Recitation 1

General properties of light waves (energy/frequency/wavelength relations)

Chapter 7: Exercise 36

One type of electromagnetic radiation has a frequency of 107.1 MHz, another type has a wavelength of 2.12×10^{-10} m, and another type of electromagnetic radiation has photons with energy equal to 3.97×10^{-19} J/photon. Identify each type of electromagnetic radiation and place them in order of increasing photon energy and increasing frequency.

Solution:

For 1st electromagnetic radiation:
$\nu_A = 107.1$ MHz $= 107.1 \times 10^6$ Hz

So, $E_A = h\,\nu_A = (6.63 \times 10^{-34}$ J s$) \times (107.1 \times 10^6$ s$^{-1}) = 7.12 \times 10^{-26}$ J/photon
$\lambda_A = c/\,\nu_A = (2.998 \times 10^8$ m/s$) / (107.1 \times 10^6$ s$^{-1}) = 2.78$ m (radio wave)

For 2nd electromagnetic radiation:
$\lambda_B = 2.12 \times 10^{-10}$ m, (X-ray wave)

So, $E_B = hc/\,\lambda_B = 9.3755 \times 10^{-16}$ J/photon
$\nu_B = c/\,\lambda_B = 1.41 \times 10^{18}$ Hz

For 3rd electromagnetic radiation:
$E_C = 3.97 \times 10^{-19}$ J/photon

So, $\lambda_C = hc/E_C = 5.0 \times 10^{-7}$ m (visible wave)
$\nu_C = E_C/\,h = 5.99 \times 10^{14}$ Hz

Finally, $E_B > E_C > E_A$
$\nu_B > \nu_C > \nu_A$

Photoelectric effect

Chapter 7: Exercise No. 39

The work function of an element is the energy required to remove electron from the surface of the solid element. The work function of lithium is 279.7 kJ/mol (that is, it takes 279.7 kJ of energy to remove one mole of electrons from one mole of Li atoms on the surface of Li metal). What is the maximum wavelength that can remove an electron from an atom on the surface of lithium metal?

Solution:

The energy required to remove a single electron is 279.7 kJ/mol
$= (279.7 \text{ kJ/mol}) \times (\text{mol}/6.022 \times 10^{23})$
$= 4.64 \times 10^{-22} \text{ kJ}$

$E = hc/\lambda$, or, $\lambda = hc/E = 4.277 \times 10^{-7} \text{ m} = 427.7 \text{ nm}$

DeBrgolie's relation

Chapter 7: Exercise No. 41

Calculate the de Broglie wavelength for each of the following.

a. an electron with a velocity 10% of the speed of light
b. a tennis ball (55g) served at 35 m/s (~80 mi/h)

Solution:

(a) 10 % velocity of light = $0.10 \times (3.00\text{x}10^{8} \text{ m/s}) = 3.00 \times 10^{7} \text{ m/s}$

$\lambda = h/mv = 6.63\text{x}10^{-34} \text{ J.s} / [(9.11\text{x}10^{-31} \text{ kg}) \times)3 \times 10^{7} \text{ m/s})]$
$= 2.4286\text{x}10^{-11} \text{ m} = 24.28 \text{ pm}$

(b) $\lambda = h/mv = 6.63\text{x}10^{-34} \text{ J.s} / (0.055 \text{ kg} \times 35 \text{ m/s}) = 3.444 \text{ x}10^{-34} \text{ m}$

This value is so small that it is essentially zero and we can not detect a wavelength so small. This means we do not have to consider the wave properties of large objects.

Bohr orbit

Calculate the radius of the third Bohr orbit in a Be^{3+} ion and the energy of the second Bohr level in a Li^{+2} ion.

Solution:

Formulas for the generalized Bohr Theory:

$$E_n = -R_H \frac{Z^2}{n^2}; \qquad r_n = a_0 \frac{n^2}{Z}$$

$$a_0 = 0.529 \ \mathring{A} \equiv 52.9 \ \mathbf{pm}$$

$$R_H = 2.178 \times 10^{-18} \ \mathbf{J} = 13.60 \text{ eV}$$

So, r (for Be^{+3}) = a_0 (n^2/z) = 0.529 $\mathring{A}$ x (3^2/4) = 1.19 $\mathring{A}$

E (for Li^{+2}) = - R_H (z^2/n^2) = -2.178x10^{-18} J x (3^2/2^2) = -30.6 eV