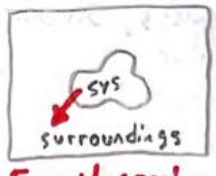
BIOCHEMISTRY EXAM 2 Study Sheet — Chapters 4, 5 & 6 — 3-4-24

Chapter 4: Energy

1) The first 3 Laws of Thermodynamics, enthalpy, entropy & free energy

1) Energy cannot be created or destroyed: it is conserved
In chemical reactions, energy flows between the system and surroundings
This is the **enthalpy change (ΔH)**. It is the energy transfered through heat or volume at constant pressure.

Endothermic
Products: higher potential E



Exothermic
products: lower potential E

2) The entropy of the universe is always increasing

Formula: $\Delta G = \Delta H - T\Delta S$

ΔG = Free Energy available to do work
ΔH = Enthalpy: change in heat
ΔS = Entropy: change in disorder
T = temp in K (°C + 273°)

$\Delta G < 0$	The reaction is spontaneous
$\Delta G > 0$	The reaction is nonspontaneous
$\Delta G = 0$	Equilibrium

3) As the temp of a perfect crystalline solid approaches 0°K, disorder approaches zero. All movement stops at atomic level

Standard Free Energy

ΔG° = defined for reactions at 25°C, 1 atm, 1.0 M conc,
$\Delta G^{\circ\prime}$ = defines for standard conditions with pH = 7 also
$\Delta G'$ = non standard conditions with pH = 7, $[H^+]$ left out of Equilibrium quotient

2) State functions (Hess's law)

1) If rxn is reversed, the sign is flipped
2) If you add rxns, add state functions
3) If you multiply rxns, multiply state Functions by the same value.

$$\Delta H_{rxn} = \Sigma \Delta H_{products} - \Sigma \Delta H_{reactants}$$

ΔH = sum of ΔH for each step

3) Entropy of the universe

$\Delta G = \Delta H - T\Delta S$

favorable	(−)	(−)	(+)
unfavorable	(+)	(+)	(−)
depend on T:	?	(−)	(−)
	?	(+)	(+)

$\Delta S > 0$: ΔS = Entropy

4) Gibbs free energy (ΔG°, $\Delta G^{\circ\prime}$) equilibrium expressions and constants

$\Delta G = \Delta G^\circ + RT \ln Q$ $\quad \Delta G = \Delta G^{\circ\prime}$ when P = 1 atm, 1.0 M, 25°C, pH = 7

if $\Delta G = 0$, then $\Delta G^\circ = -RT \ln K$

$$Q = \frac{[products]}{[reactants]} = K \text{ (at equilibrium)}$$

Hess's Law affects eq. constant
equation is reversed = $\frac{1}{K}$
multiplied by $x = (K)^x$
divided by $x = \sqrt[x]{K}$
equations are added = $K_1 \times K_2$

K	ln K	ΔG°	Result at Equilibrium
> 1	(+)	(−)	products are favored
= 1	0	0	neutral
< 1	(−)	(+)	reactants are favored

Sign of ΔG° will tell us which direction the rxn goes to reach eq.

Problem types using ΔG° and K

Given K, find ΔG° $\quad \Delta G^\circ = -RT \ln K$
Given ΔG°, find K $\quad K = e^{-\Delta G^\circ / RT}$
Find conc. of species at Equilibrium

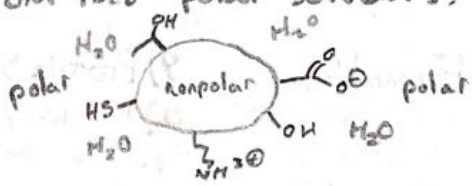
$$\ln \frac{[prod]}{[react]} = \frac{-\Delta G^{\circ\prime}}{RT}$$

5) Coupled reactions

nonspontaneous rxns can be coupled with spontaneous ones to drive a process forward. Using products from one rxn in another rxn as reactants is a common way to save E

