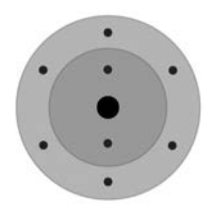
ENGAGE

1. Introduce students to the idea that electrons surround the nucleus of an atom in regions called energy levels.

Review with students that in lesson two they focused on the number of protons, neutrons, and electrons in the atoms in each element. In this lesson, they will focus on the arrangement of the electrons in each element.

Project the image *Energy level cross-section*.
www.middleschoolchemistry.com/multimedia/chapter4/lesson3#energy_level_cross_section
Explain to students that electrons surround the nucleus of an atom in three dimensions, making atoms spherical. They can think of electrons as being in the different energy levels like concentric spheres around the nucleus. Since it is very difficult to show these spheres, the energy levels are typically shown in 2 dimensions.

Project the image *Oxygen atom*.
www.middleschoolchemistry.com/multimedia/chapter4/lesson3#oxygen_atom
Tell students that this energy level model represents an atom. The nucleus is represented by a dot in the center, which contains both protons and neutrons. The smaller dots surrounding the nucleus represent electrons in the energy levels. Let students know that they will learn more about electrons and energy levels later in this lesson.



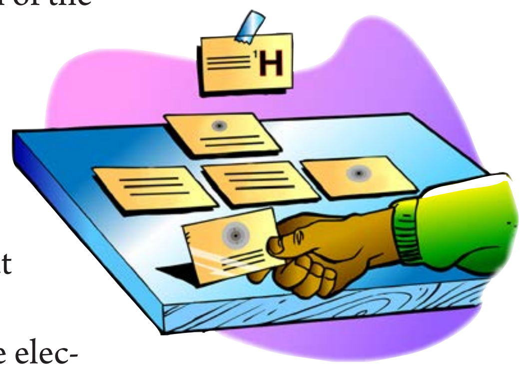
Have students look at the *Periodic table of the elements 1–20* they used in lesson 2 to answer the following question:

- **Can you identify which atom this model represents?**
  If students can't answer this question, point out that there are 8 electrons. Because neutral atoms in the periodic table have the same number of electrons as protons, the atom must have 8 protons. The number of protons is the same as the atomic number, so the atom is oxygen.

Read more about energy level models in the additional teacher background section at the end of this lesson.

2. **Have groups work together to place each card with its correct atom.**

Show students that you have 80 cards (4 for each of the first 20 elements). Before distributing the cards, explain that each card contains information about electrons and energy levels for the first 20 elements of the periodic table. The students' job is to read the card carefully, figure out which element the card is describing, and put the card at the spot in the room for that element. Remind students that they will need to count the electrons in order to identify each atom. Once students understand what their assignment is, distribute the cards to groups.



3. **Discuss the placement of the cards for two or three atoms.**

After all cards have been placed at the 20 different atoms, select two or three atoms and review whether the cards were placed correctly. This review will help reinforce the concepts about the structure of atoms and help students determine the number of protons and electrons in each atom.

Give each student a *Periodic Table of Energy Levels* activity sheet. This table contains energy level models for the first 20 elements. The electrons are included only for the atoms at the beginning and end of each period.

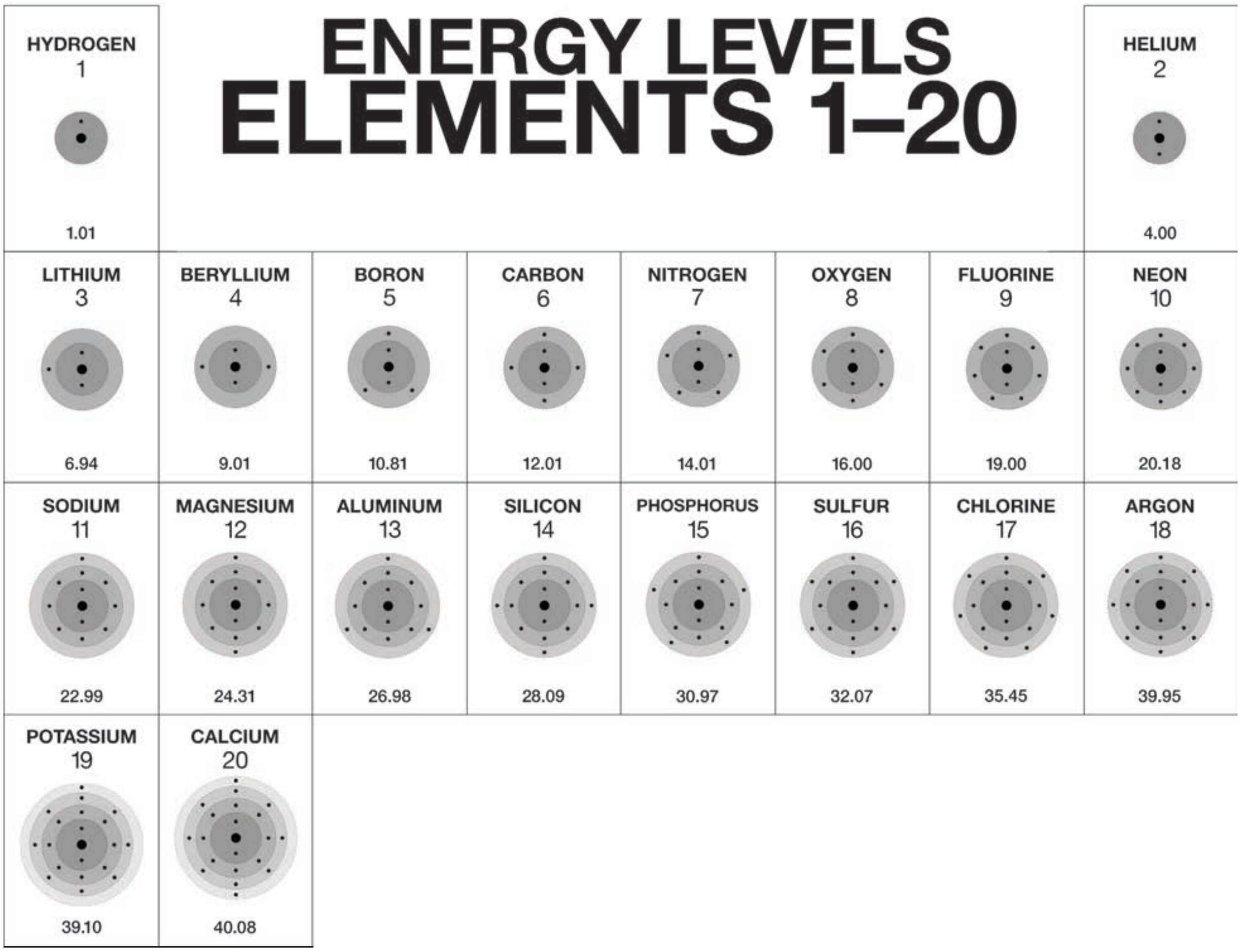
EXPLORE

4. **Project the *Periodic table of energy levels* and discuss the arrangement of electrons as students complete their activity sheet.**

Project the image *Periodic table of energy levels*.
www.middleschoolchemistry.com/multimedia/chapter4/lesson3#energy_levels

The image you project contains all of the electrons for elements 1–20. However, the periodic table on the activity sheet contains electrons only for the elements at the beginning and end of each period. Discuss the arrangement of electrons within the energy levels for these atoms and have students fill in the electrons for the other atoms.

