Chemistry 121 – Summer 2008 – Worksheet #12

1. (a) What is the energy associated with one photon of red light with a wavelength of 650 nm?

\[ E = h\nu = \frac{hc}{\lambda} \]

\[ = 6.626 \times 10^{-34} \text{ J s } \times 3.00 \times 10^{8} \text{ m s}^{-1} / 650 \times 10^{-9} \text{ m} = 3.06 \times 10^{-19} \text{ J} \]

(b) What is the energy of 1 mole of such photons? Would it be sufficient to rupture a chemical bond that requires 250 kJ/mol to break?

\[ E / \text{mol} = (E / 1 \text{ photon}) \times (N_A \text{ photons / 1 mol}) \]

\[ = 3.06 \times 10^{-19} \text{ J} \times 6.02 \times 10^{23} = 1.84 \times 10^{5} \text{ J} = 184 \text{ kJ} \]

This value is less than the energy needed to break the chemical bond specified.

2. Which particle will have the longer De Broglie wavelength?

(a) an H atom and a D (deuterium – H-2) atom moving at the same speed as a proton

De Broglie formula is \( \lambda = \frac{h}{mv} \)

\[ \lambda \text{ (H)} = \frac{h}{m(H)v} \]
\[ \lambda \text{ (D)} = \frac{h}{m(D)v} \]

\( m(D) \approx 2 m(H) \), so \( \lambda \text{ (H)} \) is larger.

(b) an electron moving 1000 times as fast as a neutron

\[ \lambda \text{ (e)} = \frac{h}{m(e)v(e)} \]
\[ \lambda \text{ (n)} = \frac{h}{m(n)v(n)} \]

\( m(n) \approx 1600 m(e) \) and \( v(n) \approx v(e) / 1000 \)

So \[ \frac{\lambda \text{ (e)}}{\lambda \text{ (n)}} = \frac{m(n)v(n)}{m(e)v(e)} \]

\[ = \frac{m(n)}{m(e)} \times \frac{v(n)}{v(e)} \]

\[ = 1600 \times (1/1000) = 1.6 \]

Therefore \( \lambda \text{ (e)} \) is larger.
3. Consider only transitions involving the \( n = 1 \) through \( n = 5 \) energy levels for the H atom (where the energy level spacings below are not to scale).

\[
\begin{align*}
\quad & n = 5 \\
\quad & n = 4 \\
\quad & n = 3 \\
\quad & n = 2 \\
\quad & n = 1 \\
\end{align*}
\]

(a) How many emission lines are possible, considering only five quantum levels?

From 5 to 1 – 4 = 4
4 to 1 – 3 = 3 etc gives 5 + 4 + 3 + 2 + 1 = 13

(b) Photons of the highest frequency are emitted in a transition from the level with \( n = \_5\_ \) to a level with \( n = \_1\_ \).

(c) The emission line having the longest wavelength corresponds to a transition from the level with \( n = \_2\_ \) to the level with \( n = \_1\_ \).

4. (a) When \( n = 4 \), what are the possible values of \( l \)?

Up to \((n-1) = 3\)

(b) When \( l = 2 \), what are the possible values of \( m_l \)?

From \( l (2) \) to \(-l (-2)\) in integer steps

\( m_l = 2, 1, 0, -1, -2 \)

(c) For a 4s orbital, what are the possible values of \( n, l \), and \( m \)?

For an s orbital, \( l = 0 \) and therefore \( m = 0 \). (only)

5. (a) When \( n = 4, l = 2 \), to what orbital type does this refer? (Give the orbital label, such as 1s.)

\( l = 2 = d \) orbital therefore 4d

(b) How many orbitals occur in the \( n = 3 \) electron shell? How many subshells? What are the letter labels of the subshells?

\[
\begin{align*}
# \text{ orbitals} &= n^2 = 9 \\
# \text{subshells} &= n = 3 = 3s, 3p \text{ and } 3d
\end{align*}
\]
6. Match the values of $l$ shown in the table below with orbital type ($s$, $p$, $d$, or $f$).

<table>
<thead>
<tr>
<th>$l$ value</th>
<th>Orbital Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>f</td>
</tr>
<tr>
<td>0</td>
<td>s</td>
</tr>
<tr>
<td>1</td>
<td>p</td>
</tr>
<tr>
<td>2</td>
<td>d</td>
</tr>
</tbody>
</table>

7. Label the orbitals depicted below as $s$, $p_x$, $d_{z^2}$ etc. (you cannot easily tell which $n$ shell they belong to). All the orbitals use the same axis system as the first one.

![Orbitals](image)