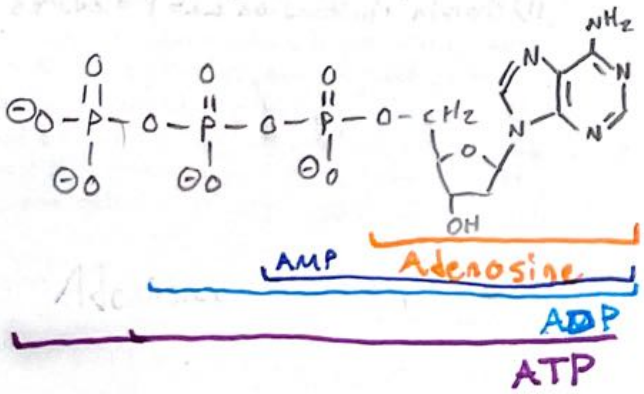
6) hydrophobic effect and folding proteins

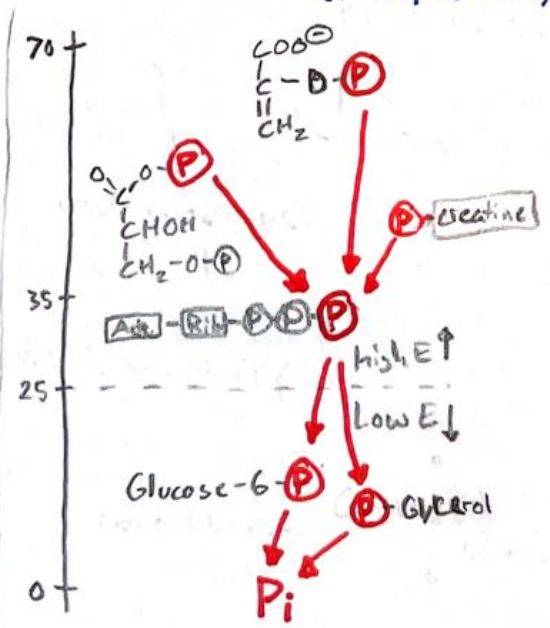
hydrophobic R groups will be found on the inside of the protein away from the polar solvents.



7) ATP and the phoshoryl-group transfer potential (phosphoanhydrides, phosphoesters, & E of hydrolysis

2 types of reactions together provide the energy required in metabolic processes
Principal electrons carriers: NADH, NADPH and $FADH_2$
Adenoside triphosphate is a nucleotide used in energy currency



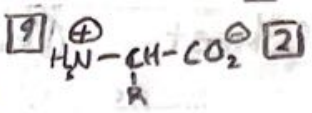


Phosphoryl-group transfer potential
Ⓟ bonded to molecules at high E drop down to make ATP
ATP is then used to couple rxns
ATP is an intermediate

8) Why we don't talk about "breaking high E bonds" to release Energy, Why is $\Delta G^{\circ\prime} < 0$

Breaking bonds takes E
Making bonds gives E
The two are coupled to form a net $-\Delta G^{\circ\prime}$

Chapter 5: Amino Acids, Peptides & Proteins



1) Names, Structures, classification, and pKa's of 20 AA

nonpolar

Glycine Gly G
Alanine Ala A
Valine Val V
Leucine Leu L
Isoleucine Ile I
Phenylalanine Phe F
Methionine Met M
Proline Pro P
Tryptophan Trp W

polar neutral

Serine Ser S
Threonine Thr T
Tyrosine Tyr Y — 10.1
Asparagine Asn N
Glutamine Gln Q
Cysteine Cys C — 8.3

Acidic AAs

Aspartate Asp D — 3.9
Glutamate Glu E — 4.3

Basic AAs

Lysine Lys K — 10.8
Arginine Arg R — 12.5
Histidine His H — 6

If pH < pka, the structu is protonated

If pH > pka, the structu is deprotonated

2) General structure

amphoteric = a compound able to react as both an acid and a base

zwitterion = compound with multiple func. with both (+) and (−) charges

3) R groups

aliphatic = non aromatic

aromatic = containing cyclic structures with planar π bonds

4) Biologically active amino acids

1) **Chemical messengers** several α amino acids, glycine and glutamate are secreted by nerve cells

2) **chemical precursors** of a variety of N containing Molecules. Eg Nitrogenous base

3) **Metabolic intermediates** rginine, component of the urea cycle

5) AA Stereoisomers

19 of the 20 AAs are chiral asymetric molecules

rotating light clockwise (+)

rotating light counterclock (−)

