific point of view. The problem with this is that students develop scientific misconceptions from unreliable sources, in terms of the science involved. A common example is misunderstanding the Chernobyl disaster. This disaster is sensationalized because it is the largest nuclear meltdown to date. History exaggerates many of the science concepts to help support and create the narrative of danger associated with the development and harnessing of nuclear energy. While this disaster was incredibly detrimental to the surrounding
environment, the actual danger has been conflated to the point where students believe that a nuclear or radioactive cloud swept over eastern Europe (Usta and Ayas, 2010). This is categorically wrong and misleading. There was an area of inhabitance surrounding the epicenter of the disaster because the radioactive material spilled out of the facility, but it did not form an ominous cloud like many students have been led to believe by media, the internet, and even some teachers. You can conduct a Google search and find many maps of the disaster and they all look very trustworthy and resourceful, but they too are misleading. The myriad of references that can be found supporting this misleading concept help perpetuate this narrative and further entrench this specific misconception before students have a legitimate foundational knowledge to accurately refute it from a scientific point of view.

It is irresponsible for us to continue to allow such misconceptions to be taught to students from those teachers outside of the content area. Even some teachers in the field believe these alternative conceptions and teach them to their students (Usta and Ayas, 2010). We must make the choice to either forgo teaching our students historical events, or take the responsible and logical approach and teach them the correct concepts associated with these historical events. This means that we should not exaggerate details to generate interest within our students because the details are inherently flawed, and this causes problems in other content areas. The question then becomes: how do we address misconceptions after they have already been taught? This is something Usta and Ayas (2010) eluded to but did not explicitly provide suggestions for. I think that science teachers are responsible for assessing prior knowledge before every lesson in order to hash out misconceptions that are present or have not gone away. This is an argument for an interleaved and spaced curricular design because this type of curriculum does just that. It periodically checks on student current foundational knowledge and provides an assessment at
that point in time whether or not misconceptions are present and if there are new misconceptions that have not been seen before. Identifying misconceptions before the start of teaching new material, as suggested by Usta and Ayas, (2010), teachers will be better prepared to rebuke them and help students develop a more robust and accurate base of knowledge.

**Chapter 3: The Spiral Curriculum**

Standards in each unit appear in successive units. The design of the Spiral Curriculum was meticulously planned. To highlight the interleaved foundations of the Spiral Curriculum, standards that reappear will be color coded using the key listed below. Only questions in the Spiral Reviews and the Summative Assessments that are embedded within each unit that are associated with each standard will be highlighted. Spiral assessments focus more intensely on interleaving than the summative assessments, thus standards will be more diverse within the spiral assessments compared to the summative assessments.

**Standards Coding**

<table>
<thead>
<tr>
<th>Unit 1: Math and Matter</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unit 2: Intro to Atomic Structure</td>
</tr>
<tr>
<td>Unit 3: Nuclear Chemistry</td>
</tr>
<tr>
<td>Unit 4: Periodic Table Trends</td>
</tr>
<tr>
<td>Unit 5: Bonding</td>
</tr>
<tr>
<td>Unit 6: Moles &amp; Stoichiometry</td>
</tr>
</tbody>
</table>

**UNIT 1: MATH AND MATTER**

**LESSON PLANS**

<table>
<thead>
<tr>
<th>Lesson Time: 45 Minutes</th>
<th>Grade Level: High School</th>
<th>Content Area: Chemistry</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unit of Study: Math and Matter</td>
<td>Lesson Title: Day 1 Significant Figures and Scientific Notation</td>
<td></td>
</tr>
</tbody>
</table>

Essential Question:
What is matter and how do we study it?
Content Standard(s):
Math Standards:
MP.4. Model with mathematics

Learning Objectives associated with the content standards:
Students will be able to (SWBAT):
SWBAT represent data using scientific notation and the correct amount of significant figures
SWBAT perform scientific calculations

Instructional Resources and Materials to engage students in learning: PowerPoint, laptop, calculator, Promethean ActivBoard, and problem set

Lesson Timeline, Instructional Strategies and Learning Tasks that support diverse student needs:

<table>
<thead>
<tr>
<th>Time</th>
<th>Teacher will...</th>
<th>Students will...</th>
</tr>
</thead>
</table>
| 0:00-7:00  | • Introduce the Do Now question  
• Cold call students to share answers  
• Provide relevance and real-world experience to create stronger connections to the content that is to be covered | • Answer the Do Now questions in their notebooks  
• Share answers with the class, having an in-depth discussion with peers |
| 7:00-13:00 | • Introduce significant figure rules  
• Answer student questions about rules  
• Guide students through worked out exemplar  
• Provide students with rules sheet  
• Assess student understanding while allowing them to perform calculations themselves | • Take down notes into notebook  
• Ask/answer questions about the rules  
• Work through the exemplar with teacher |
| 13:00-27:00| • Introduce scientific notation rules  
• Provide students with rules sheet  
• Guide students through exemplar problems for both scientific notation and significant figures  
• Assess student understanding through analyzing work samples | • Copy down notes into their notebooks  
• Ask/answer questions about the rules  
• Work with teacher through exemplar problems on scientific notation and significant figures |
| 27:00-45:00| • Distribute group worksheets  
• Break students into groups; separating students who showed the greatest amount of struggle into a small group to address their learning gap  
• Review problem set | • Work in small groups to complete the group work problem set  
• Review questions they may have questions about  
• Share answers and thought process while reviewing problems |
**Differentiation and planned universal supports:**

Differentiation during the lesson will be based on real-time assessment of student work during the *Do Now* and *guided practice problems*. Students who show more difficulty with conceptual understanding of the content will be placed into a small group that will receive more attention towards addressing the apparent learning gap (Sesen & Tarhan, 2010).

Students will be given rules for using scientific notation and significant figures, as well as have them displayed on the projector in front of the classroom for reference during the guided practice and the group problem set. Students who require additional time on assessments will be allowed to complete the problem set at home or during a free period, while having access to the necessary resources.

**Type of Student Assessments and what is being assessed:**

- **Informal Assessment:** While students are working, the teacher will be walking around the room listening and observing student conversations and work. The *Do Now* question, at the beginning of the lesson, will address concepts from the day before as a check for retention of student understanding and it will reactivate the necessary neural networks associated with learning (Huelser, 2012). The teacher will also be analyzing student work during the guided practice to assess which students require more differentiation before separating into groups to work on the problem set (the formal assessment).

- **Formal Assessment:** The problem sets are to be turned in after they are completed at the end of class. This problem set requires students to recall basic mathematical skills that were previously learned prior to entering chemistry; multiplication, division, subtraction, and addition. Practicing this recall will help assess retention of previously learned material (Brown, 2014).

- **Modifications to the Assessments:** Students who exhibited more struggles during the *Do Now* and the *guided practice* will be separated into a small group to have their needs attended to more diligently by the teacher. Students who require additional time on assessments will be allowed to complete the problem set at a later time. These students will also be required to complete at least five problems of their choice within the problem set. Students must complete at least one problem for each of the four basic mathematical operations, and one additional problem for whichever mathematical operation they choose; multiplication, division, addition, and subtraction.

**Evaluation Criteria:**

Students will be evaluated on their understanding through answering the activity questions. There are ten questions that students will be assessed on. Each question will be worth one point each, for a total of ten (10) points on the assessment. Students will need to show work in order to get credit for the correct answer.

Students who receive modifications to the assessment will be graded out of ten (10) as well but will be awarded one point for showing the correct work and another point for the correct answer.
Relevant theories and/or research best practices:

<table>
<thead>
<tr>
<th>Lesson Time: 45 Minutes</th>
<th>Grade Level: High School</th>
<th>Content Area: Chemistry</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unit of Study: Math and Matter</td>
<td>Lesson Title: Day 2 Unit Conversion &amp; Dimensional Analysis</td>
<td></td>
</tr>
</tbody>
</table>

Essential Question:
What is matter and how do we study it?

Content Standard(s):
Math Standards:
MP.4. Model with mathematics

Learning Objectives associated with the content standards:
Students will be able to (SWBAT):
SWBAT to convert units in the metric system
SWBAT use dimensional analysis to convert units in the metric system

Instructional Resources and Materials to engage students in learning: PowerPoint, laptop, calculator, Promethean ActivBoard, and problem set

Lesson Timeline, Instructional Strategies and Learning Tasks that support diverse student needs:

<table>
<thead>
<tr>
<th>Time</th>
<th>Teacher will…</th>
<th>Students will…</th>
</tr>
</thead>
</table>
| 0:00-7:00 | • Introduce the Do Now question  
            • Cold call students to share answers  
            • Provide relevance and real-world experience to create stronger connections to the content that is to be covered | • Answer the Do Now questions in their notebooks  
                                                                             • Share answers with the class, having an in-depth discussion with peers |
| 7:00-17:00 | • Introduce the metric system  
             • Answer student questions about rules  
             • Guide students through worked out exemplar  
             • Provide students with conversion sheet, that will also be up on the front of the classroom | • Take down notes into notebook  
                                                                 • Ask/answer questions about the metric system and its relevance  
                                                                 • Work through the guided practice with the teacher |
- Assess student understanding while allowing them to perform calculations themselves

### 17:00-25:00
- Introduce the concept of dimensional analysis
- Provide students with a procedure sheet that helps guide them through the process
- Guide students through exemplar problems for both scientific notation and significant figures
- Assess student understanding through analyzing work samples
- Copy down notes into their notebooks
- Ask/answer questions about the rules
- Work with teacher through exemplar problems on dimensional analysis

### 25:00-45:00
- Distribute group problem sets
- Break students into groups; separating students who showed the greatest amount of struggle into a small group to address their learning gap
- Work in small groups to complete the group work problem set
- Review questions they may have questions about
- Share answers and thought process while reviewing problems

### Differentiation and planned universal supports:
Differentiation during the lesson will be based on real-time assessment of student work during the Do Now and guided practice problems. Students who show more difficulty with conceptual understanding of the content will be placed into a small group that will receive more attention towards addressing the apparent learning gap (Sesen & Tarhan, 2010).

Students will be given rules for unit conversion and a procedural protocol for dimensional analysis. These resources will also be displayed on the projector during the group problem set. Students who require additional time on assessments will be allowed to complete the problem set at home or during a free period, while having access to the necessary resources.

### Type of Student Assessments and what is being assessed:
- **Informal Assessment:** While students are working, the teacher will be walking around the room listening and observing student conversations and work. The Do Now question, at the beginning of the lesson, will address concepts from the day before as a check for retention of student understanding and it will reactivate the necessary neural networks associated with learning (Huelser, 2012). Students will be encouraged to represent answers using scientific notation and the correct number of significant figures. The teacher will also be analyzing student work during the guided practice to assess which students require more differentiation before separating into groups to work on the problem set (the formal assessment).
- **Formal Assessment:** The problem sets are to be turned in after they are completed at the end of class. This problem set requires students to recall basic mathematical skills that were previously learned prior to entering chemistry; multiplication, division,
subtraction, and addition. Students will also be reporting their answers using the rules learned in the previous lesson pertaining to significant figures and scientific notation, as necessary in each specific problem within the problem set. Practicing this recall will help assess retention of previously learned material (Brown, 2014).

- **Modifications to the Assessments:** Students who exhibited more struggles during the *Do Now* and the *guided practice* will be separated into a small group to have their needs attended to more diligently by the teacher. Students who require additional time on assessments will be allowed to complete the problem set at a later time. These students will also be required to complete *at least* five problems of their choice within the problem set.

**Evaluation Criteria:**
Students will be evaluated on their understanding through answering the activity questions. There are ten questions that students will be assessed on. Each question will be worth one point each, for a total of ten (10) points on the assessment. Students will need to show work in order to get credit for the correct answer.

Students who receive modifications to the assessment will be graded out of ten (10) as well but will be awarded one point for showing the correct work and another point for the correct answer.

**Relevant theories and/or research best practices:**

Lesson Time: 45 Minutes
Grade Level: High School
Content Area: Chemistry
Unit of Study: Math and Matter
Lesson Title: Day 3 States of Matter

Essential Question:
What is matter and how do we study it?

**Content Standard(s):**
*Next Generation Science Standards:*
**HS-PS2-6.** Communicate scientific and technical information about why the molecular-level structure is important in the functioning of designed materials

**Learning Objectives** associated with the content standards:

Students will be able to (SWBAT):
- **SWBAT** to define matter and identify the different states of matter
- **SWBAT** explain the properties of the different states of matter and the processes associated with changing states of matter
Instructional Resources and Materials to engage students in learning: PowerPoint, laptop, calculator, Promethean ActivBoard, and problem set

Lesson Timeline, Instructional Strategies and Learning Tasks that support diverse student needs:

<table>
<thead>
<tr>
<th>Time</th>
<th>Teacher will…</th>
<th>Students will…</th>
</tr>
</thead>
<tbody>
<tr>
<td>0:00-7:00</td>
<td>• Introduce the Do Now question</td>
<td>• Answer the Do Now questions in their notebooks</td>
</tr>
<tr>
<td></td>
<td>• Cold call students to share answers</td>
<td>• Share answers with the class, having an in-depth discussion with peers</td>
</tr>
<tr>
<td></td>
<td>• Provide relevance and real-world experience to create stronger connections to the content that is to be covered</td>
<td></td>
</tr>
<tr>
<td>7:00-12:00</td>
<td>• Prompt the students to think about a definition of matter through a turn and talk to reactivate neural networks associated with learning (Brown et al., 2014)</td>
<td>• Turn and Talk with a partner about the definition for matter</td>
</tr>
<tr>
<td></td>
<td>• Ask students to share thoughts</td>
<td>• Share thoughts during class discussion about the definition for matter</td>
</tr>
<tr>
<td></td>
<td>• Provide the definition for matter</td>
<td>• Copy down the definition on board</td>
</tr>
<tr>
<td></td>
<td>• Prompt the student to think about how matter can be represented</td>
<td>• Independently think about how matter can be represented</td>
</tr>
<tr>
<td>12:00-22:00</td>
<td>• Present phase diagrams and discuss how each ball represents matter</td>
<td>• Copy the phase diagrams</td>
</tr>
<tr>
<td></td>
<td>• Go through each phase of matter and prompt the students to think about the phase changes through relevant contexts; water boiling, ice melting, etc.</td>
<td>• Share answers and provide examples of each phase change</td>
</tr>
<tr>
<td></td>
<td>• Have students provide the answers for the name of each phase change</td>
<td>• Provide definitions for each phase change through class discussions</td>
</tr>
<tr>
<td>22:00-32:00</td>
<td>• Present the properties of each state of matter</td>
<td>• Copy to properties of each state of matter</td>
</tr>
<tr>
<td></td>
<td>• Show examples to students and prompt them to think about shape and volume</td>
<td>• Turn and talk about the volume, shape, and energy of each state</td>
</tr>
<tr>
<td></td>
<td>• Prompt student to think about the energy of each state</td>
<td>• Share answers that are discussed with partner</td>
</tr>
<tr>
<td>32:00-40:00</td>
<td>• Go through the guided problems with the students about changing states of matter</td>
<td>• Work in a collaborative environment, guided by the teacher, and discuss phase change problems giving the temperatures of a given</td>
</tr>
</tbody>
</table>
### 40:00-45:00
- Administer exit ticket
- Students who exhibited difficulty during the guided practice will be given a modified assessment
- Complete exit ticket and submit at the end of class

### Differentiation and planned universal supports:
Differentiation during the lesson will be based on real-time assessment of student work during the Do Now and guided practice problems. Students who show more difficulty with conceptual understanding of the content will be given a modified assessment (Sesen & Tarhan, 2010).

Students will see the properties of each phase and a phase change diagram presented on the projector at the front of the screen. This will not give answers to any of the problems, explicitly, but will help students through the necessary thought process, if needed.

### Type of Student Assessments and what is being assessed:
- **Informal Assessment**: While students are working, the teacher will be walking around the room listening and observing student conversations and work. During the guided practice the teacher will walk around and discern which students are struggling with the concepts of phase changes will receive a modified exit ticket.
- **Formal Assessment**: The Exit Ticket will be the formal assessment for the lesson. The exit ticket will have five substances at a given temperature that students will have to discern the phase at which the substance is currently in.
- **Modifications to the Assessments**: Students who exhibited more struggles during the guided practice will be identified and administered different Exit Ticket. This will cover the three common phase changes. They will be graded out of five like the non-modified assessment, but each problem will be worth 1.5 points and an additional 0.5 points would be administered if students can answer 2 out of 3 problems correctly.

### Evaluation Criteria:
Students will be evaluated on their understanding through answering the Exit Ticket questions. There are five questions that students will be assessed on for the non-modified assessment and three questions for the modified assessment. Each question will be worth one point each, for a total of five (5) points on the non-modified assessment, and 1.67 points on the modified assessment. Additional time will be given to those who are entitled to receiving it.
Relevant theories and/or research best practices:


Lesson Time: 45 Minutes  Grade Level: High School  Content Area: Chemistry

<table>
<thead>
<tr>
<th>Unit of Study: Math and Matter</th>
<th>Lesson Title: Day 4 Pure Substances and Mixtures</th>
</tr>
</thead>
</table>

**Essential Question:**
What is matter and how do we study it?

**Content Standard(s):**
*Next Generation Science Standards:*
*HS-PS2-6.* Communicate scientific and technical information about why the molecular-level structure is important in the functioning of designed materials

**Learning Objectives** associated with the content standards:
**Students will be able to (SWBAT):**
- SWBAT Identify and differentiate between pure substances and mixtures
- SWBAT Identify the differences between homogenous and heterogenous mixtures

**Instructional Resources and Materials** to engage students in learning: PowerPoint, laptop, calculator, Promethean ActivBoard, and problem set

**Lesson Timeline, Instructional Strategies and Learning Tasks** that support diverse student needs:

<table>
<thead>
<tr>
<th>Time</th>
<th>Teacher will…</th>
<th>Students will…</th>
</tr>
</thead>
</table>
| 0:00-7:00 | • Introduce the Do Now question  
• Cold call students to share answers  
• Provide relevance and real-world experience to create stronger connections to the content that is to be covered | • Answer the Do Now questions in their notebooks  
• Share answers with the class, having an in-depth discussion with peers |
| 7:00-13:00| • Present video on pure substances and mixtures  
• Discuss video with the class asking questions directly from video  
• Introduce Particle Diagrams                                                                 | • Watch video on pure substances and mixtures  
• Ask questions and share thoughts about the video  
• Copy down the particle diagram |
| 13:00-25:00 | Prompt the students to identify pure substances through a turn and talk  
Discuss the concept of a pure substance and introduce the formal definition of pure substances  
Provide alternative examples of elements and compounds | Turn and Talk about which substances are pure and not on the prompter  
Copy down notes about pure substances |
|---|---|---|
| 25:00-35:00 | Introduce the concept and properties of mixtures  
Ask students to provide examples of mixtures  
Prompt student to derive a definition of solute and solvent  
Create a particle diagram for a heterogenous mixtures and ask students what they notice | Copy notes about homogenous and heterogenous mixtures  
Provide examples of mixtures  
Through a turn and talk, derive the definition for both term; solute and solvent |
| 35:00-45:00 | Give students an exemplar set up for the saltwater mixture.  
Provide directions to set up the solution  
Assist as needed | Student will work in pairs  
Record the weight of the salt added to their water sample  
Record the volume of water used  
Record the total weight of the solution  
Place on gentle heater overnight  
Write their predictions on what type of substance it is |

**Differentiation and planned universal supports:**
Differentiation for this lesson will be in the form of distributing printed copies of the slides for students to take as they leave class. These slides will supplement any discrepancy in note taking, ensuring that students have the correct notes. Students are still encouraged to take notes during lecture to entrench the learning into the long-term memory (Brown, 2014). Deeper learning will occur when students are more immersed in the content.

**Type of Student Assessments and what is being assessed:**
- **Informal Assessment:** Students will be sharing thoughts and ideas through a turn and talk. These will be monitored and noted throughout the class by the teacher to facilitate the following class discussions.
- **Formal Assessment:** Students will record data and write predictions on why they believe that the saltwater solution is a mixture, or pure substance. Students will have to defend their answer
- **Modifications to the Assessments:** Students who exhibited more struggles during the turn and talks will be given sentence starters for the written response.

**Evaluation Criteria:**
Students will be evaluated on their understanding through answering the written response question at the end of the data sheet. Students will be awarded two (2) points for a correct response and correctly defending their answer. One (1) points will be awarded for either
correctly identifying the mixture or correctly defending their reasoning but identifying the incorrect type of substance. Zero (0) points will be given for incorrect identification of the substance and incorrect defense of their conclusion.

Relevant theories and/or research best practices:

<table>
<thead>
<tr>
<th>Lesson Time: 45 Minutes</th>
<th>Grade Level: High School</th>
<th>Content Area: Chemistry</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unit of Study: Math and Matter</td>
<td>Lesson Title: Day 5 Chemical &amp; Physical Changes</td>
<td></td>
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</tbody>
</table>

Essential Question:
What is matter and how do we study it?

Content Standard(s):
Next Generation Science Standards:
HS-PS1-4. Develop a model to illustrate that the release or absorption of energy from a chemical reaction system depends upon the changes in total bond energy.
HS-PS1-7. Use mathematical representations to support the claim that atoms, and therefore mass, are conserved during a chemical reaction.

Learning Objectives associated with the content standards:
Students will be able to (SWBAT):
SWBAT define chemical and physical changes
SWBAT differentiate between endothermic and exothermic changes

Instructional Resources and Materials to engage students in learning: PowerPoint, laptop, calculator, Promethean ActivBoard, and problem set

Lesson Timeline, Instructional Strategies and Learning Tasks that support diverse student needs:

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</thead>
<tbody>
<tr>
<td>0:00-7:00</td>
<td>* Introduce the Do Now question</td>
<td>* Answer the Do Now questions in their notebooks</td>
</tr>
<tr>
<td></td>
<td>* Cold call students to share answers</td>
<td>* Share answers with the class, having an in-depth discussion with peers</td>
</tr>
<tr>
<td></td>
<td>* Provide relevance and real-world experience to create stronger connections to the content that is to be covered</td>
<td></td>
</tr>
<tr>
<td>7:00-12:00</td>
<td>* Introduce physical and chemical change concepts</td>
<td>* Take notes on chemical and physical changes</td>
</tr>
<tr>
<td></td>
<td>* Provide context for the two types of changes</td>
<td>* Share thoughts and ideas about physical and chemical changes</td>
</tr>
<tr>
<td></td>
<td>* Have students provide examples of both</td>
<td></td>
</tr>
</tbody>
</table>
### 12:00-22:00
- Have students check on saltwater solution
- Have students complete the data sheet
- During class discussions, ask students what phase change occurred, if it was a chemical or physical change, and have them discuss what type of substance the saltwater solution was

### 22:00-35:00
- Introduce the law of conservation of energy and endothermic and exothermic processes
- Show example of chemical equation and have students define what a reactant and a product is

### 35:00-45:00
- Break students up into groups to complete the problem set
- Separate the students who exhibit the greatest amount of struggle with the concepts into a small group

### Go weigh saltwater solution and complete the data sheet
- During the class discussion, share their data and conclusions about the processes that occurred
- Turn in completed data sheet and written responses

### Take notes on the law of conservation of energy, and endothermic and exothermic reactions
- Derive definitions for reactant and product.
- Identify that energy being released is *exiting* the system in exothermic reaction and endothermic reactions require energy to *enter* the system

### Separate into designated group to complete the problem set and turn it in by the end of class

### Differentiation and planned universal supports:
Differentiation during the lesson will be based on real-time assessment of student work during the *Do Now* and *guided practice problems*. Students who show more difficulty with conceptual understanding of the content will be placed into a small group that will receive more attention towards addressing the apparent learning gap (Sesen & Tarhan, 2010).

### Type of Student Assessments and what is being assessed:
- **Informal Assessment:** While students are working, the teacher will be walking around the room listening and observing student conversations and work. Teacher will monitor student conversations and work to differentiate groups for the formal assessment.
- **Formal Assessment:** The problem sets are to be turned in after they are completed at the end of class. Students will answer problems about topics covered in this lesson as well as some covered in previous lessons. There will be 10 multiple choice questions that are to be completed with the group.
- **Modifications to the Assessments:** Students who exhibited more struggles during the *Do Now*, the *guided practice*, and class discussion will be separated into a small group to have their needs attended to more diligently by the teacher. Students who require additional time on assessments will be allowed to complete the problem set at a later time.
time. These students will also be required to complete all 10 questions in the problem set, but will have extended time if needed.

**Evaluation Criteria:**
Students will be evaluated on their understanding through answering the activity questions. There are ten questions that students will be assessed on. Each question will be worth one points each, for a total of ten (10) points on the assessment. Students will need to show work in order to get credit for the correct answer. Students who receive modifications to the assessment will be graded out of ten (10) as well but will be afforded extended time to complete the assignment.

**Relevant theories and/or research best practices:**

### Lesson Timeline, Instructional Strategies and Learning Tasks that support diverse student needs:

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</table>

### Relevant theories and/or research best practices:
<table>
<thead>
<tr>
<th>Time</th>
<th>Activities</th>
</tr>
</thead>
<tbody>
<tr>
<td>0:00-7:00</td>
<td>• Introduce the Do Now question</td>
</tr>
<tr>
<td></td>
<td>• Cold call students to share answers</td>
</tr>
<tr>
<td></td>
<td>• Provide relevance and real-world experience to create stronger connections to the content that is to be covered</td>
</tr>
<tr>
<td></td>
<td>• Answer the Do Now questions in their notebooks</td>
</tr>
<tr>
<td></td>
<td>• Share answers with the class, having an in-depth discussion with peers</td>
</tr>
<tr>
<td>7:00-15:00</td>
<td>• Introduce lab activity</td>
</tr>
<tr>
<td></td>
<td>• Go through lab safety procedures when working with materials</td>
</tr>
<tr>
<td></td>
<td>• Create student groups</td>
</tr>
<tr>
<td></td>
<td>• Go through lab safety protocol</td>
</tr>
<tr>
<td></td>
<td>• Gather lab credit sheet</td>
</tr>
<tr>
<td>15:00-40:00</td>
<td>• Monitor student work and assist in troubleshooting with any stations that are not working properly</td>
</tr>
<tr>
<td></td>
<td>• Help clean any spills that occur</td>
</tr>
<tr>
<td></td>
<td>• Answer student questions</td>
</tr>
<tr>
<td></td>
<td>• Go through the stations and record observations</td>
</tr>
<tr>
<td></td>
<td>• After recording observations, clean up station and move on to the next</td>
</tr>
<tr>
<td></td>
<td>• After all observations are recorded complete the lab questions on the credit sheet</td>
</tr>
<tr>
<td>40:00-45:00</td>
<td>• Go over student questions about lab</td>
</tr>
<tr>
<td></td>
<td>• Collect lab credit sheets</td>
</tr>
<tr>
<td></td>
<td>• Turn in lab credit sheet</td>
</tr>
<tr>
<td></td>
<td>• Review lab and ask questions about stations</td>
</tr>
</tbody>
</table>

**Differentiation and planned universal supports:**

Differentiation during the lesson will be based on the assessment of previous student work and work during the *Do Now*. Students who have displayed difficulty throughout the unit will be placed into a small group that will receive more attention towards addressing the apparent learning gap (Sesen & Tarhan, 2010).

Students will be allowed to refer to their notes throughout the lab while answering the lab questions on the credit sheet. Students will be allowed to type written responses if they choose to do so and have access to laptops in class.

**Type of Student Assessments and what is being assessed:**

- **Informal Assessment:** While students are working, the teacher will be walking around the room listening and observing student conversations and work. The Do Now question, at the beginning of the lesson, will address concepts from the day before as a check for retention of student understanding and it will reactivate the necessary neural networks associated with learning (Huelser, 2012). This will assist in determining student groups for the lab.

- **Formal Assessment:** Students will be given a lab credit sheet that they are to complete and turn in at the end of class. This lab will require students to activate prior knowledge to foster more robust learning (Brown, 2014).
- **Modifications to the Assessments:** Students who exhibited more struggles during the *Do Now* and previous lessons will be separated into a small group to have their needs attended to more diligently by the teacher. Students who require additional time on assessments will be allowed to complete the problem set at a later time. Students will be given sentence starters to help assist in their written responses.

**Evaluation Criteria:**
Students will be evaluated on their understanding through their lab credit sheet. The lab will be graded out of 20. Six (6) points will be awarded for recording observations on their lab credit sheet. The remaining 14 points will be awarded for the seven (7) lab questions that follow. Two (2) points will be given for each question.

** Relevant theories and/or research best practices:**

<table>
<thead>
<tr>
<th>Lesson Time: (2 Days) 45 Minutes</th>
<th>Grade Level: High School</th>
<th>Content Area: Chemistry</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unit of Study: Math and Matter</td>
<td>Lesson Title: Review and Assessment</td>
<td></td>
</tr>
</tbody>
</table>

**Essential Question:**
What is matter and how do we study it?

**Content Standard(s):**
*Math Standards:*
MP.4. Model with mathematics

**Next Generation Science Standards:**
*HS-PS1-3* Plan and conduct an investigation to gather evidence to compare the structure of substances at the bulk scale to infer the strength of electrical forces between particles.
*HS-PS1-4.* Develop a model to illustrate that the release or absorption of energy from a chemical reaction system depends upon the changes in total bond energy.
*HS-PS1-7.* Use mathematical representations to support the claim that atoms, and therefore mass, are conserved during a chemical reaction.
*HS-PS2-6.* Communicate scientific and technical information about why the molecular-level structure is important in the functioning of designed materials

**Learning Objectives** associated with the content standards:
**Students will be able to (SWBAT):**
SWBAT demonstrate understanding of the properties of matter and basic chemical processes associated with changes in matter

**Instructional Resources and Materials** to engage students in learning: PowerPoint, laptop, calculator, Promethean ActivBoard, review problems, and assessment
Lesson Timeline, Instructional Strategies and Learning Tasks that support diverse student needs:

<table>
<thead>
<tr>
<th>Time</th>
<th>Teacher will…</th>
<th>Students will…</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Day 1</strong></td>
<td>• Distribute the review packet</td>
<td>• Work on review packet with partners</td>
</tr>
<tr>
<td>0:00-30:00</td>
<td>• Present the topics that will be covered on the assessment on the projector</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Walk around the room and facilitate student work</td>
<td></td>
</tr>
<tr>
<td>30:00-45:00</td>
<td>• Review problems from the packet</td>
<td>• Share answers during the review and ask questions</td>
</tr>
<tr>
<td></td>
<td>• Monitor student progress throughout the review to ensure that the packet is completed</td>
<td>• Submit packet at the end of class</td>
</tr>
<tr>
<td></td>
<td>• Review student packets to identify individual modifications for the assessment</td>
<td></td>
</tr>
<tr>
<td><strong>Day 2</strong></td>
<td>• Distribute assessment to students and monitor the room answering student questions as necessary</td>
<td>• Take assessment and complete during the allotted time</td>
</tr>
<tr>
<td>0:00-45:00</td>
<td>• Distribute individualized student modified exams with sentence starters for written response questions</td>
<td></td>
</tr>
</tbody>
</table>

Differentiation and planned universal supports:
Students who exhibited struggle with mastery of concepts throughout the unit will be given the exams with sentence starters for written responses. Students will also be given a copy of Table S from the NYS Regents Reference Table for Physical Sciences

Type of Student Assessments and what is being assessed:
- **Informal Assessment:** The review packet will serve as the informal assessment. Students will submit this packet and it will serve as an identifier for which students need modifications on the assessment for Day 2. The review packet will reactivate the necessary neural networks associated with learning (Huelser, 2012). The review packet will be randomized in question organization so that no repetition of concepts will be observed, thus creating stronger long-term connections as supported in the literature for robust learning (Rohrer, 2012).
- **Formal Assessment:** The formal assessment will be comprised of 25 questions. The test will have 15 multiple choice and 10 written response/fill in questions.
- **Modifications to the Assessments:** Students who exhibited more struggles during the unit will be given sentence starters for the written response questions. The sentence starters will help students begin their thought process and focus more demonstrating their understanding of concepts.

Evaluation Criteria:
Students will be evaluated on the formal assessment out of 50 points. Each multiple choice question will be worth two (2) points for a total of 20 points. The written response and fill-in questions will be the remaining 30 points on the assessment. Each question will vary in value.
based on the depth of the question or diagram. Students who receive modifications to the assessment will be graded based on the same criteria.

Relevant theories and/or research best practices:


Activity Rationale

<table>
<thead>
<tr>
<th>Title of Activity</th>
<th>Pure Substance, or Mixture?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Source</td>
<td>Created by John Posillico, Dr. Carleton Gaupp, and Ethel Khanis</td>
</tr>
<tr>
<td>NGSS Standard(s)</td>
<td>HS-PS1-3 Plan and conduct an investigation to gather evidence to compare the structure of substances at the bulk scale to infer the strength of electrical forces between particles.</td>
</tr>
<tr>
<td>Supplies</td>
<td>Crushed Chalk, sand, water, salt, Alka-Seltzer, wax, Magnesium Filings, Paper towels, Beakers, Lab Credit Sheet, Projector, Goggles, Apron, and gloves</td>
</tr>
<tr>
<td>Key Questions</td>
<td>How can we differentiate between a mixture, and a pure substance? How can we tell if a mixture is homogenous or heterogenous?</td>
</tr>
<tr>
<td>Narrative Summary</td>
<td>Students encounter a plethora of mixtures and pure substances every day. Helping students differentiate between substances can help enhance lives through an educated approach on how to utilize these substances. If students have dirty water, they know that this is a mixture and will be able to purify it through various physical and chemical processes. In this lab students will see which substances that they encounter every day are mixtures, or pure. Multiple concepts that are addressed throughout the unit will culminate during this lab activity.</td>
</tr>
<tr>
<td>Rationale</td>
<td>This lab is designed to assess student understanding on multiple concepts that were presented throughout the unit and will reappear in future units. Being provided a tangible experience with mixtures and pure substances will help enhance learning because of the relevant nature of the materials. This will further entrench robust learning within students.</td>
</tr>
</tbody>
</table>
Possible Misconceptions

Bicarbonate tablets are most likely a mixture of chemicals because the name is not found on the periodic table. Mixtures that can be separated must be heterogenous.

Recommendations

**Pre-Lab:** Create large volumes and weigh out excess materials to prevent having an insufficient supply in the case of spills. Also, have paper towels and cleaning supplies near stations where spills can occur. Ensure that all materials are prepared, and replacement materials are prepped in the instance of an accident.

**During Lab:** Ensure that student groups are recording observations in complete sentences. Facilitate group transitions by using a stop watch. Give the students a certain amount of time at each station and then a certain amount of time to transition. Warn that it will affect their grade if they are not moving and working efficiently.

**Post Lab:** Have waste containers ready and labeled clearly. Make sure all students submit their work before exiting the class.

---

**Assessments**

**Assessment 1:** Significant Figures and Scientific Notation

**PART 1:** Identifying the number of significant figures. For each of the following, identify the number of significant figures in each problem below

1. 90210 __________________________________________
2. 0.003423 ________________________________________
3. 10001 ________________ __________________________

**PART 2:** Rewrite each term using the correct scientific notation

4. 3,120,000 ________________________________________
5. 0.002310 ________________________________________
PART 3: Report each term in scientific notation using THREE significant digits

7. 0.3313 ___________________________

8. 0.0013702 _______________________

9. 1,579 ___________________________

10. 12,004 _________________________

Answer Key
1. 4 significant digits
2. 4 significant digits
3. 5 significant digits
4. 3.12 x 10^6
5. 2.310 x 10^-3
6. 1 x 10^-6 or 10^-6
7. 3.31 x 10^-1
8. 1.37 x 10^-3
9. 1.58 x 10^3
10. 1.20 x 10^4

Assessment 2: Unit Conversion & Dimensional Analysis

Part 1: Convert the following questions using Dimensional Analysis. Use the correct number of significant figures

1. Convert 324 kg to g

2. Convert 23.63 L to mL

3. 23.5 mg to kg

4. 43 m to cm
5. 1,802 mm to m

Part 2: Convert the following using whichever conversion method you are more comfortable with. Use the correct number of significant figures.

