Atomic Structure

1. Theory
Dalton's Atomic theory - atom is indivisible
Thompson's Plum Pudding / Resin Pudding / Watermelon model
Rutherford's α-scattering experiment (discovery of nucleus)

2. Rays
Cathode rays - JJ Thompson
Anode rays / canal rays - Goldstein
charge of e^- - Milikan - oil drop experiment.

3. mass
$m_p = 1.673 \times 10^{-27}$ kg $\quad m_n = 1.675 \times 10^{-27}$ kg
$m_e = 9.1 \times 10^{-31}$ kg.

4. particles
α-particles = doubly ionised He $[{}_2He^4]$.
β- rays = e^-
γ- rays = high energetic photons.
penetrating power = $\alpha < \beta < \gamma$.

5. size
$D_A = 10^{-10}$ m $\quad \frac{D_A}{D_N} = 10^5 \quad \frac{V_A}{V_N} = 10^{15}$.
$D_N = 10^{-15}$ m.

6. radius
Radius of nucleus $\boxed{R = R_0 A^{1/3}}$. $\quad R_0 = 1.1$ fm
A = mass no.

7. $$\text{Avg. atomic mass} = \frac{\%\text{ abundance of isotope 1} \times \text{at. wt} + \%\text{ abundance of isotope 2} \times \text{at. wt}}{100}$$

7. Isotope - same Z, diff. A
Isobar - same A, diff. Z
Isotone - same A - Z difference (same no. of neutrons)
Isodiapher - same n - p difference.
Isoster - same no. of atoms and e^-.
Isoelectronic species - same no. of e^-.

${}_Z X^A$

8. frequency
$\nu = \frac{c}{\lambda} \quad \bar{\nu} = \frac{1}{\lambda} \quad T = \frac{1}{\nu}$ $\quad \lambda$ = lambda, ν = neu

$\boxed{E = nh\nu = \frac{nhc}{\lambda}}$ $\quad$ h = Planck's constant = 6.626×10^{-34} Js.

9. **Photoelectric effect** - exhibited most effectively by K, Rb, Cs. Among them, Cs exhibits most readily.

ϕ_0 = work function. V_0 = stopping potential
ν_0 = threshold frequency

$$\boxed{\begin{aligned} E &= E_0 + KE \\ h\nu &= h\nu_0 + KE \\ \Rightarrow h\nu &= h\nu_0 + \frac{1}{2}mv^2 \quad \Rightarrow h\nu = h\nu_0 + eV_0 \end{aligned}}$$

$KE \propto \nu$ $\qquad$ $KE \not\propto$ Intensity.

10. **Bohr's postulates** - e^- revolves only in those orbits whose angular momentum is integral multiple of $\frac{h}{2\pi}$.
- e^- revolve in circular paths called stationary orbits (in the orbit, energy is constant)

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

Bohr's postulates are applicable only to single e^- species.

11. $$\boxed{r_n = \frac{n^2h^2}{4\pi^2mkze^2} = 0.529\frac{n^2}{z} A^\circ}$$

→ $\boxed{PE = \frac{-kze^2}{r}}$ $\quad$ $\boxed{KE = \frac{kze^2}{2r}}$ $\quad$ $\boxed{\text{Total energy} = \frac{-kze^2}{2r}}$

→ $\boxed{E_n = \frac{2\pi^2mk^2z^2e^4}{n^2h^2} = \frac{-13.6\,z^2}{n^2}\ eV/\text{atom}}$

→ $\boxed{V_n = 2.19\times10^6\left(\frac{z}{n}\right) m/s}$

→ $\boxed{\nu = \frac{1}{T} \propto \frac{z^2}{n^3}}$ $\qquad$ circumference $\propto \frac{n^3}{z^2}$

→ $\boxed{\bar{\nu} = \frac{1}{\lambda} = Rz^2\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]}$

