ATOMS and PERIODICITY - Atomic Models and Connecting Electronic Arrangement to Chemical Properties

This segment connects the phenomenon of fireworks to changes in the electronic structure of the atom leading students to develop particle diagrams of the earlier models of the atoms along with the current quantum mechanical model, and to develop steps to facilitate drawing electronic configurations of the atoms.

Student Science Performance	
Grade or course: 9-12 Chemistry	**Title**
Topic: Atoms & Periodicity	**Modern Atomic Theory**

Performance Expectation for GSE:

SC1. Obtain, evaluate, and communicate information about the use of the modern atomic theory and periodic law to explain the characteristics of atoms and elements.

a. Evaluate merits and limitations of different models of the atom in relation to relative size, charge, and position of protons, neutrons, and electrons in the atom.
b. Construct an argument to support the claim that the proton (and not the neutron or electron) defines the element's identity.
e. Construct an explanation of light emission and the movement of electrons to identify elements.
f. 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 (i.e. including atomic radii, ionization energy, and electronegativity).
g. Develop and use models, including electron configuration of atoms and ions, to predict an element's chemical properties.

Performance Expectations for Instruction:

1. Formulate questions to research and construct an explanation for the color caused by fireworks.
2. Analyze research and explain in detail the connection between the macroscopic phenomenon of the color of fireworks (and flame test) and the microscopic changes that occur within the structure of an atom of a metal salt.
3. Design an investigation to gather evidence in to identify four unknown powders based on their flame test color and atomic emission line spectrum.
4. Collect and analyze data to identify the unknown powders and relate the changes to infer evidence of the quantum theory of the atom.
5. Explore the early models of the atom using an online PHET simulation - Models of the Hydrogen Atoms.
6. Obtain information about different forms (isotopes) of an element. Make a claim about the identity of the atoms in the substances based on their atomic structure.
7. Draw a representation and evaluate the merits and limitations of the Billiard Ball Model (Dalton); Plum Pudding Model (Thomson); Classic Solar System Model; Bohr Model; DeBroglie Model; and Schrodinger Quantum Model in relation to the relative size, charge, and position of protons, neutrons, and electrons in the atom.
8. Research electronic configuration to develop a series of steps that facilitate drawing electronic configurations of elements (un-abbreviated, noble gas and orbital configurations).
9. Draw electronic configurations of elements.
10. Make claims about the periodic patterns in properties of elements, based on data for atomic radii, ionization energy, and electronegativity, as a result of atomic structure, electron arrangement and valence electrons.

[Additional notes on student supports]

Materials

Flame Test Investigation:
Solutions of Calcium chloride ($CaCl_2$), Lithium chloride LiCl, Potassium chloride (KCl), Sodium chloride (NaCl), Strontium chloride ($SrCl_2$), Barium chloride ($BaCl_2$), Copper chloride ($CuCl_2$)
Equipment: well-plate to hold powders; wooden splints presoaked in solutions of the listed powders; Bunsen burner; striker; tongs; beaker of water to extinguish splint; spectroscope; goggles; apron; gloves; coloring pencils
PHET Simulation: Models of the Hydrogen atom; Laptop with internet access; student worksheet for simulation (*can be downloaded from the website*)

Students will continuously obtain, evaluate, and communicate information. This is not a linear process. Students will communicate through writing and discussions to allow for formative assessment. This benefits the teacher, student, and whole group to guide instruction to clarify misconceptions or extend content.

Engaging Learners

Phenomenon
Teacher displays fireworks image (or video) to students:
Colorful Fireworks
["File:ColorfulFireworks.png." *Wikimedia Commons, the free media repository*. 24 Nov 2016, 01:11 UTC. 26 Jul 2017, 20:38.]
Guiding question: How can the structure of the atoms be connected to a colorful firework display?

Obtaining

1. In class discussion, students discuss their prior learning on the basic structure of the atom.
2. Students come up with questions that they would like to answer to connect specific aspects of atomic structure with energetic and colorful firework displays. *Here are some examples:*
   - *Why do we get different colors of fireworks?*
   - *Is this a chemical or a physical change? How do we know?*
   - *What chemicals are used in fireworks?*
   - *What are the particles in an atom and which particle(s) are responsible for the fireworks?*
   - *What is the source of energy causing the light?*
3. Teacher can provide students with websites to narrow their research. The ***American Chemical Society ChemMatters*** as well as ***Compound Interest*** have links to useful articles on the chemistry of fireworks. In groups, the students obtain information relating to their questions (*Teacher may need to guide to make sure that students are answering questions related to the topic.*) on the reaction involved, subatomic particles, energy changes during firework display, specifically the involvement of electrons in the METAL ions in the process and atomic emission spectra which may generate the need for more research. It is helpful for students to develop their own explanation from their research for words like electron, energy level, ground state, spectroscope, etc. Students could keep a running list of important terms in a journal to refer to throughout the course.

