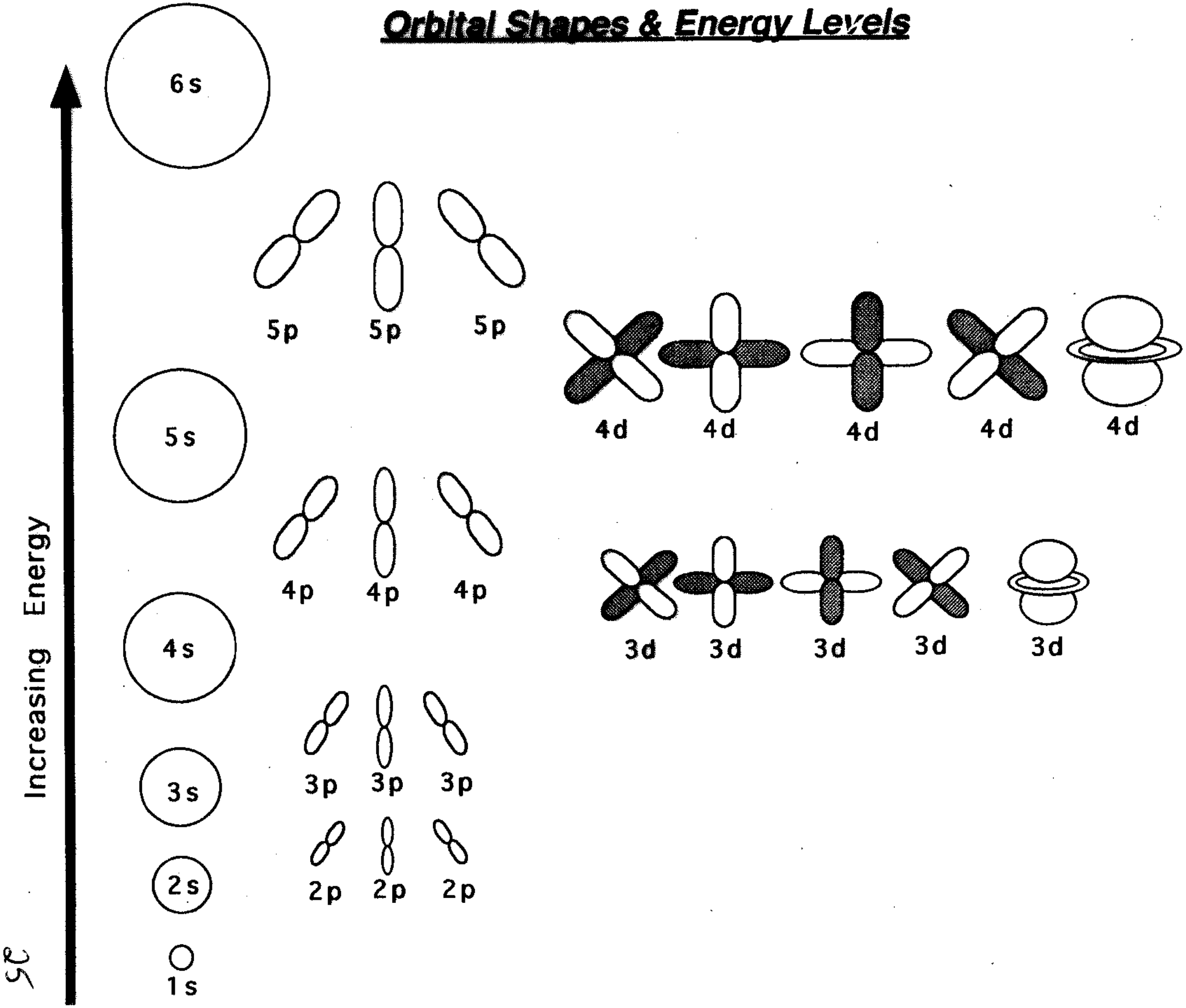
Orbital Shapes & Energy Levels



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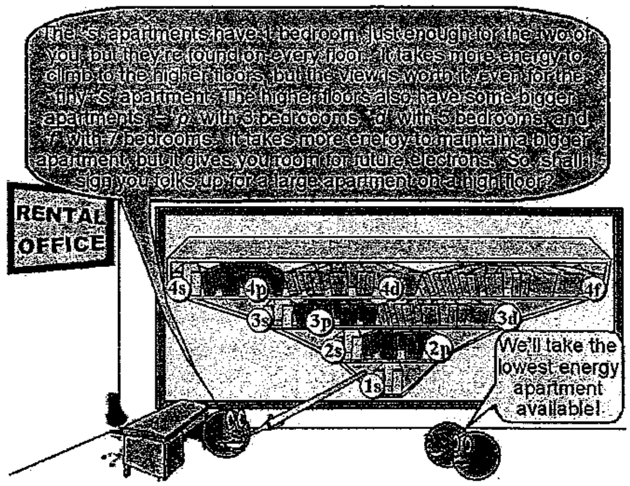
Location of Electrons

