MODERN PHYSICS

Let's Play With Physics | NEET 2025--26

1. Dual Nature of Radiation & Matter

Photon Properties

★ $E = hf = \dfrac{hc}{\lambda}$

Photon momentum $p = \dfrac{h}{\lambda} = \dfrac{hf}{c} = \dfrac{E}{c}$

Mass equivalent $m = \dfrac{h}{c\lambda} = \dfrac{E}{c^2}$

Energy in eV $E\,(\text{eV}) = \dfrac{12400}{\lambda\,(\text{Å})}$

Key: Photons have zero rest mass. $hc = 12400\,\text{eV·Å} = 1240\,\text{eV·nm}$.

de Broglie Wavelength

★ $\lambda = \dfrac{h}{p} = \dfrac{h}{mv}$

In terms of KE $\lambda = \dfrac{h}{\sqrt{2mK}}$

Accelerated charge $\lambda = \dfrac{h}{\sqrt{2meV}}$

Electron (simplified) $\lambda = \dfrac{12.27}{\sqrt{V}}$ Å (V in volts)

Proton / neutron $\lambda = \dfrac{0.286}{\sqrt{V}}$ Å

α-particle $\lambda = \dfrac{0.101}{\sqrt{V}}$ Å

Thermal (gas) $\lambda = \dfrac{h}{\sqrt{3mk_BT}} = \dfrac{h}{\sqrt{2mk_BT}}$

Use $\sqrt{3mk_BT}$ for rms speed; $\sqrt{2mk_BT}$ for average.

2. Photoelectric Effect

★ $hf = \phi + eV_s = \phi + KE_{\max}$

Work function $\phi = hf_0 = \dfrac{hc}{\lambda_0}$

Stopping potential $eV_s = hf - \phi \Rightarrow V_s = \dfrac{h}{e}f - \dfrac{\phi}{e}$

Max KE $KE_{\max} = \frac{1}{2}mv_{\max}^2 = eV_s$

Threshold freq. $f_0 = \phi/h$

Threshold wavelength $\lambda_0 = hc/\phi$

Important Graph Relations

Graph	Inference
V_s vs f	slope $= h/e$; intercept $= -\phi/e$
$KE_{\max}$ vs f	slope $= h$; starts at f_0
I vs V	I_{sat} depends on intensity
I_{sat} vs intensity	straight line (slope $\propto 1/r^2$)

$KE_{\max}$ is **independent** of intensity. Saturation current is **independent** of frequency.

3. Bohr's Atomic Model

Quantisation Condition

★ $mvr = \dfrac{nh}{2\pi} = n\hbar$

Radius of nth Orbit

★ $r_n = \dfrac{n^2}{Z} \times 0.529\ \text{Å} = \dfrac{n^2 a_0}{Z}$

For H ($Z = 1$) $r_1 = 0.529\ \text{Å} \approx 0.53\ \text{Å}$

Velocity of Electron

$v_n = \dfrac{Z}{n} \times 2.18 \times 10^6\ \text{m/s} \qquad v_n = \dfrac{Ze^2}{2\varepsilon_0 hn}$

Energy of nth Orbit

★ $E_n = -\dfrac{Z^2}{n^2} \times 13.6\ \text{eV}$

For H: $n = 1$ $E_1 = -13.6$ eV

$n = 2$ $E_2 = -3.4$ eV

$n = 3$ $E_3 = -1.51$ eV

$n = \infty$ $E_\infty = 0$ (ionisation)

KE of electron $KE_n = +\dfrac{Z^2 \times 13.6}{n^2}\ \text{eV} = -E_n$

PE of electron $PE_n = 2E_n = -\dfrac{2Z^2 \times 13.6}{n^2}\ \text{eV}$

Photon Emitted in Transition

★ $hf = E_{n_2} - E_{n_1} = 13.6\,Z^2\left(\dfrac{1}{n_1^2} - \dfrac{1}{n_2^2}\right)\text{eV}$

Wavenumber $\bar{\nu} = \dfrac{1}{\lambda} = R_H Z^2\left(\dfrac{1}{n_1^2} - \dfrac{1}{n_2^2}\right)$

