Chapter 8 - Electron Configurations and Periodicity

Section 2 – Noble Gas and Ion Configurations

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More on Electron Configurations

So far, we have learned how to fill electrons for the main group and transition metals. There were rules we followed so that electrons have lowest energy and highest stability.

Once electrons are filled there is more information you can obtain from the configuration: valence and core electrons. We can also use other ways to fill electrons, the noble gas configuration.

We will now learn how to write electron configuration for ions: cations and anions and the noble gas configuration for writing electrons.

Electronic Configuration of Periodic Table

A review on the different blocks on periodic table and the last shell filled.

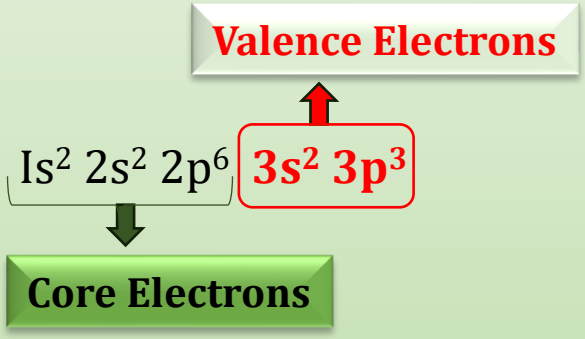
IA	IIA										IIIA	IVA	VA	VIA	VIIA	VIIIA
1 H $1s^1$																2 He $1s^2$
3 Li $2s^1$	4 Be $2s^2$										5 B $2s^2 2p^1$	6 C $2s^2 2p^2$	7 N $2s^2 2p^3$	8 O $2s^2 2p^4$	9 F $2s^2 2p^5$	10 Ne $2s^2 2p^6$
11 Na $3s^1$	12 Mg $3s^2$	IIIB	IVB	VB	VIB	VIIB		VIIIB		IB	IIB	13 Al $3s^2 3p^1$	14 Si $3s^2 3p^2$	15 P $3s^2 3p^3$	16 S $3s^2 3p^4$	17 Cl $3s^2 3p^5$	18 Ar $3s^2 3p^6$
19 K $4s^1$	20 Ca $4s^2$	21 Sc $4s^2 3d^1$	22 Ti $4s^2 3d^2$	23 V $4s^2 3d^3$	24 Cr $4s^1 3d^5$	25 Mn $4s^2 3d^5$	26 Fe $4s^2 3d^6$	27 Co $4s^2 3d^7$	28 Ni $4s^2 3d^8$	29 Cu $4s^1 3d^{10}$	30 Zn $4s^2 3d^{10}$	31 Ga $4s^2 4p^1$	32 Ge $4s^2 4p^2$	33 As $4s^2 4p^3$	34 Se $4s^2 4p^4$	35 Br $4s^2 4p^5$	36 Kr $4s^2 4p^6$
37 Rb $5s^1$	38 Sr $5s^2$	39 Y $5s^2 4d^1$	40 Zr $5s^2 4d^2$	41 Nb $5s^2 4d^3$	42 Mo $5s^1 4d^5$	43 Tc $5s^2 4d^5$	44 Ru $5s^2 4d^6$	45 Rh $5s^2 4d^7$	46 Pd $5s^2 4d^8$	47 Ag $5s^1 4d^{10}$	48 Cd $5s^2 4d^{10}$	49 In $5s^2 5p^1$	50 Sn $5s^2 5p^2$	51 Sb $5s^2 5p^3$	52 Te $5s^2 5p^4$	53 I $5s^2 5p^5$	54 Xe $5s^2 5p^6$
55 Cs $6s^1$	56 Ba $6s^2$	57 La $6s^2 5d^1$	72 Hf $6s^2 5d^2$	73 Ta $6s^2 5d^3$	74 W $6s^1 5d^5$	75 Re $6s^2 5d^5$	76 Os $6s^2 5d^6$	77 Ir $6s^2 5d^7$	78 Pt $6s^2 5d^8$	79 Au $6s^1 5d^{10}$	80 Hg $6s^2 5d^{10}$	81 Tl $6s^2 6p^1$	82 Pb $6s^2 6p^2$	83 Bi $6s^2 6p^3$	84 Po $6s^2 6p^4$	85 At $6s^2 6p^5$	86 Rn $6s^2 6p^6$

