Module-9: Electron Configurations

THE ELECTRONIC CONFIGURATIONS OF ELEMENTS

- The distribution of electrons among the orbitals of an atom is called the **electronic structure** or **electronic configuration**.
- To write the electronic configurations we have to follow the rules listed below.
  (a) Write the subshells that contain electrons (like 1s), and indicate the number of electrons in them with a superscript (like $1s^2$).
  (b) Do not place more electrons in an orbital than its capacity. For example, there are three 2p orbitals ($2p_x$, $2p_y$ & $2p_z$) with a total capacity of six electrons. Therefore, placing seven electrons in $2p$ orbitals would be incorrect.
  (c) Always follow the Pauli's exclusion principle, namely, no two electrons in an atom can have all four quantum numbers the same.
  (d) Follow the Hund's rule, which says that sharing of electrons begins only after placing electrons singly in a given orbital.
- Let us write the electronic configurations of elements starting with hydrogen, which has one electron. Hydrogen's electronic configuration is given as $1s^1$. This means that there is one electron in the $1s$ orbital.
- Helium has two electrons, and its electronic configuration is written as, $1s^2$. This configuration indicates that there are two electrons in $1s$ orbital of helium. As shown in the following table, the two electrons have three of their quantum numbers the same, but the spin quantum numbers are different.

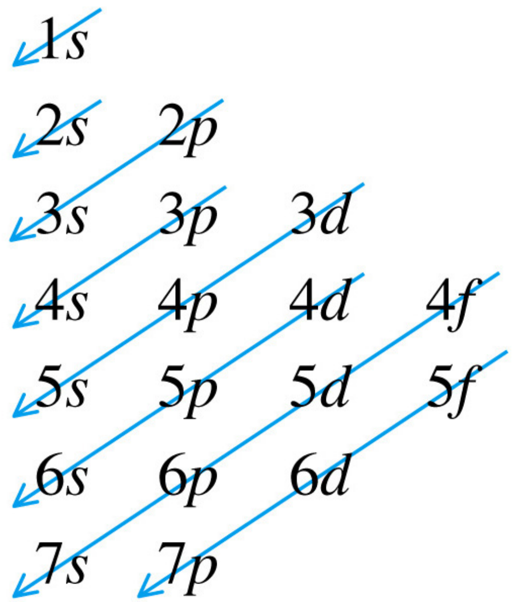
n	l	m_l	m_s
1	0	0	+ ½
1	0	0	– ½

- On moving over to the Lithium, the third element in the periodic table with three electrons, the 1*s* level is filled and we have to place the third electron in the 2*s* level. Which gives the electronic configuration of lithium as $1s^2\ 2s^1$.
- The electronic configurations of elements with atomic numbers 3 to 10, the 2nd period, are illustrated here.

Symbol (#e⁻)	Electron configuration	Orbital diagram
Li (3)	$1s^22s^1$	1s [↑↓] 2s [↑]
Be (4)	$1s^22s^2$	1s [↑↓] 2s [↑↓]
B (5)	$1s^22s^22p^1$	1s [↑↓] 2s [↑↓] 2p [↑][ ][ ]
C (6)	$1s^22s^22p^2$	1s [↑↓] 2s [↑↓] 2p [↑][↑][ ]
N (7)	$1s^22s^22p^3$	1s [↑↓] 2s [↑↓] 2p [↑][↑][↑]
O (8)	$1s^22s^22p^4$	1s [↑↓] 2s [↑↓] 2p [↑↓][↑][↑]
F (9)	$1s^22s^22p^5$	1s [↑↓] 2s [↑↓] 2p [↑↓][↑↓][↑]
Ne (10)	$1s^22s^22p^6$	1s [↑↓] 2s [↑↓] 2p [↑↓][↑↓][↑↓]

- When we write the electronic configuration for boron (B), the 2*s* level is filled and we are placing the fifth electron in the 2*p* shell.
- Notice that no two electrons in an orbital have the same spin, otherwise we'll violate the Pauli's exclusion principle.
- The element nitrogen has all three electrons in 2*p* orbitals singly placed. The pairing of electrons in 2*p* orbitals begins in oxygen because there is no other alternative, this is the essence of Hund's rule.

- As we move on to atoms with large number of electrons, we have to be watchful how we write the electronic configurations. The order in which orbitals get filled do not follow the anticipated trend. For example, after the 4*s* orbital is filled we do not place electrons in 4*p* orbitals but we place the electrons in 3*d* orbitals.
- One of the easy ways to remember the order in which electrons fill up is to refer to chart illustrated here. Note: Building up of electrons in an atom is called Aufbau principle.



