Chapter – 8

Structure of Atom

Synopsis

Energy propagates as electromagnetic waves and can have a wide variety of wavelengths. The entire range of wavelengths is known as the electromagnetic spectrum.

Max Planck broke with the continuous energy tradition of electromagnetic energy by assuming that the energy is always emitted in multiples of "hν" with his Planck's constant which has the value 6.626×10^{-34}J-S. Where "ν" is the frequency.

Using Planck's theory and Rutherford model, Bohr proposed his famous atomic model. The defects of this model were rectified by Somerfield. This Bohr- Somerfield model, though successful in accounting for the fine line structure of hydrogen atomic spectra, failed to provide a satisfactory picture of the structure of atom in general.

For finding the electron in the space around the nucleus, quantum numbers are proposed by different scientists.

There are four quantum numbers .Those are

1. Principal quantum number (n).

2.The angular-momentum quantum number (l).

3. The magnetic quantum number (m_{l}).

4. Spin Quantum number (m_{s}).

The Pauli Exclusion Principle states that two electrons of same atom can have all four quantum numbers the same.

Aufbau Principle gives the information about how orbitals are filled in the order of increasing energy.

Hund's rule of electron pairing in orbitals starts only when all available empty orbitals of the same energy are singly occupied.

1. What information does the electronic configuration of an atom provide?

Ans: 1) The distribution of electrons in shells, sub-shells, and orbitals in an atom is known as electronic configuration.

2) The distribution of electrons in various atomic orbitals provides an understanding of electron behaviour of the atom and in turn its reactivity.

3) The short notation it can be written as nl^x.

n- Denotes the principle Quantum Number.

l- Denotes the Azimuthal/Angular Quantum Number.

x- Denotes the number of electrons in orbital.

2. Rainbow is an example for continuous spectrum-Explain.

Ans: 1) Rainbow is a natural spectrum appearing in the sky just after a rain shower.

2) It is caused by dispersion of sunlight by ting water droplets present in atmosphere.

3) In rainbow in which there are no sharp boundaries in between colours.

4) Such a spectrum in which there are no sharp boundaries in between colours is known as continuous spectrum.

5) So, rainbow is also a continuous Spectrum.

3) How may elliptical Orbits are added by Somerfield in third Bohr's Orbit? What was the purpose of adding these elliptical Orbits?

Ans: In case of third Bohr's Orbit, Somerfield added 2 elliptical Orbits.

Purpose of adding elliptical Orbit:

1) Bohr's model failed to account for splitting of line spectra.

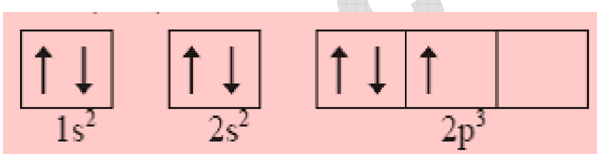
2) In an attempt to account for the structure of line spectrum, Somerfield modified Bohr's atomic model by adding elliptical Orbits.

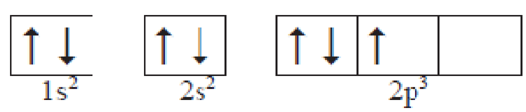
4) What is an Orbital? How is it different from Bohr's Orbit?

Ans: The region (or) space around the nucleus where the probability of finding the electron is maximum and such space is called an Orbital.

1) Bohr's Orbit has a definite boundary and fixed energy at different distances from the nucleus. They are circular in shape.
2) Orbitals have no definite boundary. It is region, where we find maximum possibility of electrons. The shape of each orbital is different.
3) Bohr's Orbit can accommodate maximum of 2n2 electrons in it, but Orbital can accommodate only 2 electrons.

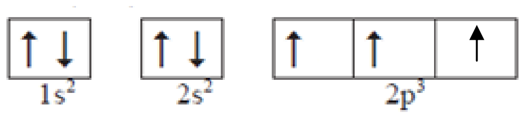
5) Following orbital diagram shows the electron configuration of nitrogen atom. Which rule doesn't support this?