Note*: In the energy level diagrams, the electrons are spread out evenly in the level. Some books show them spread out this way and some show them in pairs. The pairing of electrons is meant to represent that electrons are in separate orbitals within each energy level. At the middle school* *level, it is not necessary for students to learn about electron orbitals. This information is offered so that it is clearer to you why electrons are often shown in pairs in energy level diagrams and in the dot diagrams used as an extension at the end of this chapter. An orbital defines a region within an energy level where there is a high probability of finding a pair of electrons. There can be a maximum of two electrons in each orbital. This is why the electrons are often shown in pairs within an energy level.*



Tell students that the rows across on the periodic table are called *periods*.

Period 1

- *Hydrogen*
  Explain that hydrogen has 1 proton and 1 electron. The 1 electron is on the first energy level.
- *Helium*
  Explain that helium has 2 protons and 2 electrons. The 2 electrons are on the first energy level.

Period 2

- *Lithium*
  Explain that lithium has 3 protons and 3 electrons. There are 2 electrons on the first energy level and 1 electron on the second. Explain that the first energy level can only have 2 electrons so the next electron in lithium is on the next (second) level.
- *Neon*
  Explain that neon has 10 protons and 10 electrons. There are 2 electrons on the first energy level and 8 electrons on the second level.
- *Beryllium–fluorine*
  Help students fill in the correct number of electrons in the energy levels for the rest of the atoms in period 2.

Period 3

- *Sodium*
  Explain that sodium has 11 protons and 11 electrons. There are 2 electrons on the first energy level, 8 electrons on the second level, and 1 electron on the third energy level. Explain that the second energy level can only have 8 electrons so the next electron in sodium has to be on the next (third) level.
- *Argon*
  Explain that argon has 18 protons and 18 electrons. There are 2 electrons on the first energy level, 8 electrons on the second level, and 8 electrons on the third energy level. Have students complete the energy level model for argon in their periodic table.
- *Magnesium–chlorine*
  Help students fill in the correct number of electrons in the energy levels for the rest of the atoms in period 3.

Period 4

- *Potassium*
  Explain that potassium has 19 protons and 19 electrons. There are 2 electrons on the first energy level, 8 electrons on the second level, 8 electrons on the third energy level, and 1 on the fourth energy level. Explain that after the third energy level has 8 electrons, the next electron goes into the fourth level.
- *Calcium*
  Help students fill in the correct number of electrons in the energy levels for calcium.

***Note**: Students may wonder why an energy level can hold only a certain number of electrons. The answer to this is far beyond the scope of a middle school chemistry unit. It involves thinking of electrons as 3-dimensional waves and how they would interact with each other and the nucleus.*

5. Have students look for patterns in rows and columns of the first 20 elements in the periodic table.

Continue to project the image *Periodic table of energy levels for elements 1–20* and have students look at their activity sheets to find patterns in the number of electrons within each energy level.

Have students look at the periods (rows going across).
Number of energy levels in each period

- The atoms in the first period have electrons in 1 energy level.
- The atoms in the second period have electrons in 2 energy levels.
- The atoms in the third period have electrons in 3 energy levels.
- The atoms in the fourth period have electrons in 4 energy levels.

How the electrons fill in the energy levels

- First energy level = 1, 2
- Second energy level = 1, 2, 3, … 8
- Third energy level = 1, 2, 3, … 8
- Fourth energy level = 1, 2

Read more about the periodic table in the additional teacher background section at the end of this lesson.

A certain number of electrons go into a level before the next level can have electrons in it. After the first energy level contains 2 electrons (helium), the next electrons go into the second energy level. After the second energy level has 8 electrons (neon), the next electrons go into the third energy level. After the third energy level has 8 electrons (argon), the next 2 electrons go into the fourth energy level.

***Note**: The third energy level can actually hold up to 18 electrons, so it is not really filled when it has 8 electrons in it. But when the third level contains 8 electrons, the next 2 electrons go into the fourth level. Then, believe it or not, 10 more electrons continue to fill up the rest of the third level. Students do not need to know this.*

Have students look at the groups (columns going down).
Tell students that the vertical columns in the periodic table are called *groups* or *families*. Ask students to compare the number of electrons in the outermost energy level for the atoms in a group. Students should realize that each atom in a group has the same number of electrons in its outermost energy level. For instance, hydrogen, lithium, sodium, and potassium all have 1 electron on their outer energy level. Let students know that these electrons in the outermost energy level are called *valence* electrons. They are the electrons responsible for bonding, which students will investigate in the next lesson.

EXTEND

6. Compare the way different elements react chemically and relate this to their location on the periodic table.

Tell students that in the periodic table atoms in the same column, called a group, share certain characteristics and can react in a similar way.

Project the video *Sodium in water and potassium in water*.
www.middleschoolchemistry.com/multimedia/chapter4/lesson3#sodium_in_water
www.middleschoolchemistry.com/multimedia/chapter4/lesson3#potassium_in_water
Students will see that although potassium reacts more vigorously than sodium, the reactions are similar. Have students look at the periodic table to see where sodium and potassium are in relation to one another.

Project the video *Calcium in water*.
www.middleschoolchemistry.com/multimedia/chapter4/lesson3#calcium_in_water
Students will see that this reaction is different from the sodium and the potassium. Have them locate calcium on the periodic table and point out that it is in a different group than sodium and potassium.

Project the videos *Sodium in acid and potassium in acid*.
www.middleschoolchemistry.com/multimedia/chapter4/lesson3#sodium_in_acid
www.middleschoolchemistry.com/multimedia/chapter4/lesson3#potassium_in_acid
Show sodium reacting with acid and then potassium reacting with acid. The HCl is hydrochloric acid. The HNO_3 is nitric acid. Each acid is used in two different concentrations. Make sure students realize that the sodium and potassium react in a similar way even though the potassium reacts more vigorously.

