CHEM 103
R&R 10
13 June 2024
Adapted from an 18 June 2021 document

1. Calculate the energy required to excite the hydrogen electron from level n = 1 to n = 2. Also calculate the wavelength of light that must be absorbed by a hydrogen atom in its ground state to reach this excited state. (R = 1.097×10^{7} m^{-1}, h = 6.626×10^{-34} kg m^{2} s^{-1}, c = 3.00×10^{8} m/s.)

$$E = Rhc\left(\frac{1}{n_i^2} - \frac{1}{n_f^2}\right) = (1.097\times10^{7}\,m^{-1})(6.626\times10^{-34}\,J\cdot s)(3.00\times10^{8}\,\tfrac{m}{s})\left(1-\frac{1}{4}\right)$$

$$= 1.6\underline{3}5\times10^{-18}\,J = 1.64\times10^{-18}\,J$$

$$\frac{\cancel{hc}}{\lambda} = E = R\cancel{hc}\left(\frac{1}{n_i^2} - \frac{1}{n_f^2}\right) \Rightarrow$$

$$\lambda = \frac{1}{R\left(\frac{1}{n_i^2} - \frac{1}{n_f^2}\right)} = 1.22\times10^{-7}\,m = 122\ nm$$

2. An energy of 3.3×10^{-19} J per atom is required to cause a cesium atom on a metal surface to lose an electron. Calculate the longest possible wavelength of light that can ionize a cesium atom.

$$E = \frac{hc}{\lambda} \Rightarrow \lambda = \frac{hc}{E}.$$ ☆ minimizing E maximizes λ.

$$\lambda = \frac{(6.626\times10^{-34}\,J\cdot s)(3.00\times10^{8}\,\tfrac{m}{s})}{3.3\times10^{-19}\,J} = 6.0\times10^{-7}\,m$$

3. Which set of quantum numbers **cannot** occur together to specify an orbital or a sub-orbital?

a. n = 2, l = 1, m_l = -1
b. n = 3, l = 2, m_l = 0
c. n = 3, l = 3, m_l = 0
d. n = 4, l = 3, m_l = 0

l can take values $0, 1, \ldots, n-1$.

4. Find the maximum number of electrons that can have these quantum numbers:

a. n = 3 $2n^2 = 18$ electrons

b. n = 4, m_l = 1 (don't worry about anything past f orbitals) $l = 1, 2, 3 \Rightarrow 6$ electrons

c. n = 4, m_s = +½ $\frac{1}{2}(2n^2) = 16$ electrons

d. n = 3, l = 2 3d subshell $\Rightarrow$ 10 electrons

e. n = 2, l = 1 2p subshell $\Rightarrow$ 6 electrons

5. Calculate the longest and shortest wavelengths of light emitted by electrons in the hydrogen atom that begin in the n = 6 state and then fall to states with smaller values of n.

Longest wavelength = lowest energy $\Rightarrow$ $n=6 \rightarrow n=5$

$$\frac{1}{\lambda} = R\left(\frac{1}{n_f^2} - \frac{1}{n_i^2}\right) \Rightarrow \lambda = \frac{1}{R\left(\frac{1}{5^2} - \frac{1}{6^2}\right)} = 7.458 \times 10^{-6}\ \text{m}$$

Shortest wavelength = highest energy $\Rightarrow$ $n=6 \rightarrow n=1$

$$\lambda = \frac{1}{R\left(1 - \frac{1}{6^2}\right)} = 9.376 \times 10^{-8}\ \text{m}$$

6. An excited hydrogen atom emits light with a frequency of 1.141×10^{14} Hz to reach the energy level for which n = 4. In what principal quantum level did the electron begin?

$$\cancel{h}\nu = E = R\cancel{h}c\left(\frac{1}{n_f^2} - \frac{1}{n_i^2}\right)$$

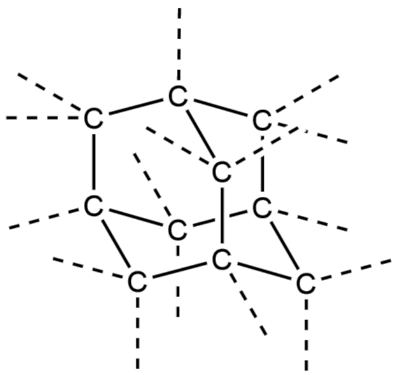
$$\frac{\nu}{Rc} = \frac{1}{4^2} - \frac{1}{n_i^2} \Rightarrow \frac{1}{16} - \frac{1.141 \times 10^{14}\ \text{s}^{-1}}{(1.097 \times 10^7\ \text{m}^{-1})(3.00 \times 10^8\ \frac{\text{m}}{\text{s}})} = \frac{1}{n_i^2}$$

$$n_i^2 = 35.93 \Rightarrow n_i = 6$$

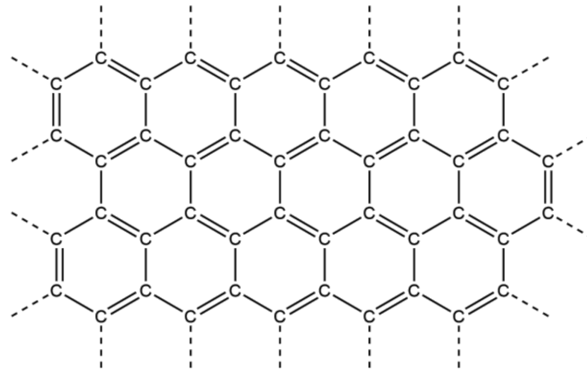
check: because the atom emitted a photon, we expect that the electron fell down to a lower energy level. $n=6 \rightarrow n=4$ is consistent with this.

7. They say that diamonds are forever, but this statement is false on a geologic time scale. Given a long enough time, diamonds will convert to graphite.

Diamond



Graphite



You will learn why graphite is so stable in the later part of Organic Chemistry 1. For now, let's use Hess's Law to determine the difference in stability between diamond and graphite. Here are some values that I found on the internet*:

$$C\text{ (diamond)} + O_2\text{ (g)} \rightarrow CO_2\text{ (g)} \qquad \Delta H_{rxn}° = -395.335 \text{ kJ mol}^{-1} \quad \times 1$$

$$C\text{ (graphite)} + O_2\text{ (g)} \rightarrow CO_2\text{ (g)} \qquad \Delta H_{rxn}° = -393.51 \text{ kJ mol}^{-1} \quad \times(-1)$$

a. Using this information, what is $\Delta H_{rxn}°$ for C (diamond) → C (graphite)?

$$C\text{(diamond)} + \cancel{O_2(g)} \longrightarrow \cancel{CO_2(g)} \qquad \Delta H = -395.335 \text{ kJ/mol}$$

$$\cancel{CO_2(g)} \longrightarrow C\text{(graphite)} + \cancel{O_2(g)} \qquad \Delta H = +393.51 \text{ kJ/mol}$$

$$C\text{(diamond)} \longrightarrow C\text{(graphite)} \qquad \Delta H = -1.83 \text{ kJ/mol}$$

$\Downarrow$

graphite more stable than diamond

b. Is the conversion from diamond to graphite endo- or exothermic? Why do or don't we observe the conversion from diamond to graphite?

Exothermic b/c $\Delta H < 0$.

Do not observe conversion b/c activation energy is <u>VERY</u> large.

* Internet sources:
https://atct.anl.gov/Thermochemical%20Data/version%201.118/species/?species_number=951
https://webbook.nist.gov/cgi/cbook.cgi?ID=C124389&Mask=1