N (z=7) ≈ 

Ans: Given electron configuration of Nitrogen is 

This is not supported by Hund's rule. According to Hund's rule, the orbitals of equal energy are occupied with one electron each before pairing of electrons starts.

The correct electronic configuration is as follows



6) i) An electron in an atom has the following set of four quantum numbers to which orbital it belongs to:

n	*l*	m	S
2	0	0	½

ii) Write the four quantum numbers for $1s^1$ electron.

Ans: i) The electron belongs to S-orbital. Since, (l=0) and with clockwise spin rotation.

ii) For $1s^1$ electron-

n	*l*	m	S
1	0	0	½

7) Collect the information regarding wave length and corresponding frequencies of three primary colours-red, blue and green.

Ans:

Colour	Frequency(THz)	Wavelength(nm)
Red	400 – 484	620 – 750
Green	526 – 606	495 – 570
Blue	606 – 668	450 – 495

1 Mark Questions

1) What is an Absorption Spectrum?

Ans: Absorption spectrum is spectrum obtained when the substances absorb energy.

It contains dark lines on bright background.

2) What is nl^x method? How it is useful?

Ans: nl^x is a short hand notation of electronic configuration. It consists of the principal quantum energy level (n) sublevel (l) and the no. of electron (x) in the sublevel. It helps to predict the values of all the four quantum number of any electron.

3) Which rule is violated in the electronic configuration? $1S^0\ 2S^2\ 2P^4$.

Ans: Aufbau principle is violated in this electronic configuration because according to Aufbau principle, Electron enters into orbital of lower energy.

Among 1s, 2s, 2p; 1s has least energy. So 1s orbital must be filled before the electron should enter into 2s.

4) Write the four Quantum Numbers for the differentiating electron of Sodium(Na) atom?

Ans: Sodium (Na). (Z=11) ---- $1s^2\ 2s^2\ 2p^6\ 3s^1$.

The differentiating electron is in 3s orbital.

The four quantum numbers.

n – 3

l – 0

m – 0

s – ½

5) What is Emission Spectrum?

Ans: The spectrum of radiation emitted by a substance from its excited state is an emission spectrum.

6) Which electronic shell is at a higher energy level K or L?

Ans: In given K, L shells

L shell is at higher energy shell. Since, it is for away from nucleus than K-shell.

7) The wave length of a radio wave is 1.0m. Find its frequency?

Ans: Wavelength of radio wave ($\lambda\nu$)= 1 m

As $C = \lambda\nu \Rightarrow 3 \times 10^8 = 1 \times \nu$

$\nu = 3 \times 10^8$ Osc/sec

C = velocity of radio wave (EM waves)

8) State Heisenberg principle of uncertainty?

Ans: According to Heisenberg's uncertainty principle,

"It is not possible to find the exact position and velocity of electron simultaneously".

4 – Mark Questions

1. **a. What is the maximum number of electrons that can be accommodated in a principal energy shell?**

   b. What is the maximum number of electrons that can be accommodated in a sub shell?

   c. What is the maximum number of electrons that can be accommodated in an orbital?

   d. How many sub-shells present in a principal energy shell?

   e. How many spin orientations are possible for an electron in an orbital?

Ans: a) The Maximum number of electrons that can be accommodate in a principal energy shell, of 'n' principal quantum number is $2n^2$

b) The maximum number of electrons that can be accommodated in a sub-shell is $2(2l + 1)$

l – Azimuthal (or) Angular Quantum number

Sub-shell	Number of Orbitals $(2l + 1)$	Number of $\bar{e}$s $2(2l + 1)$
S $(l = 0)$	1	2
P $(l = 1)$	3	6
d $(l = 2)$	5	10
F $(l = 3)$	7	14

c) The maximum of number of electrons that can be accommodated in an orbital is two

d) In a principal energy shell $(n)_1$ there (n^2) sub-shells

e) For an electron in an orbital only 2 spin orientations are possible ie,-1/2

2. In an atom, the number of electrons in M-shell is equal to the number of electrons in K and L-shells. Answer the following questions.

a) What is the outermost shell?

b) How many electrons are there in the outermost shell?

c) What is the atomic number of the element?

d) Write electronic configuration of that element.