s – block **p – block** **d - block**

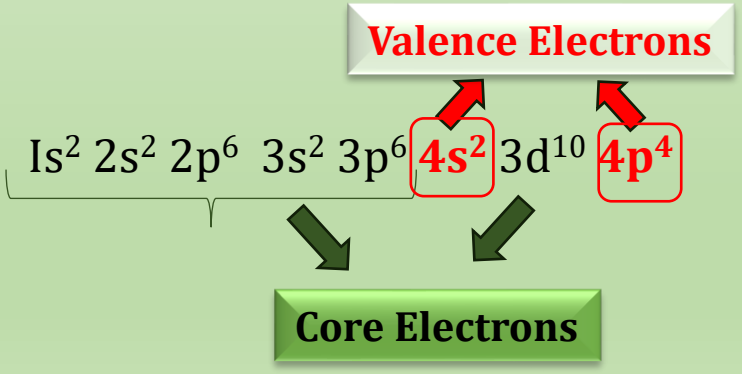
Valence and Core Electrons

Valence electrons (VE) are the outermost electrons found in the valence shell which is the outermost shell of an atom. For the main groups the group number is the number of valence electrons, e.g., Na is group I and has 1 VE ($3s^1$); Cl is in group VII and has 7 VE ($3s^2\ 3p^5$). In the electron configuration, count the number of electrons (superscripts) of the highest shell number.
All other electrons will be **core electrons**.

- Phosphorous has 5 valence electrons (those in the *n* = 3 principal shell) and 10 core electrons.



- Selenium has 6 valence electrons (those in the *n* = 4 principal shell). All other electrons, including those in the 3*d* orbitals, are core electrons.



Noble Gas Configurations

Noble gas configurations helps to shorten the electron configuration, so we don't have to write long notations. This can be used in spdf and in box notations.

To use the noble gas configuration, identify the noble gas of the **previous** period and continue filling with the rest of the electrons. The noble gas indicates that those electrons are all accounted for, and you are filling the remaining electrons.

For example, using [Kr] to fill electrons for tin indicates that out of 50 electrons, 36 electrons do not need to be written out.

To fill for Cl (17 e^-) use [Ne]; for As (33 e^-) use [Ar] etc.

A written example of bromine shown below.

- Bromine complete configuration is: $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2\ 3d^{10}\ 4p^5$
- And the noble gas configuration is: [Ar] $4s^2\ 3d^{10}\ 4p^5$
- For tin: [Kr] $5s^2\ 4d^{10}\ 5p^2$

2 He 4.003
10 Ne 20.18
18 Ar 39.95
36 Kr 83.8
54 Xe 131.3
86 Rn [222]

Solved Problem: Core and valence electrons

How many core and valence electrons are in the elements below?

a) $1s^2 2s^2 2p^3$
b) Arsenic
c) Zinc
d) Chromium

a) 5 VE – count in shell number 2 only.
b) 5 VE – in group V in periodic table.
c) 2 VE – $Is^2\ 2s^2\ 2p^6\ \ 3s^2\ 3p^6\ \mathbf{4s^2}\ 3d^{10}$
d) 1 VE - $Is^2\ 2s^2\ 2p^6\ \ 3s^2\ 3p^6\ \mathbf{4s^1}\ 3d^5$

Solved Problem: Identifying the noble gas for elements

Which noble gas is right for writing the electron configuration of the following elements.

a) Aluminum
b) Germanium
c) Iron
d) Bismuth

a) Ne
b) Ar
c) Ar
d) Xe

Configurations for Ions

In cations electrons have been removed and in anions electrons have been added. In both cases this transactions happens in the valence shell, and within the valence shell, the higher energy electron will be lost first (for cations), or electron will be accepted in the last vacant subshell (for anions).

- Cations: remove the valence shell electrons of the higher energy first.

  Al: $1s^2 2s^2\ 2p^6\ 3s^2\ 3p^1$

  Al^{3+}: $1s^2 2s^2\ 2p^6$

  Sc: $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2\ 3d^1$

  Sc+: $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^1\ 3d^1$

- Anions: add the electrons to the last empty subshell of valence shell.

  S: $1s^2 2s^2\ 2p^6\ 3s^2\ 3p^4$

  S^{2-}: $1s^2 2s^2\ 2p^6\ 3s^2\ 3p^6$

Solved Problem: Writing spdf and box configuration of ions

Write the spdf notation for the following and ions.

a) Ca^{2+}

Ca : $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2$

Ca^{2+} : $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6$

b) Fe^{3+}

Fe : $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2\ 3d^6$

Fe^{3+} : $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^5$

c) Mn^{4+}

Mn : $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2\ 3d^5$

Mn^{2+} : $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^3$

d) Br^-

Br : $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2\ 3d^{10}\ 4p^5$

Br^- : $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2\ 3d^{10}\ 4p^6$

Solved Problem: Core and valence electrons

How many core and valence electrons are in the ions below?

a) Ca^{2+}

a) Configuration is $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6$ ~~$4s^2$~~ the 2 electrons from 4th shell in s subshell are given so the next shell is 8 electrons.

