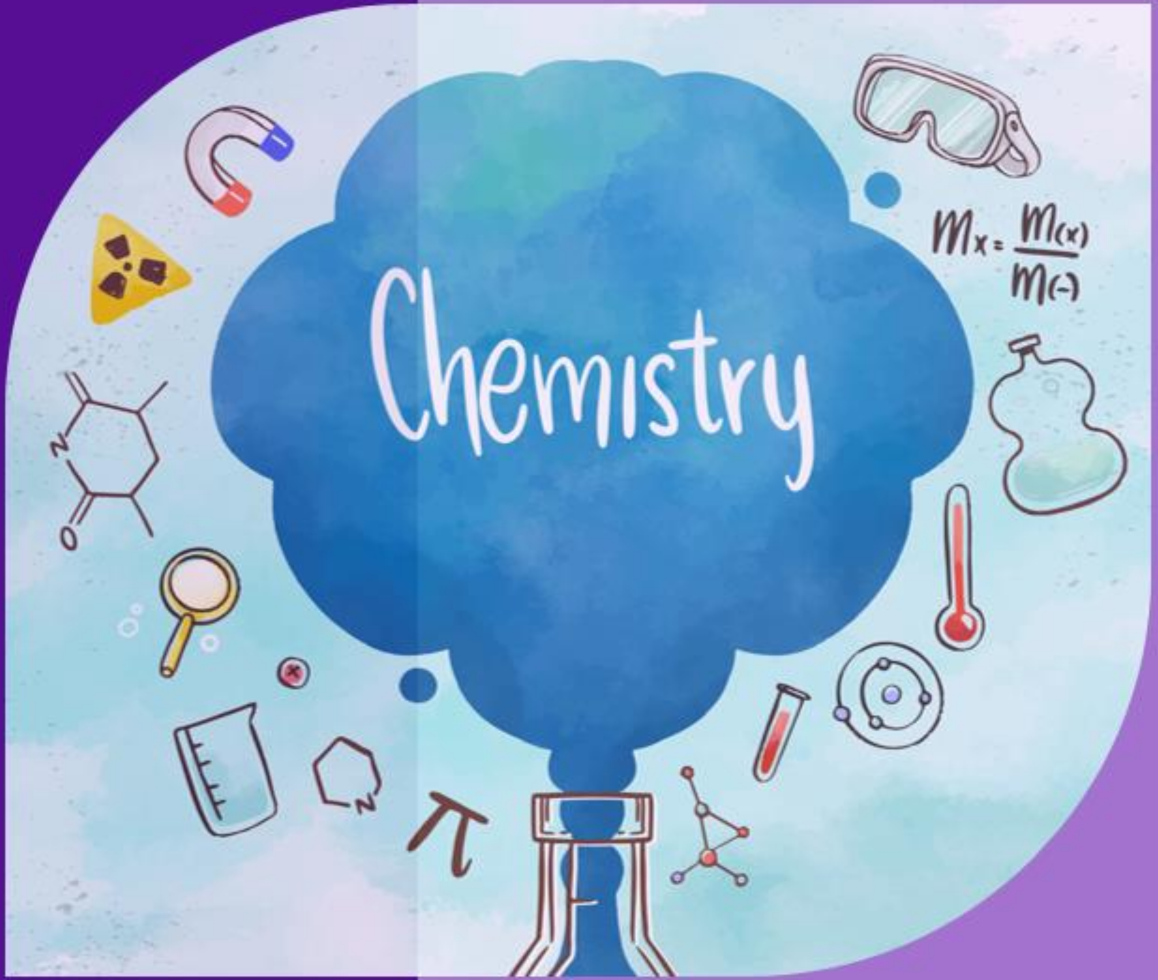
CLASS XI ACADEMIC PROGRAM 2020

CHEMISTRY

LECTURE : C-03

CHAPTER 2 : QUALITATIVE CHEMISTRY



Mathematical Problems

(1) What is the angular momentum of a rotating electron in the 3rd energy level of a hydrogen atom?

angular momentum $= mvr = \frac{nh}{2\pi}$

$= \frac{nh}{2\pi}$ $\Big\}$ $h = 6.626 \times 10^{-34}$ Js | $n = 3$

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Mathematical Problems

(2) What is the angular momentum of the rotating electron in the L energy level of a hydrogen atom?

