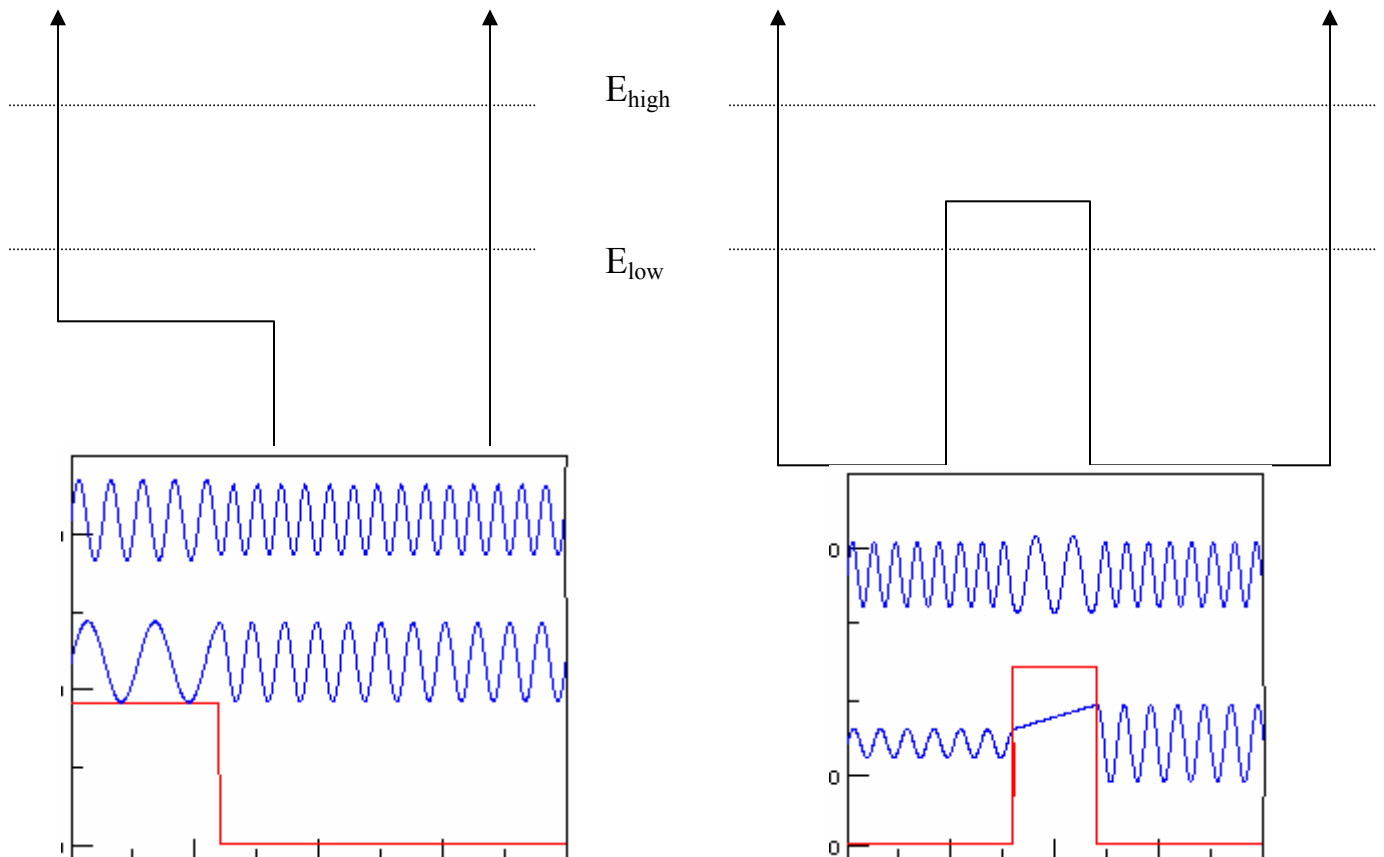


I want CANDY ... dun, dun, dun, da-dun, dun ... I want CANDY!!

1) Those damn cellophane packages – they are getting more complicated ... I want my Halloween-shaped **Peeps!** Ok, calm down ... maybe some drawing will calm me down ... maybe drawing some electron wavefunctions in various potential wells will help.

a) For each of the wells below, and for each of the two energy levels, sketch a reasonable wavefunction to correspond to those energy levels. [Note: you have the ability to choose the wavelengths you need to use, but relative to the particular energies of the electron, the wavelengths should be chosen appropriately (for example, suppose you draw the lower level wavefunction first ... then the upper level wavefunction should have a wavelength that is sized reasonably in relation to the lower energy wavefunction).]

b) Discuss the relative wavefunctions for each “section” of the two wells below (2 sections on the left well, three on the right) – indicate your intended relative sizes of wavelengths and any other relevant features of the graphs (you could also annotate some ideas on the graphs themselves, as you sketch them). If it matters, indicate on which side the electron starts.



Wavelengths on the left side are longer than the right side (since the KE is lower, the momentum would be lower, thus the wavelength is higher).

The wavelengths in the upper level are also shorter than the lower level, since the KE is bigger (momentum bigger, wavelengths smaller).

Wavelengths on sides are smaller than middle in the upper level (see reasons given in the other well).

In the lower level, the wavelengths are the same on either side, but the particle appears to have started on the right side, so the amplitude on the left should be lower.

2) Oh, sweet (get it, ‘sweet’ – get it, the topic is candy, and I used that particular slang expression?) – there is a new HYDROGEN bar – full of electrony goodness! As you shake the bar, the flavor electrons jump up into higher energy levels, and release photons as they drop back down. As I shake one particular candybar, I notice the electrons are bouncing between the 2nd and 6th energy level above the ground state (thus $n=2$ and $n=6$ energy levels).

a) Calculate all of those energy levels from $n=2$ to $n=6$.

$$E_n = -\frac{13.6}{n^2} = -3.4, -1.51, -0.85, -0.544, -0.378 \text{ eV}$$

b) Calculate the **largest** and **smallest** of the wavelengths that are released.

Large wavelength goes with smallest energy gap, smallest wavelength with largest gap:

$$\lambda_{\text{large}} = \frac{1240}{(-0.378 - (-3.4))} = 410 \text{ nm} \quad \lambda_{\text{small}} = \frac{1240}{(-0.378 - (-0.544))} = 7459 \text{ nm}$$

c) Can you shine light of wavelength **1282.17 nm** on this candybar and have it absorbed by an electron in the $n=3$ energy level? Defend your answer.

It will be absorbed only if it can jump to a higher level ... with the right amount of energy:

This wavelength gives an energy change of: $\Delta E = \frac{1240}{1282.17} = 0.967 \text{ eV}$

If you add this energy to the 3rd energy level, you get $E = -0.544 \text{ eV}$... the 5th energy level!

Yes, the electron can be absorbed.

d) **According to the discussion in the text**, what is *one success* of the Bohr model, and *two failures* of the model.

Many answers – as an example:

CORRECTLY identifies the energy levels of the Hydrogen atom
 FAILS to account for the “doublets” in the wavelength spectrum
 FAILS to predict probabilities of dropping between specific levels

3) Holy new candybar, Batman! Here is a brand new ISW candybar (infinite square well) with the square packages with the infinite walls (yeah, try and sneak that out of the store without paying!). You can again shake the electrons between the $n=2$ and $n=6$ energy levels, and watch the wavelengths that are emitted. Wait, what is that written on the side ... the width of the well is **0.2 nm**, and remember that an electron has a rest energy of 511,000 eV.

a) What is the energy of the $n=2$ level?

$$E_n = n^2 \frac{(1240)^2}{8E_0 L^2} = n^2 \frac{(1240)^2}{8(511,000)(0.2)^2} = n^2 (9.4 \text{ eV}) = 37.6 \text{ eV}$$

b) How many unique wavelengths will come from this part of the system? $5 \text{ levels} \Rightarrow 5(4)/2 = 10 \text{ unique}$

c) What is the biggest wavelength in this part of the system?

Biggest $\Rightarrow n=2 \rightarrow n=3$ levels [**different** from Bohr!] $E_3 = 9(9.4) = 84.6 \text{ eV} \quad \lambda_{\text{big}} = \frac{1240}{84.6 - 37.6} = 26.4 \text{ nm}$

d) What is the deBroglie wavelength of the electron in the $n=2$ energy level?

Consider the wavefunction for this particular level – one wavelength fits into the width L , so the wavelength is exactly 0.2 nm!!

We could also calculate it ... but I would use the conceptual answer!

$$pc = \sqrt{2E_0 KE} = \sqrt{2(511000)(37.6)} = 6199 \text{ eV} \quad \lambda = \frac{h}{p} = \frac{hc}{pc} = \frac{1240}{6200} = 0.2 \text{ nm}$$

4) Dude, that Hydrogen bar is BOHRing – you got to step up to the SE™* bar, see? This SE bar is packed with radical (and radial) wavefunctions, and you will PROBABLY like it a lot! [* SE is a trademark of the Schrodinger's Equation Candy Factory.]

a) what quantum number combinations of n and l will give the “Bohr states” for the Hydrogen atom? Oh, yeah, also explain what is so special about those “Bohr states”?

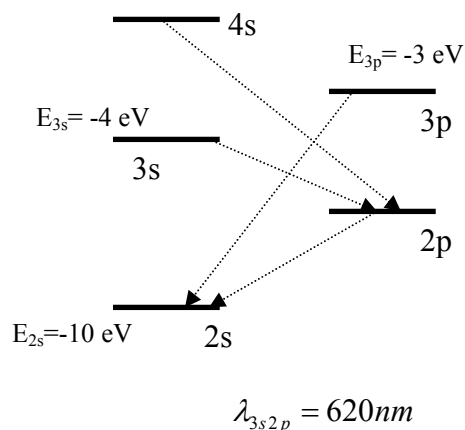
If l is one less than n [$l=n-1$], then we have the “Bohr state” where the peak of the probability curve is the Bohr radius for that energy level.

b) Calculate the most probable radius for the electron in the $n=3$ and $l=2$ quantum state. The radial probability density function has the following form: $P_{32}(r) \propto r^6 e^{-2r/3a_0}$

$$U = 2r/3a_0 \quad P(U) \propto U^6 e^{-U} \quad \frac{dP}{dU} = -U^6 e^{-U} + 6U^5 e^{-U} = 0 \quad U = 6 \quad r = 9a_0$$

5) As I was unwinding after a sugar rush, I discovered the following energy diagram, with wavelengths of transitions as indicated (the 3s-2p transition wavelength is indicated, and the 3s, 2s, and 3p level energies are given).

a) in no particular order, find the transition wavelengths between 2p2s and 3p2s, and the energy level of 2p.



$$\text{Using the } 3s2p \text{ wavelength: } \Delta E_{3s2p} = \frac{1240}{620} = 2 \text{ eV} \quad E_{2p} = \frac{1240}{620} = -6 \text{ eV}$$

$$\text{For the } 2p2s \text{ wavelength: } \Delta E_{2p2s} = 4 \text{ eV} \quad \lambda_{2p2s} = \frac{1240}{4} = 310 \text{ nm}$$

$$\text{For the } 3p2s \text{ wavelength: } \Delta E_{3p2s} = 7 \text{ eV} \quad \lambda_{3p2s} = \frac{1240}{7} = 177 \text{ nm}$$

b) What can be said about the 4s2p transition wavelength (not knowing the exact 4s level, you can't specify it directly, but what can you calculate about it)?

The 4s level has to be above the 3p level ... so we could calculate the “non allowed” 3p to 2p transition, just to get a maximum wavelength: $\Delta E_{3p2p} = 3 \text{ eV} \quad \lambda_{3p2p} = \frac{1240}{3} = 413 \text{ nm}$ (Thus wavelength must be **LESS** than 413 nm)

c) Are there any other possible transition wavelengths that are “allowed” in that diagram above that were not labeled – if so, indicate them (you don't have to draw them – just explain).

Two other possibilities: 4s-3p and 3p-3s transitions – vertical transitions are not “allowed” (not likely).

6) On my way to the store to get more candy, I like to ponder the periodic table ...

a) Why does the 4s level often fill before the 3d level (i.e., the energy level for the 4s is often lower than the 3d)? (Hint, how do the “orbits” compare?)

The 3d level is a “bohr orbit”, thus more circular .. but the 4s level is very elongated (elliptical), thus spends more time near the nucleus .. thus larger average force, thus lower energy level

b) Contrast the ionization energy for Xe with the ionization energy for Cs – explain the difference.

Xe is on the far right of the chart .. it has a completely filled energy level – quite happy – hard to rip off an electron ... Cs is at the far left .. it has a “free” 6s electron that could be easily removed – thus low ionization energy.

c) Write down the **complete (not abbreviated)** electronic configuration (i.e. $1s^2 2s^1$, etc.) for Ni (nickel) and Cu (copper). [Nickel should be created using the “standard” rules for creating the electronic configurations, and the Copper one is partially shown in your chart.] Compare these two configurations and explain why one is different – and what results from that difference?

Ni: $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^8$ Cu: $1s^2 2s^2 2p^6 3s^2 3p^6 4s^1 3d^{10}$ Copper filled its d shell at the expense of the 4s electron – leaves one electron easily ionized – thus copper is a good conductor!

d) How many electrons does an electrically neutral atom of Lawrencium (Lr) have?

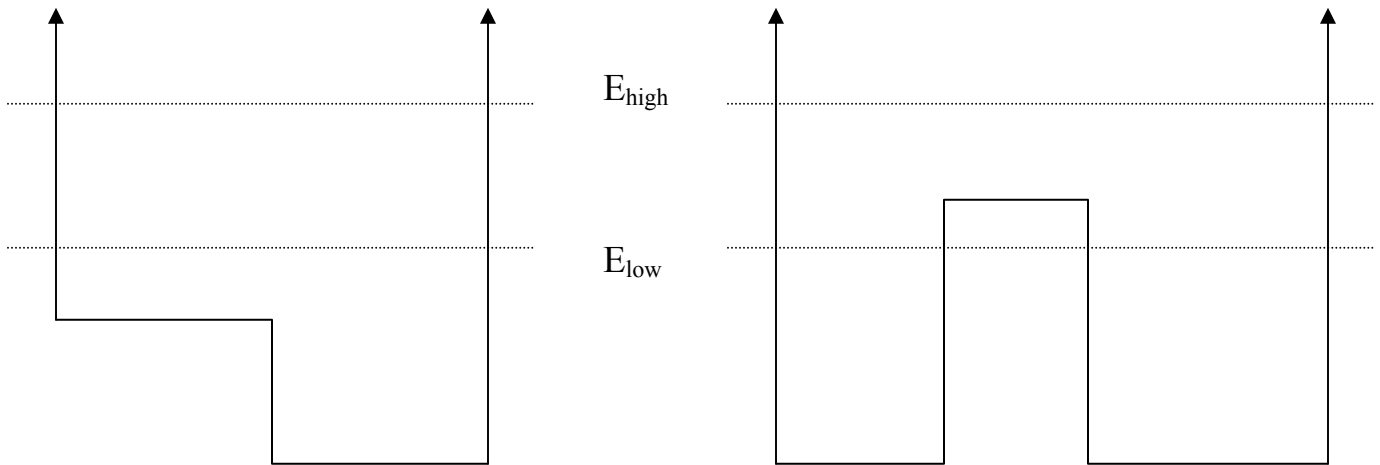
I want CANDY ... dun, dun, dun, da-dun, dun ... I want CANDY!! **Choose 5 out of 6 problems!**

Honor Code Pledge: "I have neither given nor received unauthorized aid in completing this work, nor have I presented someone else's work as my own." _____

1) Those damn cellophane packages – they are getting more complicated ... I want my Halloween-shaped **Peeps!** Ok, calm down ... maybe some drawing will calm me down ... maybe drawing some electron wavefunctions in various potential wells will help.

a) For each of the wells below, and for each of the two energy levels, sketch a reasonable wavefunction to correspond to those energy levels. [Note: you have the ability to choose the wavelengths you need to use, but relative to the particular energies of the electron, the wavelengths should be chosen appropriately (for example, suppose you draw the lower level wavefunction first ... then the upper level wavefunction should have a wavelength that is sized reasonably in relation to the lower energy wavefunction).]

b) Discuss the relative wavefunctions for each “section” of the two wells below (2 sections on the left well, three on the right) – indicate your intended relative sizes of wavelengths and any other relevant features of the graphs (you could also annotate some ideas on the graphs themselves, as you sketch them). If it matters, indicate on which side the electron starts.



2) Oh, sweet (get it, 'sweet' – get it, the topic is candy, and I used that particular slang expression?) – there is a new HYDROGEN bar – full of electrony goodness! As you shake the bar, the flavor electrons jump up into higher energy levels, and release photons as they drop back down. As I shake one particular candybar, I notice the electrons are bouncing between the 2nd and 6th energy level above the ground state (thus n=2 and n=6 energy levels).

a) Calculate all of those energy levels from n=2 to n=6.

b) Calculate the **largest** and **smallest** of the wavelengths that are released.

c) Can you shine light of wavelength **1282.17 nm** on this candybar and have it absorbed by an electron in the **n=3** energy level? Defend your answer.

d) **According to the discussion in the text**, what is *one success* of the Bohr model, and *two failures* of the model.

3) Holy new candybar, Batman! Here is a brand new ISW candybar (infinite square well) with the square packages with the infinite walls (yeah, try and sneak that out of the store without paying!). You can again shake the electrons between the $n=2$ and $n=6$ energy levels, and watch the wavelengths that are emitted. Wait, what is that written on the side ... the width of the well is **0.2 nm**, and remember that an electron has a rest energy of 511,000 eV.

a) What is the energy of the $n=2$ level?

b) How many unique wavelengths will come from this part of the system?

c) What is the **biggest** wavelength in this part of the system?

d) What is the deBroglie wavelength of the electron in the **$n=2$** energy level?

4) Dude, that Hydrogen bar is BOHRing – you got to step up to the SE™* bar, see? This SE bar is packed with radical (and radial) wavefunctions, and you will PROBABLY like it a lot! [* SE is a trademark of the Schrodinger's Equation Candy Factory.]

a) what quantum number combinations of n and l will give the “Bohr states” for the Hydrogen atom? Oh, yeah, also explain what is so special about those “Bohr states”?

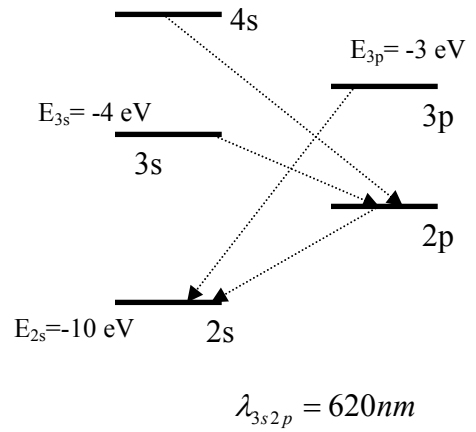
b) Calculate the most probable radius for the electron in the $n=3$ and $l=2$ quantum state. The radial probability density function has the following form: $P_{32}(r) \propto r^6 e^{-2r/3a_0}$

c) In the $n=1, l=0$ state, what is the probability of finding the electron between $0.5a_0$ and $1.5a_0$?

As a reminder – for this state : $U = \frac{2r}{a_0}$ $P(U) = \frac{1}{2} U^2 e^{-U}$

5) As I was unwinding after a sugar rush, I discovered the following energy diagram, with wavelengths of transitions as indicated (the 3s-2p transition wavelength is indicated, and the 3s, 2s, and 3p level energies are given).

a) in no particular order, find the transition wavelengths between 2p2s and 3p2s, and the energy level of 2p.



b) What can be said about the 4s2p transition wavelength (not knowing the exact 4s level, you can't specify it directly, but what **can** you calculate about it)?

c) Are there any other possible transition wavelengths that are "allowed" in that diagram above that were not labeled – if so, indicate them (you don't have to draw them – just explain).

6) On my way to the store to get more candy, I like to ponder the periodic table ...

a) Why does the **4s** level often fill before the **3d** level (i.e., the energy level for the **4s** is often lower than the **3d**)? (Hint, how do the “orbits” compare?)

b) Contrast the ionization energy for Xe with the ionization energy for Cs – explain the difference.

c) Write down the **complete (not abbreviated)** electronic configuration (i.e. $1s^22s^1$, etc.) for Ni (nickel) and Cu (copper). [Nickel should be created using the “standard” rules for creating the electronic configurations, and the Copper one is partially shown in your chart.] Compare these two configurations and explain why one is different – and what results from that difference?

d) How many electrons does an electrically neutral atom of Lawrencium (Lr) have?