8 VE and 8 core electrons.

b) Cr^{3+}

b) Configuration is $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6$ ~~$4s^2$~~ $3d^4$ the three electrons lost are 2 from $4s^2$ and 1 from $3d^4$ to give $3d^3$. Total count is 3+2+6 = 11 from the 3rd shell.

11 VE and 8 core electrons

c) Cl^-

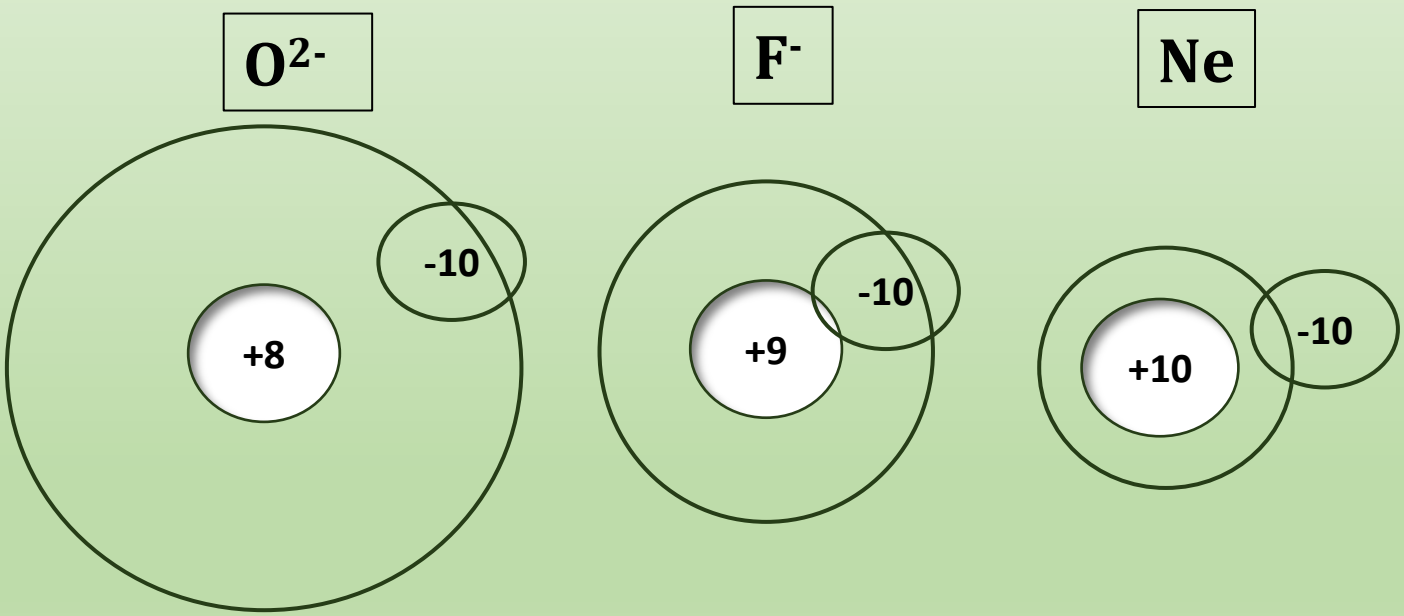
c) Configuration is $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6$. Chlorine has 7 VE from being in group VII and add one more since it has accepted one electron.

8 VE and 8 core electrons

Isoelectric Elements/Ions

Isoelectric means when two or more species having the same electron configuration but different charges. These species can be positive, negative or neutral, they just need to have the same number of electrons.

The atomic properties of these atoms or ions will change significantly.



Solved Problem: Isoelectronic ions/elements

Group the elements and ions as isoelectronic and give the number of electrons in that group.

C^{4+}, He, Be, Cl^-, P^{3-}, Ca^{2+}, H^-, Ne, Si^{4-}, Ga^{3+}

Find number of electrons in each ion, element first.

C^{4+},	He,	Be,	P^{3-},	Ca^{2+},	H^-,	Ne,	Si^{4-},	N^{3-},	Cl^-,	Ga^{3+}
2,	2,	4,	18,	18,	2,	10,	18,	10,	18	18

Now group them in their isoelectronic groups.

$2e^-$: C^{4+}, He, H^-

$18e^-$: P^{3-}, Ca^{2+}, Si^{4-}, Cl^-, Ga^{3+}

$10e^-$: Ne, N^{3-}

Be does not have any isoelectronic element.

Paramagnetism and Diamagnetism

A **paramagnetic substance** is one that is weakly attracted by a magnetic field, usually as the result of *unpaired electrons*.

A **diamagnetic substance** is not attracted by a magnetic field generally because it has *only paired electrons*.

Key Words

- Noble gas configuration
- Valence and core electrons
- Electronic configuration of ions
- Paramagnetic
- Diamagnetic