K, L, M, N

↓

$n = 2$

$a.m = \frac{2 \times h}{2\pi}$

Mathematical Problems

(3) What will be the velocity of the electron rotating in the M orbit of an atom? Orbit radius $3.6x10^{-8}$ cm.

K L M

M orbit = 3 = n

$$r = 3.6\times10^{-8}\ cm = 3.6\times10^{-10}\ m$$

$$mvr = \frac{nh}{2\pi} \quad | \quad m = 9.11\times10^{-31}\ kg$$

$$v = \frac{nh}{2\pi \times mr} = 9.6\times10^{5}\ ms^{-1}$$

Mathematical Problems

(4) What will be the velocity of the electron rotating in the 2nd orbit of an atom? Orbit radius 2.5×10^{-8} cm.

$mvr = \frac{nh}{2\pi}$

$n = 2$

$r = 2.5 \times 10^{-8}$ cm $= 2.5 \times 10^{-10}$ m

$m = 9.11 \times 10^{-31}$ kg

$h = 6.626 \times 10^{-34}$ Js

$v = ?$

Mathematical Problems

(5) If the orbital radius of a hydrogen atom is 8.5×10^{-8} cm and the velocity of the electron is 5.4452×10^{7} cms^{-1}, in which orbit is the electron rotating?

(n)

$r = 8.5 \times 10^{-8}$ cm $= 8.5 \times 10^{-10}$ m

$mvr = \frac{nh}{2\pi}$

$v = 5.4452 \times 10^{7}$ cms^{-1}

$= 5.4452 \times 10^{5}$ ms^{-1}

$n = \frac{mvr \, 2\pi}{h}$

$m = 9.11 \times 10^{-31}$ kg = mass of electron

Mathematical Problems

(6) If the energy difference between two different energy levels of a hydrogen atom is 245.9 kJ mol^{-1}, what will be the wavelength and frequency of the radiated light ray if the electron jumps from the higher energy level to the lower energy level?

$\Delta E = 245.9 \text{ kJ mol}^{-1}$

$= 245.9 \times 10^3 \text{ J}$

$\nu = f = \text{frequency}$

$\Delta E = h\nu = hf \; ; \; f = \frac{\Delta E}{h} = \frac{245.9 \times 10^3}{6.626 \times 10^{-34}} = \square \text{ Hz}$

$f = \frac{c}{\lambda} \; ; \; \lambda = \frac{c}{f} = \frac{3 \times 10^8}{\square}$

Mathematical Problems

(7) What is the radius of the second bore orbit of lithium atom, velocity of rotating electron, energy?

bohr

$$r_n = \frac{n^2h^2}{4\pi^2 m e^2 Z}$$

r_n = nth shell's radius

$$V_n = \frac{2\pi e^2 Z}{h \times n}$$

V_n = nth shell's e's velocity

$$E_n = \frac{-2\pi^2 m e^4 Z^2}{n^2h^2}$$

E_n = nth shell's energy

m = mass of electron $= 9.11 \times 10^{-31}$ kg

h = Plank's const $= 6.626 \times 10^{-34}$ Js

n = shell/energy shell

e = e's charge $= -1.6 \times 10^{-19}$ C

Z = proton number = atomic number

$n = 2$, $Z = 3$

Mathematical Problems

(8) What is the radius of 3rd energy level of hydrogen atom, velocity of rotating electron, energy?

$Z = 1 \qquad n = 3$

$n, Z \rightarrow$ variable

radius: $r_n = \dfrac{n^2h^2}{4\pi^2 m e^2 Z}$

velocity: $V_n = \dfrac{2\pi e^2 Z}{hn}$

Energy: $E_n = \dfrac{-2\pi^2 m e^4 Z^2}{n^2 h^2}$

Mathematical Problems

(9) What is the energy of 3rd energy shell if the 1st shell's energy is -13.5815 eV?

