Atoms, Molecules, Photons and Energy Conversion

To capture the energy of the sun is to convert the energy of each photon directly into useful work or into chemical energy. To explore this concept, it is worthwhile to consider the interaction of photons with individual atoms and molecules.

Photons and the Hydrogen Atom

The hydrogen atom interacts with photons in much the same way as an isolated atom of any element. When a photon is absorbed by an atom, the energy of the photon is transferred to the electron within the atom. Given the fact that there are discrete energy levels for the electron within the atom, the only photons which can be absorbed are those with energies exactly matching the energy differences between any two states of the atom. Thus, very little of the continuous spectrum of electromagnetic radiation from a hot source, such as the sun, can be absorbed by an atom.

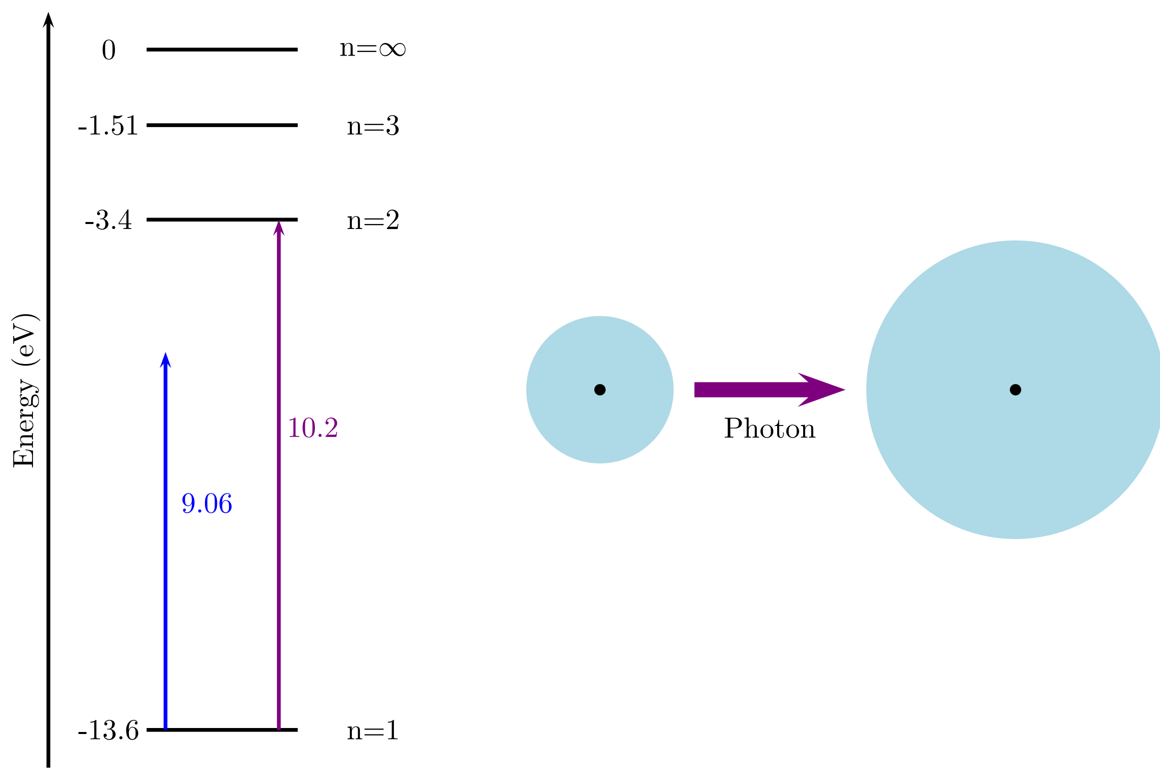

Figure 1: Hydrogen atom spectrum and depiction of the excited atom. On the left is a partial spectrum of the hydrogen atom. Of the two photons depicted, only the 10.2 eV photon can be absorbed. The consequence of this excitation is depicted on the right as an increase the effective diameter of the atom. The blue area is the region of space in which the electron is most likely to be found.

When an H atom is subjected to ultraviolet light of energy 10.2 eV, it will be excited from the ground state $n = 1$ to the first excited state $n = 2$, as depicted in Figure 1. Though the average distance of the electron from the nucleus increases, the electron is still bound to the positively charged proton. The electron can return to the ground state by emitting another 10.2 eV photon or dissipating this energy as heat to the surroundings. There is no way to insert wires to try to convert the energy of the $n = 2$ state into useful electrical work.