R = rydberg constant
$= 1.1\times10^7\ m^{-1}$

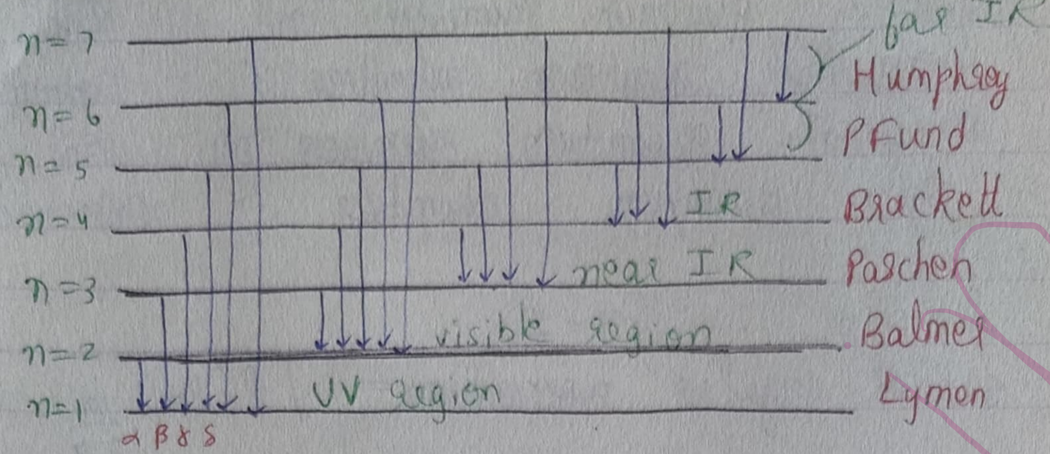
$\frac{1}{R} = 912\ A^\circ$

In H atom -
$n=1 \Rightarrow -13.6$ eV
$n=2 \Rightarrow -3.4$ eV
$n=3 \Rightarrow -1.51$ eV
$n=4 \Rightarrow -0.85$ eV
$n=5 \Rightarrow -0.54$ eV
$n=6 \Rightarrow -0.35$ eV
$n=\infty \Rightarrow 0$ eV

12. nth separation energy = energy of $(n+1)^{th}$ orbit.

H spectrum

α-line ⇒ highest wavelength
last line = limiting line ⇒ lowest λ.



$$\boxed{\text{No. of lines in spectrum} = \frac{(n_2 - n_1 + 1)(n_2 - n_1)}{2}}$$

13. **De-broglie hypothesis** - proposed dual nature
(waves associated with material particles called matter waves)

$$\boxed{2\pi r = n\lambda}$$

no. of waves = no. of orbits (in in-phase diagram).

14. $$\boxed{\lambda = \frac{h}{p} = \frac{h}{\sqrt{2mK}} = \frac{h}{\sqrt{2mqV}}}$$ (V = voltage).

For gases
$$\lambda = \frac{h}{\sqrt{3mKT}}$$

For e^-	For proton	For α-particle
$\lambda_{(A^\circ)} = \sqrt{\dfrac{150}{V(\text{in volts})}}$	$\lambda = \dfrac{0.286}{\sqrt{V}}$	$\lambda = \dfrac{0.101}{\sqrt{V}}$

$\lambda_e > \lambda_p > \lambda_\alpha$ (for same voltage).

15. **Heisenberg Uncertainty Principle** - It is impossible to determine the exact change in position and change in momentum simultaneously for a microscopic particle. (Not applicable to macroscopic particles).

$$\boxed{\Delta x \cdot \Delta p \geq \frac{h}{4\pi}} \Rightarrow \boxed{\Delta x \, m . \Delta v \geq \frac{h}{4\pi}}$$

16. **Schrodinger Wave Equation** -

$$\boxed{\frac{\partial^2 \psi}{\partial x^2} + \frac{\partial^2 \psi}{\partial y^2} + \frac{\partial^2 \psi}{\partial z^2} + \frac{8\pi^2 m}{h^2}(E - V)\psi = 0}$$

17. Maximum no. of e^-s in an orbit/shell = $\boxed{2n^2}$.
→ Principal quantum number (n) – Bohr
→ Azimuthal quantum number (l) – Sommerfeld
→ Magnetic quantum number (m) – Lind
→ Spin quantum number (s) – Uhlenbeck, Goudsmith.

18. $l = 0, 1, \ldots (n-1)$.

$l = 0 \Rightarrow s$
$l = 1 \Rightarrow p$
$l = 2 \Rightarrow d$
$l = 3 \Rightarrow f$

orbital angular momentum = $\boxed{\sqrt{l(l+1)}\dfrac{h}{2\pi}}$.

