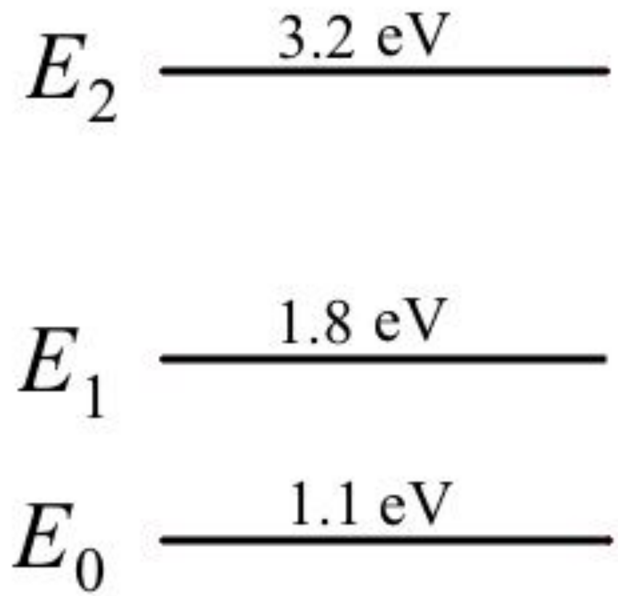
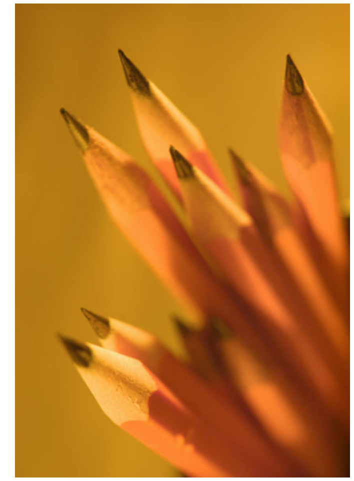
A molecule has the energy levels shown in the diagram at the right. We begin with a large number of these molecules in their ground states. We want to raise a lot of these molecules to the state labeled E_2 by shining light on it. What energy photon should we use?

A. 0.7 eV
B. 1.1 eV
C. 1.4 eV
D. 1.8 eV
E. 2.1 eV
F. 3.2 eV
G. Something else



What is the wavelength of the light?



$$E = hf$$

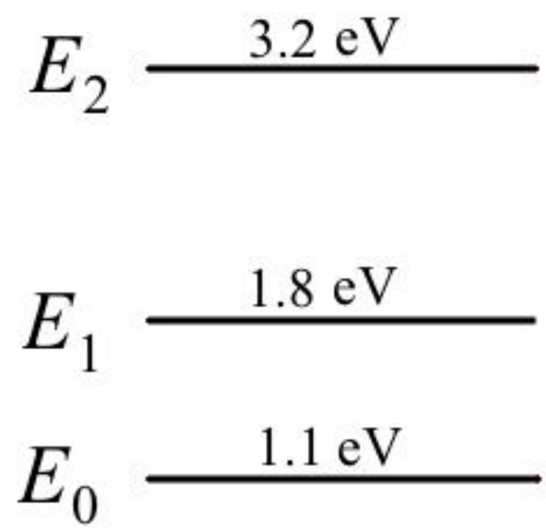
$$f\lambda = c$$

$$hc = 1234 \text{ eV-nm}$$

$$c = 3 \times 10^8 \text{ m/s}$$

A molecule has the energy levels shown in the diagram at the right. We have a large number of these molecules in the state E_2. The state decays by emitting photons. What might we expect about the wavelength of the emitted photons?

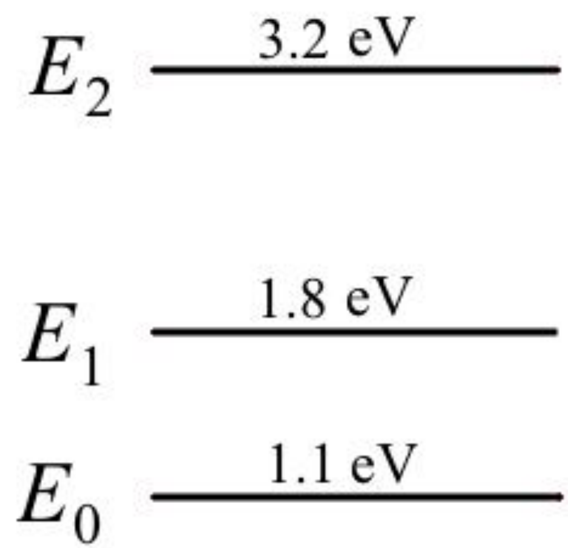
A. They will be the same as the wavelength of the photons that were used to pump the molecules up to state E_2.
B. Some might be the same wavelength, but some might be shorter.
C. Some might be the same wavelength, but some might be longer.
D. You only expect to see shorter wavelengths.
E. You only expect to see longer wavelengths.
F. You will see longer, shorter, and the same wavelengths.