6. 10 km to m

7. 42.5 L to mL

8. 84.3 mL to L

9. 324 g to kg

10. 42 mg to g

Answer Key
1. 324,000 g
2. 23,630 mL
3. 0.0000235 kg
4. 4,300 cm
5. 1.802 m
6. 10,000 m
7. 42,500 mL
8. 0.0843 L
9. 0.324 kg
10. 0.042 g

Assessment 3: States of Matter

Answer each of the following:

1. During the process of melting, what is the initial state of matter and the resulting state of matter after melting?

2. What is the process called when a substance goes from solid to gas?

3. Which state of matter generally has the lowest amount of energy and is most dense?
4. During the process of freezing, is the energy of the substance changing?

5. When a gas is lowered in energy enough to become a liquid, it goes through this phase change?

**Answer Key**
1. Solid to liquid
2. Sublimation
3. Solid
4. No, energy remains constant during a phase change
5. Condensation

**Assessment 4: Saltwater Mixture**

**Follow the instructions:**
You will create a saltwater solution. You will need to record the volume of water used and the weight of the salt that you put into the water. Once you put the salt in the water, you will weigh the solution, make sure the salt is dissolved completely. After weighing the solution, label your beaker and place the beaker on the heater and leave it there overnight. Tomorrow when we get into class, we will weigh our beakers again and record our observations.

**PART 1:** Record your data for the following

Weight of the beaker _____________________________

Weight of the Salt _______________________________

Volume of Water ________________________________

Weight of Saltwater ______________________________

In the space below, state if you think the solution is pure, homogenous, or heterogenous. Defend your answer
PART 2: Find your beaker and remove the label. Once you remove the label, weigh the beaker. Record your data:

Weight of the beaker ____________________________

Weight of the Salt ______________________________

Volume of Water ________________________________

Weight of Saltwater ____________________________

In the space below, did your previous hypothesis change? Why or why not?

**Answer Key:**

Students should state that the mixture is homogenous. They will state that there is no observable salt particles in the solution. They should also mention how the solution is able to be separated which is a characteristic distinct of mixture and not pure substances.

**Assessment 5: Chemical & Physical Changes**

Answer the following questions. Use the NYS Physical Science Reference Table to support your answers for questions as needed.

**PART 1:** Label each as a chemical or physical change

1. Dissolving salt in water ______________________________

2. Burning toast ______________________________________

3. Spoiled milk _______________________________________

4. Boiling water _______________________________________

5. Melting ice in water ________________________________

**PART 2:** Label each as either exothermic or endothermic
6. \( \text{CH}_4 + \text{O}_2 \rightarrow \text{CO}_2 + \text{H}_2\text{O} + \text{heat} \)  

7. \( \text{H}_2\text{O} (s) + \text{heat} \rightarrow \text{H}_2\text{O} (l) \)  

8. Melting gold  

9. Combustion of gasoline  

10. \( 2\text{H}_2 (g) + \text{O}_2 (g) \rightarrow 2\text{H}_2\text{O} (g) + \text{heat} \)  

**Answer Key:**  
1. Physical  
2. Chemical  
3. Chemical  
4. Physical  
5. Physical  
6. Exothermic  
7. Endothermic  
8. Endothermic  
9. Exothermic  
10. Exothermic  

**Assessment 6: Lab Activity- Is it Pure?**  

**Part 1:** In the table below record observations for each station. You will be rotating around the room to each station. Your observations must include what you see, smell, feel, and hear (DO NOT TASTE ANYTHING). Be sure to be thorough in your observation recordings.

<table>
<thead>
<tr>
<th>Station</th>
<th>Observation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crushed Chalk</td>
<td></td>
</tr>
<tr>
<td>Material</td>
<td>Answer</td>
</tr>
<tr>
<td>---------------------------</td>
<td>--------</td>
</tr>
<tr>
<td>Sand water</td>
<td></td>
</tr>
<tr>
<td>Dissolved Alka-Seltzer</td>
<td></td>
</tr>
<tr>
<td>Melted Wax</td>
<td></td>
</tr>
<tr>
<td>Dissolved Salt</td>
<td></td>
</tr>
<tr>
<td>Magnesium Filings</td>
<td></td>
</tr>
</tbody>
</table>

**Part 2:** Answer the following questions to the best of your ability. Use your observations and knowledge of chemistry to support your conclusions.

1. Which of the materials that you observed were pure?
2. Which of the materials that you observed were mixtures?
3. Which mixtures were heterogenous? Why?
4. Which materials were elements?
5. How could you separate the homogenous mixtures? (Be specific)
6. Can the pure substances be separated? Why?
Answer Key
1. Melted Wax & Magnesium Filings, Crushed Chalk
2. Dissolved Salts, Dissolved Alka-Seltzer, Sand & Water
3. Sand & Water was heterogenous because that mixture could be separated by physical means, such as using a filter.
4. The Magnesium Filings were the only pure substance that is an element
5. You could separate the homogenous mixtures in the lab by chemical processes, such as boiling the water in the saltwater solution.
6. Pure substances can only be separated through chemical means, or nuclear reactions.

Assessment 7: Summative Assessment

PART 1: All questions in the multiple-choice section will be worth two points each.

1. The process of a substance going from solid to gas is called:
   a. Melting
   b. Condensation
   c. Freezing
   d. Sublimation

2. Which of the following correctly represents 5,340,000 written in scientific notation?
   a. $5.34 \times 10^3$
   b. $5.34 \times 10^4$
   c. $5.34 \times 10^6$
   d. $5.34 \times 10^{-6}$

3. Which of the following represents an exothermic reaction?
   a. Freezing water
   b. Boiling water
   c. Melting Ice
   d. Subliming solid CO$_2$

4. Which correctly describes an endothermic reaction?
   a. A reaction that requires heat to be released
   b. A reaction that requires heat to be absorbed
   c. A reaction that requires two reactants to combine and form a product
   d. A reaction between two states of matter of the same substance

5. H$_2$O is a:
   a. Compound
   b. Element
   c. Homogenous Mixture
   d. Reactant
6. Convert 1.40 L to mL
   a. 0.00140 mL
   b. 140 mL
   c. 1,400 mL
   d. 0.0140 mL

7. Convert 23,451 mg to kg
   a. 23 kg
   b. 23.451 kg
   c. 0.0023451 kg
   d. 2.3451 kg

8. Which of the following choices is the correct scientific notation for 12,900
   a. 0.129 x 10^4
   b. 1.3 x 10^4
   c. 1.29 x 10^4
   d. 129 x 10^4

9. Which of the following is an element?
   a. Hg^2
   b. 2CH_4 + 3O_2 → 2CO_2 + 2H_2O + heat
   c. Mg_2SO_4
   d. H_2SO_4

10. True or False: During a phase change energy remains constant?
    a. True
    b. False

**PART 2:** All questions in the written response section will be worth 3 points each.

11. Describe the properties of a homogenous mixture

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

12. Explain the difference between a compound and an element? Give an example of each.

________________________________________________________________________
13. Explain the difference between an exothermic reaction and an endothermic reaction

________________________________________________________________________

________________________________________________________________________

14. Explain what type of change (chemical or physical) the following example is: Cooking a turkey.

________________________________________________________________________

________________________________________________________________________

15. Give an example of a physical change and state why it’s physical and not chemical

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________
16. Explain the differences between pure compounds and mixtures

________________________________________________________________________
________________________________________________________________________
________________________________________________________________________

17. Label the following reactants, products, and whether it is exothermic or endothermic

\[2\text{CH}_4 + 3\text{O}_2 \rightarrow 2\text{CO}_2 + 2\text{H}_2\text{O} + \text{heat}\]

18. Explain the Law of Conservation of Energy

________________________________________________________________________
________________________________________________________________________
________________________________________________________________________

19. Define what it is to be a heterogeneous mixture

________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
20. Using the template below, label all processes for phase changes

Answer Key
1. D
2. C
3. A
4. B
5. A
6. C
7. B
8. C
9. A
10. A

Student short answer response examples:
11. A homogenous mixture is a mixture that is comprised of two or more substances that are evenly distributed throughout. These mixtures can be separated by chemical means, isolating each individual substance within the mixture.
12. A compound is a substance that is made up of two or more different elements. An element is a singular atom that is not bonded to other different atoms.
13. An exothermic reaction is one that releases heat during the process, such as freezing or condensation. An endothermic reaction is one that absorbs heat during the process, such as melting or vaporization.
14. Cooking a turkey is a chemical change because during cooking, the compounds within the food are being altered in a way that is irreversible which is characteristic of a chemical change.
15. Water changing phases is a physical change because changing phases is a reversible process.
16. Pure compounds are different from mixtures in that a pure compound is the same thing throughout the entire sample. A mixture is a sample that is comprised of multiple substances.
17. Reactants CH₄ & O₂

Products H₂O, heat & CH₄

Exothermic

18. Energy cannot be created or destroyed, but it can change forms.
19. A heterogeneous mixture is one that has visible sediments or particles can be separated by physical means.
20.

UNIT 2: ATOMIC THEORY & STRUCTURE

LESSON PLANS
Lesson Time: 45 Minutes  Grade Level: High School  Content Area: Chemistry

Unit of Study: Atomic Theory & Structure  Lesson Title: Atomic Theory

Essential Question: How does the structure of an atom influence its behavior?

Content Standard(s):

Next Generation Science Standards:
HS-PS2-6 Communicate scientific and technical information about why the molecular-level structure is important in the functioning of designed materials

Learning Objectives associated with the content standards:

Students will be able to (SWBAT):
SWBAT explain the progression of atomic theory from its beginning to the modern definition.

Instructional Resources and Materials to engage students in learning: PowerPoint, laptop, Promethean ActivBoard, and Learning Walk Sheet

Lesson Timeline, Instructional Strategies and Learning Tasks that support diverse student needs:

<table>
<thead>
<tr>
<th>Time</th>
<th>Teacher will...</th>
<th>Students will...</th>
</tr>
</thead>
</table>
| 0:00-7:00  | • Prompt students with Do Now question using a turn and talk about the most fundamental unit of matter  
             • Promote collaboration to stimulate a positive learning environment (Brown et al., 2014) | • Turn and Talk about what is the simplest form of matter  
             • Share answers with partners and class during discussions |
| 7:00-13:00 | • Introduce Atomic Theory progression and significant figures in the dawn of this body of science  
             • Create student groups for Learning Walk preparation  
             • Assign a scientist that was a prominent figure in atomic theory development | • Take notes on the significant figures in atomic theory and important dates  
             • Get placed into groups for Atomic Theory Learning Walk  
             • Record their scientist for the Learning Walk |
| 13:00-40:00| • Facilitate group research during preparation for the Learning Walk  
             • Monitor groups and provide sufficient resources to the class | • Research their scientists and the theories they are accredited for in the evolution of atomic theory.  
             • Create an artifact with their group compiling their research that will be displayed during the Learning Walk |
| 40:00-45:00| • Analyze student work and have them reflect on what they have learned | • Reflect on their progress and finalize their artifact they created with their groups |
**Differentiation and planned universal supports:**
Students will be placed in small groups based on learning needs. Students who exhibit the largest struggles with completion of assignments or displaying mastery of concepts will be placed in a small homogenous group. This group can have its learning needs met more directly than being placed in heterogenous groups. These students will also have additional time, if needed to complete their artifact.

**Type of Student Assessments and what is being assessed:**
- **Informal Assessment:** While students are working, the teacher will be walking around the room listening and observing student conversations and work. The Do Now question, at the beginning of the lesson, will address concepts from the day before as a check for retention of student understanding and it will reactivate the necessary neural networks associated with learning (Huelser, 2012). Teacher will also monitor student work during the work time allotted during class and facilitate group research based on student conversations.
- **Formal Assessment:** Student group artifacts will be graded based on accuracy and meeting expectations that aligned with the rubric.
- **Modifications to the Assessments:** Students will be placed in small homogenous groups to ensure that their learning needs are met more directly. These students will be given the opportunity to have extra time to work on this assignment, given that they do not complete the work in class.

**Evaluation Criteria:**
Students will be evaluated on a ten (10) point grading scale. There will be two parts to grading this assignment. The first part will be out of five (5) points for the groups’ artifacts that they create following a rubric. The other five (5) points will be awarded based on the Exit Ticket after the next lesson that is based on the information that they learned during the Learning Walk on each of the scientists who were prominent figures is the evolution of Atomic Theory.

**Relevant theories and/or research best practices:**

<table>
<thead>
<tr>
<th>Lesson Time: 45 Minutes</th>
<th>Grade Level: High School</th>
<th>Content Area: Chemistry</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unit of Study: Atomic Theory &amp; Structure</td>
<td>Lesson Title: Atomic Theory Learning Walk</td>
<td></td>
</tr>
</tbody>
</table>

**Essential Question:** How does the structure of an atom influence its behavior?

**Content Standard(s):**
*Next Generation Science Standards:*
**HS-PS2-6** Communicate scientific and technical information about why the molecular-level structure is important in the functioning of designed materials
Learning Objectives associated with the content standards:
Students will be able to (SWBAT):
SWBAT explain the progression of atomic theory from its beginning to the modern definition
SWBAT identify the subatomic particles and their location within the atom

Instructional Resources and Materials to engage students in learning: PowerPoint, laptop, Promethean ActivBoard, and Learning Walk Sheet

Lesson Timeline, Instructional Strategies and Learning Tasks that support diverse student needs:

<table>
<thead>
<tr>
<th>Time</th>
<th>Teacher will…</th>
<th>Students will…</th>
</tr>
</thead>
</table>
| 0:00-10:00 | • Help students finalize details for the Learning Walk  
• Facilitate the creation of artifacts | • Finalize details for their created artifact for the Learning Walk  |
| 10:00-35:00| • Rotate students around the room during the Learning Walk, providing a fixed amount of time at each artifact  
• Ensure students remain on task, and are working efficiently  
• Remind students to record only the necessary information, encouraging them to take concise notes | • Rotate around the room to each artifact for a scientist who served an integral part in the evolution of Atomic Theory  
• Record notes at each station |
| 35:00-45:00| • Administer an exit ticket and monitor student progress  
• Walk around the room and answer student questions | • Complete an exit ticket using their notes that they took from the Learning Walk  
• Ask questions as necessary to help them complete the exit ticket |

Differentiation and planned universal supports:
Students will be placed in small groups based on learning needs. Students who exhibit the largest struggles with completion of assignments or displaying mastery of concepts will be placed in a small homogeneous group. This group can have its learning needs met more directly than being placed in heterogenous groups. These students will also have additional time, if needed to complete their artifact. Students will also be allowed to use the notes they took during the learning walk to supplement their completion of the Exit Ticket.

Type of Student Assessments and what is being assessed:
• **Informal Assessment:** While students are working, the teacher will be walking around the room listening and observing student conversations and work. The Do Now question, at the beginning of the lesson, will address concepts from the day before as a check for retention of student understanding and it will reactivate the necessary neural networks associated with learning (Huelser, 2012). Teacher will also monitor student work during the work time allotted during class and facilitate group research based on student conversations.
Formal Assessment: The Exit Ticket will align with what they learned during the Learning Walk. The students will be assessed on their understanding of the models each scientist is responsible for and how they influenced the evolution of Atomic Theory.

Modifications to the Assessments: Students will be allowed to complete their Exit Ticket using their notes they took during the Learning Walk. This will encourage students to engage with the content during the Learning Walk and help overcome any obstacles they may experience during the Exit Ticket.

Evaluation Criteria:
Students will be evaluated on a ten (10) point grading scale. There will be two parts to grading this assignment. The first part will be out of five (5) points for the groups’ artifacts that they create following a rubric. The other five (5) points will be awarded based on the Exit Ticket after the next lesson that is based on the information that they learned during the Learning Walk on each of the scientists who were prominent figures is the evolution of Atomic Theory.

Relevant theories and/or research best practices:

<table>
<thead>
<tr>
<th>Lesson Time: 45 Minutes</th>
<th>Grade Level: High School</th>
<th>Content Area: Chemistry</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unit of Study: Atomic Theory &amp; Structure</td>
<td>Lesson Title: Subatomic Particles</td>
<td></td>
</tr>
</tbody>
</table>

Essential Question: How does the structure of an atom influence its behavior?

Content Standard(s):
Next Generation Science Standards:
HS-PS1-1. Use the periodic table as a model to predict the relative properties of elements based on the patterns of electrons in the outermost energy level of atoms
HS-PS1-3. Plan and conduct an investigation to gather evidence to compare the structure of substances at the bulk scale to infer the strength of electrical forces between particles.

Learning Objectives associated with the content standards:
Students will be able to (SWBAT):
SWBAT differentiate between the charges and masses of each subatomic particle
SWBAT calculate the number of each subatomic particle in a given atom

Instructional Resources and Materials to engage students in learning: PowerPoint, laptop, calculator, Promethean ActivBoard, and activity packet
Lesson Timeline, Instructional Strategies and Learning Tasks that support diverse student needs:

<table>
<thead>
<tr>
<th>Time</th>
<th>Teacher will…</th>
<th>Students will…</th>
</tr>
</thead>
</table>
| 0:00-7:00 | • Prompt students to discuss the structure of an atom where the particles are located  
• Facilitate student discussions during Turn and Talk | • Turn and Talk with a partner to discuss the structure of an atom and where the subatomic particles are located |
| 7:00-20:00 | • Discuss how certain atomic theories are still useful to use because of the applications  
• Introduce how to read atomic symbols on the periodic table and how to calculate number of each subatomic particle | • Take notes on how to read the atomic symbols of each atom  
• Ask questions involving calculations of each subatomic particle and the usefulness |
| 20:00-30:00 | • Distribute problem set to designated groups of students to work on during the period  
• Facilitate groups who appear to struggle | • Work with partner to complete the problem set  
• Ask questions, as needed |
| 30:00-38:00 | • Review the problem set  
• Answer any questions that the students may have for solving the problem sets  
• Call on students to share answers | • Share answers and thought process used when solving problems within the set  
• Ask questions |
| 38:00-45:00 | • Administer Exit Ticket  
• Monitor student work | • Complete exit ticket on their own |

Differentiation and planned universal supports:
Students will be placed in small groups based on learning needs. Students who exhibit the largest struggles with completion of assignments or displaying mastery of concepts will be placed in a small homogenous group. This group can have its learning needs met more directly than being placed in heterogenous groups. These students will also have additional time, if needed to complete their artifact. Students will also be allowed to use the notes they took during the learning walk to supplement their completion of the Exit Ticket.
Type of Student Assessments and what is being assessed:

- **Informal Assessment:** While students are working, the teacher will be walking around the room listening and observing student conversations and work. The Do Now question, at the beginning of the lesson, will address concepts from the day before as a check for retention of student understanding and it will reactivate the necessary neural networks associated with learning (Huelser, 2012).

- **Formal Assessment:** The problem sets are to be turned in after they are completed at the end of class or at a later date. This problem set requires students to recall previous atomic structure unit. Practicing this recall will help assess retention of previously learned material (Brown, 2014).

- **Modifications to the Assessments:** Students will be given a calculator to help perform the required math necessary to solve the problems in the set. This will be given on both the problem set and exit ticket.

Evaluation Criteria:

Students will receive a grade on the problem set only for this lesson. The exit ticket will influence the following lesson, providing an accurate portrayal on individual learning and the gaps that need to be addressed. The problem set will be worth ten (10) points, one (1) point for each question.

Relevant theories and/or research best practices:


**Lesson Time:** 45 Minutes  
**Grade Level:** High School  
**Content Area:** Chemistry

**Unit of Study:** Atomic Theory & Structure  
**Lesson Title:** Spiral Review

**Essential Question:** How does the structure of an atom influence its behavior?

**Content Standard(s):**

**Math Standards:**

MP.4. Model with mathematics

**Next Generation Science Standards:**

**HS-PS1-1.** Use the periodic table as a model to predict the relative properties of elements based on the patterns of electrons in the outermost energy level of atoms  
**HS-PS1-3.** Plan and conduct an investigation to gather evidence to compare the structure of substances at the bulk scale to infer the strength of electrical forces between particles.  
**HS-PS1-7.** Use mathematical representations to support the claim that atoms, and therefore mass, are conserved during a chemical reaction.  
**HS-PS2-6** Communicate scientific and technical information about why the molecular-level structure is important in the functioning of designed materials
Learning Objectives associated with the content standards:

Students will be able to (SWBAT):

- **SWBAT** demonstrate understanding of the properties of matter and basic chemical processes associated with changes in matter
- **SWBAT** explain the progression of atomic theory from its beginning to the modern definition
- **SWBAT** identify the subatomic particles and their location within the atom

### Instructional Resources and Materials to engage students in learning:

- Spiral Review sheet

### Lesson Timeline, Instructional Strategies and Learning Tasks that support diverse student needs:

<table>
<thead>
<tr>
<th>Time</th>
<th>Teacher will...</th>
<th>Students will...</th>
</tr>
</thead>
<tbody>
<tr>
<td>0:00-25:00</td>
<td>• Administer the Spiral Review</td>
<td>• Complete the Spiral Review</td>
</tr>
<tr>
<td></td>
<td>• Walk around and monitor student work</td>
<td>• As questions, as needed</td>
</tr>
<tr>
<td></td>
<td>• Answer questions</td>
<td></td>
</tr>
<tr>
<td>25:00-45:00</td>
<td>• Lead review of the Spiral Review providing how to work through each question individually</td>
<td>• Participate in Spiral Review discussion</td>
</tr>
<tr>
<td></td>
<td>• Answer questions and call on students to share</td>
<td>• Ask questions to the teacher and students who share their approaches towards answering questions</td>
</tr>
</tbody>
</table>

### Differentiation and planned universal supports:

Students will be allowed to use calculators if they wish to. All questions will be multiple choice, and therefore no sentence starters will be necessary. Students who require additional time will be given it.

### Type of Student Assessments and what is being assessed:

- **Informal Assessment**: Class discussion during the breakdown of the Spiral Review where students are discussing with one another about the questions on the spiral
- **Formal Assessment**: The Spiral Review will provide a metric of student learning from the very beginning of the academic year to the current time
- **Modifications to the Assessments**: Students will be graded on the same scale. Modifications to the assessment will appear in the form of students being given the choice to have problems read to them out loud. Students who wish to work in a separate location where that will occur will be allowed to take advantage of this.

### Evaluation Criteria:

The Spiral Review will be ten (10) questions all worth one (1) point each. The Spiral Review will be worth a total of ten (10) points.

### Relevant theories and/or research best practices:

<table>
<thead>
<tr>
<th>Lesson Time: 45 Minutes</th>
<th>Grade Level: High School</th>
<th>Content Area: Chemistry</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unit of Study: Atomic Theory &amp; Structure</td>
<td>Lesson Title: Lewis and Bohr Diagrams</td>
<td></td>
</tr>
</tbody>
</table>

**Essential Question:** How does the structure of an atom influence its behavior?

**Content Standard(s):**

*Next Generation Science Standards:*

- **HS-PS1-1.** Use the periodic table as a model to predict the relative properties of elements based on the patterns of electrons in the outermost energy level of atoms
- **HS-PS2-6** Communicate scientific and technical information about why the molecular-level structure is important in the functioning of designed materials

**Learning Objectives** associated with the content standards:

- **Students will be able to (SWBAT):**
  - SWBAT Model atomic structure using both Lewis and Bohr Diagrams

**Instructional Resources and Materials** to engage students in learning:

- PowerPoint, Problem Set, Calculators

**Lesson Timeline, Instructional Strategies and Learning Tasks** that support diverse student needs:

<table>
<thead>
<tr>
<th>Time</th>
<th>Teacher will…</th>
<th>Students will…</th>
</tr>
</thead>
<tbody>
<tr>
<td>0:00-7:00</td>
<td>• Ask students about Bohr’s atomic theory and model of representing an atom</td>
<td>• Discuss the Bohr Model of an atom</td>
</tr>
<tr>
<td></td>
<td>• Facilitate class discussion</td>
<td>• Ask questions directed at the teacher and classmates</td>
</tr>
<tr>
<td>7:00-15:00</td>
<td>• Define a Bohr Diagram and how to construct them</td>
<td>• Take notes on the Bohr Diagram</td>
</tr>
<tr>
<td></td>
<td>• Ask students to help model how to create the diagram after showing the exemplar</td>
<td>• Provide the necessary steps to construct a Bohr Diagram after viewing exemplar demonstration by the teacher</td>
</tr>
<tr>
<td>15:00-25:00</td>
<td>• Provide students time to work on Bohr Diagram problems in designated student work groups</td>
<td>• Work in collaboration with classmates in designated groups to construct Bohr Diagrams</td>
</tr>
<tr>
<td></td>
<td>• Facilitate student work as needed</td>
<td>• Ask questions as needed</td>
</tr>
<tr>
<td></td>
<td>• Review the 5 Bohr Diagram problems, calling on students to present their work</td>
<td>• Present work to classmates during review</td>
</tr>
<tr>
<td>25:00-30:00</td>
<td>• Define valence electrons using student explanations</td>
<td>• Derive a definition for valence electrons</td>
</tr>
<tr>
<td></td>
<td>• Show exemplar Lewis Diagram</td>
<td>• View and take notes on Lewis Diagram</td>
</tr>
<tr>
<td></td>
<td>• Have students construct Lewis Diagram as a class</td>
<td>• Construct Lewis Diagram as a class</td>
</tr>
</tbody>
</table>
| 30:00-40:00 | • Allow students to continue to work on problem set  
• Facilitate group work as needed  
• Review 5 Lewis Diagram problems, calling on students to present their work | • Work in collaboration with classmates in designated groups to construct Lewis Diagrams  
• Ask questions as needed  
• Present work to classmates during review |
|-------------|-------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------|
| 40:00-45:00 | • Administer Exit Ticket  
• Monitor student progress | • Complete Exit Ticket |

**Differentiation and planned universal supports:**

Students will be placed in small groups based on learning needs. Students who exhibit the largest struggles with completion of assignments or displaying mastery of concepts will be placed in a small homogenous group. This group can have its learning needs met more directly than being placed in heterogenous groups. These students will also have additional time, if needed to complete their artifact.

**Type of Student Assessments and what is being assessed:**

- **Informal Assessment:** While students are working, the teacher will be walking around the room listening and observing student conversations and work. The Do Now question, at the beginning of the lesson, will address concepts from the day before as a check for retention of student understanding and it will reactivate the necessary neural networks associated with learning (Huelser, 2012). Teacher will also monitor student work during the work time allotted during class and facilitate group research based on student conversations.

- **Formal Assessment:** Students will be measured on their mastery that is displayed on their problem set.

- **Modifications to the Assessments:** Students will be placed in small homogenous groups to ensure that their learning needs are met more directly. These students will be given the opportunity to have extra time to work on this assignment, given that they do not complete the work in class. Students will also be given the option to use their notes while working on the Exit Ticket if they were in the separate student group that showed difficulty in mastering concepts.

**Evaluation Criteria:**

There will be 10 (10) problems on the problem set, each question will be worth one (1) point. Students will complete Part 1 during the first work period, and then Part 2 will be completed during the second work period within the class time.

**Relevant theories and/or research best practices:**


Lesson Time: 45 Minutes  |  Grade Level: High School  |  Content Area: Chemistry

| Unit of Study: Atomic Theory & Structure | Lesson Title: Ions & Isotopes |

Essential Question: How does the structure of an atom influence its behavior?

Content Standards:
Next Generation Science Standards:
HS-PS1-1. Use the periodic table as a model to predict the relative properties of elements based on the patterns of electrons in the outermost energy level of atoms
HS-PS1-3. Plan and conduct an investigation to gather evidence to compare the structure of substances at the bulk scale to infer the strength of electrical forces between particles.
HS-PS2-6. Communicate scientific and technical information about why the molecular-level structure is important in the functioning of designed materials

Learning Objectives associated with the content standards:
Students will be able to (SWBAT):
SWBAT Model atomic structure using both Lewis and Bohr Diagrams

Instructional Resources and Materials to engage students in learning:
PowerPoint, Problem Set, Calculators

Lesson Timeline, Instructional Strategies and Learning Tasks that support diverse student needs:

<table>
<thead>
<tr>
<th>Time</th>
<th>Teacher will…</th>
<th>Students will…</th>
</tr>
</thead>
</table>
| 0:00-7:00| • Ask students to Turn and Talk about charges and masses of each subatomic particle  
• Ask them to construct Lewis Diagram independently  
• Facilitate class discussion  | • Discuss the charges and masses of subatomic particles  
• Construct a Lewis Diagram independently  
• Ask questions directed at the teacher and classmates  |
| 7:00-15:00| • Define ions, cations, and anions and how to calculate the number of electrons for each ion  
• Ask students to help model how to create the diagram after showing the exemplar for ions  | • Take notes on ions  
• Provide the necessary steps to construct Lewis Diagrams for ions  |
| 15:00-25:00| • Provide students time to work on problems involving ions in their designated student work groups  
• Facilitate student work as needed  
• Review the problems in Part 1: Ions on the problem set  | • Work in collaboration with classmates in designated groups to work on ion problems in the problem set  
• Ask questions as needed  
• Present work to classmates during review  |
| 25:00-35:00 | • Define isotopes  
• Show how to calculate the subatomic particles for isotopes  
• Have students derive the amount for each subatomic particle | • Derive a definition for isotopes  
• View and take notes on isotopes  
• Calculate the number of each subatomic particle for each isotope |
| 35:00-45:00 | • Allow students to continue to work on problem set  
• Facilitate group work as needed  
• Review the problem in Part 2 | • Work in collaboration with classmates in designated groups to work on ion problems in the problem set  
• Ask questions as needed  
• Present work to classmates during review |

**Differentiation and planned universal supports:**
Students will be placed in small groups based on learning needs. Students who exhibit the largest struggles with completion of assignments or displaying mastery of concepts will be placed in a small homogenous group. This group can have its learning needs met more directly than being placed in heterogenous groups. These students will also have additional time, if needed to complete their problem set.

**Type of Student Assessments and what is being assessed:**
- **Informal Assessment:** While students are working, the teacher will be walking around the room listening and observing student conversations and work. The Do Now question, at the beginning of the lesson, will address concepts from the day before as a check for retention of student understanding and it will reactivate the necessary neural networks associated with learning (Huelser, 2012). Teacher will also monitor student work during the work time allotted during class and facilitate group research based on student conversations.

- **Formal Assessment:** Students will be measured on their mastery that is displayed on their problem set. This is a group assessment because it requires the concepts covered from Lesson 3 to be applied to this problem set (Brown et al., 2014).

- **Modifications to the Assessments:** Students will be placed in small homogenous groups to ensure that their learning needs are met more directly. These students will be given the opportunity to have extra time to work on this assignment, given that they do not complete the work in class. Students will also be given the option to use their notes while working on the Exit Ticket if they were in the separate student group that showed difficulty in mastering concepts.

**Evaluation Criteria:**
There will be ten (10) problems on the problem set, each question will be worth one (1) point. Students will complete Part 1 during the first work period, and then Part 2 will be completed during the second work period within the class time.
Relevant theories and/or research best practices:

<table>
<thead>
<tr>
<th>Lesson Time: 45 Minutes</th>
<th>Grade Level: High School</th>
<th>Content Area: Chemistry</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unit of Study: Atomic Theory &amp; Structure</td>
<td>Lesson Title: Spiral Review 2</td>
<td></td>
</tr>
</tbody>
</table>

**Essential Question:**
How does the structure of an atom influence its behavior?

**Content Standard(s):**

**Math Standards:**
- MP.4. Model with mathematics

**Next Generation Science Standards:**
- HS-PS1-1. Use the periodic table as a model to predict the relative properties of elements based on the patterns of electrons in the outermost energy level of atoms
- HS-PS1-3. Plan and conduct an investigation to gather evidence to compare the structure of substances at the bulk scale to infer the strength of electrical forces between particles.
- HS-PS1-7. Use mathematical representations to support the claim that atoms, and therefore mass, are conserved during a chemical reaction.
- HS-PS2-6 Communicate scientific and technical information about why the molecular-level structure is important in the functioning of designed materials

**Learning Objectives** associated with the content standards:

**Students will be able to (SWBAT):**
- SWBAT demonstrate understanding of the properties of matter and basic chemical processes associated with changes in matter
- SWBAT explain the progression of atomic theory from its beginning to the modern definition
- SWBAT identify the subatomic particles and their location within the atom

**Instructional Resources and Materials** to engage students in learning:
- Spiral Review sheet
### Lesson Timeline, Instructional Strategies and Learning Tasks

<table>
<thead>
<tr>
<th>Time</th>
<th>Teacher will…</th>
<th>Students will…</th>
</tr>
</thead>
<tbody>
<tr>
<td>0:00-25:00</td>
<td>• Administer the Spiral Review</td>
<td>• Complete the Spiral Review</td>
</tr>
<tr>
<td></td>
<td>• Walk around and monitor student work</td>
<td>• As questions, as needed</td>
</tr>
<tr>
<td></td>
<td>• Answer questions</td>
<td></td>
</tr>
<tr>
<td>25:00-45:00</td>
<td>• Lead review of the Spiral Review providing how to work through each question individually</td>
<td>• Participate in Spiral Review discussion</td>
</tr>
<tr>
<td></td>
<td>• Answer questions and call on students to share</td>
<td>• Ask questions to the teacher and students who share their approaches towards answering questions</td>
</tr>
</tbody>
</table>

### Differentiation and planned universal supports:

Students will be allowed to use calculators if they wish to. All questions will be multiple choice, and therefore no sentence starters will be necessary. Students who require additional time will be given it.

### Type of Student Assessments and what is being assessed:

- **Informal Assessment**: Class discussion during the breakdown of the Spiral Review where students are discussing with one another about the questions on the spiral
- **Formal Assessment**: The Spiral Review will provide a metric of student learning from the very beginning of the academic year to the current time
- **Modifications to the Assessments**: Students will be graded on the same scale. Modifications to the assessment will appear in the form of students being given the choice to have problems read to them out loud. Students who wish to work in a separate location where that will occur will be allowed to take advantage of this.

### Evaluation Criteria:

The Spiral Review will be ten (10) questions all worth one (1) point each. The Spiral Review will be worth a total of ten (10) points.

### Relevant theories and/or research best practices:

**HS-PS1-1.** Use the periodic table as a model to predict the relative properties of elements based on the patterns of electrons in the outermost energy level of atoms.

**HS-PS1-3** Plan and conduct an investigation to gather evidence to compare the structure of substances at the bulk scale to infer the strength of electrical forces between particles.

**HS-PS2-6** Communicate scientific and technical information about why the molecular-level structure is important in the functioning of designed materials.

**Learning Objectives** associated with the content standards:

**Students will be able to (SWBAT):**

**SWBAT** Model atomic structure using both Lewis and Bohr Diagrams for ions, isotopes, and ground state.

**Instructional Resources and Materials** to engage students in learning:

PowerPoint, Calculators, Atomic Models, Activity Sheet

**Lesson Timeline, Instructional Strategies and Learning Tasks** that support diverse student needs:

<table>
<thead>
<tr>
<th>Time</th>
<th>Teacher will…</th>
<th>Students will…</th>
</tr>
</thead>
<tbody>
<tr>
<td>0:00-7:00</td>
<td>• Introduce the activity and place students into designated groups</td>
<td>• Get into their designated groups and ask questions about the task</td>
</tr>
<tr>
<td>7:00-37:00</td>
<td>• Facilitate group work and rotate groups after a designated period of time (3 minutes for each station)</td>
<td>• Rotate around working to complete the task at each station</td>
</tr>
<tr>
<td></td>
<td>• Work with small group that showed significant struggle with mastery of concepts involving atomic structure</td>
<td>• Work collaboratively</td>
</tr>
<tr>
<td>37:00-45:00</td>
<td>• Facilitate group completion of the activity questions at the end of the activity sheet</td>
<td>• Work within their group to complete the activity questions at the end of the activity sheet</td>
</tr>
<tr>
<td></td>
<td>• Collect all completed student work</td>
<td>• Submit the complete work</td>
</tr>
</tbody>
</table>

**Differentiation and planned universal supports:**

Students will be placed in small groups based on learning needs. Students who exhibit the largest struggles with completion of assignments or displaying mastery of concepts will be placed in a small homogenous group. This group can have its learning needs met more directly than being placed in heterogenous groups. These students will have a calculator to use and also have additional time with assistance from the teacher in their small group, if needed to complete their activity sheets.

**Type of Student Assessments and what is being assessed:**

- **Informal Assessment:** Teacher will monitor student work during the work time allotted during class and facilitate group completion of the tasks based on student conversations. Teacher will also place students into homogenous groups predicated on perceived mastery of concepts measured on past assignments. Making the same types of errors will help facilitate learning within the group (Huesler & Metcalf, 2012).

