3.091 Fall Term 2002

Homework #2

Solutions

From the text:

3-7. For = 440 Hz: Assume the speed of sound is 1116 ft/sec

(3-6) $$\left(\frac{440 \text{ cycles}}{\text{s}}\right)\lambda = 1116\frac{\text{ft}}{\text{s}}$$

$$\lambda = \left(1116\frac{\text{ft}}{\text{s}}\right)\left(\frac{\text{s}}{440 \text{ cycles}}\right) = 2.54\frac{\text{ft}}{\text{cycle}}$$

For 880 Hz:

$$\left(\frac{880 \text{ cycles}}{\text{s}}\right)\lambda = 1116\frac{\text{ft}}{\text{s}}$$

$$\lambda = \left(1116\frac{\text{ft}}{\text{s}}\right)\left(\frac{\text{s}}{880 \text{ cycles}}\right) = 1.27\frac{\text{ft}}{\text{cycle}}$$

As the frequency increased by a factor of 2 the wavelength is decreased by a factor of ½. The speed at which the sound travels to your ear remains constant at 1116 ft/s.

3-25. $$\left(\frac{243.4\text{kJ}}{\text{mole}}\right)\left(\frac{1000\text{J}}{\text{kJ}}\right)\left(\frac{1 \text{ mole}}{6.022\times10^{23} \text{ molecules } Cl_2}\right) = \frac{4.042\times10^{-19}\text{ J}}{\text{molecule } Cl_2}$$

(3-25)

$E = h\nu = hc/\lambda$

$\lambda = hc/E$

$$\lambda = \left(\frac{6.626\times10^{-34}\text{Js}\times2.997925\times10^{8}\text{m/s}}{4.042\times10^{-19}\text{J/molecule } Cl_2}\right) = 4.914\times10^{-7}\text{m}$$

This radiation falls in the visible light portion of the electromagnetic spectrum.

3-201. first, let's look at the isoelectronic series, which consists of a mix of cations, anions, and neutrals – all with the same electronic structure

(3-107) ranking of ionization energies: $O^{2-} < F^{-} < Ne < Na^{+} < Mg^{2+}$
ranking of radii: $Mg^{2+} < Na^{+} < Ne < F^{-} < O^{2-}$

since these atoms all have the same electronic structure, differences can be attributed to variation in the positive charge on the nucleus

now, let's revisit the same group of elements, but this time they are all neutral, and therefore each has a distinct electronic structure

ranking of ionization energies: Na < Mg < O < F < Ne
ranking of radii: Ne < F < O < Mg < Na

Additional questions:

1. From quantum condition we have

$$\mathrm{mvr} = \frac{\mathrm{nh}}{2\pi}$$

$$\therefore \mathrm{v} = \frac{\mathrm{nh}}{2\pi \mathrm{mr}}$$ get r from the Bohr model, r = 0.529 Å when n=1.

$$= \frac{1 \times 6.6 \times 10^{-34}}{2\pi 9.11 \times 10^{-31} \times 0.529 \times 10^{-10}}$$

$$= 2.18 \times 10^{6} \text{ m/s.}$$

2. $c = \nu \lambda, \quad \therefore \lambda_{min} = \frac{c}{\nu_{max}}; \quad \lambda_{max} = \frac{c}{\nu_{min}}$

AM $\lambda_{min} = \frac{3 \times 10^{8} \text{ m/s}}{1600 \times 10^{3} \text{ Hz}} = 188 \text{ m}$ $\lambda_{max} = \frac{3 \times 10^{8}}{530 \times 10^{3}} = 566 \text{ m}$

FM $\lambda_{min} = \frac{3 \times 10^{8}}{108 \times 10^{6}} = 2.78 \text{ m}$ $\lambda_{max} = \frac{3 \times 10^{8}}{88 \times 10^{6}} = 3.41 \text{ m}$

3. $E_{\text{incident photon}} = E_{\text{binding}} + E_{\text{scattered e-}}$

$$E_{\text{binding}} = -K\left(\frac{1}{3^2}\right) \qquad E_{\text{scattered}} = \frac{1}{2}\text{mv}^2$$

$$E_{\text{incident photon}} = \frac{\text{hc}}{\lambda} \qquad \therefore \frac{\text{hc}}{\lambda} = \frac{K}{9} + \frac{1}{2}\text{mv}^2 \qquad \therefore \left[\left(\frac{\text{hc}}{\lambda} - \frac{K}{9}\right)\frac{2}{\text{m}}\right]^{\frac{1}{2}} = \text{v}$$

$$\left[\left(\frac{6.6\times10^{-34}\times3\times10^{8}}{3.091\times10^{-7}} - \frac{2.18\times10^{-18}}{9}\right)\frac{2}{9.11\times10^{-31}}\right]^{\frac{1}{2}} = \text{v}$$

$\therefore$ v = 9.35×10^5 m/s.

4. $\Delta E_{1\to6} = \text{q}V \qquad \therefore\ V = \frac{\Delta E_{1\to6}}{\text{q}}$

$$\Delta E_{1\to6} = -K\left(\frac{1}{1^2} - \frac{1}{6^2}\right) = \frac{35}{36}K$$

q = +2e

$$\therefore V = \frac{35}{36}\times\frac{2.18\times10^{18}}{2\times1.6\times10^{-19}} = 6.62V$$

5. $\bar{v} = Z^2R\left(\frac{1}{1^2} - \frac{1}{2^2}\right) = 3^2 \times 1.1\times10^7\left(\frac{3}{4}\right)$

$= 7.43 \times 10^7\ \text{m}^{-1}$

6. $\Delta E_{1\to4} = -Z^2K\left(\frac{1}{4^2} - \frac{1}{1^2}\right) = \frac{15}{16}KZ^2 = \frac{\text{hc}}{\lambda}$

for He, $Z = 2$

$$\therefore \lambda = \frac{\text{hc}}{KZ^2}\bullet\frac{16}{15} = 2.42\times10^{-8}\text{m}$$