Electrons are in regions of the atom known as orbitals. Roughly speaking, they are located in principal energy levels similar to the shells or energy levels of the Bohr model. Each of the energy levels is designated by a quantum number, *n*, from 1 to 7. None of the known elements has atoms with more than 7 principal energy levels. The principal energy level with the lowest energy is 1. The highest is 7. Principal energy levels can be thought of as being subdivided into energy sublevels. The maximum number of sublevels in a principal energy level is *n*, but none of the existing elements use more than 4 sublevels even in principal energy levels 5–7. Sublevels are designated by the letters s, p, d, and f, in increasing order of energy The orbitals are regions within a sublevel where electrons of a given energy are likely to be found. There are a maximum of 2 electrons in an orbital. A useful analogy to help you visualize this is an apartment building. Each floor represents a different principal energy level. Each apartment represents a sublevel. Each bedroom represents an orbital. The electrons are the tenants in the bedrooms. Electrons are most likely to be found in the lowest energy locations available. Knowing this, it is possible to figure out how the electrons are arranged in an atom.



The most common difficulty renting to electrons

The number of orbitals within a sublevel varies in a predictable pattern. The number of orbitals within a sublevel and the maximum number of electrons is as follows:

Sublevel	s	p	d	f
Number of orbitals	1	3	5	7
Maximum Number of Electrons	2	6	10	14

The first energy level has only one sublevel, s; the second energy level has two sublevels, s and p; the third energy level has three sublevels, s, p, and, d; and so on. This results in the pattern shown below.

Summary

Principal Quantum Number (n)	Number of Orbitals (n^2)	Orbitals per Sublevel				Maximum Number of Electrons ($2n^2$)
		s	p	d	f	
1	1	1	-	-	-	2
2	4	1	3	-	-	8
3	9	1	3	5	-	18
4	16	1	3	5	7	32

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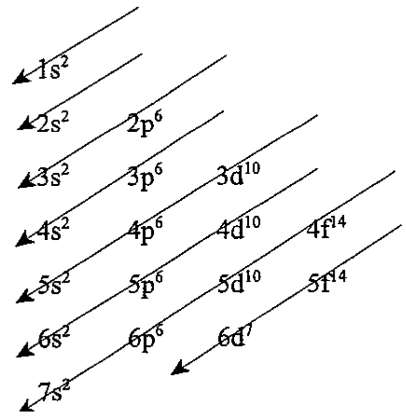
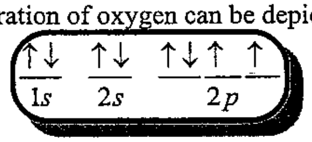
The electrons are arranged according to the following rules:

1. the number of electrons equals the number of protons (atomic number)
2. electrons occupy orbitals in sequence beginning with those of the lowest energy (see diagram to the right)
3. in a given sublevel, a second electron is not added to an orbital until each orbital in the sublevel contains one electron



This results in the order of filling for elements 1 to 109 pictured to the right. Follow each arrow from beginning to end. Then go to the beginning of the next arrow down. When you follow this pattern, you will note that no more than four orbitals are occupied in the outermost principal energy level. This is because, once the p sublevel is filled, the next energy sublevel is always the s in the next principal energy level. Oxygen has 8 protons and 8 electrons. Its electron configuration in sublevel notation is as follows: $1s^2 2s^2 2p^4$. This means there are 2 electrons in the first level and 6 in the second (add the superscripts). As a result the electron arrangement can also be written as follows: 2–6. This is known as Bohr notation.

Remember, electrons never pair in an orbital until every orbital in a sublevel has an electron. When they do pair, they spin in opposite directions. This reduces the repulsion between them. The opposite spins of the electrons are represented by up arrows and down arrows. The electron configuration of oxygen can be depicted as follows:



Each horizontal line represents an orbital in a sublevel. Each arrow represents an electron in an orbital. This is called orbital notation.