- **Formal Assessment:** Students will be measured on their mastery that is displayed on their activity sheet. The activity sheet will be worth twenty (20) points total.
• **Modifications to the Assessments:** Students will be placed in small homogenous groups to ensure that their learning needs are met more directly. These students will be given the opportunity to have extra time to work on this assignment, given that they do not complete the work in class. Students will also be given the option to use their notes while working on the activity and the questions at the end. Students will also be permitted to use a calculator if they wish to do so.

**Evaluation Criteria:**
There will be ten (10) stations in this activity. Each station will be worth one (1) point, awarded for correct models that were created. The five (5) activity questions will be worth two (2) points each. One (1) point will be awarded for complete sentences, and the one (1) point will be awarded for correct responses. This accounts for the twenty (20) total points for the entire activity.

**Relevant theories and/or research best practices:**

<table>
<thead>
<tr>
<th>Lesson Time: (2 Days) 45 Minutes</th>
<th>Grade Level: High School</th>
<th>Content Area: Chemistry</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unit of Study: Atomic Theory &amp; Structure</td>
<td>Lesson Title: Review and Assessment</td>
<td></td>
</tr>
</tbody>
</table>

**Essential Question:**
How does the structure of an atom influence its behavior?

**Content Standard(s):**
*Next Generation Science Standards:*
- **HS-PS1-1.** Use the periodic table as a model to predict the relative properties of elements based on the patterns of electrons in the outermost energy level of atoms
- **HS-PS1-3** Plan and conduct an investigation to gather evidence to compare the structure of substances at the bulk scale to infer the strength of electrical forces between particles.
- **HS-PS2-6** Communicate scientific and technical information about why the molecular-level structure is important in the functioning of designed materials

**Learning Objectives** associated with the content standards:
- **Students will be able to (SWBAT):**
  - SWBAT review all Unit 2 Topics in Atomic Theory & Structure
  - SWBAT demonstrate understanding of Atomic Theory and Structure

**Instructional Resources and Materials** to engage students in learning: PowerPoint, laptop, calculator, Promethean ActivBoard, review problems, and assessment
### Lesson Timeline, Instructional Strategies and Learning Tasks

that support diverse student needs:

<table>
<thead>
<tr>
<th>Time</th>
<th>Teacher will…</th>
<th>Students will…</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Day 1</strong></td>
<td>• Distribute the review packet</td>
<td>• Work on review packet with partners</td>
</tr>
<tr>
<td>0:00-30:00</td>
<td>• Present the topics that will be covered on the assessment on the projector&lt;br&gt;• Walk around the room and facilitate student work</td>
<td></td>
</tr>
<tr>
<td>30:00-45:00</td>
<td>• Review problems from the packet&lt;br&gt;• Monitor student progress throughout the review to ensure that the packet is completed&lt;br&gt;• Review student packets to identify individual modifications for the assessment</td>
<td>• Share answers during the review and ask questions&lt;br&gt;• Submit packet at the end of class</td>
</tr>
<tr>
<td><strong>Day 2</strong></td>
<td>• Distribute assessment to students and monitor the room answering student questions as necessary&lt;br&gt;• Distribute individualized student modified exams with sentence starters for written response questions</td>
<td>• Take assessment and complete during the allotted time</td>
</tr>
<tr>
<td>0:00-45:00</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Differentiation and planned universal supports:

Students who exhibited struggle with mastery of concepts throughout the unit will be given the exams with sentence starters for written responses. Students will also be given a copy of Table S from the NYS Regents Reference Table for Physical Sciences.

### Type of Student Assessments and what is being assessed:

- **Informal Assessment:** The review packet will serve as the informal assessment. Students will submit this packet and it will serve as an identifier for which students need modifications on the assessment for **Day 2**. The review packet will reactivate the necessary neural networks associated with learning (Huelser, 2012). The review packet will be randomized in question organization so that no repetition of concepts will be observed, thus creating stronger long-term connections as supported in the literature for robust learning (Rohrer, 2012).

- **Formal Assessment:** The formal assessment will be comprised of 25 questions. The test will have 15 multiple choice and 10 written response/fill in questions.

- **Modifications to the Assessments:** Students who exhibited more struggles during the unit will be given sentence starters for the written response questions. The sentence starters will help students begin their thought process and focus more demonstrating their understanding of concepts.

### Evaluation Criteria:

Students will be evaluated on the formal assessment out of 25 points. Each multiple choice question will be worth one (1) point for a total of 10 points. The five (5) written response and
fill-in questions will be the remaining 15 points on the assessment; three (3) points for each question.

**Relevant theories and/or research best practices:**

**Activity Rationale**

<table>
<thead>
<tr>
<th>Title of Activity</th>
<th>Atomic Theory Learning Walk</th>
</tr>
</thead>
<tbody>
<tr>
<td>Source</td>
<td>Created by John Posillico</td>
</tr>
<tr>
<td>NGSS Standard(s)</td>
<td><strong>HS-PS2-6</strong> Communicate scientific and technical information about why the molecular-level structure is important in the functioning of designed materials</td>
</tr>
<tr>
<td>Supplies</td>
<td>Laptops, PPT, Activity Sheet, Creative utensils (markers, crayons, colored pencils)</td>
</tr>
<tr>
<td>Key Questions</td>
<td>How has atomic theory developed to our current model? What is the significance of understanding the evolution of atomic theory/models?</td>
</tr>
<tr>
<td>Narrative Summary</td>
<td>Students will explore the evolution of atomic theory through conducting their own research with their group. Students will come to realize that theories are just theories and they are subject to change over time. This helps highlight that science is not a crystallized body of work, but a fluid one that is constantly changing every day. This concept dates back to the earliest parts of our recorded history.</td>
</tr>
<tr>
<td>Rationale</td>
<td>This lab is designed to assess student understanding on conducting research and the development of atomic theory. Students are provided an opportunity to creatively represent their research and learn from their classmates.</td>
</tr>
<tr>
<td>Possible Misconceptions</td>
<td>We can determine the exact location of an electron within an atom. The planetary model is the current model of the atom. Atoms are the smallest structures in the universe</td>
</tr>
</tbody>
</table>
Title of Activity | Lewis and Bohr Diagrams for Ions, Isotopes, and the Ground State
---|---
Source | Created by John Posillico
NGSS Standard(s) | HS-PS1-1. Use the periodic table as a model to predict the relative properties of elements based on the patterns of electrons in the outermost energy level of atoms  
HS-PS1-3 Plan and conduct an investigation to gather evidence to compare the structure of substances at the bulk scale to infer the strength of electrical forces between particles.  
HS-PS2-6 Communicate scientific and technical information about why the molecular-level structure is important in the functioning of designed materials
Supplies | PowerPoint, Calculators, Atomic Models, Activity Sheet
Key Questions | How does atomic structure and models change for ions and isotopes, compared to the ground state?
Narrative Summary | Ions and isotopes are what drive many biochemical processes. These ions and isotopes make cellular activity possible by driving concentration gradients, and much more complicated processes. Students will have an opportunity to understand the foundation of ions and isotopes in order to expand their understanding of these biochemical processes.
Rationale | Students will have an opportunity to test multiple concepts that are covered within the unit during this final activity for Unit 2. This culminating activity will assess student understanding of all concepts covered in the unit.
Possible Misconceptions | All atoms of an element are the exact same  
Interchanging of the definition for ions and isotopes  
The excited state of an atom is the same as an ion
Recommendations | **Pre-Lab:** Laminate copies of the Bohr Model templates, this way students can use dry-erase markers on them to do work to minimize the amount of paper needed for this lab.  
**During Lab:** Facilitate student research and ensure that they remain on task. Encourage group thinking.
Post Lab: Recycle the laminated templates and clean them off so that the next class is ready to use them immediately.

**ASSESSMENTS**

*Assessment 1: Atomic Theory Learning Walk*

Group Scientist: _______________________________

Instructions: Your group will be responsible for creating an artifact that accurately and creatively depicts your scientist’s contribution to the evolution of atomic theory. In this artifact, you will make sure to include the year of the discovery, the name of their model, a picture of their model, and the major findings of their theory. On Day 2, you will do a Learning Walk around the classroom and go through the class and look at the artifacts that other groups created. You will fill in the data in the table below with the same necessary information that you included in your artifact (year, name of the model, picture of the model, and major findings of their contributions).

<table>
<thead>
<tr>
<th>Scientist</th>
<th>Contributions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dalton</td>
<td></td>
</tr>
<tr>
<td>Thomson</td>
<td></td>
</tr>
<tr>
<td>Rutherford</td>
<td></td>
</tr>
<tr>
<td>Bohr</td>
<td></td>
</tr>
<tr>
<td>Scientist</td>
<td>Contributions</td>
</tr>
<tr>
<td>-----------</td>
<td>---------------</td>
</tr>
<tr>
<td>Dalton</td>
<td>1803, Billiard Ball model, there is a small indivisible particle of matter called the atom</td>
</tr>
<tr>
<td>Thomson</td>
<td>1897, plum pudding model, there are charges randomly dispersed throughout the atom</td>
</tr>
<tr>
<td>Rutherford</td>
<td>1912, Nuclear model, there are densely positively charged particles within the center of the atom</td>
</tr>
</tbody>
</table>
Bohr Model, electrons travel in fixed paths around the nucleus.

Heisenberg, Einstein, etc.
1930, Electron Cloud Model, Electrons travel in random paths within the confines of an orbital. The position of each individual electron is unable to be located at a given point in time.

Assessment 2: Subatomic Particle Exit Ticket
Using the atomic symbol below, fill in the following information

\[ ^{12}_{6}C \]

# of Protons: ____________

# of Neutrons: ____________

# of Electrons: ____________

\[ ^{59}_{28}Co \]

# of Protons: ____________

# of Neutrons: ____________

# of Electrons: ____________

Answer Key

\[ ^{12}_{6}C \]

# of Protons: 6

# of Neutrons: 6

# of Electrons: 6

\[ ^{59}_{28}Co \]

# of Protons: 28

# of Neutrons: 31

# of Electrons: 28

Assessment 3: Spiral Review 1

1. Convert 43,800 g to kg, using proper scientific notation
   a. $4.38 \times 10^3$ kg
   b. $4.4 \times 10^3$ kg
   c. $4.38 \times 10^4$ kg
2. Which of the following is a compound?
   a. H₂O
   b. Saltwater
   c. Sugar and Water
   d. H₂

3. When dry ice (solid CO₂) becomes CO₂ gas instantly, that process is called:
   a. Melting
   b. Boiling
   c. Condensation
   d. Sublimation

4. Which scientist created the Planetary Model?
   a. Neils Bohr
   b. Albert Einstein
   c. Ernest Rutherford
   d. Carl Sagan

5. Which subatomic particle has mass, but does not have charge?
   a. Electron
   b. Neutron
   c. Proton
   d. Higg’s Boson

6. How many protons are in an atom of Sulfur?
   a. 16
   b. 32
   c. 6
   d. 17

7. What is the current atomic model?
   a. The Bohr Model
   b. The Plum Pudding Model
   c. The Electron Cloud Model
   d. The Billiard Ball Model

8. An element is a
   a. Homogenous Mixture
   b. Heterogenous Mixture
   c. Pure Substance
   d. Compound

9. The difference between Heterogenous and Homogenous mixtures is:
   a. There is none
b. Homogenous mixtures can be separated by physical means; heterogenous mixtures cannot

c. Heterogenous mixtures can be separated by physical means; Homogenous mixtures cannot

d. Heterogenous mixtures are evenly mixed throughout; Homogenous mixtures are not even mixed throughout

10. Convert 23.8 L to mL, using proper scientific notation
   a. $2.38 \times 10^3$ mL
   b. $2.4 \times 10^3$ mL
   c. $2.38 \times 10^3$ mL
   d. $2.38 \times 10^4$ mL

Answer Key:
1. C
2. A
3. D
4. A
5. B
6. A
7. C
8. C
9. C
10. D

Assessment 4: Lewis and Bohr Diagrams

Part 1: Create a Lewis Diagram for the following elements:

1. Helium
2. Sulfur
3. Oxygen
4. Silicon
5. Carbon

Part 2: Create a Bohr Diagram for the following elements:

1. Helium
2. Sulfur
3. Oxygen
4. Silicon
5. Carbon

Answer Key
Part 1: Lewis Diagrams
Part 2: Bohr Diagrams

6. He

7. S

8. O
Assessment 5: Ions and Isotopes

Part 1: Record the number of protons and electrons for each element
1. Na+  
2. S2-  
3. Cu2+  
4. O2-  
5. H+  

Part 2: Record the number of protons and neutrons for each element
6. 13C  
7. 15N  
8. 64Cu  
9. 131I  
10. 13C  

Answer Key  
1. 11 protons, 10 electrons  
2. 16 protons, 18 electrons  
3. 29 protons, 27 electrons  
4. 8 protons, 10 electrons  
5. 1 proton, 0 electrons  
6. 6 protons, 8 neutrons  
7. 7 protons, 8 neutrons  
8. 29 protons, 35 neutrons  
9. 53 protons, 78 neutrons  
10. 6 protons, 7 neutrons  

Assessment 6: Spiral Review 2  
1. How many neutrons does 14C have?  
   a. 14  
   b. 6  
   c. 7  
   d. 8
2. Draw a Lewis Diagram for He

3. Draw a Bohr Diagram for neutral Carbon

4. How many electrons does Na- have?
   a. 14
   b. 10
   c. 11
   d. 12

5. Which subatomic particle doesn’t have mass, but does have charge?
   a. Electron
   b. Neutron
   c. Proton
   d. Higg’s Boson

6. How many protons are in an atom of Sulfur?
   a. 16
   b. 32
   c. 6
   d. 17

7. What is the Thomson atomic model?
   a. The Bohr Model
   b. The Plum Pudding Model
   c. The Electron Cloud Model
   d. The Billiard Ball Model

8. What is the difference between an ion and an isotope?
   a. An ion has a different number of protons; isotopes have different number of electrons
   b. Isotopes have a different number of neutrons; ions have a different number of electrons
   c. There is no difference
   d. Isotopes have a different number of electrons; ions have a different number of neutrons

9. How many protons are in a sample of 131-I?
   a. 53
   b. 55
   c. 78
   d. 54

10. Convert 23.8 m to mm, using proper scientific notation
    a. 23.8 x 10³ mm
1. At each workstation there is an energy level diagram, an element symbol for a neutral atom, and representative electrons. Record the symbol of the neutral atom on the Data Table.
2. Determine the number of protons contained in the atom (Refer to the periodic table.) Record the atomic number on the Data Table.
3. Determine the number of electrons in the atom. Record the electron number on the Data Table.
4. Count out this number of representative electrons.
5. Fill the electron energy levels with the correct number of representative electrons, from lowest energy level to highest. This is called the **aufbau principle**. Record the number of electrons in each energy level on the Data Table.
6. Remove the pennies from the energy level diagram back into the cup and proceed to the next station.

### Data Table:

<table>
<thead>
<tr>
<th>Station</th>
<th>Symbol of Atom</th>
<th>Name of Element</th>
<th>Number of Protons</th>
<th>Number of Neutrons</th>
<th>Number of Electrons</th>
<th>Number of Electrons in Level 1 (1\text{st} orbital)</th>
<th>Number of Electrons in Level 2 (2\text{nd} orbital)</th>
<th>Number of Electrons in Level 3 (3\text{rd} orbital)</th>
<th>Number of Electrons in Level 4 (4\text{th} orbital)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Na\textsuperscript{+}</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>He</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### Discussion / Conclusion:
Answer the questions in FULL sentences on google classroom.

1. What did you notice about where electrons are located when there are less than 10?
2. What did you notice about where electrons are located when there are more than 10 electrons?
3. Since the nucleus has protons and is positively charged, and the electrons are negatively charged, what do you think happens between the electrons in Level 1 and the protons in the nucleus?
4. What pattern(s) do you see about the electron configuration?
5. What would be a way to go further with this experiment?

### Answer Key

<table>
<thead>
<tr>
<th>Station</th>
<th>Symbol of Atom</th>
<th>Name of Atom</th>
<th>Number of Protons</th>
<th>Number of Neutrons</th>
<th>Number of Electrons</th>
<th>Number of Electrons in Level 1 (1st orbital)</th>
<th>Number of Electrons in Level 2 (2nd orbital)</th>
<th>Number of Electrons in Level 3 (3rd orbital)</th>
<th>Number of Electrons in Level 4 (4th orbital)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Na+</td>
<td>Sodium</td>
<td>11</td>
<td>13</td>
<td>10</td>
<td>2</td>
<td>8</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>B</td>
<td>He</td>
<td>Helium</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>C</td>
<td>Fe3+</td>
<td>Iron</td>
<td>26</td>
<td>30</td>
<td>23</td>
<td>2</td>
<td>8</td>
<td>13</td>
<td>0</td>
</tr>
<tr>
<td>D</td>
<td>Mg2+</td>
<td>Magnesium</td>
<td>12</td>
<td>12</td>
<td>10</td>
<td>2</td>
<td>8</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>E</td>
<td>14C</td>
<td>Carbon</td>
<td>6</td>
<td>8</td>
<td>6</td>
<td>2</td>
<td>4</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>F</td>
<td>64Cu</td>
<td>Copper-64</td>
<td>29</td>
<td>35</td>
<td>29</td>
<td>2</td>
<td>8</td>
<td>18</td>
<td>0</td>
</tr>
<tr>
<td>G</td>
<td>B</td>
<td>Boron</td>
<td>5</td>
<td>6</td>
<td>5</td>
<td>2</td>
<td>3</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>
1. The first two levels could hold up to 10 electrons, all together.
2. Whenever an element had more than 10 electrons, they were located in higher energy levels.
3. The electrons in the first energy level have the strongest affinity for the nucleus compared to electrons in higher energy levels.
4. Higher energy levels can hold more electrons than the lower energy level orbitals.
5. Ions typically gain electrons to fill an orbital, or lose enough electrons resulting in completely filled orbitals.

Assessment 8: Summative Assessment

1. How many neutrons does ¹⁴C have?
   a. 14
   b. 6
   c. 7
   d. 8

2. Which scientist is responsible for the Nuclear Model?
   a. Rutherford
   b. Thomson
   c. Dalton
   d. Bohr

3. How many electrons does the first electron orbital hold?
   a. 2
   b. 8
   c. 18
   d. 10

4. Which of the following is a cation?
   a. O²⁻
   b. S²⁻
   c. Cl⁻
   d. H⁺

5. Which subatomic particle has mass and charge?
   a. Electron
b. Neutron
c. Proton
d. Higg’s Boson

6. Convert $23.8 \times 10^3$ mm to m, using proper scientific notation
   a. 23.8 m
   b. 2.4 m
   c. 2.38 m
   d. 0.238 m

7. What is the Thomson atomic model?
   a. The Bohr Model
   b. The Plum Pudding Model
   c. The Electron Cloud Model
   d. The Billiard Ball Model

8. What is the difference between an ion and an isotope?
   a. An ion has a different number of protons; isotopes have different number of electrons
   b. Isotopes have a different number of neutrons; ions have a different number of electrons
   c. There is no difference
   d. Isotopes have a different number of electrons; ions have a different number of neutrons

9. How many neutrons are in a sample of $^{131}$-I?
   a. 53
   b. 55
   c. 78
   d. 54

10. When there is a difference between the number of electrons and protons, the atom is referred to as:
    a. A nucleus
    b. An Ion
    c. An Isotope
    d. Radioactive

11. Fill in the Table below

<table>
<thead>
<tr>
<th>Particle</th>
<th>Charge</th>
<th>Mass</th>
</tr>
</thead>
<tbody>
<tr>
<td>Proton</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Neutron</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Electron</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
12. Draw a Bohr Diagram for O$_2$.


15. Draw a Bohr Diagram for Nitrogen.

**Answer Key**

1. D  
2. A  
3. A  
4. D  
5. C  
6. A  
7. B  
8. B  
9. C  
10. B  
11.  

<table>
<thead>
<tr>
<th>Particle</th>
<th>Charge</th>
<th>Mass</th>
</tr>
</thead>
<tbody>
<tr>
<td>Proton</td>
<td>+1</td>
<td>1</td>
</tr>
<tr>
<td>Neutron</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Electron</td>
<td>0</td>
<td>-1</td>
</tr>
</tbody>
</table>

12. 

13.
**UNIT 3: NUCLEAR CHEMISTRY**

**LESSON PLANS**

<table>
<thead>
<tr>
<th>Lesson Time: 45 Minutes</th>
<th>Grade Level: High School</th>
<th>Content Area: Chemistry</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unit of Study: Nuclear Chemistry</td>
<td>Lesson Title: Intro to Application</td>
<td></td>
</tr>
</tbody>
</table>

**Essential Question:**
How can we harness the energy located within the nucleus of an atom?

**Content Standard(s):**
*Next Generation Science Standards:*

HS-PS2-6 Communicate scientific and technical information about why the molecular-level structure is important in the functioning of designed materials

**Learning Objectives** associated with the content standards:
Students will be able to (SWBAT):

SWBAT identify application and relevance of studying nuclear chemistry

**Instructional Resources and Materials** to engage students in learning: PowerPoint, laptop, calculator, Promethean ActivBoard, and Twitter Template

**Lesson Timeline, Instructional Strategies and Learning Tasks** that support diverse student needs:

<table>
<thead>
<tr>
<th>Time</th>
<th>Teacher will…</th>
<th>Students will…</th>
</tr>
</thead>
<tbody>
<tr>
<td>0:00-7:00</td>
<td>- Present the <em>Do Now</em> question that prompts students to brainstorm what they know about nuclear chemistry. Collaboration will help promote a stronger learning environment that is more engaging (Brown, 2014).</td>
<td>- Work in small groups to discuss what they know about nuclear chemistry&lt;br&gt;- Share out their prior knowledge</td>
</tr>
<tr>
<td>Time</td>
<td>Activity</td>
<td>Activity</td>
</tr>
<tr>
<td>--------------</td>
<td>--------------------------------------------------------------------------</td>
<td>--------------------------------------------------------------------------</td>
</tr>
<tr>
<td>7:00-13:00</td>
<td>• Facilitate class discussion about prior knowledge about nuclear chemistry</td>
<td>• Present a video that shows the applications of nuclear chemistry in commonplace</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Initiate class discussion about where nuclear chemistry can also be used, outside of the context of the video</td>
</tr>
<tr>
<td>13:00-20:00</td>
<td>• Review previously learned academic vocabulary that is relevant in this unit (Brown, 2014)</td>
<td>• Define radioisotope and radioactivity with the class</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>25:00-45:00</td>
<td>• Assign groups radioisotopes to research and create a Tweet that can explain the use in 140 characters or less</td>
<td>• Research a radioisotope and its uses</td>
</tr>
</tbody>
</table>

**Differentiation and planned universal supports:**
Students will be placed in small groups based on learning needs. Students who exhibit the largest struggles with completion of assignments or displaying mastery of concepts will be placed in a small homogenous group. This group can have its learning needs met more directly than being placed in heterogenous groups. These students will also have additional time, if needed to complete their Tweet. Students will also be allowed to use the notes they have recording during the lesson and throughout the school year to facilitate creation of the Tweet.

**Type of Student Assessments and what is being assessed:**
- **Informal Assessment:** Students will be assessed on prior knowledge based on the Do Now discussion. Misconceptions about nuclear chemistry applications will be addressed during the discussion and through the mini-lesson video that follows. (Huelser, 2012).
- **Formal Assessment:** The tweet that the students will be creating about their radioisotope will represent their introductory knowledge about nuclear chemistry while also assessing their retention of prior learning from earlier in the year (Brown, 2014).
- **Modifications to the Assessments:** Students will be given a supplemental vocabulary and be allowed to use their notes to facilitate the research. Students may also go over the 140-character limit on their Tweet if they show great struggle to write in a concise manner.
**Evaluation Criteria:**
Students will earn up to five (5) points for their created tweet. They earn one (1) point for correctly representing their radioisotope, two (2) points for identifying the uses, and two (2) points for creatively representing their radioisotope through their tweet and citing their sources.

**Relevant theories and/or research best practices:**

<table>
<thead>
<tr>
<th>Lesson Time: 45 Minutes</th>
<th>Grade Level: High School</th>
<th>Content Area: Chemistry</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unit of Study: Nuclear Chemistry</td>
<td>Lesson Title: Modes of Decay</td>
<td></td>
</tr>
</tbody>
</table>

**Essential Question:**
How can we harness the energy located within the nucleus of an atom?

**Content Standard(s):**
*Next Generation Science Standards:*
- **HS-PS1-8** Develop models to illustrate the changes in the composition of the nucleus of the atom and the energy released during the processes of fission, fusion, and radioactive decay.
- **HS-PS2-6** Communicate scientific and technical information about why the molecular-level structure is important in the functioning of designed materials

**Learning Objectives** associated with the content standards:
- **SWBAT** identify the different modes of decay

**Instructional Resources and Materials** to engage students in learning: PowerPoint, laptop, calculator, Promethean ActivBoard, and Problem Set

**Lesson Timeline, Instructional Strategies and Learning Tasks** that support diverse student needs:

<table>
<thead>
<tr>
<th>Time</th>
<th>Teacher will…</th>
<th>Students will…</th>
</tr>
</thead>
</table>
| 0:00-10:00    | - Present the *Do Now* question that prompts students to discuss about radioactivity. Collaboration will help promote a stronger learning environment that is more engaging (Brown, 2014).  
  - Facilitate class discussion about radioactivity and mention nuclear disasters | - Work in small groups to discuss what they know about radioactivity  
  - Share out their prior knowledge and questions about nuclear disasters |
10:00-15:00
- Introduce radioactivity and modes of decay: alpha decay
- Model alpha decay equation
- Have students walk through alpha decay as a class
- Students will observe the modeling of alpha decay equations
- Work together as a class to complete an alpha decay equation

15:00-20:00
- Facilitate alpha decay equation completion in the problem set
- Call on students to share work on the board
- Complete alpha decay in problem set

20:00-25:00
- Model beta decay equation
- Have students walk through beta decay as a class
- Students will observe the modeling of beta decay equations
- Work together as a class to complete an beta decay equation

25:00-30:00
- Facilitate beta decay equation completion in the problem set
- Call on students to share work on the board
- Complete beta decay in problem set

30:00-37:00
- Model positron emission and electron capture equations
- Have students walk through these modes decay as a class
- Students will observe the modeling of two modes of decay equations
- Work together as a class to complete equations for both modes of decay

37:00-45:00
- Facilitate completion in the problem set
- Call on students to share work on the board
- Complete the problem set

**Differentiation and planned universal supports:**
Students will be placed in small groups based on learning needs. Students who exhibit the largest struggles with completion of assignments or displaying mastery of concepts will be placed in a small homogenous group. This group can have its learning needs met more directly than being placed in heterogenous groups. These students will also have additional time, if needed to complete their problem set. Students will also be allowed to use the notes they have recording during the lesson and throughout the school year to facilitate the completion of the problem set.
Type of Student Assessments and what is being assessed:

- **Informal Assessment:** Students will be assessed on prior knowledge based on the Do Now discussion. Misconceptions about nuclear chemistry concepts will be addressed during the discussion and through the mini-lesson that follows. (Huelser, 2012).

- **Formal Assessment:** Students will be constructing nuclear decay equations using concepts that were covered in previous units; reading atomic symbols and atomic structure (Brown, 2014). Students will complete 16 questions in the problem set for the four modes of decay.

- **Modifications to the Assessments:** Students will be given a supplemental vocabulary and be allowed to use their notes to facilitate the research. Students who also display greater struggles and take a longer time to complete the problem set will be graded on one equation in each of the four sections of the problem set.

**Evaluation Criteria:**
Students will earn up to sixteen (16) points for their problem set. They earn one (1) point for correctly completing the equation for the mode of decay. Students who receive modifications to the assessment will be graded out of four (4): one (1) point awarded for each correct nuclear decay equation.

**Relevant theories and/or research best practices:**

<table>
<thead>
<tr>
<th>Lesson Time: 45 Minutes</th>
<th>Grade Level: High School</th>
<th>Content Area: Chemistry</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unit of Study: Nuclear Chemistry</td>
<td>Lesson Title: Spiral Review</td>
<td></td>
</tr>
</tbody>
</table>

**Essential Question:**
How can we harness the energy located within the nucleus of an atom?

**Content Standard(s):**
Math Standards:
MP.4. Model with mathematics

**Next Generation Science Standards:**

**HS-PS1-1.** Use the periodic table as a model to predict the relative properties of elements based on the patterns of electrons in the outermost energy level of atoms.

**HS-PS1-3.** Plan and conduct an investigation to gather evidence to compare the structure of substances at the bulk scale to infer the strength of electrical forces between particles.

**HS-PS1-7.** Use mathematical representations to support the claim that atoms, and therefore mass, are conserved during a chemical reaction.

**HS-PS1-8.** Develop models to illustrate the changes in the composition of the nucleus of the atom and the energy released during the processes of fission, fusion, and radioactive decay.

**HS-PS2-6** Communicate scientific and technical information about why the molecular-level structure is important in the functioning of designed materials.
Learning Objectives associated with the content standards:

**Students will be able to (SWBAT):**

**SWBAT** demonstrate understanding of the properties of matter and basic chemical processes associated with changes in matter

**SWBAT** explain the progression of atomic theory from its beginning to the modern definition

**SWBAT** identify the subatomic particles and their location within the atom

Instructional Resources and Materials to engage students in learning:

Spiral Review sheet

Lesson Timeline, Instructional Strategies and Learning Tasks that support diverse student needs:

<table>
<thead>
<tr>
<th>Time</th>
<th>Teacher will…</th>
<th>Students will…</th>
</tr>
</thead>
</table>
| 0:00-25:00 | • Administer the Spiral Review  
• Walk around and monitor student work  
• Answer questions                     | • Complete the Spiral Review  
• As questions, as needed               |
| 25:00-45:00 | • Lead review of the Spiral Review providing how to work through each question individually  
• Answer questions and call on students to share | • Participate in Spiral Review discussion  
• Ask questions to the teacher and students who share their approaches towards answering questions |

Differentiation and planned universal supports:

Students will be allowed to use calculators if they wish to. All questions will be multiple choice, and therefore no sentence starters will be necessary. Students who require additional time will be given it.

Type of Student Assessments and what is being assessed:

- **Informal Assessment:** Class discussion during the breakdown of the Spiral Review where students are discussing with one another about the questions on the spiral

- **Formal Assessment:** The Spiral Review will provide a metric of student learning from the very beginning of the academic year to the current time

- **Modifications to the Assessments:** Students will be graded on the same scale. Modifications to the assessment will appear in the form of students being given the choice to have problems read to them out loud. Students who wish to work in a separate location where that will occur will be allowed to take advantage of this.

Evaluation Criteria:

The Spiral Review will be ten (10) questions all worth one (1) point each. The Spiral Review will be worth a total of ten (10) points.

Relevant theories and/or research best practices:

Lesson Time: 45 Minutes  |  Grade Level: High School  |  Content Area: Chemistry

Unit of Study: Nuclear Chemistry  |  Lesson Title: Modes of Decay Gizmo

Essential Question:
How can we harness the energy located within the nucleus of an atom?

Content Standard(s):
Next Generation Science Standards:
HS-PS1-8 Develop models to illustrate the changes in the composition of the nucleus of the atom and the energy released during the processes of fission, fusion, and radioactive decay.
HS-PS2-6 Communicate scientific and technical information about why the molecular-level structure is important in the functioning of designed materials

Learning Objectives associated with the content standards:
Students will be able to (SWBAT):
SWBAT identify the different modes of decay with mastery

Instructional Resources and Materials to engage students in learning: PowerPoint, laptop, calculator, Promethean ActivBoard, and Gizmo Instructions

Lesson Timeline, Instructional Strategies and Learning Tasks that support diverse student needs:

<table>
<thead>
<tr>
<th>Time</th>
<th>Teacher will…</th>
<th>Students will…</th>
</tr>
</thead>
<tbody>
<tr>
<td>0:00-5:00</td>
<td>• Present the Do Now question requiring students to complete a decay equation (Brown, 2014).</td>
<td>• Work in small groups to complete the decay equations presented on the board</td>
</tr>
<tr>
<td>5:00-10:00</td>
<td>• Introduce the Gizmo module and answer procedural questions that students may have</td>
<td>• Listen to the directions and get into designated groups</td>
</tr>
<tr>
<td></td>
<td>• Place students into groups</td>
<td>• Ask questions about how to complete/access the Gizmo</td>
</tr>
<tr>
<td>15:00-40:00</td>
<td>• Facilitate student group completion of the Gizmo problem set</td>
<td>• Complete the problem set with their group</td>
</tr>
<tr>
<td>40:00-45:00</td>
<td>• Review questions and problems that groups may have in common</td>
<td>• Ask questions about the Gizmo and review answers</td>
</tr>
</tbody>
</table>

Differentiation and planned universal supports:
Students will be placed in small groups based on learning needs. Students who exhibit the largest struggles with completion of assignments or displaying mastery of concepts will be placed in a small homogenous group. This group can have its learning needs met more directly than being placed in heterogenous groups.
These students will also have additional time, if needed to complete their problem set.
Students will also be allowed to use the notes they have recording during the lesson and throughout the school year to facilitate the completion of the problem set.

Type of Student Assessments and what is being assessed:
- Informal Assessment: Students will be assessed on prior knowledge based on the Do Now discussion. Misconceptions about nuclear chemistry concepts will be addressed
during the time allotted for the Do-Now and through the work period that follows. (Huelser, 2012).

- **Formal Assessment:** Students will be constructing nuclear decay equations using concepts that were covered in previous units; reading atomic symbols and atomic structure (Brown, 2014). Students will complete Gizmo problem set

- **Modifications to the Assessments:** Students will be given a supplemental vocabulary and be allowed to use their notes to facilitate the research. Students who also display greater struggles and take a longer time to complete the problem set will be given additional time to complete the problem set at no penalty.

**Evaluation Criteria:**
Students will earn up to twenty-five (25) points for their problem set. They earn one (1) point for correctly responding to each question within the problem set.

**Relevant theories and/or research best practices:**

---

**Lesson Time:** 45 Minutes  
**Grade Level:** High School  
**Content Area:** Chemistry

**Unit of Study:** Nuclear Chemistry  
**Lesson Title:** Nuclear Disasters

**Essential Question:**
How can we harness the energy located within the nucleus of an atom?

**Content Standard(s):**
*Next Generation Science Standards:*
- **HS-PS1-8** Develop models to illustrate the changes in the composition of the nucleus of the atom and the energy released during the processes of fission, fusion, and radioactive decay.
- **HS-PS2-6** Communicate scientific and technical information about why the molecular-level structure is important in the functioning of designed materials
- **PS1. C: Nuclear Processes.** Spontaneous radioactive decays follow a characteristic exponential decay law.

**Learning Objectives** associated with the content standards:
**Students will be able to (SWBAT):**
- SWBAT identify the different modes of decay with mastery

**Instructional Resources and Materials** to engage students in learning: PowerPoint, laptop, calculator, Promethean ActivBoard, and Gizmo Instructions
**Lesson Timeline, Instructional Strategies and Learning Tasks** that support diverse student needs:

<table>
<thead>
<tr>
<th>Time</th>
<th>Teacher will…</th>
<th>Students will…</th>
</tr>
</thead>
<tbody>
<tr>
<td>0:00-5:00</td>
<td>• Present the <em>Do Now</em> question requiring students discuss what they know about the Cold War.</td>
<td>• Work in small groups discussing the Cold War</td>
</tr>
<tr>
<td>5:00-20:00</td>
<td>• Show video on atomic bombs and Fukushima meltdown</td>
<td>• Watch the video on nuclear disasters and discuss why it’s necessary to exercise caution when working with radioisotopes.</td>
</tr>
<tr>
<td></td>
<td>• Discuss the cautions of working with radioisotopes and the potential environmental hazards associated with them (Usta &amp; Ayas, 2010)</td>
<td></td>
</tr>
<tr>
<td>20:00-40:00</td>
<td>• Place students into groups</td>
<td>• Go into designated groups</td>
</tr>
<tr>
<td></td>
<td>• Provide exemplar posters that students will use as a model to create their own caution poster for nuclear facilities</td>
<td>• Create a warning sign for nuclear facilities that encourage them to exercise caution</td>
</tr>
<tr>
<td></td>
<td>• Guide student work and facilitate the creation of the artifact</td>
<td>• Explain why the warnings are warranted</td>
</tr>
<tr>
<td>40:00-45:00</td>
<td>• Call students up to share warning posters</td>
<td>• Share their warning posters to the class and ask the groups questions about why they used specific warnings</td>
</tr>
<tr>
<td></td>
<td>• Encourage group presentation, but make note that they will not adversely impact their grade</td>
<td></td>
</tr>
</tbody>
</table>

**Differentiation and planned universal supports:**
Students will be placed in small groups based on learning needs. Students who exhibit the largest struggles with completion of assignments or displaying mastery of concepts will be placed in a small homogenous group. This group can have its learning needs met more directly than being placed in heterogenous groups.
Students in the homogenous group that need more direct instruction will be allowed to complete the warning poster at a later time.

