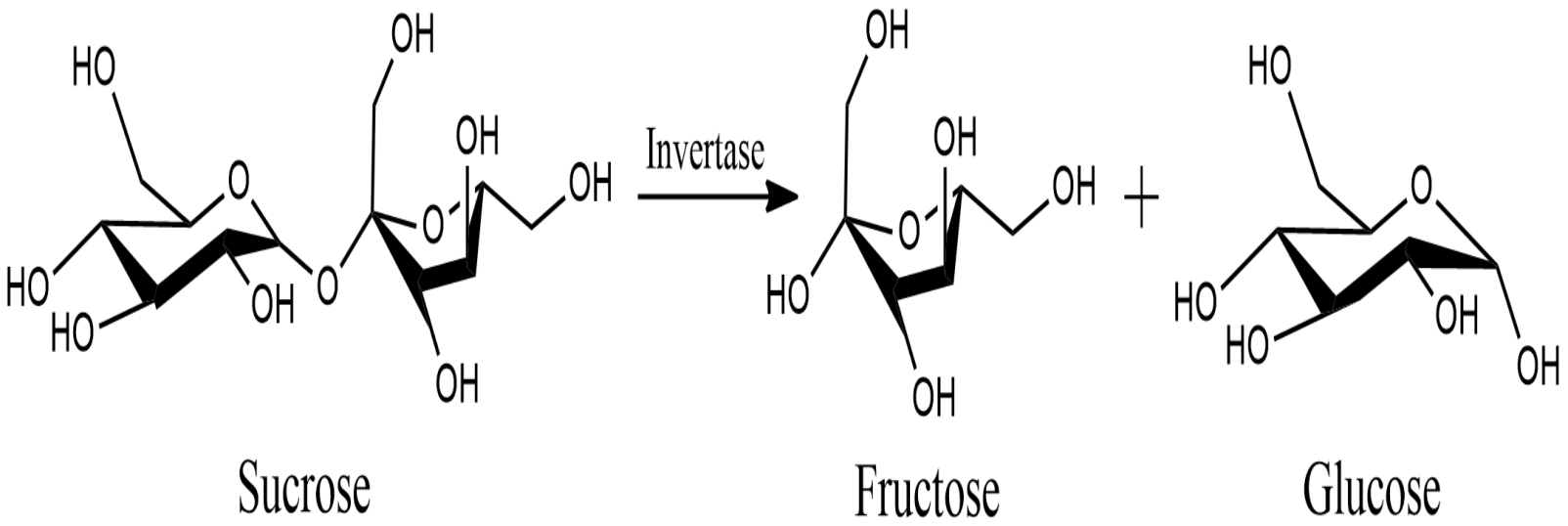
Enzymes

Definition

- Enzymes (E) are protein-based compounds that catalyze biological reactions in which a substrate (S) is converted into a product (P).

- The compound transformed by an enzyme is called a substrate, and the compound obtained is called a product.