Project the video *Calcium in acid*.
www.middleschoolchemistry.com/multimedia/chapter4/lesson3#calcium_in_acid
Point out that calcium reacts differently from the sodium and the potassium.

Ask students:

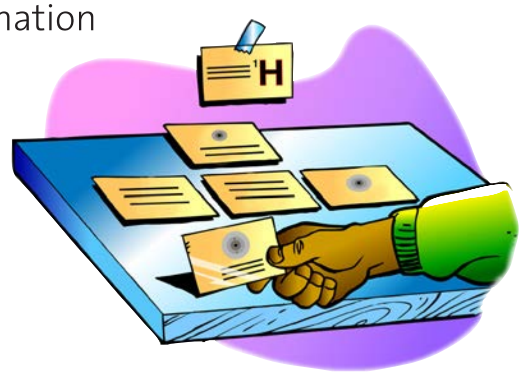
- **Do elements in the same group have similar properties and react in similar ways?**
  Students should realize that sodium and potassium are in the same group and react similarly. Calcium is near them on the periodic table, but is in a different group, so it reacts differently.

Activity Sheet
Chapter 4, Lesson 3
The Periodic Table and Energy Level Models

Name ____________________

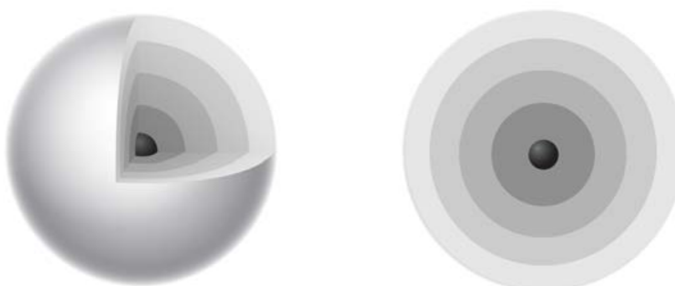
Date ____________________

Your group will receive a set of cards with information about the energy levels of a particular atom. Your job is to figure out which atom the card describes and to place it in the area in your classroom for that atom. Use the activity sheet from lesson 2 along with this activity sheet as a reference.



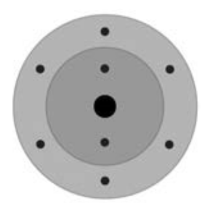
Energy levels

Electrons surround the nucleus of an atom in regions called *energy levels*. Even though atoms are spherical, the energy levels in an atom are more easily shown in concentric circles.



Which atom is this supposed to be?

The larger dot in the center of this atom represents the nucleus, which contains both protons and neutrons. The smaller dots surrounding the nucleus represent electrons. In order to figure out which atom this represents, count up the number of electrons. There are 8 electrons in this atom. Because the number of electrons and protons is the same in an atom, this atom has 8 protons. Look at the chart Periodic Table, Elements 1–20. The number of protons is the same as the atomic number, so this drawing represents an oxygen atom.

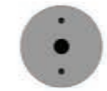


ENERGY LEVELS ELEMENTS 1–20

Complete each energy level model by drawing the correct number of electrons in their corresponding energy levels.

HYDROGEN
1

1.01

HELIUM
2

4.00

LITHIUM
3

6.94

BERYLLIUM
4

9.01

BORON
5

10.81

CARBON
6

12.01

NITROGEN
7

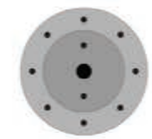
14.01

OXYGEN
8

16.00

FLUORINE
9

19.00

NEON
10

20.18

SODIUM
11

22.99

MAGNESIUM
12

24.31

ALUMINUM
13

26.98

SILICON
14

28.09

PHOSPHORUS
15

30.97

SULFUR
16

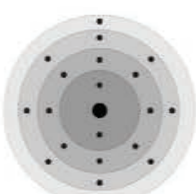
32.07

CHLORINE
17

35.45

ARGON
18

39.95

POTASSIUM
19

39.10

CALCIUM
20

40.08

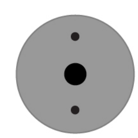
Additional Teacher Background
Chapter 4 Lesson 3, p. 291

As the note on page 292 points out, there are other ways to model the electron energy levels of atoms. Some middle school texts show the electrons in pairs on an energy level. This pairing of electrons is intended to suggest information about the substructure *within* energy levels. This substructure is made up of regions called *orbitals* which comprise each energy level. The shape and size of the orbital is defined by the space around the nucleus where there is a high probability of finding electrons. There can be a maximum of two electrons in any orbital so showing electrons in pairs on an energy level model is an attempt to suggest information about the orbitals within the level.

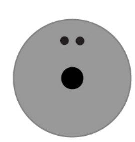
In Middle School Chemistry, we chose to spread electrons out evenly on energy levels to indicate only the *number* of electrons on a level and not to suggest anything about the substructure of orbitals *within* energy levels. An understanding that the different energy levels can accommodate a certain number of electrons seems enough for students in middle school. They will see more refined models in high school and college when they learn more details about the orbitals within energy levels.

Some teachers might like to use a different model that shows more details of orbitals because it is more complete, even if they do not intend to explain those aspects of the model in much detail. Another argument is that a model showing paired and unpaired electrons may be useful for certain discussions about bonding. Other teachers may be more comfortable showing a less-detailed model even if it leaves out certain aspects of energy levels because they do not intend to discuss those details and they intend to handle bonding in a more general way. No model can be complete and accurate for all purposes and all have limitations. All models involve aspects of judgment and compromise. A good model focuses on the important points without too much to distract from those main features. The model you choose will have a lot to do with how much you think is important to explain and what the students are able to understand.

Some energy level models you might see and what they represent
For helium (atomic number 2), the energy level model in Middle School Chemistry is:



Helium has two electrons on the first energy level.



Some other middle school texts might show an energy level model for helium like this:

The *first* energy level has only one orbital. This is known as the 1s orbital. The "1" means that it is in the first energy level and the "s" stands for an orbital within that energy level with a particular shape. This 1s orbital can hold up to two electrons. So helium has its two electrons in the 1s orbital. The practice of showing the electrons together or *paired* in an energy level is meant to indicate how many orbitals in that level have been completely occupied by two electrons. For the first energy level, the pairing is not very useful for showing which orbitals are full and which aren't because there is only one orbital. But it becomes more useful for atoms that have more orbitals where some orbitals may be filled and others not.

