PHYS143
Module IV – Modern Physics

Constants:

$h = 6.63 \times 10^{-34}$ J.s

$\hbar = 1.055 \times 10^{-34}$ J.s

$1\text{ u} = 1.660\,539 \times 10^{-27}$ Kg

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

$k_e = 8.9876 \times 10^{9}\ N.m^2/C^2$

$c = 3.00 \times 10^{8}$ m/s

$a_o = 0.0529$ nm

$1\text{ u} = 931.494\ \text{MeV/c}^2$

$m_e = 9.11 \times 10^{-31}$ Kg

$Z = 1$ for Hydrogen atom

$\sigma = 5.670 \times 10^{-8}$ W/m^2.K^4

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

$1\text{ eV} = 1.602176 \times 10^{-19}$ J

$R_H = 1.097\,373\,2 \times 10^{7}$ m^{-1}

Formulas:

Lorentz Transformations:

$$x' = \gamma(x - vt) \qquad y' = y \qquad z' = z \qquad t' = \gamma\left(t - \frac{v}{c^2}x\right)$$

$$x = \gamma(x' + vt') \qquad y = y' \qquad z = z' \qquad t = \gamma\left(t' + \frac{v}{c^2}x'\right)$$

$$\left.\begin{aligned}\Delta x' &= \gamma(\Delta x - v\,\Delta t)\\ \Delta t' &= \gamma\left(\Delta t - \frac{v}{c^2}\Delta x\right)\end{aligned}\right\}\text{S} \rightarrow \text{S}' \qquad \left.\begin{aligned}\Delta x &= \gamma(\Delta x' + v\,\Delta t')\\ \Delta t &= \gamma\left(\Delta t' + \frac{v}{c^2}\Delta x'\right)\end{aligned}\right\}\text{S}' \rightarrow \text{S}$$

$$u'_x = \frac{u_x - v}{1 - \dfrac{u_x v}{c^2}} \qquad u'_y = \frac{u_y}{\gamma\left(1 - \dfrac{u_x v}{c^2}\right)} \quad \text{and} \quad u'_z = \frac{u_z}{\gamma\left(1 - \dfrac{u_x v}{c^2}\right)}$$

Wien's displacement law:

$$\lambda_{\max} T = 2.898 \times 10^{-3}\ \text{m.K}$$

Stefan's law

$$P = \sigma A e T^4$$

Rayleigh-Jeans Law:

$$I(\lambda, T) = \frac{2\pi c k_B T}{\lambda^4}$$

Planck's Wavelength Distribution Function:

$$I(\lambda, T) = \frac{2\pi h c^2}{\lambda^5\left(e^{hc/\lambda k_B T} - 1\right)}$$

de Broglie wavelength and Frequency:

$$\lambda = \frac{h}{p} = \frac{h}{mu} \qquad\qquad f = \frac{E}{h}$$

Emission Spectrum of Hydrogen:

$$\frac{1}{\lambda} = R_{\mathrm{H}}\left(\frac{1}{2^2} - \frac{1}{n^2}\right)$$

Lyman series:

$$\frac{1}{\lambda} = R_{\mathrm{H}}\left(1 - \frac{1}{n^2}\right) \quad n = 2, 3, 4, \ldots$$

Paschen series:

$$\frac{1}{\lambda} = R_{\mathrm{H}}\left(\frac{1}{3^2} - \frac{1}{n^2}\right) \quad n = 4, 5, 6, \ldots$$

Brackett series:

$$\frac{1}{\lambda} = R_{\mathrm{H}}\left(\frac{1}{4^2} - \frac{1}{n^2}\right) \quad n = 5, 6, 7, \ldots$$

The radii of the Bohr orbits

$$r_n = \frac{n^2\hbar^2}{m_e k_e e^2} \quad n = 1, 2, 3, \ldots \qquad\qquad r_n = \left(n^2\right)\frac{a_o}{Z}$$

