Ohio Standards

Connection:

Physical Sciences

Benchmark C
Describe how atoms and molecules can gain or lose energy only in discrete amounts.

Indicator 12
Describe how different atomic energy levels are associated with the electron configurations of atoms and electron configurations (and/or conformations) of molecules.

Lesson Summary:
In this lesson, the students will learn the proper filling order of electrons in the energy levels of an atom. They will learn how to “read” these occupied energy levels as electron configurations and demonstrate their understanding through creative presentations.

Estimated Duration: Two hours and 15 minutes

Commentary:
This lesson provides students with concrete analogies for the abstract concept of atomic energy levels. The lesson begins by having students move to higher levels on stairs to simulate placing electrons in higher energy levels, and the lesson concludes with students creating their own creative examples of atomic energy levels.

Pre-Assessment:
• For the best effect, conduct the pre-assessment on a set of steps or bleachers, using the different levels of height to help the students better visualize the different energy sublevels of an atom.
• Mark at least seven different levels, as indicated in the diagram in Attachment F, Energy Level Diagram.
• Be sure to label each level with the sublevel name (1s, 2s, 2p, and so on) and place separation lines between the orbitals.
• Represent each orbital with two X’s, showing that each orbital can hold two electrons.
• If steps or bleachers are not available, consider pre-arranging the desks in the room to represent the energy sublevels with the front of the room being the nucleus and closest desks being the lowest energy sublevel, 1s. In lieu of this, place tape or papers on the floor to represent the same situation.
• Lead the students to the pre-marked steps. Divide the class into four groups. Then ask the students to pretend they are electrons filling the sublevels of an atom’s electron shells.
Energy Levels and Electron Configurations – Grade 12

- Have each group alternate sending one student at a time into the orbitals as if they were electrons filling the energy levels from lowest to highest energy.
- If the students follow the proper sequencing (1s, 2s, 2pₓ, 2pᵧ, 2pₗ, etc.) and placement of individual electrons, ask them to arrange themselves to represent a particular element, such as titanium, and to “read” their arrangement as an electron configuration (Answer: 1s²2s²2p⁶3s²3p⁶4s²3d²).
- If the students do not follow the proper sequencing or pair the electrons in an orbital before the other orbitals of different orientation have single electrons, ask them to come back to ground level and return to the classroom.

**Scoring Guidelines:**
Use the pre-assessment as an engagement activity and to guide the level of instruction that is needed.

**Post-Assessment:**
Have students creatively present the relationship between electron energy levels and electron configurations of atoms (e.g., skit, poem, song, rap, poster, dance, etc.). See Attachment A, *Student Instructions for the Post-Assessment*.

**Scoring Guidelines:**
See Attachment B, *Rubric for Grading Oral Presentations for Individuals*. Provide students a copy of the rubric when the assignment is given.

**Instructional Procedures:**
1. Direct the students to assemble themselves into small groups of no more than four to research electron configurations, especially the electron filling order, using their textbooks or other references.
2. Have the students collaborate as a class and reach consensus regarding the proper filling order of electrons into the energy levels. Ask the students to read in their texts about the Aufbau (building up) principle, which states that electrons in an atom will occupy the lowest available energy level. Make sure they also understand Hund’s rule, which states that electrons in an energy sublevel will occupy each orbital singly before pairing up because of the electron repulsion within a single orbital.
3. Take students back to the marked steps and ask them to demonstrate proper filling order by arranging themselves in the correct order by energy levels as if they were electrons.
4. If the students still cannot perform this correctly, guide them through the process.
5. Ask the students to write a brief paragraph explaining the process of how one goes about writing a correct electron configuration for an element. Tell them to include such factors as:
   a. Knowledge of energy levels;
   b. Types of energy sublevels;
   c. Electron repulsion and spin.
6. Present Attachment C, *Electron Filling Order Diagram* and demonstrate how to write electron configurations both as diagrams (   ) and numbered energy levels (1s²2s²2p⁶).
7. Give the students a worksheet that allows them to identify an element when given the proper electron configuration, to provide the electron configuration when given the element and to find errors in electron configurations. See Attachment D, Student Worksheet.