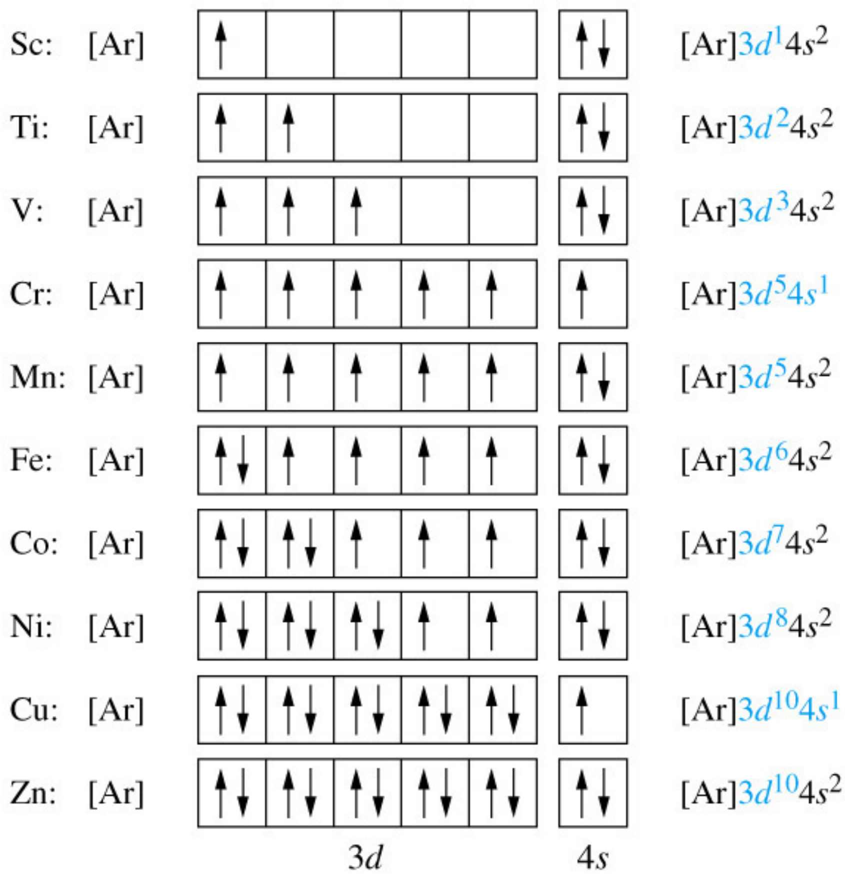
- Beginning with the top line, follow the arrows to find the order in which electrons fill up different orbitals. For example, in an atom with large number of electrons, after 4*s* orbital is filled, further electrons are added to orbitals in the following sequence, 3d→4p →5s→4d….
- Note that half-filled orbitals and completely filled orbitals are more stable than partially filled orbitals. As a consequence, the electronic configuration of chromium and copper do not follow the expected trends.

Element	Expected electronic configurations	Observed electronic configurations
Chromium	**[Ar] $3d^4\ 4s^2$**	**[Ar] $3d^5\ 4s^1$**
Copper	**[Ar] $3d^9\ 4s^2$**	**[Ar] $3d^{10}\ 4s^1$**

- Notice that we are not writing the electronic configuration of chromium starting from 1*s* orbital. Since the first eighteen electrons in chromium has the same configuration as in the noble gas argon (Ar), we simply write the atomic symbol Ar for the first 18-electrons and then write out the configuration for the remaining electrons.

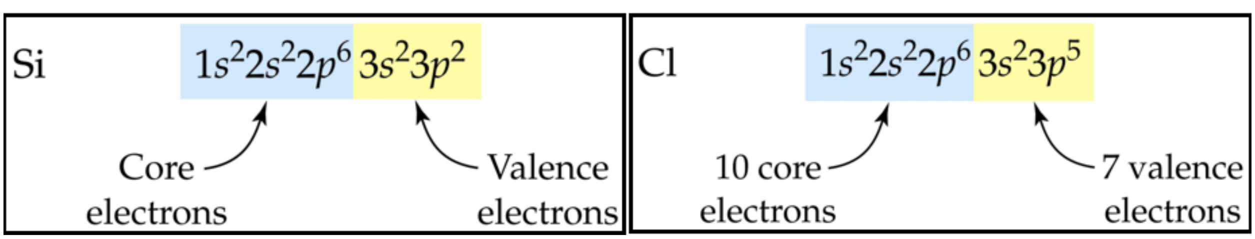
Electronic configuration of argon (Ar)	$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6$
Electronic configuration of chromium (Cr)	$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^5\ 4s^1$
Abbreviated electronic configuration of chromium (Cr)	$[Ar]\ 3d^5\ 4s^1$

