2.1 Basic Concepts and Formulae

Wave number

\[ \tilde{\nu} = \frac{1}{\lambda} \quad (2.1) \]

1 fm = 10^{-15} m; 1 Å = 10^{-10} m; 1 nm = 10^{-9} m; 1 μm = 10^{-6} m; \ h c = 197.3 \ \text{Mev} – \text{fm}

Photon energy

\[ E = h \nu \quad (2.2) \]

Photon momentum

\[ p = h \nu / c \]

Photon energy – wavelength conversion

\[ \lambda (\text{nm}) = \frac{1241}{E (\text{ev})} \quad (2.3) \]

de Broglie wavelength

\[ \lambda = h / p \quad (2.4) \]

\[ \lambda (\text{electron}) : \lambda (\text{Å}) = (150 / V)^{1/2} \quad (2.5) \]

\[ \lambda (\text{neutron}) : \lambda (\text{Å}) = 0.286 \ E^{-1/2} \ \text{(E in ev)} \quad (2.6) \]

Atomic units

The Bohr radius \( \hbar^2 / m_e e^2 \) is frequently used as the unit of length in atomic physics. In atomic units the energy is measured in multiples of the ionization energy of hydrogen atom that is \( m_e e^4 / 2 \hbar^2 \). In these units \( \hbar^2 = 1 \), \( e^2 = 2 \) and \( m_e = \frac{1}{2} \) in all equations.
Natural units

\[ \hbar = c = 1 \]  \hspace{1cm} (2.7)

Mosley’s law (for characteristic X-rays)

\[ \sqrt{\nu} = A(Z - b) \]  \hspace{1cm} (2.8)

where \( Z \) is the atomic number, \( A \) and \( b \) are constants.

For \( K_{\alpha} \) line

\[ \lambda = \frac{1.200}{(Z - 1)^2} \text{Å} \]  \hspace{1cm} (2.9)

X-rays absorption

\[ I = I_0 e^{-\mu x} \]  \hspace{1cm} (2.10)

Duane–Hunt law (for continuous X-rays)

\[ \lambda_c = \frac{c}{v_{\text{max}}} = \frac{hc}{eV} = \frac{1.240}{V} \text{pm} \]  \hspace{1cm} (2.11)

where \( e \) is the electron charge and \( V \) is the P.D through which the electrons have been accelerated in the X-ray tube.

**Doppler effect** (Non-relativistic)

\[ v = v_0(1 + \beta c \cos \theta^*) \]  \hspace{1cm} (2.12)

where \( v \) is the observed frequency, \( v_0 \) the frequency of light in the rest frame of source emitted at angle \( \theta^* \), \( v = \beta c \) is the source velocity. The inverse transformation is

\[ v_0 = v(1 - \beta c \cos \theta) \]  \hspace{1cm} (2.13)

**Hydrogen atom** (Bohr’s model)

Angular momentum

\[ L = n\hbar, \quad n = 1, 2, 3 \ldots \ldots \]  \hspace{1cm} (2.14)

Energy of photon emitted from energy level \( E_i \) to final level \( E_f \).

\[ h\nu = E_i - E_f \]  \hspace{1cm} (2.15)

Radius of the \( n \)th orbit

\[ r_n = \frac{\varepsilon_0 h^2 n^2}{\pi \mu e^2 z} \]  \hspace{1cm} (2.16)