eV = electro-volt

$$1\,eV = 1.6\times10^{-19}\,J$$

$$x\,eV = x \times [\ \ ]$$

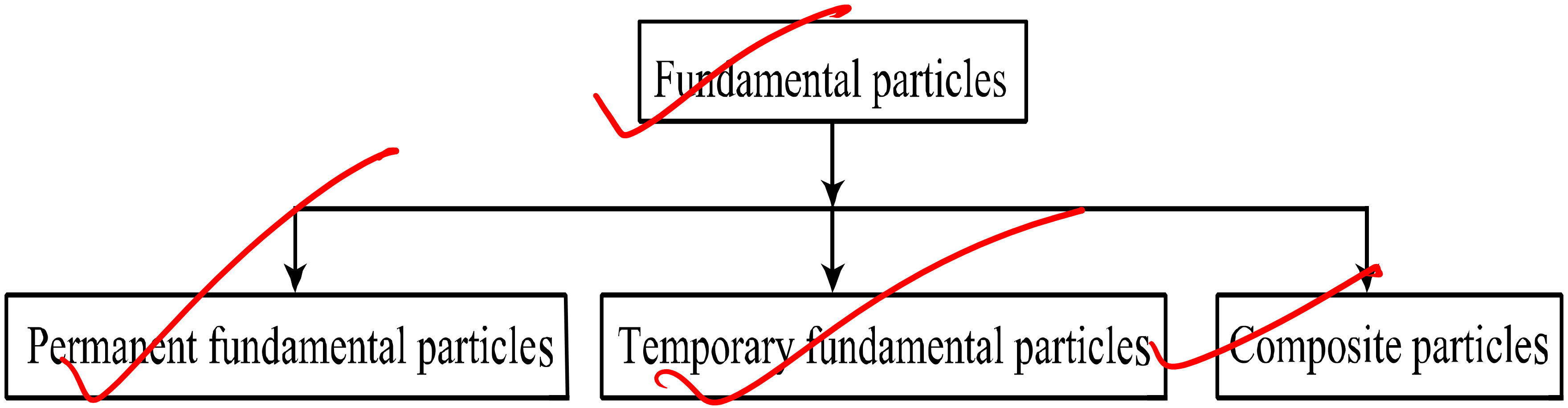
E_n = nth shell's energy

$$E_n = E_1 \times \frac{1}{n^2}$$

$$E_1 = -13.5815\,eV$$

$$E_3 = E_1 \times \frac{1}{3^2} = \frac{E_1}{9} = Ans$$

Atom & it's fundamental particles



Permanent fundamental particle

Particle	Symbol	Mass (g)	Charge (Coulomb)	Relative charge
(i) Electron	e	9.1×10^{-28}	-1.6×10^{-19}	-1
(ii) Proton	p	1.673×10^{-24}	$+1.6 \times 10^{-19}$	$+1$
(iii) Neutron	n	1.675×10^{-24}	0	0

❖ Temporary fundamental particle:

(i) Pion (ii) Muon (iii) Neutrino

(iv) Anti-neutrino (v) Positron (vi) Meson

❖ Composite particle:

(i) Deuteron particle (ii) Alpha particle

Atomic number and atomic mass

- Atomic number (Z) → Proton number
- Atomic mass (A) → (P+n)