Evaluating
In groups, students will write a paragraph that summarizes their research. Teachers should inspect student's research and guide students in their research.
Their paragraph should identify that fireworks are initiated by a chemical reaction to produce energy to cause color changes in the metal ions. The

	focus of student research is on the METAL IONS in fireworks and their electronic rearrangements. Include examples of the metals used in fireworks. The electrons in the metal ions absorb this energy and become excited in the process. They move from their ground state to a higher excited energy level. This is unstable, and the electron eventually returned to its ground state releasing the excess energy as light of a particular wavelength which determines the color.
	Communicating Students share their paragraphs with other groups. Students may revise their conclusions and explanations based on input from other groups. *There are many ways of sharing information, such as:* ● *One student can present their data to the class.* ● *One group member stays at their station to share their data while the other group members rotate stations and listen/interact to presentations by other students.*
Exploring	*Obtaining* Student Investigation: 1. The teacher asks the students (*in groups of 2-3*) to design an investigation to gather evidence to identify four unknown powders based on their color in a flame (akin to fireworks) and the resulting atomic emission line spectrum. A student worksheet that could be used for teacher evaluation linked. Sample Flame Test Worksheet 2. Students are first expected to investigate the characteristic colors using flame tests *(standard procedure for performing a flame test is provided in the student worksheet)* and analyze the line spectrum in the spectroscope of each of the powders. *It is also useful if teachers provide students with an online resource showing the line spectrum for each of the powders under investigation, so students can compare with what they are observing in the spectroscope.* ***Bunsen safety should be reviewed with students and ANZI Z87 splash-proof goggles, apron and gloves should be worn during the investigation.*** 3. Students, in groups, will develop a data table to collect their color observations during the flame tests as well as line spectrum information (*or a drawing using coloring pencils*). This will act as a key in identifying the four unknown powders. 4. The teacher will put out four unknown powders in beakers labeled A, B, C, D. *(Preferably choose 4 white powders but do not use sodium chloride. For advanced classes, one of the beakers could contain a mixture but make students aware that beaker A contains 2 substances.)* The students will then perform flame tests and spectroscopic analysis of the four unknown powders. Students compare these results with the student-developed data base to identify the unknown powders. 5. The students, individually, will make an identification of each unknown and provide supporting evidence from their data. 6. The students, individually, will answer analysis questions that allow them to tie their observations with the modern quantum theory of the atom.
	Communicating Students will: ● Communicate their data in a group-developed data table. An example

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is shown in evaluation below.

Share their data and conclusions with other groups/teacher allowing them to revise and modify their investigation as needed.
Perform an error analysis of their investigation. Reevaluate data and improve model if necessary.
Individually identify their unknown powder and provide evidence to support their claim.
Individually answer analysis questions allowing them to link their observations with the quantum theory of the atom.

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Evaluating
Teachers should check the student communication and address any students' misconceptions. A sample data table showing expected colors for the flame tests is below:
<table>
<tr><th></th><th>Salt</th><th>Color (observations)</th><th>Drawing of atomic Emission Spectra</th></tr>
<tr><td>1</td><td>$BaCl_2$</td><td>Green-Yellow</td><td></td></tr>
<tr><td>2</td><td>$CuCl_2$</td><td>Blue/Green</td><td></td></tr>
<tr><td>3</td><td>LiCl</td><td>Fuchsia</td><td></td></tr>
<tr><td>4</td><td>KCl</td><td>Purple/Lilac</td><td></td></tr>
<tr><td>5</td><td>NaCl</td><td>Orange-Yellow</td><td></td></tr>
<tr><td>6</td><td>$CaCl_2$</td><td>Orange-Red</td><td></td></tr>
<tr><td>7</td><td>$SrCl_2$</td><td>Red/Crimson</td><td></td></tr>
</table>
Resource: Atomic Emission Line Spectra website (cK-12)
The analysis questions are important in checking for student understanding of the quantum mechanical model. Here, students should link their research, data and learning during their investigation.
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<td>Formative Assessment of Student Learning</td>
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<td>Explaining
Finalizing Model</td>
<td>
Obtaining
Through their investigation and research, students have now finalized the modern theory of the atom.

