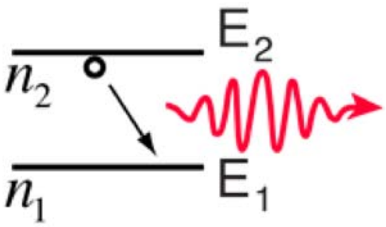
Electron Transitions

The Bohr model for an electron transition in hydrogen between quantized energy levels with different quantum numbers n yields a photon by emission with quantum energy:



A downward transition involves emission of a photon of energy:

$$E_{photon} = h\upsilon = E_2 - E_1$$

Given the expression for the energies of the hydrogenic electron states for atoms of atomic number Z:

$$h\upsilon = \frac{Z^2 m e^4}{8h^2\varepsilon_0^2}\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right] = -13.6Z^2\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right] eV$$

This is often expressed in terms of the inverse wavelength or "wave number" as follows:

$$\frac{1}{\lambda} = R_H Z^2\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right] \quad \text{where} \quad R_H = \frac{me^4}{8h^3 c\varepsilon_0^2}$$ is called the Rydberg constant.

$R_H = 1.09677576 x 10^7 m^{-1}$ for hydrogen.

$R_\infty = 1.0973731 x 10^7 m^{-1}$ in the limiting case for heavy elements

The reason for the variation of R is that for hydrogen the mass of the orbiting electron is not negligible compared to the proton at the high accuracy at which spectral measurement is done. So the reduced mass of the electron is needed. But for heavier elements the movement of the nucleus can be neglected.

Index

Atomic structure concepts

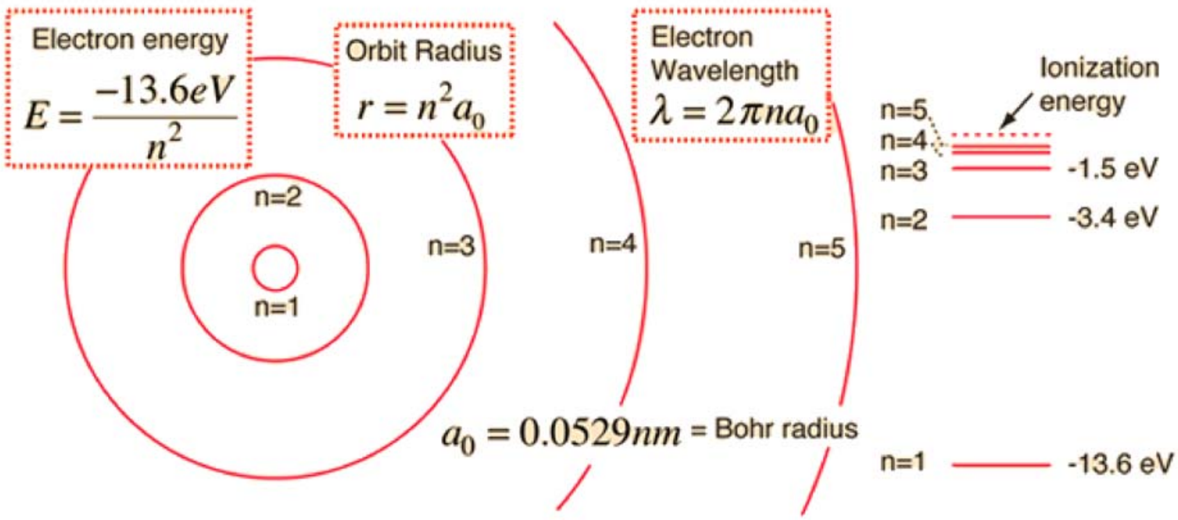
HyperPhysics***** Quantum Physics R Nave Go Back

Hydrogen Energy Levels

Index

Hydrogen

The basic hydrogen energy level structure is in agreement with the Bohr model. Common pictures are those of a shell structure with each main shell associated with a value of the principal quantum number n.



This Bohr model picture of the orbits has some usefulness for visualization so long as it is realized that the "orbits" and the "orbit radius" just represent the most probable values of a considerable range of values. If the radial probabilities for the states are used to make sure you understand the distributions of the probability, then the Bohr picture can be superimposed on that as a kind of conceptual skeleton.

