

Förster energy transfer

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Signature: Carmeljcaruana (talk)

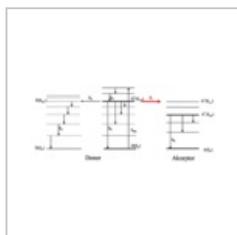
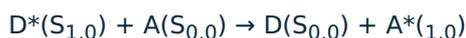


OK - BUT I WONDER WHETHER YOU UNDERSTOOD WHAT YOU WROTE

Introduction

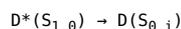
Lots of molecules can be brought in an electronic excited state by absorbing a photon. If the emission of that photon then occurs in a singlet state, we can describe it as fluorescence. Under certain circumstances the energy of an excited molecule can be transferred to another molecule without radiation, known as Förster resonance energy transfer.

The Förster resonance energy transfer happens between two molecules that we can define as acceptor (A) chromophore and donor (D) chromophore. Let's assume the following: an excited (*) D chromophore molecule in the first excited singlet state ($S_{1,0}$) is in a distance (r) of an A molecule ($S_{0,0}$) that is in an electronic ground state. Both can not move from their position, they are embedded in a fixed matrix. The energy between the two molecular systems ($D \rightarrow A$) is being transferred in a nonradiation process through dipole-dipole coupling:



Depiction of the electronic excitation (k_{abs}) of a donor molecule and its deactivations via fluorescence (k_{fl}), inner transformation (k_{ic}) with following nonradiative deactivation (k_{nr}) and the energy transmission (k_t) to an acceptor molecule.

The transmissions



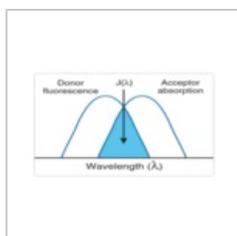
correspond to the transmissions of the excited donor molecule in the different oscillation states of the electronic ground state and reflect the fluorescent spectrum Ψ^D of the donor molecule.

The transmission



corresponds to the transmission of the acceptor molecule A in the different oscillation states of the first excited $S_{1,0}$ state and thus, corresponds to the absorption spectrum $A \epsilon$ of the acceptor molecule.

This emphasizes that the energy transfer is only possible, if the absorption spectrum of the acceptor with the emission spectrum of the donor overlaps. This spectral overlap is defined as $J(\lambda)$.



The main part of the electronic interaction is being given by the dipole-dipole coupling. It represents the interaction of the transfer-dipole μ^D of the emission of the donator molecule and the transfer-dipole μ^A of the absorption of the acceptor molecule. The transition rate of the energy transmission can be derived by using the following equation:

k^2 = relative orientation between the dipoles of the molecules Q_D = photon effect of the donor, if there are no acceptor molecules n = refraction index N_A = avogadro constant r = distance between donor and acceptor τ = fluorescing life span of the donor, if there are no acceptor molecules R_0 = Förster-distance ϵ_A = molar decadic absorption coefficient of the acceptor Ψ_{norm}^D = standardized fluorescent spectrum of the donator:

$$\Psi_{norm}^D = \Psi^D \cdot \left[\int_0^\infty \Psi^D d\nu \right]^{-1}$$

$$k_t = \frac{1}{\tau_D} \left(\frac{\epsilon_A^0}{\epsilon_D^0} \frac{9000 \ln 10}{4 \pi^2 128 \pi^2 N_A} \right) \int \Psi_{norm}^D \frac{\epsilon_A}{\nu^4} d\nu$$

$$k_t = \frac{1}{\tau_D} \left(\frac{R_0}{r} \right)^6$$

If we compare these equations we will get R_0 :

$$R_0 = \left(\frac{\epsilon_A^0}{\epsilon_D^0} \frac{9000 \ln 10}{4 \pi^2 128 \pi^2 N_A} \int \Psi_{norm}^D \frac{\epsilon_A}{\nu^4} d\nu \right)^{\frac{1}{6}}$$

The transmission of energy is in concurrence with the fluorescing process of the donor molecule. Short transfer-times result in an effective energy transfer to the acceptor and vice versa. The energy transfer efficiency E is defined as the part of the absorpt photons that the donator transfers to the acceptor:

$$E = \frac{k_t}{\tau_D^{-1} + k_t}$$

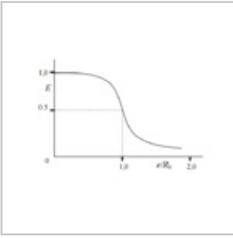
We can put this equation in the one mentioned above:

$$k_t = \frac{1}{\tau_D} \left(\frac{R_0}{r} \right)^6$$

this equals to:

$$E = \frac{R_0^6}{R_0^6 + r^6}$$

The graph of the energy transfer efficiency of the donor-acceptor-radius shows a functional connection:



If $r=R_0$ the transfer efficiency is 50% (definition of the Förster radius).

Discussion

The strong distance-dependence of the Förster resonance energy transfer efficiency has been widely utilized in studying the structure and dynamics of proteins and nucleic acids, in the detection and visualization of intermolecular association and in the development of intermolecular binding assays. Förster resonance energy transfer is a particularly useful tool in molecular biology as the fraction, or efficiency, of energy that is transferred can be measured, and depends on the distance between the two fluorophores.

References

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