The relationship between the number of electrons, protons and neutrons

$^{23}_{11}Na \rightarrow$

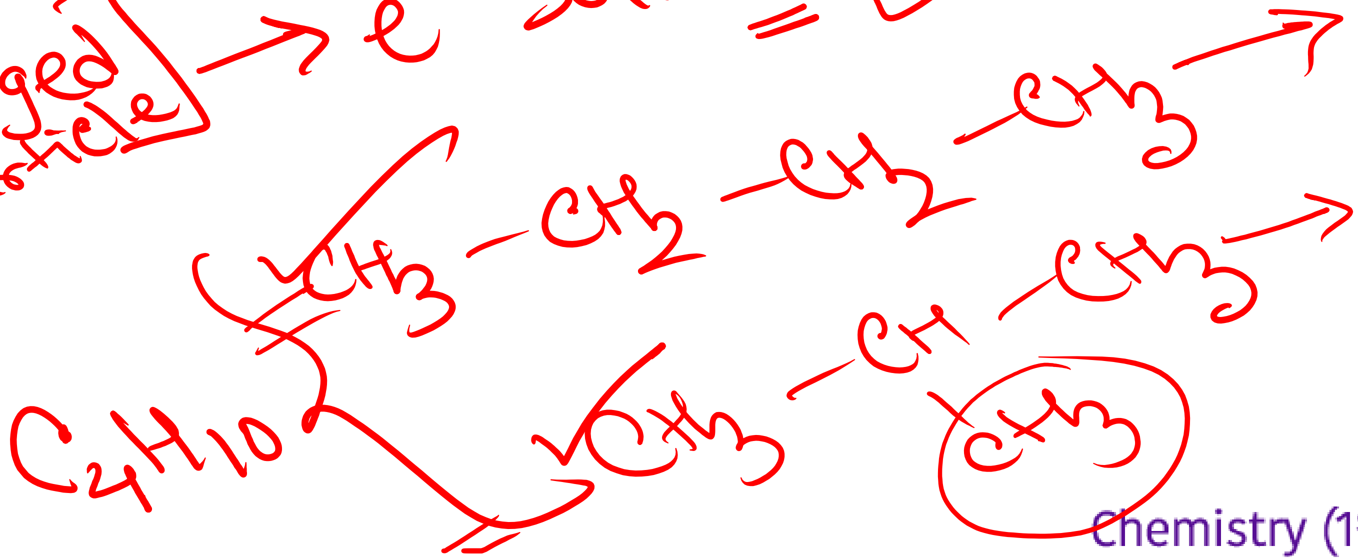
P = 11

e = 11

m = 23

n = 12

- Isotope → Proton same
- Isotone → neutron same
- Isobar → mass same (p+n)
- Isomer → molecular formula same but diff structure
- Isoelectronic → [charged particle] → e^- same



i. $^{58}_{26}Fe$, $^{58}_{27}Ni$

ii. $^{23}_{11}Na$, $^{24}_{12}Mg$

iii. $^{16}_{8}O$, $^{15}_{7}N$, $^{14}_{6}C$

iv. $^{14}_{6}C$, $^{12}_{6}C$, $^{13}_{6}C$

v. $^{23}_{11}Na^{+}$, $^{19}_{9}F^{-}$, $^{24}_{12}Mg^{2+}$

Poll Question -01

Which one of the following pair is isobar to each other?

(a) $^{64}Cu_{29}$, $^{64}Zn_{30}$

(b) $^{35}Cl_{17}$, $^{34}S_{16}$

(c) $^{30}Si_{14}$, $^{31}P_{15}$

(d) $^{1}H_{1}$, $^{2}H_{1}$

Atomic mass and relative atomic mass

According to the carbon scale, relative atomic mass of element = $\frac{\text{Mass of 1 atom}}{\text{Mass of one atom of C}-12\times\frac{1}{12}}$

a.m.u = atomic mass unit

1 a.m.u = 1.6605×10^{-27} kg

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Mathematical problems

- If one atom of Ca's mass is 6.65×10^{-26} kg, then calculate the relative atomic mass.

$$r.a.m = \frac{6.65 \times 10^{-26}}{1.6605 \times 10^{-27}}$$

$$= 40.06$$

Ans

The relative percentage of the isotope and the atomic mass of the element

The relative abundances of three isotopes of an element are a%, b% and c% and each of their atomic masses are $M_1 \mathrm{a.m.u.}$, $M_2 \mathrm{a.m.u.}$ and $M_3 \mathrm{a.m.u.}$ respectively, so average mass of one atom of that element = $\frac{aM_1+bM_2+cM_3}{100}$ a.m.u and it relative atomic mass would be the same.

Mathematical problems

- There are two isotopes of Copper existing in nature. They are - ${}^{63}_{29}Cu$ & ${}^{65}_{29}Cu$.

If the average relative atomic mass of Copper is 63.5, then calculate the percentage of those isotopes available in nature.