- The electronic configurations of first row transition elements are



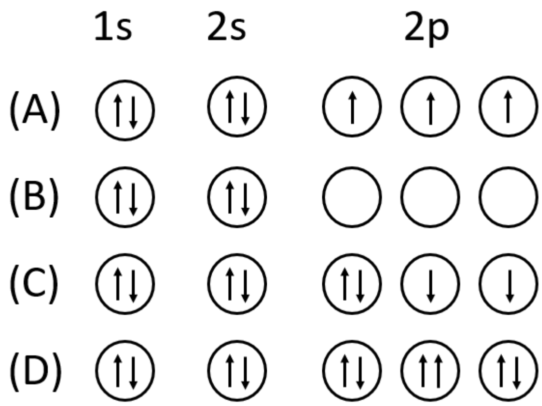
THE VALENCE AND CORE ELECTRONS

- Core Electrons: These are the electrons in the inner shells, the electronic configuration of core electrons resembles that of the nearest noble gas electronic configuration.
- Valence Electrons: These are the electrons present in the outer shell or outside the noble gas core. Only the valence electrons are involved in bonding and in chemical reactions.

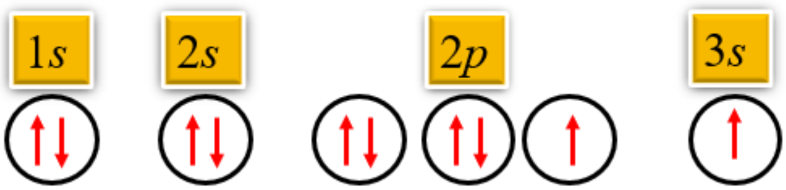


Practice Problems

1. Which of the following orbital diagrams violates the Pauli exclusion principle?



2. Which principle or rule is violated by the following orbital diagram of an atom in its ground state?



(A) Aufbau principle
(B) Pauli's exclusion principle
(C) Hund's rule
(D) Heisenberg uncertainty principle

3. Which one these elements would have five electrons in the valence shell?

(A) oxygen
(B) nitrogen
(C) chlorine
(D) boron

4. What is the electronic configuration of K^+ ion?

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

5. Which of the following electron configurations corresponds to the ground state of an atom of a transition element?

(A) $1s^22s^22p^5$
(B) $1s^22s^22p^63s^23p^63d^{10}4s^24p^2$
(C) $1s^22s^22p^63s^23p^63d^64s^2$
(D) $1s^22s^22p^63s^23p^64s^1$

6. The ground-state valence-shell configuration of a particular atom is $4d^{10}\ 5s^2\ 5p^1$. The element is a

(A) *s*-block element (B) *p*-block element

(C) transition element (D) lanthanide element

7. What is the total number of electrons in *p* orbitals in a ground-state vanadium atom?

(A) 6 (B) 10 (C) 12 (D) 0

8. Which ground-state electron configuration is <u>incorrect</u>?

(A) Br: [Ar] $3d^{10}$ $4s^2$ $4p^5$ (B) Ca: [Ar] $4s^2$ (C) Mg: [Ne] $3s^2$ (D) Fe: [Ar] $4d^6$ $4s^2$

9. Which of the following electron configurations represents an excited state of the indicated atom?

(A) Ne: $1s^2$ $2s^2$ $2p^6$ (B) N: $1s^2$ $2s^2$ $2p^3$ (C) He: $1s^2$ (D) P: $1s^2$ $2s^2$ $2p^6$ $3s^2$ $3p^2$ $4s^1$

9. What is the electronic configuration of Co^{2+} ion?

(A) Co^{2+}: [Ar] $3d^7$ (B) Co^{2+}: [Ar] $3d^5 4s^2$ (C) Co^{2+}: [Ar] $3d^6$ $4s^1$ (D) Co^{2+}: [Ar] $3d^6$

10. Which of the following sets of four quantum numbers (n, l, m_l, m_s) correctly describes one of the valence electrons in a ground-state radium (Ra) atom?

	n	l	m_l	m_s
(A)	7	0	0	+ ½
(B)	6	1	1	– ½
(C)	7	1	0	+ ½
(D)	7	2	1	– ½