Homework 2 Key

1. Photosynthetic organisms including green plants have proteins containing pigments which absorb light. The light energy is eventually converted in chemical bond energy. Using the spectra below, determine the following properties for chlorophyll b at its peak absorbance:

a. (10 points) Wavelength in nm units.

The peak absorbance is 442 nm by measuring on the spectrum.

b. (10 points) Wavenumber in cm^{-1} units.

The peak absorbance is $\frac{1}{442\times10^{-7}(cm)} = 2.26\times10^{4}(cm^{-1})$.

c. (10 points) Energy in kJ/mol units.

$$E = N_A h\nu = N_A h\frac{c}{\lambda} = 6.02\times10^{23}(mol^{-1})\times6.63\times10^{-34}(J\cdot s)\times\frac{3\times10^{8}(m\cdot s^{-1})}{442\times10^{-9}(m)} = 2.71\times10^{2}(kJ\cdot mol^{-1})$$

d. (10 points) Temperature in K units.

$$T = \frac{E}{N_A\cdot k} = \frac{2.71\times10^{5}(J\cdot mol^{-1})}{6.02\times10^{23}(mol^{-1})\times1.38\times10^{-23}(J\cdot K^{-1})} = 3.26\times10^{4}(K)$$

e. (10 points) Green plants have high concentrations of phycoerythin and phycocyanin pigments in their leaves. In a few sentences provide a hypothesis for why this could be advantageous to the plant.

The solar radiation spectra has its peak intensity at around 500-600 nm. These two pigments can absorb energy with wavelength in this range, and the energy can be used for the plant to produce sugar from CO_2.

2. The chemical reaction driven by photosynthesis is:

$$2\ NADP^{+} + 2\ H_2O \rightarrow 2\ NADPH + O_2 + 2H^{+}$$

$NADP^{+}$ is nicotinamide adenine dinucleotide phosphate and NADPH is the reduced form of NADPH.

a. (15 points) For this reaction, ΔG = 438 kJ/mol. Determine the minimum number of 540 nm photons which must be absorbed to drive formation of one molecule of O_2.

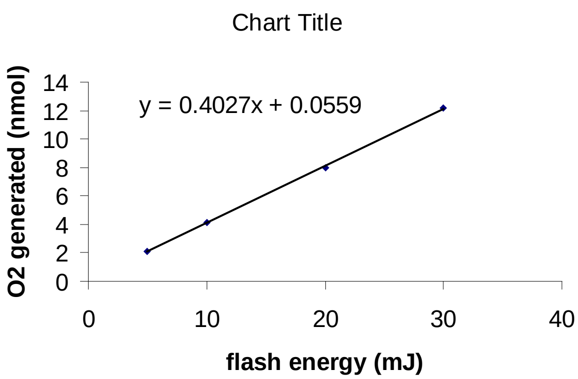
The energy of 540 nm photon in unit of kJ/mol is

$$E = N_A h\nu = N_A h\frac{c}{\lambda} = 6.02\times10^{23}(mol^{-1})\times 6.63\times10^{-34}(J\cdot s)\times\frac{3\times10^{8}(m\cdot s^{-1})}{540\times10^{-9}(m)} = 2.22\times10^{2}(kJ\cdot mol^{-1})$$

Assume all the absorbed energy is used to drive the formation of O_2, the number of photons needed for producing one molecule of O_2 is $\frac{438kJ\cdot mol^{-1}}{222kJ\cdot mol^{-1}} \approx 2$.

b. (15 points) In the 1930s-1960s, experiments were done in which green alga were exposed to flashes of light of different energies and mol O_2 was measured. Using the data below and linear least-squares fitting, determine the experimental number of 540 nm photons required to generate one molecule of O_2.

Flash energy (millijoule)	O_2 generated (nanomol)
5	2.1
10	4.1
20	8.0
30	12.2



According to the fitting equation, the energy needed to produce 1 mol O_2 is

$$\frac{10^{9}-0.0559}{0.4027} = 2.48\times10^{9}(mJ/mol) = 2480(kJ/mol)$$

Thus, the number of 540 nm photons is $\frac{2480kJ\cdot mol^{-1}}{222kJ\cdot mol^{-1}} \approx 12$

c. (10 points) Calculate the fraction of photon energy which is used for O_2 generation.

The fraction of energy used for O_2 generation is $\frac{2}{12}\times100\% = 16.7\%$

d. (10 points) In one or a few sentences, provide a hypothesis for the fate of the energy which is not used for O_2 generation.

The energy may turn into heat, for example, when the green plants absorb energy from the sun, the body temperature of these plants will increase.