Ans: Number of electrons in M shell is equal to the number of the electrons in K and L shells-

i.e. the number of electrons in M shell is 2 + 8 = 10 electrons

Total electrons in the element = 2 + 8 + 10 + 2 = 22 electrons

(K) (L) (M) (N)

So,

a) 4^{th} spell (N) is the outermost shell

b) 2 electrons were there in N-shell (outer most shell)

c) Atomic number of that element is 22

d) Electronic configuration of that element is $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2\ 3d^2$

3. Explain the significance of three Quantum numbers in predicting the positions of an electron in an atom.

Ans: Each electron in an atom is described by a set of three quantum numbers – n, *l*, m.

These numbers indicate the probability of finding the electron in the space around nucleus.

1. Principal Quantum Number (n)

The Principal Quantum number is related to size and energy of the main shell. It is denoted by ‘n’.

- ‘n’ has positive integer values (1, 2, 3, …)
- Number of electrons in a shell is limited to $2n^2$

2. Azimuthal (or) Angular Quantum Number (*l*)

This Azimuthal Quantum Number defines the shape of the Orbital occupied by the electron and the orbital angular momentum of the electrons in motion.

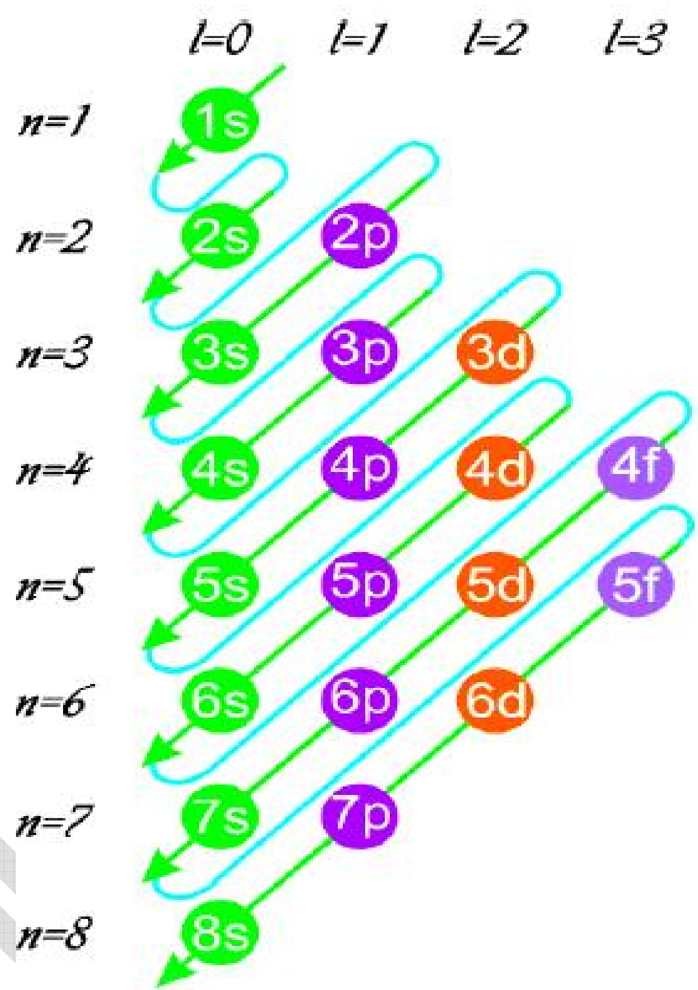
- Due to this, it is also called as Angular Quantum momentum
- It is denoted by *l*
- ‘*l*’ has integer values from 0 to (n+1) for each value of n
- The Quantum number ‘*l*’ also governs the degree with which the electron is attached the nucleus.
- The larger is the value of ‘*l*’, smaller is bond with which it attached with the nucleus.