A molecule has the energy levels shown in the diagram at the right. We have a large number of these molecules in the state E_2. The state decays by emitting photons. What energy photons might we expect to see?

A. 0.7 eV
B. 1.1 eV
C. 1.4 eV
D. 1.8 eV
E. 2.1 eV
F. 3.2 eV

1. B D F
2. B D
3. C
4. C E
5. A C E
6. Some other set



In the transitions you found in the last slide, which energy corresponds to the longest wavelength? (and what is it)

A. 0.7 eV
B. 1.4 eV
C. 2.1 eV

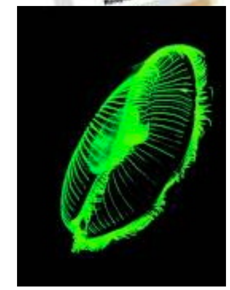
$$E = hf$$

$$f\lambda = c$$

$$hc = 1234 \text{ eV-nm}$$

$$c = 3 \times 10^{8} \text{ m/s}$$

The jellyfish *Aequorea Victoria* creates a protein (GFP) that, when illuminated with blue light (λ = 395 nm) emits green light (λ = 508 nm). One way this conversion of frequencies could work is the following:



A. The blue light is less energetic than the green light. 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.

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.

E. None of the above.

When high energy electrons are incident on a tungsten target, a broad spectrum of x-rays are given off. Most of the x-ray photons are spread over a range of energies, but there are a large number of x-rays with a specific energy -about 60 keV. This sharp x-ray line arises because:

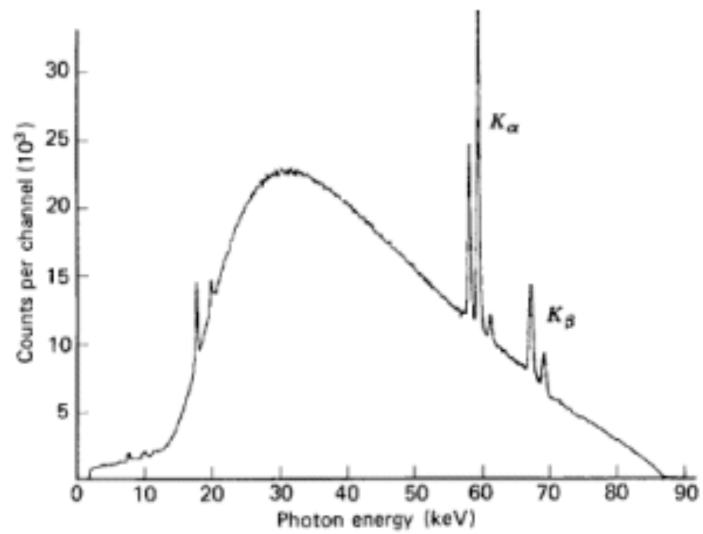
A. An electron bounces off a tungsten atom and since accelerating a charge leads to radiation, it gives off an x-ray when it does so.

B. An electron excites a tungsten atom into a particular excited state and it gives off a particular x-ray when it returns to its original state.

C. An electron slows via many collisions with electrons in many tungsten atoms. The combined effect of these collisions leads to the sharp x-ray line.

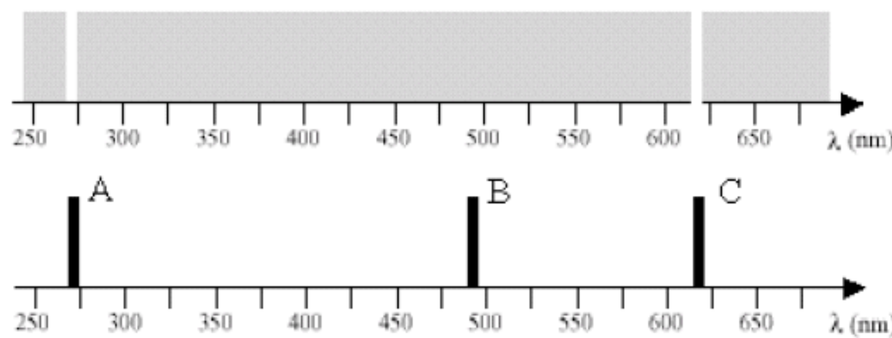
D. An electron is absorbed by a nucleus of tungsten and converted into energy.

E. None of the above.



The spectrum from a tungsten target x-ray tube operated at 87 kVp.

Observations of an interstellar gas give an absorption spectrum, part of which is shown in the upper part of the figure. The gas is cold, such that when not excited, all electrons are in the ground state. Astronomers suspect the gas to be helium, but aren't sure. When they excite a sample of helium in the laboratory, they observe an emission spectrum, shown in the lower part of the figure below.



Max says "line B cannot come from the same gas, or we would see it in the absorption spectrum. It must be from some other gas." Werner says, "I think that the same substance is responsible for all 5 lines.”

Who do you agree with?

A. Max
B. Werner
C. Both
D. Neither