Effect of Visible and Near-Infrared Light on Adenosine Triphosphate (ATP)

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ABBREVIATIONS AND SYMBOLS

ADP, Adenosine diphosphate.

AMP, Adenosine monophosphate.

ATP, Adenosine triphosphate.

β-NADPH, Beta-nicotine amine dinucleotide phosphate (reduced form).

C, coulomb, unit of electric charge.

c, *celeritas*, speed of the light in the vacuum (2.99792457×10^{8} m/s).

E, intensity of the electric field.

e, elementary charge of the electron (1.60210×10^{-19} C).

EM, electromagnetic.

ε, *epsilon*, permittivity (electric constant) of a medium.

ε_0, permittivity of the vacuum (8.854×10^{-12} F/m).

F, faraday, unit of electric charge quantity (96,500 coulomb = 1 faraday).

G6PDH, glucose 6 phosphate dehydrogenase.

h, Planck's constant (6.6256 x 10^{-34} Joules. second).

IR, infrared

J/cm^2, joules per square centimeter (radiant exposure units).

k, constant of the light -luminescence- decay (in the Luciferine-luciferase reaction).

k, restoring-force constant acting on bound electrons (after a polarization of a medium due to electromagnetic fields).

k_m, Michaelis constant of a Michaelis-Menten enzymatic reaction.

λ, *lambda*, wavelength of electromagnetic waves (light).

μ, *mu*, permeability (magnetic constant) of a medium.

N, number of displaced electrons in a chemical bond by an electrical field.

n, refractive index of a medium.

ν, *nu*, frequency of electromagnetic waves (light).

P, macroscopic polarization of a medium due to an electrical field.

π, *pi*, the ratio of the circumference to the diameter of a circle ($\pi \approx 3.1416$).

RI, refractive index of a medium.

UV, ultraviolet.

V, volt, unit of electric potential.

v, velocity of electromagnetic waves (light) in a medium.

$\mathbf{v_{max}}$, maximum velocity of a Michaelis-Menten enzymatic reaction.

$\mathbf{V_0}$, peak voltage of the luminescent signal in the Luciferine-luciferase reaction.

V(t), exponential function (voltage vs. time) of the luminescent signal (Luciferine-luciferase reaction).

ω, *omega*, angular frequency of electromagnetic waves (light).

$\boldsymbol{\omega_0}$, resonance angular frequency of electromagnetic waves (light).

ABSTRACT

ATP is a key molecule in cellular metabolism. In this thesis, I examined the effects of visible (635 and 655 nm) and near-infrared (810 and 830 nm) light on ATP in solution. I also examined were the biochemical behavior of light-exposed ATP in the luciferine-luciferase reaction and hexokinase reaction, the initial step in glycolysis that begins extra mithocondrial ATP synthesis. Irradiated groups in the luciferine-luciferase reaction showed an improvement in the kinetic parameters V_0 and k, and more ATP molecules reacted with the enzyme when they were excited by light. When irradiated ATP was added to the hexokinase reaction, the experimental groups showed significant differences in the Michaelis-Menten kinetic parameters (k_m for ATP and v_{max}) and the rate of product synthesis was greater. Changes in both reactions were wavelength and dose dependant.

When ATP was excited with UV photons, it fluoresced. This fluorescence decreased when Mg^{2+} was added, probably because the ion binds the phosphates, which are the part of the molecule responsible for light emission. Irradiating the ATP-Mg^{2+} solution with 655 nm and 830 nm light increased the fluorescence resulting from a displacement of charges in the phosphor-oxygen bond that repels Mg^{2+}.

The refraction of light in an ATP solution was observed by the Michelson interferometer and by directly measuring the refractive index. The refractive index changed after red and near-infrared light interaction due to a change in the electrical permittivity of the medium.

Since ATP in water is transparent to visible and near-infrared light, and is therefore not a chromophore for those wavelengths, I conclude that the observed light interaction with ATP is not due to photon absorption but to the electromagnetic disturbance produced by the light, which leads to a polarization of the dielectric molecule that is ATP.

This interaction of visible and near-infrared electromagnetic energy with ATP offers new perspectives for explaining light interaction at subcellular level.