Edgenuity

Warm-Up | Atomic Numbers and Electron Configurations

Lesson Objectives

By the end of this lesson, you should be able to:

- Identify electron [configurations] as a scientific model, and explain its usefulness and limitations.
- Express the [arrangement] of electrons of atoms using electron configurations.
- Use atomic orbitals to write quantum numbers for electrons.

Science Practice: Use specific symbols to represent the arrangement of electrons in [atoms].

Words to Know

Fill in this table as you work through the lesson. You may also use the glossary to help you.

angular momentum quantum number	the number that describes the shape of an orbital
aufbau principle	the principle that states that an atom's electron configuration is developed by progressively adding electrons that assume their most stable conditions in electron orbitals with respect to the nucleus and the other electrons
electron configuration	a representation that shows how electrons are positioned in an atom
electron spin quantum number	the number that describes the spin or orientation of an individual electron within an orbital
electron subshell	a set of orbitals with the same principal quantum number, *n*, and the same angular momentum quantum number, *l*

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Words to Know

Hund's rule	the rule that in the ground state, electrons in the same sublevel (*p*, *d*, or *f*) are placed in individual orbitals before they are paired up in order to increase atomic stability
magnetic quantum number	the number that describes the orientation of an orbital in space
orbital notation	a diagram that uses lines and arrows to show shells, subshells, and orbitals for electrons in an atom
orbitals	the regions that surround the nucleus and in which the electrons are located
Pauli exclusion principle	the principle that states that no two electrons in the same atom can have the same four quantum numbers; orbitals may contain only one or two electrons that have opposite spin
principal quantum number	the number that describes the size of the orbital
quantum numbers	the numbers that describe the location of an electron in an atom
shell	the electron configuration around the nucleus of an atom in which the electrons share the same principal quantum number

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Lesson Question

How can scientists describe the arrangement of electrons in an atom?

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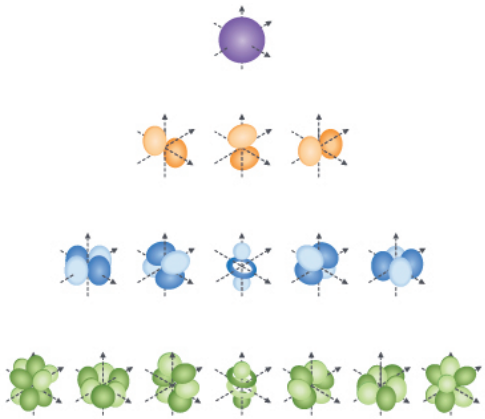
Quantum Orbitals

In the electron cloud model, electrons exist in orbitals.

- **Orbital**: location in an atom where an electron can be
- **Quantum number**: describes the location of the electron
  - *n* (principal **quantum number**) = orbital size
  - *l* (angular **momentum quantum number**) = orbital shape
  - *m* (magnetic **quantum number**) = orbital orientation



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Quantum Number Combinations

Quantum numbers cannot have any random [value].

- Quantum numbers are always integers.
- Possible values of *l* depend on the value of *n* for a given [orbital].
- Possible values of *m* depend on the value of *l* for a given orbital.

Quantum No.	Possible Values
n	Nonzero positive integers (1, 2, 3, 4, . . .)
l	[Positive] integers between 0 and *n* – 1
m	Integers between –*l* and +*l*

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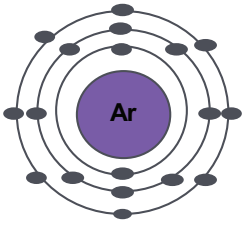
Electron Shell

An **electron shell** is a set of orbitals with the same principal quantum number, *n*.

- [Shells] are filled consecutively in atoms.
- Shells hold different numbers of electrons.
- Full shells are more [stable].
- Shells are often represented by [circles].



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Electron Subshells

An **electron subshell** is a set of orbitals with the same [principal] quantum number, *n*, and the same angular [momentum] quantum number, *l*.

- Represented by letters
  - *s*: $l = 0$
  - *p*: $l = 1$
  - *d*: $l = 2$
  - *f*: $l = 3$
- Values of [*m*] indicate number of subshells of each type

How to Calculate the Number of Electrons

How many electrons can the $n = 3$ shell hold?

- $n = 3$, so $l = 0$, 1, or 2
- Identify subshells:
  - 3*s* ($l = 0$, $m = 0$)
  - 3*p* ($l = 1$, $m = –1, 0, 1$)
  - 3*d* ($l = 2$, $m = –1, –2, 0, 1, 2$)
- Calculate number of orbitals
- Determine [number] of electrons (2 × number of orbitals)
- Total number of electrons = 2 + 6 + 10 = [18]
- Total number of electrons = [$2n^2$]

Subshell	No. of Orbitals	No. of Electrons
3s	1	2
3p	3	6
3d	5	10

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Electron Configuration and Orbital Notation

Electron configuration shows how electrons are [positioned] in an atom.

