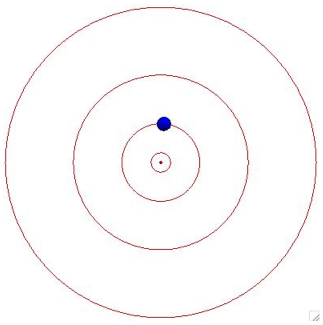
CH 27-2 Bohr Model

Important Ideas

- In the Bohr model, just as planets orbit a star, an electron attracted to a proton orbits the proton. However, unlike planet-star systems, the electron-proton system is only allowed to have certain orbits, i.e. circular orbits with certain radii and certain energies. These allowed orbits are labeled $n = 1$, $n = 2$, etc., with $n = 1$ being the lowest radius (and lowest energy) orbit.



- In the Bohr model, an electron orbits the proton in a circular orbit at a certain distance away. Only certain orbits are allowed. Those orbits are the ones where the sum of the kinetic energy of the electron, the kinetic energy of the proton, and the coulomb potential energy of the electron-proton interaction is

$$E = K + U_{elec} = \frac{-13.6 \text{ eV}}{n^2} \qquad \text{n} = 1,\ 2,\ 3,\ ... \tag{1}$$

where n is an integer that represents the energy state (i.e. the particular orbit in the Bohr model) of the atom. The lowest energy of the atom is called the *ground state*, $n = 1$.

- When a H atom gains energy, the electron moves to a higher orbit. When a H atom loses energy, the electron moves to a lower orbit. If $E < 0$ then the electron remains bound. If the atom gains enough energy so that $E > 0$, then the electron is unbound and escapes the proton. This is called *ionization.*

- Light can be modeled as a particle called the *photon.* A photon has no mass, thus it's unlike other particles, like the electron and proton, that you are familiar with. However, it still has energy and momentum. Because its mass is zero, a photon has zero rest energy (since $E_{rest} = mc^2$); therefore, all of its energy is kinetic energy. Its kinetic energy (and total energy) is

$$\begin{aligned} E_{photon} &= hf \\ E_{photon} &= \frac{hc}{\lambda} \end{aligned}$$

where f is the frequency of the photon, h is Planck's constant (6.626×10^{-34} J s or 4.136×10^{-15}eV s), and $hc = 1240$ eV $\cdot$ nm. In the wave model, light is an electromagnetic wave whose electric field and magnetic field oscillate with a frequency f. The wavelength of the wave and its frequency are related by

$$c = \lambda f \tag{2}$$

where c is the speed of light in a vacuum, 3×10^8 m/s.

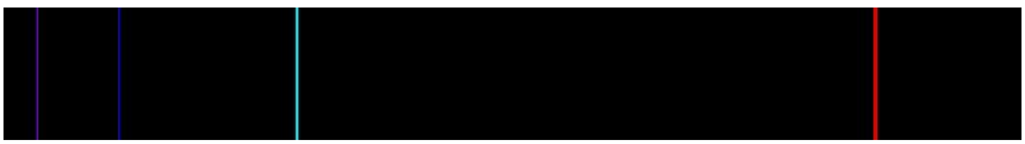
- If a continuous spectrum of light (meaning that the light contains photons of all energies) shines on atomic hydrogen gas (the atoms are not bound as molecules), then the hydrogen atoms will absorb certain photons and will increase in energy to a new energy level. The photons absorbed are the ones that correspond exactly to a change in energy between allowed energy levels.

$$|\Delta E_H| = E_{photon}$$

  If an atom in a higher energy level drops to a lower energy level, then it emits a photon equal to the change in energy of the atom. The energy of photons absorbed by the gas is equal to the energy of photons emitted by the gas. If the hydrogen atom absorbs a photon, then the atom gains energy and ΔE_H is positive. If it emits a photon, then the atom loses energy and ΔE_H is negative.

- When a gas absorbs photons, dark lines ("missing" light) appears in the spectrum.

  When a gas emits photons, bright lines appears in the spectrum.



Examples

1. What are the first 6 energy levels of Hydrogen?

2. What is the energy of the photon absorbed when the atom makes the following transitions?

Table 1: Atomic Transitions

n_1	n_f	$\|\Delta E\|$ (eV)	f (Hz)	λ (nm)	region
1	2				
1	3				
2	3				
2	4				
2	5				
2	6				
3	4				
3	5				
3	6				

If the atom transitions from a higher state to a lower state in each of the cases above (such as from $n = 2$ to $n = 1$), how would it change your answers?

3. For each of the transitions in the previous table calculate the frequency, and wavelength of the photon emitted or absorbed.

4. For each of the transitions in the previous table indicate the region of the emitted or absorbed photon.

5. Suppose you had a collection of a large number of hypothetical atoms, each of whose individual energy levels were -4.1 eV, -2.5 eV, -1.7 eV, and -0.9 eV. If nearly all of these identical objects were in the ground state, what would be the energies of dark spectral lines in an absorption spectrum if visible white light (1.8 to 3.1 eV) passes through the gas?

6. For the gas in the previous question, if the atoms are excited so that some atoms are in each of the energy states, what are the energies of the emitted photons?

7. The energy levels of a particular atom are -9.9 eV, -4.8 eV, and -2.8 eV. If a collection of these atoms is bombarded by an electron beam so that there are some objects in each excited state, what are the energies of the photons that will be emitted?

8. A certain material is kept at very low temperature. It is observed that when photons with energies between 0.2 and 0.9 eV strike the material, only photons of 0.4 eV and 0.7 eV are absorbed. Next the material is warmed up so that it starts to emit photons. When it has been warmed up enough that 0.7 eV photons begin to be emitted, what other photon energies are also observed to be emitted by the material? Explain briefly.

9. Suppose we have reason to suspect that a certain quantum object has only three quantum states. When we excite such an object we observe that it emits electromagnetic radiation of three different energies: 2.48 eV (green), 1.91 eV (orange), and 0.57 eV (infrared). (a) Propose two possible energy-level schemes for this system. (b) Explain how to use an absorption measurement to distinguish between the two proposed schemes.