For boron (atomic number 5), the energy level model in Middle School Chemistry is:

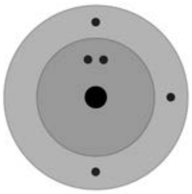
Boron has 2 electrons on the first energy level and 3 electrons on the second level.

Some other middle school texts might show an energy level model for boron like this:

The model shows that boron has two electrons in the 1s orbital of the first energy level which are shown as paired. It also has 3 electrons in the second energy level.

The second energy level is made up of four orbitals. There is a spherical orbital called 2s. The "2" means that it is in the second energy level. It is like the 1s orbital but is further from the nucleus. The second energy level also has 3 other orbitals that are all the same shape and distance from the nucleus but oriented in different directions. These orbitals are called 2p. The "p" orbitals are a different shape than the "s" orbitals. The 2s orbital can hold up to two electrons and each of the 2p orbitals can also hold up to 2 electrons. So the second energy level can hold up to eight electrons in its four orbitals. In this model of boron, two electrons are shown as paired in the 2s orbital and the last electron is shown in one of the 2p orbitals.

Another middle school text might show a model of boron like this:



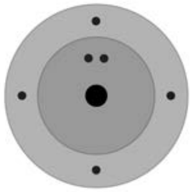
Here, they paired the electrons in the 1s orbital but did not show the detail of pairing the electrons in the 2s orbital of the second energy level. They chose to spread the three electrons out on the second energy level.

For carbon (atomic number 6), the energy level model in Middle School Chemistry is:

Carbon has 2 electrons on the first energy level and 4 on the second. Some other middle school texts might show a model of carbon like this:

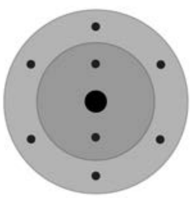
This model shows that carbon has two electrons in the 1s orbital of the first energy level which are shown as paired. It also has 4 electrons in the second energy level. In this model, two electrons are shown as paired in the 2s orbital and the other two electrons are shown separately or unpaired. This is done to indicate that each of the electrons is in a separate 2p orbital. One of the details of orbitals is that an electron goes into an empty available orbital of the same type before it goes into an orbital that already has an electron in it.

Another middle school text might show a model of carbon like this:



This model pairs the 1s electrons but spreads out the four electrons in the second energy level regardless of what orbital they are in. This approach would show electrons being paired on the second energy level for the first time in nitrogen.

For oxygen (atomic number 8), the energy level model in Middle School Chemistry is:



Oxygen has 2 electrons on the first energy level and 6 on the second. Oxygen is an interesting example because the other two types of models come out with the same result which looks like this:

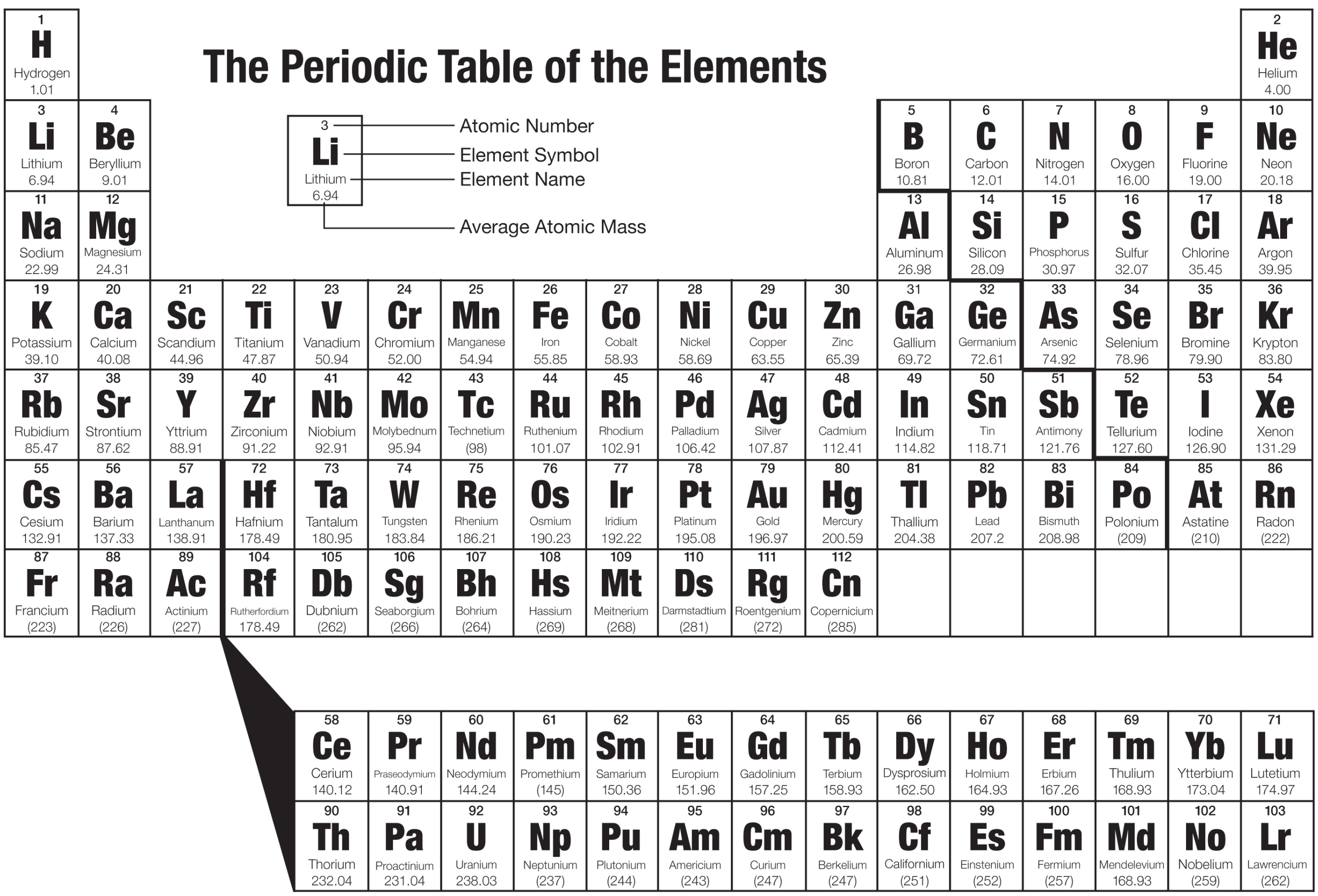
Here, the electrons are paired in the 1s orbital. In the second energy level, whether the electrons are paired in the 2s to begin with or whether they are spread out and only paired after placing 1 electron in each of the four orbitals and then adding the last two electrons to make two pairs, the result is the same.

