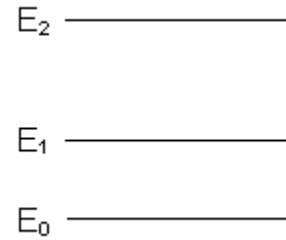


Absorbing and emitting photons

A quantum system (a molecule) has the energy levels shown in the diagram at the right. The energies are as follows:

- $E_0 = 1.1 \text{ eV}$
- $E_1 = 1.8 \text{ eV}$
- $E_2 = 3.2 \text{ eV}$



We begin with a large number of these molecules in their ground states.

- A. We want to raise a lot of these molecules to the state labeled E_2 by shining light on it. What wavelength of light should we use?
- B. If we expose our molecules to a continuous spectrum of light, photons of particular energies might be absorbed. What energy photons would you expect to absorb? Explain.
- C. If we manage to successfully excite a number of the molecules to the state E_2 , they can decay by emitting photons. What energy photons might you expect to see? Explain.

A. $2.1 \text{ eV} = hc/\lambda$ $\lambda = hc/2.1\text{eV} = \mathbf{5.9 \times 10^{-7} \text{ m}}$

B. $n=0$ to $n=2$ **0.7 eV**, $n=1$ to $n=2$ **1.4 eV**, and $n=0$ to $n=2$ **2.1 eV**

C. $n=2$ to $n=0$: **2.1 eV** or $n=2$ to $n=1$: **1.4 eV** and $n=1$ to $n=0$ **0.7 eV** If electrons are in the $n=2$ state of 3.2 eV they could relax directly to $n=0$ or all use a two step process of $n=1$ then $n=0$.

Jellyfish glow

The jellyfish *Aequorea Victoria* creates a protein (GFP) that, when illuminated with blue light ($\lambda = 395 \text{ nm}$) emits green light ($\lambda = 508 \text{ nm}$) The gene for producing GFP is known and can be inserted into any cell and attached to the gene that creates any other protein we might be interested in. So when the cell builds the protein of interest, it attaches a GFP "tag" to it. The protein of interest can then be tracked in the living cell. One way this conversion of frequencies could work is the following:

- a. **The blue light is less energetic than the green light.** *Not true* The blue photon scatters off a protein and extracts energy from it, coming out green.
- b. **The blue light is more energetic than the green light. The blue photon is absorbed by the protein, which then goes into a highly excited state. It decays back to the ground state in two stages, going through an intermediate excited state and emitting two photons of smaller energy, one of which is green.**
- c. The protein acts as a prism, changing the wavelength of the blue light as it moves through the protein, stretching it into green light. *This is crazy not true since prisms do not change the color of light!!! They simply break white light into its constituent colors.*

- d. The energy is not the relevant quantity. The blue light has a higher frequency than the green light. The blue light sets some of the electrons in the protein oscillating at a high frequency. The lower frequency is excited in conjunction with it in the way that a crystal goblet, rung by a pure tone, vibrates with other associated tones. *Interesting logic but also not true. They don't explain how an oscillating electron makes a green photon.*
- e. None of the above.