In groups of two, students will use the PHET simulation- Models of the Hydrogen atom (not yet available for Chromebooks but website is working on this) to explore and contrast earlier theories of the atom and link the current model of the atom to the periodic table. Models of the Hydrogen atom
(Attribution: PhET Interactive Simulations University of Colorado Boulder https://phet.colorado.edu PHET is a free and interactive simulation provided by the University of Colorado. It can be used online or downloaded. The resource can be used with or without registering. Registering on the site is free and provides access to

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	additional resources related to the simulations.) 2. Student worksheets are provided for teacher download on the website and teachers can customize these to the ability level of their students. The simulation allows the students to explore, compare and contrast specifically the following models of the atoms: Billiard Ball Model (Dalton); Plum Pudding Model (Thomson); Classic Solar System Model; Bohr Model of the atom (and explore its limitations to hydrogen); DeBroglie Model; and Schrodinger Quantum Model. 3. The students may need to perform additional research on each of the models. 4. The students should produce a timeline and draw a representation of each model along with a brief paragraph summarizing the particles and their location. The students then evaluate the merits and limitations of each model in relation to relative size, charge, and position of protons, neutrons, and electrons in the atom.
	Evaluating Teacher should evaluate student drawings and paragraphs on each model. Different groups are selected to present one of their models to the class allowing students to revise and correct their models as necessary. The student should correctly evaluate the merits and limitations of each model in relation to relative size, charge, and position of protons, neutrons, and electrons in the atom.
	Communicating Have students draw models on large whiteboards or posters to use in their class presentations and read their paragraphs to the class. Monitor class discussions to allow students to clarify any misconceptions as they arise while students present their models.
Elaborating Applying Model to Solve a Problems	**Phenomenon** Flame Tests and Fireworks **Guiding Question**: Teacher asks students to research why most of colorful flames were produced by group 1 and group 2 metal ions?
	Obtaining 1. Students perform research (online and/or textbook) and come up with their answer to the question. *Guide students to see the link between valence electrons and properties of elements along with their position on the periodic table.* 2. Students watch a Bozeman video (10 minutes) on Electron Configuration. 3. The teacher demonstrates the drawing of electron configuration for a number of elements. Students are introduced to the rules governing the filling of orbitals - Aufbau, Hund's and Pauli. 4. Students synthesize a step by step process to draw electronic configurations of elements. 5. Students draw the electron configuration for several elements. Remind them to include titles, labels and pertinent information.
	Evaluating Students: ● Develop steps to follow in writing electronic configurations. ● Draw electronic configuration of any element.

	• Draw noble gas configuration of any element. • Draw orbital diagram which models the filling of the individual orbitals by valence electrons. • Relate electronic configuration of orbitals to the modern quantum theory of the atom. • Evaluate the importance of the relationship between electron configuration and properties of atom such as atomic radius, ionization energy and electronegativity. This could be a CER response item and/ or could be a visual presentation.
	Communicating • Students should initially work in groups of two as they first start to develop the procedure and then draw electronic configurations. It is helpful if the students can share their electron configurations with the rest of the class. Options could include individual whiteboard or chart paper. • Groups compare their configurations with other groups and revise and relearn as necessary. Teachers will monitor and reteach as necessary. • Individually, students complete electronic configurations first as worksheet on Google forms and then a quiz.
	Assessment of Student Learning
	Formative Assessments: • Paragraph written by the student that researches the connection between the electronic rearrangement in atoms to color firework displays. Class along with teacher feedback is given when read by the students. • Data table for Flame Test Investigation - monitored by teacher to ensure procedure and analysis is accurate. • Draw an atom: Prior to instruction or research, student draws what student thinks an atom would look like if it could be seen (pre-assessment). This should be dated. Prior to the introduction of successive models, students repeat this process. This serves as a formative assessment, opportunity for feedback, and as a support for the summative model drawing assessment. • Student communication of research at each stage. Teachers should monitor carefully and foster discussions that correct any misconceptions or guide students in a different direction. • PHET - Models of the Hydrogen Atom - worksheet for website simulation. • Claims, Evidence, Reason response on relationship of proton number to element identity. **Summative Assessments:** • Flame Test Investigation - Identification of unknown powders along with supporting evidence • Flame Test Investigation - Answers to Analysis Questions • Drawing of each of the models of the atoms along with paragraph describing the arrangement of particles. This could be submitted as a poster. • Quiz - electronic Configuration. • Unit Test - evaluate students on the early models of the atom, modern

