Modern Physics

Bremsstrahlung

Problem 1.- What does bremsstrahlung refers to in the production of X-rays?

Solution: In the production of X-rays, the term bremsstrahlung refers to the smooth, continuous X-ray spectra produced by rapidly decelerating electrons in the target metal of an X-ray tube.

Problem 2.- What would be the shortest wavelength produced by bremsstrahlung when 1kV electrons hit a metallic target?

Solution: The shortest wavelength will happen when the total kinetic energy of the electron is traded for one single photon, in which case:

$$\frac{hc}{\lambda} = 1keV$$

Here we ignore any work function of the target because it will be small with respect to 1000 volts. The shortest wavelength will be:

$$\lambda = \frac{hc}{1000eV} = \frac{4.135\times10^{-15}eVs(3\times10^{8}m/s)}{1000eV} = \mathbf{1.24\ nm}$$

Problem 2a.- Calculate the shortest wavelength of X-rays when a target is bombarded with 20kV electrons.

Solution: The shortest wavelength happens when all the kinetic energy of the electron is converted into the energy of a single photon:

$$\text{Energy} = \text{hc}/\lambda_{\text{shortest}} \rightarrow \lambda_{\text{shortest}} = \frac{\text{hc}}{\text{Energy}}$$

So, given that the energy is 20,000 eV we have:

$$\lambda_{\text{shortest}} = \frac{(4.1357\times10^{-15}\text{eVs})(3\times10^{8}\text{m/s})}{20{,}000\text{eV}} = \mathbf{6.2\times10^{-11}\ m}$$

Problem 3.- Find the shortest wavelength created by a beam of electrons moving at 99% the speed of light that hit a W target.

Solution: The kinetic energy needs to be calculated relativistically:

$K.E. = (\gamma - 1)mc^2$, and: $\gamma = \frac{1}{\sqrt{1 - v^2/c^2}} = \frac{1}{\sqrt{1 - 0.99^2}} = 7.09$, so:

$$K.E. = (7.09 - 1)mc^2 = 6.09mc^2$$

Assuming all this kinetic energy is converted into a single photon:

$$\frac{hc}{\lambda} = 6.09mc^2 \rightarrow \lambda = \frac{h}{6.09mc} = \frac{6.62\times10^{-34}\,Js}{6.09(9.1\times10^{-31}\,kg)(3\times10^{8}\,m/s)} = \mathbf{3.98\times10^{-13}\ m}$$