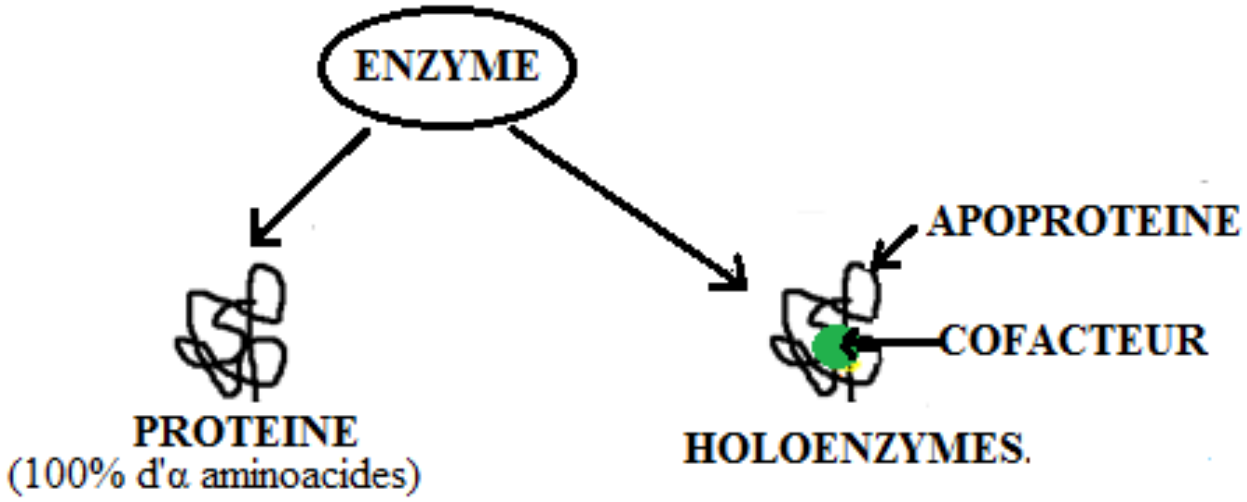
- All enzymes are proteins, with the exception of certain RNA molecules known as ribozymes, which catalyze reactions involving the synthesis and cleavage of phosphodiester bonds.


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OH
Sucrose
Fructose
Glucose


E
S
P1
P2

Enzyme structure

- Enzymes are highly specialized proteins