8. Show the students how to write the electron configuration shorthand, using the core of the previous noble gas. For example, sodium, Na, is [Ne]4s\(^1\). Give them several practice examples, such as:
   - Arsenic, As (Answer: [Ar]4s\(^2\)3d\(^{10}\)4p\(^3\))
   - Yttrium, Y (Answer: [Kr]5s\(^2\)4d\(^1\)).

9. With a periodic table in front of them, ask the students to identify elements by the ends of their electron configurations.
   a. Ask them to identify the element ending in 5s\(^1\). (Answer: rubidium, Rb). Discuss with the students the fact that the element had to be in the fifth period because the last electron was entering the fifth energy level. Point out that the last level was in an “s” energy sublevel so the element had to be an alkali or alkaline earth and since there was only 1 s sublevel electron present, the element had to be rubidium, Rb.
   b. Ask the students to identify the element ending in 3d\(^2\). (Answer: titanium, Ti). Ask the students in which period titanium is found. Discuss with them why the last electron is entering the third energy level, even though the element is located in the fourth period and has two electrons in the fourth energy level. Be sure students also notice that titanium is 3d\(^2\) and is two places over in the d-block of elements in the periodic table. Help your students to see the pattern of elements in the s-, p-, and d-blocks.
   c. Ask the students to identify the element ending in 4d\(^6\). (Answer: ruthenium, Ru). Again, you should point out that the electrons entering the d-orbitals are entering the fourth energy level, even though the fifth energy level has already been started.
   d. Ask your students in which energy level the f-block elements have their last electrons. Make sure they understand that although the lanthanide series elements’ electrons end in the 4f sublevel, the elements are actually located in the sixth period and have valence electrons in the sixth energy level. The actinide series elements’ electrons end in the 5f sublevel, even though the valence electrons are in the seventh energy level. Ask them to write an electron configuration for an f-block element, such as samarium, a component of some strong magnets. (Answer: [Xe] 6s\(^2\) 4f\(^6\))
   e. Let your students know that there are deviations from the expected pattern among the d and f orbitals because half-filled shells, like d\(^5\) and f\(^7\) are especially stable so chromium, Cr, is not [Ar]4s\(^2\)3d\(^4\), but rather [Ar]4s\(^1\)3d\(^5\). An electron is “borrowed” out of the s orbital to complete the half-filled d energy sublevel. Also, in higher energy levels, the s, d, and f orbitals have very nearly the same energy so we see some not-so-predictable electron configurations, such as gadolinium, Gd, with an electron configuration of [Xe] 6s\(^2\)5d\(^1\)4f\(^7\).
Differentiated Instructional Support:
Instruction is differentiated according to learner needs, to help all learners either meet the intent of the specified indicator(s) or, if the indicator is already met, to advance beyond the specified indicator(s).
- Have students work independently, in pairs, or heterogeneous groups to complete the research of electron filling order.
- Provide filling order diagram and demonstrate the proper use of the electron configuration shorthand.
- Offer students a variety of presentation modes such as skit, poem, song, rap, colorful poster, dance, or multimedia production.
- Challenge students to discern why there are exceptions to the rules of electron configurations and how these affect the properties of those exceptional elements.

Extensions:
Have students conduct an Internet search of three or more transition metals that have electron configurations that do not follow the rules of electron filling order. Tell them to report what the electron configurations are, what we would have predicted them to be, why they are different, and how their electron configurations affect their chemical and physical properties.

Interdisciplinary Connections:
English Language Arts
- Oral and Visual
  - Benchmark F: Give presentations using a variety of delivery methods, visual displays and technology.
  - Indicator 9: Deliver formal and informal descriptive presentations that convey relevant information and descriptive details.