3. Magnetic Orbital Quantum Number(m):

- To Explain the Zeeman Effect and Stark Effect, magnetic orbital quantum number is introduced.
- The orientation of orbital with external magnetic field determine magnetic orbital quantum number(m_l)
- Magnetic Quantum number (m_l) has integer values between $-l$ *to* $+l$ including zero.
- Thus for a certain value of *l* there are ($2l + 1$) integer values of m_l

5 Mark Questions

Moeller Chart



Fill in the Blanks

1. If n = 1 then angular momentum quantum number (l) =_________. (0)

2. If a sub-shell is denoted as 2p then its magnetic quantum number values are ____, ____, ____. (-1,0,1)

3. Maximum number of electrons that an M-shell contains is/are _________. (18)

4. For 'n', the minimum value is ______and the maximum value is ______. (1, n)

5. For 'l', the minimum value is _______and the maximum value is _______. (1, n-1)

6. For 'm_l' the minimum value is _____and the maximum value is _____. (-l, l)

7. According to _________ Principle no two electrons of the same atom can have the four quantum numbers the same. (Pauli's exclusion)

8. Spectrum is a group of _________. (wavelengths)

9. The space around the nucleus where the probability of finding of electron is maximum is called_________. (orbital)

10. As long as electron revolves in a _________Orbit nether loses (or) gains energy. (stationary)

11. Quantum theory is proposed by _________. (Max Planck)

12. _________Principle states that lowest energy orbitals are filled first. (Aufbau's)

13. The orbitals of equal energy are occupied with one electron each. It is ………… Rule. (Hund's)

14. Electromagnetic energy of radiation is given by the equation E _______. (hν)

15. According to wave theory, light is considered as wave_______. (electro magnetic)

16. _________Quantum number defines the shape of the orbital. (Azimuhal / angular)

17. Quantum mechanical model of atom was developed by_____. (Erwin Schrodinger)

Multiple Choice Questions

1. **An emission spectrum consists of bright spectral lines on a dark back ground. Which one of the following does not correspond to the bright spectral lines?**

[ ]

a) Frequency of emitted radiation

b) Wave length of emitted radiation

c) Energy of emitted radiations

d) Velocity of light

2. **The maximum number of electrons that can be accommodated in the L – shell of an atom is :**

a) 2 b) 4 c) 8 d) 16

[ ]

3. **If l = 1 for an atom then the number of orbitals in its sub-shell is**

a) 1 b) 2 c) 3 d) 0

[ ]

4. **The quantum number which explains about size and energy of the orbit or shell is?**

[ ]

a) Principal b) Azimuthal c) Magnetic d) Spin

5. Shape of a –orbital is …………..

[ ]

a) Dumbell b) Double dumbel

c) Spherical d) No shape

6. Quantum theory was proposed by?

[ ]

a) Bohr b) Max Planck

c) Sommerfeld d) Erwin Schrödinger

7. Splitting of spectral lines in electric field is known as?

[ ]

a) Zeeman Effect b) Stark Effect

c) Photoelectric Effect d) None

8. The lowest energy state of the electron is known as …………. State.

[ ]

a) Excited b) Stationary

c) Ground d) Higher energy

9. Name the orbital for l = 1 is-

[ ]

a) s b) p

c) d d) f

10. The number of electrons in a shell is limited to?

[ ]

a) $2l + 1$ b) $2(2l + 1)$

c) $2n^2$ d) n^2

11. If there are no sharp boundaries in between colours, then the spectrum is called as ______.

[ ]

a) Line spectrum b) Band spectrum

c) Continuous spectrum d) None

12. ________ Quantum number explains about the size and energy of the orbital.