Orbital notation for H

Orbital notation is a diagram that uses lines and arrows to show shells, [subshells], and orbitals for electrons in an atom.

Orbital Notation for He

- Lines represent unoccupied orbitals.
- Numbers and letters on the bottom represent the orbital name.
- Arrows represent the [electrons].

The Pauli Exclusion Principle

The **Pauli exclusion principle** states that no two electrons can have identical quantum numbers.

- Fourth quantum number: electron [spin] quantum number, m_s
  - Values of +½ or –½
  - Indicated with arrows
- Explains two electrons per [orbital]

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Orbital Notation

Write the orbital notation for lithium and beryllium.

- Identify the number of electrons from the periodic table.

	Number of electrons
lithium	3
beryllium	4

- Fill the orbitals in order.

Li $\underset{1s}{\uparrow\downarrow}$ $\underset{2s}{\boxed{\uparrow}}$

Be $\underset{1s}{\uparrow\downarrow}$ $\underset{2s}{\boxed{\uparrow\downarrow}}$

Electrons always go to the lowest energy state, and once that is filled (two e- per orbital), then proceed to the next orbital, subshell, or shell.

Subshell	*n*	*l*	Max No. of Electrons
1*s*	1	0	2
2*s*	2	0	2
2*p*	2	1	6
3*s*	3	0	2
3*p*	3	1	6
3*d*	3	2	10
4*s*	4	0	2
4*p*	4	1	6
4*d*	4	2	10
4*f*	4	3	14

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Orbital Notation

Write the orbital notation for boron and carbon.

- Identify the number of electrons from the periodic table.

	Number of electrons
boron	5
carbon	6

- Fill the orbitals in order.

B $\frac{\uparrow\downarrow}{1s}$ $\frac{\uparrow\downarrow}{2s}$ $\frac{\uparrow}{2p}$

C $\frac{\uparrow\downarrow}{1s}$ $\frac{\uparrow\downarrow}{2s}$ $\frac{?}{2p}$

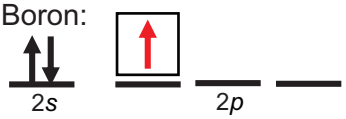
While writing the orbital notation of elements, you should keep in mind that $n = 2$ has two subshells, *s* and *p*; *s* has [one] orbital, and [*p*] has up to three orbitals. Make sure to show all three 2*p* [orbitals].

Hund's Rule

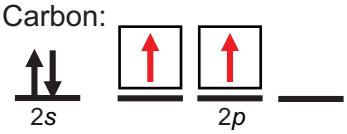
Hund's rule states that electrons in the same sublevel (*p*, *d*, or *f*) are placed in individual orbitals, before they are paired up, to increase atomic [stability]. Electrons added to empty orbitals have the same [spin] quantum number.

Draw arrows to represent the additional electrons in each orbital.

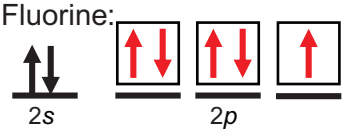
Boron:



Carbon:



Fluorine:



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The Aufbau Principle

The **aufbau principle** states that electrons fill orbitals from lowest energy to [highest] energy.

- Electrons generally fill from lower *n* to higher *n*.
  - *d* and *f* [orbitals] are an exception.

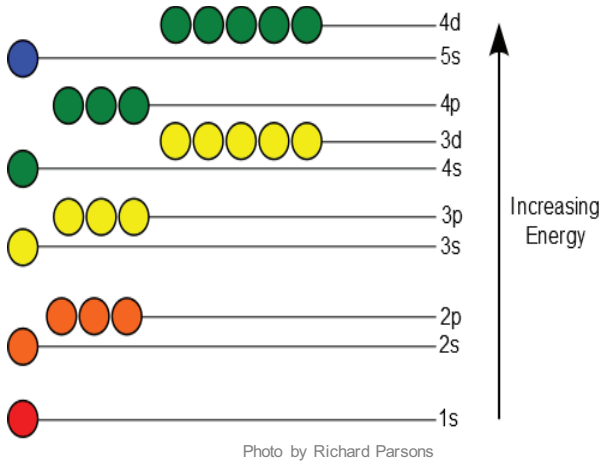


Photo by Richard Parsons

How to Apply the Aufbau Principle in Writing Electron Configurations

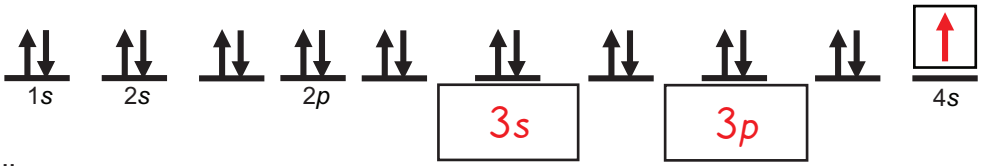
Write the electron configurations for potassium and vanadium.

- Identify the number of electrons from the periodic table.