${}^{63}_{29}Cu \rightarrow x\%$

${}^{65}_{29}Cu \rightarrow (100-x)\%$

$$\therefore 63.5 = \frac{63x + 65(100-x)}{100}$$

$x = 25\%$

75%

Quantum numbers and their significance

- Quantum Numbers:
  For an electron in an atom-
  (i) the location of the atom’s energy level in which it exists
  (ii) the nature of the energy level (meaning its shape and size)
  (iii) the orientation of the orbital of the electron due to the effect of a magnetic field
  (iv) the direction of rotation about its own axis are expressed by some numbers which are called quantum numbers

According to quantum mechanics, 4 quantum numbers are used for fully expressing the position of an electron inside an atom. The names of the quantum numbers are:

(i) Principal quantum number, n
(ii) Azimuthal or subsidiary quantum number, l
(iii) Magnetic quantum number, m
(iv) Spin quantum number, s.

Orbital and orbital

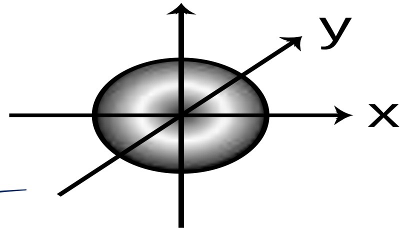
$m = -l$ to $+l$

orbital	l	m
s	0	0 (s)
p	1	-1 / p_x, 0 / p_y, 1 / p_z
d	2	-2 / d_{xy}, -1 / d_{yz}, 0 / d_{zx}, 1 / $d_{x^2-y^2}$, 2 / d_{z^2}
f	3	$-3, -2, -1, 0, 1, 2, 3$

$p_y \rightarrow l = 1$, $m = 0$

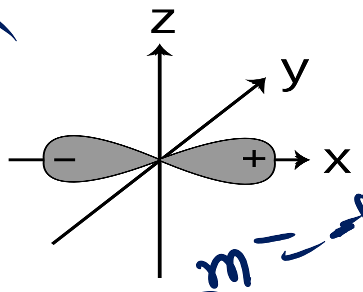
shape of the orbital

- The shape of the **s** orbital is spherical.



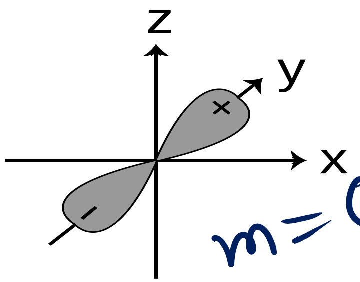
l=0, m=0

- The shape of the p orbital is like that of a dumbell. They are three in number and their size, shape and energy is the same. They have different directions.



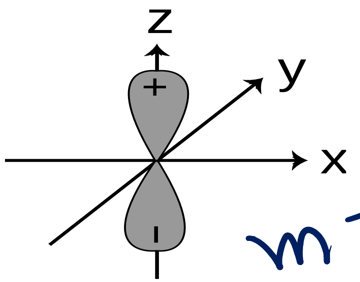
l = 1, [redacted]

px Orbital



l = 1, [redacted]