- That may consist entirely of α-amino acids
- Or require-in addition to the protein component-a cofactor essential for their function.The latter are known as holoenzymes, with the protein component referred to as an apoprotein or apoenzyme.



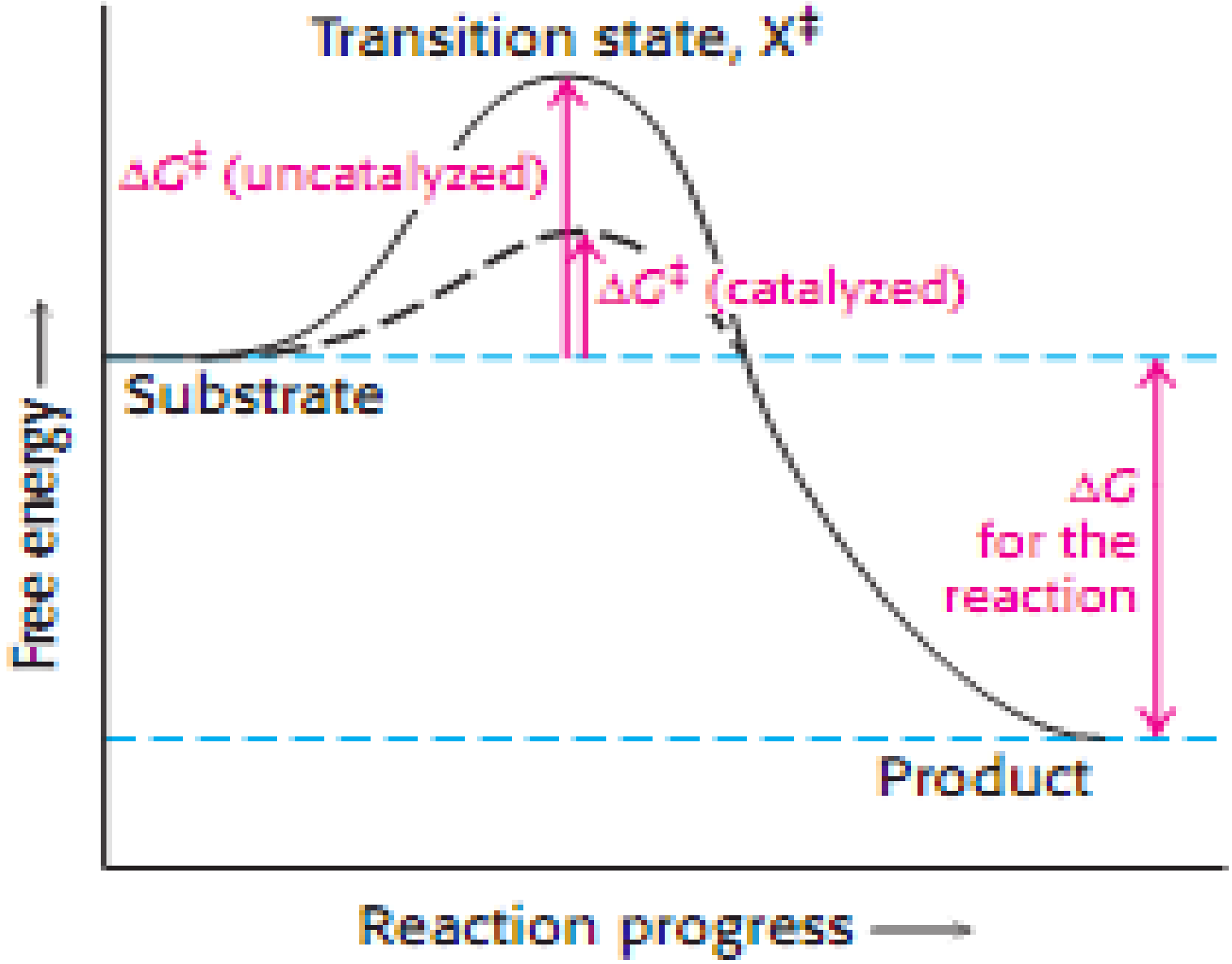
- A cofactor can be:
- an inorganic ion, such as magnesium,
- or an organic group known as a coenzyme.

