Physics 25 Chapter 30 Practice Problems

1. What are the possible wavelengths of light that could be emitted by a gas of hydrogen atoms in the third-excited (n = 4) state?

2. What wavelength of light will ionize a hydrogen atom that is in the n = 1 quantum state?

3. A gas of excited hydrogen atoms emits light of various wavelengths. One of the wavelengths is 411 nm. Which transition accounts for this wavelength?

4. What is the speed of the electron in the fourth quantum level of hydrogen?

5. Calculate the speed of the electron in Problem 4 using the concept of constructive interference of deBroglie waves.

6. A relaxing electron in hydrogen falls down to its nearest neighbor orbit and emits a photon whose energy is 0.0236 eV. the electron continues to de-excite, and makes a transition to its nearest-neighbor orbit, emitting a photon whose energy is 0.0319 eV. What two transitions occurred?

Solutions

1. The wavelengths in the table below represent a portion of the "emission spectra" of hydrogen. For electrons in the 4^{th} quantum level of hydrogen, there are six possible wavelengths of electromagnetic waves that can be emitted as the electron eventually ends up in the ground state.

The ΔE's in the table below are the changes in the energies of the relaxing electron. The absolute values of the ΔE's are the energies of the photons that leave with the lost energy.

m (initial)	n (final)	E_m $-13.6/m^2$ (eV)	E_n $-13.6/n^2$ (eV)	ΔE $E_n - E_m$ (eV)	$\|\Delta E\|$ Photon Energy (eV)	λ $1243 / \|\Delta E\|$ (nm)	Color
4	3	-0.85	-1.51	-0.66	0.66	1883	infrared
4	2	-0.85	-3.40	-2.55	2.55	487	green
4	1	-0.85	-13.60	-12.75	12.75	97	ultraviolet
3	2	-1.51	-3.40	-1.89	1.89	658	orange
3	1	-1.51	-13.60	-12.09	12.09	103	ultraviolet
2	1	-3.40	-13.60	-10.20	10.20	122	ultraviolet

2. Objects that are "bound" to a central attractor--as is the case for electrons orbiting a proton--have *negative* energies. *Unbound* (free) electrons have energies equal to, or greater than, zero. In order to break loose from the attractive pull, the electron must have its energy elevated from its negative value up to zero by adding energy.

To raise the electron in its ground state up to zero energy, it must absorb 13.6 eV of energy, either through heating, or by absorbing a photon whose energy is 13.6 eV. We say that the "ionization energy" of hydrogen is 13.6 eV.

Once the electron is removed from the hydrogen atom, the object left behind is a hydrogen ion, and the atom is said to have been "ionized."

The wavelength of light that will ionize hydrogen in its usual state--the ground state--is given below:

Wavelength: $\lambda = 1243/13.6$
$= 91.4$ nm (ultraviolet)

3. $E = 1243/411$
$= 3.02$ eV

Which transition emits a 3.02 eV photon, i.e., which pair of orbital energies differ by 3.02 eV?

Consulting the table below, we see the answer is $6 \rightarrow 2$.

n	E_n $-13.6/n^2$
1	-13.60
2	-3.40
3	-1.51
4	-0.85
5	-0.54
6	-0.38
7	-0.28
8	-0.21
9	-0.17

4.
$m = 9.11 \times 10^{-31}$ kg
$k = 9 \times 10^{9}$ N-m^2/C^2
$e = 1.6 \times 10^{-19}$ C
$r_n = n^2$ (0.53 Å)
$r_4 = (4)^2\ 0.53 \times 10^{-10}$
$= 8.48 \times 10^{-10}$ m

$E_4 = -13.6/4^2$
$= -0.85$ eV
$= -0.85(1.6 \times 10^{-19})$ J
$= -1.36 \times 10^{-19}$ J

$\frac{1}{2} mv^2 - ke^2/r = -1.36 \times 10^{-19}$
$\frac{1}{2} (9.11 \times 10^{-31})v^2 - 9 \times 10^{9} (1.6 \times 10^{-19})^2/8.48 \times 10^{-10} = -1.36 \times 10^{-19}$ J

$$v = 5.5 \times 10^{5} \text{ m/s}$$

There is a much more satisfying--and simpler--way to find the speed, as shown in the solution to Problem 5.

5. $C = 2\pi r$

$= 2\pi\,(8.48 \times 10^{-10})$

$= 5.33 \times 10^{-9}$ m

Fourth quantum level: Four wavelengths fit perfectly around orbit, constructively interfering.

$4\lambda = 5.33 \times 10^{-9}$

$\lambda = 1.33 \times 10^{-9}$ m

$mv = h/\lambda$

$v = h/(m\lambda)$

$= 6.63 \times 10^{-34} / [(9.11\times10^{-31})\,(1.33\times10^{-9})]$

$= 5.5 \times10^{5}$ m/s

6.

Energy Before = $-13.6/n^2$

Energy After = $-13.6/(n - 1)^2 + 0.0236$ eV

Energy is Conserved:

Energy Before = Energy After

$-13.6/n^2 = -13.6/(n - 1)^2 + 0.0236$ eV

Solver: n = 11

Possible Solver Issues: The equation is quadratic, meaning that the highest power of the unknown is 2, so there will be two solutions--one bad one, one good.

If your unlucky with your choice of the "seed," the starting value, you will get n = 0.5000000000567.

You have to reject this answer because n cannot be less than 1.
If you're really unlucky, your calculator might get stuck and report an error.

You don't *have to* solve an equation to get the answer. You can use the "trial and error method." Guess a value for n, then check to see if the difference in energies $E_{n-1} - E_n = 0.0236$; if not, keep guessing and checking.

As for the second transition, no calculation is necessary: We know the new transition is from n - 1 to n - 2: 10 to 9