

ChemQuest 13

Electron Configurations

Name: _____

Date: _____

Hour: _____

Information: Energy of Sublevels

Each sublevel has a different amount of energy. For example, orbitals in the 3p sublevel have more energy than orbitals in the 2p sublevel. The following is a list of the sublevels from lowest to highest energy:

1s, 2s, 2p, 3s, 3p, 4s, 3d, 4p, 5s, 4d, 5p, 6s, 4f, 5d, 6p, 7s, 5f, 6d...

To help you, here is the above list with the orbitals included. Recall that each blank represents an orbital:

1s⁻, 2s⁻, 2p⁻⁻⁻, 3s⁻, 3p⁻⁻⁻, 4s⁻, 3d⁻⁻⁻⁻⁻, 4p⁻⁻⁻, 5s⁻, 4d⁻⁻⁻⁻⁻, 5p⁻⁻⁻, 6s⁻, 4f⁻⁻⁻⁻⁻

Note that d and f sublevels appear to be out of place. This is because they have extra high energies. For example, the 3d sublevel has a higher energy than a 4s sublevel and the 4f sublevel has a higher energy than the 6s sublevel.

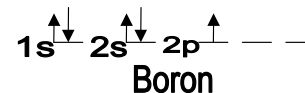
When electrons occupy orbitals, they try to have the lowest amount of energy possible. (This is called the *Aufbau Principle*.) An electron will enter a 2s orbital only after the 1s sublevel is filled up and an electron will enter a 3d orbital only after the 4s sublevel is filled. Recall that only two electrons can fit in each orbital. (This is called the *Pauli Exclusion Principle*.) When two electrons occupy the same orbital they must spin in opposite directions—one clockwise and the other counterclockwise.

Critical Thinking Questions

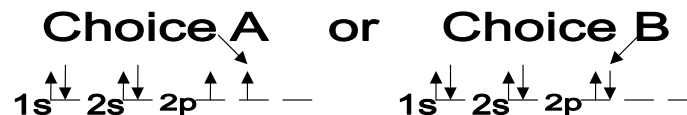
- How many electrons would an atom need to have before it can begin filling the 3s sublevel?
10; Before the 3s can be filled, all these orbitals must be filled with two electrons in each orbital: 1s⁻ 2s⁻ 2p⁻⁻⁻
 - What is the first element that has enough electrons to have one in the 3s sublevel? (Use your periodic table.)
The 11th electron goes into the 3s sublevel. The atom with 11 electrons is sodium.
- How many electrons would an atom need to have before it can begin filling the 3d sublevel?
20 electrons because all of these orbitals need to be filled: 1s⁻ 2s⁻ 2p⁻⁻⁻ 3s⁻ 3p⁻⁻⁻ 4s⁻
 - What is the first element that has enough electrons to begin placing electrons in the 3d sublevel?
The 21st electron goes into the 3d sublevel. The atom with 21 electrons is scandium.

Information: Hund's Rule

Electrons can be "paired" or "unpaired". Paired electrons share an orbital with their spins parallel. Unpaired electrons are by themselves. For example, boron has one unpaired electron. Boron's orbital diagram is below:

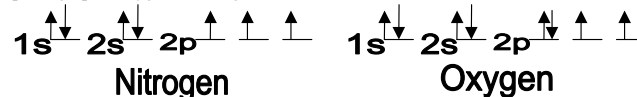


If we added one more electron to boron's orbital diagram we will get carbon's orbital diagram. One important question is: where does the next electron go? The electron has a choice between two equal orbitals—which of the 2p orbitals will it go in?

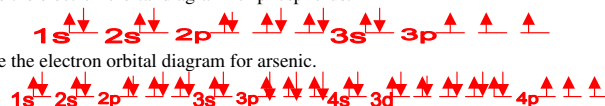


Hund's rule tells us which of the above choices is correct. **Hund's rule** states: when electrons have a choice of entering two equal orbitals they enter the orbitals so that a maximum number of unpaired electrons result. Also, the electrons will have parallel spins. Therefore Choice A is carbon's actual orbital diagram because the p electrons are in separate orbitals and they have parallel spins!

The following are the electron orbital diagrams for the next elements, nitrogen and oxygen. Notice that nitrogen's 2p electrons are all unpaired to obey Hund's Rule. The 2p electrons are forced to begin pairing up in oxygen's configuration.

**Critical Thinking Questions**

- How many "unpaired" electrons are in a nitrogen atom? 3
- Why does carbon's sixth electron have to go into another p orbital? Why can't it go into a 2s orbital? Why can't it go into a 3s orbital?
The 2s sublevel is already full. It can't go into a 3s orbital until all of the 2p orbitals are filled.
- Write the electron orbital diagram for phosphorus.
- Write the electron orbital diagram for arsenic.



7. Compare the orbital diagrams for nitrogen (given above), phosphorus and arsenic. What is similar about the electrons in the last sublevel for each of them?

They all have 3 electrons in a p sublevel.

Information: Electron Configurations vs. Orbital Diagrams

The electron orbital diagram of an atom can be abbreviated by using what is called **electron configurations**. The following is the electron configuration for carbon: $1s^2 2s^2 2p^2$. The following is the electron configuration for several elements whose orbital diagrams are given above:

Carbon: $1s^2 2s^2 2p^2$ nitrogen: $1s^2 2s^2 2p^3$ oxygen: $1s^2 2s^2 2p^4$

Critical Thinking Questions

8. What are the small superscripts (for example, the ⁴ in oxygen) representing in an electron configuration?
The superscripts tell us how many electrons are in the sublevel. The 4 in oxygen tells us that there are 4 electrons in the 2p sublevel.
9. What information is lost when using electron configurations instead of orbital diagrams? When might it be more helpful to have an orbital diagram instead of an electron configuration?
We cannot tell as easily if the electrons are unpaired or paired. It would be more helpful to have an orbital diagram when evaluating paired or unpaired electrons.
10. How many unpaired electrons are in a sulfur atom? What did you need to answer this question— an orbital diagram or an electron configuration?
There are two unpaired electrons. The orbital diagram was necessary (below).



11. Write the electron configuration for zirconium (atomic # = 40).
 $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^{10} 4p^6 5s^2 4d^2$
12. Write the configuration for argon (atomic # = 18).
 $1s^2 2s^2 2p^6 3s^2 3p^6$
13. Write the electron configuration for calcium (atomic # = 20). Notice that calcium has all of argon's electrons plus two additional ones in a 4s orbital.
 $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2$