4. Hydrogen Spectrum Series

Series	n_1	n_2	Region
Lyman	1	$2, 3\ldots$	UV
Balmer	2	$3, 4\ldots$	Visible
Paschen	3	$4, 5\ldots$	IR
Brackett	4	$5, 6\ldots$	IR
Pfund	5	$6, 7\ldots$	Far IR

Rydberg const. $R_H = 1.097 \times 10^7\ \text{m}^{-1}$

Max lines from n Lines $= \dfrac{n(n-1)}{2}$

Ionisation energy (H) $E_i = 13.6$ eV

Balmer series 1st line (n: $3 \to 2$) $= 656.3$ nm (red). Lyman series lies entirely in UV.

5. X-Rays

★ $\lambda_{\min} = \dfrac{hc}{eV} = \dfrac{12400}{V\,(\text{volt})}$ Å

Moseley's law $\sqrt{f} = a(Z - b)$ ($b \approx 1$ for K_α)

K_α transition $n : 2 \to 1$; $K_\beta : 3 \to 1$

$\lambda_{\min}$ (cut-off) depends only on accelerating voltage V, not on target material.

6. Nuclear Physics

Nuclear Size & Density

Nuclear radius $R = R_0 A^{1/3}$, $R_0 = 1.2$ fm

Nuclear density $\rho \approx 2.3 \times 10^{17}\ \text{kg/m}^3$ (const.)

Mass Defect & Binding Energy

★ $\Delta m = Zm_p + Nm_n - M_{\text{nucleus}}$

★ $BE = \Delta m \times 931.5$ MeV

BE per nucleon $BE/A = \dfrac{\Delta m \times 931.5}{A}$ MeV

^{56}Fe has the highest BE/A (≈ 8.8 MeV). Fission & fusion both increase BE/A.

Radioactive Decay Law

★ $N = N_0\, e^{-\lambda t}$

Activity $A = A_0\, e^{-\lambda t} = \lambda N$

Half-life $T_{1/2} = \dfrac{\ln 2}{\lambda} = \dfrac{0.693}{\lambda}$

Mean life $\tau = \dfrac{1}{\lambda} = \dfrac{T_{1/2}}{0.693} = 1.44\,T_{1/2}$

★ $N = N_0\left(\dfrac{1}{2}\right)^{t/T_{1/2}} = \dfrac{N_0}{2^n}$ (n = no. of half-lives)

Amount decayed $N_{\text{dec}} = N_0\left(1 - e^{-\lambda t}\right)$

Activity unit $1\ \text{Ci} = 3.7 \times 10^{10}\ \text{dps} = 3.7 \times 10^{10}$ Bq

Decay Types

Decay	ΔZ	ΔA	Particle
α	-2	-4	$^4_2$He
β^-	$+1$	0	e^-, $\bar{\nu}_e$
$\beta+$	-1	0	e^+, ν_e
γ	0	0	photon

7. Important Constants & Standard Values

Planck's constant h	6.626×10^{-34} J·s	Speed of light c	3×10^{8} m/s
Electron charge e	1.6×10^{-19} C	Electron mass m_e	9.1×10^{-31} kg
Proton mass m_p	1.673×10^{-27} kg	Neutron mass m_n	1.675×10^{-27} kg
Rydberg constant R_H	1.097×10^{7} m^{-1}	Bohr radius a_0	0.529 Å
hc	1240 eV·nm = 12400 eV·Å	1 amu	931.5 MeV/c^2
Boltzmann const. k_B	1.38×10^{-23} J/K	1 eV	1.6×10^{-19} J

8. Bohr Model Quick Reference (Hydrogen, $Z = 1$)

n	r_n (Å)	v_n ($\times 10^{6}$ m/s)	E_n (eV)	KE (eV)	PE (eV)
1	0.529	2.18	−13.6	+13.6	−27.2
2	2.116	1.09	−3.4	+3.4	−6.8
3	4.761	0.727	−1.51	+1.51	−3.02
4	8.464	0.545	−0.85	+0.85	−1.70