[ ]

a) Principal b) Orbital

c) Magnetic d) Spin

13. Quantum mechanical model of atom was developed by ________.

[ ]

a) Bohr b) Erwin Schrödinger

c) Max Planck d) Somerfield

14. Splitting of spectral lines in magnetic field is known as …………. [ ]

a) Zeeman Effect b) Stark Effect

c) Photo Electric Effect d) None

15. The region of space around the nucleus where the probability of finding an electron is minimum is called?

[ ]

a) Orbit b) Node

c) Orbital d) Energy level

Key:

1) d; 2) c; 3) c; 4) a; 5) b; 6) b;

7) b; 8) c; 9) b; 10) c; 11) c; 12) a;

13)b; 14) a; 15) b.

Matching

1.	Group – A		Group – B
i)	Value of n	[ ]	a) o to (n - 1)
ii)	Value of l	[ ]	b) +1/2, -1/2
iii)	Value of M_l	[ ]	c) Non- zero integers
iv)	Value of M_s	[ ]	d) $-l$ to $+ l$
v)	d- orbital	[ ]	e) l = 1
			f) $l = 2$

Key:

i) c; ii) a; iii) d; iv) b; v) f;

2.

	Group – A		Group – B
i)	Size and energy of an orbit	[ ]	a) Hund's rule
ii)	Shape of orbit	[ ]	b) Aufbau's principle
iii)	Building up rule	[ ]	c) Principal Quantum number
iv)	Spin of electrons about own axes	[ ]	d) Azimuthal Quantum number
v)	Orientation of orbital with external magnetic field	[ ]	e) Magnetic Quantum number
			f) Spin Quantum number

Key:

i) c; ii) d; iii) b; iv) f; v) e;

3.

	Group – A		Group – B
i)	Quantum theory	[ ]	a) Moeller
ii)	Stationary orbits	[ ]	b) Max plank
iii)	Relative energies of orbits	[ ]	c) Erwin Schrödinger
iv)	Quantum model of an atom	[ ]	d) Niels Bohr
v)	No two electrons have same set of four Quantum numbers	[ ]	e) Wolfgang Pauli

Key:

i) b; ii) d; iii) a; iv) c; v) e;

4.	**Group – A**		**Group – B**
i)	Continuous spectrum	[ ]	a) Gaseous atoms
ii)	Line spectrum	[ ]	b) 589nm – 589.6nm
iii)	Band spectrum	[ ]	c) Rainbow
iv)	Absorption spectrum	[ ]	d) Molecules
v)	Wave length range of sodium vapour	[ ]	e) Absorption energy

Key:

i) c; ii) a; iii) d; iv) e; v) b;

5.	**Group – A**		**Group – B**
i)	Size and shape of main shell	[ ]	a) l
ii)	sub- shells	[ ]	b) M_s
iii)	Orientation of orbitals	[ ]	c) n
iv)	Direction of spin	[ ]	d) electronic configuration
v)	Distribution of electrons	[ ]	e) m_l

Key:

i) c; ii) a; iii) e; iv) b; v) d;

