Production of X-Rays

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1)

$$E_{elec.pot} = E_{xray}$$

$$qV = \frac{hc}{\lambda}$$

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$$\lambda = \frac{hc}{qV} = \frac{4.14\times10^{-15}\,eV\cdot s(3.0\times10^{8}\,{}^{m}\!/\!{}_{s})}{1e(11.1\times10^{3}V)}$$

$$\boxed{\lambda = 1.12\times10^{-10}m}$$

high energy X-ray

2)

$$E_{elec.pot} = E_{xray}$$

$$qV = \frac{hc}{\lambda}$$

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$$V = \frac{hc}{q\lambda}$$

$$V = \frac{4.14\times10^{-15}\,eV\cdot s(3.0\times10^{8}\,{}^{m}\!/\!{}_{s})}{1e(0.370\times10^{-9}m)}$$

$$\boxed{V = 3.36\times10^{3}V}$$

3)

$$E_{elec.pot} = E_{xray}$$

$$\tfrac{1}{2}mv^2 = hf$$

/4

$$f = \frac{\tfrac{1}{2}mv^2}{h}$$

$$f = \frac{\tfrac{1}{2}(9.11\times10^{-31}kg)(5.2\times10^{4}\,{}^{m}\!/\!{}_{s})^2}{6.63\times10^{-34}\,J\cdot s}$$

$$\boxed{f = 1.9\times10^{12}Hz}$$

4)

$$E_{elec.pot} = E_{xray}$$

$$qV = hf$$

$$f = \frac{qV}{h}$$

/5

$$f = \frac{1e(50\times10^{3}V)}{4.14\times10^{-15}\,eV\cdot s}$$

$$\boxed{f = 1.2\times10^{19}Hz}$$

hazardous for prolonged exposure only

5)

$$E_{elec.pot} = E_{xray}$$

$$qV = \frac{hc}{\lambda}$$

/4 $$\lambda = \frac{hc}{qV}$$

$$\lambda = \frac{6.63\times10^{-34}\,J\cdot s(3.0\times10^{8}\,{}^{m}\!/\!_{s})}{3.20\times10^{-19}\,C(320\times10^{3}V)}$$

$$\boxed{\lambda = 1.94\times10^{-12}\,m}$$

6) a) Calculate # of electrons (n)

$$q = It$$

$$q = (5.0\times10^{-6}\,A)(4.2\times10^{-6}\,s)$$

$$q = 2.1\times10^{-11}\,C$$

/9 $$n = \frac{2.1\times10^{-11}\,C}{1.60\times10^{-19}\,C/e^{-}}$$

$$n = 1.3\times10^{8}\,e^{-}$$

$\therefore 1.3\times10^{8}$ photons are emitted

b) Calculate energy per photon

$$E_{photon} = \frac{E_T}{n}$$

$$E_{photon} = \frac{1.4\times10^{-11}\,J}{1.3\times10^{8}}$$

$$E_{photon} = 1.07\times10^{-19}\,J$$

c) Calculate wavelength of photon

$$\lambda = \frac{hc}{E}$$

$$\lambda = \frac{6.63\times10^{-34}\,J\cdot s(3.00\times10^{8}\,{}^{m}\!/\!_{s})}{1.07\times10^{-19}\,J}$$

$$\boxed{\lambda = 1.9\times10^{-6}\,m}$$

The Compton Effect

1) In an elastic collision both **kinetic energy** and **momentum** are conserved.
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2) He used Einstein's idea that mass and energy are equivalent.

$$E = mc^2$$

/3 $$hf = mc^2$$

$$\boxed{m = \frac{hf}{c^2} \text{ or } \frac{h}{\lambda c}}$$

3) In the everyday world of large objects, the light we see from objects is either reflected off or emitted by the object. In either case the momentum of the photons leaving the object is
/3 so small that the position or momentum of the object is not changed by the collision or emission. For an electron, the scattering of light does cause the electron to change its position and or momentum. Therefore, we do not see electrons without changing what the electron is doing. We can never see electrons as they are, only as they were.