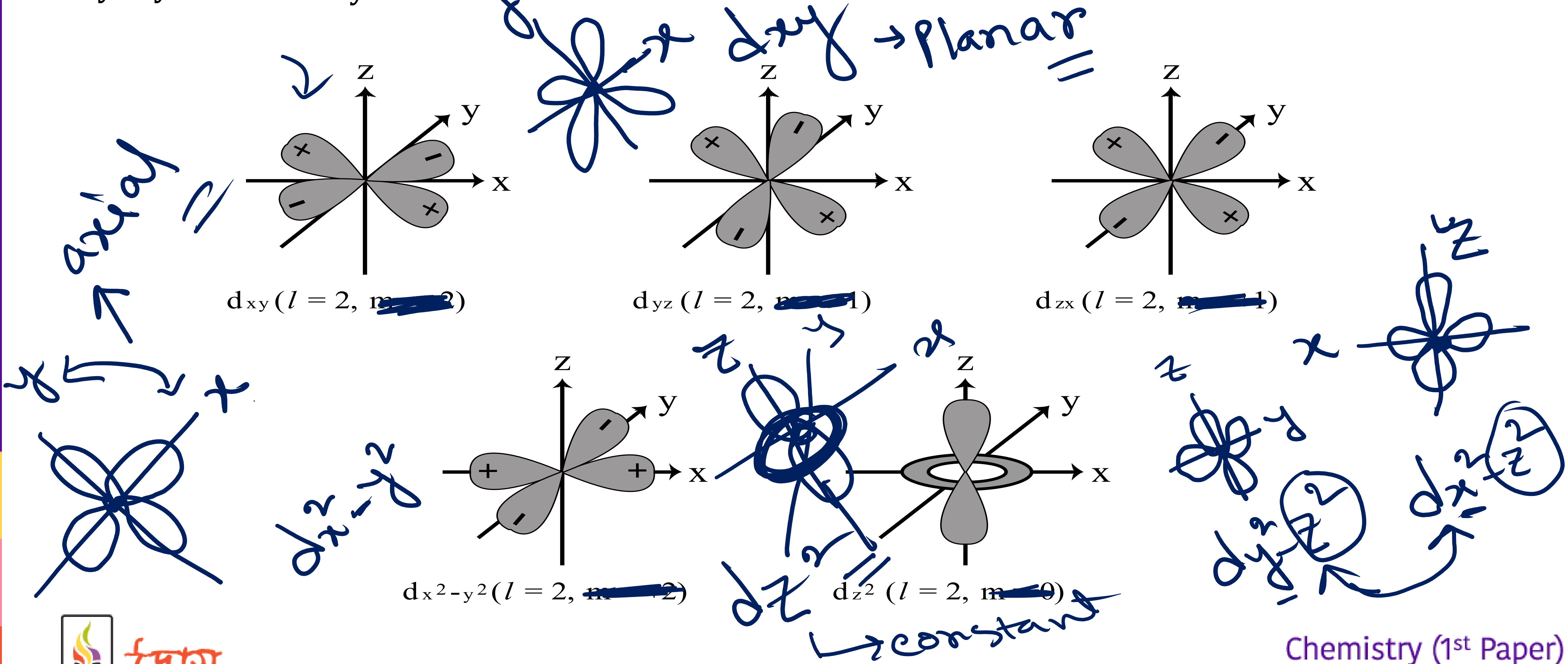
py Orbital



l = 1, [redacted]

pz Orbital

The geometric shape of d orbital is complex. They are 5 in number they are respectively d_{xy}, d_{yz}, d_{zx}, $d_{x^2-y^2}$ and d_{z^2}. They have the same energy but each has a different shape.



d_{xy} (l = 2, [redacted])

d_{yz} (l = 2, [redacted])

d_{zx} (l = 2, [redacted])

$d_{x^2-y^2}$ (l = 2, [redacted])

d_{z^2} (l = 2, [redacted])

Different orbital and electron holding capacity

Determination of maximum number of electrons in different sub energy level using Pauli's exclusion principle					
Sub energy level	n	l	m	s	Maximum e^- number
1s	1	0	0	$\pm\frac{1}{2}$	2
2p	2	1	$-1, 0, +1$	$\pm\frac{1}{2}, \pm\frac{1}{2}, \pm\frac{1}{2}$	6
3d	3	2	$-2, -1, 0, +1, +2$	$\pm\frac{1}{2}, \pm\frac{1}{2}, \pm\frac{1}{2}, \pm\frac{1}{2}, \pm\frac{1}{2}$	10