**Type of Student Assessments and what is being assessed:**
- **Informal Assessment:** Students will be assessed on prior knowledge based on the Do Now discussion. Misconceptions about nuclear chemistry concepts will be addressed during the time allotted for the Do-Now and through the work period that follows. (Huelser, 2012).
- **Formal Assessment:** Students will be constructing a warning poster that accurately displays reasons why caution needs to be exercised in nuclear facilities.
- **Modifications to the Assessments:** Students will be given a supplemental vocabulary and be allowed to use their notes to facilitate the research. Students who also display greater struggles and take a longer time to complete the problem set will be given additional time to complete the warning poster, if needed.
**Evaluation Criteria:**
Students will earn up to five (5) points based on accuracy of the information and creativity of the warning sign. Two (2) points will be awarded to posters that include pictures that accurately represent concerns that are associated with nuclear catastrophe. Three (3) points will be awarded for accurate information on the poster.

**Relevant theories and/or research best practices:**

<table>
<thead>
<tr>
<th>Lesson Time: 45 Minutes</th>
<th>Grade Level: High School</th>
<th>Content Area: Chemistry</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unit of Study: Nuclear Chemistry</td>
<td>Lesson Title: Fusion and Fission</td>
<td></td>
</tr>
</tbody>
</table>

**Essential Question:**
How can we harness the energy located within the nucleus of an atom?

**Content Standard(s):**
*Next Generation Science Standards:*
- **HS-PS1-8** Develop models to illustrate the changes in the composition of the nucleus of the atom and the energy released during the processes of fission, fusion, and radioactive decay.
- **HS-PS2-6** Communicate scientific and technical information about why the molecular-level structure is important in the functioning of designed materials

**Learning Objectives** associated with the content standards:
**Students will be able to (SWBAT):**
- SWBAT compare and contrast fission and fusion reactions

**Instructional Resources and Materials** to engage students in learning: PowerPoint, laptop, calculator, Promethean ActivBoard, problem set

**Lesson Timeline, Instructional Strategies and Learning Tasks** that support diverse student needs:

<table>
<thead>
<tr>
<th>Time</th>
<th>Teacher will...</th>
<th>Students will...</th>
</tr>
</thead>
</table>
| 0:00-5:00    | • Ask students to explain how a nuclear bomb works  
• Facilitate group discussions (Usta & Ayas, 2010) | • Discuss how nuclear bombs work at a foundational level |
| 5:00-12:00   | • Go through Fission Reactions as a class.  
• Model the first example for the class | • Go through model with the teacher  
• Class creates the next equation together  
• Individual creation of the fission example |
<table>
<thead>
<tr>
<th>Time</th>
<th>Activities</th>
</tr>
</thead>
<tbody>
<tr>
<td>12:00-20:00</td>
<td>• Place students into groups to answer the 3 questions that follow</td>
</tr>
<tr>
<td></td>
<td>• Work in groups to answer the three questions</td>
</tr>
<tr>
<td></td>
<td>• Go through Fission Reactions as a class</td>
</tr>
<tr>
<td></td>
<td>• Model the first example for the class</td>
</tr>
<tr>
<td></td>
<td>• Call on student to walk through the second example</td>
</tr>
<tr>
<td></td>
<td>• Have students do the third example individually</td>
</tr>
<tr>
<td></td>
<td>• Go through model with the teacher</td>
</tr>
<tr>
<td></td>
<td>• Class creates the next equation together</td>
</tr>
<tr>
<td></td>
<td>• Individual creation of the fusion example</td>
</tr>
<tr>
<td></td>
<td>• Listen to the directions and get into designated groups</td>
</tr>
<tr>
<td>20:00-25:00</td>
<td>• Work in groups to answer the 3 questions in the problem set</td>
</tr>
<tr>
<td></td>
<td>• Work in groups to answer the three questions</td>
</tr>
<tr>
<td></td>
<td>• Work with small groups to answer the three questions</td>
</tr>
<tr>
<td></td>
<td>• Have students break out of groups and answer the final four questions of the problem set individually</td>
</tr>
<tr>
<td>25:00-35:00</td>
<td>• Individually work on the remainder of the problem set</td>
</tr>
<tr>
<td></td>
<td>• Have students break out of groups and answer the final four questions</td>
</tr>
<tr>
<td></td>
<td>• Work with small groups to answer the three questions</td>
</tr>
<tr>
<td></td>
<td>• Work in groups to answer the three questions</td>
</tr>
<tr>
<td>35:00-45:00</td>
<td>• Individually work on the remainder of the problem set</td>
</tr>
</tbody>
</table>

**Differentiation and planned universal supports:**
Students will be placed in small groups based on learning needs. Students who exhibit the largest struggles with completion of assignments or displaying mastery of concepts will be placed in a small homogenous group. This group can have its learning needs met more directly than being placed in heterogenous groups. These students will also have additional time, if needed to complete their problem set. Students will also be allowed to use the notes they have recording during the lesson and throughout the school year to facilitate the completion of the problem set.

**Type of Student Assessments and what is being assessed:**
- **Informal Assessment:** Students will be assessed on prior knowledge based on the Do Now discussion. Misconceptions about nuclear chemistry concepts will be addressed during the time allotted for the Do-Now and through the work period that follows. (Huelser, 2012).
- **Formal Assessment:** Students will be working on a problem set with their groups for the first six (6) questions. The problem set will introduce fusion and fission concepts while incorporating previous concepts of nuclear decay and atomic structure (Brown et al., 2014).
- **Modifications to the Assessments:** Students will be given a supplemental vocabulary and be allowed to use their notes to facilitate the research. Students who also display greater struggles and take a longer time to complete the problem set will be given additional time to complete the problem set at no penalty. Students who were identified to struggle with concepts will also be graded on the three (3) out of the six
(6) problems that were worked on in the groups and choose two (2) of the last four (4) individual questions at the end of the problem set to be graded on.

**Evaluation Criteria:**
Students will earn up to ten (10) points for their problem set. They earn one (1) point for correctly responding to each question within the problem set. Students who receive modifications to the assessment will be graded out of five (5). One point will be awarded for each correct answer.

**Relevant theories and/or research best practices:**

<table>
<thead>
<tr>
<th>Lesson Time: 45 Minutes</th>
<th>Grade Level: High School</th>
<th>Content Area: Chemistry</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unit of Study: Nuclear Chemistry</td>
<td>Lesson Title: Spiral Review</td>
<td></td>
</tr>
</tbody>
</table>

**Essential Question:**
How can we harness the energy located within the nucleus of an atom?

**Content Standard(s):**

**Next Generation Science Standards:**
- **HS-PS1-1.** Use the periodic table as a model to predict the relative properties of elements based on the patterns of electrons in the outermost energy level of atoms
- **HS-PS1-3.** Plan and conduct an investigation to gather evidence to compare the structure of substances at the bulk scale to infer the strength of electrical forces between particles.
- **HS-PS1-7.** Use mathematical representations to support the claim that atoms, and therefore mass, are conserved during a chemical reaction.
- **HS-PS1-8.** Develop models to illustrate the changes in the composition of the nucleus of the atom and the energy released during the processes of fission, fusion, and radioactive decay.
- **HS-PS2-6.** Communicate scientific and technical information about why the molecular-level structure is important in the functioning of designed materials
- **PS1. C: Nuclear Processes.** Spontaneous radioactive decays follow a characteristic exponential decay law

**Learning Objectives** associated with the content standards:
- **Students will be able to (SWBAT):**
  - SWBAT demonstrate understanding of the properties of matter and basic chemical processes associated with changes in matter
  - SWBAT explain the progression of atomic theory from its beginning to the modern definition
  - SWBAT identify the subatomic particles and their location within the atom
**Instructional Resources and Materials** to engage students in learning:

- Spiral Review sheet

**Lesson Timeline, Instructional Strategies and Learning Tasks** that support diverse student needs:

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<thead>
<tr>
<th>Time</th>
<th>Teacher will…</th>
<th>Students will…</th>
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</thead>
<tbody>
<tr>
<td>0:00-25:00</td>
<td>• Administer the Spiral Review</td>
<td>• Complete the Spiral Review</td>
</tr>
<tr>
<td></td>
<td>• Walk around and monitor student work</td>
<td>• As questions, as needed</td>
</tr>
<tr>
<td></td>
<td>• Answer questions</td>
<td></td>
</tr>
<tr>
<td>25:00-45:00</td>
<td>• Lead review of the Spiral Review providing how to work through each question individually</td>
<td>• Participate in Spiral Review discussion</td>
</tr>
<tr>
<td></td>
<td>• Answer questions and call on students to share</td>
<td>• Ask questions to the teacher and students who share their approaches towards answering questions</td>
</tr>
</tbody>
</table>

**Differentiation and planned universal supports:**

Students will be allowed to use calculators if they wish to. All questions will be multiple choice, and therefore no sentence starters will be necessary. Students who require additional time will be given it.

**Type of Student Assessments and what is being assessed:**

- **Informal Assessment:** Class discussion during the breakdown of the Spiral Review where students are discussing with one another about the questions on the spiral
- **Formal Assessment:** The Spiral Review will provide a metric of student learning from the very beginning of the academic year to the current time
- **Modifications to the Assessments:** Students will be graded on the same scale. Modifications to the assessment will appear in the form of students being given the choice to have problems read to them out loud. Students who wish to work in a separate location where that will occur will be allowed to take advantage of this.

**Evaluation Criteria:**

The Spiral Review will be ten (10) questions all worth one (1) point each. The Spiral Review will be worth a total of ten (10) points.

**Relevant theories and/or research best practices:**


<table>
<thead>
<tr>
<th>Lesson Time: 45 Minutes</th>
<th>Grade Level: High School</th>
<th>Content Area: Chemistry</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unit of Study: Nuclear Chemistry</td>
<td></td>
<td>Lesson Title: Half-Life</td>
</tr>
</tbody>
</table>

**Essential Question:**

How can we harness the energy located within the nucleus of an atom?
Content Standard(s):
Math Standards:
MP.4. Model with mathematics

Next Generation Science Standards:
HS-PS1-8 Develop models to illustrate the changes in the composition of the nucleus of the atom and the energy released during the processes of fission, fusion, and radioactive decay.
HS-PS2-6 Communicate scientific and technical information about why the molecular-level structure is important in the functioning of designed materials

PS1. C: Nuclear Processes. Spontaneous radioactive decays follow a characteristic exponential decay law

Learning Objectives associated with the content standards:
Students will be able to (SWBAT):
SWBAT define half-life
SWBAT calculate half-life

Instructional Resources and Materials to engage students in learning: PowerPoint, laptop, calculator, Promethean ActivBoard, problem set, NYS regents physical sciences reference table

Lesson Timeline, Instructional Strategies and Learning Tasks that support diverse student needs:

<table>
<thead>
<tr>
<th>Time</th>
<th>Teacher will…</th>
<th>Students will…</th>
</tr>
</thead>
<tbody>
<tr>
<td>0:00-5:00</td>
<td>• Present the Do Now question asking students to spend half of a bank account for 7 days straight and to determine how much money is left after the 7th day of spending • Call on students to share work on the board</td>
<td>• Work with a partner to calculate how much money is left in a bank account after spending half of it for 7 straight days. • Share work on board</td>
</tr>
<tr>
<td>5:00-20:00</td>
<td>• Present a mini-lesson on half-life and deriving the formula for calculating half life (Usta &amp; Ayas, 2010) • Ask students to help derive the formula for half-life while guiding them to the formula</td>
<td>• Take notes and ask questions during the mini-lesson • Discuss the importance of half-lives and how that influences their usage</td>
</tr>
<tr>
<td>20:00-40:00</td>
<td>• Distribute problem set for half-life and create student groups • Facilitate student work during this period • Ensure that students have the necessary tools to succeed during the problem set</td>
<td>• Get into designated student groups for the problem set • Work on the set with their group • Reference notes, the NYS physical science reference table and utilize a calculator</td>
</tr>
<tr>
<td>40:00-45:00</td>
<td>• Review problems and provide answers</td>
<td>• Check work and hand in problem set</td>
</tr>
</tbody>
</table>
### Differentiation and planned universal supports:
Students will be placed in small groups based on learning needs. Students who exhibit the largest struggles with completion of assignments or displaying mastery of concepts will be placed in a small homogenous group. This group can have its learning needs met more directly than being placed in heterogenous groups. These students will also have additional time, if needed to complete their problem set. Students will also be allowed to use their notes and calculators during the completion of the problem set.

### Type of Student Assessments and what is being assessed:
- **Informal Assessment:** Students will be assessed on prior knowledge based on the Do Now discussion. Misconceptions about nuclear chemistry concepts will be addressed during the time allotted for the Do-Now and through the work period that follows. (Huelser, 2012). Mainly math skills are assessed during this portion of the lesson.
- **Formal Assessment:** Students will be completing half-life problems within a set. There will be ten (10) problems in the set. Students will have access to all resources in the classroom and their notes.
- **Modifications to the Assessments:** Students will be given a supplemental vocabulary and be allowed to use their notes to facilitate the research. Students who also display greater struggles and take a longer time to complete the problem set will be given additional time to complete the problem set at no penalty. These students will also be responsible for completing five (5) problems of their choice to complete.

### Evaluation Criteria:
Students will earn up to ten (10) points for their problem set. They earn one (1) point for correctly responding to each question within the problem set. Students who receive modifications to the assessment will be graded out of five (5). One point will be awarded for each problem that they get correct.

### Relevant theories and/or research best practices:

<table>
<thead>
<tr>
<th>Lesson Time: 45 Minutes</th>
<th>Grade Level: High School</th>
<th>Content Area: Chemistry</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unit of Study: Nuclear Chemistry</td>
<td>Lesson Title: Half-Life of Candium</td>
<td></td>
</tr>
</tbody>
</table>

**Essential Question:**
How can we harness the energy located within the nucleus of an atom?

**Content Standard(s):**
**Math Standards:**
MP.4. Model with mathematics
Next Generation Science Standards:

**HS-PS1-8** Develop models to illustrate the changes in the composition of the nucleus of the atom and the energy released during the processes of fission, fusion, and radioactive decay.

**HS-PS2-6** Communicate scientific and technical information about why the molecular-level structure is important in the functioning of designed materials

**PS1. C: Nuclear Processes.** Spontaneous radioactive decays follow a characteristic exponential decay law

**Learning Objectives** associated with the content standards:

**Students will be able to (SWBAT):**

- SWBAT define half-life
- SWBAT calculate half-life

**Instructional Resources and Materials** to engage students in learning: PowerPoint, laptop, calculator, Promethean ActivBoard, activity packet, NYS regents physical sciences reference table

**Lesson Timeline, Instructional Strategies and Learning Tasks** that support diverse student needs:

<table>
<thead>
<tr>
<th>Time</th>
<th>Teacher will…</th>
<th>Students will…</th>
</tr>
</thead>
</table>
| 0:00- 5:00 | • Present the students with a half-life problem on the board  
|         | • Call on students to share work on the board                                | • Work with a partner to calculate half-life for the problem presented to the class  
|         | • Present the lesson challenge                                               | • Share work on board                                                        |
| 5:00-12:00 | • Go through the materials and instructions                                  | • Take notes and ask questions during the mini-lesson                        |
|         | • Designate student groups                                                   | • Discuss the importance of half-lives and how that influences their usage (Usta & Ayas, 2010) |
|         | • Distribute materials                                                       | • Follow the instructions in the activity guide                              |
|        |                                                                             | • Work collaboratively (Brown et al., 2014)                                   |
| 12:00- | • Facilitate student group work                                              | • Ensure that a safe lab environment is maintained throughout the lesson     |
| 40:00 | • Answer questions                                                           |                                                                             |
|       | • Guide students back on track, if needed                                    |                                                                             |
|       | • Ensure that a safe lab environment is maintained throughout the lesson     |                                                                             |
|       | • Review problems and answer questions about concepts, if needed             | • Ask questions and submit completed work                                    |

**Differentiation and planned universal supports:**

Students will be placed in small groups based on learning needs. Students who exhibit the largest struggles with completion of assignments or displaying mastery of concepts will be placed in a small homogenous group. This group can have its learning needs met more directly than being placed in heterogenous groups. These students will also have additional time, if needed to complete their problem set. Students will also be allowed to use their notes and calculators during the completion of the activity.
Type of Student Assessments and what is being assessed:

- **Informal Assessment**: Students will be assessed on prior knowledge based on the Do Now discussion. Misconceptions about nuclear chemistry concepts will be addressed during the time allotted for the Do-Now and through the work period that follows. (Huelser, 2012). Mainly math skills are assessed during this portion of the lesson.

- **Formal Assessment**: Students will be completing the lab packet. There are 10 questions in the packet, one graph, and a data table. Students will answer questions about how they are making connections to concepts that are represented throughout the activity.

- **Modifications to the Assessments**: Students will be given a supplemental vocabulary and be allowed to use their notes to facilitate the research. Students who also display greater struggles and take a longer time to complete the problem set will be given additional time to complete the problem set at no penalty.

### Evaluation Criteria:
Students will earn up to twenty (20) points. One (1) point for each question that is answer correctly, five (5) points for a completed data table, and (5) points for a properly constructed graph.

### Relevant theories and/or research best practices:


### Lesson Time: (2 Days) 45 Minutes

<table>
<thead>
<tr>
<th>Grade Level: High School</th>
<th>Content Area: Chemistry</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unit of Study: Nuclear Chemistry</td>
<td>Lesson Title: Review and Assessment</td>
</tr>
</tbody>
</table>

**Essential Question:**
How can we harness the energy located within the nucleus of an atom?

**Content Standard(s):**

*Math Standards:*
MP.4. Model with mathematics

*Next Generation Science Standards:*

**HS-PS1-8** Develop models to illustrate the changes in the composition of the nucleus of the atom and the energy released during the processes of fission, fusion, and radioactive decay.

**HS-PS2-6** Communicate scientific and technical information about why the molecular-level structure is important in the functioning of designed materials

**PS1. C: Nuclear Processes.** Spontaneous radioactive decays follow a characteristic exponential decay law
Learning Objectives associated with the content standards:

Students will be able to (SWBAT):

SWBAT review all Unit 3 Topics in Nuclear Chemistry
SWBAT demonstrate an understanding of Nuclear Chemistry

Instructional Resources and Materials to engage students in learning: PowerPoint, laptop, calculator, Promethean ActivBoard, review problems, and assessment

Lesson Timeline, Instructional Strategies and Learning Tasks that support diverse student needs:

<table>
<thead>
<tr>
<th>Time</th>
<th>Teacher will…</th>
<th>Students will…</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Day 1</strong></td>
<td>• Distribute the review packet</td>
<td>• Work on review packet with partners</td>
</tr>
<tr>
<td>0:00-30:00</td>
<td>• Present the topics that will be covered on the assessment on the projector</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Walk around the room and facilitate student work</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Review problems from the packet</td>
<td>• Share answers during the review and ask questions</td>
</tr>
<tr>
<td>30:00-45:00</td>
<td>• Monitor student progress throughout the review to ensure that the packet is completed</td>
<td>• Submit packet at the end of class</td>
</tr>
<tr>
<td></td>
<td>• Review student packets to identify individual modifications for the assessment</td>
<td></td>
</tr>
<tr>
<td><strong>Day 2</strong></td>
<td>• Distribute assessment to students and monitor the room answering student questions as necessary</td>
<td>• Take assessment and complete during the allotted time</td>
</tr>
<tr>
<td>0:00-45:00</td>
<td>• Distribute exams</td>
<td>• Students with modifications will be given extra time to complete the exam</td>
</tr>
</tbody>
</table>

Differentiation and planned universal supports:

Students who exhibited struggle with mastery of concepts throughout the unit will be given the exams with sentence starters for written responses. Students will also be given a copy of the NYS Regents Reference Table for Physical Sciences

Type of Student Assessments and what is being assessed:

- **Informal Assessment**: The review packet will serve as the informal assessment. Students will submit this packet and it will serve as an identifier for which students need modifications on the assessment for **Day 2**. The review packet will reactivate the necessary neural networks associated with learning (Huelser, 2012). Misconceptions within this unit were addressed based on commonly observed misconceptions reported by Usta and Ayas (2010). The review packet will be randomized in question organization so that no repetition of concepts will be observed, thus creating stronger long-term connections as supported in the literature for robust learning (Rohrer, 2012)

- **Formal Assessment**: The formal assessment will be comprised of 25 questions. The test will have 25 multiple choice

- **Modifications to the Assessments**: Students who exhibited more struggles during the unit will be given additional time to complete the assessment
**Evaluation Criteria:**
Students will be evaluated on the formal assessment out of 25 points. Each multiple choice question will be worth one (1) point for a total of 25 points.

**Relevant theories and/or research best practices:**

**ACTIVITIES RATIONALE**

<table>
<thead>
<tr>
<th>Title of Activity</th>
<th>Half-Life of Candium</th>
</tr>
</thead>
<tbody>
<tr>
<td>Source</td>
<td>Created by John Posillico and Dr. Carleton Gaupp</td>
</tr>
<tr>
<td>Math Standard</td>
<td>MP.4. Model with mathematics</td>
</tr>
<tr>
<td>NGSS Standard(s)</td>
<td>HS-PS1-8 Develop models to illustrate the changes in the composition of the nucleus of the atom and the energy released during the processes of fission, fusion, and radioactive decay. HS-PS2-6 Communicate scientific and technical information about why the molecular-level structure is important in the functioning of designed materials PS1. C: Nuclear Processes. Spontaneous radioactive decays follow a characteristic exponential decay law</td>
</tr>
<tr>
<td>Supplies</td>
<td>Laptop, powerpoint, calculator, skittles, activity packet, NYS Regents Physical Science Reference Table</td>
</tr>
<tr>
<td>Key Questions</td>
<td>What is Half-Life? How can we observe and calculate half-life?</td>
</tr>
<tr>
<td>Narrative Summary</td>
<td>Half-life is an abstract concept when it comes to conceptualizing it at a molecular/atomic level. Students will have a more tangible experience to supplement their understanding of half-life through this lab experiment. Providing an opportunity for students to see half-life and observe it will create connections to in class discussions and readings (Usta &amp; Ayas, 2010). Students have constantly read about the harms of nuclear energy because of its great potential to cause destruction to the environment. In this lab students will see that half-life is a predictable and constant process.</td>
</tr>
</tbody>
</table>
It will also help them realize that half-life never reaches a true zero point of remaining radioactive isotope, but instead reaches a point where it is negligible and safe to be exposed to without the risk of harm.

### Rationale
This lab is designed to assess student understanding on multiple concepts that were covered previously as well as current concepts being addressed in class. This lab is a tangible experience with half-life that clarifies misconceptions that student may possess prior to the activity (Usta & Ayas, 2010). Students will gain an experience that allows them to visualize that there is no zero-point to radioactivity within a sample, especially those with long half-lives.

### Possible Misconceptions
- Half-life goes to zero
- Radioisotopes all decay at the same rate and with the same decay mode
- All radioisotopes will cause extreme harm with minimal exposure
- Radioisotopes only have harmful uses, and do not serve humans any benefit

### Recommendations

**Pre-Lab:** Ensure that no students have a food allergy to the materials used. If students are allergic to chocolate, then use skittles. If there is a gelatin allergy/religious obstacle, then use pennies. Any object that has *only* two faces to it will be sufficient. Designate small groups for students that differentiates based on ability. Homogenous grouping allows for more individualized education and increases the teacher’s ability to meet individual student needs (Kaanklao & Suwanthanpornkil, 2012).

**During Lab:** Make sure students are maintaining a safe lab environment. Ensure that students are all making the necessary observations and working diligently throughout the period. Make sure nobody eats any materials.

**Post Lab:** Dispose of any items that could be considered food. Do not allow students to eat the materials when they are done because multiple people will be touching the candies.

### ASSESSMENTS

**Assessment 1: Tweet**

Instructions: Using the resources given to you, research one way that nuclear gets used in modern times? Create a tweet with a #hashtag to describe how nuclear gets used. (ex: Fluorine gets my brain activity with #PET #Neurology #FluorineAndI)
Assessment 2: Modes of Decay

**Alpha Decay**

1. $^{210}_{84}\text{Po} \rightarrow \underline{\quad} + \underline{\quad}$

2. $^{238}_{92}\text{U} \rightarrow \underline{\quad} + \underline{\quad}$

3. $^{238}_{90}\text{Th} \rightarrow \underline{\quad} + \underline{\quad}$

4. $^{222}_{86}\text{Rn} \rightarrow \underline{\quad} + \underline{\quad}$

**Beta Decay**

5. $^{14}_{6}\text{C} \rightarrow \underline{\quad} + \underline{\quad}$

6. $^{90}_{38}\text{Sr} \rightarrow \underline{\quad} + \underline{\quad}$

7. $^{40}_{19}\text{K} \rightarrow \underline{\quad} + \underline{\quad}$

8. $^{13}_{7}\text{N} \rightarrow \underline{\quad} + \underline{\quad}$

**Electron Capture**
9. $^{106}_{47}$Ag + __________ $\rightarrow$ __________

10. $^{116}_{50}$Sn + __________ $\rightarrow$ __________

11. $^{190}_{78}$Pt + __________ $\rightarrow$ __________

12. $^{123}_{53}$I + __________ $\rightarrow$ __________

**Positron Emission**

13. $^{116}_{50}$Sn $\rightarrow$ __________ + __________

14. $^{64}_{29}$Cu $\rightarrow$ __________ + __________

15. $^{30}_{16}$S $\rightarrow$ __________ + __________

16. $^{85}_{38}$Sr $\rightarrow$ __________ + __________

**Answer Key**

1. $^4_2$He + $^{206}_{82}$Pb

2. $^4_2$He + $^{234}_{90}$Th

3. $^4_2$He + $^{234}_{88}$Ra

4. $^4_2$He + $^{218}_{84}$Po

5. $^0_{-1}$e + $^{14}_7$N
6. $^0_1e + {}^{90}_{39}Y$

7. $^0_1e + {}^{40}_{20}Ca$

8. $^0_1e + {}^{13}_{8}O$

9. $^0_1e \rightarrow {}^{106}_{46}Pd$

10. $^0_1e \rightarrow {}^{116}_{51}Sn$

11. $^0_1e \rightarrow {}^{190}_{78}Pt$

12. $^0_1e \rightarrow {}^{123}_{54}Xe$

13. $^0_1e + {}^{116}_{49}In$

14. $^0_1e + {}^{61}_{28}Ni$

15. $^0_1e + {}^{30}_{15}P$

16. $^0_1e + {}^{85}_{37}Rb$

Assessment 3: Spiral 1

1. Convert 43,800 g to kg, using proper scientific notation
   e. $43.8 \times 10^3$ kg
   f. $4.4 \times 10^3$ kg
   g. $4.38 \times 10^4$ kg
   h. $4.38 \times 10^4$ kg
2. Which of the following is an alpha particle?
   a. He
   b. $^0_2\text{He}$
   c. $^0_1\text{He}$
   d. $^4_2\text{He}$

3. Which of the following is a beta particle?
   a. $^0_{-1}\text{e}$
   b. $^0_1\text{He}$
   c. $^4_2\text{e}$
   d. $^0_1\text{e}$

4. Which scientist created the Planetary Model?
   a. Neils Bohr
   b. Albert Einstein
   c. Ernest Rutherford
   d. Carl Sagan

5. What is the definition for a radioisotope?
   a. A radioactive ion
   b. A nucleus that emits only alpha particles
   c. A radioactive isotope because an atom is unstable
   d. Higg’s Boson

6. How many protons are in an atom of Sulfur?
   a. 16
   b. 32
   c. 6
   d. 17

7. What is the current atomic model?
   a. The Bohr Model
   b. The Plum Pudding Model
   c. The Electron Cloud Model
   d. The Billiard Ball Model

8. A compound is a
   a. Homogenous Mixture
   b. Heterogenous Mixture
   c. Pure Substance
   d. Element

9. The mass number and charge of a positron is:
10. Convert 23.8 L to mL, using proper scientific notation
   a. $2.38 \times 10^3$ mL
   b. $2.4 \times 10^3$ mL
   c. $2.38 \times 10^3$ mL
   d. $2.38 \times 10^4$ mL

**Answer Key**

1. D  
2. D  
3. A  
4. A  
5. C  
6. A  
7. C  
8. C  
9. C  
10. D

**Assessment 4: Modes of Decay Gizmo**

**Vocabulary**: alpha particle, atomic number, beta particle, daughter product, gamma ray, isotope, mass number, nuclear decay, positron, radioactive, subatomic particle

**Prior Knowledge Questions** (Do these BEFORE using the Gizmo.)

The chart below gives the locations, charges, and approximate masses of three subatomic particles. The approximate mass of each particle is given in universal mass units (u).

<table>
<thead>
<tr>
<th>Particle</th>
<th>Location</th>
<th>Charge</th>
<th>Approximate mass</th>
</tr>
</thead>
<tbody>
<tr>
<td>Proton</td>
<td>Nucleus</td>
<td>1+</td>
<td>1 u</td>
</tr>
<tr>
<td>Neutron</td>
<td>Nucleus</td>
<td>0</td>
<td>1 u</td>
</tr>
<tr>
<td>Electron</td>
<td>Orbitals</td>
<td>1-</td>
<td>0 u</td>
</tr>
</tbody>
</table>

1. The mass number of an atom is equal to the sum of protons and neutrons in the nucleus.

   A helium atom has 2 protons and 2 neutrons. What is the mass number of this atom? _____
2. The **atomic number** of an element is equal to the number of protons in each atom of the element. All helium atoms have 2 protons. What is the atomic number of helium? _____

**Gizmo Warm-up**

While most atoms are stable, some are **radioactive**, which means that they have a tendency to undergo spontaneous **nuclear decay**. The decay of radioactive atoms generally results in the emission of particles and/or energy.

Several types of nuclear decay can be explored with the *Nuclear Decay Gizmo™*. On the Gizmo, check that **Alpha decay** and **Uranium** are selected.

1. Click **Play** (▶), and then click **Pause** (■) when the **alpha particle** is clearly visible. What is an alpha particle made of? _____________________________________________

2. Click **Play** and observe. Besides the alpha particle, what else is emitted from the nucleus during alpha decay? ________________________________________________________

**Gamma rays** are energetic electromagnetic waves; they are often emitted in nuclear decay.

<table>
<thead>
<tr>
<th>Activity A:</th>
<th>Get the Gizmo ready:</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Alpha decay</strong></td>
<td>• Click <strong>Reset</strong> (🔍).</td>
</tr>
<tr>
<td></td>
<td>• Check that <strong>Alpha decay</strong> and <strong>Uranium</strong> are selected.</td>
</tr>
</tbody>
</table>

**Question:** How does alpha decay change the nucleus of a radioactive atom?

1. **Predict:** As you observed in the warm-up activity, an alpha particle consists of two protons and two neutrons. How will the emission of an alpha particle affect the following?

   A. The atomic number of the atom: _________________________________________________

   B. The mass number of the atom: _________________________________________________
2. **Calculate:** Turn on **Write equation.** What you see is an equation that shows the original uranium atom on the left. The boxes on the right represent the daughter product—the atom produced by radioactive decay—and the emitted alpha particle.

   A. In the top left box, write the mass number of the daughter product and press
   “Enter” on your keyboard. What is this number? ______________

   B. In the bottom left box, write the atomic number of the daughter product and press
   “Enter.” What is this number? ______________

   C. In the next set of boxes, enter the mass number and atomic number of the alpha particle, which has the same composition as the nucleus of a helium (He) atom. After filling in the boxes in the Gizmo, write the completed equation below:

   
   ![Equation Diagram]

   D. According to your equation, what **isotope** remains after the alpha decay of uranium-238? (Note: You can look up element symbols on the periodic table.)

   _____________________________________________________________________

3. **Check:** Turn on **Show equation,** and click **Play.** The equation will appear at the end of the animation. Was your prediction correct? ______________ If not, modify your equation above.

   *(Activity A continued on next page)*

   **Activity A (continued from previous page)**

4. **Practice:** Click **Reset,** turn off **Show equation,** and select **Polonium.** Write an equation for the alpha decay of polonium, and then use the Gizmo to check your answer.
5. **Practice**: Click **Reset**, turn off **Show equation**, and select **Radium**. Write an equation for the alpha decay of radium, and then use the Gizmo to check your answer.

\[ _{88}^{226}\text{Ra} \rightarrow _{84}^{212}\text{Po} + _2^4\text{He} \]

What dangerous gas is produced by the decay of radium-226? ________________

6. **Practice**: Americium-241 is a radioactive isotope used in smoke detectors. Write an equation for the alpha decay of Americium-241 below.

\[ _{95}^{241}\text{Am} \rightarrow _{93}^{239}\text{Np} + _2^4\text{He} \]

7. **Analyze**: In each equation, how is the mass number on the left side of the arrow related to the sum of mass numbers on the right side of the arrow? Is this true for atomic numbers?

_________________________________________________________________________

_________________________________________________________________________

8. **Summarize**: In general, how can you determine the mass number of the daughter product after alpha decay has taken place? How can you determine the atomic number?

_________________________________________________________________________

_________________________________________________________________________

9. **Think and discuss**: Helium is the second most abundant element in the universe, but it is rare in Earth’s atmosphere. Most of the helium used to fill balloons and blimps must be extracted from Earth’s crust. How do you think this helium formed?
Activity B: Beta decay

Get the Gizmo ready:
• Click Reset, and turn off Show equation.
• Select Beta decay from the Type of decay menu.
• Check that Carbon is selected.

Question: How does beta decay change the nucleus of a radioactive atom?

1. Observe: Click Play and watch the animation.
   A. What happens to the decaying neutron during beta decay? ____________________
   __________________________________________________________________________
   B. What is emitted from the nucleus during beta decay? _________________________
   C. What is the mass number and charge of the emitted particle?
   Mass number: _______     Charge: _______

2. Predict: During beta decay, a neutron is transformed into a proton and an electron (the beta particle), which is emitted. Gamma rays are often emitted during beta decay as well.
   How will beta decay affect the atomic number and mass number of the atom?
   __________________________________________________________________________

3. Calculate: Turn on Write equation. Fill in the first set of boxes with the mass number and atomic number of the daughter product and the next set of boxes with the mass number and atomic number of the beta particle. (Note: The atomic number of an electron is -1.)

\[
\begin{array}{c}
\text{14} \\
\text{6}
\end{array}
\text{C} \rightarrow \boxed{\text{___}} + \boxed{\text{___}}
\]
Check your answer by turning on **Show equation** and clicking **Play**. Modify your equation if necessary. What isotope is produced by the beta decay of carbon-14?

__________

4. **Practice:** Turn off **Show equation**. Fill in the equations for the beta decay of iodine-131 and sodium-24 in the spaces below. Use the Gizmo to check your answers.

\[
^{131}_{53} \text{I} \rightarrow \quad + \\
^{24}_{11} \text{Na} \rightarrow \quad + 
\]

<table>
<thead>
<tr>
<th>Activity C: Protons into neutrons</th>
<th>Get the Gizmo ready:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>- Click <strong>Reset</strong>, and turn off <strong>Show equation</strong>.</td>
</tr>
<tr>
<td></td>
<td>- Select <strong>Positron emission</strong>.</td>
</tr>
<tr>
<td></td>
<td>- Check that <strong>Carbon</strong> is selected.</td>
</tr>
</tbody>
</table>

**Introduction:** A **positron** is a type of antimatter that is equivalent to an electron. If a positron and an electron meet, they will annihilate one another in a burst of gamma rays.

**Question:** How do positron emission and electron capture change an atom?

1. **Observe:** Click **Play** and watch the animation.
   
   A. What happens to the decaying proton during positron emission? _____________

   B. What is the mass number and charge of the emitted positron? _____________

   Mass number: _______ Charge: _______

2. **Predict:** During positron emission, a proton is transformed into a neutron and a positron, which is emitted. The positron will fly through space until it encounters an electron. How will positron emission affect the atomic number and mass number of the atom?