Energy level plot | **Energies in eV** | **Hydrogen spectrum**

Electron energy level diagrams

concepts

Atomic structure concepts

HyperPhysics***** Quantum Physics

R Nave

Go Back

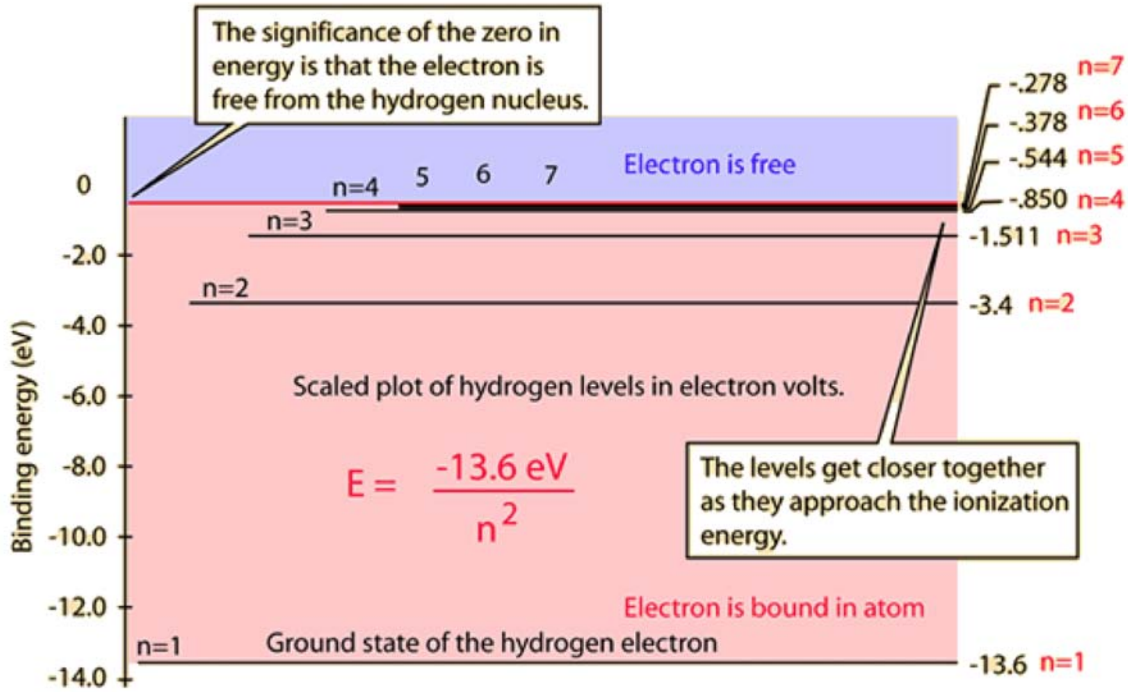
Hydrogen Energy Level Plot

Index

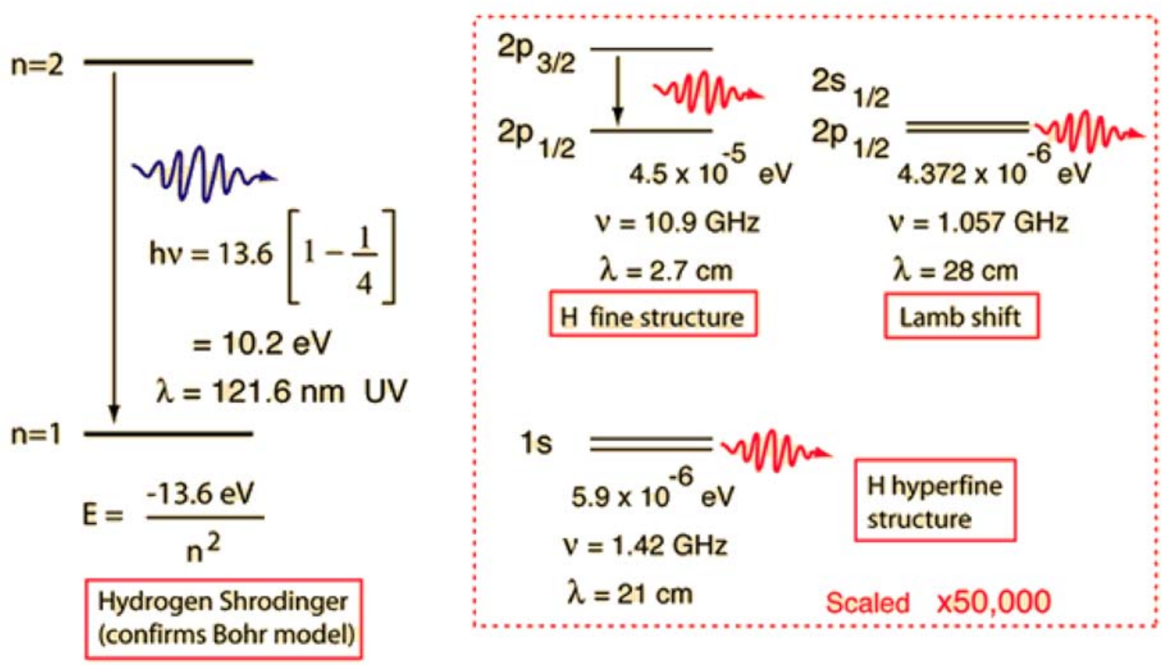
Hydrogen concepts

Atomic structure concepts

The basic structure of the hydrogen energy levels can be calculated from the Schrodinger equation. The energy levels agree with the earlier Bohr model, and agree with experiment within a small fraction of an electron volt.