Important images

1. An electromagnetic wave

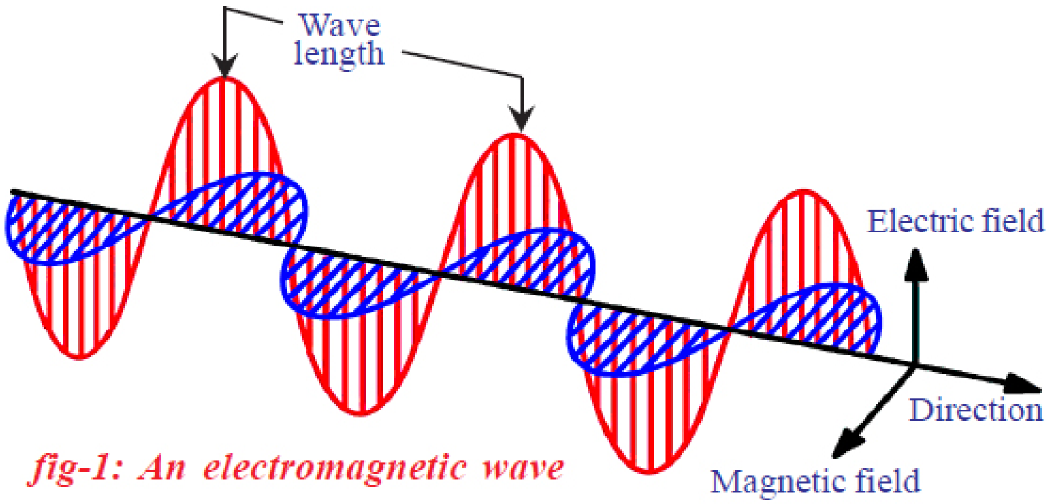


fig-1: An electromagnetic wave

2. Electromagnetic spectrum

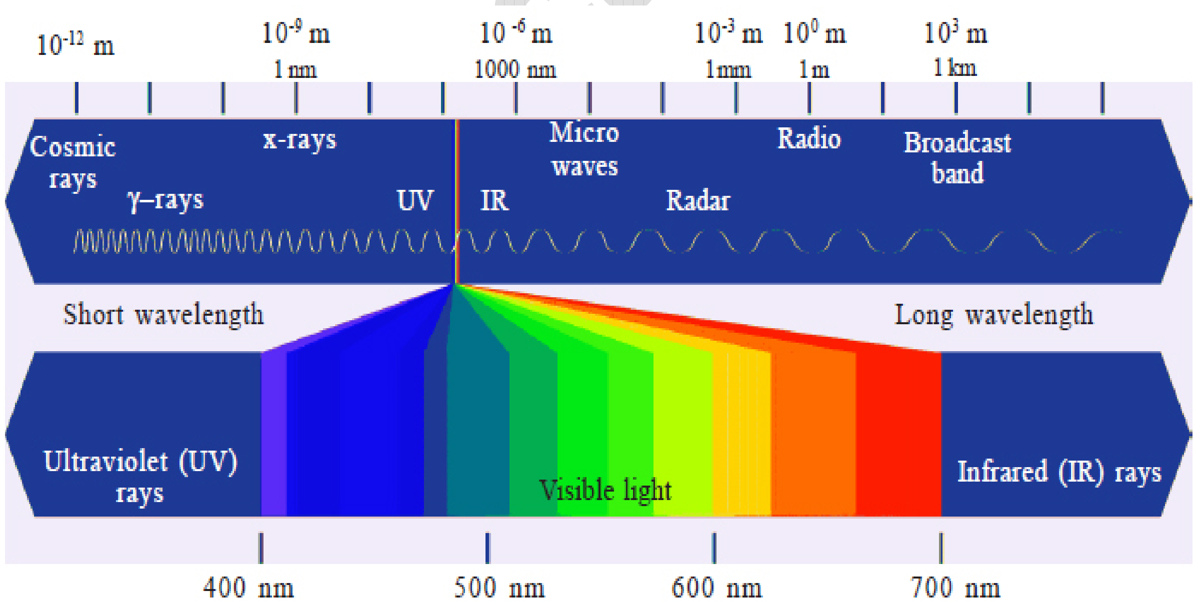


fig-2: Electromagnetic Spectrum

3. Hydrogen spectrum

fig-3: Hydrogen Spectrum

4. Bohr - Sommerfield model

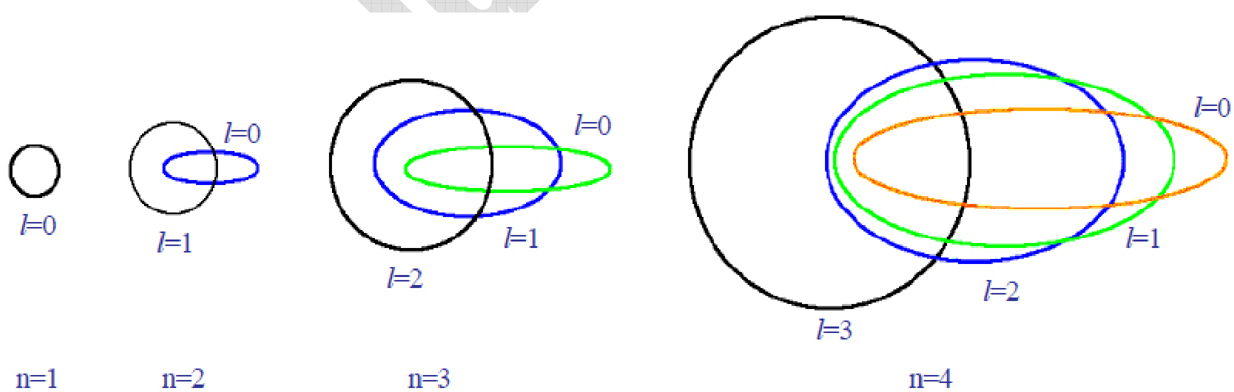