________________________________________________________________________
3. **Calculate**: Turn on **Write equation**. Fill in the first set of boxes with the mass number and atomic number of the daughter product and the next set of boxes with the mass number and atomic number of the positron. (Note: The atomic number of a positron is 1.)

\[
\begin{array}{c}
\text{C} \\
^6_6 \text{C}
\end{array} \rightarrow \begin{array}{c}
\text{+} \\
\text{+}
\end{array} \begin{array}{c}
\text{+} \\
\text{+}
\end{array}
\]

Check your answer by turning on **Show equation** and clicking **Play**. Modify your equation if necessary. What isotope is produced when carbon-11 emits a positron?

_______________

4. **Practice**: Turn off **Show equation**. Fill in the equations for the positron emission of xenon118 and manganese-50 in the spaces below. Use the Gizmo to check your answers.

\[
\begin{array}{c}
\text{Xe} \\
^118_54 \text{Xe}
\end{array} \rightarrow \begin{array}{c}
\text{+} \\
\text{+}
\end{array} \begin{array}{c}
\text{+} \\
\text{+}
\end{array}
\]

\[
\begin{array}{c}
\text{Mn} \\
^50_25 \text{Mn}
\end{array} \rightarrow \begin{array}{c}
\text{+} \\
\text{+}
\end{array} \begin{array}{c}
\text{+} \\
\text{+}
\end{array}
\]

(Activity C continued on next page)

Activity C (continued from previous page)

5. **Observe**: Click **Reset**. Select **Electron capture**, and make sure **Tungsten** is selected. Click **Play** and watch the animation.

A. What happened to the proton after absorbing an electron? ________________

___________________________________________________________________

B. What is the mass number and charge of the absorbed electron?

Mass number: _______ Charge: _______

6. **Predict**: During electron capture, an electron is absorbed into the nucleus, causing a proton to transform into a neutron. How will electron capture affect the atomic number and mass number of the atom?
7. **Calculate**: Note that in this equation the particle is absorbed, rather than emitted. Fill in the first set of boxes with the mass number and atomic number of the absorbed electron. Fill in the last set of boxes with the mass number and atomic number of the daughter product.

\[
\begin{array}{c}
\text{W} \quad 179 \\
\text{74}
\end{array}
\quad \rightarrow

\begin{array}{c}
\text{[ ]} \\
\text{[ ]}
\end{array}
\]

Turn on **Show equation** and click **Play** to check. Modify your equation if necessary.

What isotope is produced when tungsten-179 absorbs an electron? ___________________

8. **Practice**: Turn off **Show equation**. Fill in the electron capture equations for gold-195 and neodymium-141 in the spaces below. Use the Gizmo to check your answers.

\[
\begin{array}{c}
\text{Au} \quad 195 \\
\text{79}
\end{array}
\quad \rightarrow

\begin{array}{c}
\text{[ ]} \\
\text{[ ]}
\end{array}
\]

\[
\begin{array}{c}
\text{Nd} \quad 141 \\
\text{60}
\end{array}
\quad \rightarrow

\begin{array}{c}
\text{[ ]} \\
\text{[ ]}
\end{array}
\]

**Answer Key**

1. 4
2. 2
3. 2 protons and 2 neutrons
4. Gamma radiation
5. Decreases by 2; Decreases by 4
6. 234; 90; Th; thorium-234
7. Yes
8. Lead-208
9. Radon-222
10. Alpha particle and Neptunium-237
11. The sum of the masses on both sides of the arrow equal one another. This is true for the atomic number as well.
12. You can determine the mass and atomic numbers by subtracting the mass and atomic number of the alpha particle from the radioisotope.
13. Answers will vary
14. The neutron turns into a proton; Gamma radiation and a beta particle; 0 & -1
15. The atomic number will increase by one
16. Nitrogen-14
17. Xe-131; Mg-24
18. It emits a positron and becomes a neutron; 0 & 1
19. The daughter atom will decrease in atomic number by 1
20. Boron-11
21. Iodine-118; Chromium-50
22. It becomes a neutron; 0 & -1
23. It will decrease the atomic number by 1
24. Tantalum-179
25. Platinum-195; Praseodymium-141

Assessment 5: Warning Posters

Example:

WARNING
Radioisotope Uranium-238 must be handled with care!
This radioisotope has a half-life that lasts over 10,000 years! In case of an accident
please contact emergency, services and evacuate a civilians within a 10 mile radius
of the epicenter

This is not a matter to be taken lightly!

Assessment 6: Fusion and Fission Problem Set

Model 1: Fission
The process of fission occurs when a nucleus splits into smaller pieces. Fission can be induced
by a nucleus capturing slow moving neutrons, which results in the nucleus becoming very
unstable.

The following equations represent fission reactions, where n = neutron.
What is fission?

2. The fission equations show the production of many different elements, even though each reaction begins with uranium-235 and one neutron. How is this possible given the conservation laws for nuclear reactions?

3. What quantities are conserved in this nuclear transmutation?

Model 2: Fusion
Fusion occurs when two nuclei join together to form a larger nucleus. Fusion is brought about by bringing together two or more small nuclei under conditions of tremendous pressure and heat.

The following equations represent fusion reactions, where p = proton.

\[ {^2}_1H + {^2}_1H \rightarrow {^3}_1H + {^1}_1p \]
\[ {^3}_2He + {^3}_2He \rightarrow {^4}_2He + 2{^1}_1H \]
\[ {^2}_1H + {^3}_1H \rightarrow {^4}_2He + {^1}_0n \]

Questions:

1. What is fusion?

2. The fusion equations show the production of atoms of several different elements, even though each reaction begins with isotopes of hydrogen. Knowing the starting elements, can one predict what element will form as a result of a given reaction? Explain why or why not.

3. What is conserved in this nuclear transmutation?

Exercises:

1. An equation in the models shows the fusion of two deuterium nuclei to form a nucleus of tritium (hydrogen-3). Suggest another product that might form in this reaction.
2. Find the identity of the species $X$ in the equation.

$$^{235}\text{U} + ^1\text{n} \rightarrow ^{152}\text{Nd} + X + 3^1\text{n}.$$  

**Reactants:** mass # = 236  
**Products:** mass # = 155  
atomic # (charge) = 92  
atomic # (charge) = 60  
∴ 92 – 60 = 32

3. An atom of U-235 absorbs a neutron and produces an atom of Sb-125 and four neutrons. Identify the other nuclide formed in this reaction.

$$^{235}\text{U} + ^1\text{n} \rightarrow ^{125}\text{Sb} + 4^1\text{n} +$$

4. Identify the following equations as fission or fusion.

<table>
<thead>
<tr>
<th>Fission or Fusion?</th>
</tr>
</thead>
<tbody>
<tr>
<td>$^2\text{H} + ^2\text{H} \rightarrow ^3\text{H} + ^1\text{p}$</td>
</tr>
<tr>
<td>$^{235}\text{U} + ^1\text{n} \rightarrow ^{141}\text{Ba} + ^{92}\text{Kr} + 3^1\text{n}$</td>
</tr>
<tr>
<td>$^{235}\text{U} + ^1\text{n} \rightarrow ^{138}\text{Xe} + ^{95}\text{Kr} + 3^1\text{n}$</td>
</tr>
<tr>
<td>$^3\text{He} + ^3\text{He} \rightarrow ^4\text{He} + 2^1\text{H}$</td>
</tr>
</tbody>
</table>

**Answer Key**

1. Fission is the process by which an atoms’ nucleus is bombarded by a neutron, causing it to split into smaller atoms.
2. As long as the mass number and the electrical charge are conserved, the uranium atom can break into different atoms.
3. The mass number total and atomic number total (electrical charge) are conserved.
4. Fusion is the process by which 2 smaller nuclei (atoms) join together to form one larger nucleus (atom).
5. Not necessarily, there are many isotopes of Hydrogen that can react to form many different products.
6. The mass number total and atomic number total (electrical charge) are conserved.
7. $^2\text{H} + ^2\text{H} \rightarrow ^3\text{H} + ^1\text{p}$
8. $^{81}\text{Ge}$
9. $^{107}\text{Nb}$
10. Fusion, Fission, Fission, Fusion

Assessment 7: Spiral 2
1. What is the difference between fission and fusion?
   a. Fission and fusion split a nucleus
   b. Fusion combines two nuclei, and fission splits a nucleus
   c. Fusion splits a nucleus, fission combines two nuclei
   d. Fission and Fusion both combine two nuclei

2. Which of the following is an alpha particle?
   a. He
   b. $^4_2$He
   c. $^3_1$He
   d. $^2_2$He

3. Which of the following is the highest energy in radiation?
   a. Gamma radiation
   b. Alpha Decay
   c. Infrared Light
   d. Beta Decay

4. Which scientist performed the gold foil experiment?
   a. Neils Bohr
   b. Albert Einstein
   c. Ernest Rutherford
   d. Carl Sagan

5. A nuclear bomb does what type of reaction?
   a. REDOX
   b. Fission
   c. Fusion
   d. Combustion

6. How many protons are in an atom of Uranium?
   a. 234
   b. 92
   c. 96
   d. 238

7. What is the current atomic model?
   a. The Bohr Model
   b. The Plum Pudding Model
   c. The Electron Cloud Model
   d. The Billiard Ball Model

8. Saltwater is a
   a. Homogenous Mixture
   b. Heterogenous Mixture
c. Pure Substance
d. Element

9. The mass number and charge of a beta particle is:
   a. 4, 2
   b. 1, -1
   c. 0, 1
   d. 0, -1

10. Convert 23.8 L to mL, using proper scientific notation
    a. 23.8 x 10³ mL
    b. 2.4 x 10³ mL
    c. 2.38 x 10³ mL
    d. 2.38 x 10⁴ mL

Answer Key
1. B
2. D
3. A
4. C
5. B
6. B
7. C
8. B
9. C
10. D

Assessment 8: Half-Life Problem Set

Directions: Use the graph below to answer questions 1-9; then answer questions 10-12 on the back.
1. What was the original mass of the Iodine-125?

2. How many grams of iodine remain after 180 days?

3. What is the half-life of Iodine-125?

4. If three half-lives have passed, how many grams of iodine-125 remain unchanged?

5. What percent of iodine has decayed if 5 half-lives have passed?

6. What fraction of iodine-125 remains radioactive after 300 days?

7. How many half-lives must I-125 go through until only 25% of the original sample remains?
8. How much time must elapse if only 1/8 of the original sample is remaining?

9. What happens to the half-life of I-125 as it decays?

10. In 6.20 hours, a 100-gram sample of Ag-112 decays to 25.0 grams. What is the half-life of Ag-112?

Assessment 9: Half-Life of Candium

**Background:** Many people have heard the term "half-life" and know that it is related to radioactive elements. Half-life is defined as: "The time required for half of any given amount of a radioactive substance (parent atoms) to decay into another substance (daughter atoms)." Radioactive decay is a constant process where the unstable radioactive element breaks down to become a more stable element by releasing radioactive particles and radiation. In this lab, you will use M&Ms to simulate how atoms radioactively decay and how that information can be used to determine half-life and/or the age of a substance.

The process of using the decay of radioactive isotopes to estimate the age of something is called **radioactive dating**. In radioactive dating, different radioisotopes are used to determine the age of a substance; the specific radioisotope used depends on the nature of the substance and its predicted age. For example, because the element carbon is present in anything organic—in other words, anything that is living—the radioisotope C-14 is typically used to determine the age of something that was once living; however, because Carbon-14's half-life is only 5,730 years, it cannot be used to date extremely old fossils like dinosaurs (typically, after a substance undergoes 10 half-lives, its level of radioactivity is too low to detect). Uranium dating, on the other hand, can be used to date the most ancient, non-living substances like rocks, since U-238 is commonly present in rocks and it has a long enough half-life of 4.47 billion years.

In radioactive dating, the age of a substance is calculated by comparing the amount of the original radioactive isotope present in the substance (parent atom) to the amount of the newly formed, more stable isotope present in the substance (daughter atom). By comparing these amounts, we can use the half-life to determine how long the substance must have been decaying, and therefore, determine its age.
Procedure: You will be given a sample of a radioactive element from a rock known as Candium (M&M’s), 50 candies. Radioactive Candium stabilizes into a more stable element Beanium (black beans). Read the procedure before you start the lab.

1. Place the 50 candies in the cup, leave the beans to the side for now. Each M&M represents an atom of unstable Candium. We will assume at the start that all of the atoms are unstable and undecayed.

2. Shake the cup- not too vigorously! Shake the cup for 7.13 seconds (this represents 713 million years passing). This represents time to decay or one half-life.

3. Carefully pour the Candium atoms onto a paper towel.

4. From this point on, Candium atoms that land M side up are undecayed and still radioactive. Atoms that are M side down have decayed and become stable.

5. Remove all the stable Candium atoms—those with the "M" side down. Stable Candium atoms are really a new element: Beanium atoms.

6. Put the unstable Candium atoms back in the cup and replace the stable ones you removed with an equal number of black beans (Beanium). Beanium is the daughter element that the Candium becomes when it decays.

7. The total number of M&M’s and beans in your cup must be the same as the number of M&M’s you started with (50). Atoms are never lost they just decay from the radioactive atoms (M&Ms) to more stable ones (flipped over M&M’s or beans).

8. Repeat steps 2, 3 and 4 until all the candies “decayed” (flipped ‘M’ side down) or 10 shakes of the cup—which ever happens first.

Data Table

<table>
<thead>
<tr>
<th>(# of shakes)</th>
<th>Time elapsed (in millions of years)</th>
<th># of “undecayed” radioactive Candium atoms remaining with the “M” side up. “Parent” atoms.</th>
<th># of Beanium atoms. The stable “daughter” atoms.</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>50</td>
<td>0</td>
</tr>
<tr>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
**Data Analysis**

Please use the grid below to create a double line graph of your data of parent (undecayed) and daughter (decayed) atoms versus the time passed (millions of years).
Answers the following questions in complete sentences:
1. The M&M's represent the ______________________.

2. The black beans represent the ________________________.

3. How much of a radioactive element becomes stable in a half-life?

4. What is the half-life of Candium?

5. If you started with 100 M&M's, would the half-life change? Please explain.

6. Suppose you had 20 radioactive M&M's remaining. Using your graph, determine how many years must have passed.

7. Using your graph, determine how many radioactive M&M's would be left after 2,000 million years had passed. Number of decayed M&M's?

8. Looking at the table of elements used in radioactive dating, circle which element the radioactive M&M's represent.

<table>
<thead>
<tr>
<th>Elements used in radioactive dating</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Radioactive element</strong></td>
</tr>
<tr>
<td>carbon-14</td>
</tr>
<tr>
<td>potassium-40</td>
</tr>
<tr>
<td>rubidium-87</td>
</tr>
<tr>
<td>thorium-232</td>
</tr>
<tr>
<td>uranium-235</td>
</tr>
<tr>
<td>uranium-238</td>
</tr>
</tbody>
</table>

9. Which of the above radioisotopes can be used to determine the age of humanoid fossils? Why?
10. If you have a 100g sample of carbon-14, how many years will it take for all of the original sample to decay? Explain.

Assessment 10: Summative Assessment

1. Which statement best describes gamma radiation?
   1. It has a mass of 1 and a charge of 1.
   2. It has a mass of 0 and a charge of -1.
   3. It has a mass of 0 and a charge of 0.
   4. It has a mass of 4 and a charge of +2.

2. If 3.0 grams of strontium-90 in a rock sample remained in 1989, approximately how many grams of strontium-90 were present in the original rock sample in 1933?
   1. 9.0 g
   2. 6.0 g
   3. 3.0 g
   4. 12. g

3. Which equation represents a spontaneous nuclear decay?
   1. \( C + O_2 \rightarrow CO_2 \)
   2. \( H_2CO_3 \rightarrow CO_2 + H_2O \)
   3. \( \frac{27}{13} Al + \frac{4}{2} He \rightarrow \frac{30}{15} P + \frac{1}{0} n \)
   4. \( \frac{90}{38} Sr \rightarrow \frac{0}{-1} e + \frac{90}{39} Y \)

4. For most atoms with an atomic number less than 20, nuclear stability occurs when the ratio of neutrons to protons is 1:1. Which of the following atoms would be most likely to have an unstable nucleus?
   1. \( \frac{4}{2} He \)
   2. \( \frac{12}{6} C \)
   3. \( \frac{16}{7} N \)
   4. \( \frac{24}{12} Mg \)

5. Which equation represents the radioactive decay of \( \frac{226}{88} Ra \)?
1. \(^{226}\text{Ra} \rightarrow ^{222}\text{Rn} + ^{4}\text{He}\)
2. \(^{226}\text{Ra} \rightarrow ^{226}\text{Ac} + ^{0}\text{e}\)
3. \(^{226}\text{Ra} \rightarrow ^{226}\text{Fr} + ^{0}\text{He}\)
4. \(^{226}\text{Ra} \rightarrow ^{226}\text{Rn} + ^{0}\text{n}\)

6. Which reaction is an example of natural transmutation?

1. \(^{239}\text{Pu} \rightarrow ^{235}\text{U} + ^{4}\text{He}\)
2. \(^{27}\text{Al} + ^{4}\text{He} \rightarrow ^{30}\text{P} + ^{0}\text{n}\)
3. \(^{238}\text{U} + ^{0}\text{n} \rightarrow ^{239}\text{Pu} + ^{2}\text{He}\)
4. \(^{239}\text{Pu} + ^{0}\text{n} \rightarrow ^{147}\text{Ba} + ^{90}\text{Sr} + ^{3}\text{n}\)

7. In a nuclear fusion reaction, the mass of the products is

1. less than the mass of the reactants because some of the mass has been converted to energy
2. less than the mass of the reactants because some of the energy has been converted to mass
3. more than the mass of the reactants because some of the mass has been converted to energy
4. more than the mass of the reactants because some of the energy has been converted to mass

8. Compared to \(^{37}\text{K}\), the isotope \(^{42}\text{K}\) has a

1. shorter half-life and the same decay mode
2. shorter half-life and a different decay mode
3. longer half-life and the same decay mode
4. longer half-life and a different decay mode

9. Types of nuclear reactions include fission, fusion, and

1. single replacement       3. oxidation-reduction
2. neutralization       4. Transmutation

10. What is the mass of an original 5.60-gram sample of iron-53 that remains unchanged after 25.53 minutes?

1. 0.35 g
2. 0.70 g
3. 1.40 g
4. 2.80 g

11. Which conditions are required to form \( ^4_2 \text{He} \) during the fusion reaction in the Sun?

1. high temperature and low pressure
2. high temperature and high pressure
3. low temperature and low pressure
4. low temperature and high pressure

12. Positrons are spontaneously emitted from the nuclei of

1. potassium-37   3. nitrogen-16
2. radium-226      4. thorium-232

13. The amount of energy released from a fission reaction is much greater than the energy released from a chemical reaction because in a fission reaction

1. mass is converted into energy
2. energy is converted into mass
3. ionic bonds are broken
4. covalent bonds are broken

14. Fission and fusion reactions both release energy. However, only fusion reactions

1. require elements with large atomic numbers
2. create radioactive products
3. use radioactive reactants
4. combine light nuclei

15. Which nuclear emission has the greatest mass?

1. α   3. β−
2. γ   4. β+

16. Which equation represents a transmutation reaction?
Radioisotopes used for medical diagnosis must have

1. long half-lives and be quickly eliminated by the body
2. long half-lives and be slowly eliminated by the body
3. short half-lives and be quickly eliminated by the body
4. short half-lives and be slowly eliminated by the body

Bombarding a nucleus with high-energy particles that change it from one element into another is called

1. a half-reaction
2. a breeder reaction
3. artificial transmutation
4. natural transmutation

Which type of reaction converts one element to another element?

1. neutralization  3. substitution
2. polymerization  4. transmutation

The graph represents the decay of a radioactive isotope.

Based on Reference Table N, which radioactive isotope is best represented by the graph?

1. 32P
2. 131I
3. 198Au
4. 222Rn

The half-life of a radioactive isotope is 20.0 minutes. What is the total amount of a 1.00-gram sample of this isotope remaining after 1.00 hour?

1.0.500g
2. 0.333 g
3. 0.250 g
4. 0.125 g

22. Which of these types of radiation has the greatest penetrating power?
   1. alpha            3. gamma
   2. beta             4. positron

23. The decay of which radioisotope can be used to estimate the age of the fossilized remains of an insect?
   1. Rn-222    3. Co-60
   2. I-131     4. C-14

24. Which notation of a radioisotope is correctly paired with the notation of its emission particle?
   1. $^{37}\text{Ca}$ and $\frac{4}{2}\text{He}$
   2. $^{235}\text{U}$ and $\frac{0}{1}\text{e}$
   3. $^{16}\text{N}$ and $\frac{1}{1}\text{P}$
   4. $^{3}\text{H}$ and $\frac{-1}{1}\text{e}$

25. After 30 days, 5.0 grams of a radioactive isotope remains from an original 40.0-gram sample. What is the half-life of this element?
   1. 5 days    3. 15 days
   2. 10 days   4. 20 days

**Answer Key**
1. 3
2. 1
3. 4
4. 3
5. 1
6. 1
7. 4
8. 2
9. 4
10. 3
11. 2
12. 1
UNIT 4: PERIODIC TABLE

LESSON PLANS

<table>
<thead>
<tr>
<th>Lesson Time: 45 Minutes</th>
<th>Grade Level: High School</th>
<th>Content Area: Chemistry</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unit of Study: Periodic Table Trends</td>
<td>Lesson Title: Organization Activity</td>
<td></td>
</tr>
</tbody>
</table>

**Essential Question:**
Why is the periodic table structured the way it is?

**Content Standard(s):**

*Next Generation Science Standards:*

- **HS-PS1-1.** Use the periodic table as a model to predict the relative properties of elements based on the patterns of electrons in the outermost energy level of atoms
- **PS1.A.** The periodic table orders elements horizontally by the number of protons in the atom’s nucleus and places those with similar chemical properties in columns. The repeating patterns of this table reflect patterns of outer electron states

**Learning Objectives** associated with the content standards:

**Students will be able to (SWBAT):**

- SWBAT demonstrate understanding of the foundation of how the periodic table was organized

**Instructional Resources and Materials** to engage students in learning:

- ActivBoard, activity packet, scissors, glue, construction paper
### Lesson Timeline, Instructional Strategies and Learning Tasks

**That support diverse student needs:**

<table>
<thead>
<tr>
<th>Time</th>
<th>Teacher will…</th>
<th>Students will…</th>
</tr>
</thead>
<tbody>
<tr>
<td>0:00-3:00</td>
<td>• Present a picture of an organized closet &lt;br&gt; • Ask students how the closet is organized &lt;br&gt; • Facilitate a Turn and Talk (Brown et al., 2014)</td>
<td>• Turn and talk with partner about the closet and how it is organized &lt;br&gt; • Share answers out loud</td>
</tr>
<tr>
<td>3:00-35:00</td>
<td>• Present the activity and the task &lt;br&gt; • Place students into designated groups &lt;br&gt; • Hand out extra materials as needed</td>
<td>• Get into groups that they are assigned to &lt;br&gt; • Complete the task and compile all necessary information</td>
</tr>
<tr>
<td>35:00-40:00</td>
<td>• Review how the students organized materials should look &lt;br&gt; • Provide each student with an exemplar to compare their work to &lt;br&gt; • Answer student questions</td>
<td>• Compare their copy to the exemplar and highlight any errors that they made during the learning task &lt;br&gt; • Ask questions, if needed</td>
</tr>
<tr>
<td>40:00-45:00</td>
<td>• Explain how this applies to the foundation of the structure of the periodic table of elements &lt;br&gt; • Ensure that they are made aware of the fact that they will be going through this more thoroughly over the entire unit</td>
<td>• Participate in a class discussion about the structure of the periodic table &lt;br&gt; • Ask questions, if needed</td>
</tr>
</tbody>
</table>

### Differentiation and planned universal supports:

Students will be placed in homogenous groups. Homogenous grouping allows students needs to be met more efficiently and directly because they have the same misconceptions (Huelser, 2012). This type of differentiation is effective in meeting diverse needs of larger groups of students.

### Type of Student Assessments and what is being assessed:

- **Informal Assessment:** Class discussion during the Do Now. See if students are able to recognize patterns, and to what extent they are able to do it.
- **Formal Assessment:** Students will submit their work to see if they are able to recognize patterns more effectively at the end of the lesson. If they cannot, the patterns will be more explicitly taught throughout the unit, thus revisiting this concept (Brown et al., 2014).
- **Modifications to the Assessments:** Students will be graded on the same scale. Modifications to the assessment will be allowing more time for students to work on the assignment. They will be allowed to work on this with another para-professional, if they are permitted to have contact with one
Evaluation Criteria:
Students will be graded on a scale of one (1) to five (5). One (1) point awarded if they complete a row/period correctly. There are 5 total rows/periods.

Relevant theories and/or research best practices:

<table>
<thead>
<tr>
<th>Lesson Time: 45 Minutes</th>
<th>Grade Level: High School</th>
<th>Content Area: Chemistry</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unit of Study: Periodic Table Trends</td>
<td>Lesson Title: Metals, Non-Metals, Metalloids</td>
<td></td>
</tr>
</tbody>
</table>

Essential Question:
Why is the periodic table structured the way it is?

Content Standard(s):
Next Generation Science Standards:
HS-PS1-1. Use the periodic table as a model to predict the relative properties of elements based on the patterns of electrons in the outermost energy level of atoms
PS1.A. The periodic table orders elements horizontally by the number of protons in the atom’s nucleus and places those with similar chemical properties in columns. The repeating patterns of this table reflect patterns of outer electron states

Learning Objectives associated with the content standards:
Students will be able to (SWBAT):
SWBAT demonstrate understanding of the foundation of how the periodic table was organized

Instructional Resources and Materials to engage students in learning:
ActivBoard, activity packet, scissors, glue, construction paper

Lesson Timeline, Instructional Strategies and Learning Tasks that support diverse student needs:

<table>
<thead>
<tr>
<th>Time</th>
<th>Teacher will…</th>
<th>Students will…</th>
</tr>
</thead>
<tbody>
<tr>
<td>0:00-5:00</td>
<td>• Compare a sample of aluminum, and a clear balloon filled with helium</td>
<td>• Turn and talk with partner about the two substances and how they are the same and different</td>
</tr>
<tr>
<td></td>
<td>• Have students Turn and Talk about the differences between the two substances (Brown et al., 2014)</td>
<td>• Share answers out loud</td>
</tr>
<tr>
<td>5:00-15:00</td>
<td>• Introduce the three classifications of metals, non-metals, and metalloids</td>
<td>• Take notes on the classifications of elements</td>
</tr>
<tr>
<td></td>
<td>• Discuss what makes them unique based on their properties</td>
<td>• Ask questions</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Color code a periodic table to help visualize the basic structure and</td>
</tr>
</tbody>
</table>
- Have students color code a periodic table so they can see the organization
- Ensure that students are accurately coloring their periodic table

15:00-35:00
- Present students with the challenge of discovering the unknown sample classification
- Place students into homogenous groups
- Facilitate group work
- Get into their homogenous groups for the learning task
- Work together to solve the identity of the substance; metal, non-metal, metalloid
- Ask questions and complete the activity

35:00-45:00
- Review the activity
- Collect student work
- Answer questions
- Review the activity as a whole
- Ask questions and share out reasoning behind their answers

Differentiation and planned universal supports:
Students will be placed in homogenous groups. Homogenous grouping allows students needs to be met more efficiently and directly because they have the same misconceptions (Huelser, 2012). This type of differentiation is effective in meeting diverse needs of larger groups of students.

Type of Student Assessments and what is being assessed:
- **Informal Assessment:** Class discussion during the Do Now. Determine if students need small group differentiation
- **Formal Assessment:** Students will work together to solve five mystery substance classifications. They will have to look through the properties of the substance and compare it to others on the NYS Reference Table for Physical Sciences. If they can correctly identify the element and the classification they have, they will record their reasoning on the sheet.
- **Modifications to the Assessments:** Students will be graded on the same scale. Modifications to the assessment will be allowing more time for students to work on the assignment. They will be allowed to work on this with another para-professional, if they are permitted to have contact with one.

Evaluation Criteria:
Students will be graded on a scale of one (1) to ten (10). One (1) point awarded if they correctly identify the elements classification and another one (1) point is awarded for justifying how they figured it out.
Relevant theories and/or research best practices:


<table>
<thead>
<tr>
<th>Lesson Time: 45 Minutes</th>
<th>Grade Level: High School</th>
<th>Content Area: Chemistry</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unit of Study: Periodic Table Trends</td>
<td>Lesson Title: Spiral Review 1</td>
<td></td>
</tr>
</tbody>
</table>

**Essential Question:** Why is the periodic table structured the way it is?

**Content Standard(s):**

**Math Standards:**

MP.4. Model with mathematics

**Next Generation Science Standards:**

**HS-PS1-1.** Use the periodic table as a model to predict the relative properties of elements based on the patterns of electrons in the outermost energy level of atoms  
**PS1.A.** The periodic table orders elements horizontally by the number of protons in the atom’s nucleus and places those with similar chemical properties in columns. The repeating patterns of this table reflect patterns of outer electron states  
**HS-PS1-3.** Plan and conduct an investigation to gather evidence to compare the structure of substances at the bulk scale to infer the strength of electrical forces between particles.  
**HS-PS1-7.** Use mathematical representations to support the claim that atoms, and therefore mass, are conserved during a chemical reaction.  
**HS-PS1-8.** Develop models to illustrate the changes in the composition of the nucleus of the atom and the energy released during the processes of fission, fusion, and radioactive decay.  
**HS-PS2-6** Communicate scientific and technical information about why the molecular-level structure is important in the functioning of designed materials  
**PS1. C: Nuclear Processes.** Spontaneous radioactive decays follow a characteristic exponential decay law

**Learning Objectives** associated with the content standards:

**Students will be able to (SWBAT):**

SWBAT demonstrate understanding of chemistry concepts from units 1, 2, 3, and 4  
SWBAT demonstrate understanding of mathematical procedures as they apply to chemistry concepts

**Instructional Resources and Materials** to engage students in learning:

Spiral Review sheet
Lesson Timeline, Instructional Strategies and Learning Tasks that support diverse student needs:

<table>
<thead>
<tr>
<th>Time</th>
<th>Teacher will…</th>
<th>Students will…</th>
</tr>
</thead>
<tbody>
<tr>
<td>0:00-25:00</td>
<td>• Administer the Spiral Review</td>
<td>• Complete the Spiral Review</td>
</tr>
<tr>
<td></td>
<td>• Walk around and monitor student work</td>
<td>• As questions, as needed</td>
</tr>
<tr>
<td></td>
<td>• Answer questions</td>
<td></td>
</tr>
<tr>
<td>25:00-45:00</td>
<td>• Lead review of the Spiral Review providing how to work through each question individually</td>
<td>• Participate in Spiral Review discussion</td>
</tr>
<tr>
<td></td>
<td>• Answer questions and call on students to share</td>
<td>• Ask questions to the teacher and students who share their approaches towards answering questions</td>
</tr>
</tbody>
</table>

Differentiation and planned universal supports:
Students will be allowed to use calculators if they wish to. All questions will be multiple choice, and therefore no sentence starters will be necessary. Students who require additional time will be given it.

Type of Student Assessments and what is being assessed:
- **Informal Assessment**: Class discussion during the breakdown of the Spiral Review where students are discussing with one another about the questions on the spiral
- **Formal Assessment**: The Spiral Review will provide a metric of student learning from the very beginning of the academic year to the current time
- **Modifications to the Assessments**: Students will be graded on the same scale. Modifications to the assessment will appear in the form of students being given the choice to have problems read to them out loud. Students who wish to work in a separate location where that can happen will be allowed to take advantage of this.

Evaluation Criteria:
The Spiral Review will be ten (10) questions all worth one (1) point each. The Spiral Review will be worth a total of ten (10) points.

Relevant theories and/or research best practices:
**HS-PS1-1.** Use the periodic table as a model to predict the relative properties of elements based on the patterns of electrons in the outermost energy level of atoms

**PS1.A.** The periodic table orders elements horizontally by the number of protons in the atom’s nucleus and places those with similar chemical properties in columns. The repeating patterns of this table reflect patterns of outer electron states.

**Learning Objectives** associated with the content standards:

**Students will be able to (SWBAT):**

SWBAT demonstrate understanding of the foundation of how the periodic table was organized.

**Instructional Resources and Materials** to engage students in learning:

ActivBoard, activity packet, scissors, glue, construction paper

**Lesson Timeline, Instructional Strategies and Learning Tasks** that support diverse student needs:

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<tr>
<td>0:00-5:00</td>
<td>• Ask students to come up with a class definition for columns and rows (Brown et al., 2014)</td>
<td>• Derive a definition for columns and rows based off of prior knowledge of what they are</td>
</tr>
<tr>
<td>5:00-15:00</td>
<td>• Define periods and groups on the periodic table</td>
<td>• Observe a Lewis structure for 2 Group 17 elements and discuss what is similar between them</td>
</tr>
<tr>
<td></td>
<td>• Draw out Lewis structures for 2 Group 17 elements and have students turn and talk about the similarities</td>
<td>• Create another Lewis Structure for an element in Group 17</td>
</tr>
<tr>
<td></td>
<td>• Direct students to create another Lewis Structure for an element in Group 17</td>
<td>• Discuss what they all have in common</td>
</tr>
<tr>
<td></td>
<td>• Repeat this for Group 15 and 16</td>
<td>• Repeat this for Group 15 and 16</td>
</tr>
<tr>
<td>15:00-30:00</td>
<td>• Place students into predetermined groups for groupwork</td>
<td>• Get into their homogenous groups for the learning task</td>
</tr>
<tr>
<td></td>
<td>• Have students determine the valence electron configuration for the Group XA elements</td>
<td>• Determine the valence electron configuration for the Group XA elements</td>
</tr>
<tr>
<td>35:00-45:00</td>
<td>• Review the activity and highlight the similarities in valence electron configuration is the reason that the elements have similar properties</td>
<td>• Review the activity as a whole</td>
</tr>
<tr>
<td></td>
<td>• Answer questions</td>
<td>• Ask questions and share out reasoning behind their answers</td>
</tr>
</tbody>
</table>

**Differentiation and planned universal supports:**

Students will be placed in homogenous groups. Homogenous grouping allows students needs to be met more efficiently and directly because they have the same misconceptions (Huelser, 2012). This type of differentiation is effective in meeting diverse needs of larger groups of students.
Type of Student Assessments and what is being assessed:

- **Informal Assessment:** Class discussion during the Do Now and the Mini-Lesson. Determine if students need to be placed into small group differentiation to have their needs met more directly.

- **Formal Assessment:** Students will work together to identify the valence electron configuration of the elements of each group in the periodic table. They will have to look through 8 groups on the periodic table (Groups 1, 2, 13, 14, 15, 16, 17, 18) and determine the valence electron configuration for those groups. They will then have to answer questions to identify how many valence electrons a particular element has.

- **Modifications to the Assessments:** Students will be graded on the same scale. Modifications to the assessment will be allowing more time for students to work on the assignment. They will be allowed to work on this with another para-professional, if they are permitted to have contact with one. These students will only have to determine the number of electrons for each group. They will not have to complete the questions where they have to identify how many valence electrons there are for a particular element in one of those groups.

**Evaluation Criteria:**
Students will be graded on a scale of one (1) to ten (10). Five (5) points are awarded if they correctly identify the valence electron configuration for each group on the periodic table. The remaining five (5) points will be if they can identify how many valence electron has for a given element.