The energy of any orbit is

$$En = \frac{-13.606}{n^2}(Z^2) \quad eV$$

$$E_n = -\frac{k_e e^2}{2a_o}\left(\frac{Z^2}{n^2}\right) \quad n = 1, 2, 3, \ldots$$

Speed of electron in its orbit:

$$v^2 = \frac{k_e e^2}{m_e r}$$

Frequency and Wavelength of Emitted Photons:

$$f = \frac{E_i - E_f}{h} = \frac{k_e e^2}{2a_o h}\left(\frac{1}{n_f^2} - \frac{1}{n_i^2}\right) \qquad\qquad \frac{1}{\lambda} = \frac{f}{c} = \frac{k_e e^2}{2a_o hc}\left(\frac{1}{n_f^2} - \frac{1}{n_i^2}\right) = R_H\left(\frac{1}{n_f^2} - \frac{1}{n_i^2}\right)$$

Average radius of nucleus is:

$$r = aA^{1/3} \quad (a = 1.2 \times 10^{-15}\ \mathrm{m})$$

Binding Energy:

$$E_b = [ZM(\mathrm{H}) + Nm_n - M({}^{A}_{Z}\mathrm{X})] \times 931.494\ \mathrm{MeV/u}$$

Disintegration Energy:

$$Q = (M_x - M_Y - M_\alpha)c^2$$

For e^- decay and electron capture:

$$Q = (M_x - M_Y)c^2$$

For e^+ decay:

$$Q = (M_x - M_Y - 2m_e)c^2$$

Doppler Shift:

$$f' = \frac{\sqrt{1+v/c}}{\sqrt{1-v/c}} f$$

Compton Effect:

$$\lambda' - \lambda_o = \frac{h}{m_e c}(1 - \cos\theta)$$

$L = m_e v r \quad L = \sqrt{\ell(\ell+1)}\hbar \quad \ell = 0,1,2,\ldots,n-1 \quad L_z = m_\ell \hbar \quad \cos\theta = \frac{L_z}{L} = \frac{m_\ell}{\sqrt{\ell(\ell+1)}}$

$$S = \sqrt{s(s+1)}\hbar = \frac{\sqrt{3}}{2}\hbar \qquad S_z = m_s \hbar = \pm\tfrac{1}{2}\hbar$$

$$E = K + U = \frac{1}{2}m_e v^2 - k_e\frac{e^2}{r} \qquad m_e v r = n\hbar \quad n = 1, 2, 3, \ldots$$

$$E = -\frac{k_e e^2}{2r}$$

Time Dilation:

$$\Delta t = \frac{\Delta t_p}{\sqrt{1-\frac{v^2}{c^2}}} = \gamma \Delta t_p$$

$$\text{where } \gamma = \frac{1}{\sqrt{1-\frac{v^2}{c^2}}}$$

Length Contraction:

$$L = \frac{L_P}{\gamma} = L_P\sqrt{1-\frac{v^2}{c^2}}$$

Photoelectric Effect:

$$E_n = n\,h\,f$$

$$K_{\max} = e\,\Delta V_s$$

$$K_{max} = hf - \varphi$$

$$\lambda_c = \frac{c}{f_c} = \frac{hc}{\varphi}$$

Radioactivity:

$$N = N_o e^{-\lambda t}$$

$$R = \left|\frac{dN}{dt}\right| = \lambda N = R_o e^{-\lambda t}$$

$$R_o = N_o \lambda$$

$$T_{1/2} = \frac{\ln 2}{\lambda} = \frac{0.693}{\lambda}$$

$$N = N_o\,(1/2)^n$$

Atomic Subshell Notations

ℓ	Subshell Symbol
0	*s*
1	*p*
2	*d*
3	*f*
4	*g*
5	*h*

Atomic Shell Notations

n	Shell Symbol
1	K
2	L
3	M
4	N
5	O
6	P