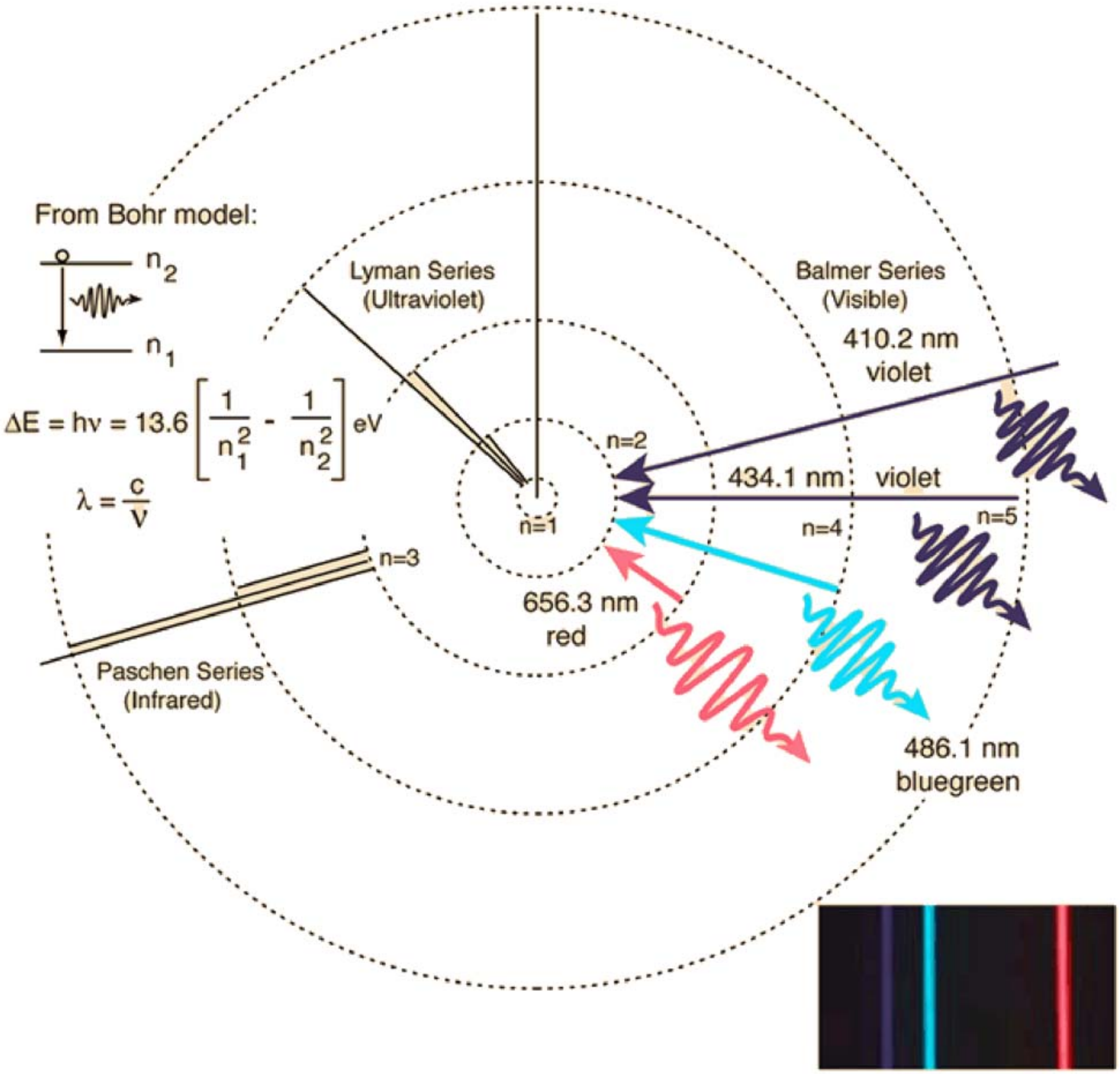
If you look at the hydrogen energy levels at extremely high resolution, you do find evidence of some other small effects on the energy. The 2p level is split into a pair of lines by the spin-orbit effect. The 2s and 2p states are found to differ a small amount in what is called the Lamb shift. And even the 1s ground state is split by the interaction of electron spin and nuclear spin in what is called hyperfine structure.