For each of the elements below, write the sublevel notation, the Bohr notation, and the orbital notation.

Element	Atomic Number	Electron Configuration		
		Sublevel Notation	Bohr Notation	Orbital Notation
H	1			
N	7			
Ca	20			
Al	13			
Cu	29			
C	6			
Ar	18			
Na	11			
S	16			
Ne	10			
P	15			

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Element	Atomic number	Atomic Mass	# of Protons	# of neutrons	# of electrons	Electron Configuration. (both ways)	Valence electrons
C	6	12.0111 AMU	6	6	6	↑↓ (1s) ↑↓ (2s) ↑ (2p) ↑ (2p) _ (2p) $1s^2 2s^2 2p^2$	4
Cl^-							
Na^+							
Al							
Li							
H							
Ca^{+2}							
Ne							
He							
Mg							
S							
Ar							
Be							
N							
P							
B							
O^{-2}							
F							
Si							

Sublevels

1. An orbital is a region of space where there is a high probability of finding

A) a proton B) a positron
C) a neutron D) an electron

2. Which phrase describes an atom?

A) a positively charged electron cloud surrounding a positively charged nucleus
B) a positively charged electron cloud surrounding a negatively charged nucleus
C) a negatively charged electron cloud surrounding a positively charged nucleus
D) a negatively charged electron cloud surrounding a negatively charged nucleus

3. What is the total number of sublevels in an atom's fourth principal energy level?

A) 8 B) 16 C) 3 D) 4

4. What is the maximum number of electrons in an orbital of any atom?

A) 1 B) 2 C) 6 D) 10

5. What is the total number of sublevels in the fourth principal energy level?

A) 1 B) 2 C) 3 D) 4

6. What is the total number of sublevels in the third principal energy level?

A) 1 B) 2 C) 3 D) 4

7. What is the total number of sublevels in the second principal energy level?

A) 1 B) 2 C) 3 D) 4

8. A maximum of 6 electrons can occupy

A) an *s* orbital B) an *s* sublevel
C) a *p* orbital D) a *p* sublevel

9. The total number of sublevels in the fourth principal energy level of an atom is

A) 1 B) 2 C) 3 D) 4

10. Which statement describes a concept included in the wave-mechanical model of the atom?

A) Positrons are located in shells outside the nucleus.
B) Neutrons are located in shells outside the nucleus.
C) Protons are located in orbitals outside the nucleus.
D) Electrons are located in orbitals outside the nucleus.

11. Which principal energy level has a maximum of three sublevels?

A) 1 B) 2 C) 3 D) 4

12. What is the maximum number of electrons that can occupy the second principal energy level?

A) 6 B) 8 C) 18 D) 32

13. The total number of *d* orbitals in the third principal energy level is

A) 1 B) 5 C) 3 D) 7

14. Which of the following sublevels contains the greatest number of orbitals?

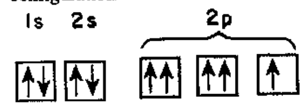
A) *p* B) *s* C) *f* D) *d*

15. Which group of atomic models is listed in historical order from the earliest to the most recent?

A) hard-sphere model, wave-mechanical model, electron-shell model
B) hard-sphere model, electron-shell model, wave-mechanical model
C) electron-shell model, wave-mechanical model, hard-sphere model
D) electron-shell model, hard-sphere model, wave-mechanical model

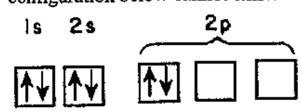
Box and Arrow and excited state

1. Which of the following explains why the electron configuration below cannot exist?



A) Hund's rule
B) Pauli exclusion principle
C) Heisenberg uncertainty principle
D) Bohr's model of the atom
E) It can exist

2. Which of the following explains why the electron configuration below cannot exist?



A) Hund's Rule
B) Pauli exclusion principle
C) Heisenberg uncertainty principle
D) Rutherford's empty space model
E) It can exist

3. Which of the following is the correct electron configuration for a neutral atom of oxygen in the ground state?

A) $1s^2 2p^4$ B) $1s^2 2s^4$
C) $1s^2 2s^2 2p^2$ D) $1s^2 2s^2 2p^4$
E) $1s^2 2s^2 2p^6 3s^2 3p^4$

4. Which of the following could not represent the electron configuration of a neutral atom in the ground state?

A) $1s^2 2s^2 2p^6 3s^2 3p^4$ B) $1s^2 2s^2 2p^2$
C) $1s^2 2s^2 2p^6 3s^3 3p^4$ D) $1s^2 2s^2 2p^6 3s^2$
E) $1s^2 2s^2 2p^6 3s^1$

5. Base your answer to the following question on the choices below.

(A) Pauli exclusion principle
(B) Heisenberg uncertainty principle
(C) Hund's rule
(D) Wave nature of matter
(E) Photoelectric effect

Which states that electrons half fill an orbital with parallel spin, before completely filling it?