Materials and Resources:
The inclusion of a specific resource in any lesson formulated by the Ohio Department of Education should not be interpreted as an endorsement of that particular resource, or any of its contents, by the Ohio Department of Education. The Ohio Department of Education does not endorse any particular resource. The Web addresses listed are for a given site’s main page, therefore, it may be necessary to search within that site to find the specific information required for a given lesson. Please note that information published on the Internet changes over time, therefore the links provided may no longer contain the specific information related to a given lesson. Teachers are advised to preview all sites before using them with students.

For the teacher:  Bleachers or steps, masking tape, periodic table reference, textbook or other reference materials, computer with Internet access.

For the students:  Bleachers or steps, masking tape, periodic table reference, textbook or other reference materials, computer with Internet access.
Energy Levels and Electron Configurations – Grade 12

Vocabulary:
- electron configuration
- orbital
- filling order
- energy level
- energy sublevel
- transition metal
- Aufbau principle
- Hund’s rule

Technology Connections:
- Provide students with Internet access for their research on electron configurations and the transition metals (extension).
- Provide students with computer access to create multimedia presentations for the post-assessment.

Research Connections:
  Kinesthetic activities help to enhance a student’s understanding of the content.

  Cooperative groups enhance learning and help motivate students to progress faster.

  Brain-based research says that when students write their answers, rather than giving them orally, the brain is forced to do more analytical thinking.

  Research has shown that repetition increases recall.

General Tips:
- If students are working in small groups, monitor them to ensure that they remain on task and understand electron filling order. Be mindful of any misconceptions that they may have.
- For the pre-assessment, be sure your masking tape markings are affixed prior to class.
- Add heavier elements to the worksheet if students require more challenging problems to solve.
Energy Levels and Electron Configurations – Grade 12

**Attachments:**
Attachment A, *Student Instructions for the Post-Assessment*
Attachment B, *Rubric for Grading Oral Presentations for Individuals*
Attachment C, *Electron Filling Order Diagram*
Attachment D, *Student Worksheet*
Attachment E, *Answers to Student Worksheet*
Attachment F, *Energy Level Diagram*
Now that we have completed our study of electron configurations, you are to creatively present what you know about the electron configurations of atoms, especially emphasizing the relationship between electron energy levels and electron configurations. Your presentation may be in the form of a skit, poem, song, rap, colorful poster, dance or any creative multimedia production of your choice and must be pre-approved by the instructor. Use your imagination! Presentations may be individual or in groups of no more than four students.
### Attachment B
Rubric for Grading Oral Presentations for Individuals

<table>
<thead>
<tr>
<th>Factor</th>
<th>Excellent</th>
<th>Good</th>
<th>Satisfactory</th>
<th>Needs Improvement</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Depth of Understanding</strong></td>
<td>Students show a thorough understanding of the relationship between electron energy levels and electron configurations. Patterns and trends in filling order are identified, discussed, and extended through interpolation or extrapolation.</td>
<td>Students show an understanding of the relationship between electron energy levels and electron configurations. Patterns and/or trends in filling order are identified.</td>
<td>Students show an understanding of the relationship between electron energy levels and electron configurations. Patterns or trends in filling order are suggested or implied.</td>
<td>Students may not show an understanding of the relationship between electron energy levels and electron configurations. Patterns and trends in filling order are unclear or inaccurate.</td>
</tr>
<tr>
<td><strong>Communication</strong></td>
<td>Scientific information is communicated clearly and precisely but may also include inventive/expressive dimensions.</td>
<td>Scientific information is communicated clearly.</td>
<td>Scientific information has some clarity.</td>
<td>Scientific information is unclear.</td>
</tr>
</tbody>
</table>

Adapted from Council of Chief State School Officers State Collaborative on Assessment and Student Standards (SCASS) Science Project, April 1997.
To predict the electron filling order, follow the arrows from top to bottom.
**Electron Configurations**

Part I.
Complete the table.

<table>
<thead>
<tr>
<th>Element</th>
<th>Symbol</th>
<th>Number of Electrons</th>
<th>Electron Configuration</th>
<th>Electron Configuration Notation</th>
<th>Period</th>
<th>Group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon</td>
<td>C</td>
<td>6</td>
<td>2p↑↑↑, 2s↑↓, 1s↑↓</td>
<td>1s²2s²2p²</td>
<td>2</td>
<td>IVA</td>
</tr>
<tr>
<td>He</td>
<td></td>
<td>2</td>
<td></td>
<td></td>
<td>3</td>
<td>VIA</td>
</tr>
</tbody>
</table>

Carbon: 1s²2s²2p²
He: 1s²2s²2p⁶
Part II. Decide whether the following electron configurations are correct or not. If they are correct, write that on the line, but if they are wrong, state the error.

1. $1s^22s^23p^64s^2$ ________________________________

2. $1s^22s^12p^6$ ________________________________

3. $1s^22s^22p^2$ ________________________________
# Electron Configurations

**Part I.**

Directions: Below is an incomplete table of elements with their electron configurations and other pertinent data. Notice that the data for carbon has been supplied as an example for you. Please complete the remainder of the table.

<table>
<thead>
<tr>
<th>Element</th>
<th>Symbol</th>
<th>Number of Electrons</th>
<th>Electron Configuration</th>
<th>Electron Configuration Notation</th>
<th>Period</th>
<th>Group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon</td>
<td>C</td>
<td>6</td>
<td>2p↑↑↑↑ 3s^-</td>
<td>1s²2s²2p³</td>
<td>2</td>
<td>IVA</td>
</tr>
<tr>
<td>Helium</td>
<td>He</td>
<td>2</td>
<td>1s↑↓</td>
<td>1s²</td>
<td>1</td>
<td>VIIIA</td>
</tr>
<tr>
<td>Nitrogen</td>
<td>N</td>
<td>7</td>
<td>2p↑↑↑↑ 3s↑↓</td>
<td>1s²2s²2p³</td>
<td>2</td>
<td>VA</td>
</tr>
<tr>
<td>Sulfur</td>
<td>S</td>
<td>16</td>
<td>3p↑↑↑↑ 3s↑↓ 2p↑↑↑↑</td>
<td>1s²2s²2p³3s³3p⁴</td>
<td>3</td>
<td>VIA</td>
</tr>
<tr>
<td>Sodium</td>
<td>Na</td>
<td>11</td>
<td>3s↑↑↑↑ 2p↑↑↑↑ 2s↑↓</td>
<td>1s²2s²2p³3s³</td>
<td>3</td>
<td>IA</td>
</tr>
</tbody>
</table>
Part II. Decide whether the following electron configurations are correct or not. If they are correct, write that on the line, but if they are wrong, state the error.

1. $1s^22s^23p^64s^2$  
   The 2p and then 3s sublevels are lower energy than the 3p and will fill first. If this element has 12 electrons then the correct electron configuration is $1s^22s^22p^63s^2$.

2. $1s^22s^12p^6$  
   The 2s sublevel fills with two electrons before any electrons go into the higher energy 2p level.

3. $1s^22s^22p^2$  
   This is a correct electron configuration.
# Energy Levels and Electron Configurations – Grade 12

## Attachment F

### Energy Level Diagram

<table>
<thead>
<tr>
<th>Energy Level</th>
<th>Step</th>
</tr>
</thead>
<tbody>
<tr>
<td>3d</td>
<td>7th</td>
</tr>
<tr>
<td>4s</td>
<td>6th</td>
</tr>
<tr>
<td>3p</td>
<td>5th</td>
</tr>
<tr>
<td>3s</td>
<td>4th</td>
</tr>
<tr>
<td>2p</td>
<td>3rd</td>
</tr>
<tr>
<td>2s</td>
<td>2nd</td>
</tr>
<tr>
<td>1s</td>
<td>1st</td>
</tr>
</tbody>
</table>

**Ground Level**

X represents an electron

[ ] represents an orbital