left

50%

1/2

right

50%

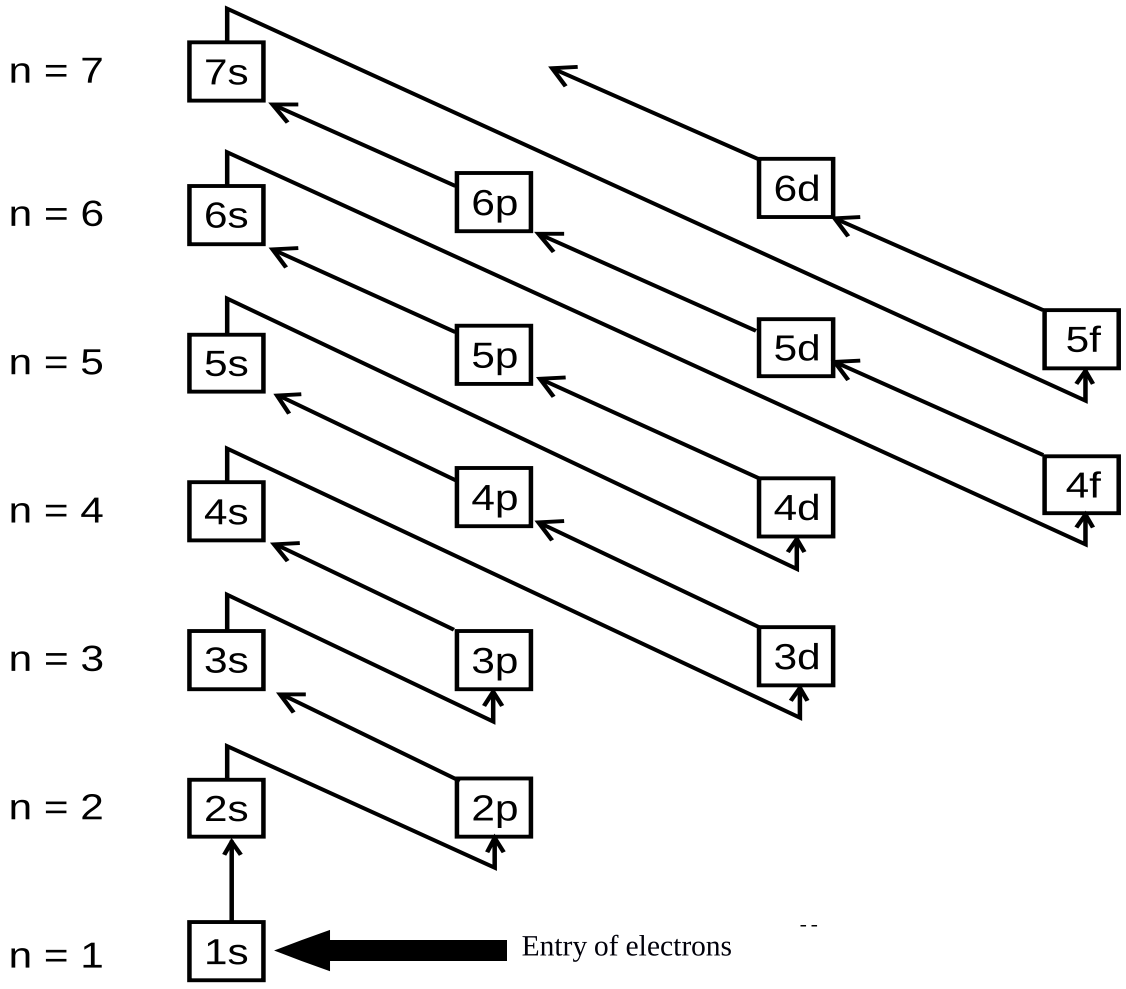
1/2

Atomic electron configuration and various principles

- **Aufbau principle:**

  "The electrons in atom will at first fill up the orbitals with lower energy and gradually fill orbitals with higher energy."

The order of e^- configuration in different energy levels -



Poll Question -02

In which of the following will the electron enter first?

(a) 4f (b) 5d
(c) 6p (d) 7s

❑ **Hund's rule**:

"The electrons will distribute themselves in different degenerate orbitals in such a way that maximum number of electrons remain in unpaired state. The spin of the unpaired electrons will be in the same direction."

Hund's rule tells more that, any half-filled or complete filled orbitals, are more stable than incomplete electronic configuration.

❑ Pauli's exclusion principle:

The four quantum numbers of two electrons in same atom can never be same. If 3 quantum numbers of two electrons are same then the fourth quantum number must be different. Such as-in an atom with two electrons -

For 1st electron, $n = 1,\ l = 0,\ \ m = 0, s = +\frac{1}{2}$

For 2nd electron, $n = 1,\ l = 0,\ \ m = 0, s = -\frac{1}{2}$

That means for 2 electrons of same atom the size (n), shape (*l*) and angular position (m) of orbital can be same if the directions of their rotation in their own axes are opposite to each other. So the main idea of Pauli's exclusion principle is - "There may be highest two electrons in an atomic orbital if their rotation or spins are in opposite directions."