Maximum no. of electrons in a subshell (s/p/d/f/g) = $\boxed{4l+2}$

19. Shape of orbitals – (i) s = non-directional
(ii) p = dumbel shaped (iii) d = double dumbel shaped
(iv) f = complex.

20. no. of orbitals = m = $\boxed{2l+1}$

$\dfrac{h}{2\pi} = \hbar$

values of $m = -l, \ldots 0, \ldots, +l$.

$\left.\begin{matrix} p_x \\ p_y \end{matrix}\right\} \pm 1$ $p_z = 0$ $d_{z^2} = 0$ $d_{yz}, d_{zx} = \pm 1$

$d_{x^2-y^2}, d_{xy} = \pm 2$.

21. Total spin = $s = \dfrac{n}{2}$ (n = no. of unpaired e^-s.)

For an e^-
$s = +1/2$ or $-1/2$.

Spin multiplicity = $\boxed{2s+1}$
Spin angular momentum = $\boxed{\sqrt{s(s+1)}\dfrac{h}{2\pi}}$.

22. Node/Radial node/Spherical Node/Nodal region = $\boxed{n-l-1}$
(finding probability of e^- is zero)
Nodal Plane/Angular node = $\boxed{l}$
Total nodes = $\boxed{n-1}$.

23. Anomalous configuration –
Cu = 29 = $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^1\ 3d^{10}$
Cr = 24 = $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^1\ 3d^5$

24. Magnetic moment = $\boxed{\mu = \sqrt{n(n+2)}\ Bm}$ (Bm = Bohr magneton, n = no. of unpaired e^-s.)

25. Ψ_{420} → n, l, m

$n=4$
$l=2$ ∴ 4d orbital
$m=0$ ∵ $m=0$ ∴ d_{z^2}.

26. For Hydrogen atom-

$1s < 2s = 2p < 3s = 3p = 3d < 4s = 4p = 4d = 4f \ldots$

27. Auf-bau rule ⇒ Moeller's diagram
(n+l) rule ⇒ subshell with lower (n+l) value is filled first.
⇒ if two subshells have same (n+l) value, then subshell with lower $\underline{\underline{n}}$ value is filled first.

Hund's maximum multiplicity ⇒ all orbitals (having equal energy) are filled singly first, then only pairing occurs.

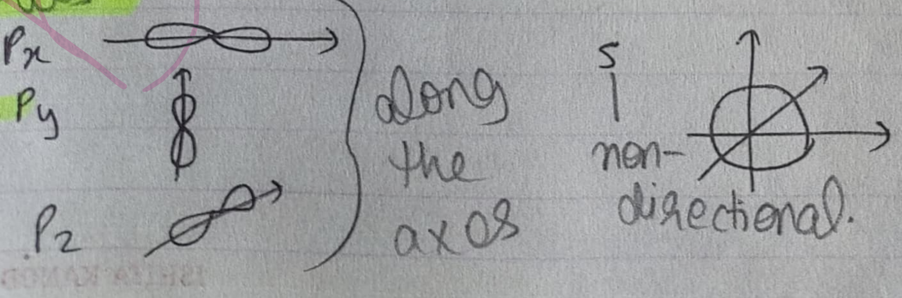
Pauli's Exclusion principle ⇒ No 4 quantum numbers are same/equal for any 2 e^-s. At least, they differ in spin quantum number.

28. Exchange energy - when e^- is involved in exchange with adjacent e^-s having same spin, then some energy is released. The released energy is called exchange energy.

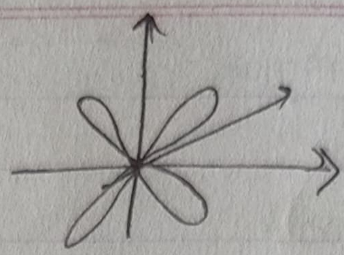
→ ↑ exchanges ⇒ ↑ release of energy
⇒ ↓ in internal energy
⇒ stability ↑.

∴ $\boxed{\text{no. of exchanges} = \frac{n(n-1)}{2}}$ n = no. of vacant/half/partially filled orbitals.

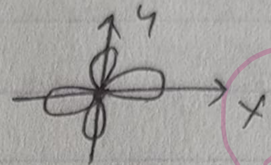
orbitals and axes



→ $\left.\begin{array}{l} d_{xy} \\ d_{yz} \\ d_{zx} \end{array}\right\}$ in between the axes



→ $d_{x^2-y^2}$ } along the axis



→ d_{z^2} ⇒
(along the axis).