D & L, R & S

Dextro ↷ Levo ↶

All amino acids are L in proteins and form right turning α helixes

α helixes turn to the right due to L-amino acids

6) pI calculations

pI = Isoelectric point

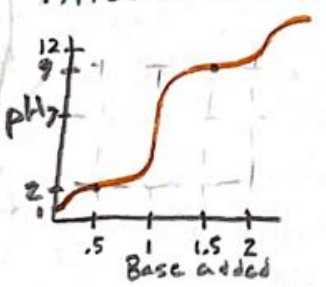
The point where the amino acid is neutral

$$pI = \frac{pka_1 + pka_2}{2} = pH$$

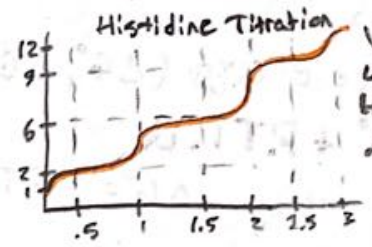
Avg of pka_1 ⊕ → N and pka_2 N → ⊖

Steps 1) add NH_3^+ and CO_2^-
2) Drop nonion groups
3) start at pH = 1
4) go through each pka
5) avg the pka_1 and pka_2

Titration curves



non ionizable R group AA



Verticle at whole CO_2 base
Horizontal at .5 eq base added

7) Peptides

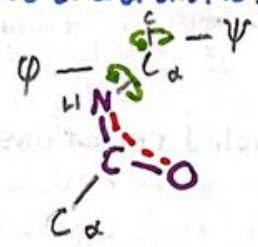
Nomenclature = N→C direction

Name by adding yl in place of ine or ic

Exceptions: 1) C terminus leave as ine
2) Gln = glutaminyl, Asn = asparaginyl
Glu = glutamyl, Cys = cysteinyl

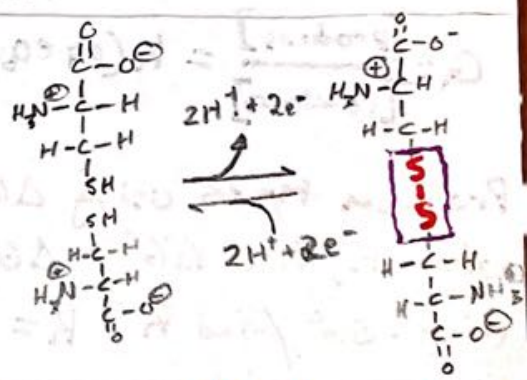
AA Double bond characteristics

The N-C-O bonds form a partial double bond, limiting rotation of 1/3 of AA bonds



8) Cysteine Redox

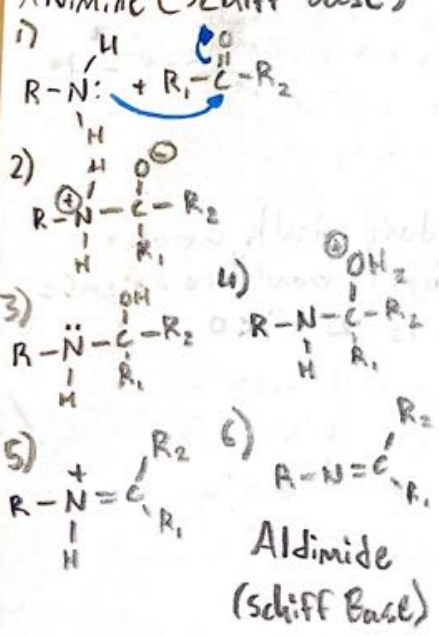
Formation of a disulfide bridge. 2 cysteine R groups oxidize together to form a crosslinking bond common in proteins



Schiff Base Formation

Nucleophilic addition reaction a primary amine N attacks the electrophilic carbon of a carbonyl group to form an alkoxide product.

