

107 Answer Key HW #9- Chapter 14 assignment

Conceptual: 16, 18, 19

Problems: 2, 6, 8

November 9, 2005

1 Conceptual Exercises

16.) “In Figure 14.11, which quantum jump creates the higher frequency photon, N=4 to N=3 or N=4 to N=2?”

The jump from N=4 to N=2 is a larger change in energy, so this photon will have a larger energy. Since energy and frequency are directly related: $E = h * (freq)$, the jump from N=4 to N=2 will create the higher frequency photon.

18.) “The four spectral lines of hydrogen photographed in Figure 14.2 have wavelengths and frequencies that agree precisely with the four lowest-energy transitions into hydrogen’s N=2 energy level. Which three of these four lines are graphed in Figure 14.12? Give the initial and final N values for all four lines in the photo.”

In the photograph Figure 14.2 for hydrogen, frequency is increasing to the right. Looking at Figure 14.12, we find 3 lines under the bracket "N=2" - i.e. three transitions into N=2. Since these are the three lowest-energy transitions into the N=2 state (from Figure 14.11), they correspond to the first three lines (starting from the left) in the photograph. Explicitly, the first line is N=3 to N=2; the second N=4 to N=2; the third line is N=5 to N=2. The last line, which is not graphed in Figure 14.12, is the next highest transition into N=2, i.e. N=6 to N=2. The last is not pictured since it would've overlapped with the "N=3" bracket.

19.) “Arrange the following objects in order, beginning with the object having the largest range of possibilities and ending with the one having the smallest: proton, glucose molecule $C_6H_{12}O_6$, helium atom, baseball, electron, grain of dust, water molecule, automobile.”

The range of possibilities for a given object is the indeterminacy in its position multiplied by the indeterminacy in its speed: $\Delta x * \Delta s$. This product can also be expressed in another way, by help of the Indeterminacy principle: $\Delta x * \Delta s = \frac{h}{mass}$. Thus, the larger the mass, the smaller the range of possibilities: this makes sense, as the large objects we're used to dealing with don't seem to have a large range of indeterminacy in their position or speed. Ordering the objects from smallest mass (largest range of possibilities) to largest mass (smallest range of possibilities), we have:

Electron, proton, helium atom, water molecule, glucose molecule,
grain of dust, baseball, automobile.

2 Problems

2.) "For the hydrogen atom, the energy difference $E_3 - E_2$ between the second and third levels (Figure 14.9) is $3 * 10^{-19} J$. Find the frequency of the photon emitted when a hydrogen atom quantum jumps from state 3 to state 2. In which region of the spectrum is this (Figure 9.7)?"

The energy difference between states is equal to the energy of the photon: $E_{photon} = 3 * 10^{-19} J$; but the energy of a photon is equal to $h * (freq)$, so we have:

$$E_{photon} = 3 * 10^{-19} J = 6.6 * 10^{-34} J * s * (freq)_{3 \rightarrow 2} \Rightarrow (freq)_{3 \rightarrow 2} = \boxed{4.54 * 10^{14} \text{ Hz.}} \quad (1)$$

Looking at Figure 9.7, we see that this lies in the visible region of the spectrum, and is approximately yellow.

6.) "Calculate the diameter of an atom having $N=100$, expressing your answer in millimeters. How many ground state hydrogen atoms could fit into the volume occupied by one such giant atom?"

We are told in previous problems that the diameter of a ground state hydrogen atom is $10^{-10} m = 10^{-7} mm$, expressing the answer in millimeters. We are also told that the radius is proportional to N^2 . This is all we need if we attack the problem using proportionalities. Since the radius is proportional to N^2 , so is the diameter, since the diameter is just twice the radius. So: $Diameter \sim N^2$. If we increase N from 1 to 100, then the diameter must increase by: $(100N)^2 = 100^2 N^2 \sim 100^2 (Diameter)$. Notice that the diameter increases by a factor of 100! Since we started with a diameter of $10^{-7} mm$, for $N = 100$ we have $Diameter = 100^2 * 10^{-7} mm = 10^{-3} mm = \boxed{.001 \text{ mm!}}$

The volume of an atom is $Volume = 4\pi * (Radius)^3 / 3$. Given the volume of the $N = 100$ atom and the ground state atom, the number of ground

states we can fit in the huge atom is:

$$\text{Number of ground state} = \frac{\text{Vol of } N = 100}{\text{Vol of ground}} = \frac{4\pi * (10^{-3}mm)^3/3}{4\pi * (10^{-7}mm)^3/3} = 4.1888*10^{-9}/4.1888*10^{-21} \quad (2)$$

This is a trillion ground state atoms (literally)!!

8.) “A proton (mass $1.7 * 10^{-27}kg$) has a speed indeterminacy $\Delta s = 1 m/s$. How large must its position indeterminacy be? Express your answer in millimeters.”

From the Indeterminacy Principle, we have $\Delta x \Delta s = h/(mass)$. Solving for Δx :

$$\Delta x = \frac{h}{mass * \Delta s} = \frac{6.6 * 10^{-34} J * s}{(1.7 * 10^{-27} kg) 1 m/s} = 3.88 * 10^{-7} m = \boxed{3.88 * 10^{-4} mm}. \quad (3)$$