Electron level calculation	Energies in eV

Go Back

Hydrogen Spectrum



Further splitting of hydrogen energy levels

This spectrum was produced by exciting a glass tube of hydrogen gas with about 5000 volts from a transformer. It was viewed through a diffraction grating with 600 lines/mm. The colors cannot be expected to be accurate because of differences in display devices.

For atomic number Z = ,

Index

Great experiments of physics

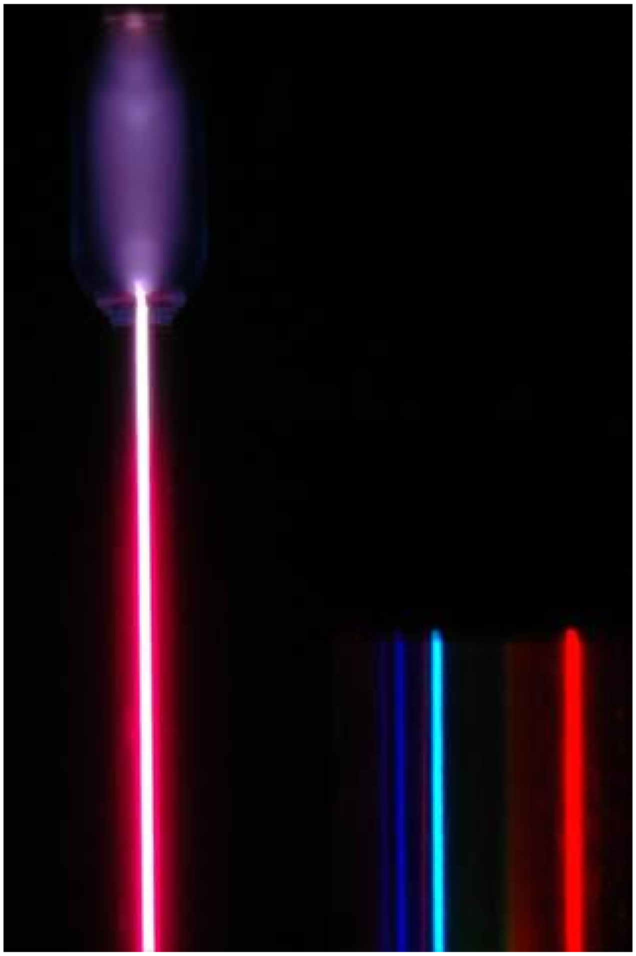
Hydrogen concepts

Atomic structure concepts

a transition from n_2 = [ ] to n_1 = [ ]

will have wavelength λ = [ ] nm

and quantum energy hν = [ ] eV



At left is a hydrogen spectral tube excited by a 5000 volt transformer. The three prominent hydrogen lines are shown at the right of the image through a 600 lines/mm diffraction grating.

An approximate classification of spectral colors:

- Violet (380-435nm)
- Blue(435-500 nm)
- Cyan (500-520 nm)
- Green (520-565 nm)
- Yellow (565- 590 nm)
- Orange (590-625 nm)
- Red (625-740 nm)

Radiation of all the types in the electromagnetic spectrum can come from the atoms of different elements. A rough classification of some of the types of radiation by wavelength is:

- Infrared > 750 nm
- Visible 400 - 750 nm
- Ultraviolet 10-400 nm
- Xrays < 10 nm

Bohr model | **Measured hydrogen spectrum** | **Other spectra**

HyperPhysics***** Quantum Physics *R Nave* Go Back

Measured Hydrogen Spectrum

The measured lines of the Balmer series of hydrogen in the nominal visible region are:

Wavelength (nm)	Relative Intensity	Transition	Color
383.5384	5	9 -> 2	Violet
388.9049	6	8 -> 2	Violet
397.0072	8	7 -> 2	Violet
410.174	15	6 -> 2	Violet
434.047	30	5 -> 2	Violet
486.133	80	4 -> 2	Bluegreen (cyan)
656.272	120	3 -> 2	Red
656.2852	180	3 -> 2	Red

The red line of deuterium is measurably different at 656.1065 (.1787 nm difference).

