Lecture 20

Outline of Last Lecture

- To understand the quantum-mechanical model of an atom, we have to know about electromagnetic radiation.
- Section 7.2: Light behaves as a wave. It has a frequency (v) and a wavelength (λ) that are related by its speed. It refracts and diffracts
- It undergoes constructive and destructive interference.

  V.λ = C

  c=2.99792458x10^8m/s

- Section 7.4: But light also behaves like a particle. The photoelectron effect (pp 319-321), in particular, was best explained if light consisted of small "packets" of energy (photons). The energy of a photon is related to its frequency.

  E= v . h

  h= 6.62606931x10^-34J.s

Outline of Current Lecture

- quantized.
- Atomic line spectra
- wave function (Q)
- atomic orbital
- quantum numbers

Current Lecture

-If a substance absorbs light energy, it has to absorb a whole number of photons. If a substance emits light energy, it has to emit a whole number of photons. The energy is **quantized.**

-Atomic line spectra (section 7.3)

Atoms and monatomic ions can absorb and emit light.

-How ever only specific frequencies of light are absorbed or emitted by a given atom or ion. That is: only certain energies of light are absorbed or emitted.

-This energy is emitted or absorbed by the electrons in the atom/ion. Only specific energies (frequencies of photons) can be emitted or absorbed because the electrons are restricted to certain energy levels. the energy of an electron in an atom is quantized!

-The energy levels in hydrogen could be fit to an equation (equations 7.6-7.9)

-Niels Bohr realized that the spectrum of hydrogen could be explained if the electrons were restricted to specific orbits (specific distances from the nucleus). The lines seen corresponded to the energy differences between these "allowed" orbit distances.

-What Bohr could not explain was why the electrons would be restricted to these specific orbits. [see figure 7.16 on page 324.] Note: The energy levels get closer together as n increases.

Q: Do the following electron transitions correspond to emission or absorption of light?

n=5 -----> n = 4 Emission

n=1-----> n = 3 absorption

n=2-----> n = 1 emission

n=3-----> n = 2 emission

Q: rank these transitions from smallest in energy to largest in energy (in absolute terms)

A: Smallest Energy Hights Energy

5 ----> 4 < 3-----> 2 < 2-----> 1 <1----->3

- Louis de Broglie: if light could be both a wave and a particle, then particles such as electrons might also be waves. He defined the wavelength of the 'particle-wave' as.

$$\lambda = h/mv$$

- where m is the mass of the particle in kg and v is the speed of the particle (in m/s).

Q: Which will have a longer wavelength: an electron moving at 3.00×107 m/s or an electron moving at 3.00×10^6m/s?

The slow e- has the longer wavelength.

Q: Which has more kinetic energy?

A: The fast e- has more kinetic energy.

Q: How about an electron and a neutron, each moving at 3.00×10^6m/s?

A: The neutron has more kinetic energy the e- has the longer wavelength

- **How does this explain atomic spectra?**

  -If the circumference of the orbit is exactly a whole number of wavelengths, the wave reinforces itself (constructively interferes) to form a stable standing wave.

  -If the circumference is not exactly $n\lambda$, the wave will be out of phase with itself on each "loop". It will destructively interfere and cancel itself out.

  -The wavelength of the electron is set by its mass and velocity (its kinetic energy).

  So only radii where $2\pi = n\lambda$ will work. That defines and explains Bohr's orbits.

-There is more than one wave, but each one has the same equation with a different value of n. [n is a quantum number. n= 1, 2, 3, ...]

- Note that the number of nodes (z = 0) increases as n increases.

This is far too simplistic for an actual atom:

• The electron occupies a 3-D space. This requires spherical harmonics.

• The electron vibrates as an electric field and an magnetic field (5 dimentions).

• We have ignored all potential energy considerations. [There is a charged nucleus in the

center.] The math gets more complicated, but the ideas still hold true.

- The Schrödinger equation defines the conditions that an electron wave must meet in order to be stable inside an atom.

- A solution to the Schrödinger equation is called a wave function (Q): a mathematical description of the electron wave.

- Each wave function represents an atomic orbital: an allowed energy level of the electron

- Mathematically, all wave functions are quite similar. They differ only in a set of 'coefficients' for the parts of the equation. These 'coefficients' are called quantum numbers.

- A set of three quantum numbers defines a specific atomic orbital.

-n : associated with the shell or "level" related to the size of the orbital. n is always a positive integer (1, 2, 3 ...)

-L : l determines the subshell (sublevel)

l is related to the shape of the orbital.

l may be any integer from 0 to n-1

s-orbitals have l = 0, p-orbitals have l = 1, d-orbitals have l = 2, f-orbitals have l = 3