4)

$$p = \frac{hf}{c}$$

/3

$$p = \frac{6.63\times10^{34}\,J\cdot s(9.65\times10^{14}\,Hz)}{3.0\times10^{8}\ ^{m}\!/_{s}}$$

$$\boxed{p = 2.13\times10^{-27}\ \frac{kg\cdot m}{s}}$$

5)

$$E = pc$$

$$p = \frac{E}{c}$$

/3

$$p = \frac{(225\times10^{3}\,eV)(1.60\times10^{-19}\ ^{J}\!/_{eV})}{3.0\times10^{8}\ ^{m}\!/_{s}}$$

$$\boxed{p = 1.2\times10^{-22}\ \frac{kg\cdot m}{s}}$$

6)

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$$\lambda = 2.00\times10^{-11}\,m$$

$$v = 2.90\times10^{7}\ ^{m}\!/_{s}$$

$$\lambda' = ?$$

$$E_{xray} = E_{k\,e^-} + E'_{xray}$$

$$\frac{hc}{\lambda} = \tfrac{1}{2}mv^2 + \frac{hc}{\lambda'}$$

$$\lambda' = \frac{hc}{\frac{hc}{\lambda} - \tfrac{1}{2}mv^2}$$

$$\lambda' = \frac{6.63\times10^{-34}\,J\cdot s(3.00\times10^{8}\ ^{m}\!/_{s})}{\frac{6.63\times10^{-34}\,J\cdot s(3.00\times10^{8}\ ^{m}\!/_{s})}{2.00\times10^{-11}\,m} - \tfrac{1}{2}(9.11\times10^{-31}\,kg)(2.90\times10^{7}\ ^{m}\!/_{s})^2}$$

$$\boxed{\lambda' = 2.08\times10^{-11}\,m}$$

$$\lambda_f - \lambda_i = \frac{h}{mc}(1-\cos\theta)$$

$$\theta = \cos^{-1}\left(1 - \frac{mc(\lambda_f - \lambda_i)}{h}\right)$$

$$\theta = \cos^{-1}\left(1 - \frac{9.11\times10^{-31}\,kg(3.00\times10^{8}\ ^{m}\!/_{s})(2.08\times10^{-11}\,m - 2.00\times10^{-11}\,m)}{6.63\times10^{-34}\,J\cdot s}\right)$$

$$\boxed{\theta = 48.0^\circ}$$

7)

$$\lambda = 2.30\times10^{-11} m$$
$$f' = 5.6\times10^{17} Hz$$
$$v = ?$$
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$$m = 9.11\times10^{-31} kg$$

$$E_{xray} = E_{ke^-} + E'_{xray}$$
$$E_{ke^-} = E_{xray} - E'_{xray}$$
$$\tfrac{1}{2}mv^2 = \frac{hc}{\lambda} - hf'$$
$$v = \sqrt{\frac{\frac{hc}{\lambda} - hf'}{\frac{1}{2}m}}$$
$$v = \sqrt{\frac{h\left(\frac{c}{\lambda} - f'\right)}{\frac{1}{2}m}}$$
$$v = \sqrt{\frac{6.63\times10^{-34} J\cdot s\left(\frac{3.00\times10^{8} \, m/s}{2.300\times10^{-11} m} - 1.154\times10^{19} Hz\right)}{\frac{1}{2}(9.11\times10^{-31} kg)}}$$
$$\boxed{v = 4.68\times10^{7} \, m/s}$$

8)
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$$\Delta\lambda = \frac{h}{mc}(1-\cos\theta)$$
$$\Delta\lambda = \frac{6.63\times10^{-34} J\cdot s}{(9.11\times10^{-31} kg)(3.00\times10^{8} \, m/s)}(1-\cos 120)$$
$$\boxed{\Delta\lambda = 3.64\times10^{-12} m}$$

9) The maximum change in wavelength will occur when the x-ray is scattered through 180°

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$$\Delta\lambda = \frac{h}{mc}(1-\cos\theta)$$
$$\Delta\lambda_{max} = \frac{h}{mc}(1-\cos 180)$$
$$\Delta\lambda_{max} = \frac{2h}{mc}$$

for an electron

$$\Delta\lambda_{max} = \frac{2h}{mc}$$
$$\Delta\lambda_{max\,e^-} = \frac{2(6.63\times10^{-34} J\cdot s)}{(9.11\times10^{-31} kg)(3.00\times10^{8} \, m/s)}$$
$$\Delta\lambda_{max\,e^-} = 4.85\times10^{-12} m$$

for a nitrogen molecule

$$\Delta\lambda_{max} = \frac{2h}{mc}$$
$$\Delta\lambda_{max\,N_2} = \frac{2(6.63\times10^{-34} J\cdot s)}{(2\times14\times1.67\times10^{-27} kg)(3.00\times10^{8} \, m/s)}$$
$$\Delta\lambda_{max\,N_2} = 9.45\times10^{-17} m$$

A nitrogen molecule is 5.13 x 10^4 times more massive than an electron with a commensurate inverse difference in the change in wavelength of the scattered photon.