If the energy level models in Middle School Chemistry are different than those in your text book, you can use either one to teach that energy levels only have a certain number of electrons. You could also use the difference to suggest that there is more detail about energy levels that students may learn about later.

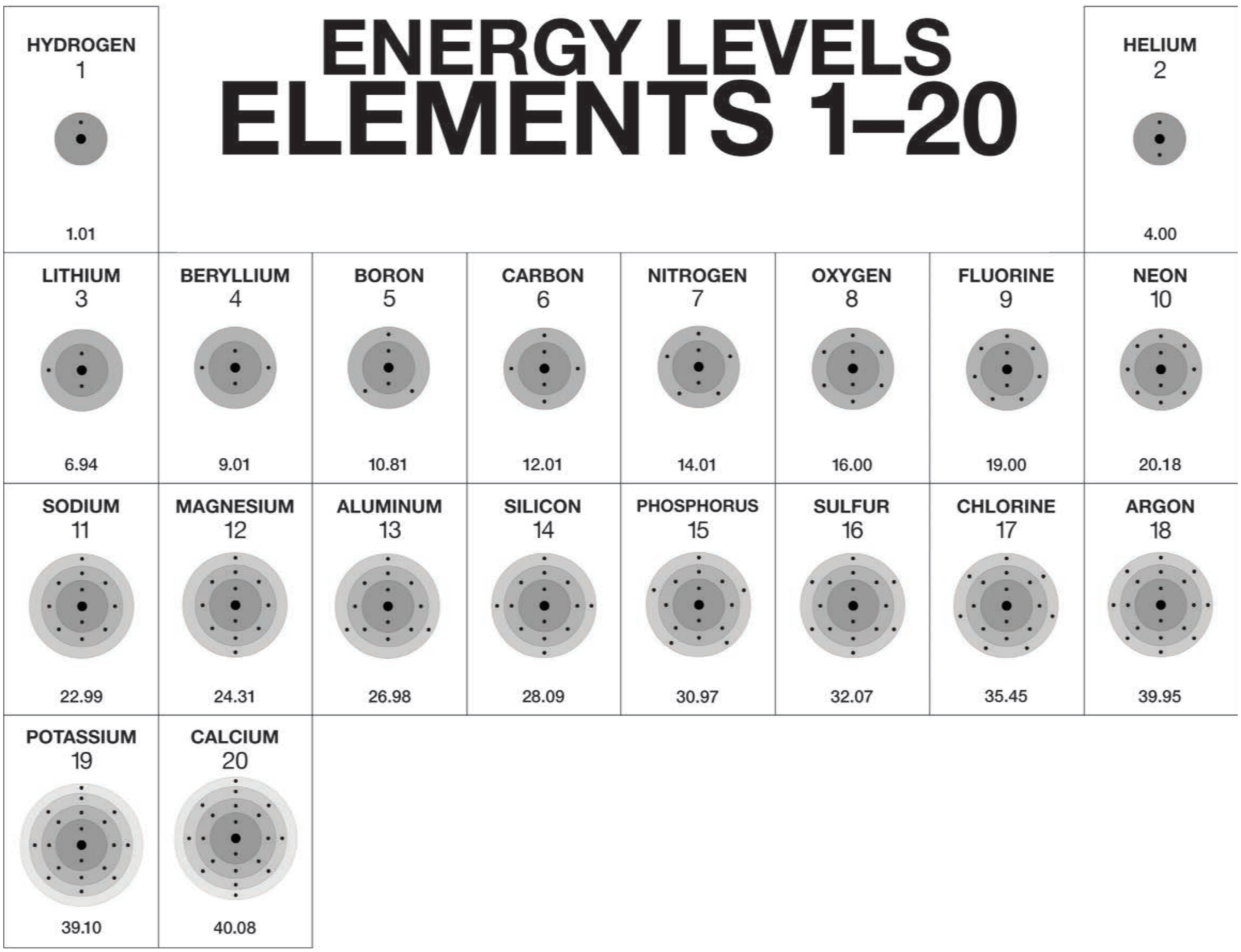
Additional Teacher Background
Chapter 4 Lesson 3, p. 295

What determines the shape of the standard periodic table?
One common question about the periodic table is why it has its distinctive shape. There are actually many different ways to represent the periodic table including circular, spiral, and 3-D. But in most cases, it is shown as a basically horizontal chart with the elements making up a certain number of rows and columns. In this view, the table is not a symmetrical rectangular chart but seems to have steps or pieces missing.

The key to understanding the shape of the periodic table is to recognize that the characteristics of the atoms themselves and their relationships to one another determine the shape and patterns of the table.



A helpful starting point for explaining the shape of the periodic table is to look closely at the structure of the atoms themselves. You can see some important characteristics of atoms by looking at the chart of energy level diagrams. Remember that an energy level is a region around an atom's nucleus that can hold a certain number of electrons. The chart shows the number of energy levels for each element as concentric shaded rings. It also shows the number of protons (atomic number) for each element under the element's name. The electrons, which equal the number of protons, are shown as dots within the energy levels. The relationship between atomic number, energy levels, and the way electrons fill these levels determines the shape of the standard periodic table.



What determines the sequence of the elements?

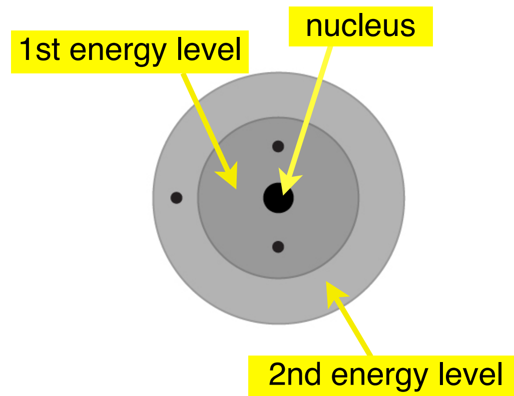
One of the main organizing principles of the periodic table is based on the atomic number (number of protons in the nucleus) of the atoms. If you look at any row, the atoms are arranged in sequence with the atomic number increasing by one from left to right. Since the number of electrons equals the number of protons, the number of electrons also increases by one from left to right across a row.

What do the rows represent?