Ionization and atom or molecule requires an energetic photon beyond the visual range (13.6 eV for hydrogen), so little of the solar spectrum can be used. However, the ionization does lead to separation of the the positive (p^+) and negative (e^-) charges. Though liberated electrons can now be directed through an electrical load, as shown in Figure 2, there is no segregation of the positive and negative charges into different regions of space. A wire will encounter as many positive as negative charges in an ionized gas. Thus, no electrical energy can be extracted.

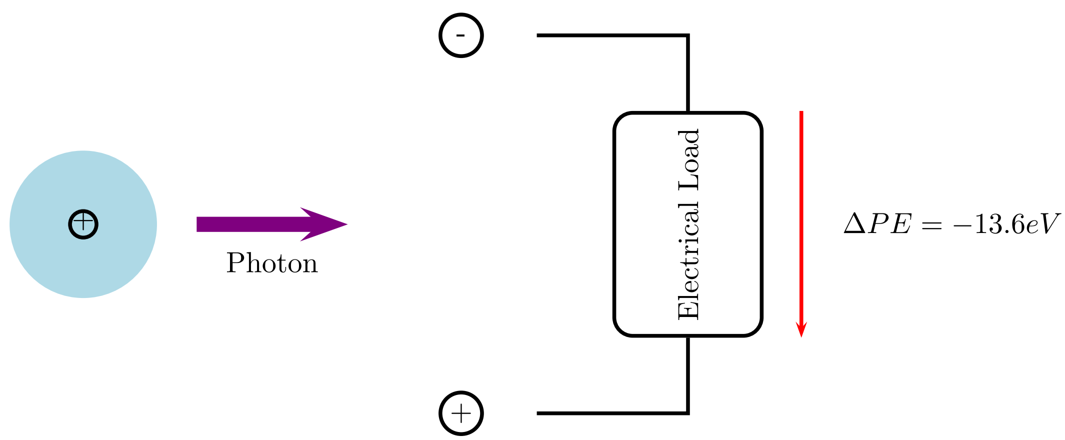

Figure 2: Ionization of a hydrogen atom with an energetic photon (13.6 eV) results in separation of the charges. Passage of the electron through an external circuit would yield 13.6 eV of electrical work.

To use more of the solar spectrum and create directionality for created charges, a molecular charge transfer pair can be used. The two molecules need to be very close to each other. When one molecule absorbs a photon, the state of the two-molecule system is described as an excited A and a ground state B, or A^*B. This state is of higher energy than the state A^+B^-, so an electron will be quickly transferred from A to B. Now, since A^+B^- is a state of higher energy than the double ground state AB, the energy difference can be tapped if the electron is directed through an external circuit back to the A^+ ion. This must happen before the electron jumps directly back to the nearby A^+. This is depicted in Figure 3.

One could image bonding A and B molecules to different but closely spaced wires ($\approx 1nm$). But since this is difficult to accomplish and the system would have to be sealed in a clean environment, this concept does not seem practical. It would be better to search for a system which automatically assembled itself into an ordered structure with the required electrical conductivity and the prospect for the required directionality.

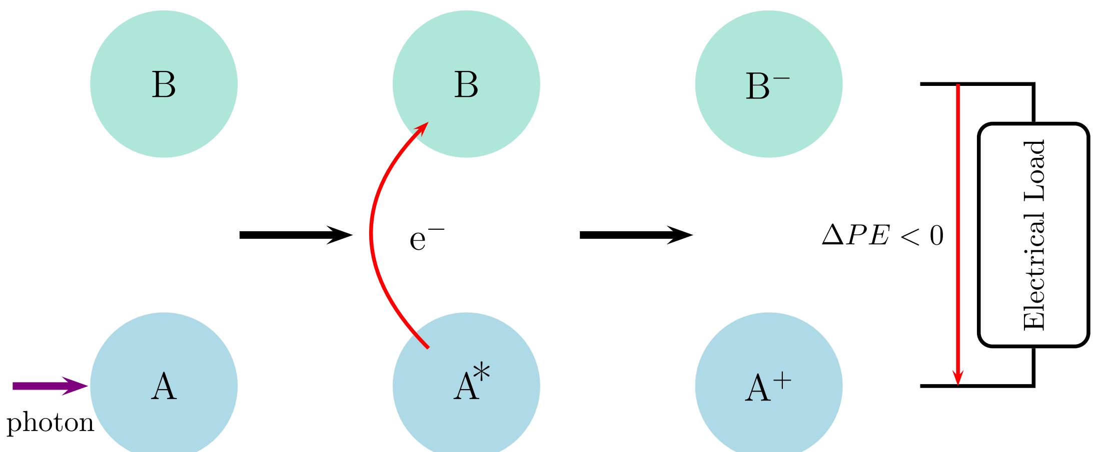

Figure 3: Molecular charge transfer can be used to separate charges and deliver them to an external circuit.