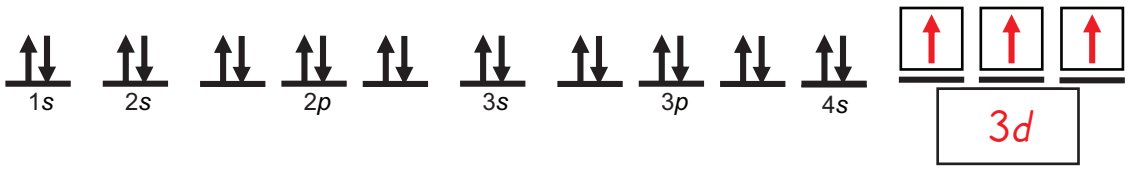
	Number of electrons
potassium	19
vanadium	23

- Fill the orbitals in order.

Potassium:



Vanadium:



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How to Use the Diagonal Rule to Write Electron Configurations

Write the complete electron configurations for cobalt (Co).

- Identify the number of electrons from the periodic table.

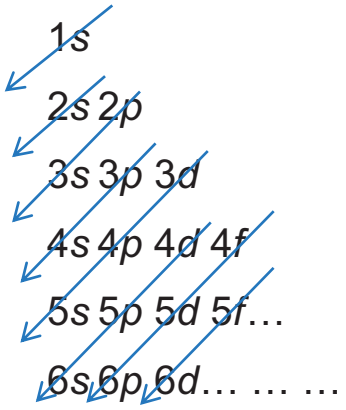
	Number of electrons
cobalt	27

- Fill the subshells according to the aufbau principle until the correct number of electrons is reached.

$1s^2, 2s^2, 2p^6, 3s^2, 3p^6,$ [$4s^2$], [$3d^7$]

- Check your work

$2 + 2 + 6 + 2 + 6 + 2 + 7 =$ [27]



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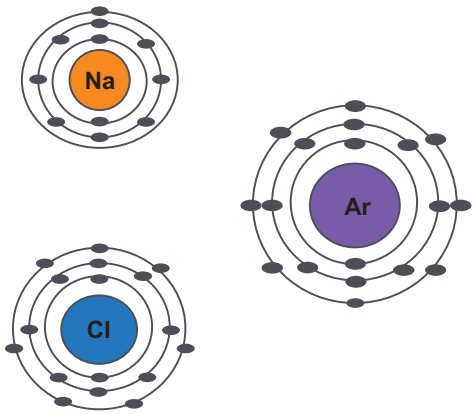
Representing Electrons: Dot Structures

Dot Structures

- Circle = electron shell
- Dot = electron
- Does not show size, shape, orientation of orbitals/ electrons accurately
- Convenient way of showing distribution of electrons in electron shells



Summary | Atomic Numbers and Electron Configurations

Lesson Question

How can scientists describe the arrangement of electrons in an atom?

Answer

(Sample answer) The arrangement of electrons in an atom can be described by writing out the orbital notation, which uses lines and arrows to show shells, subshells, and orbitals; writing out the electron configuration, which shows the sequence of how electrons fill the orbital shells; and dot structures, which show a rough idea of the physical structure of the atom.

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Four Quantum Numbers

- The principal quantum number, *n*, describes the [size] of the orbital.
- The [angular] momentum quantum number, *l*, describes the shape of the orbital (*s*, *p*, *d*, and *f*).
- The [magnetic] quantum number, *m*, refers to the orientation of the orbitals.
- The magnetic spin quantum number, [m_s], describes the spin or orientation of an individual electron within an orbital.

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Quantum Numbers

- The principal quantum number, *n*, describes the size of the orbital and can have positive integer values.
- The angular momentum quantum number, *l*, describes the shape of the orbital and can have integer values from 0 to $n - 1$.
- The magnetic quantum number, *m*, describes the orientation of the orbital in space and can have integer values from $-l$ to $+l$.

Shells and Subshells

- An electron shell is a group of orbitals that has the same value of *n*, ranging from one to seven.
- An energy sublevel (electron subshell) is a group of orbitals that has the same values of *n* and *l*.
- Subshells are represented by letters. The $l = 0$ subshells are called *s* subshells, the $l = 1$ subshells are called *p* subshells, the $l = 2$ subshells are called *d* subshells, and the $l = 3$ subshells are called *f* subshells.
- The number of orbitals in each type of subshell varies. An *s* subshell contains one orbital, a *p* subshell contains three orbitals, a *d* subshell contains five orbitals, and an *f* subshell contains seven orbitals.
- Each orbital can hold a maximum of two electrons, so it is possible to calculate the maximum number of electrons each shell or subshell can contain.

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Electron Configurations

- Electrons fill orbitals in an atom in a specific order.
- Hund's rule, the Pauli exclusion principle, and the aufbau principle dictate the order in which orbitals are filled.
- The configuration of electrons in an atom can be represented using orbital notation, written electron configurations, or dot structures.
- Each model of electron configuration has strengths and weaknesses.

Use this space to write any questions or thoughts about this lesson.