- A coenzyme may be a vitamin or a vitamin derivative.
- When the coenzyme is tightly bound to the enzyme, it is called a prosthetic group

Characteristics of enzymes

Reduction of activation energy

- Enzymes accelerate the rates of biochemical reactions by decreasing the Gibbs free energy of activation, denoted $\Delta G‡$.
- This energy is required to bring the substrate S to a transition state X‡, which has a higher free energy than that of the substrate or the product
(S $\rightarrow$X‡$\rightarrow$P).

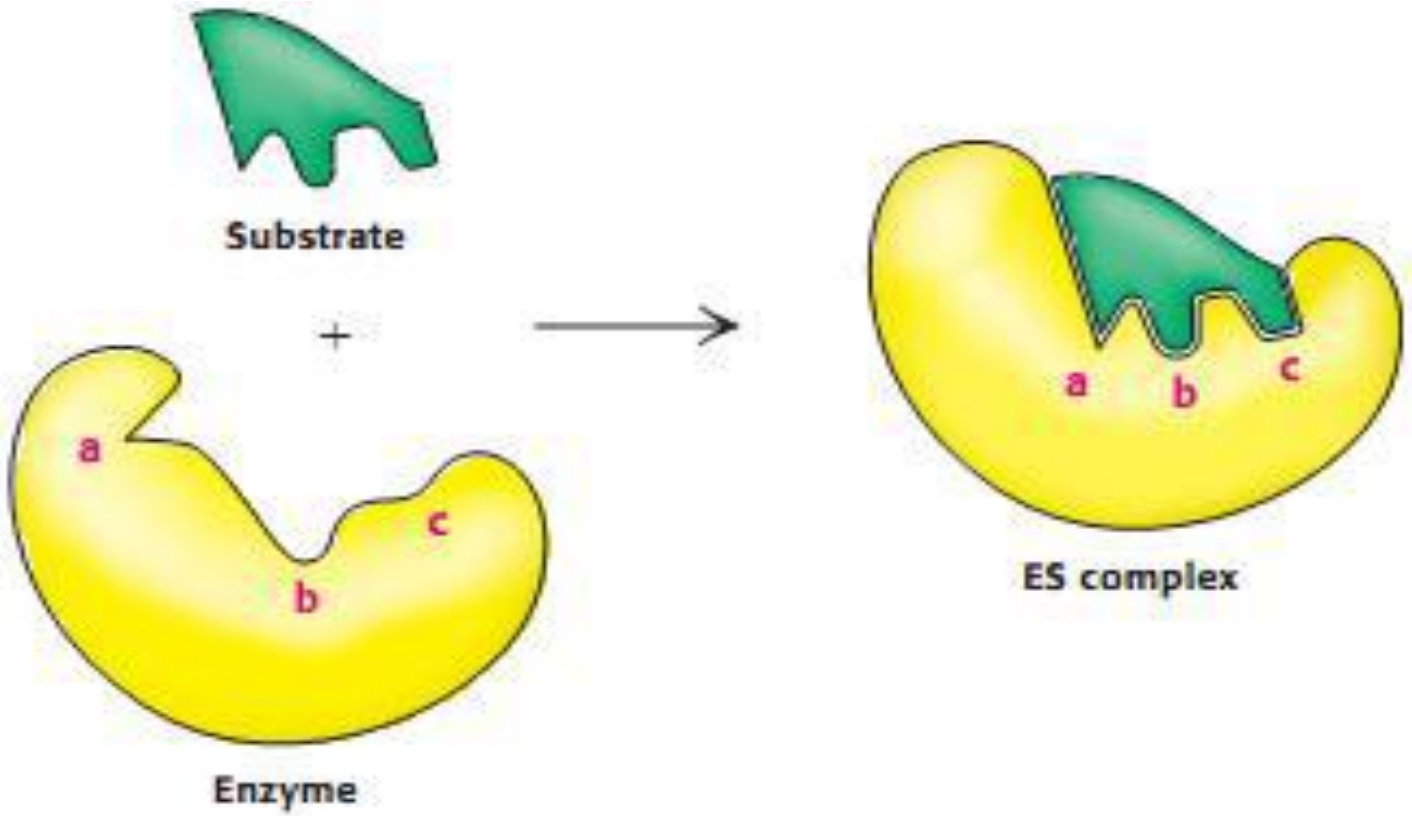

Transition state, X‡
ΔG‡ (uncatalyzed)
ΔG‡ (catalyzed)
Substrate
ΔG for the reaction
Product
Free energy
Reaction progress

Properties of enzymes

Specificity

- Enzymes are characterized by an active site, a cavity providing a specific environment where the transformation of substrate into product can occur.

- The active site consists of a binding site and a catalytic site.



❑The binding of the substrate (S) to the enzyme occurs via weak bonds and induces a conformational change in the enzyme, thereby activating the catalytic site.

❑Enzymes act with a twofold specificity:

➢ To the substrate: A given enzyme can bind to only one specific substrate

➢To the catalyzed reaction: as each enzyme can catalyze only one type of reaction.

❑Some enzymes exhibit broader substrate specificity and can recognize a range of substrates: hexokinase catalyzes the phosphorylation of hexoses such as D-glucose, D-fructose, and D-mannose.

Regulation

❑Enzymes are molecules whose activity can be regulated according to cellular needs; there are two ways to achieve this:

➢ Direct regulation: binding of an activator or inhibitor to the enzyme, or covalent modification of the enzyme.

➢Indirect regulation: control of enzyme synthesis (gene control).

Efficiency

Enzymes are extremely efficient; for example, OMP decarboxylase increases the rate of a reaction by a factor of 10^7.

Non-consumption

At the end of the catalytic process, enzymes are recycled (regenerated) and thus remain intact at the end of the reaction.

Effective at low doses

Due to their efficiency and the fact that they are not consumed by the end of the reaction, enzymes act at very low concentrations (or quantities) compared to the concentrations of the substrate.

In addition to these three main characteristics of enzymes, it should also be noted that enzymes act in an aqueous environment at an optimal temperature and pH; they do not alter the equilibrium of the reaction.