Poll Question -03

Configuration with which quantum number (n, l, m, s) is not possible?

(a) (4, 2, −3, +1/2)
(b) (3, 2, 1,+1/2)
(c) (2, 1, 0, −1/2)
(d) (1, 0, 0, +1/2)

Exceptions

The radioactivity of the element and the radioactive isotope

The spontaneous change in a nucleus by radiating different types of rays is known as radioactivity.

Radioactivity is a spontaneous process. If the difference between the number of neutrons and protons is more than 3 then the instability increases. So the nucleus changes and gives rise to radioactivity.

- **Comparison of alpha (α), beta (β) and gamma (γ) rays:**

Ray or particle	Relative charge	Relative mass	Nature of ray or particle	Permittivity(relative)
α-ray	+2	4 units	Bipositive charge (He^{2+})	1
β-ray	–1	0	Unit negative (e^{-})	1,000
γ-ray	0	0	Electromagnetic wave	10,000

- Emission of γ-ray does not change the nucleus. This is because γ-ray is an electromagnetic ray. γ-ray has no charge or mass.

- Every radioactive emission contains γ rays. α and β rays cannot be emitted together.

Mathematical problems

Nuclear reaction

- **Nuclear fusion:**

When two small nuclei join together (fuses) and reforms as a single and relatively heavier nucleus, the reaction is called nuclear fusion reaction. It is also called thermonuclear reaction, as the reaction is carried out at 10^8K temperature with numerous tiny nuclei. A huge amount of energy is also released in this reaction.

$$^{2}_{1}\mathrm{H} + \ ^{1}_{1}\mathrm{H} \xrightarrow[10^8\ \mathrm{K}]{\text{fusion}} \ ^{3}_{2}\mathrm{He} + \quad + \text{huge amount of energy}$$

$$^{2}_{1}\mathrm{H} + \ ^{3}_{1}\mathrm{H} \xrightarrow[10^8\ \mathrm{K}]{\text{fusion}} \ ^{4}_{2}\mathrm{He} + \ ^{1}_{0}\mathrm{n} + \text{huge amount of energy}$$

The source of energy for sun and other stars is nuclear fusion reactions. Nuclear fusion is also carried out in a hydrogen bomb.

- **Nuclear fission:**

It is the nuclear reaction that occurs when very heavy nucleus of elements, like ${}^{235}_{92}U$ and ${}^{239}_{94}Pu$, are hit by high velocity neutrons producing two different nuclei of having nearly the similar mass. This also produces huge amount of energy. For example -

$$\underset{\text{Uranium}}{{}^{235}_{92}U} + {}^{1}_{0}n \rightarrow \underset{\text{Barium}}{{}^{141}_{56}Ba} + \underset{\text{Krypton}}{{}^{92}_{36}Kr} + 3{}^{1}_{0}n + \text{huge amount of heat energy}$$

$${}^{235}_{92}U + {}^{1}_{0}n \rightarrow {}^{144}_{56}Ba + {}^{90}_{36}Kr + 2{}^{1}_{0}n + \text{huge amount of heat energy}$$

The energy produced in these nuclear reactions is many times greater than that in chemical reactions. Atom bombs and nuclear reactors produces huge amount of energy as a result of fission reactions in them.

Poll Question -03

What is X in the nuclear reaction given below? ${}^{14}_{7}N + \alpha \rightarrow {}^{17}_{8}O + X$

(a) proton
(b) β-particle
(c) γ-ray
(d) Neutron

Mass defect and Nuclear Binding Energy

If the total mass of protons, neutrons and electrons of an atom are determined separately, it can be seen that it is slightly higher than the actual mass of that atom, e.g. ${}^{4}_{2}He$ has 2 p and 2 n. The relative masses of p and n are 1.0074amu and 1.0086amu respectively. So the total mass of the atom should be $m = 2m_p + 2m_n = (2 \times 1.0074 + 2 \times 1.0086) = 4.032amu$. But the actual mass of the He atom is 4.003amu. This extra mass is known as mass defect. So mass defect of the He atom, $\Delta m = (4.032 - 4.003)amu = 0.029amu$; [The mass of e^- is taken to be negligible.]

Mathematical problems

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