**Relevant theories and/or research best practices:**


**Lesson Time:** 45 Minutes  
**Grade Level:** High School  
**Content Area:** Chemistry  
**Unit of Study:** Periodic Table Trends  
**Lesson Title:** Flame Test

**Essential Question:**
Why is the periodic table structured the way it is?

**Content Standard(s):**

*Next Generation Science Standards:*

**HS-PS1-1.** Use the periodic table as a model to predict the relative properties of elements based on the patterns of electrons in the outermost energy level of atoms

**PS1.A.** The periodic table orders elements horizontally by the number of protons in the atom’s nucleus and places those with similar chemical properties in columns. The repeating patterns of this table reflect patterns of outer electron states

**PS3.A.** At the macroscopic scale, energy manifests itself in multiple ways, such as in motion, sound, light, and thermal energy.
Learning Objectives associated with the content standards:

Students will be able to (SWBAT):

SWBAT explain how groups on the periodic table exhibit similar colors due to the color produced during the flame test

SWBAT apply knowledge of commonality of properties within a group to identify an unknown element

Instructional Resources and Materials to engage students in learning:
Popsicle Sticks, Bunsen Burner, Beakers, Sparker, Ionic Metal Solutions, Fire Extinguisher, Fire Blanket, Eye Wash Station, Gloves, Goggles, Erlenmeyer Flasks

Lesson Timeline, Instructional Strategies and Learning Tasks that support diverse student needs:

<table>
<thead>
<tr>
<th>Time</th>
<th>Teacher will...</th>
<th>Students will...</th>
</tr>
</thead>
</table>
| 0:00-5:00 | • Ask students to review the trend in periodic table based off of valence electron configuration  
            • Facilitate discussion                                               | • Turn and talk with partner trend in periodic table based off of valence electron configuration  
                                                                        • Share answers out loud                                               |
| 5:00-15:00 | • Introduce learning task  
            • Place students into predetermined homogenous groups  
            • Set up materials                                                    | • Get into homogenous groups  
                                                                        • Help set up materials, as needed by the teacher |
| 15:00-40:00 | • Conduct the flame test at the front of the room where students can record observations from their desks  
            • Allow groups to come up to the desk and record observations  
            • Make sure lights are off to see flames better                  | • Record their observations for each flame in the flame test  
                                                                        • Ensure that they are recording data in the correct location for each metal.  
                                                                        This will help them determine the identity of the unknown metal solution  
                                                                        • Work with partners to analyze data and answer questions to figure out which metal the unknown is |
| 40:00-45:00 | • Review the activity  
            • Collect student work  
            • Answer questions                                                   | • Review the activity as a whole  
                                                                        • Ask questions and share out reasoning behind their answers |

Differentiation and planned universal supports:

Students will be placed in homogenous groups. Homogenous grouping allows students needs to be met more efficiently and directly because they have the same misconceptions (Huelser, 2012). This type of differentiation is effective in meeting diverse needs of larger groups of students.
### Type of Student Assessments and what is being assessed:

- **Informal Assessment:** Class discussion during the Do Now. Determine if students need small group differentiation
- **Formal Assessment:** Students will work together to solve identify of unknown metal substance. Students will record their observations of the flame test and conference with their group to determine the identity of the unknown metal
- **Modifications to the Assessments:** Students will be graded on the same scale. Modifications to the assessment will be allowing more time for students to work on the assignment. They will be allowed to work on this with another para-professional, if they are permitted to have contact with one.

### Evaluation Criteria:

Students will be graded on a scale of one (1) to ten (10). One (1) point awarded if they correctly identify the unknown element’s classification and one (1) point is awarded for answering each of the four conclusion questions that follow the lab. Five (5) points will be awarded if the data table is thorough and completed.

### Relevant theories and/or research best practices:


---

<table>
<thead>
<tr>
<th>Lesson Time: 45 Minutes</th>
<th>Grade Level: High School</th>
<th>Content Area: Chemistry</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Unit of Study:</strong> Periodic Table Trends</td>
<td><strong>Lesson Title:</strong> POGIL Trends</td>
<td></td>
</tr>
</tbody>
</table>

**Essential Question:**

Why is the periodic table structured the way it is?

**Content Standard(s):**

*Next Generation Science Standards:*

**HS-PS1-1.** Use the periodic table as a model to predict the relative properties of elements based on the patterns of electrons in the outermost energy level of atoms

**PS1.A.** The periodic table orders elements horizontally by the number of protons in the atom’s nucleus and places those with similar chemical properties in columns. The repeating patterns of this table reflect patterns of outer electron states

**Learning Objectives** associated with the content standards:

Students will be able to (SWBAT):

- SWBAT identify trends in properties of elements
- SWBAT explain the organization of the periodic table

**Instructional Resources and Materials** to engage students in learning:

- ActivBoard, activity packet, scissors, glue, construction paper

**Lesson Timeline, Instructional Strategies and Learning Tasks** that support diverse student needs:

<table>
<thead>
<tr>
<th>Time</th>
<th>Teacher will...</th>
<th>Students will...</th>
</tr>
</thead>
</table>

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198
<table>
<thead>
<tr>
<th>Time</th>
<th>Activity</th>
<th>Activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>0:00-5:00</td>
<td>• Have students Turn and Talk about how some elements produce different colors than others and why they believe that occurs (Brown et al., 2014)</td>
<td>• Turn and talk with partner about the Flame Test lab and why they observed what they observed • Share answers out loud</td>
</tr>
<tr>
<td>5:00-10:00</td>
<td>• Introduce the learning task • Determine homogenous groups based on ability • Distribute POGIL packet</td>
<td>• Get into homogenous groups that were determine by the teacher • Ask questions about expectations</td>
</tr>
<tr>
<td>15:00-40:00</td>
<td>• Facilitate group work • Work with small homogenous groups to further differentiation with the instruction • Answer any questions that arise</td>
<td>• Work with group members to finish activity packet on the trends of the periodic table • Ask questions, use notes to reference throughout the activity • Annotate the excerpts within the POGIL</td>
</tr>
<tr>
<td>40:00-45:00</td>
<td>• Review the activity • Collect student work • Answer questions</td>
<td>• Review the activity as a whole • Ask questions and share out reasoning behind their answers</td>
</tr>
</tbody>
</table>

**Differentiation and planned universal supports:**
Students will be placed in homogenous groups. Homogenous grouping allows students needs to be met more efficiently and directly because they have the same misconceptions (Huelser, 2012). This type of differentiation is effective in meeting diverse needs of larger groups of students.

**Type of Student Assessments and what is being assessed:**
- **Informal Assessment:** Class discussion during the Do Now. Determine if students need small group differentiation
- **Formal Assessment:** Students will complete an inquiry activity where they are creating their own learning through groupwork and problem solving (Huelser 2012). Students will work on a POGIL activity to learn more about trends in ionization energy, electronegativity, and atomic radius.
- **Modifications to the Assessments:** Students will be graded on the same scale. Modifications to the assessment will be allowing more time for students to work on the assignment. They will be allowed to work on this with another para-professional, if they are permitted to have contact with one.

**Evaluation Criteria:**
Students will be graded on a scale of one (1) to fourteen (14). One (1) point awarded if they respond to each question correctly. Students who receive modifications to the assessment will be graded on the same scale, just only they will be granted more time to complete the assessment.
Relevant theories and/or research best practices:

<table>
<thead>
<tr>
<th>Lesson Time: (2 Days) 45 Minutes</th>
<th>Grade Level: High School</th>
<th>Content Area: Chemistry</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unit of Study: Nuclear Chemistry</td>
<td>Lesson Title: Review and Assessment</td>
<td></td>
</tr>
</tbody>
</table>

Essential Question:
Why is the periodic table structured the way it is?

Content Standard(s):
*Next Generation Science Standards:*
**HS-PS1-1.** Use the periodic table as a model to predict the relative properties of elements based on the patterns of electrons in the outermost energy level of atoms
**PS1.A.** The periodic table orders elements horizontally by the number of protons in the atom’s nucleus and places those with similar chemical properties in columns. The repeating patterns of this table reflect patterns of outer electron states
**PS3.A.** At the macroscopic scale, energy manifests itself in multiple ways, such as in motion, sound, light, and thermal energy.

Learning Objectives associated with the content standards:
Students will be able to (SWBAT):
SWBAT review all Unit 4 Topics in Periodic Table Trends
SWBAT demonstrate an understanding of Periodic Table Trends

Instructional Resources and Materials to engage students in learning: PowerPoint, laptop, calculator, Promethean ActivBoard, review problems, and assessment

Lesson Timeline, Instructional Strategies and Learning Tasks that support diverse student needs:

<table>
<thead>
<tr>
<th>Time</th>
<th>Teacher will…</th>
<th>Students will…</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Day 1</strong></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
| 0:00-30:00     | • Distribute the review packet  
• Present the topics that will be covered on the assessment on the projector  
• Walk around the room and facilitate student work                                                                                                                                                                          | • Work on review packet with partners                                                                 |
| 30:00-45:00    | • Review problems from the packet  
• Monitor student progress throughout the review to ensure that the packet is completed  
• Review student packets to identify individual modifications for the assessment                                                                                                                                               | • Share answers during the review and ask questions  
• Submit packet at the end of class                                                                                                                                  |
**Day 2**

| 0:00-45:00 | • Distribute assessment to students and monitor the room answering student questions as necessary  
• Distribute exams  
• Take assessment and complete during the allotted time  
• Students with modifications will be given extra time to complete the exam |

**Differentiation and planned universal supports:**
Students who exhibited struggle with mastery of concepts throughout the unit will be given the exams with sentence starters for written responses. Students will also be given a copy of the NYS Regents Reference Table for Physical Sciences.

**Type of Student Assessments and what is being assessed:**
- **Informal Assessment:** The review packet will serve as the informal assessment. Students will submit this packet and it will serve as an identifier for which students need modifications on the assessment for **Day 2**. The review packet will reactivate the necessary neural networks associated with learning (Huelser, 2012). The review packet will be randomized in question organization so that no repetition of concepts will be observed, thus creating stronger long-term connections as supported in the literature for robust learning (Rohrer, 2012).
- **Formal Assessment:** The formal assessment will be comprised of 25 questions. The test will have 25 multiple choice.
- **Modifications to the Assessments:** Students who exhibited more struggles during the unit will be given additional time to complete the unit.

**Evaluation Criteria:**
Students will be evaluated on the formal assessment out of 20 points. Each multiple-choice question will be worth one (1) point for a total of 20 points.

**Relevant theories and/or research best practices:**

**Activity Rationale**

<table>
<thead>
<tr>
<th>Title of Activity</th>
<th>Flame Test</th>
</tr>
</thead>
<tbody>
<tr>
<td>Source</td>
<td>Created by John Posillico, Dr. Carleton Gaupp, and Ethel Khanis</td>
</tr>
</tbody>
</table>
| NGSS Standard(s)  | HS-PS1-1: Use the periodic table as a model to predict the relative properties of elements based on the patterns of electrons in the outermost energy level of atoms  
PS1.A. The periodic table orders elements horizontally by the number of protons in the atom’s nucleus and places those with |
similar chemical properties in columns. The repeating patterns of this table reflect patterns of outer electron states **PS3.A.** At the macroscopic scale, energy manifests itself in multiple ways, such as in motion, sound, light, and thermal energy.

### Supplies
- Popsicle Sticks, Bunsen Burner, Beakers, Sparker, Ionic Metal Solutions, Fire Extinguisher, Fire Blanket, Eye Wash Station, Gloves, Goggles, Erlenmeyer Flasks

### Key Questions
- What are the observable differences between the different ionic metal solutions?
- What is the unknown ionic metal solution?
- Why do we see different colors for different ionic metal solutions?
- How can we predict general trends in the colors of metal ion solutions?

### Narrative Summary
Students love to see brilliant colors produced in person. Seeing fireworks during the summer is always a fun attraction for kids and adults. This lab will address misconceptions associated with the colors that fireworks produce, making real-world phenomena less abstract. Students will be given stock solutions of various metal ion solutions that will all be labeled except one. Students will work with partners and record their data in a lab packet (heterogenous grouping is used relative to students’ academic performance). Students will have to use their data and knowledge about electron configuration of metal ions to conclude what the unknown metal ion solution will be. This activity will address multiple concepts that have been previously addressed through the spiral curriculum and will reappear throughout the remainder of the year.

### Rationale
This lab is designed to assess student understanding on multiple concepts that were covered previously as well as current concepts being addressed in class. This lab helps enlighten electron excitation by making the abstract concepts more explicit and observable through a kinesthetic and visual experience. This activity also helps elaborate why fireworks produce a variety of colors. This is something most students are familiar with, but have misconceptions about. Students will be exposed to an analytical technique that relies upon atomic structure, thus highlighting the relevance of understanding atomic structure beyond chemical reactions.

### Possible Misconceptions
- Electrons stay in the excited state and therefore the energy that is used to excite the compound is what we are seeing during the flame test.
- Fireworks use dyes in their explosive parts to produce different colors.
- Only heat can excite an electron out of the ground state.
The color that is emitted is the same wavelength as the color that is absorbed.
All metals in the same group will emit the same color and have the same wavelength.

Recommendations

**Pre-Lab:** Create large volumes of stock metal ion solutions for each metal ion and the unknown. This will avoid running out of solutions in the instance of spills. Also soak the popsicle sticks overnight so the solution works up into the popsicle stick and will produce a more concentrated colored flame during the flame test.

**During Lab:** Do not allow students to work without the water running at a controlled rate while their Bunsen burner is on. This will help prevent fires from getting out of control because students will be able to drop popsicle sticks into the sink when needed. Also, do not let students hold popsicle sticks without using gloves.

**Post Lab:** Have separate waste beakers for each metal ion solution. Some metals need to be disposed of differently than others and therefore it makes clean up safer and more efficient.

**ASSESSMENTS**

Assessment 1: Alien Periodic Table

Background:

Most physical science and chemistry textbooks report a wealth of numerical data to identify periodic trends in the properties of the elements. Ionization energies, atomic radii, electronegativity, and electron affinities – all are dutifully tabulated and graphed. But what do all the numbers mean?

The Modern Periodic Table is based on Periodic Law. This Law states that, physical and chemical properties of elements are a function of their atomic numbers. By using Periodic Law, we can find a variety of trends in both physical and chemical properties.

Within each group, all the elements in that column will be exactly the same in some way (Key Similarity) AND must also share some feature that changes regularly as you move down the group (Varying Trait). Similarly, within each period, all the elements in the row must be exactly the same as you move across the period (Key Similarity) AND must also share some feature that changes regularly as you move across the row (the Varying Trait ).

Experiment Overview:

In cooperative activity, you will use the 40 cards and construct an Alien Periodic Table. You will arrange the Aliens in some logical pattern so that they form an organized regular block. The resulting table is visually impressive and clearly the meaning of periodic trends.
1. Color each of the Aliens in the alien pictures.
2. Cut out each of the Aliens.
3. Arrange the pictures into eight families or groups.
4. Arrange the families into five periods.
5. Glue the Aliens onto the Alien Periodic Table. They must be glued on in their groups and periods.

Answer Key:
Aliens are arranged based on body shape, number of fingers, number of hairs on their heads.

Assessment 2: Metals, Non-metals, Metalloids
11. The ability of copper to be drawn into a wire refers to which property?
   a. Conductivity
   b. Malleability
   c. Pliability
   d. Ductility
12. Metals that can be hammered into sheets easily are said to be very:
   a. Conductivity
   b. Malleability
   c. Pliability
   d. Ductility
13. Which element is the most metallic?
   a. Oxygen
   b. Sulfur
   c. Carbon
   d. Sodium
14. Helium is classified as which of the following:
   a. Metal
   b. Non-Metal
   c. Metalloid
   d. It fills up balloons
15. Which of the following are non-conductive elements?
   a. Sodium and chlorine
   b. Tungsten and Oxygen
   c. Nitrogen and Argon
   d. Argon and Potassium
16. Ge is an example of which type of classification?
   a. Metal
   b. Non-Metal
   c. Metalloid
   d. Spheroid
17. These types of elements are typically used as semiconductors
   a. Metalloids
   b. Metals
c. Non-metals
d. Gasses

18. These elements are usually not solid at room temperature:
   a. Metals
   b. Non-metals
   c. Metalloids
   d. Solids

19. True or False: Metals are conductive elements, while nonmetals are not

20. True or False: Non-metals are brittle

Answer Key:
1. D
2. B
3. D
4. B
5. C
6. C
7. A
8. B
9. True
10. True

Assessment 3: Spiral 1

1. Which of the following is an alpha particle?
   a. He
   b. \(^{4}\text{He}\)
   c. \(^{1}\text{He}\)
   d. \(^{2}\text{He}\)

2. These types of elements are typically used as semiconductors
   a. Metalloids
   b. Metals
   c. Non-metals
   d. Gasses

3. The ability of copper to be drawn into a wire refers to which property?
   a. Conductivity
   b. Malleability
   c. Pliability
   d. Ductility

4. How many protons are in an atom of Sulfur?
   a. 16
   b. 32
   c. 6
   d. 17

5. Convert 8.23 L to mL, using proper scientific notation
   a. 82.3 x 10^3 mL
   b. 8.2 x 10^3 mL
   c. 8.23 x 10^3 mL
6. A compound is a  
   a. Homogenous Mixture  
   b. Heterogenous Mixture  
   c. Pure Substance  
   d. Element  
7. The mass number and charge of a positron is:  
   a. 4, 2  
   b. -1, -1  
   c. 0, 1  
   d. 1, 1  
8. Which of the following is an element?  
   a. Hg  
   b. $2\text{CH}_4 + 3\text{O}_2 \rightarrow 2\text{CO}_2 + 2\text{H}_2\text{O} + \text{heat}$  
   c. $\text{Mg}_2\text{SO}_4$  
   d. $\text{H}_2\text{SO}_4$  
9. What is the current atomic model?  
   a. The Bohr Model  
   b. The Plum Pudding Model  
   c. The Electron Cloud Model  
   d. The Billiard Ball Model  
10. A nuclear bomb does what type of reaction?  
   a. REDOX  
   b. Fission  
   c. Fusion  
   d. Combustion  

**Answer Key:**  
1. D  
2. A  
3. D  
4. A  
5. C  
6. C  
7. C  
8. A  
9. C  
10. C  

**Assessment 4: Valence Electron and the Periodic Table**  

**Part 1:** The periodic table has a structure that depends on a variety of properties. Some of those properties are determined by atomic structure. Go through the following groups and identify their valence electron configuration: Groups 1, 2, 13, 14, 15, 16, 17, 18.

Group 1:  
Group 2:
Part 2: Determine the valence electrons for each of the following elements

1. Oxygen
2. Nitrogen
3. Potassium
4. Iodine
5. Silicon

Answer Key
Group 1: 1
Group 2: 2
Group 13: 3
Group 14: 4
Group 15: 5
Group 16: 6
Group 17: 7
Group 18: 8

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

Assessment 5: Flame Test

Purpose

To observe the characteristic colors produced by certain metallic ions when vaporized in a flame; and to identify an unknown metallic ion by means of its flame test.

Materials & Equipment

- wooden splints
- spectrometer
- Bunsen burner
- waste beaker with water
- 7 different metals ions in solution
Data: Fill in the data table based on your observations of the metal ion solutions

<table>
<thead>
<tr>
<th>Metal Ion Solution</th>
<th>Metal Ion</th>
<th>Flame Color</th>
</tr>
</thead>
<tbody>
<tr>
<td>KCl</td>
<td>Na⁺</td>
<td></td>
</tr>
<tr>
<td>BaCl₂</td>
<td>Ba²⁺</td>
<td></td>
</tr>
<tr>
<td>CaCl₂</td>
<td>Li⁺</td>
<td></td>
</tr>
<tr>
<td>CuCl₂</td>
<td>Ca²⁺</td>
<td></td>
</tr>
<tr>
<td>Unknown</td>
<td>---</td>
<td>---</td>
</tr>
</tbody>
</table>

1. Based on the flame color, what could the unknown metal ion be?
2. Why did the flame color change with different elements?
3. Why did the electrons gain energy?
4. Define the excited state?
5. Do electrons stay in the excited state?

Answer Key

<table>
<thead>
<tr>
<th>Metal Ion Solution</th>
<th>Metal Ion</th>
<th>Flame Color</th>
</tr>
</thead>
<tbody>
<tr>
<td>NaCl</td>
<td>Na⁺</td>
<td>Yellow</td>
</tr>
<tr>
<td>BaCl₂</td>
<td>Ba²⁺</td>
<td>Green</td>
</tr>
<tr>
<td>CaCl₂</td>
<td>Li⁺</td>
<td>Pink</td>
</tr>
<tr>
<td>CuCl₂</td>
<td>Ca²⁺</td>
<td>Orange</td>
</tr>
<tr>
<td>Unknown</td>
<td>---</td>
<td>Red</td>
</tr>
</tbody>
</table>

1. Strontium Bromide; Sr²⁺
2. Different colored flames were observed because electrons were entering the excited states. Depending on the ion, it takes a particular amount of energy to enter the excited state. When an electron relaxes back to the ground state, it emits a color which is what is being observed.
3. The electrons gained enough energy from the flame test to enter the excited state. If the energy was insufficient, the electrons would not enter the excited state.
4. The excited state is a state in which electrons enter a higher energy state than where they are typically observed. The electrons absorb energy and then when they relax back down to the ground state, they emit a particular color that is directly correlated to the energy they absorbed.
5. Electrons do not remain in the excited state, they release any absorbed energy to enter back into the ground state.

Assessment 6: POGIL Trends

The periodic table is often considered to be the “best friend” of chemists and chemistry students alike. It includes information about atomic masses and element symbols, but it can also be used to make predictions about atomic size, electronegativity, ionization energies, bonding, solubility, and reactivity. In this activity you will look at a few periodic trends that can help you make those predictions. Like most trends, they are not perfect, but useful just the same.

1. Consider the data in Model 1 on the following page.
A. Each element has three numbers listed under it. Which value represents the atomic radius?

B. What are the units for the atomic radius?

C. Write a complete sentence to convey your understanding of atomic radius. Note: You may not use the word “radius” in your definition.

2. In general, what is the trend in atomic radius as you go down a group in Model 1? Support your answer, using examples from three groups.

3. Using your knowledge of Coulombic attraction and the structure of the atom, explain the trend in atomic radius that you identified in Question 2. Hint: You should discuss either a change in distance between the nucleus and outer shell of electrons or a change in the number of protons in the nucleus.

4. In general, what is the trend in atomic radius as you go across a period (left to right) in Model 1? Support your answer, using examples from two periods.

5. Using your knowledge of Coulombic attraction and the structure of the atom, explain the trend in atomic radius that you identified in Question 4.

6. The ionization energy is the amount of energy needed to remove an electron from an atom.
   1. Using your knowledge of Coulombic attraction, explain why ionization—removing an electron from an atom—takes energy.
   2. Which takes more energy, removing an electron from an atom where the nucleus has a tight hold on its electrons, or a weak hold on its electrons? Explain.

7. In general, what is the trend in ionization energy as you go down a group? Support your answer using examples from three groups.

8. Using your knowledge of Coulombic attraction and the structure of the atom, explain the trend in ionization energy that you identified in Question 7.

9. In general, what is the trend in ionization energy as you go across a period? Support your answer using examples from two periods.

10. Using your knowledge of Coulombic attraction and the structure of the atom, explain the trend in ionization energy that you identified in Question 9.

11. Atoms with loosely held electrons are usually classified as metals. They will exhibit high conductivity, ductility, and malleability because of their atomic structure. Would you expect metals to have high ionization energies or low ionization energies? Explain your answer in one to two complete sentences.

Read This!

Electronegativity is a measure of the ability of an atom’s nucleus to attract electrons from a different atom within a covalent bond. A higher electronegativity value correlates to a stronger pull on the electrons in a bond. This value is only theoretical. It cannot be directly measured in the lab.

12. Using the definition stated in the Read This! box above, select the best visual representation for electronegativity. Explain your reasoning.
13. Locate the electronegativity values in Model 1.

   A. What is the trend in electronegativity going down a group in Model 1?
   B. Explain the existence of the trend described in part a in terms of atomic structure and Coulombic attraction.
   C. What is the trend in electronegativity going across a period in Model 1?
   D. Explain the existence of the trend described in part c in terms of atomic structure and a. Coulombic attraction.

14. The two diagrams below can summarize each of the three trends discussed in this activity. Write “atomic radius,” “ionization energy,” and “electronegativity” under the appropriate diagram.

Answer Key:
1. A. the third number. B. picometers. C. The atomic radius refers to how large the atom is.
2. Atomic radius increases as you go down a group
3. As the number of protons and electrons increase across a period, so does the Columbic attraction, thus a smaller atomic radius across a period
4. Going across a period, the atomic radius gets smaller
5. As the number of protons and electrons increase across a period, so does the Columbic attraction, thus a smaller atomic radius across a period
6. A. Removing an electron requires energy because you are going against the Columbic Attraction of that electron with the nucleus. B. The tighter the hold on an electron by the nucleus, the more energy required to remove it.
7. Ionization energy decreases as you go down a group.
8. The ionization energy decreases as you go down a group because Columbic Attraction decreases
9. Ionization energy increases as you go across a group.
10. Ionization energy increases as you go across a group because the columbic Attraction increases
11. Metals that lose electrons will have low ionization energies because there is a weak Columbic Attraction
12. B
13. A. Going down a group, electronegativity decreases. B. As atomic radius increases, electronegativity decreases. C. Electron negativity increases as you go across a group. D. As atomic radius decreases across a group, electronegativity increases.
14. LEFT: Ionization Energy, Electronegativity; RIGHT: Atomic Radius
Assessment 7: Summative Assessment

1. True or False: Metals are not conductive
2. True or False: Non-Metals are malleable
3. True or False: Metalloids exhibit properties of both metals and non-metals
4. True or False: Non-metals are typically solid at room temperature
5. True or False: Metals tend to lose electrons more easily than non-metals
6. What is the trend in electronegativity?
   A. Electronegativity increases as you move right to left across a period
   B. Electronegativity decreases as you move right to left across a period
   C. Electronegativity increases as you move up and down across a period
   D. Electronegativity decreases as you move up a group
7. What is the trend in ionization energy?
   A. Ionization energy decreases as you move right to left across a period
   B. Ionization energy increases as you move right to left across a period
   C. Ionization energy increases as you move up and down across a period
   D. Ionization energy decreases as you move up a group
8. The ability of copper to be drawn into a wire refers to which property?
   A. Conductivity
   B. Malleability
   C. Pliability
   D. Ductility
9. Which of the following are non-conductive elements?
   A. Sodium and chlorine
   B. Tungsten and Oxygen
   C. Nitrogen and Argon
   D. Argon and Potassium
10. What is the definition for the excited state?
    A. A state in which electrons enter a higher energy state than where they are typically observed.
    B. A state where electrons are relaxed
    C. A state where electrons exist forever
    D. A state that has a lot of electrons that float around and do a lot of things
11. Why are colors observed during the Flame Test?
    A. Because protons are attracting more electrons
    B. Electrons are being placed into the super state
    C. Electrons are relaxing back down from the excited state
    D. Neutrons are being emitted
12. If atomic radius decreases across a period, what must increase?
    A. Conductivity
    B. Ionization Energy
    C. Atomic Radius
    D. Strength of bonds
13. Which pair of atomic properties increase together?
    A. Ionization Energy and Atomic Radius
    B. Atomic Radius and Electronegativity
C. Electronegativity and Ionization Energy
D. Atomic Radius and Atomic number

14. Group 17 elements have how many valence electrons?
   A. 5
   B. 6
   C. 7
   D. 8

15. Group 1 elements have how many valence electrons?
   A. 3
   B. 2
   C. 1
   D. 4

16. Atomic Radius is measured in which unit:
   A. Millimeters
   B. Nanometers
   C. Femtometers
   D. Picometers

17. Which of the following elements is diatomic?
   A. Oxygen
   B. Carbon
   C. Sulfur
   D. Aluminum

18. Which of the following is most influential in the structure of the periodic table?
   A. Protons
   B. Valence Electrons
   C. Neutrons
   D. Electronegativity

19. If metals lose electrons, they form what?
   A. An isotope
   B. A Radioisotope
   C. An Ion
   D. A compound

20. Which of the following most accurately explains Columbic Attraction?
   A. An attraction between a proton and a neutron
   B. An attraction between a proton and another atoms proton
   C. An attraction between a proton and an electron within the same atom
   D. A repulsive force between two protons

Answer Key
1. True
2. False
3. True
4. False
5. True
6. B
7. A
UNIT 5: BONDING

LESSON PLANS

<table>
<thead>
<tr>
<th>Lesson Time: 45 Minutes</th>
<th>Grade Level: High School</th>
<th>Content Area: Chemistry</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unit of Study: Bonding</td>
<td>Lesson Title: Introduction to Bonds</td>
<td></td>
</tr>
</tbody>
</table>

Essential Question:
What is a bond and why are they important?

Content Standard(s):
Next Generation Science Standards:
HS-PS1-1. Use the periodic table as a model to predict the relative properties of elements based on the patterns of electrons in the outermost energy level of atoms
HS-PS1-4. Develop a model to illustrate that the release or absorption of energy from a chemical reaction system depends upon the changes in total bond energy.
PS1.A. The periodic table orders elements horizontally by the number of protons in the atom’s nucleus and places those with similar chemical properties in columns. The repeating patterns of this table reflect patterns of outer electron states

Learning Objectives associated with the content standards:
Students will be able to (SWBAT):
SWBAT define what a bond is and how they generally form

Instructional Resources and Materials to engage students in learning:
ActivBoard, problem set, notes

Lesson Timeline, Instructional Strategies and Learning Tasks that support diverse student needs:

<table>
<thead>
<tr>
<th>Time</th>
<th>Teacher will…</th>
<th>Students will…</th>
</tr>
</thead>
<tbody>
<tr>
<td>0:00-8:00</td>
<td>• Ask students to turn and talk, discussing what makes atoms so reactive.</td>
<td>• Turn and talk with partner about why atoms differ in reactivity and why Lewis Structure follow an octet rule</td>
</tr>
<tr>
<td></td>
<td>• Ask students why Lewis Structures follow an octet rule (Brown et al., 2014)</td>
<td>• Share answers out loud</td>
</tr>
</tbody>
</table>
| 8:00-25:00 | • Prompt the class to derive a definition for a chemical bond  
• Discuss the subatomic particles that influence how bonds are formed  
• Discuss that energy is involved with bond breaking and forming  
• Introduce the different types of bonds | • Derive a definition with the class for bonds  
• Take notes on bond breaking and forming (endo- and exothermic)  
• Discuss, as a class, the different types of bonds (metallic, covalent, and ionic) |
| 20:00-35:00 | • Determine homogenous groups for the problem set  
• Facilitate group work | • Get into their homogenous groups for the learning task  
• Work together to complete the problem set |
| 35:00-45:00 | • Review the activity  
• Collect student work  
• Answer questions | • Review the activity as a whole  
• Ask questions and share out reasoning behind their answers |

**Differentiation and planned universal supports:**

Students will be placed in homogenous groups. Homogenous grouping allows students needs to be met more efficiently and directly because they have the same misconceptions (Huelser, 2012). This type of differentiation is effective in meeting diverse needs of larger groups of students.

**Type of Student Assessments and what is being assessed:**

- **Informal Assessment:** Class discussion during the Do Now. Determine if students need small group differentiation
- **Formal Assessment:** Students will work together to complete the 5 (5) problems in the problem set. This problem set will assess students’ understanding of ionic bonding at a foundational level, as well as assessing their retention of prerequisite knowledge in atomic structure
- **Modifications to the Assessments:** Students who receive modifications to the assessment will be graded on two (2) out of the five (5) questions on the assessment. These students will be given the same resources as the rest of the class. They will have the option to choose two (2) out of the five (5) questions on the assessment.

**Evaluation Criteria:**

Students will be graded on a scale of one (1) to five (5). One (1) point awarded if they correctly respond to each question in the problem set. Students who receive modifications to the assessment will be graded on two (2) out of the five (5) questions on the assessment.

**Relevant theories and/or research best practices:**

Lesson Time: 45 Minutes  
Grade Level: High School  
Content Area: Chemistry

Unit of Study: Bonding  
Lesson Title: Ionic Bonds

Essential Question:
What is a bond and why are they important?

Content Standard(s):
Next Generation Science Standards:
HS-PS1-1. Use the periodic table as a model to predict the relative properties of elements based on the patterns of electrons in the outermost energy level of atoms  
HS-PS1-4. Develop a model to illustrate that the release or absorption of energy from a chemical reaction system depends upon the changes in total bond energy.  
PS1.A. The periodic table orders elements horizontally by the number of protons in the atom’s nucleus and places those with similar chemical properties in columns. The repeating patterns of this table reflect patterns of outer electron states

Learning Objectives associated with the content standards:
Students will be able to (SWBAT):
SWBAT identify ionic bonds  
SWBAT explain why ionic bonds are different from other types of bonds

Instructional Resources and Materials to engage students in learning:
ActivBoard, problem set, notes

Lesson Timeline, Instructional Strategies and Learning Tasks that support diverse student needs:

<table>
<thead>
<tr>
<th>Time</th>
<th>Teacher will…</th>
<th>Students will…</th>
</tr>
</thead>
</table>
| 0:00-8:00  | • Ask students to turn and talk, discussing why they believe salt dissolves in water  
            • Facilitate class discussions (Brown et al., 2014) | • Turn and talk with partner about why salt dissolves in water  
            • Share answers out loud |
| 32:00-40:00 | - Get students back into groups to complete the problem set  
- Provide students the problems where they write the ionic formula for ionic compounds | - Get into their homogenous groups for the learning task  
- Work together to complete the questions involving writing ionic compounds |
| 40:00-45:00 | - Review the activity  
- Collect student work  
- Answer questions | - Review the activity as a whole  
- Ask questions and share out reasoning behind their answers |

**Differentiation and planned universal supports:**
Students will be placed in homogenous groups. Homogenous grouping allows students needs to be met more efficiently and directly because they have the same misconceptions (Huelser, 2012). This type of differentiation is effective in meeting diverse needs of larger groups of students.

**Type of Student Assessments and what is being assessed:**
- **Informal Assessment:** Class discussion during the Do Now. Determine if students need small group differentiation
- **Formal Assessment:** Students will work together to complete the ten (10) problems in the problem set. This problem set will assess students’ understanding of ionic bonding at a foundational level, as well as assessing their retention of prerequisite knowledge in atomic structure
- **Modifications to the Assessments:** Students who receive modifications to the assessment will be graded on five (5) out of the ten (10) questions on the assessment. These students will be given the same resources as the rest of the class. They will have the option to choose five (5) out of the ten (10) questions on the assessment.

**Evaluation Criteria:**
Students will be graded on a scale of one (1) to ten (10). One (1) point awarded if they correctly respond to each question in the problem set. Students who receive modifications to the assessment will be graded on five (5) out of the ten (10) questions on the assessment.

**Relevant theories and/or research best practices:**

<table>
<thead>
<tr>
<th>Lesson Time: 45 Minutes</th>
<th>Grade Level: High School</th>
<th>Content Area: Chemistry</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unit of Study: Bonding</td>
<td>Lesson Title: Covalent Bonds</td>
<td></td>
</tr>
</tbody>
</table>

**Essential Question:**
What is a bond and why are they important?

**Content Standard(s):**
*Next Generation Science Standards:*
HS-PS1-1. Use the periodic table as a model to predict the relative properties of elements based on the patterns of electrons in the outermost energy level of atoms.

HS-PS1-4. Develop a model to illustrate that the release or absorption of energy from a chemical reaction system depends upon the changes in total bond energy.

PS1.A. The periodic table orders elements horizontally by the number of protons in the atom’s nucleus and places those with similar chemical properties in columns. The repeating patterns of this table reflect patterns of outer electron states.

HS-PS2-6. Communicate scientific and technical information about why the molecular-level structure is important in the functioning of designed materials.

Learning Objectives associated with the content standards:

Students will be able to (SWBAT):

- SWBAT identify covalent bonds
- SWBAT explain why colvalent bonds are different from other types of bonds

Instructional Resources and Materials to engage students in learning:

ActivBoard, problem set, notes

Lesson Timeline, Instructional Strategies and Learning Tasks that support diverse student needs:

<table>
<thead>
<tr>
<th>Time</th>
<th>Teacher will…</th>
<th>Students will…</th>
</tr>
</thead>
</table>
| 0:00-8:00 | • Ask students to turn and talk, discussing why they believe oil doesn’t dissolve in water  
• Facilitate class discussions (Brown et al., 2014) | • Turn and talk with partner about why oil doesn’t dissolve in water  
• Share answers out loud |
| 8:00-20:00| • Go through definition of covalent bonds  
• Explain characteristics  
• Provide exemplar of how to represent covalent bonds using Lewis Structures | • Discuss the characteristics of a covalent bonds with a partner and how they differ from ionic bonds  
• Take notes and ask questions |
| 20:00-35:00| • Determine homogenous groups  
• Distribute problem set and facilitate student discussion/groupwork  
• Ensure that students are using their notes to help work through the problem set | • Get into their homogenous groups for the learning task  
• Work together to complete the questions using notes, as needed |
| 35:00-45:00| • Review the activity  
• Collect student work  
• Answer questions | • Review the activity as a whole  
• Ask questions and share out reasoning behind their answers |

Differentiation and planned universal supports:

Students will be placed in homogenous groups. Homogenous grouping allows students needs to be met more efficiently and directly because they have the same misconceptions (Huelser, 2012). This type of differentiation is effective in meeting diverse needs of larger groups of students.
**Type of Student Assessments and what is being assessed:**

- **Informal Assessment:** Class discussion during the Do Now. Determine if students need small group differentiation
- **Formal Assessment:** Students will work together to complete the ten (10) problems in the problem set. This problem set will assess students’ understanding of covalent bonding at a foundational level, as well as assessing their retention of prerequisite knowledge in atomic structure (Brown et al., 2014). This assessment will also have students compare ionic bonds to covalent bonds
- **Modifications to the Assessments:** Students who receive modifications to the assessment will be graded on five (5) out of the ten (10) questions on the assessment. These students will be given the same resources as the rest of the class. They will have the option to choose five (5) out of the ten (10) questions on the assessment.