Classification of enzymes

- The International Union of Biochemistry (IUB) has established a classification system in which each enzyme is categorized according to the type of reaction it catalyzes

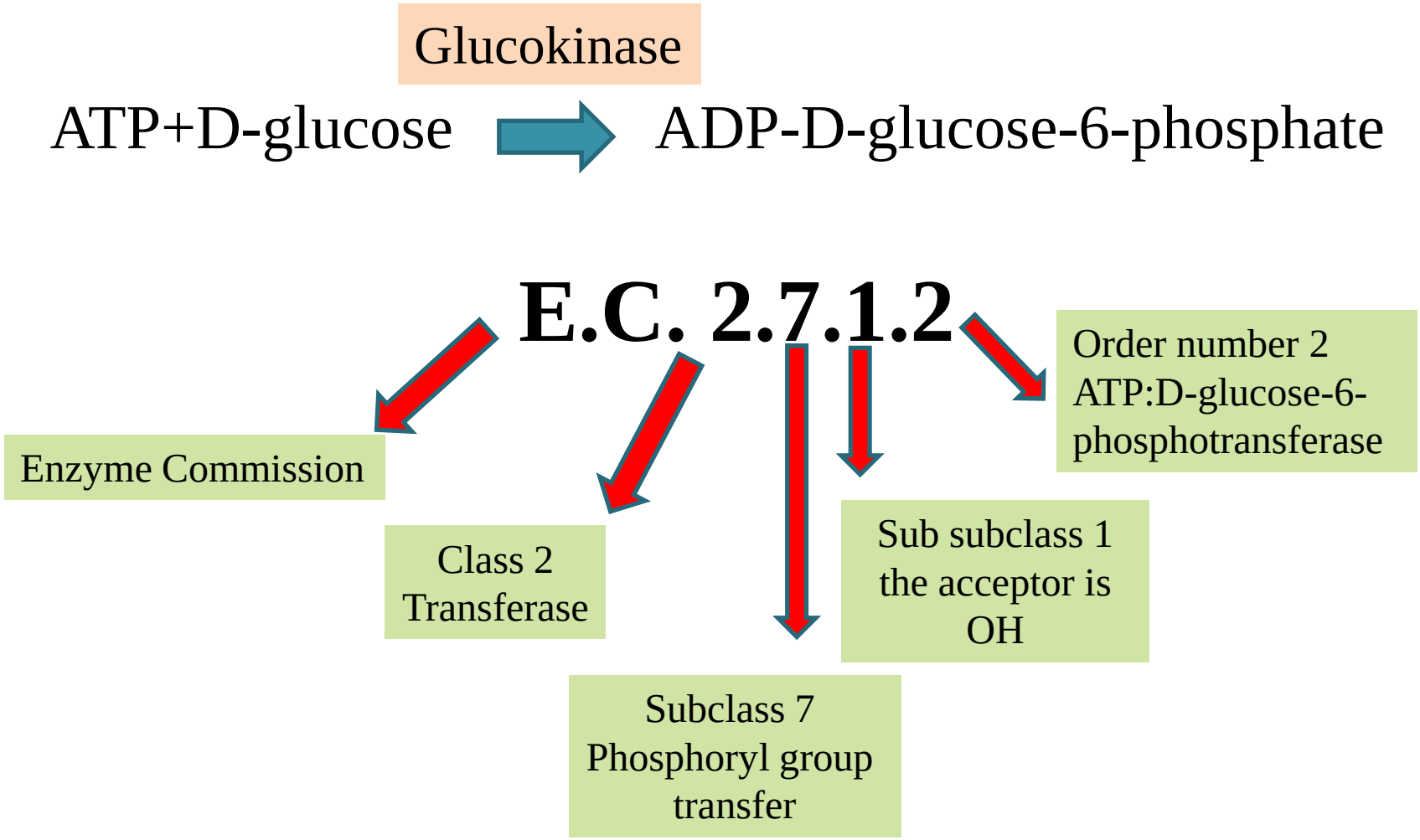
- There are 6 classes of enzymes, numbered 1 through 6.