A) A B) B C) C D) D E) E

6. The ground state electronic configuration for an atom of neon, $^{20}_{10}Ne$, is

A) $1s^2 2s^2$ B) $1s^2 2s^2 2p^6$
C) $1s^2 2s^2 2p^6 3s^1$ D) $1s^2 2s^2 2p^6 3s^2 3p^6$
E) $1s^2 2s^4 2p^4$

7. Which species has the same number of electrons as the magnesium ion, Mg^{2+}?

A) Ca^{2+} B) Na^+ C) F D) Ne^+ E) Ba^{2+}

8. The atomic number of an element whose electronic configuration is $1s^2 2s^2 2p^1$ is

A) 1 B) 2 C) 3 D) 4 E) 5

9. The electronic configuration of the S^{2-} ion is

A) $1s^2 2s^2 2p^6 3s^2 3p^2$ B) $1s^2 2s^2 2p^6 3s^2 3p^4$
C) $1s^2 2s^2 2p^6 3s^2 3p^5$ D) $1s^2 2s^2 2p^6 3s^2 3p^6$
E) $1s^2 2s^2 2p^6 3s^4 3p^4$

10. The electronic configuration of the neon atom, $^{20}_{10}$ Ne, is

A) $1s^2 2s^2 2p^6$
B) $1s^2 2s^2 2p^6 3s^1$
C) $1s^2 2s^2 2p^6 3s^2$
D) $1s^2 2s^2 2p^6 3s^2 3p^6 3d^2$
E) $1s^2 2s^2 2p^6 3s^2 3p^8$

11. The shell electron configuration of nitrogen, $_7N$, is

A) 2, 5 B) 2, 7
C) 2, 8, 4 D) 2, 8, 5
E) 5, 2

12. Lithium, $_3Li$, has the ground state electron configuration of

A) $1s^22s^1$
B) $1s^22s^2$
C) $1s^22s^2$
D) $1s^22s^22p^63s^1$
E) $2s^3$

13. Potassium ion, K^+ has the same electronic structure as a neutral atom of

A) argon
B) calcium
C) sulfur
D) xenon
E) neon

14. In the excited state, a possible electron configuration of aluminum, $_{13}Al$, is

A) $1s^22s^22p^63s^3$
B) $1s^22s^22p^63s^23d^1$
C) $1s^22s^22p^63s^23p^1$
D) $1s^22s^22p^63s^23d^64s^24p^1$
E) $1s^22s^22p^63s^23p^2$

15. The electron configuration $1s^22s^22p^63s^13p^1$ could represent a

A) sodium ion
B) manganese atom
C) calcium atom in the ground state
D) sodium ion in an excited state
E) magnesium atom in an excited state

16. How many *subshells* are shown in this configuration?

$1s^22s^22p^63s^23p^63d^74s^2$

A) 4 B) 7 C) 12 D) 15 E) 27

17. Which is an 'impossible' configuration?

A) $1s^22s^22p^63s^23p^6$
B) $1s^22s^22p^63s^23p^63d^{10}4s^04p^1$
C) $1s^22s^22p^93s^23p^63d^{10}4s^24p^2$
D) $1s^22s^22p^63s^23p^63d^{10}4s^24p^3$
E) $1s^22s^22p^63s^23p^4$

18. Which is an *impossible* configuration?

A) $1s^22s^22p^63s^23p^6$
B) $1s^22s^22p^63s^33p^63d^{10}$
C) $1s^22s^22p^63s^23p^63d^54s^2$
D) $1s^22s^22p^63s^23p^63d^{10}4s^2 5s^2$
E) $1s^22s^22p^63s^23p^64s^1$

19. How many electrons are in *each* orbital of a completed 3d–sublevel?

A) 2 B) 6 C) 10 D) 14 E) 18

20. What is the maximum number of subshells in the 3rd energy level of an atom?

A) 2 B) 3 C) 8 D) 9 E) 18