Chapter 2

Exercise Solutions

E2.1

(a) $$E = h\nu = \frac{hc}{\lambda} = \frac{\left(6.625x10^{-34}\right)\left(3x10^{10}\right)}{10{,}000x10^{-8}}$$

or

$$\underline{E = 1.99x10^{-19}\ J}$$

Also

$$E = \frac{1.99x10^{-19}}{1.6x10^{-19}} \Rightarrow \underline{E = 1.24\ eV}$$

(b)

$$E = \frac{hc}{\lambda} = \frac{\left(6.625x10^{-34}\right)\left(3x10^{10}\right)}{10x10^{-8}}$$

or

$$\underline{E = 1.99x10^{-16}\ J}$$

Also

$$E = \frac{1.99x10^{-16}}{1.6x10^{-19}} \Rightarrow \underline{E = 1.24x10^{3}\ eV}$$

E2.2

(a) $$\lambda = \frac{h}{p} \Rightarrow p = \frac{h}{\lambda} = \frac{6.625x10^{-34}}{180x10^{-10}}$$

or

$$p = 3.68x10^{-26}\ kg - m/s$$

Then

$$E = \frac{p^2}{2m} = \frac{\left(3.68x10^{-26}\right)^2}{2\left(5x10^{-31}\right)}$$

or

$$\underline{E = 1.35x10^{-21}\ J = 8.46x10^{-3}\ eV}$$

(b)

$$E = 0.020\ eV = 3.2x10^{-21}\ J$$

$$E = \frac{p^2}{2m} \Rightarrow p = \sqrt{2mE}$$

So

$$p = \sqrt{2\left(9.11x10^{-31}\right)\left(3.2x10^{-21}\right)}$$

or

$$p = 7.64x10^{-26}\ kg - m/s$$

Then

$$\lambda = \frac{h}{p} = \frac{6.625x10^{-34}}{7.64x10^{-26}} \Rightarrow \underline{\lambda = 86.7\ A^{\circ}}$$

E2.3

$$\Delta p \Delta x = \hbar$$

Then

$$\Delta p = \frac{\hbar}{\Delta x} = \frac{6.625x10^{-34}}{2\pi\left(12x10^{-10}\right)} \Rightarrow$$

or

$$\underline{\Delta p = 8.79x10^{-26}\ kg - m/s}$$

Then

$$\Delta E = \frac{(\Delta p)^2}{2m} = \frac{\left(8.79x10^{-26}\right)^2}{2\left(9.11x10^{-31}\right)} \Rightarrow$$

or

$$\underline{\Delta E = 4.24x10^{-21}\ J = 0.0265\ eV}$$

E2.4

$$\Delta E \Delta t = \hbar$$

Now

$$\Delta E = 1.2\ eV \Rightarrow 1.92x10^{-19}\ J$$

So

$$\Delta t = \frac{\hbar}{\Delta E} = \frac{6.625x10^{-34}}{2\pi\left(1.92x10^{-19}\right)} \Rightarrow$$

or

$$\underline{\Delta t = 5.49x10^{-16}\ s}$$

E2.5

$$E_n = \frac{\hbar^2 n^2 \pi^2}{2ma^2} = \frac{\left(1.054x10^{-34}\right)^2 n^2 \pi^2}{2\left(9.11x10^{-31}\right)\left(10x10^{-10}\right)^2}$$

or

$$E_n = n^2\left(6.02x10^{-20}\right) J = n^2(0.376)\ eV$$

Then

$$\underline{E_1 = 0.376\ eV}$$

$$\underline{E_2 = 1.50\ eV}$$

$$\underline{E_3 = 3.38\ eV}$$

E2.6

$$m = \frac{\hbar^2 \pi^2}{2E_1 a^2}$$

Now

$$E_1 = (0.025)\left(1.6x10^{-19}\right) = 4x10^{-21}\ J$$

Then

$$m = \frac{\left(1.054x10^{-34}\right)^2 \pi^2}{2\left(4x10^{-21}\right)\left(100x10^{-10}\right)^2} \Rightarrow$$

or

$$\underline{m = 1.37x10^{-31}\ kg}$$

E2.7

$$E = \frac{1}{2}mv^2 = \frac{1}{2}\left(9.11x10^{-31}\right)\left(10^5\right)^2$$
$$= 4.56x10^{-21}\ J$$

Now

$$K_2 = \sqrt{\frac{2m}{\hbar^2}\left(V_o - E\right)} \qquad \text{Set } V_o = 3E$$

Then

$$K_2 = \frac{1}{\hbar}\sqrt{2m(2E)}$$
$$= \frac{\left[2\left(9.11x10^{-31}\right)(2)\left(4.56x10^{-21}\right)\right]^{1/2}}{1.054x10^{-34}}$$

or

$$K_2 = 1.22x10^9\ m^{-1}$$

(a) $d = 10\ A^\circ = 10x10^{-10}\ m$

$$P = \exp\left[-2\left(1.22x10^9\right)\left(10x10^{-10}\right)\right]$$

or

$$\underline{P = 0.0872 \Rightarrow 8.72\%}$$

(b) $d = 100\ A^\circ = 100x10^{-10}\ m$

$$P = \exp\left[-2\left(1.22x10^9\right)\left(100x10^{-10}\right)\right]$$

or

$$\underline{P = 2.53x10^{-11} \Rightarrow 2.53x10^{-9}\%}$$

E2.8

$$K_2 = \sqrt{\frac{2m\left(V_o - E\right)}{\hbar^2}}$$

$$= \left\{\frac{2\left(9.11x10^{-31}\right)(1-0.2)\left(1.6x10^{-19}\right)}{\left(1.054x10^{-34}\right)^2}\right\}^{1/2}$$

or

$$K_2 = 4.58x10^9\ m^{-1}$$

Now

$$T \cong 16\left(\frac{0.2}{1}\right)\left(1 - \frac{0.2}{1}\right)\exp\left[-2\left(4.58x10^9\right)\left(15x10^{-10}\right)\right]$$

or

$$\underline{T \cong 2.76x10^{-6}}$$

E2.9 Computer plot

E2.10

$$10^{-5} \cong 16\left(\frac{0.04}{0.4}\right)\left(1 - \frac{0.04}{0.4}\right)\exp\left(-2K_2 a\right)$$

so

$$\exp\left(+2K_2 a\right) = 1.44x10^5$$

or

$$2K_2 a = 11.88$$

Now

$$K_2 = \sqrt{\frac{2m\left(V_o - E\right)}{\hbar^2}}$$

$$= \left\{\frac{2\left(9.11x10^{-31}\right)(0.4-0.04)\left(1.6x10^{-19}\right)}{\left(1.054x10^{-34}\right)^2}\right\}^{1/2}$$

or

$$K_2 = 3.07x10^9\ m^{-1}$$

Then

$$a = \frac{11.88}{2\left(3.07x10^9\right)} = 1.93x10^{-9}\ m$$

or\

$$\underline{a = 19.3\ A^\circ}$$

E2.11

$$E_1 = \frac{-me^4}{2\left(4\pi \in_o\right)^2 \hbar^2}$$

$$= \frac{-\left(9.11x10^{-31}\right)\left(1.6x10^{-19}\right)^4}{2\left[4\pi\left(8.85x10^{-12}\right)\right]^2\left(1.054x10^{-34}\right)^2}$$

or

$$\underline{E_1 = -2.17x10^{-18}\ J = -13.6\ eV}$$