Early quantum problem set

A) In the hydrogen atom, an electron in the energy level n = 3 absorbs 1.815 x 10^{-19} J. What energy level does the electron reach?

$$\Delta E = \text{RH}\left(\frac{1}{{n_f}^2} - \frac{1}{{n_i}^2}\right)$$

Where ΔE = 1.815 x 10^{-19} J

R_H = -2.178 x 10^{-18} J

n_i = 3

Solving for n_f: 1.815 x 10^{-19} J = -2.178 x 10^{-18} J $\left(\frac{1}{{n_f}^2} - \frac{1}{3^2}\right)$

-0.08333 = $\frac{1}{{n_f}^2} - \frac{1}{9}$

$\frac{1}{{n_f}^2}$ = 0.02778

${n_f}^2$ = 36.00

n_f = 6

B) If this energy corresponds to a photon, what would its wavelength be? Its frequency?

Finding the wavelength through $\frac{1}{lambda} = R\infty\left(\frac{1}{{n_{in}}^2} - \frac{1}{{n_{out}}^2}\right)$

Or finding the frequency first through E = h nu ,

and then lambda through c = lambda x nu

lambda = 1095 nm

nu = 2.739 x 10^{14} s^{-1}

C) What part of the electromagnetic spectrum does this photon fall in? Can you name it?

The photon is an infrared emission.

D) Line spectra were first analyzed with hydrogen. However, scientists soon realized that Bohr's model wasn't directly transposable to other elements. To calculate the changes in energy of non-hydrogen atoms containing one electron (He^+, Li^{2+}, Be^{3+}, etc), scientists developed this equation:

$$\Delta E = -B \cdot Z^2\left(\frac{1}{{n_f}^2} - \frac{1}{{n_i}^2}\right)$$

where B is the constant for each particular element

Z is the atomic number of that particular element.

How much energy is involved in a similar transition as in A) in an atom of Li^{2+} for one electron (B = 27448 kJ/mol)?

$$\Delta E = -B \cdot Z^2\left(\frac{1}{{n_f}^2} - \frac{1}{{n_i}^2}\right)$$

Where B = 27448 kJ/mol

Z = 3

n_f = 6

n_i = 3

First, the value of B has to be established in J/atom:

$\frac{27448\ kJ}{1\ mol}$ x $\frac{1000 J}{1\ kJ}$ x $\frac{1\ mol}{6.022\ x\ 10E23\ atoms}$ = 4.558 x 10^{-17} J

Then, solving

$$\Delta E = -B \cdot Z^2 \left(\frac{1}{{n_f}^2} - \frac{1}{{n_i}^2}\right)$$

ΔE = 3.418 x 10^{-17} J

E) How does this amount of energy compare to the similar transition in the hydrogen atom? Explain.
The energy required to make a transition from n = 3 to n = 6 in a Li atom containing one electron is greater as the pull from the nucleus is greater, compared to a hydrogen atom where Z = 1.

F) Given that 4.840 x 10^{-19} J are released from a hydrogen atom, on what energy level did the electron start its journey, if it landed in n = 2?

$$\Delta E = \text{RH} \left(\frac{1}{{n_f}^2} - \frac{1}{{n_i}^2}\right)$$

Where ΔE = - 4.840 x 10^{-19} J

R_H = -2.178 x 10^{-18} J

n_f = 2

Solving for n_i: - 4.840 x 10^{-19} J = -2.178 x 10^{-18} J $\left(\frac{1}{2^2} - \frac{1}{{n_i}^2}\right)$

0.2222 = $\frac{1}{4} - \frac{1}{{n_i}^2}$

$-\frac{1}{{n_i}^2}$ = -0.0278

${n_i}^2$ = 36.00

n_i = 6