Lecture 23: Photochemical Energy Conversion

Photosynthesis

Photosynthesis is the light-driven conversion of solar energy into chemical potential energy.

Photosynthesis: $CO_2 + 2H_2O + h\nu \rightarrow [CH_2O] + O_2 + H_2O$

Products contain ΔH more energy than reactants

Combustion: $[CH_2O] + O_2 \rightarrow CO_2 + H_2O + \text{heat}$

ΔH released as heat of combustion

ΔH = 4.8 eV per C atom 'fixed' into carbohydrate

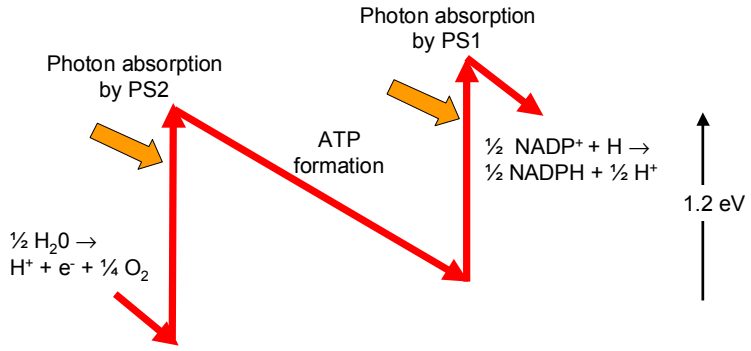
[CH2O] represents one unit of a complex carbohydrate. *e.g.* for glucose:
$6CO_2 + 12H_2O + h\nu \rightarrow C_6H_{12}O_6 + 6O_2 + 6H_2O$, ΔH = 28.8 eV per glucose molecule.

Energy density in dry biomass: typically 15 – 20 MJ kg^{-1}

Photosynthetic Z scheme for the light reactions: (figure)

Process completed in dark reaction (Reducing agent 2×NADPH converts CO2 to CH_2O)

Require 4 × PS1 + 4 × PS2 photons to fix one C atom into carbohydrate



Efficiency of photosynthesis:

Initial photosynthetic reaction: $\eta = \dfrac{\Delta H \text{ gained}}{\sum \text{photon E absorbed}} \approx 33\%$

In plants under solar irradiation: $\eta = \dfrac{\Delta H \text{ gained / area / time}}{\text{Average solar irradiance}}$. Typically 1-2%.

Solar Fuels:

Solid biomass impractical as fuel. Convert to liquids *e.g.* ethanol or gases *e.g.* methane for ease of transport and higher E density.

Examples:
- Production of ethanol from sugarcane [$C_{12}H_{22}O_{11}$ + **1** $H_2O \rightarrow$ **4** C_2H_5OH + **4** CO_2]. Economically viable as automotive fuel
- Production of biogas (methane + CO_2) from waste carbohydrate in sewage or landfill waste using anaerobic fermentation. Low temperature, low cost process.