BRAIN MAP — Dual nature of matter and radiation & atoms and nuclei

Dual nature of matter and radiation

Photoelectric effect
It is the phenomenon of emission of photoelectrons when light of suitable frequency falls on the metal surface.

Photons
Packets of energy which are emitted by a source of radiation.

Energy of photon, $E = h\upsilon = \frac{hc}{\lambda}$

Laws of photoelectric emission
For a given photosensitive material and frequency of incident radiation,
(i) the photoelectric current is directly proportional to the intensity of incident light.
(ii) saturation current is found to be proportional to the intensity of incident radiation whereas the stopping potential is independent of its intensity.
(iii) there exists a certain minimum cut-off frequency, below which no emission of photoelectrons takes place. The maximum kinetic energy of the emitted photoelectrons increases linearly with frequency of the incident radiation, but is independent of its intensity.
(iv) the photoelectric emission is an instantaneous process without apparent time lag (-10^{-9} s or less) between the incidence of radiation and the emission of photoelectrons.

Einstein's photoelectric equation

$$K_{max} = \frac{1}{2}mv^2_{max} = h\upsilon - \phi = h\upsilon - h\upsilon_0$$

$$= hc\left(\frac{1}{\lambda} - \frac{1}{\lambda_0}\right)$$

de-Broglie hypothesis
de-Broglie wavelength, $\lambda = \frac{h}{p} = \frac{h}{mv} = \frac{h}{\sqrt{2mK}}$

de-Broglie wavelength associated with electron accelerated under a potential difference V volt,

$$\lambda = \frac{12.27}{\sqrt{V}}\ \text{Å}$$

Atoms and nuclei

Atomic models

Rutherford α-ray scattering
Distance of closest approach,

$$r_0 = \frac{2Ze^2}{4\pi\varepsilon_0 K}$$

Impact parameter

$$b = \frac{1}{4\pi\varepsilon_0}\frac{Ze^2\cot\frac{\theta}{2}}{K}$$

Bohr's model of hydrogen atom
• Angular momentum of electron orbiting in n^{th} orbit

$$L_n = mv_nr_n = \frac{nh}{2\pi}$$

Radius of Bohr's stationary n^{th} orbit

$$r_n = \left(\frac{n^2}{m}\right)\left(\frac{h}{2\pi}\right)^2\frac{4\pi\varepsilon_0}{Ze^2}$$

Velocity of electron in n^{th} orbit

$$v_n = \frac{1}{4\pi\varepsilon_0}\frac{2\pi Ze^2}{nh} = \frac{e^2Z}{2\varepsilon_0 nh}$$

Frequency of electron in n^{th} orbit

$$\upsilon_n = \frac{Ze^2}{4\pi\varepsilon_0 nhr}$$

Total energy of electron in n^{th} orbit

$$E_n = -\frac{me^4}{8n^2\varepsilon_0^2h^2} = \frac{-13.6}{n^2}\ \text{eV}$$

Rydberg formula for spectrum of hydrogen atom

$$\frac{1}{\lambda} = R\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]$$

Atomic nucleus

Nuclear radius
$R = R_0A^{1/3}$

Nuclear density

$$\rho = \frac{3m}{4\pi R_0^3}$$

Binding energy
The energy with which nucleons are bound in the nucleus.

Mass defect,

$$\Delta m = [Zm_p + (A - Z)\, m_n - m_N]$$

Total binding energy $(B.E) = (\Delta m)c^2$

$$= [Zm_p + (A - Z)m_n - m_N]c^2$$

Average B.E. per nucleon $= \frac{[Zm_p + (A-Z)m_n - m_N]c^2}{A}$

Packing fraction $= \frac{\text{mass excess}}{\text{mass number}} = \frac{M - A}{A}$

Radioactivity
The spontaneous emission of some types of invisible rays from some substances is called radioactivity and these substances are called radio activity substances.

Radioactive decay law,

$$-\frac{dN}{dt} = \lambda N$$

Half life, $T_{1/2} = \frac{0.6931}{\lambda}$

Average life, $\tau = \frac{1}{\lambda} - \frac{1}{0.6931/T_{1/2}} = 1.44\,T_{1/2}$

where λ is disintegration constant.

Activity, $R = -\frac{dN}{dt}$

Nuclear fission
The phenomenon of splitting of heavy nucleus into two or more smaller nuclei.

Nuclear fusion
The phenomenon of fusing of two or more lighter nuclei to form a single heavy nucleus.

Symbols Used

h = planck's constant, υ = frequency, ϕ_0 = work function, λ = wavelength, v = velocity, T = temperature, Z = atomic number, ε_0 = permittivity of vacuum, K= kinetic energy, m_n = mass of neutron, m_p = mass of proton, m_N = mass of nucleus, A = mass number, N = number of atoms left undecayed, c = speed of light, $R_0 = 1.2 \times 10^{-15}$ m, m = average mass of nucleon, $R = 1.03 \times 10^7$ m^{-1}