Illustration of transitions

Hydrogen fine structure (3->2 transition)

More extensive table of spectral lines

Index

Hydrogen concepts

Atomic spectra

HyperPhysics***** Quantum Physics

R Nave

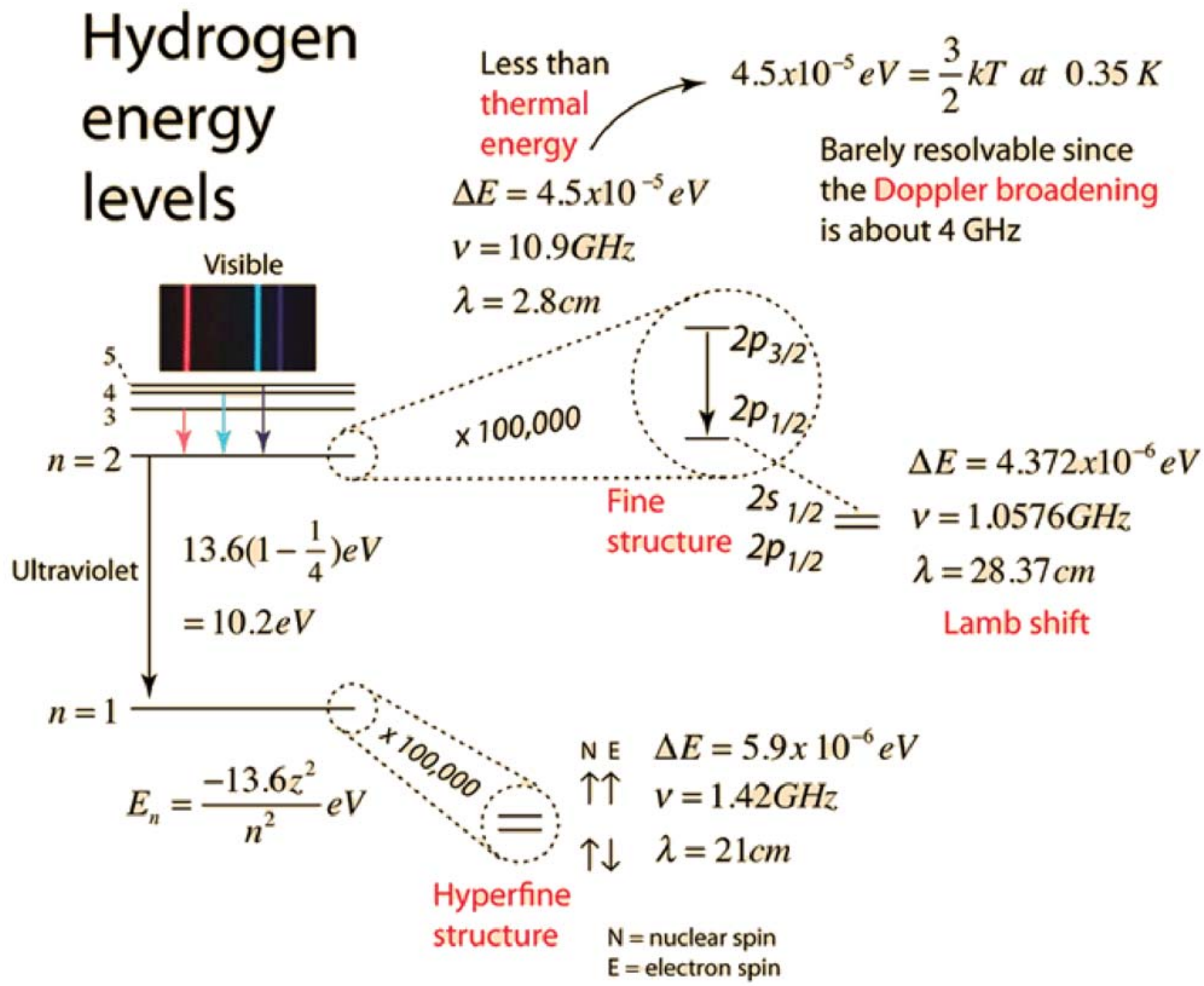
Go Back

Hydrogen Energy Levels

Index

Hydrogen concepts

Atomic spectra



Active illustration: click for more detail

Illustration of transitions