Tutorial 1 Solutions

T1.1 When Li is irradiated with light, the kinetic energy of the ejected electrons is 2.935×10^{-19} J for wavelength of 300 nm and 1.28×10^{-19} J for wavelength of 400 nm. Calculate the (a) Planck's constant (b) threshold frequency and (c) the workfunction of Li from these data.

Einstein's photoelectric equation

$$hv = hv_0 + KE$$

$$\frac{hc}{\lambda} = \varphi + KE$$

(a)

$$KE_1 - KE_2 = hc\left(\frac{1}{\lambda_1} - \frac{1}{\lambda_2}\right)$$

$$1.655 \times 10^{-19} = h \times 3 \times 10^8 \left(\frac{1}{3 \times 10^{-7}} - \frac{1}{4 \times 10^{-7}}\right)$$

$$h = 6.62 \times 10^{-34} JS$$

(b)

$$\frac{hc}{\lambda_1} = hv_0 + KE_1$$

$$v_0 = 0.556 \times 10^{15} S^{-1}$$

(c)

$$\varphi = hv_0 = 3.687 \times 10^{-19} J$$

Tutorial 1 Solutions

T1.2 Calculate the number of photons present in a light pulse of energy 5 μJ at wavelength 400 nm.

$$E = nh\upsilon$$

$$n = \frac{E\lambda}{hc} = 100 \times 10^{11}$$

T1.3 Calculate the kinetic energy of an electron with de Broglie wavelength 500 nm.

$$\lambda = \frac{h}{mv}$$

$$v = \frac{h}{\lambda m}$$

$$KE = \frac{1}{2}mv^2 = 96.5 \times 10^{-27} J$$

T1.4 In Planck's black body radiation equation, show that the quantity $\rho_\upsilon(T)d\upsilon$ has the dimension of energy per volume.

Planck's equation

$$\rho_\upsilon(T)d\upsilon = \frac{8\pi h}{c^3}\frac{\upsilon^3 d\upsilon}{e^{h\upsilon/k_B T} - 1}$$

$$dimension = \frac{kg.m^2.s^{-1}}{m^3 s^{-3}}s^{-4} = \frac{kg.m^2.s^{-2}}{m^3} = \frac{Unit\ of\ energy}{Unit\ of\ volume}$$

Tutorial 1 Solutions

T1.5 You are doing Compton scattering experiments on electron using visible light of wavelength 500 nm and x-ray of wavelength 5 nm and you do not observe Compton scattering using the visible light. Explain why.

Compton shift

$$\Delta\lambda = \lambda' - \lambda = \frac{h}{mc}(1 - \cos\theta)$$

In this equation, the quantity *h/mc* is called Compton wavelength (λ_c) of the scattering particle. This quantity is a constant for a given particle and for electron

$$\lambda_c = \frac{h}{mc} = \frac{6.626 \times 10^{-34}}{9.1 \times 10^{-31} \times 3 \times 10^{8}} = 2.426 \times 10^{-12} m$$

Since $\Delta\lambda = \lambda_c(1 - \cos\theta)$, the shift will be maximum for $\theta = 180^o$.

Hence, $\Delta\lambda = 0.005 \times 10^{-9}$ nm for electron at $\theta = 180^o$.

For visible and x-rays under consideration, the shifts are 0.001 % and 0.1 % of the corresponding wavelengths. Hence, it's difficult to detect the shift for visible light as compared to x-rays.

T1.6 Beiser, Page 72.