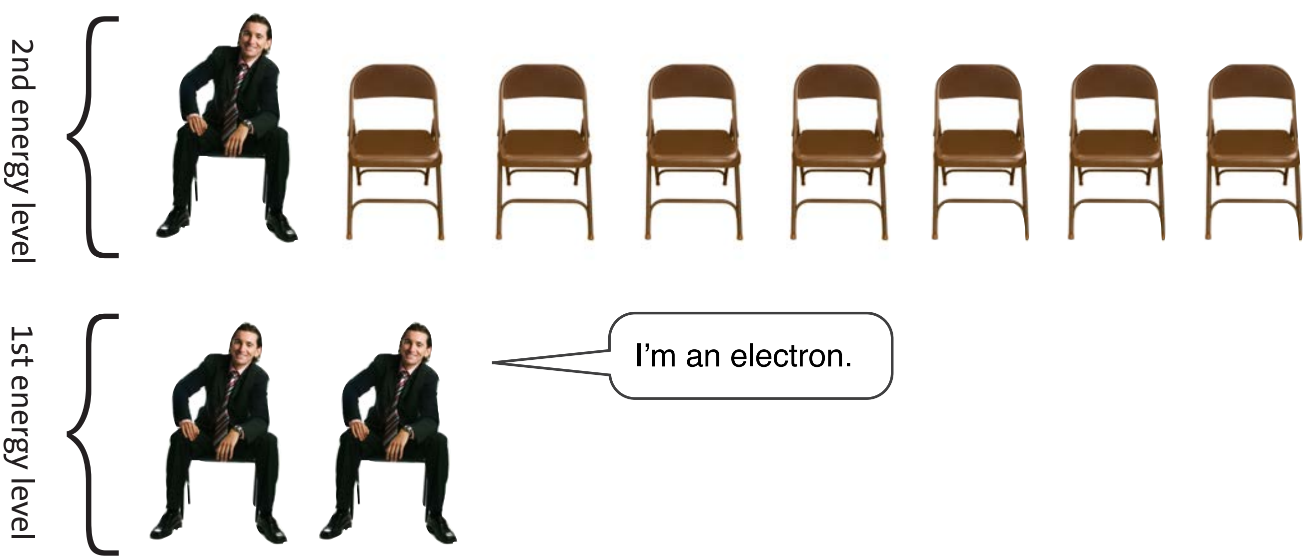
The rows in the periodic table correspond to the number of energy levels of the atoms in that row. If you look at the chart, you can see that the atoms in the first row have one energy level. The atoms in the second row have two energy levels and so on. Understanding how electrons are arranged within the energy levels can help explain why the periodic table has as many rows and columns as it does. Let's take a closer look.

Electrons and Energy Levels

Every atom contains different energy levels that can hold a specific number of electrons. For a moment, let's imagine the simplest possible scenario: once all the positions are occupied within one energy level, any remaining electrons begin filling positions in the next energy level.



To picture this, imagine people filling rows of chairs in an auditorium. If each person sits next to another person until one row is filled, any remaining people must begin taking their seats in the second row, and so on.

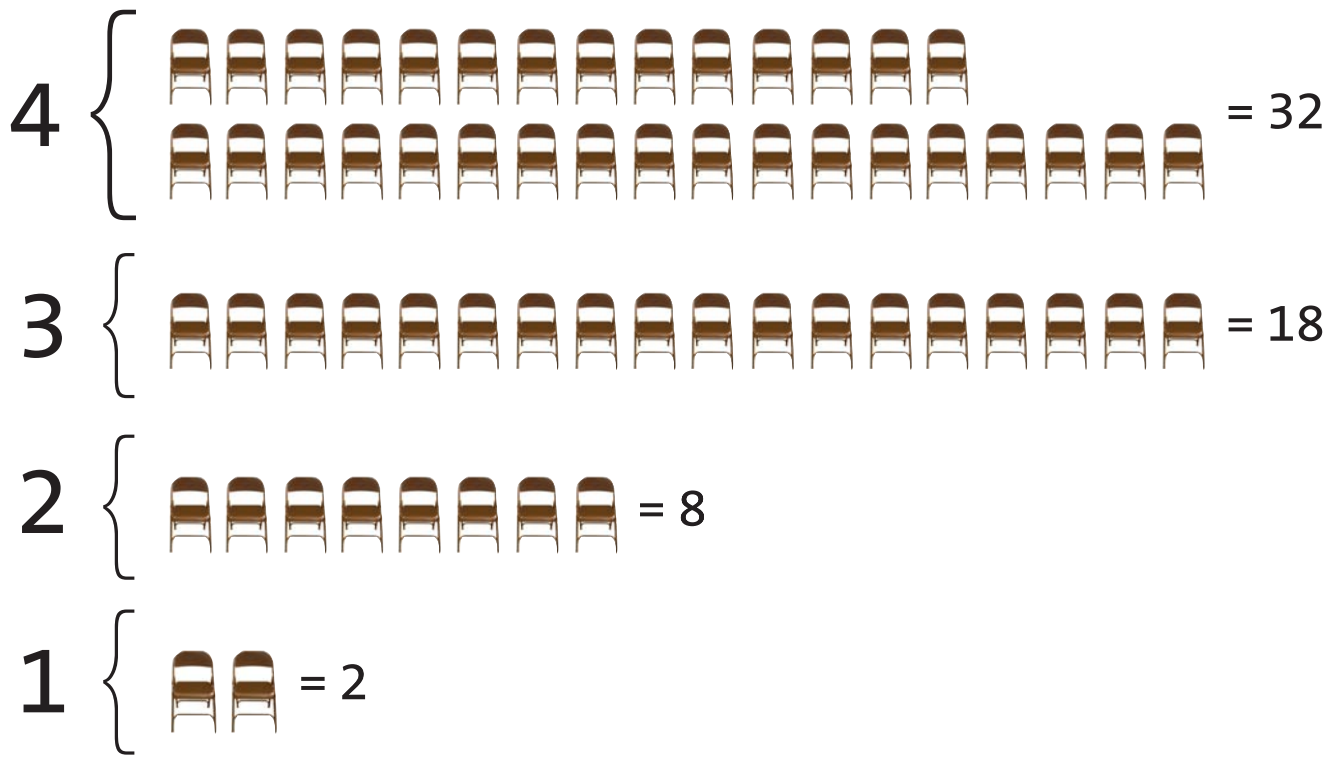


Not so bad, right? In general, this simple case is a helpful analogy. Electrons fill a given section until it is full, and then any more electrons move on to another unoccupied section where they continue filling there. Electrons begin filling the lowest energy level (closest to the nucleus) and then move on to higher energy levels (further form the nucleus). Unfortunately, the actual process is a bit more complicated. Let's see why.