**Evaluation Criteria:**
Students will be graded on a scale of one (1) to ten (10). One (1) point awarded if they correctly respond to each question in the problem set. Students who receive modifications to the assessment will be graded on five (5) out of the ten (10) questions on the assessment.

**Relevant theories and/or research best practices:**


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<table>
<thead>
<tr>
<th>Lesson Time: 45 Minutes</th>
<th>Grade Level: High School</th>
<th>Content Area: Chemistry</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Unit of Study: Bonding</td>
<td>Lesson Title: Spiral Review 1</td>
</tr>
</tbody>
</table>

**Essential Question:**
What is a bond and why are they important?

**Content Standard(s):**

*Next Generation Science Standards:*

**HS-PS1-1.** Use the periodic table as a model to predict the relative properties of elements based on the patterns of electrons in the outermost energy level of atoms

**PS1.A.** The periodic table orders elements horizontally by the number of protons in the atom’s nucleus and places those with similar chemical properties in columns. The repeating patterns of this table reflect patterns of outer electron states

**HS-PS1-3.** Plan and conduct an investigation to gather evidence to compare the structure of substances at the bulk scale to infer the strength of electrical forces between particles.

**HS-PS1-4.** Develop a model to illustrate that the release or absorption of energy from a chemical reaction system depends upon the changes in total bond energy.

**HS-PS1-7.** Use mathematical representations to support the claim that atoms, and therefore mass, are conserved during a chemical reaction.

**HS-PS1-8.** Develop models to illustrate the changes in the composition of the nucleus of the atom and the energy released during the processes of fission, fusion, and radioactive decay.
HS-PS2-6 Communicate scientific and technical information about why the molecular-level structure is important in the functioning of designed materials

**PS1. C: Nuclear Processes.** Spontaneous radioactive decays follow a characteristic exponential decay law

**Learning Objectives** associated with the content standards:

**Students will be able to (SWBAT):**

- SWBAT demonstrate understanding of chemistry concepts from units 1, 2, 3, and 4
- SWBAT demonstrate understanding of mathematical procedures as they apply to chemistry concepts

**Instructional Resources and Materials** to engage students in learning:

- Spiral Review sheet

**Lesson Timeline, Instructional Strategies and Learning Tasks** that support diverse student needs:

<table>
<thead>
<tr>
<th>Time</th>
<th>Teacher will…</th>
<th>Students will…</th>
</tr>
</thead>
<tbody>
<tr>
<td>0:00-25:00</td>
<td>• Administer the Spiral Review</td>
<td>• Complete the Spiral Review</td>
</tr>
<tr>
<td></td>
<td>• Walk around and monitor student work</td>
<td>• As questions, as needed</td>
</tr>
<tr>
<td></td>
<td>• Answer questions</td>
<td></td>
</tr>
<tr>
<td>25:00-45:00</td>
<td>• Lead review of the Spiral Review providing how to work through each question individually</td>
<td>• Participate in Spiral Review discussion</td>
</tr>
<tr>
<td></td>
<td>• Answer questions and call on students to share</td>
<td>• Ask questions to the teacher and students who share their approaches towards answering questions</td>
</tr>
</tbody>
</table>

**Differentiation and planned universal supports:**

Students will be allowed to use calculators if they wish to. All questions will be multiple choice, and therefore no sentence starters will be necessary. Students who require additional time will be given it.

**Type of Student Assessments and what is being assessed:**

- **Informal Assessment:** Class discussion during the breakdown of the Spiral Review where students are discussing with one another about the questions on the spiral
- **Formal Assessment:** The Spiral Review will provide a metric of student learning from the very beginning of the academic year to the current time
- **Modifications to the Assessments:** Students will be graded on the same scale. Modifications to the assessment will appear in the form of students being given the choice to have problems read to them out loud. Students who wish to work in a separate location where that can happen will be allowed to take advantage of this.

**Evaluation Criteria:**

The Spiral Review will be ten (10) questions all worth one (1) point each. The Spiral Review will be worth a total of ten (10) points.
Relevant theories and/or research best practices:

<table>
<thead>
<tr>
<th>Lesson Time: 45 Minutes</th>
<th>Grade Level: High School</th>
<th>Content Area: Chemistry</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Unit of Study: Bonding</td>
<td>Lesson Title: Polyatomic Ions</td>
</tr>
</tbody>
</table>

**Essential Question:**
What is a bond and why are they important?

**Content Standard(s):**
*Next Generation Science Standards:*

**HS-PS1-1.** Use the periodic table as a model to predict the relative properties of elements based on the patterns of electrons in the outermost energy level of atoms

**HS-PS1-4.** Develop a model to illustrate that the release or absorption of energy from a chemical reaction system depends upon the changes in total bond energy.

**PS1.A.** The periodic table orders elements horizontally by the number of protons in the atom’s nucleus and places those with similar chemical properties in columns. The repeating patterns of this table reflect patterns of outer electron states

**Learning Objectives** associated with the content standards:
**Students will be able to (SWBAT):**
- **SWBAT** identify metallic bonds
- **SWBAT** explain why metallic bonds are different from other types of bonds

**Instructional Resources and Materials** to engage students in learning:
- ActivBoard, problem set, notes

**Lesson Timeline, Instructional Strategies and Learning Tasks** that support diverse student needs:

<table>
<thead>
<tr>
<th>Time</th>
<th>Teacher will…</th>
<th>Students will…</th>
</tr>
</thead>
</table>
| 0:00-8:00  | • Have students turn and talk about how ionic and covalent bonds contrast and how they are similar  
• Facilitate class discussions (Brown et al., 2014)  | • turn and talk with a partner about how ionic and covalent bonds contrast and how they are similar  
• Share answers out loud  |
| 8:00-20:00 | • Go through definition of polyatomic ions and how to name them  
• Explain characteristics  
• Provide exemplar of how to represent metallic bonds using Lewis Structures  | • Discuss the characteristics of polyatomic ions with a partner and how they differ from ionic bonds  
• Take notes and ask questions |
### Differentiation and planned universal supports:
Students will be placed in homogenous groups. Homogenous grouping allows students needs to be met more efficiently and directly because they have the same misconceptions (Huelser, 2012). This type of differentiation is effective in meeting diverse needs of larger groups of students.

### Type of Student Assessments and what is being assessed:
- **Informal Assessment:** Class discussion during the Do Now. Determine if students need small group differentiation
- **Formal Assessment:** Students will work together to complete the ten (10) problems in the problem set. This problem set will assess students’ understanding of polyatomic ions, as well as assessing their retention of prerequisite knowledge in atomic structure (Brown et al., 2014). This assessment will have students name polyatomic compounds.
- **Modifications to the Assessments:** Students who receive modifications to the assessment will be graded on five (5) out of the ten (10) questions on the assessment. These students will be given the same resources as the rest of the class. They will have the option to choose five (5) out of the ten (10) questions on the assessment.

### Evaluation Criteria:
Students will be graded on a scale of one (1) to ten (10). One (1) point awarded if they correctly respond to each question in the problem set. Students who receive modifications to the assessment will be graded on five (5) out of the ten (10) questions on the assessment.

### Relevant theories and/or research best practices:

<table>
<thead>
<tr>
<th>Lesson Time: 45 Minutes</th>
<th>Grade Level: High School</th>
<th>Content Area: Chemistry</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unit of Study: Bonding</td>
<td>Lesson Title: Bonding Lab</td>
<td></td>
</tr>
</tbody>
</table>

**Essential Question:** What is a bond and why are they important?
Content Standard(s):
Next Generation Science Standards:
HS-PS1-1. Use the periodic table as a model to predict the relative properties of elements based on the patterns of electrons in the outermost energy level of atoms
HS-PS1-4. Develop a model to illustrate that the release or absorption of energy from a chemical reaction system depends upon the changes in total bond energy.
PS1.A. The periodic table orders elements horizontally by the number of protons in the atom’s nucleus and places those with similar chemical properties in columns. The repeating patterns of this table reflect patterns of outer electron states

Learning Objectives associated with the content standards:
Students will be able to (SWBAT):
SWBAT identify different types of bonds
SWBAT determine how to properly name compounds; ionic and covalent

Instructional Resources and Materials to engage students in learning:
ActivBoard, activity packet, notes, laptops

Lesson Timeline, Instructional Strategies and Learning Tasks that support diverse student needs:

<table>
<thead>
<tr>
<th>Time</th>
<th>Teacher will…</th>
<th>Students will…</th>
</tr>
</thead>
</table>
| 0:00-5:00 | • Have students name two compounds on the board; one ionic and one covalent  
• Facilitate class discussions (Brown et al., 2014) | • With a partner, name the two compounds on the board; one ionic and one covalent  
• Share answers out loud |
| 5:00-8:00 | • Distribute laptops  
• Introduce the learning task  
• Set expectations for group work  
• Place students into homogenous groups | • Understand the learning task  
• Log into the simulation  
• Get into their predetermined groups |
| 8:00-40:00| • Facilitate classroom learning  
• Ensure that students are aware of time during the activity  
• Pause the class periodically to check-in  
• Work intensively with small homogenous group that showed greatest struggle with concepts | • Get into their homogenous groups for the learning task  
• Reading all information on the activity sheet  
• Work together to complete the questions using notes, as needed |
| 40:00-45:00| • Review the activity  
• Collect student work  
• Answer questions | • Review the activity as a whole  
• Ask questions and share out reasoning behind their answers |

Differentiation and planned universal supports:
Students will be placed in homogenous groups. Homogenous grouping allows students needs to be met more efficiently and directly because they have the same misconceptions (Huelser, 2012). This type of differentiation is effective in meeting diverse needs of larger groups of students.
Type of Student Assessments and what is being assessed:

- **Informal Assessment:** Class discussion during the Do Now. Determine if students need small group differentiation
- **Formal Assessment:** Students will work together to complete activity sheet that involves naming compounds. This sheet is coupled with an online simulation that mimics bonding at the quantum level. Students will be assessed on their understanding of naming compounds, how bonds form, and if charges are present as a result of the bond forming. These concepts encompass many previously learned topics in previous units (Brown et al., 2014).
- **Modifications to the Assessments:** Students who receive modifications to the assessment will be graded on the same scale. These students will have extended time to complete this assessment during another class period

Evaluation Criteria:
This activity is comprised of multiple parts. Part 1 will be graded out of five (5) total points; one for each correctly answered question. Part 2 will be graded out of three (3) points based off the previously stated criteria.

Relevant theories and/or research best practices:


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<table>
<thead>
<tr>
<th>Lesson Time: (2 Days) 45 Minutes</th>
<th>Grade Level: High School</th>
<th>Content Area: Chemistry</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Unit of Study: Bonding</td>
<td>Lesson Title: Review and Assessment</td>
</tr>
</tbody>
</table>

Essential Question:
How can we harness the energy located within the nucleus of an atom?

Content Standard(s):

**Next Generation Science Standards:**

**HS-PS1-1.** Use the periodic table as a model to predict the relative properties of elements based on the patterns of electrons in the outermost energy level of atoms

**HS-PS1-4.** Develop a model to illustrate that the release or absorption of energy from a chemical reaction system depends upon the changes in total bond energy.

**PS1.A.** The periodic table orders elements horizontally by the number of protons in the atom’s nucleus and places those with similar chemical properties in columns. The repeating patterns of this table reflect patterns of outer electron states

Learning Objectives associated with the content standards:

**Students will be able to (SWBAT):**

SWBAT review all Unit 5 Topics in Bonding
SWBAT demonstrate an understanding of the nature of bonding

Instructional Resources and Materials to engage students in learning: PowerPoint, laptop, calculator, Promethean ActivBoard, review problems, and assessment
Lesson Timeline, Instructional Strategies and Learning Tasks that support diverse student needs:

<table>
<thead>
<tr>
<th>Time</th>
<th>Teacher will…</th>
<th>Students will…</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Day 1</strong></td>
<td>• Distribute the review packet</td>
<td>• Work on review packet with partners</td>
</tr>
<tr>
<td>0:00-30:00</td>
<td>• Present the topics that will be covered on the assessment on the projector</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Walk around the room and facilitate student work</td>
<td></td>
</tr>
<tr>
<td>30:00-45:00</td>
<td>• Review problems from the packet</td>
<td>• Share answers during the review and ask questions</td>
</tr>
<tr>
<td></td>
<td>• Monitor student progress throughout the review to ensure that the packet is completed</td>
<td>• Submit packet at the end of class</td>
</tr>
<tr>
<td></td>
<td>• Review student packets to identify individual modifications for the assessment</td>
<td></td>
</tr>
<tr>
<td><strong>Day 2</strong></td>
<td>• Distribute assessment to students and monitor the room answering student questions as necessary</td>
<td>• Take assessment and complete during the allotted time</td>
</tr>
<tr>
<td>0:00-45:00</td>
<td>• Distribute exams</td>
<td>• Students with modifications will be given extra time to complete the exam</td>
</tr>
</tbody>
</table>

Differentiation and planned universal supports:
Students who exhibited struggle with mastery of concepts throughout the unit will be given the exams with sentence starters for written responses. Students will also be given a copy of the NYS Regents Reference Table for Physical Sciences.

Type of Student Assessments and what is being assessed:
- **Informal Assessment:** The review packet will serve as the informal assessment. Students will submit this packet and it will serve as an identifier for which students need modifications on the assessment for **Day 2**. The review packet will reactivate the necessary neural networks associated with learning (Huelser, 2012). The review packet will be randomized in question organization so that no repetition of concepts will be observed, thus creating stronger long-term connections as supported in the literature for robust learning (Rohrer, 2012).
- **Formal Assessment:** The formal assessment will be comprised of 25 questions. The test will have 25 multiple choice.
- **Modifications to the Assessments:** Students who exhibited more struggles during the unit will be given additional time to complete the assessment.

Evaluation Criteria:
Students will be evaluated on the formal assessment out of 20 points. Each multiple choice question will be worth one (1) point for a total of 20 points.
Relevant theories and/or research best practices:

**Activity Rationale**

<table>
<thead>
<tr>
<th>Title of Activity</th>
<th>Bonding Lab</th>
</tr>
</thead>
<tbody>
<tr>
<td>Source</td>
<td>Created by John Posillico</td>
</tr>
<tr>
<td>NGSS Standard(s)</td>
<td>HS-PS1-1. Use the periodic table as a model to predict the relative properties of elements based on the patterns of electrons in the outermost energy level of atoms. <strong>HS-PS1-4.</strong> Develop a model to illustrate that the release or absorption of energy from a chemical reaction system depends upon the changes in total bond energy. <strong>PS1.A.</strong> The periodic table orders elements horizontally by the number of protons in the atom’s nucleus and places those with similar chemical properties in columns. The repeating patterns of this table reflect patterns of outer electron states</td>
</tr>
<tr>
<td>Supplies</td>
<td>ActivBoard, activity packet, notes, laptops</td>
</tr>
<tr>
<td>Key Questions</td>
<td>What are the differences between covalent and ionic bonds? How do we name ionic and covalently bonded compounds?</td>
</tr>
<tr>
<td>Narrative Summary</td>
<td>Bonding is a very abstract concept because students cannot see bonds unless they’re modeled for them. In order to explicitly see chemical bonds, both ionic and covalent, students must be able to observe certain properties of these compounds. Students need to build a foundational understanding of what elements can be involved in particular types of bonds (Stein, Larrabee, And Barman, 2008). Students will need to display mastery in understanding the nuances of bonding before progressing into successive units; stoichiometry and chemical reactions.</td>
</tr>
<tr>
<td>Rationale</td>
<td>This lab is designed to assess student understanding on multiple concepts that were covered previously as well as current concepts being addressed in class. This simulation will model how bonds are formed and why certain elements can take place in particular types of bonding compared to others. This lab highlights exactly what is involved in ionic bond formation and how to name such compounds. This will facilitate student learning in future units because mastery in naming compounds is essential to chemical understanding. Knowing what</td>
</tr>
</tbody>
</table>
Atoms and compounds are present in the texts they will encounter allows them to make connections to the future material much more feasibly (Taylor & Rohrer, 2009). Students will have prior exposure to these concepts and therefore be presented an opportunity to display their mastery of concepts. Students who display struggle with this concept are afforded an opportunity to work towards mastery through this lab simulation.

**Possible Misconceptions**

- Anytime two non-metals are bonded together, it is always covalent.
- Ionic bonds only form positive or negative ions
- Covalent compounds dissolved and break apart in water.
- Energy is absorbed when bonds are broken and released when they are formed.

**Recommendations**

**Pre-Lab:** Ensure that the simulation works well on their laptops. Make sure all laptops preload the website to troubleshoot any issues that students may encounter. Also make sure students work in groups so there are excess laptops in the case that some laptops malfunction.

**During Lab:** Monitor student screens to ensure that they are constantly working on the activity. Facilitate the group work and focus on the differentiated group.

**Post Lab:** Have students turn in all work. Allow the students who need more to take the work home with them and provide them directions on how to get to the simulation if they need to at home.

**ASSESSMENTS**

**Assessment 1: Intro to Bonds**

1. What subatomic particles are involved in bonding?
2. What happens when bonds are broken?
3. What happens when bonds are formed?
4. How many valence electrons do Group 1 and Group 17 elements have?
5. Define what a chemical bond is.

**Answer Key**

1. The subatomic particles that are involved in bonding are the electrons
2. When bonds are broken, energy is released which was previously stored inside them chemical bond?
3. When bonds are formed, it requires energy to be put into the formation of the bond. If a bond is formed it typically results in a more stable product following a chemical reaction.
4. Group 1 elements have 1 valence electron, and Group 17 elements have 7 valence electrons
5. A chemical bond is the partnering of two atoms requiring energy to hold them together.

**Assessment 2: Ionic Bonds**

1. Which of the following are the correct pair of ions in the ionic compound LiCl
   a. Li+ & Cl+
   b. Li- & Cl+
2. Which of the following are the correct pair of ions in the ionic compound MgCl₂
   a. Mg⁺ & Cl⁻
   b. Mg²⁺ & Cl⁻
   c. Mg₂⁻ & Cl⁺
   d. Mg⁻ & Cl⁻

3. Which of the following are the correct pair of ions in the ionic compound CaCl₂
   a. Ca²⁺ & Cl₂⁻
   b. Ca⁻ & Cl⁺
   c. Ca₂⁻ & Cl₂⁻
   d. Ca²⁻ & Cl⁻

4. Which of the following are the correct pair of ions in the ionic compound LiCl
   a. Li⁺ & Cl⁺
   b. Li⁻ & Cl⁺
   c. Li⁺ & Cl⁻
   d. Li⁻ & Cl⁻

5. Which of the following are the correct pair of ions in the ionic compound CsBr
   a. Cs⁺ & Br⁺
   b. Cs⁻ & Br⁺
   c. Cs⁺ & Br⁻
   d. Cs⁻ & Br⁻

6. Which of the following is the correct name for NaCl
   a. Chloro sodium
   b. Sodium chlorine
   c. Sodium chloride
   d. Sodide Chloride

7. Which of the following is the correct name for LiCl
   a. Chloro lithium
   b. Lithium chloride
   c. Lithide chloride
   d. Litho Chloride

8. Which of the following is the correct name for MgBr₂
   a. Magno bromo
   b. Magnesium bromide
   c. Bromo magnide
   d. Magnesium bromine

9. Which of the following is the correct name for BeO
   a. Beryllium oxide
   b. Berylde oxide
   c. Berylide oxygen
   d. Oxygen berylium

10. Which of the following is the correct name for MgS
    a. Magno sulfide
    b. Magnesium sulfur
    c. Sulfur magnide
d. Magnide sulfide

Answer Key
1. C
2. B
3. A
4. D
5. C
6. C
7. B
8. B
9. A
10. A

Assessment 3: Covalent Bonds
1. What compound forms when C and H bond together?
   a. HC
   b. CH₄
   c. HCHC
   d. C₂H
2. What is the name of this compound NO₂
   a. Nitrogen dioxide
   b. Nitrous oxygen
   c. Oxo-nitrogen
   d. Nitrous oxide
3. What is the name of this compound: CO₂
   a. Carbon oxide
   b. Carbon monoxide
   c. Carbon dioxide
   d. Carbon Oxygen
4. Covalent bonds do what?
   a. Unevenly share electrons
   b. Do not share electrons
   c. Share electrons between two atoms
   d. Nothing ever, at all…
5. When dissolved in water, covalent bonds DO NOT
   a. Ionize
   b. Melt
   c. Change phases
   d. Break
6. A covalent bond is formed between which types of elements?
   a. Metalloid and Metal
   b. Metal and Non-Metal
   c. Non-Metal and Metalloid
   d. Non-Metal and Non-Metal
7. Covalent bonds are different from ionic bonds because
a. Ionic bonds share electrons while covalent bonds do not
b. Ionic bonds and covalent bonds are the exact same
c. Covalent bonds share electrons between two atoms while ionic bonds do not
d. Neither share electrons, but covalent is between a metal and non-metal

8. Why do non-metals covalently bond?
   a. They want full electron shells
   b. Because they just feel like it
   c. They need 6 electrons each
   d. They want to create new compounds to help us live forever

9. What is the chemical compound when Nitrogen and Chlorine bond?
   a. N₂Cl₄
   b. NCl₃
   c. N₂Cl
   d. N₂Cl₃

10. The type of bond that exists between diatomic molecules is called:
    a. Columbic Attraction
    b. Ionic
    c. Heat
    d. Covalent

Answer Key
1. B
2. A
3. C
4. C
5. A
6. D
7. C
8. A
9. B
10. D

Assessment 4: Spiral 1

11. The type of bond that exists between diatomic molecules is called:
    a. Columbic Attraction
    b. Ionic
    c. Heat
    d. Covalent

12. These types of elements are typically used as semiconductors
    a. Metalloids
    b. Metals
    c. Non-metals
    d. Gasses

13. The ability of copper to be drawn into a wire refers to which property?
    a. Conductivity
    b. Malleability
c. Pliability
d. Ductility

14. How many protons are in an atom of Nitrogen?
   a. 14
   b. 22
   c. 7
   d. 8

15. When dissolved in water, covalent bonds DO NOT
   a. Ionize
   b. Melt
   c. Change phases
   d. Break

16. Saltwater is considered to be a
   a. Homogenous Mixture
   b. Heterogenous Mixture
   c. Pure Substance
   d. Element

17. Which of the following are the correct pair of ions in the ionic compound CsBr
   a. Cs+ & Br-
   b. Cs- & Br+
   c. Cs+ & Br+
   d. Cs- & Br-

18. Which of the following is an element?
   a. Mg
   b. 2CH4 + 3O2 → 2CO2 + 2H2O + heat
   c. Mg2SO4
   d. H2SO4

19. Which of the following is the correct name for MgS
   a. Magno sulfide
   b. Magnesium sulfur
   c. Sulfur magnide
   d. Magnide sulfide

20. What is the nuclear reaction that occurs on only on the sun?
   a. REDOX
   b. Fission
   c. Fusion
   d. Combustion

Answer Key
1. D
2. A
3. D
4. C
5. A
6. B
7. C
Assessment 5: Polyatomic Ions

1. What is the name of this polyatomic ion: NH₄⁺
   a. Ammonia
   b. Ammonium
   c. Nitro-methane
   d. Nitrogen

2. What is the name of this polyatomic ion: ClO₂⁻
   a. Chlorate
   b. Chloride
   c. Chlorite
   d. Cyanide

3. What is the name of this polyatomic ion: HSO₃⁻
   a. Bisulfite
   b. Bisulfate
   c. Hydrosulfide
   d. Bicarbonate

4. What is the name of this polyatomic ion: MnO₄⁻
   a. Permanganate
   b. Manganese
   c. Oxalate
   d. Nitrile

5. What is the name of this polyatomic ion: PO₄³⁻
   a. Phosphate
   b. Phosphite
   c. Phosphorus
   d. Dioxalate

6. What is the name of this polyatomic ion: C₂O₄²⁻
   a. Permanganate
   b. Manganese
   c. Oxalate
   d. Nitrite

7. What is the name of this polyatomic ion: CO₃⁻
   a. Chromate
   b. Chlorate
   c. Oxalate
   d. Carbonate

8. What is the name of this polyatomic ion: OH⁻
   a. Hydroxide
   b. Hydronium
   c. Oxalate
   d. Water

9. What is the name of this polyatomic ion: H₃O⁺
a. Hydroxide
b. Manganese
c. Hydronium
d. Hypochlorate

10. What is the name of this polyatomic ion: NO$_3$-
   a. Nitrite
   b. Nitrate
   c. Nitrile
   d. Cyanide

**Answer Key**

1. B  
2. C  
3. A  
4. A  
5. A  
6. C  
7. D  
8. A  
9. C  
10. B

**Assessment 6: Bonding Lab**

**Background**

In this investigation you will bond select atoms. Based upon the types of atoms that you choose to combine, you will create either an ionic compound or a covalent compound. You will have the opportunity to analyze the differences between these different types of compounds and to predict the number of atoms needed to create each, as well as learn how to appropriately name them.

[http://www.teachchemistry.org/bonding](http://www.teachchemistry.org/bonding)

**Part 1: Ionic Bonding**

1. Choose Sodium (Na).
   a. What *type of element* is it?

   b. How many valence electrons does it have?

2. Choose Fluorine (F).
   a. What *type of element* is it?

   b. How many valence electrons does it have?
3. Answer the question on the screen, “What type of bond is this combination likely to form?”

   a. Circle: Ionic or Covalent?

   b. Choose the appropriate number of atoms to make the bond. Record the number of each atom below:

4. Watch the final animation closely (it will play continuously).

   a. Describe the change in the number of valence electrons in the atoms as the bond is successfully formed:

   b. What does the positive (+) charge indicate (mention specific subatomic particles in your answer)?

   c. What does the negative (-) charge indicate (mention specific subatomic particles in your answer)?

   d. What is the final overall charge?

   e. Record the name and molecular formula for the compound below:

5. You will first investigate 5 diatomic molecules. Diatomic molecules are made up of 2 atoms.
a. Select 2 fluorine atoms. How many valence electrons are in each fluorine atom?

b. Is a fluorine atom a metal or a non-metal?

c. Did the combination of these atoms create a covalent or ionic bond?

d. How are the valence electrons organized to form a bond between these atoms?

e. How is this different from the ionic bonds formed in the previous part of the activity?

Part 2: Naming and predicting the formula

6. More than two atoms can also be combined to form a covalent molecule. These molecules may form different shapes and will also follow a particular naming system. Select the following combinations of atoms, and complete the rest of the table as you interact with the simulation:

<table>
<thead>
<tr>
<th>1st atom choice</th>
<th>2nd atom choice</th>
<th>Predict Formula</th>
<th>Molecular Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>S</td>
<td>F</td>
<td></td>
<td></td>
</tr>
<tr>
<td>N</td>
<td>Cl</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cl</td>
<td>F</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Answer Key**

1. Metal; 1 VE
2. Non-metal; 7 VE
3. Ionic; 1:1
4. Na⁺ cation; F⁻ anion \(\rightarrow\) NaF Sodium Flouride
5. 7 VE; Non-metal; covalent; single bonded; electrons are shared equally between the two atoms in the bond

6.

<table>
<thead>
<tr>
<th>1st atom choice</th>
<th>2nd atom choice</th>
<th>Predict Formula</th>
<th>Molecular Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>S</td>
<td>F</td>
<td>SF₂</td>
<td>Sulfur difluoride</td>
</tr>
<tr>
<td>N</td>
<td>Cl</td>
<td>NCl₃</td>
<td>Nitrogen trichloride</td>
</tr>
<tr>
<td>Cl</td>
<td>F</td>
<td>ClF</td>
<td>Chlorine monofluoride</td>
</tr>
</tbody>
</table>

Assessment 7: Summative Assessment

1. What is the name of this polyatomic ion: H₃O⁺  
   a. Hydroxide  
   b. Manganese  
   c. Hydronium  
   d. Hypochlorate

2. What is the name of this polyatomic ion: C₂O₄⁻  
   a. Permanganate  
   b. Manganese  
   c. Oxalate  
   d. Nitrile

3. Covalent bonds are different from ionic bonds because  
   a. Ionic bonds share electrons while covalent bonds do not  
   b. Ionic bonds and covalent bonds are the exact same  
   c. Covalent bonds share electrons between two atoms while ionic bonds do not  
   d. Neither share electrons, but covalent is between a metal and non-metal

4. Ionic compounds  
   a. Evenly share electrons  
   b. Dissolve in water to form ions  
   c. Do not form ions  
   d. Are bonds between two non-metals

5. In every ionic compound, which of the following must always be present?  
   a. Gamma Rays and Alpha Particles  
   b. NaCl and water  
   c. Cations and anions  
   d. Sugar and water

6. What is the name of this compound: CO₂  
   a. Carbon oxide  
   b. Carbon monoxide  
   c. Carbon dioxide  
   d. Carbon Oxygen

7. What happens when bonds are broken?  
   a. Atoms are joined together  
   b. Energy is absorbed
c. Energy is released
d. An atom is split (fission)
8. When happens when bonds are formed?
   a. Atoms are joined together
   b. Energy is absorbed
   c. Energy is released
   d. An atom is split (fission)
9. When a metal and non-metal bond together, what type of bond is likely to form?
   a. Metallic
   b. Diatomic
   c. Covalent
   d. Ionic
10. What is the name of this polyatomic ion: OH-
   a. Hydroxide
   b. Hydronium
   c. Oxalate
   d. Water
11. Which of the following are the correct pair of ions in the ionic compound LiCl
   a. Li+ & Cl-
   b. Li- & Cl+
   c. Li+ & Cl-
   d. Li- & Cl+
12. Which of the following are the correct pair of ions in the ionic compound MgF2
   a. Mg+ & F-
   b. Mg2+ & F-
   c. Mg+ & F-
   d. Mg2+ & F-
13. Which of the following contains a polyatomic ion?
   a. H2O2
   b. NaCl
   c. MgSO4
   d. C6H12O6
14. Which of the following are the correct classifications of elements?
   a. Metals, Non-metals, Metalloids
   b. Ions, Covalent compounds, metalloids
   c. Metalloids, Non-metals, ions
   d. Metalloids, Non-metals, Metals, ions
15. Which of the following is the correct pairing for the Fluorine ion?
   a. F-
   b. F2
   c. F+
   d. F2-
16. H3PO4 contains the phosphate polyatomic ion. What is the charge of the phosphate ion?
   a. +3
   b. -3
   c. +1
17. MnO₄⁻ is the permanganate ion. What is the charge of Manganese in this ion?
   a. +5
   b. +8
   c. +7
   d. -7

18. What is the name of this ionic compound: KCl
   a. Calcium chloride
   b. Potassium Chloride
   c. Calcium Chlorine
   d. Potassium Chlorine

19. What is the definition for a polyatomic ion?
   a. An ion that is comprised of two or more ions
   b. An ion that has only 3 atoms
   c. An ion that is only 2 atoms
   d. An ion that is 1 atom

20. What is the name of the following compound: KMnO₄
   a. Permanganate
   b. Potassium Manganese Tetroxide
   c. Potassium Manganate
   d. Potassium Permanganate

Answer Key
1. C
2. C
3. C
4. B
5. C
6. C
7. C
8. B
9. D
10. A
11. C
12. D
13. C
14. A
15. A
16. B
17. C
18. B
19. A
20. D

Unit 6: Moles & Stoichiometry
**Lesson Plans**

<table>
<thead>
<tr>
<th>Lesson Time: 45 Minutes</th>
<th>Grade Level: High School</th>
<th>Content Area: Chemistry</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unit of Study: Moles and Stoichiometry</td>
<td>Lesson Title: Avogadro’s Number</td>
<td></td>
</tr>
</tbody>
</table>

**Essential Question:**
How do we determine how much of each reactant we need in a reaction?

**Content Standard(s):**
Math Standards:
MP.4. Model with mathematics

**Next Generation Science Standards:**

- **HS-PS1-2.** Construct and revise an explanation for the outcome of a simple chemical reaction based on the outermost electron states of atoms, trends in the periodic table, and knowledge of the patterns of chemical properties
- **HS-PS1-7.** Use mathematical representations to supports the claim that atoms, and therefore mass, are conserved during a chemical reaction

**Learning Objectives** associated with the content standards:

**Students will be able to** (SWBAT):

- SWBAT define moles
- SWBAT determine how many atoms are in a given sample using Avogadro’s number

**Instructional Resources and Materials** to engage students in learning:
ActivBoard, problem set, notes

**Lesson Timeline, Instructional Strategies and Learning Tasks** that support diverse student needs:

<table>
<thead>
<tr>
<th>Time</th>
<th>Teacher will…</th>
<th>Students will…</th>
</tr>
</thead>
</table>
| 0:00-8:00 | • Ask students how many atoms they think are in 100 mL of water and if they think it is possible to count  
• Facilitate class discussions (Brown et al., 2014) | • Turn and talk with a partner about the Do Now question  
• Share answers out loud |
| 8:00-20:00 | • Introduce the concept of Avogadro’s Number and how it is useful  
• Discuss how to calculate the number of atoms in a sample  
• Define the term mole | • Participate in class discussion on Avogadro’s number  
• Practice calculation with guidance from teacher  
• Define the term mole |
| 20:00-35:00 | • Determine homogenous groups  
• Distribute problem set and facilitate student discussion/groupwork  
• Ensure that students are using their notes to help work through the problem set | • Get into their homogenous groups for the learning task  
• Work together to complete the questions using notes, as needed |
| 35:00-45:00 | • Review the activity  
• Collect student work  
• Answer questions | • Review the activity as a whole  
• Ask questions and share out reasoning behind their answers |

**Differentiation and planned universal supports:**
Students will be placed in homogenous groups. Homogenous grouping allows students needs to be met more efficiently and directly because they have the same misconceptions (Huelser, 2012). This type of differentiation is effective in meeting diverse needs of larger groups of students.

**Type of Student Assessments and what is being assessed:**
- **Informal Assessment:** Class discussion during the Do Now. Determine if students need small group differentiation
- **Formal Assessment:** Students will work together to complete the ten (10) problems in the problem set. (Brown et al., 2014). This assessment will have students calculate the number of molecules in a sample using Avogadro’s number.
- **Modifications to the Assessments:** Students who receive modifications to the assessment will be given extra time to complete the assessment. They can work on it with another para-professional, if they are granted to have access to one.

**Evaluation Criteria:**
Students will be graded on a scale of one (1) to ten (10). One (1) point awarded if they correctly respond to each question in the problem set.

**Relevant theories and/or research best practices:**

**Lesson Time:** 45 Minutes  
**Grade Level:** High School  
**Content Area:** Chemistry

**Unit of Study:** Moles and Stoichiometry  
**Lesson Title:** Gram Formula Mass

**Essential Question:**
How do we determine how much of each reactant we need in a reaction?

**Content Standard(s):**
Math Standards:  
MP.4. Model with mathematics

**Next Generation Science Standards:**
- **HS-PS1-2.** Construct and revise an explanation for the outcome of a simple chemical reaction based on the outermost electron states of atoms, trends in the periodic table, and knowledge of the patterns of chemical properties
- **HS-PS1-7.** Use mathematical representations to supports the claim that atoms, and therefore mass, are conserved during a chemical reaction
Learning Objectives associated with the content standards:

Students will be able to (SWBAT):
SWBAT identify metallic bonds
SWBAT explain why metallic bonds are different from other types of bonds

Instructional Resources and Materials to engage students in learning:
ActivBoard, problem set, notes

Lesson Timeline, Instructional Strategies and Learning Tasks that support diverse student needs:

<table>
<thead>
<tr>
<th>Time</th>
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</thead>
</table>
| 0:00-8:00  | • Ask students to calculate number of moles of a substance, given the number of atoms present  
          | • Facilitate class discussions (Brown et al., 2014)                       | • Turn and talk with a partner about the Do Now question  
          |                                                                  | • Share answers out loud                                 |
| 8:00-20:00 | • Interleave gram formula mass, GFM into mini-lesson (Brown et al., 2014)  
          | • Discuss how to calculate GFM working with knowing the number of atoms or moles present | • Participate in class discussion on calculating the GFM when given the number of atoms or moles of a substance  
          |                                                                  | • Practice calculation with guidance from teacher        |
| 20:00-35:00| • Determine homogenous groups  
          | • Distribute problem set and facilitate student discussion/groupwork  
          | • Ensure that students are using their notes to help work through the problem set | • Get into their homogenous groups for the learning task  
          |                                                                  | • Work together to complete the questions using notes, as needed |
| 35:00-45:00| • Review the activity  
          | • Collect student work  
          | • Answer questions | • Review the activity as a whole  
          |                                                                  | • Ask questions and share out reasoning behind their answers |

Differentiation and planned universal supports:

Students will be placed in homogenous groups. Homogenous grouping allows students needs to be met more efficiently and directly because they have the same misconceptions (Huelser, 2012). This type of differentiation is effective in meeting diverse needs of larger groups of students.