- Each class contains subclasses, sub-subclasses, and a serial number.

- An enzyme is identified by a 4-digit code (E.C. X1.X2.X3.X4),
E.C.: Enzyme Commission.

Class	Catalyzed reaction
Oxidoreductases	Oxidation-reduction
Transferases	Functional group transfer
Hydrolases	Hydrolysis of bonds
Lyases	The breaking of C-C, C-O, and C-N bonds.
Isomerases	Intramolecular rearrangements
Ligases (synthetases)	Formation of bonds between two molecules. C-O, C-S, C-N, C-C

Example: glucokinase E.C. 2.7.1.2
Glucokinase catalyzes the phosphorylation of D-glucose to D-glucose-6-phosphate



Michaelis-Menten kinetics



Leonor Michaelis

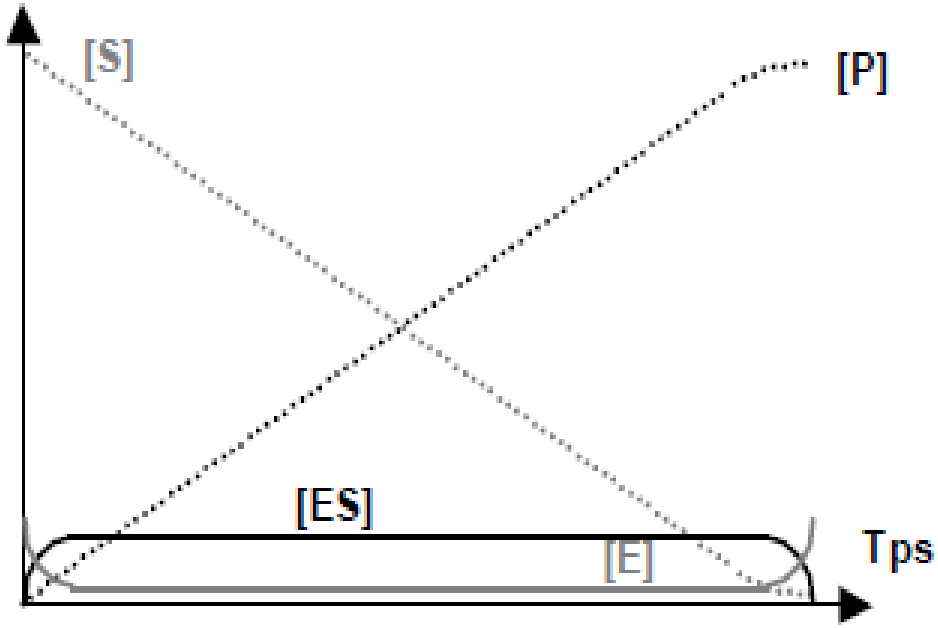


Maud Menten

Initial reaction rate

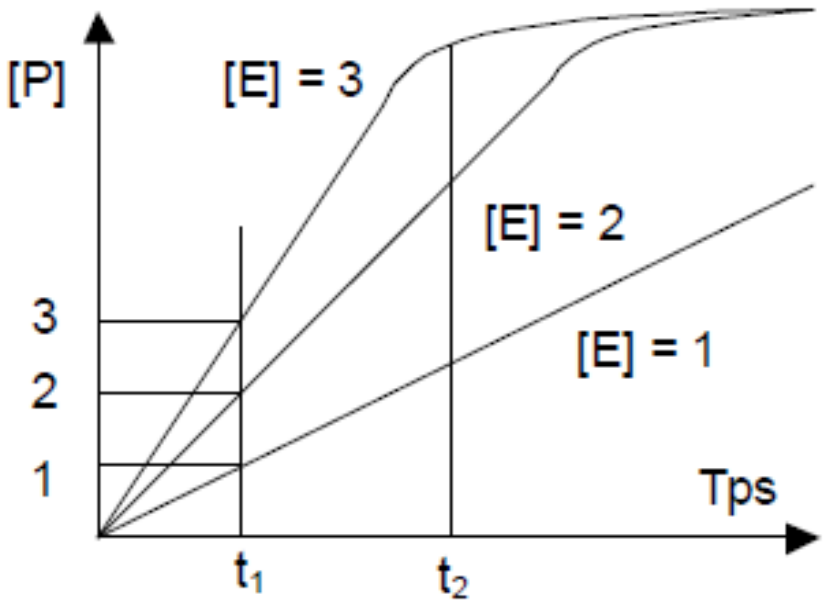
Measurement of the appearance of the product over time.

$S+E \leftrightarrow ES \rightarrow E+P$



