1. Calculate the energy efficiency of cyclic and non-cyclic photosynthesis using 680nm light under standard conditions. Consider NADPH to have the equivalent “cost” of 2.5 ATP. What would the efficiency be with 500 nm light?

**Non cyclic:**

\[ E = \frac{hc}{\lambda}, \text{ for } 680\text{nm} 1 \text{ mole (Einstein)} = -42 \text{ kcal/mol} \]

8 photons yields (see pg 556) 2 NADPH and 3 ATP ∼ (2.5 *2) +3ATP = 8 ATP “equivalents” * -7.3 kcal/mol = 58.4 kcal/mol to synthesize. 8 mol photons * -42 kcal/mol = -336 kcal. And 58.4/336 * 100% = 17% efficiency

\[ E = \frac{hc}{\lambda}, \text{ for } 500\text{nm} 1 \text{ mole (Einstein)} = -57.2 \text{ kcal/mol} * 8 = -457.6 \text{ kcal} \text{ so } 58.4/457.6 * 100% = 12.8 \% \text{ efficiency} \]

**Cyclic:**

4 photons yields (see pg 557) 2 ATP
for 680nm, 4 * -42 kcal/mol = -168 kcal/mol
2* (7.3)/-168 * 100% = 8.7% efficiency.

4 photons yields (see pg 557) 2 ATP
for 500 nm, 4 * -57.2 kcal/mol = -229 kcal/mol
2* (7.3)/-229 * 100% = 6.4% efficiency

**So even though the book says cyclic is “somewhat more productive” it is not unless you assume it is “free” to produce NADPH!**

Under actual cell physiological conditions, the ΔG’ for ATP hydrolysis is about -12 kcal/mol. What would the efficiencies be under real conditions?

8 ATP “equivalents” * -12 kcal/mol = 96 kcal/mol to synthesize
And 96/336 * 100% = 29% efficiency

96/457.6 * 100% = 21% efficiency

**Cyclic:**

4 photons yields (see pg 557) 2 ATP
for 680nm, 4 * -42 kcal/mol = -168 kcal/mol
2* (12)/-168 * 100% = 14.2% efficiency.

4 photons yields (see pg 557) 2 ATP
for 500 nm, 4 * -57.2 kcal/mol = -229 kcal/mol
2* (12)/-229 * 100% = 10.5% efficiency
2. What is the minimum pH gradient necessary to synthesize ATP in the chloroplast? Assume 4 H+/ATP, \( \Delta \Psi = 0 \) mV, \( T = 25 \) C and the “real” physiological conditions for ATP synthesis above in #1.

\[
\Delta G = 2.3 \times R \times T \times (pH_{\text{thylakoid}} - pH_{\text{stroma}}) + F \times \Delta \Psi_{\text{out relative to in}}
\]

\[
\Delta G = -12 = 2.3 \times 0.00199 \times 298 \times x
\]

\[
-12 / 1.36 = x = 8.8 = \Delta pH \text{ for 1 H+}. \text{ So } 8.8/4 = 2.2 = \text{minimum } \Delta pH \text{ for 4 H+/ATP under cellular conditions} \text{(-12 kcal/mol)}
\]

3. Although animals cannot show a net synthesis of glucose from acetyl CoA, if a rat is fed 14C acetate some label will appear in glycogen extracted from the muscle. Explain and diagram the metabolic pathways involved.

\[
\text{Acetate} \rightarrow \text{acetyl CoA} \rightarrow \text{TCA} \rightarrow \ \*\text{Oxaloacetate (labeled in all carbons)} \rightarrow
\]

\[
\text{PEP} \rightarrow \rightarrow \text{Glucose-6-phosphate} \leftrightarrow \text{Glucose-1-Phosphate} \rightarrow \text{UDP-Glucose} \rightarrow \text{glycogen}
\]