Type of Student Assessments and what is being assessed:

- **Informal Assessment**: Class discussion during the Do Now. Determine if students need small group differentiation
- **Formal Assessment**: Students will work together to complete the ten (10) problems in the problem set. This problem set will assess students’ understanding of calculating the gram formula mass of compounds, as well as assessing their retention of prerequisite knowledge in atomic structure (Brown et al., 2014).
- **Modifications to the Assessments**: Students who receive modifications to the assessment will be graded on five (5) out of the ten (10) questions on the assessment.
These students will be given the same resources as the rest of the class. They will have the option to choose five (5) out of the ten (10) questions on the assessment.

**Evaluation Criteria:**
Students will be graded on a scale of one (1) to ten (10). One (1) point awarded if they correctly respond to each question in the problem set. Students who receive modifications to the assessment will be graded on five (5) out of the ten (10) questions on the assessment.

**Relevant theories and/or research best practices:**

<table>
<thead>
<tr>
<th>Lesson Time: 45 Minutes</th>
<th>Grade Level: High School</th>
<th>Content Area: Chemistry</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unit of Study: Moles and Stoichiometry</td>
<td>Lesson Title: Balancing Equations</td>
<td></td>
</tr>
</tbody>
</table>

**Essential Question:**
How do we determine how much of each reactant we need in a reaction?

**Content Standard(s):**
- Math Standards:
  - MP.4. Model with mathematics

**Next Generation Science Standards:**
- **HS-PS1-2.** Construct and revise an explanation for the outcome of a simple chemical reaction based on the outermost electron states of atoms, trends in the periodic table, and knowledge of the patterns of chemical properties
- **HS-PS1-7.** Use mathematical representations to supports the claim that atoms, and therefore mass, are conserved during a chemical reaction

**Learning Objectives** associated with the content standards:
- **Students will be able to (SWBAT):**
  - SWBAT to balance chemical equations
  - SWBAT understand that atoms, and therefore mass, are conserved in a chemical reaction

**Instructional Resources and Materials** to engage students in learning:
- ActivBoard, problem set, notes

**Lesson Timeline, Instructional Strategies and Learning Tasks** that support diverse student needs:

<table>
<thead>
<tr>
<th>Time</th>
<th>Teacher will…</th>
<th>Students will…</th>
</tr>
</thead>
</table>
| 0:00-8:00  | • Ask students to calculate number of moles of a substance, given the number of atoms present  
             • Facilitate class discussions (Brown et al., 2014)  | • Turn and talk with a partner about the Do Now question  
             • Share answers out loud  |
| 8:00-20:00 | • Interleave gram formula mass, GFM into mini-lesson (Brown et al., 2014)  
• Discuss how to calculate GFM working with knowing the number of atoms or moles present | • Participate in class discussion on calculating the GFM when given the number of atoms or moles of a substance  
• Practice calculation with guidance from teacher |
| --- | --- | --- |
| 20:00-35:00 | • Determine homogenous groups  
• Distribute problem set and facilitate student discussion/groupwork  
• Ensure that students are using their notes to help work through the problem set | • Get into their homogenous groups for the learning task  
• Work together to complete the questions using notes, as needed |
| 35:00-45:00 | • Review the activity  
• Collect student work  
• Answer questions | • Review the activity as a whole  
• Ask questions and share out reasoning behind their answers |

**Differentiation and planned universal supports:**

Students will be placed in homogenous groups. Homogenous grouping allows students needs to be met more efficiently and directly because they have the same misconceptions (Huelser, 2012). This type of differentiation is effective in meeting diverse needs of larger groups of students.

**Type of Student Assessments and what is being assessed:**

- **Informal Assessment:** Class discussion during the Do Now. Determine if students need small group differentiation
- **Formal Assessment:** Students will work together to complete the ten (10) problems in the problem set. This problem set will assess students’ understanding of balancing chemical equations.
- **Modifications to the Assessments:** Students who receive modifications to the assessment will be graded on five (5) out of the ten (10) questions on the assessment. These students will be given the same resources as the rest of the class. They will have the option to choose five (5) out of the ten (10) questions on the assessment.

**Evaluation Criteria:**

Students will be graded on a scale of one (1) to ten (10). One (1) point awarded if they correctly respond to each question in the problem set. Students who receive modifications to the assessment will be graded on five (5) out of the ten (10) questions on the assessment.

**Relevant theories and/or research best practices:**

Lesson Time: 45 Minutes  
Grade Level: High School  
Content Area: Chemistry

Unit of Study: Moles and Stoichiometry  
Lesson Title: Spiral Review 1

Essential Question: Why is the periodic table structured the way it is?

Content Standard(s):
Math Standards:
MP.4. Model with mathematics

Next Generation Science Standards:
HS-PS1-1. Use the periodic table as a model to predict the relative properties of elements based on the patterns of electrons in the outermost energy level of atoms
PS1.A. The periodic table orders elements horizontally by the number of protons in the atom’s nucleus and places those with similar chemical properties in columns. The repeating patterns of this table reflect patterns of outer electron states
HS-PS1-2. Construct and revise an explanation for the outcome of a simple chemical reaction based on the outermost electron states of atoms, trends in the periodic table, and knowledge of the patterns of chemical properties
HS-PS1-3. Plan and conduct an investigation to gather evidence to compare the structure of substances at the bulk scale to infer the strength of electrical forces between particles.
HS-PS1-7. Use mathematical representations to support the claim that atoms, and therefore mass, are conserved during a chemical reaction.
HS-PS1-8. Develop models to illustrate the changes in the composition of the nucleus of the atom and the energy released during the processes of fission, fusion, and radioactive decay.
HS-PS2-6 Communicate scientific and technical information about why the molecular-level structure is important in the functioning of designed materials
PS1. C: Nuclear Processes. Spontaneous radioactive decays follow a characteristic exponential decay law

Learning Objectives associated with the content standards:
Students will be able to (SWBAT):
SWBAT demonstrate understanding of chemistry concepts from all previous units
SWBAT demonstrate understanding of mathematical procedures as they apply to chemistry concepts

Instructional Resources and Materials to engage students in learning:
Spiral Review sheet
Lesson Timeline, Instructional Strategies and Learning Tasks that support diverse student needs:

<table>
<thead>
<tr>
<th>Time</th>
<th>Teacher will…</th>
<th>Students will…</th>
</tr>
</thead>
<tbody>
<tr>
<td>0:00-25:00</td>
<td>• Administer the Spiral Review</td>
<td>• Complete the Spiral Review</td>
</tr>
<tr>
<td></td>
<td>• Walk around and monitor student work</td>
<td>• As questions, as needed</td>
</tr>
<tr>
<td></td>
<td>• Answer questions</td>
<td></td>
</tr>
<tr>
<td>25:00-45:00</td>
<td>• Lead review of the Spiral Review providing how to work through each question individually</td>
<td>• Participate in Spiral Review discussion</td>
</tr>
<tr>
<td></td>
<td>• Answer questions and call on students to share</td>
<td>• Ask questions to the teacher and students who share their approaches towards answering questions</td>
</tr>
</tbody>
</table>

Differentiation and planned universal supports:
Students will be allowed to use calculators if they wish to. All questions will be multiple choice, and therefore no sentence starters will be necessary. Students who require additional time will be given it.

Type of Student Assessments and what is being assessed:
- **Informal Assessment**: Class discussion during the breakdown of the Spiral Review where students are discussing with one another about the questions on the spiral
- **Formal Assessment**: The Spiral Review will provide a metric of student learning from the very beginning of the academic year to the current time
- **Modifications to the Assessments**: Students will be graded on the same scale. Modifications to the assessment will appear in the form of students being given the choice to have problems read to them out loud. Students who wish to work in a separate location where that can happen will be allowed to take advantage of this.

Evaluation Criteria:
The Spiral Review will be ten (10) questions all worth one (1) point each. The Spiral Review will be worth a total of ten (10) points.

Relevant theories and/or research best practices:

<table>
<thead>
<tr>
<th>Lesson Time: 45 Minutes</th>
<th>Grade Level: High School</th>
<th>Content Area: Chemistry</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unit of Study: Moles and Stoichiometry</td>
<td>Lesson Title: Limiting Reagent</td>
<td></td>
</tr>
</tbody>
</table>

**Essential Question:**
How do we determine how much of each reactant we need in a reaction?

**Content Standard(s):**
Math Standards:
MP.4. Model with mathematics
**Next Generation Science Standards:**

**HS-PS1-2.** Construct and revise an explanation for the outcome of a simple chemical reaction based on the outermost electron states of atoms, trends in the periodic table, and knowledge of the patterns of chemical properties

**HS-PS1-7.** Use mathematical representations to support the claim that atoms, and therefore mass, are conserved during a chemical reaction

**Learning Objectives** associated with the content standards:

**Students will be able to (SWBAT):**

SWBAT determine how much a reaction can yield if one reagent is in excess

**Instructional Resources and Materials** to engage students in learning:

ActivBoard, problem set, notes

**Lesson Timeline, Instructional Strategies and Learning Tasks** that support diverse student needs:

<table>
<thead>
<tr>
<th>Time</th>
<th>Teacher will…</th>
<th>Students will…</th>
</tr>
</thead>
</table>
| 0:00-8:00| • Ask students to calculate number of moles of a substance, given the number of atoms present  
• Facilitate class discussions (Brown et al., 2014) | • Turn and talk with a partner about the Do Now question  
• Share answers out loud |
| 8:00-20:00| • Interleave gram formula mass, GFM into mini-lesson (Brown et al., 2014)  
• Discuss how to calculate GFM working with knowing the number of atoms or moles present | • Participate in class discussion on calculating the GFM when given the number of atoms or moles of a substance  
• Practice calculation with guidance from teacher |
| 20:00-35:00| • Determine homogenous groups  
• Distribute problem set and facilitate student discussion/groupwork  
• Ensure that students are using their notes to help work through the problem set | • Get into their homogenous groups for the learning task  
• Work together to complete the questions using notes, as needed |
| 35:00-45:00| • Review the activity  
• Collect student work  
• Answer questions | • Review the activity as a whole  
• Ask questions and share out reasoning behind their answers |

**Differentiation and planned universal supports:**

Students will be placed in homogenous groups. Homogenous grouping allows students needs to be met more efficiently and directly because they have the same misconceptions (Huelser, 2012). This type of differentiation is effective in meeting diverse needs of larger groups of students.
Type of Student Assessments and what is being assessed:

- **Informal Assessment**: Class discussion during the Do Now. Determine if students need small group differentiation
- **Formal Assessment**: Students will work together to complete the ten (10) problems in the problem set. This problem set will assess students’ understanding of calculating the yield in theoretical limiting reagent problems, as well as assessing their retention of prerequisite knowledge in atomic structure (Brown et al., 2014).
- **Modifications to the Assessments**: Students who receive modifications to the assessment will be graded on five (5) out of the ten (10) questions on the assessment. These students will be given the same resources as the rest of the class. They will have the option to choose five (5) out of the ten (10) questions on the assessment.

**Evaluation Criteria:**
Students will be graded on a scale of one (1) to ten (10). One (1) point awarded if they correctly calculate the yield for each problem, and two if they correctly identify the limiting reagent.

**Relevant theories and/or research best practices:**

<table>
<thead>
<tr>
<th>Lesson Time: 45 Minutes</th>
<th>Grade Level: High School</th>
<th>Content Area: Chemistry</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unit of Study: Moles and Stoichiometry</td>
<td>Lesson Title: Cooking Lab</td>
<td></td>
</tr>
</tbody>
</table>

**Essential Question:**
How do we determine how much of each reactant we need in a reaction?

**Content Standard(s):**
Math Standards:
MP.4. Model with mathematics

**Next Generation Science Standards:**
*HS-PS1-2*. Construct and revise an explanation for the outcome of a simple chemical reaction based on the outermost electron states of atoms, trends in the periodic table, and knowledge of the patterns of chemical properties
*HS-PS1-7*. Use mathematical representations to supports the claim that atoms, and therefore mass, are conserved during a chemical reaction

**Learning Objectives** associated with the content standards:
**Students will be able to (SWBAT):**
SWBAT apply knowledge of stoichiometry and limiting reagents to cook a recipe for the entire class
SWBAT work collaboratively to solve a problem that affects a large group

**Instructional Resources and Materials** to engage students in learning:
### ActivBoard, activity packet, notes, eggs, sugar, butter, flour, baking soda, milk, vanilla extract, measuring cups, teaspoons, tablespoons

### Lesson Timeline, Instructional Strategies and Learning Tasks that support diverse student needs:

<table>
<thead>
<tr>
<th>Time</th>
<th>Teacher will…</th>
<th>Students will…</th>
</tr>
</thead>
</table>
| 0:00-8:00  | • Ask students to balance an equation, reactivating neural networks (Brown et al., 2014)  
• Facilitate class discussions | • Turn and talk with a partner about the Do Now question  
• Share answers out loud |
| 8:00-20:00 | • Show students a cooking video that involves recipe that the class will be using for this activity  
• Discuss what was in the video and if everyone is ok with eating that dish  
• Ensure that nobody has a food allergy | • Watch cooking video that has specific recipe  
• Record all ingredients used in the video  
• Discuss what was done in the video and how that can apply to class |
| 20:00-40:00| • Present the learning task where students will have to expand the recipe to accommodate 10 people  
• Place students into predetermined homogenous groups | • Get into their homogenous groups for the learning task  
• Work together to determine how much of each ingredient that they would need to expand the recipe to accommodate 10 servings |
| 40:00-45:00| • Lead class discussion about the amount of each ingredient that they would need for their dish | • Participate in discussion about the amount of each ingredient that they would need for their dish |

### Differentiation and planned universal supports:

Students will be placed in homogenous groups. Homogenous grouping allows students needs to be met more efficiently and directly because they have the same misconceptions (Huelser, 2012). This type of differentiation is effective in meeting diverse needs of larger groups of students.

### Type of Student Assessments and what is being assessed:

- **Informal Assessment:** Class discussion during the Do Now. Determine if students need small group differentiation. Placing students into homogenous groups allows for easier and more direct differentiation.
- **Formal Assessment:** Students will be graded on their ability to apply stoichiometry concepts to real-life scenarios. This application will assess students’ ability to reason with ratios and proportionality. It will expand these concepts and include limiting reagent questions to address problems they may encounter in the real-life.
- **Modifications to the Assessments:** Students will be placed into small homogenous groups. The groups that display struggle with concepts using mathematical procedures will be allowed to use calculators and have access to other resources in the room made to address the discrepancies in mathematical ability. Students will also be permitted to use their notes.
Evaluation Criteria:
The completed table will be worth ten (10) total points. The conclusion questions that follow
the completion of the table will be worth six (6) points, two (2) points for each question.
Each question will be graded by giving one (1) point for complete sentences and one (1) point
for a correct answer.

Relevant theories and/or research best practices:
  University Press.
  do not know it. Memory & Cognition 40, 514-527

Lesson Time: (2 Days)
45 Minutes

Grade Level: High School

Content Area: Chemistry

Unit of Study: Moles and Stoichiometry

Lesson Title: Review and Assessment

Essential Question:
Why is the periodic table structured the way it is?

Content Standard(s):
Math Standards:
MP.4. Model with mathematics

Next Generation Science Standards:
HS-PS1-2. Construct and revise an explanation for the outcome of a simple chemical reaction
based on the outermost electron states of atoms, trends in the periodic table, and knowledge
of the patterns of chemical properties
HS-PS1-7. Use mathematical representations to supports the claim that atoms, and therefore
mass, are conserved during a chemical reaction

Learning Objectives associated with the content standards:
Students will be able to (SWBAT):
SWBAT review all Unit 6 Topics in Moles and Stoichiometry
SWBAT demonstrate an understanding of Moles and Stoichiometry

Instructional Resources and Materials to engage students in learning: PowerPoint, laptop,
calculator, Promethean ActivBoard, review problems, and assessment

Lesson Timeline, Instructional Strategies and Learning Tasks that support diverse student
needs:

<table>
<thead>
<tr>
<th>Time</th>
<th>Teacher will…</th>
<th>Students will…</th>
</tr>
</thead>
<tbody>
<tr>
<td>Day 1</td>
<td>• Distribute the review packet</td>
<td>• Work on review packet with partners</td>
</tr>
<tr>
<td>0:00-30:00</td>
<td>• Present the topics that will be covered on the assessment on the projector</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Walk around the room and facilitate student work</td>
<td></td>
</tr>
<tr>
<td>Time</td>
<td>Activities</td>
<td></td>
</tr>
<tr>
<td>------------</td>
<td>-----------------------------------------------------------------------------</td>
<td></td>
</tr>
</tbody>
</table>
| 30:00-45:00| • Review problems from the packet  
• Monitor student progress throughout the review to ensure that the packet is completed  
• Review student packets to identify individual modifications for the assessment  
• Share answers during the review and ask questions  
• Submit packet at the end of class |
| Day 2 0:00-45:00 | • Distribute assessment to students and monitor the room answering student questions as necessary  
• Distribute exams  
• Take assessment and complete during the allotted time  
• Students with modifications will be given extra time to complete the exam |

**Differentiation and planned universal supports:**
Students who exhibited struggle with mastery of concepts throughout the unit will be given the exams with sentence starters for written responses. Students will also be given a copy of the NYS Regents Reference Table for Physical Sciences

**Type of Student Assessments and what is being assessed:**
- **Informal Assessment:** The review packet will serve as the informal assessment. Students will submit this packet and it will serve as an identifier for which students need modifications on the assessment for **Day 2**. The review packet will reactivate the necessary neural networks associated with learning (Huelser, 2012). The review packet will be randomized in question organization so that no repetition of concepts will be observed, thus creating stronger long-term connections as supported in the literature for robust learning (Rohrer, 2012)
- **Formal Assessment:** The formal assessment will be comprised of 25 questions. The test will have 25 multiple choice
- **Modifications to the Assessments:** Students who exhibited more struggles during the unit will be given additional time to complete the assessment

**Evaluation Criteria:**
Students will be evaluated on the formal assessment out of 20 points. Each question will be worth one (1) point for a total of 20 points.

**Relevant theories and/or research best practices:**

**Activity Rationale**
<table>
<thead>
<tr>
<th>Title of Activity</th>
<th>Cooking Lab</th>
</tr>
</thead>
<tbody>
<tr>
<td>Source</td>
<td>Created by John Posillico</td>
</tr>
<tr>
<td>Math Standard</td>
<td>MP.4. Model with mathematics</td>
</tr>
<tr>
<td>---------------</td>
<td>------------------------------</td>
</tr>
<tr>
<td>NGSS Standard(s)</td>
<td><strong>Next Generation Science Standards:</strong></td>
</tr>
<tr>
<td></td>
<td><strong>HS-PS1-2.</strong> Construct and revise an explanation for the outcome of a simple chemical reaction based on the outermost electron states of atoms, trends in the periodic table, and knowledge of the patterns of chemical properties</td>
</tr>
<tr>
<td></td>
<td><strong>HS-PS1-7.</strong> Use mathematical representations to supports the claim that atoms, and therefore mass, are conserved during a chemical reaction</td>
</tr>
</tbody>
</table>

| Supplies | ActivBoard, activity packet, notes, eggs, sugar, butter, flour, baking soda, milk, vanilla extract, measuring cups, teaspoons, tablespoons |
| Key Questions | How can we apply stoichiometry outside of the class? What is the limiting reagent and how can it impact our desired outcome? |
| Narrative Summary | Whether students are aware of it or not, science is the pillar of cooking. Understanding what compounds mix and taste better with others is essential towards becoming a master chef. Students also need to understand stoichiometry for cooking because although they may love the taste of one ingredient, when combined with another it could have a negative impact on the outcome of the dish or treat, they are cooking. Students will have exposure to creating a dish that serves a large amount of people using concepts learned in this unit. This activity engages students by creating the real-world connections between concepts and practice (Patall, Pituch, Steingut, Vasquez, Yates, & Kennedy, 2019). |
| Rationale | The rationale behind this lab is to help highlight the connections between concept and application. Providing the students the opportunity to create these connections will allow for more robust learning to take place, thus leading to mastery (Sesen & Tarhan, 2010). |
| Possible Misconceptions | Combining all reagents at any ratio will yield the desired amount of product. Students believe that the limiting reagent does not have an influence on the yield, as long as the reagents are present, the products will be formed. |
| Recommendations | **Pre-Lab:** Find a cooking video where the students can follow along and record the ingredients. Have them record the ingredients during the video so that you can compile a list of necessary ingredients after watching the video. Once the video is completed, gather the student answers onto chart paper and post it on the board. Make sure they are aware of the number of servings that will be made.  
**During Lab:** Monitor student screens to ensure that they are constantly working on the activity. Facilitate the group work and
focus on the differentiated group. Do not let students touch ingredients, but only use their eyes to observe the ingredient list.

**Post Lab:** Have a cake pre-made for students to serve as a treat for completing the lab. Ensure that all student work is completed and lab stations are cleaned up.

**ASSESSMENTS**

Assessment 1: Avogadro’s Number

1. How many molecules are in 3 mols of Na metal?
   a. $6.02 \times 10^{23}$ molecules
   b. $1.20 \times 10^{24}$ molecules
   c. $1.81 \times 10^{24}$ molecules
   d. $6.02$ molecules

2. How many molecules are in 2.5 mols of H$_2$O?
   a. $1.51 \times 10^{24}$ molecules
   b. $6.02 \times 10^{23}$ molecules
   c. $1.81 \times 10^{24}$ molecules
   d. $1.20 \times 10^{24}$ molecules

3. How many molecules are in 6 mols of Li metal?
   a. $3.61 \times 10^{23}$ molecules
   b. $36.1 \times 10^{24}$ molecules
   c. $1.81 \times 10^{24}$ molecules
   d. $3.61 \times 10^{24}$ molecules

4. What is Avogadro’s Number?
   a. $6.02 \times 10^{23}$
   b. $6.02 \times 10^{24}$
   c. $6.02 \times 10^{21}$
   d. $6.02 \times 10^{22}$

5. Which of the following is the definition for mol?
   a. A unit in chemistry that unites mass, volume, and number of particles
   b. A rodent that burrows underground
   c. A unit in chemistry that unites mass and volume
   d. A unit in chemistry that unites # of particles and mass

6. How many atoms are in 2 mols of NaH?
   a. $1.20 \times 10^{23}$ molecules
   b. $120 \times 10^{24}$ molecules
   c. $1.20 \times 10^{24}$ molecules
   d. $12.0 \times 10^{24}$ molecules
7. What is the difference between an atom and a molecule?
   a. An atom is a combination of molecules
   b. A molecule is the same as an atom
   c. Atoms are the singular units that make up molecules
   d. Molecules are smaller than atoms

8. What is the number of atoms in 2.67 mols of NaCl?
   a. 16.1 x 10^{24} molecules
   b. 1.61 x 10^{24} molecules
   c. 1.61 x 10^{24} molecules
   d. 0.161 x 10^{23} molecules

9. If there are 0.67 mols of KCl, how many atoms are present?
   a. 403 x 10^{24} molecules
   b. 40.3 x 10^{24} molecules
   c. 0.043 x 10^{24} molecules
   d. 4.03 x 10^{23} molecules

10. In 1 mol of KMnO₄ there are how many atoms present?
    a. 3.61 x 10^{23} atoms
    b. 36.1 x 10^{24} atoms
    c. 1.81 x 10^{24} atoms
    d. 3.61 x 10^{24} atoms

**Answer Key**
1. C
2. A
3. D
4. A
5. A
6. C
7. C
8. B
9. D
10. D

**Assessment 2: Gram Formula Mass**
1. Calculate the GFM for AgNO₂
2. Calculate the GFM for Fe(NO₃)₃
3. Calculate the GFM for H₂SO₄
4. Calculate the GFM for C₆H₁₂O₆
5. Calculate the GFM for KMnO₄
6. Calculate the GFM for HCl
7. Calculate the GFM for MgSO₄
8. Calculate the GFM for C₂O₂
9. Calculate the GFM for HClO₄
10. Calculate the GFM for NaCl

**Answer Key**
1. 169.9 g/mol
2. 241.9 g/mol
3. 98.1 g/mol
4. 180.1 g/mol
5. 158.0 g/mol
6. 36.5 g/mol
7. 120.4 g/mol
8. 54.0 g/mol
9. 100.5 g/mol
10. 58.4 g/mol

**Assessment 3: Balancing Equations**
1. _____ H₂ + _____ Cl₂ → _____ HCl
2. _____ Fe + _____ Cl₂ → _____ FeCl₃
3. _____ C₄H₆O₃ + _____ H₂O → _____ C₂H₄O₂
4. _____ C₇H₁₆ + _____ O₂ → _____ CO₂ + _____ H₂O
5. _____ C₇H₉ + _____ O₂ → _____ CO₂ + _____ H₂O
6. _____ C₇H₁₆ + _____ HNO₃ → _____ C₇H₆(NO₂)₃ + _____ H₂O
7. _____ C₅H₅O₂ + _____ NaH + _____ HCl → _____ C₅H₁₂O₂ + _____ NaCl
8. _____ C₂H₄ + _____ O₂ → _____ CO₂ + _____ H₂O
9. _____ FeBr₃ + _____ H₂SO₄ → _____ Fe₂(SO₄)₃ + _____ HBr
10. _____ H₂ + _____ O₂ → _____ H₂O

**Answer Key**
1. 1,1,2
2. 2,3,2
3. 1,3,2,2
4. 1,3,1,3
5. 1,3,1,3
6. 1,1,7,8
7. 1,2,2,1,2
8. 1,3,2,2
9. 2,3,1,6
10. 2,1,2

**Assessment 4: Spiral 1**
1. The ability of copper to be drawn into a wire refers to which property?
   e. Conductivity
   f. Malleability
   g. Pliability
   h. Ductility
2. Which of the following is the correct name for MgS
   A. Sulfur magnide
   B. Magnesium sulfide
   C. Magnide sulfide
   D. Magno sulfide

3. If there are 0.67 mols of KCl, how many atoms are present?
   A. 403 x 10^24 molecules
   B. 40.3 x 10^24 molecules
   C. 0.043 x 10^24 molecules
   D. 4.03 x 10^23 molecules

4. The type of bond that exists between diatomic molecules is called:
   A. Columbic Attraction
   B. Ionic
   C. Heat
   D. Covalent

5. Balance the following equation
   
   _____ FeBr₃ + _____ H₂SO₄ → _____Fe₂(SO₄)₃ + _____ HBr

6. Which of the following are the correct pair of ions in the ionic compound CsBr
   A. Cs⁺ & Br⁺
   B. Cs⁻ & Br⁺
   C. Cs⁺ & Br⁻
   D. Cs⁻ & Br⁻

7. What is the difference between an atom and a molecule?
   A. An atom is a combination of molecules
   B. A molecule is the same as an atom
   C. Atoms are the singular units that make up molecules
   D. Molecules are smaller than atoms

8. Balance the following equation
   
   _____ C₅H₈O₂ + _____ NaH + _____ HCl → _____C₅H₁₂O₂ + _____ NaCl

9. Covalent bonds do what?
   A. Share electrons between two atoms
   B. Unevenly share electrons
   C. Do not share electrons
   D. Nothing ever, at all…

10. What compound forms when C and H bond together?
    A. HC
B. CH₄
C. HCHC
D. C₂H

**Answer Key**

1. D
2. B
3. D
4. D
5. 2,3,1,6
6. C
7. C
8. 1,2,2,1,2
9. A
10. B

**Assessment 5: Limiting Reagent**

1. If you have 0.050 g of H₂O and 0.001 g of NO₂, how many grams of HNO₃ can be produced?

   \[3 \text{ NO}_2 + \text{ H₂O} \rightarrow 2\text{ HNO}_3 + \text{ NO}\]

2. If you have 0.0148 g of H₂O and 1.620 g of C₂H₄, how many grams of C₂H₅OH can be produced?

   \[\text{C}_2\text{H}_4 + \text{ H}_2\text{O} \rightarrow \text{C}_2\text{H}_5\text{OH}\]

3. There are 20.00 g of KAuCl₄ and 25.00 g of Na₂CO₃. Which is the limiting reagent, and how much Au(OH)₃ can be produced?

   \[2 \text{ KAuCl}_4 + 3 \text{ Na}_2\text{CO}_3 + 3 \text{ H}_2\text{O} \rightarrow 2 \text{ Au(OH)}_3 + 6\text{NaCl} + 2 \text{KCl} + 3 \text{CO}_2\]

4. How many grams of CO₂ can be made by reacting 125 g of CaCO₃ with 125 g of HCl?
\[ \text{CaCO}_3 + 2 \text{HCl} \rightarrow \text{CO}_2 + \text{CaCl}_2 + \text{H}_2\text{O} \]

5. How many grams of NO can form if you mix 30.00 g \( \text{NH}_3 \) and 40.00 g \( \text{O}_2 \)?

\[ 4 \text{NH}_3 + 5 \text{O}_2 \rightarrow 4 \text{NO} + 6 \text{H}_2\text{O} \]

**Answer Key**
1. 0.913 mg \( \text{HNO}_3 \)
2. 0.69 mg \( \text{HNO}_3 \)
3. 13.13 g \( \text{Au(OH)}_3 \)
4. 55.0 g \( \text{CO}_2 \)
5. 30.01 g \( \text{NO} \)

**Assessment 6: Cooking Lab**

Directions: You are given a recipe for a cake that serves 4 people, one serving each. However, each person wants at least two servings. You are tasked with baking a cake that accommodates 10 servings (in case someone is a little extra hungry). Complete the table below with the recipe:

<table>
<thead>
<tr>
<th>Ingredient</th>
<th>4 Servings</th>
<th>10 Servings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sugar</td>
<td>1 cup</td>
<td></td>
</tr>
<tr>
<td>Butter</td>
<td>½ cup</td>
<td></td>
</tr>
<tr>
<td>Eggs</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Flour</td>
<td>1 ½ cups</td>
<td></td>
</tr>
<tr>
<td>Baking Soda</td>
<td>2 teaspoons</td>
<td></td>
</tr>
<tr>
<td>Milk</td>
<td>½ cup</td>
<td></td>
</tr>
<tr>
<td>Vanilla Extract</td>
<td>2 teaspoons</td>
<td></td>
</tr>
</tbody>
</table>

Once you finish determining the quantity of each ingredient, answer the following questions:
1. If we had 3 cups of flour, 2 cups of butter, and 2.5 cups of sugar, would we have enough to make 10 servings? If not, which ingredient would be our limiting reagent?

2. Define **Limiting Reagent** and why it is necessary to identify it during a chemistry experiment

3. Define **Yield** and explain how it is affected by a limiting reagent

**Answer key**

<table>
<thead>
<tr>
<th>10 Servings</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.5 cups</td>
</tr>
<tr>
<td>1.25 cups</td>
</tr>
<tr>
<td>5 eggs</td>
</tr>
<tr>
<td>3.75 cups</td>
</tr>
<tr>
<td>5 teaspoons</td>
</tr>
<tr>
<td>1.25 cups</td>
</tr>
<tr>
<td>5 teaspoons</td>
</tr>
</tbody>
</table>

1. Wouldn’t have enough for 10 servings because our limiting reagent is flour which can only yield up to 8 servings.
2. Limiting Reagents is the reagent that limits how much product can be yielded during a reaction. Knowing which is the limiting reagent would allow you to plan your experiment accordingly.
3. Yield is defined as the amount of product formed during a chemistry experiment. It is affected by the limiting reagent because the yield will be restricted, in terms of quantity of product formed.

**Assessment 7: Summative Assessment**

1. If you have 0.0148 g of H₂O and 1.620 g of C₂H₄, how many grams of C₂H₅OH can be produced?

   \[ C₂H₄ + H₂O \rightarrow C₂H₅OH \]

2. How many molecules are in 6 mols of Li metal?
   a. \( 3.61 \times 10^{23} \) molecules
b. 36.1 x 10^{24} molecules
c. 1.81 x 10^{24} molecules
d. 3.61 x 10^{24} molecules

3. If there are 0.67 mols of KCl, how many atoms are present?
   a. 403 x 10^{24} molecules
   b. 40.3 x 10^{24} molecules
   c. 0.043 x 10^{24} molecules
   d. 4.03 x 10^{23} molecules

4. What is the difference between an atom and a molecule?
   a. An atom is a combination of molecules
   b. A molecule is the same as an atom
   c. Atoms are the singular units that make up molecules
   d. Molecules are smaller than atoms

5. How many grams of NO can form if you mix 30.00 g NH_{3} and 40.00 g O_{2}?

   \[ \text{NH}_{3} + 5 \text{O}_{2} \rightarrow 4 \text{NO} + 6 \text{H}_{2}\text{O} \]

6. _____ C_{4}H_{6}O_{3} + _____ H_{2}O \rightarrow _____ C_{2}H_{4}O_{2}

7. _____ H_{2} + _____ O_{2} \rightarrow _____ H_{2}O

8. What is the number of atoms in 2.67 mols of NaCl?
   a. 16.1 x 10^{24} molecules
   b. 1.61 x 10^{24} molecules
   c. 161 x 10^{24} molecules
   d. 0.161 x 10^{23} molecules

9. _____ CH_{4} + _____ O_{2} \rightarrow _____ CO_{2} + _____ H_{2}O

10. _____ Cu + _____ O_{2} \rightarrow _____ CuO

11. _____ Ca(NO_{3})_{2} + _____ Li_{3}PO_{4} \rightarrow _____ LiNO_{3} + _____ Ca_{3}(PO_{4})_{2}

12. _____ H_{2}SO_{4} + _____ NaOH \rightarrow _____ H_{2}O + _____ Na_{2}SO_{4}

13. If you need 3.5 mols of Pb for a reaction, how many grams is that?
   a. 207.2 g Pb
   b. 414.4 g Pb
   c. 724.5 g Pb
   d. 1014.5 g Pb

14. If I have a cup of water with 180 g H_{2}O in it, how many mols is that?
   a. 1 mol
   b. 5 mol
   c. 8 mol
   d. 10 mol
15. If I have an experiment that made 24.6 g of CuSO₄ how many mols did I make?
   a. 1.5 mols
   b. 0.015 mols
   c. 0.155 mols
   d. 15.5 mols

16. What is the GFM of H₂SO₄
   a. 97.97 g/mol
   b. 95.96 g/mol
   c. 99.98 g/mol
   d. 98.98 g/mol

17. What is the GFM of (NH₄)₂SO₄
   a. 268.04 g/mol
   b. 132.02 g/mol
   c. 76.01 g/mol,
   d. 114.02 g/mol

18. What is the definition for a limiting reagent?
   a. The reactant that is in excess
   b. The reactant that also appears in the products
   c. The reactant that determines the amount of product that forms
   d. The reactant that does not appear in the products

19. How many grams of CO₂ can be made by reacting 125 g of CaCO₃ with 125 g HCl?

   \[\text{CaCO}_3 + 2 \text{HCl} \rightarrow \text{CO}_2 + \text{CaCl}_2 + \text{H}_2\text{O}\]

20. Balance the equation:

   _____ H₂ + _____ Cl₂ \rightarrow _____ HCl

Answer Key
1. 0.069 g HNO₃
2. D
3. D
4. C
5. 30.01 g NO
6. 1,3,2,2
7. 2,1,2
8. B
9. 1,2,1,2
10. 2,1,2
11. 3,2,6,1
12. 1,2,2,1
13. C
14. D
15. C
16. A
17. B
18. C
19. 55.03 g CO$_2$
20. 1,1,2
REFERENCES