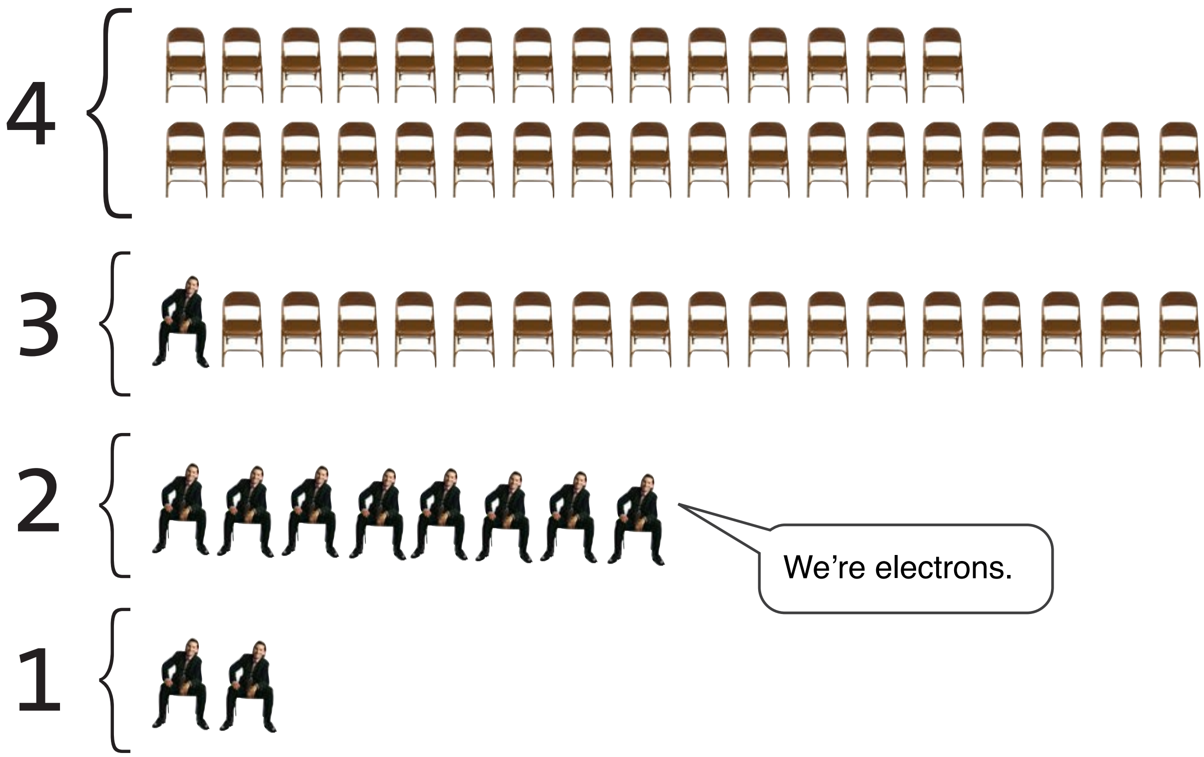
Energy Levels Can Hold Different Numbers of Electrons

One thing that is slightly tricky about electrons filling these energy levels is that not all the energy levels can hold the same number of electrons. While the first energy level can hold only 2 electrons, the second energy level can hold 8, the third can hold 18, and the fourth can hold 32. We'll stop there for now.

If we return to our rows of chairs analogy, it would be as if the first row was shorter than the second or third or fourth rows, so that after 2 people, any people remaining would have to begin occupying the second row. Then, if the second row were longer than the first row (but shorter than the third row), after 8 more people had been seated, any remaining individuals would have to begin occupying the third row.



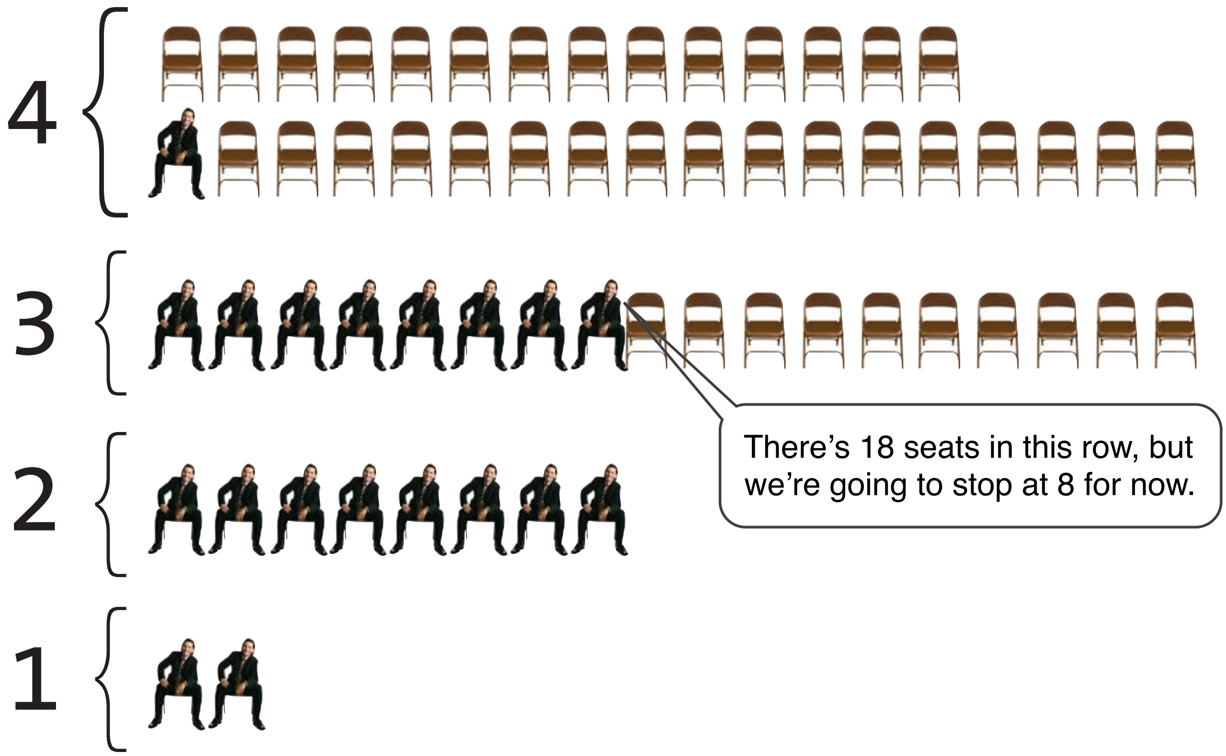
Extending our analogy of theater patrons as electrons, let's look at how the element sodium, with its 11 electrons, might fill these energy levels.



