Chemistry 2720 Fall 2001 Assignment 8 Solutions

1. One 550 nm photon has an energy of

$$E = h\nu = \frac{hc}{\lambda} = \frac{(6.626\,068\,8 \times 10^{-34}\,\mathrm{J/Hz})(2.997\,924\,58 \times 10^{8}\,\mathrm{m/s})}{550 \times 10^{-9}\,\mathrm{m}} = 3.61 \times 10^{-19}\,\mathrm{J}.$$

55 W is 55 J/s. The number of photons per second is therefore

$$n = \frac{55\,\mathrm{J/s}}{3.61 \times 10^{-19}\,\mathrm{J/photon}} = 1.5 \times 10^{20}\,\mathrm{photons/s}.$$

2. (a) For this reaction, $\Delta\bar{n}_{\mathrm{gas}} = 2 - 1 = 1$.

$$\begin{aligned} \Delta\bar{E} &= \Delta\bar{H} - RT\Delta\bar{n}_{\mathrm{gas}} \\ &= 242\,\mathrm{kJ/mol} - (8.314\,510 \times 10^{-3}\,\mathrm{kJ\,K^{-1}mol^{-1}})(298.15\,\mathrm{K})(1) \\ &= 239.5\,\mathrm{kJ/mol}. \end{aligned}$$

(b) 239.5 kJ/mol is

$$\frac{239.5 \times 10^{3}\,\mathrm{J/mol}}{6.022\,142\,0 \times 10^{23}\,\mathrm{mol^{-1}}} = 3.98 \times 10^{-19}\,\mathrm{J}$$

per photon. The frequency is

$$\nu = \frac{E}{h} = \frac{3.98 \times 10^{-19}\,\mathrm{J}}{6.626\,068\,8 \times 10^{-34}\,\mathrm{J/Hz}} = 6.00 \times 10^{14}\,\mathrm{Hz}.$$

These photons are in the yellow-green region of the visible spectrum.

(c) The momentum of the photon is

$$p = \frac{E}{c} = \frac{3.98 \times 10^{-19}\,\mathrm{J}}{2.997\,924\,58 \times 10^{8}\,\mathrm{m/s}} = 1.33 \times 10^{-27}\,\mathrm{kg\,m/s}.$$

This momentum is transferred to the two chlorine atoms. The total mass of two chlorine atoms is

$$\begin{aligned} m &= 2(34.9688\,\mathrm{amu}) = 69.9376\,\mathrm{amu} \equiv 69.9376\,\mathrm{g/mol} \\ &\equiv \frac{69.9376 \times 10^{-3}\,\mathrm{kg/mol}}{6.022\,142\,0 \times 10^{23}\,\mathrm{mol^{-1}}} = 1.16134 \times 10^{-25}\,\mathrm{kg}. \end{aligned}$$

The change in the speed is therefore

$$\Delta v = \frac{\Delta p}{m} = \frac{1.33 \times 10^{-27}\,\mathrm{kg\,m/s}}{1.16134 \times 10^{-25}\,\mathrm{kg}} = 0.0114\,\mathrm{m/s}.$$

3. We can calculate the interplanar distances from the angles using the Bragg formula $d = \lambda/(2\sin\theta)$:

Reflection	d (Å)
100	3.871
110	2.738
111	2.234

The ratio of d_{100} to d_{110} is 1.413. This is very close to $\sqrt{2}$, so the structure could be either simple or face-centered, but body-centered cubic is excluded. The ratio of d_{100} to d_{111} is 1.733. This is very close to $\sqrt{3}$, so the structure must be simple cubic.