fig-4: The allowed electronic orbits for the main Quantum numbers by Bohr - Sommerfeld model

5. Shapes of orbitals in s, p and d subshells

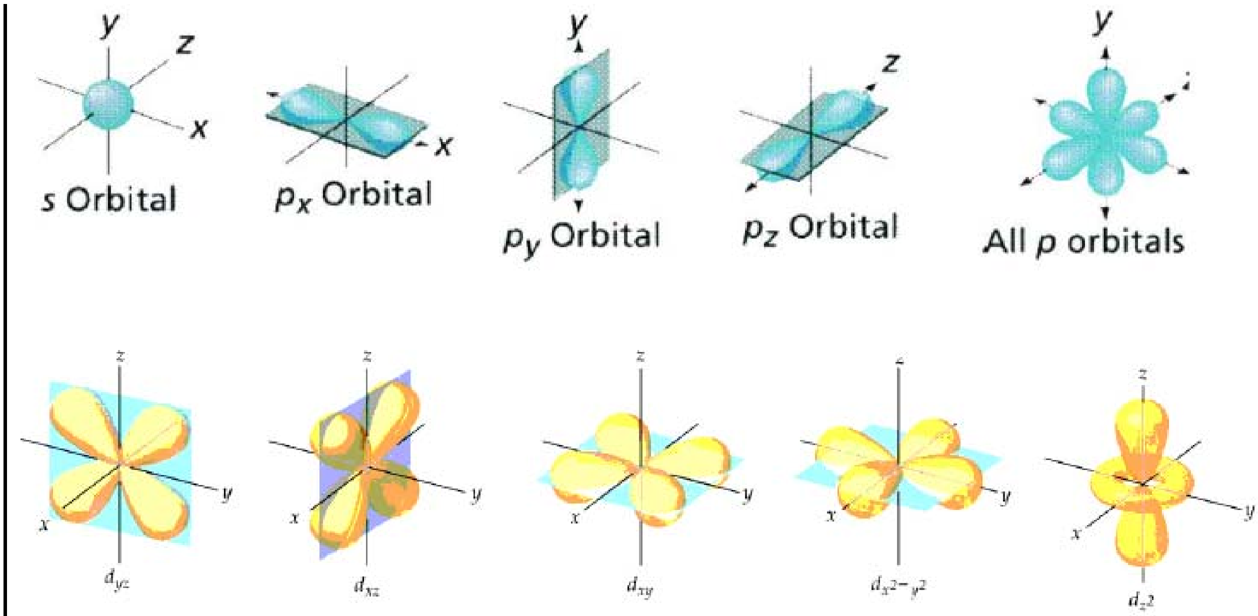


fig-5: Shapes of orbitals in s, p and d subshells

6. Electron configuration of H, He, Li, Be, B

H(Z=1)	$1s^1$	↑				
He(Z=2)	$1s^2$	↑↓				
Li(Z=3)	$1s^2 2s^1$	↑↓	↑			
Be(Z=4)	$1s^2 2s^2$	↑↓	↑↓			
B(Z=5)	$1s^2 2s^2 2p^1$	↑↓	↑↓	↑		