Because sodium has 11 electrons, it fills up the first energy level, which can hold only 2 electrons. It also fills up the second energy level, because it can only hold 8. Together, the first and second energy levels can hold a total of 10 electrons. Sodium has 11 electrons, so that final remaining electron that can't be accommodated by the first and second energy level begins filling in the third energy level. This pattern generally holds for the first 18 elements, up through argon, which has 18 electrons.

Energy Levels are Further Divided into Sections

But something funny happens beginning with potassium. Potassium has 19 electrons. Because the first, second, and third energy levels can hold a total of 28 electrons (2+8+18=28) it would seem that all the electrons of potassium could be "seated" within the third energy level. It turns out, however, that even though the third energy level has a total capacity of 18, only 8 "seats" are filled before the electrons begin filling the fourth energy level. So, potassium would fill up the energy levels like this:

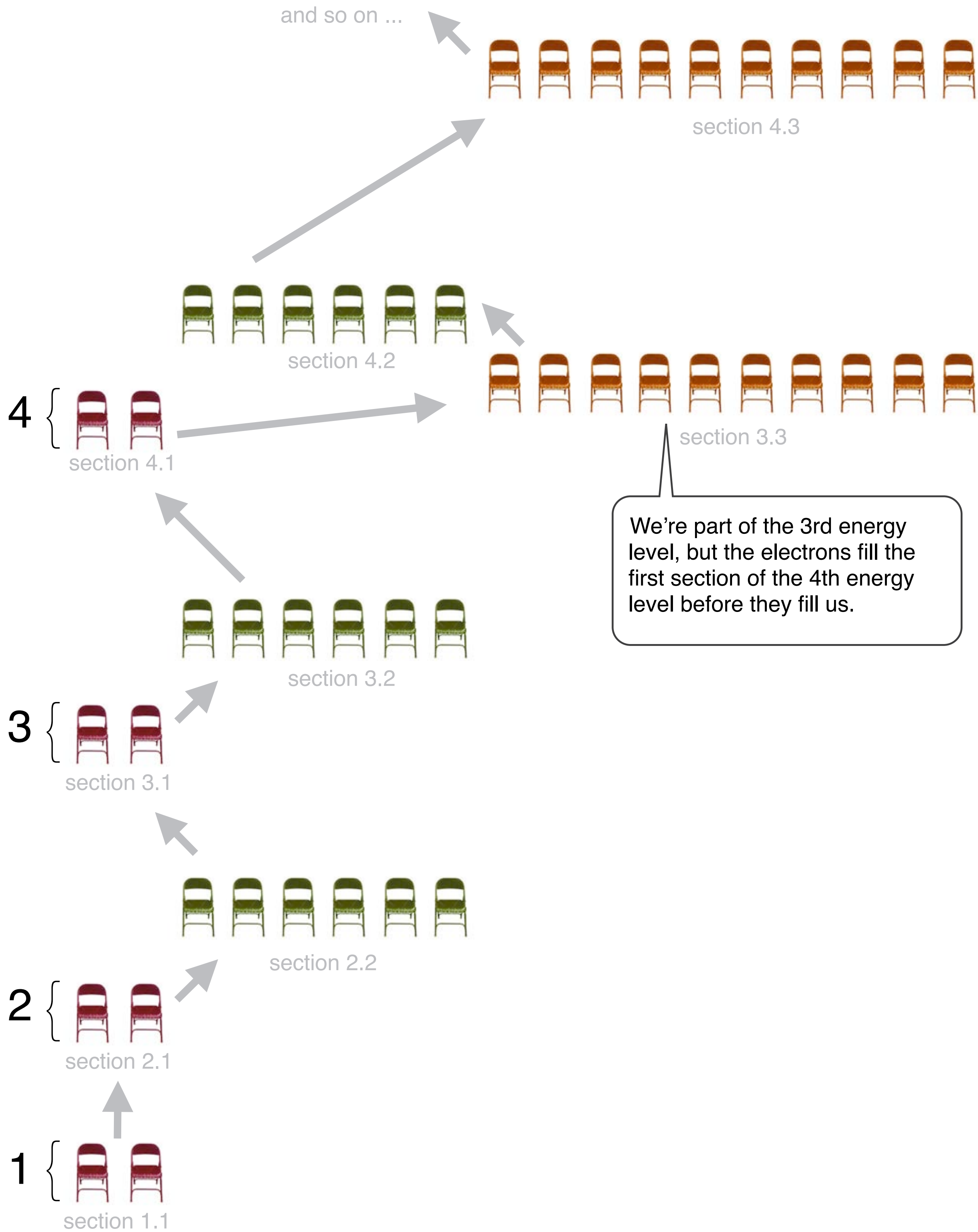


Whoa. *Whoa*. That's crazy. Why does *that* happen?

This is the second complication with our simple chairs analogy. It turns out that in addition to distinct energy levels (first, second, third, etc.) each energy level is further divided into sections where electrons can be found.

In terms of our analogy, the first row would have just one section. The second row would have two sections. The third row would have 3 sections and the fourth row would have four sections. As you can see, the number of sections an energy level has is equal to the number of that energy level.

The reason why that last electron from potassium begins filling the fourth energy level rather than continuing to fill the third energy level is that the first section of the fourth energy level is actually closer (or at lower energy) than the last section of the third energy level (the last 10 "seats"). So, really, our chairs would now look something like this:


and so on ...
section 4.3
section 4.2
4
section 4.1
section 3.3
We're part of the 3rd energy level, but the electrons fill the first section of the 4th energy level before they fill us.
section 3.2
3
section 3.1
section 2.2
2
section 2.1
1
section 1.1

Admittedly, this doesn't look much like rows of charis in an auditoruim anymore, but the idea is still the same. Electrons will continue filling energy levels, one section at at time, until all the electrons are used up. When one section of the next energy level is actually lower in energy than the next section of the same energy level, the electrons will begin filling there. This is what we depicted in the diagram for potassium. Its last electron filled the first section in the fourth energy level, because that section was actually closer (at lower energy) than the last section of the third energy level.

Eventually, the electrons will continue filling the empty section in the third energy level. The idea is exactly what we've just described. Unusual as it might seem, in some cases, the first section of the next energy level is filled before the electrons continue to fill the last section of the preceding energy level.

Consider, for example, the element Iron. Its 26 electrons would fill energy levels like this: