Student ID:______________________________

1.

a) The human body needs at least 1.03×10^{-2} mol O_2 every minute. If all of this oxygen is used for the cellular respiration reaction that breaks down glucose($C_6H_{12}O_6$), how many grams of glucose does the human body consume each minute?

Hint: the balanced equation for respiration reaction is:

$$C_6H_{12}O_6 + 6O_2 \Rightarrow 6CO_2 + 6H_2O$$

The balanced chemical reaction shows that for 1 mole $C_6H_{12}O_6$ we need 6 moles of O_2

We are given 1.03×10^{-2} mol of O_2

∴ The number of moles of $C_6H_{12}O_6$ needed

$$= \frac{1.03 \times 10^{-2} \text{ mole of } O_2 \times 1 \text{ mole of } C_6H_{12}O_6}{6 \text{ mole of } O_2}$$

$= 0.0017$ mole of $C_6H_{12}O_6$

Now, inorder to find grams of glucose, we need to find the Molecular weight (M.W) of $C_6H_{12}O_6$

∴ M.W of $C_6H_{12}O_6 = 6 \times 12.01 + 12 \times 1.008 + 6 \times 16.00$
$= 180.156$ g/mole

∴ Amount of glucose consumed $= 0.0017$ mole $\times 180.156$ g/mol

$\simeq$ **0.306 g**

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b) In the space shuttle, the CO_2 that the crew exhales is removed from the air by a reaction with lithium hydroxide (LiOH) to form lithium carbonate (Li_2CO_3) and water. On average, each astronaut exhales about 20.0 mol of CO_2 daily. What volume of water will be produced when this amount of CO_2 reacts with an excess of LiOH?

Hint: the density of water is about $1.00\frac{g}{cm^3}$

Consider the following reaction

$$CO_2 + 2LiOH \longrightarrow Li_2CO_3 + H_2O$$

The reaction shows that 1 mole of CO_2 produces 1 mol of H_2O on reaction with 2 moles of LiOH
We have 20.0 mol of CO_2 and excess of LiOH

$$\underset{20.0\ mol}{CO_2} + \underset{excess}{2\ LiOH} \longrightarrow Li_2CO_3 + \underset{?}{H_2O}$$

∴ The moles of H_2O produced $= \frac{20\ mol\ of\ CO_2 \times 1\ mol\ H_2O}{1\ mol\ CO_2}$

$= 20$ mol of H_2O

M.W of $H_2O = 2 \times 1.008 + 1 \times 16.00 = 18.016$ g/mol

∴ Mass of H_2O produced $= 20$ mol $H_2O \times 18.016$ g/mol
$= \underline{360.32\ g}$

Density = mass ÷ volume

∴ Volume of water produced $= \frac{360.32\ g}{1.00\ \frac{g}{cm^3}}$

$= \underline{\underline{360.32\ cm^3}}$

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2. Sodium and silver have work functions of 2.46 eV and 4.73 eV, respectively.

a) If the surfaces of both metals are illuminated with a light of wavelength 200 nm,

- Which metal will give off electrons with a higher speed?

$E_{photon} = K.E + \phi \Rightarrow K.E = h\nu - \phi$ (K.E = Kinetic Energy, ϕ = Work function)

Higher ϕ results in lower K.E

$K.E = \frac{1}{2}mv^2$ ∴ Higher ϕ results in lower velocity.

As sodium has lower ϕ, it will give off electrons with higher speed.

- Calculate the difference between the maximum speeds of the electrons emitted from the two metals.

$K.E = h\nu - \phi \Rightarrow \frac{1}{2}mv^2 = \frac{hc}{\lambda} - \phi$

$\Rightarrow v = \sqrt{\frac{2}{m}\left(\frac{hc}{\lambda} - \phi\right)}$

$$V_{Na} = \sqrt{\frac{2}{9.1\times10^{-31}\,kg}\left[\frac{6.63\times10^{-34}\,J.s\times3\times10^{8}\,m/s}{200\times10^{-9}\,m} - (2.46\times1.6\times10^{-19}\,J.s)\right]}$$

$V_{Na} = 1.14\times10^{6}$ m/s

$$V_{Ag} = \sqrt{\frac{2}{9.1\times10^{-31}\,kg}\left[\left(\frac{6.63\times10^{-34}\,J.s\times3\times10^{8}\,m/s}{200\times10^{-9}\,m}\right) - (4.73\times1.6\times10^{-19}\,J.s)\right]}$$

$V_{Ag} = 7.2\times10^{5}$ m/s

$\Delta V = V_{Na} - V_{Ag} = 4.2\times10^{5}$ m/s

b) Calculate the threshold frequency for each material.

Threshold frequency = ν_0

$h\nu_0 = \phi \Rightarrow \nu_0 = \phi/h$

∴ $\nu_{0\,Na} = \frac{2.46\times1.6\times10^{-19}\,J}{6.63\times10^{-34}\,J.s} = 5.94\times10^{14}$ Hz

∴ $\nu_{0\,Ag} = \frac{4.73\times1.6\times10^{-19}\,J}{6.63\times10^{-34}\,J.s} = 1.14\times10^{15}$ Hz

c) Say that sodium is illuminated with light of wavelength 300 nm. Calculate the de Broglie wavelength of the ejected electron.

$K.E = h\nu - \phi \Rightarrow \frac{1}{2}mv^2 = \frac{hc}{\lambda} - \phi \Rightarrow v = \sqrt{\frac{2}{m}\left(\frac{hc}{\lambda} - \phi\right)}$

$$∴ V = \left\{\frac{2}{9.1\times10^{-31}\,kg}\left[\left(\frac{6.63\times10^{-34}\,J.s\times3\times10^{8}\,m/s}{300\times10^{-9}\,m}\right) - 2.46\times1.6\times10^{-19}\,J\right]\right\}^{1/2}$$

∴ $V = 7.69\times10^{5}$ m/s

using de Broglie equation $\lambda_{dB} = \frac{h}{p} = \frac{h}{mv}$

$$\lambda_{dB} = \frac{h}{mv} = \frac{6.63\times10^{-34}\,J.s}{9.1\times10^{-31}\,kg\times7.69\times10^{5}\,m/s} = 9.47\times10^{-10}\,m$$

∴ de Broglie wavelength of ejected electron = 9.47 Å

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3.

a) Calculate the number of electrons in the following species:

i) F^-

9+1 = 10

ii) Ca^{2+}

20 — 2 = 18

iii) Fe^{3+}

26 — 3 = 23

b) Write down the electronic configuration of the following species:

i) Al

[Ne] 3s2 3p1 Or 1s2 2s2 2p6 3s2 3p1

ii) Cr

[Ar] 3d5 4s1 Or 1s2 2s2 2p6 3s2 3p6 3d5 4s1

iii) Cl^-

[Ne] 3s2 3p6 Or [Ar]

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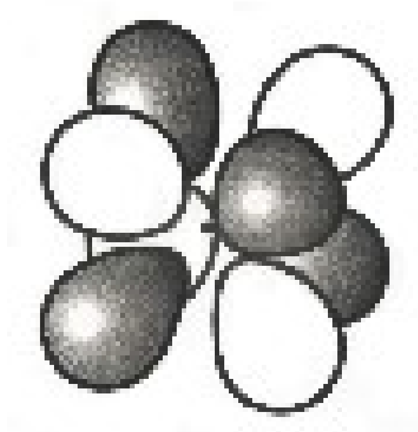
c) How many angular nodes are there in the following orbital? (White denotes positive values and gray negative values)

Given that the orbital has no radial nodes, determine the identity of the orbital.



angular nodes = 3

l = 3

radial nodes = 0

(according to the question)

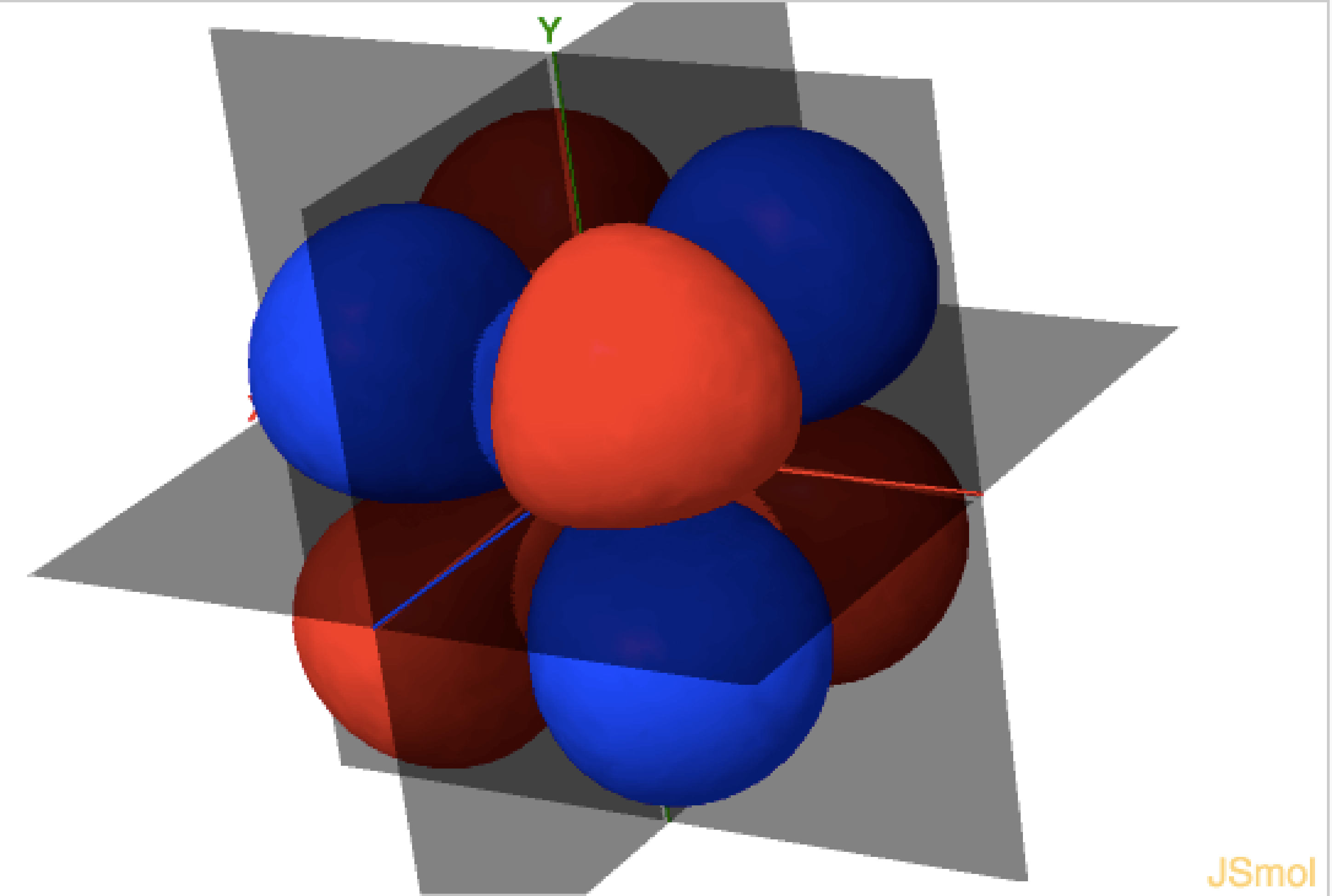
$n - l - 1 = 0$

$n - 3 - 1 = 0$

$n = 4$

orbital = 4f

No need to specify the orientation!


Y
JSmol

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4. The radial part of 4d orbital in hydrogen is

$$R_{4d}(r) = \frac{1}{96\sqrt{5\,a_0^3}}(6-\rho)\rho^2 e^{-\frac{\rho}{2}} \quad (\rho = \frac{r}{2a_0})$$

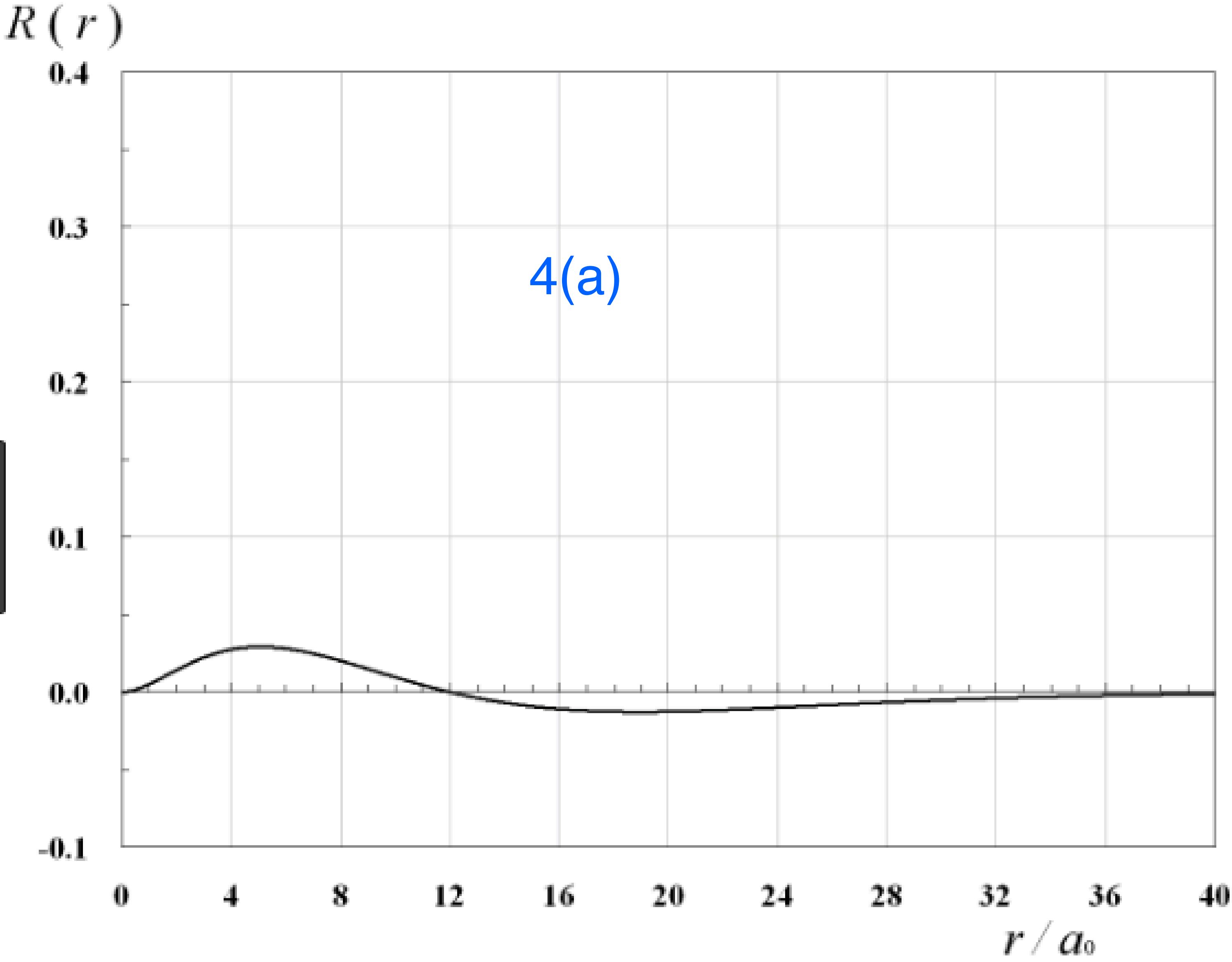
a) Roughly sketch the radial part of the hydrogen 4d orbital.

b) Roughly sketch $4\pi r^2[R_{4d}(r)]^2$

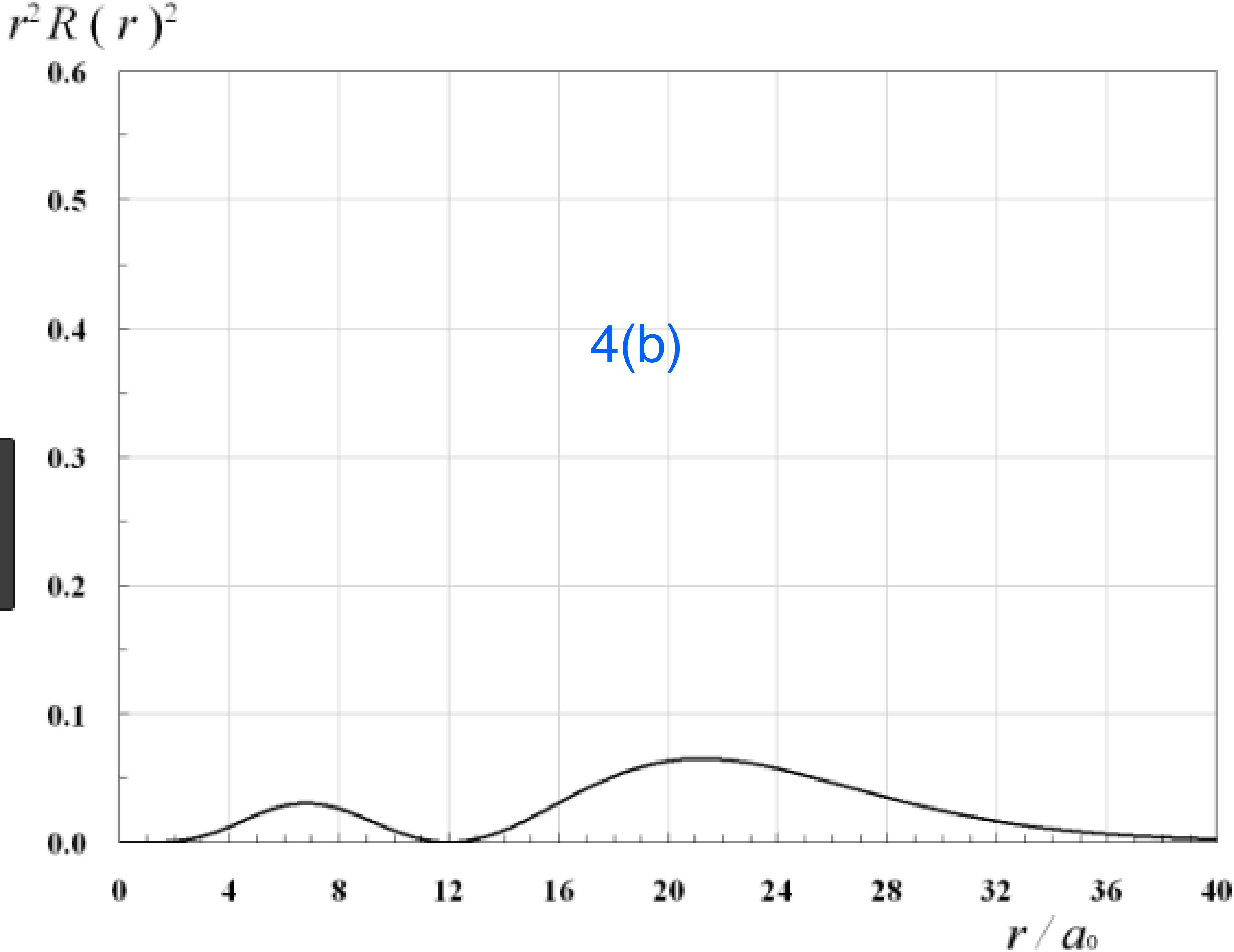
See Next Page

c) Find the radial nodes of the 4d orbital

d) What is the probability of finding the electron at distance between a_0 and $1.0001a_0$ from the nucleus?



R (r)
0.4
0.3
0.2
0.1
0.0
-0.1
4(a)
0
4
8
12
16
20
24
28
32
36
40
r / a0


$r^2 R(r)^2$
0.6
0.5
0.4
0.3
0.2
0.1
0.0
4(b)
0
4
8
12
16
20
24
28
32
36
40
r / a_0

4(c)

$\rho - 6 = 0$, so $(r/2a_0) = 6$; hence $r = 12a_0$
Note that $r = 0$ is NOT a radial node.
Although the function becomes zero but its sign does not change.

4(d)

Probability of finding an e between $(r, r+dr)$
$= 4\pi r^2 |R(r)|^2 dr$

$P(a_0, a_0+1.0001a_0) =$
$4\pi a_0^2 |R(a_0)|^2 (0.0001a_0) = 3.1 * 10^{-8}$

Since the two points are close enough there is no need to do the integration.

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5.

a) Suppose that for an ion with only one electron, the transition from an n = 8 state to an n = 4 state will lead to emission of a photon with a wavelength 216 nm. Based on that, determine the identity of the ion.

Energy of photon: $E = \frac{hc}{\lambda} = \frac{4.14 \times 10^{-15} eV \cdot s \times 3 \times 10^{8} m/s}{216} = 5.76 eV$

$\Delta E = R_\infty Z^2 \cdot \left(\frac{1}{n_f^2} - \frac{1}{n_i^2}\right) = 13.6 eV \times \left(\frac{1}{16} - \frac{1}{64}\right) Z^2$

$= 0.6375 eV \cdot Z^2$

thus $0.6375 eV \cdot Z^2 = 5.76 eV$

$Z^2 \doteq 9 \Rightarrow Z = 3 \Rightarrow$ **The ion is Li^{2+}**

b) Suppose we shine light of a certain frequency on a Li^{2+} ion whose electron is in its n=2 energy state, and we observe that the electron absorbs a photon and is ejected from the ion with a kinetic energy of 3.0 eV (i.e., the electron not only moved infinitely away from the nucleus but also got an extra 3.0 eV of kinetic energy). Calculate the frequency of the photon.

$E(n=2) = -R_\infty \frac{Z^2}{n^2} = -13.6 eV \times \frac{9}{4} = -30.6 eV$

$\Delta E = 3.0 eV - E(n=2) = 33.6 eV$

$\Delta E = h\nu \Rightarrow \nu = \frac{\Delta E}{h} = \frac{33.6 eV}{4.14 \times 10^{-15} eV \cdot s}$

$= $ **$8.1 \times 10^{15} Hz$**