Two phases can be observed: 1) a constant slope, implying a constant rate, followed by 2) the gradual emergence of a plateau, where the rate decreases—this occurs because the initial conditions no longer hold, primarily due to the depletion of the substrate.

Influence of enzyme concentration on the rate



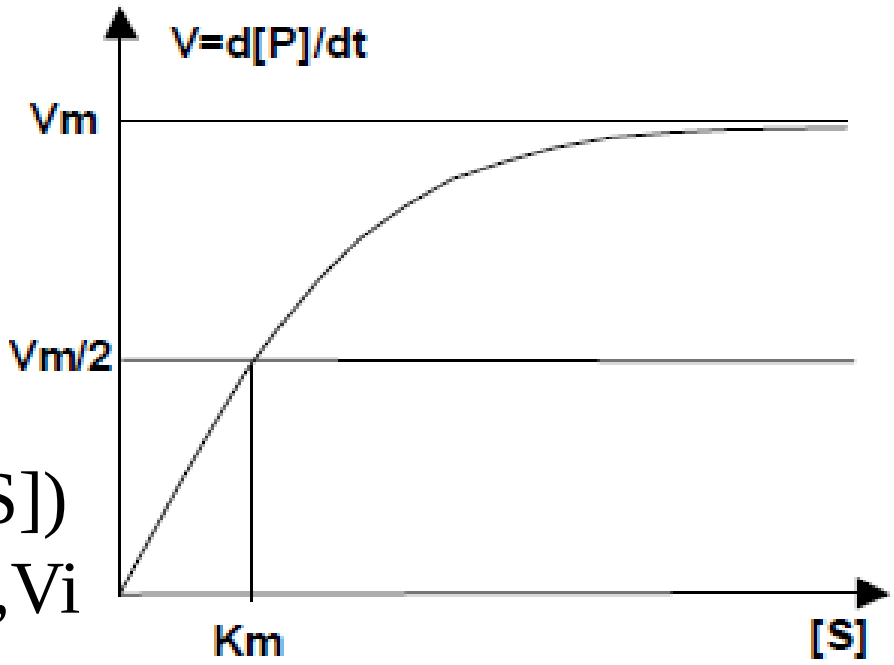
At t1, under initial rate conditions, there is a proportionality between [E] and the amount of product formed.

The curve V = f([E]) is a straight line (V = d[P]/dt).

At t2, the initial conditions are no longer met; therefore, proportionality ceases.
Theoretically, all curves have the same plateau.

Influence of substrate concentration

Michaelis – Menten equation (1913)



We plot the curve V = f([S])
As [S] increases, Vi approaches Vmax

$$S + E \underset{K-1}{\overset{K1}{\leftrightarrow}} ES \underset{K-2}{\overset{K2}{\leftrightarrow}} E + P$$

[Et] = total enzyme, [ES] = enzyme-substrate complex; therefore, [EL] = [Et] - [ES] = free enzyme; [S] = substrate, where [S] >> [Et].