	theory and structure of the atom, atomic emission spectra, flame tests, valence electrons, energy levels, atomic orbitals, probability, electronic configurations and connections between valence electrons and element properties and periodic table organization.
SEP, CCC, DCI	**Science Essentials**
Science and Engineering Practices	• Asking questions and defining problems • Developing and using models • Planning and carrying out investigations • Analyzing and interpreting data • Constructing explanations and designing solutions • Engaging in argument from evidence • Obtaining, evaluating and communicating information
Crosscutting Concepts	• Patterns • Systems and system models • Structure and function
Disciplinary Core Ideas	• Atomic structure • Models of the atom • Electronic configurations • Atomic emission spectra

<u>Additional Supports for struggling learners:</u> **The following supports are suggestions for this lesson and are not the only options to support students in the classroom. These supports target students that struggle with science material, this lesson or a previous lesson. These are generalized supports and do not take the place of IEP accommodations as required by each student's Individualized Education Program.**
General supports for the following categories:

Reading:	Writing:	Math:
1. Provide reading support by reading aloud or doing partner reads 2. Have the teacher model what they are thinking when reading the text 3. Annotate the text with students so that they may refer to it as they work through the lab	1. The teacher can provide a sentence starter for the students. 2. The teacher can give students an audience to write to (i.e. Write a letter to your sibling explaining this topic). 3. The teacher can provide constructive feedback during the writing process to help students understand the expectations.	1. Provide calculators as needed. 2. Provide graph paper as needed.

Supports for this specific lesson if needed:

Performance expectations for instruction:

1. The teacher should provide information to students in various formats to reach as many students as possible.
2. The students should be given adequate time to complete each part of the lesson.
3. The students should be allowed to express their knowledge in various formats.
4. The teacher should be sure to provide multiple ways for the students to communicate their knowledge of the material.

Engage:

1. The teacher should ask if students have seen fireworks before and then ask students to describe what they noticed when watching fireworks.
2. The teacher should have clear and consistent guidelines for class discussion. This should help students feel more comfortable participating.
3. The teacher should consider giving students question stems to get them started in writing questions.
4. The teacher should consider having the class discuss the questions that have been generated to determine which ones are more important and which questions should be researched. The teacher can help guide students to choose the questions that relate to the standard and lesson.
5. The teacher should provide resources for students to research answers to their questions.
6. The teacher should provide an organizer for students to record the questions, research and begin to form their explanation.
7. The teacher should use flexible and intentional grouping to form student groups. Best practice is to use data to group students.
8. The teacher should consider giving students multiple formats to express their knowledge. These formats could include drawing, writing or designing a presentation.
9. Students may need additional time to complete their assignments.
10. The teacher should have clear and consistent guidelines for student presentations. This should make students feel more comfortable explaining their ideas to their peers.
11. The teacher should consider providing students with a rubric to evaluate their own work. This leads to more student ownership of their work and an understanding of the requirements for the

assignment.

Exploring:

1. The teacher should use intentional and flexible grouping. Best practice is to use data to group students.
2. The flame test can be done as a demo rather than a lab based on student needs. The teacher should consider the student population, safety requirements and student needs before deciding if a lab or demonstration is more appropriate.
3. The teacher should provide an organizer to assist students in designing an experiment.
4. The teacher should remind students of safety directions.
5. The teacher should consider showing a video of the flame test to allow them to see the results again.
6. The teacher should consider providing a data table to students, this data table could be blank, have some pieces filled in or give options to students of what to have in each place. The teacher should consider student needs when deciding what type of table to provide.
7. The teacher may need to explicitly teach students to collect data and how to record it in the table.
8. Students may need additional time to collect data and answer the questions.
9. The students can individually answer the questions and then compare their answers with other groups members. The students can discuss the correct answer and revise as necessary.
10. Have the students reflect on their lab or demo and discuss why there might be discrepancies in the data that the students collected. Why might they have seen a different color than they should have? How did the lab go? Why did they see different colors?
11. A connection to the real world or extension idea: have students think of a discipline of science where the color change of flames might be used and justify.

