In the stilbene *photoisomerization* paper on the website handouts page refer to Figure 3.

(a) How does the wavelength and timing of fluorescence depend on IVR?
(b) Which rate is faster: $k_{IVR}$ or $k_{ISO}$?
(c) In these experiments with sub-picosecond laser pulses, does one need to take into account possible effects due to rotation of the molecules?

On Planet X, photosynthetic plants absorb 300 nm light. The energy is used to drive a light reaction in which each photon potentially creates a single charge separated state. The quantum yield of this light reaction is some number $Q$.

Following this light reaction, a dark reaction then uses six charge separated states to reduce a single CO$_2$ molecule. The energy cost of reducing CO$_2$ is 480 kJ/mol. The energy efficiency for this overall photosynthetic process is 49%. What is the light reaction quantum yield $Q$?

A chemist has tagged a polymer with three different fluorescent moieties and is trying to understand the polymer’s folding behavior by using FRET. The substituted chromophores are simply called Red, Green and Blue. The absorption/emission spectra of the three chemicals are shown below, with the blue spectra representing the absorption profile, and the red one indicating emission.

The chemist excites her sample with three different colors and then measures the resulting fluorescence. The figure below on the right illustrates five different possible conformers of the polymer. Some conformers will result in certain fluorescent bands appearing when irradiated with specific colors of light. Put a check mark in each box that corresponds to a fluorescent signal. Leave all other boxes blank. Assume that the resonant transfer has a range of approximately 2 residue diameters and is an all-or-nothing affair (i.e. you either get 100% percent transfer of all available energy or none at all). There are no secondary transfer effects (i.e. energy resonantly transferred from one moiety to another cannot then be transferred to yet another moiety).
Consider the following abstract. Provide an explanation of the observations with a detailed energy level diagram and 1 or 2 paragraphs of text. (You may find more detail in the article itself, if needed).

Photophysics of protoporphyrin ions in vacuo: Triplet-state lifetimes and quantum yields

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Lifetimes of triplet-state molecules and triplet quantum yields are important parameters in photobiology as they determine the generation of singlet-oxygen upon irradiation with visible light. Here we report lifetimes of protoporphyrin IX (pp) in vacuo measured in an ion storage ring. We find that after 532 nm photon absorption pp(-) (free base and negatively charged carboxylate) and pp(+) (single protonation of ring nitrogen) have triplet-state lifetimes of 12 and 6 ms, respectively. After 415 or 390 nm absorption the lifetime of the anion is shorter (1.5 and 0.6 ms) as expected from the increase in temperature. Triplet quantum yields of pp(-) and pp(+) are similar, 0.6-0.7, close to values reported for the free base and monocation in solution. The other channel, direct decay to the electronic ground state and subsequent dissociation of vibrationally excited ions, is much faster than triplet-singlet intersystem crossing. We measured lifetimes of 63 mus, 96 mus, and 0.3 ms after 390, 415, and 532 nm excitation, respectively. A fit of a statistical model to the pp- decay results in an Arrhenius activation energy of 0.5 +/- 0.2 eV for CO2 loss and a low preexponential factor (10(6)-10(1) s(-)1), indicative of an entropic barrier.
A ray of 500 nm vertically polarized light passes through a block of optically active material that is exactly 1 cm long. The indices of refraction in the material for left- and right-circularized polarized light are $n_L = 1$ and $n_R = 1.5$

a) What are the frequencies for the left- and right-circularly polarized components of the ray? (e.g. how many times do they complete a full circle per second?).

b) How many periods will the left-handed light complete while traveling through the block? How many periods will the right-handed light complete? Remember that $n = \frac{c}{v}$, where $n$ the index of refraction, $c$ is the speed of light in a vacuum, and $v$ is the speed of light in the material. Also remember that a given photon’s frequency remains constant, even when its velocity has been altered.

c) What will the polarization of the beam be after it exits the block? Answer in degrees relative to the vertical, with positive numbers indicating a clockwise slant when viewing the beam as it travels towards the observer:

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This would be called +45°
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This would be called -45°
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d) Now, a ray of 500 nm vertically polarized light passes through a 1 cm block of circularly dichroic material. The indices of refraction are equal for both left- and right-circularly polarized light. It turns out that the block absorbs half of the left-circularly polarized light but none of the right-handed light. The resulting exit beam is therefore elliptically polarized. What is the ratio of that ellipse’s major axis vs its semi-major axis?

e) What will be the orientation of that ellipse’s major axis? Use the same convention used in part c.
The diagram below depicts the potential energies for the O₂ molecule.

(a) Sketch which transitions you expect and sketch the spectrum you expect in the visible and/or the UV.

(b) Discuss in one paragraph (150 words max) the implications of these potentials for atmospheric chemistry.