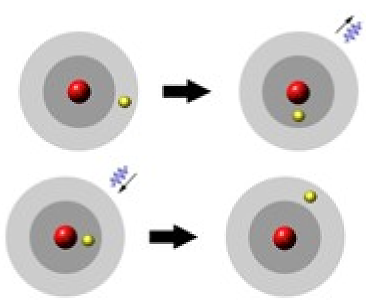
Hydrogen Is Your Friend

Ever since the Big Bang has thought to have happened about 14 billion years ago, hydrogen gas has been everywhere in the universe. Being the lightest and most abundant element, it consists of only one proton and one electron (in its most common form) and accounts for roughly 75% of all the elemental mass in the entire universe. Yes, there is a lot of hydrogen out there. Furthermore, it is the element that fuels the burning in most stars (when stars use up their hydrogen they start to use heavier elements, like helium, as their fuel).

Since hydrogen is everywhere in the universe, astronomers can use it to measure the temperature and pressure in the atmosphere of a star. This is done by using the shadow hydrogen casts. Think of a time when you were outside and it was foggy. You could still see things in front of you but the fog interfered with your view. Depending on how far an object you were looking at was from you and how much fog there was, your view would be obstructed differently (if there was more fog, your view would be obstructed more). This is generally how astronomers use hydrogen to measure the temperature and pressure in the atmosphere of a star. A star shines its light through its atmosphere which is rich in hydrogen. When the light reaches us it has been interfered with by the hydrogen. By careful analysis of how exactly hydrogen interfered with the light, the temperature and pressure of the star's atmosphere can be measured.

In every atom, the electrons orbiting around the nucleus are quantized (this is just a fancy way of saying there are specific energy levels). These energy levels exist in all atoms, but the actual energies change. However, in all cases, *the farther an electron is from the nucleus, the more energy it has*. So, if an electron wants to move to a different energy level, it needs to either lose or gain energy. This energy difference comes in the form of light. A more scientific way of saying light is by using the word "photon", which is basically a very small particle of light. In order for an electron to move to a lower energy level, it has to lose energy, meaning it emits a photon. In order for an electron to move to a higher energy level, it has to gain energy, meaning it absorbs a photon.



Hydrogen atom emitting a photon   Hydrogen atom absorbing a photon

Here there is a nice experiment that shows a hydrogen atom with one electron. By clicking in the different energy levels the electron will move, and a photon will

either be absorbed, or it will be emitted. Under the atom, the resulting emission or absorption lines will be shown (we will discuss this more later). Play around a bit and have some fun.
http://www.colorado.edu/physics/2000/quantumzone/lines2.html

We can calculate how much energy is gained or lost in an energy transition using the Planck relation:

$$\Delta E = h\nu$$

Where is the change is energy, is Planck's constant (4.13566733x10-27 eV·s), and is the frequency. The units for frequency are s^{-1}, so then energy has units of electronvolts (eV). If the electron moves to a higher energy level the change in energy will be positive, since the electron gains energy. If the electron moves to a lower energy level the change in energy will be negative, since the electron loses energy. The wavelength can then be calculated knowing that frequency, wavelength, and the speed of light ($c = 3x10^8$ m/s), are related by the equation, This gives:

$$\Delta E = \frac{hc}{\lambda}$$

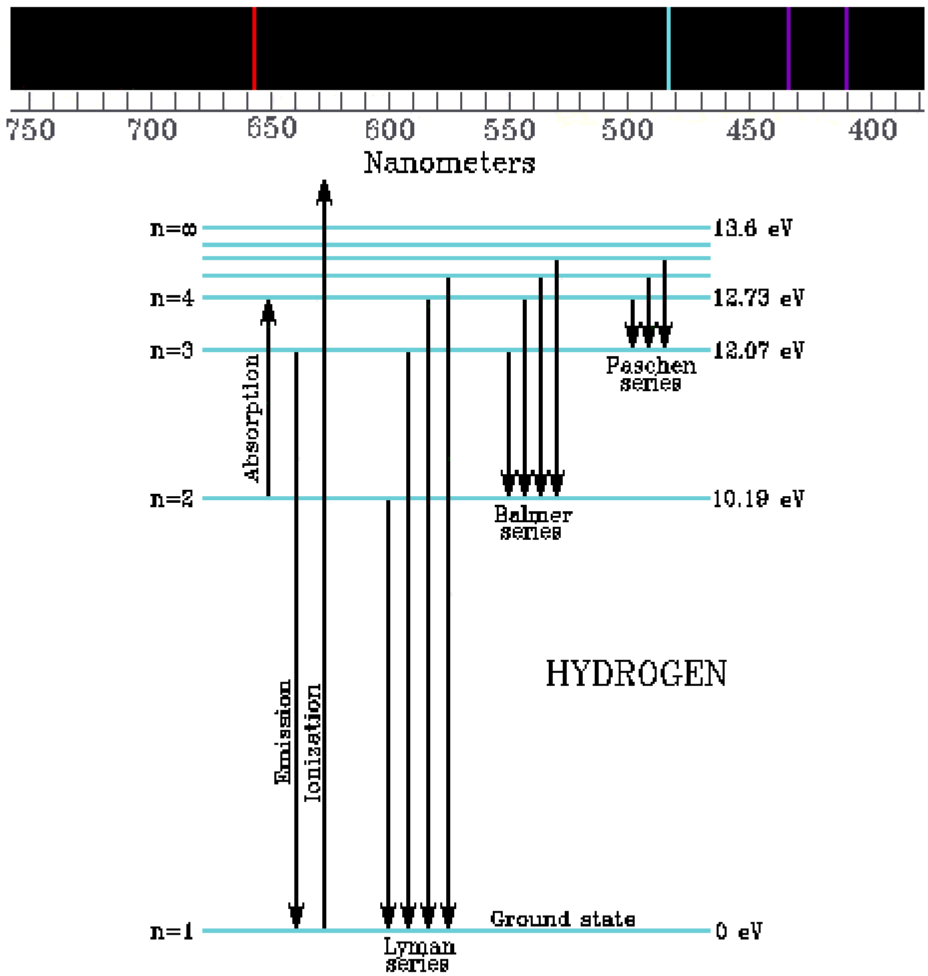
Solving for wavelength gives us:

$$\lambda = \frac{hc}{\Delta E}$$

Ignoring any numbers and focusing on units, wavelength has units of: .

Simplifying this, we find that wavelength is in meters. Since we can now calculate the change in energy from one energy level to another, let's look at the diagram below, showing the energy levels of hydrogen and all of the possible transitions between these energy levels. Neutral hydrogen (only one electron to match its one proton) emits photons with a 21.1cm wavelength. This is very helpful because there are not any other strong emission lines near the 21.1cm wavelength point, making the observer sure they are looking at hydrogen.

Side Note: Neutral hydrogen emits photons with a 21.1cm wavelength because the one electron in the atom changes from spinning parallel around the nucleus to spinning antiparallel to the nucleus.



http://www.physics.udel.edu/~watson/scen103/99s/clas0414.html

<u>Practice:</u>

1. What is the change of energy in a hydrogen atom if a photon with a wavelength of 410 nanometers (1nm = 10^{-9}m) is emitted?

2. What is the wavelength of a photon emitted by a hydrogen atom which results in an energy difference of -10.19eV?