CHMG-141
General and Analytical Chemistry I
with Dr. Bailey

Name________________

The Quantum – Mechanical Model of the Atom

(Chapter 2)

Sample and Practice Problems

Sample problem 1

A cell phone sends signals at about 850 MHz (1 MHz = 1 x 10^6 Hz or cycles per second).

(a) What is the wavelength of this radiation?
(b) What is the energy of 1.0 mol of protons with a frequency of 850 MHz?
(c) Compare the energy in part (b) with energy of a mole of photons of blue light (420 nm).
(d) Comment on the difference in energy between 850 MHz radiation and blue light.

(a) $\lambda = \frac{c}{v} = \frac{2.998 \times 10^8 \text{ m} \cdot \text{s}^{-1}}{850 \times 10^6 \text{ s}^{-1}} = 0.35 \text{ m}$

(b) $E = hv = (6.626 \times 10^{-34} \text{ J}\cdot\text{s})(850 \times 10^6 \text{ s}^{-1}) \cdot \frac{6.02 \times 10^{23} \text{ photons}}{1.00 \text{ mol}} = 0.34 \text{ J/mol}$

(c) $E = \frac{hc}{\lambda} = \frac{(6.626 \times 10^{-34} \text{ J} \cdot \text{s})(2.998 \times 10^8 \text{ m} \cdot \text{s}^{-1})}{4.2 \times 10^{-7} \text{ m}} \cdot \frac{6.02 \times 10^{23} \text{ photons}}{1.00 \text{ mol}} = 2.8 \times 10^5 \text{ J/mol}$

$\frac{2.8 \times 10^5 \text{ J/mol}}{0.34 \text{ J/mol}} = 84{,}000$

(d) Blue light is 84,000 times more energetic than the radiation sent from cell phones.

Practice problem 1

Assume your eyes receive a signal consisting of blue light, $\lambda = 470$ nm. The energy of the signal is 2.50 x 10^{-14} J.
How many photons reach your eyes?

Practice problem 2

Radiation in the ultraviolet region of the electromagnetic spectrum is quite energetic. It is this radiation that causes dyes to fade and your skin to develop a sunburn.
If you are bombarded with 1.00 mol of photons with a wavelength of 375 nm, what amount of energy, in kJ per mole of photons, are you being subject to?

Sample problem 2

A beam of electrons ($m = 9.11 \times 10^{-31}$ kg/electron) has an average speed of 1.3×10^{8} m/s. What is the wavelength 0f electrone having this average speed?

$$\lambda = \frac{h}{mv} = \frac{6.626 \times 10^{-34}\ \mathrm{J \cdot s}}{(9.11 \times 10^{-31}\ \mathrm{kg})(1.3 \times 10^{8}\ \mathrm{m \cdot s^{-1}})} = 5.6 \times 10^{-12}\ \mathrm{m}$$

Practice problem 3

A rifle bullet (mass = 1.50 g) has a velocity 7.00×10^{2} mph. What is the wavelength associated with this bullet?

Practice problem 4

Calculate the wavelength, in nanometers, associated with a 1.0×10^{2} g golf ball moving at 30 m/s (about 67 mph).

How fast must the ball travel to have a wavelength of 5.6×10^{-3} nm?

Sample problem 3

The most prominent line in the spectrum of mercury is at 253.652 nm. Other lines are located at 365.015 nm, 404.656 nm, 435.833 nm, and 1013.975 nm.

(a) Which of these lines represents the most energetic line?
(b) What is the frequency of the most prominent line?
What is the energy of one photon with this wavelength?
(c) Are any of these lines found in the spectrum of mercury shown in the lecture slide? What colors are these lines?

(a) The most energetic line has the shortest wavelength, 253.652 nm.

(b) $253.652\ \text{nm} \cdot \dfrac{10^{-9}\ \text{m}}{1\ \text{nm}} = 2.53652 \times 10^{-7}\ \text{m}$

$$\nu = \frac{c}{\lambda} = \frac{2.997925 \times 10^{8}\ \text{m}\cdot\text{s}^{-1}}{2.53652 \times 10^{-7}\ \text{m}} = 1.18190 \times 10^{15}\ \text{s}^{-1}$$

$$E = h\nu = (6.626069 \times 10^{-34}\ \text{J}\cdot\text{s})(1.18190 \times 10^{15}\ \text{s}^{-1}) = 7.83135 \times 10^{-19}\ \text{J/photon}$$

(c) The 404.656 nm line is violet, while the 435.833 nm line is blue.

Practice problem 5

The most prominent line in the spectrum of neon is found at 865.438 nm. Other lines are located at 837.761 nm, 878.062 nm, 878.375 nm, and 1885.387 nm.

(a) In what region of the electromagnetic spectrum are these lines found?
(b) Are any of these lines found in the spectrum of neon shown in the lecture slide?
(c) Which of these lines represents the most ene4rgetic light?
(d) What is the frequency of the most prominent line?
What is the energy of one photon with this wavelength?

Sample problem 4

$$E_{photon\,released} = -\Delta E_{hydrogen\,electron} = -(E_{final} - E_{initial})$$
$$h\nu = \frac{hc}{\lambda} = -\left[\left(-2.18\times10^{-18}\,J\left(\frac{1}{n_{final}^2}\right)\right) - \left(-2.18\times10^{-18}\,J\left(\frac{1}{n_{initial}^2}\right)\right)\right]$$

Example : Calculate the wavelength of light emitted when the hydrogen electron transitions from $n = 6$ to $n = 5$

Given:	$n_i = 6$, $n_f = 5$
Find:	λ, m
Concept Plan:	$n_i, n_f \rightarrow \Delta E_{atom} \rightarrow E_{photon} \rightarrow \lambda$
Relationships:	$E = -R_H\left(\frac{1}{n^2}\right)$ $\Delta E_{atom} = -E_{photon}$ $\lambda = \frac{h \bullet c}{E}$ $E = hc/\lambda$, $E_n = -2.18 \times 10^{-18}\,J\,(1/n^2)$
Solve:	$\Delta E_{atom} = -2.18\times10^{-18}\,J\left(\frac{1}{5^2} - \frac{1}{6^2}\right) = -2.6644\times10^{-20}\,J$

$E_{photon} = -(-2.6644 \times 10^{-20}\,J) = 2.6644 \times 10^{-20}\,J$

$$\lambda = \frac{hc}{E} = \frac{(6.626\times10^{-34}\,\cancel{J}\cdot\cancel{s})(3.00\times10^{8}\,\frac{m}{\cancel{s}})}{(2.6644\times10^{-20}\,\cancel{J})} = 7.46\times10^{-6}\,m$$

Check:	the unit is correct, the wavelength is in the infrared, which is appropriate because less energy than 4→2 (in the visible)

$$\Delta E_{atom} = -2.18\times10^{-18}\,J\left(\frac{1}{n_f^2} - \frac{1}{n_{in}^2}\right)$$
$$E_{photon} = -\Delta E_{atom}$$

Practice problem 6

Calculate the wavelength and frequency of light emitted when an electron changes from n = 4 to n = 3 in the H atom. In what region of the spectrum is this radiation found?

Practice problem 7

The energy emitted when an electron moves from a higher energy state to a lower energy state in any atom can be observed as electromagnetic radiation.

(a) Which involves the emission of less energy in the H atom, an electron moving from n = 4 to n = 2 or an electron moving from n= 3 to n = 2?

(b) Which involves the emission of more energy in the H atom, an electron moving from n = 4 to n = 1 or an electron moving from n = 5 to n = 2? Explain fully.