Explaining:

1. The teacher should provide the PHET sheet to the students.
2. The teacher should practice flexible and intentional grouping. Best practice is to use data to group students.
3. The teacher should consider giving students a Venn diagram to students to use for the compare and contrast part of the lesson.
4. The teacher should consider reinforcing the compare and contrast portion with a manipulative. On small slips of paper give students the information that they need to know about each model and have the students sort into categories.
5. The teacher should consider having students do a gallery walk rather than having students present to the class. This should help some students feel more comfortable.
6. The teacher should consider providing templates for drawings, research and timelines.
7. The teacher should consider giving students multiple options to express their knowledge. These options could include writing, drawing or designing a presentation.

Elaborating:

1. The teacher may need to provide the video to students so that students can watch more than once.
2. The teacher should explicitly show students how to draw an electron configuration. The teacher should consider showing students how to draw one then have the students practice in groups or with the teachers help and finally practice on their own.
3. The teacher should consider giving students some electron configurations that are drawn incorrectly and having students correct them.

4. The teacher should consider giving students the CER template.
5. The teacher should consider giving students multiple options to express their knowledge. These options could include writing, drawing or designing a presentation.
6. The teacher should use intentional and flexible grouping. Best practice is to use data to group students.

Evaluating:

1. The teacher should consider giving students multiple options to express their knowledge. These options could include writing, drawing or designing a presentation.
2. The teacher should consider having students explain their models, data and reasoning as they move through the lesson.
3. The teacher should complete a formative assessment several times throughout the lesson and re-teach, review and enrich as needed.

Investigation - identification of Unknown Powders Using Flame Test and Atomic Emission Spectrums

Engagement:

Guiding Question: *How can the impressive array of colors produced by fireworks allow us to infer the atomic structure and identity of elements?*

Come up with questions to help your research into the cause of the color in fireworks. Construct an explanation at the atomic level that explains our colorful observations on the 4th of July night sky.

Questions to guide research:

Research Notes:

Research Paragraph:

Exploration – Guiding Question – ***Identify four unknown powders using flame tests.*** Use a flame test to determine the emission line spectrum of 4 unknown powders.

Materials:

You may use any of the following materials during your investigation:

Consumables	**Equipment**	
• Calcium chloride ($CaCl_2$) • Copper (II) chloride ($CuCl_2$) • Lithium chloride (LiCl) • Potassium chloride (KCl) • Sodium chloride (NaCl) • Strontium chloride ($SrCl_2$) • Barium Chloride ($BaCl_2$)	• Well plate to hold powders • Beaker of water • Four beakers of unknown salts labeled A, B, C, D	• Wooden splints presoaked in distilled water • Bunsen burner and Striker • Tongs • Goggles, apron & gloves • Coloring pencils • Optional: Spectroscope and gas discharge tube

Safety:

Wear goggles and apron. Follow all Bunsen safety recommendations. Wash your hands before leaving the lab.

Safe Procedure for performing a flame test:

1. Obtain pre-soaked splints.
2. For each test, slightly dip one end of the presoaked splint into a small beaker of water. Then slightly dip the wet splint into the selected salt crystals. Tap to remove any excess crystals.
3. Using tongs, place splint into the top of the inner blue flame. Observe and record the color.
   REMOVE the splint before it burns.
4. Use a spectroscope to observe the line spectrum of the colored light.

Procedure:

Design a procedure using the above materials that will allow you to gather data and conduct an investigation to identify the powders. Use the following questions to guide your procedure.

- How will you identify a substance using a flame test?
- What observations or data will you need to record? How will you collect your data?
- How will you reduce errors in your data?

Data tables

- Organize your data into a table.

Conclusion:

Develop a claim that answers your guiding question and identifies your four unknown powders. Provide a justification or evidence for each claim. Explain what was occurring at a microscopic level.

Powder	Identity of Powder with supporting evidence
A	

B	
C	
D	

Error Analysis:

- Upon reflection of your lab, what are some possible errors that your group made? How did these errors affect your data? If repeating your experiment, what steps could you take to avoid making these errors again?

Explanations – Finalizing Model:

1. Based on your data, what elements could be responsible for the following colors in fireworks –Green fireworks, red fireworks, blue fireworks and purple fireworks. Justify your answer.

2. Why do chemicals have to be heated in a flame before the colored light is produced?

3. Metal ions are used as coloring agents in fireworks.
    a. Explain the occurrences within the atom that generate the color.

    b. How does this evidence relate to and support he quantum theory of the atom?

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