Aldimine (Schiff base)



9) Protein Structure

a) Primary Structure

Specific peptide order

H_3N^+-Glu-Val-Cys-Tyr-CO_2^-

String of amino acids

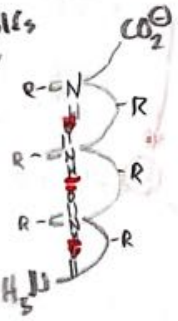
b) Secondary Structure

polypeptides consisting of several repeating pattern

α Helix: rigid rod like structure, right handed turning. H bonds form between the N-H and the C=O, 4 AA away

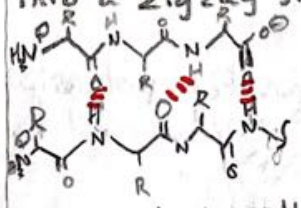
The H bond holds the α helix very tight

R groups are found on the outside of the α helix



β sheets

peptide segment Folded into a zigzag structure



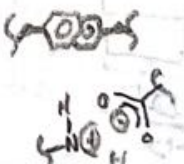
H Bonds hold peptide chains together parallel and antiparallel

Supersecondary = grouping of α helix and β sheets together. Many globular proteins contain supersecondary structure.

c) Tertiary Structure

3d structure of a single peptide chain and includes R group stabalization

Interactions:
Hydrophobic:
Electrostatic:

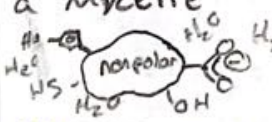


Hydrogen bonds
Covalent bonds
Disulfide bridges
Hydration: H_2O

d) Quaternary Struct. multiple polypeptides Multy chains of AA working togethe

10) globular vs Fibrous Proteins

water soluble hide nonpolar R groups in center of protein. Makes a micelle



high secondary structure concentration
Structural roles
Lots of repeats
α helix = 1 helix
Coiled = 2 helix
Protofilament = 2 coils
Filament = 4 protofilamen

11) Protein Purification Lab procedures

a) Gel filtration = bigger flows faster into
b) Ion Exchange = sep by charge with beads
c) Affinity chromatography = binds to affinite compounds covalently bonded to the bead Then elute with more affinite comp.
d) Electrophoresis = PAGE smaller moves faster through the gel
2D Electr. Isoelectric focus = uses a pH gradient. Proteins move lower and become

Chapter 6: Enzymes

1) Characteristics of Enzymes

a) **Enormous increase in rate** up to 10^7 to 10^{19} as fast

b) **High specificities**: substrate, product & stereochemistry

c) **Controllable**: turn on and off with a signal

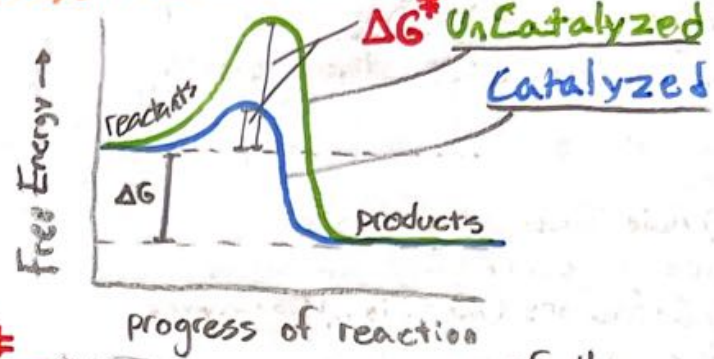
d) **Other**: Obey the laws of thermodynamics, catalyze the forward and backward of reversable reactions, usually present in low concentrations, not consumed by rxns.

Enzyme Catalysts Basics

Catalyst: enhances the rate of a chemical reaction without being perminantly altered by the reaction. Catalysts provide an alt. reaction pathway that requires less activation energy.

$\Delta G^{\ddagger}$ = free energy of activation The amount of energy required to turn 1 mol of substrate into the transition state molecule. (highest point of energy in the reaction.

Catalyst Activation E Graph



$\Delta G^{\ddagger}$ = Distance in energy of the transition state of rxn from reactant state energy

Catalysts have no effect on ΔG

2) Activity Coefficients & non ideality factor (Γ)

Enzymes operate in crowded situations. In the lab they are performed in low conc. buffers. Ideal solutions contain solutes in such low concentration that interactions such as steric repulsion or attractive forces are non. Effective concentration ($a = \gamma c$)

γ = activity coefficent - dependant on size and charge of species and on the ionic strength.

C = conc. $\frac{mol}{L}$

Equilibrium constant for reaction under non ideal conditions $K_{eq}^{\circ} = \frac{\gamma_B[B]}{\gamma_A[A]} = K_{eq}^{i}\Gamma^{i}$

K_{eq}^{i} = ideal constant, Γ = nonideality factor

3) The 6 classifications of Enzymes

1) **Oxidoreductases** (redox enzymes) Involves 1 or 2 e^- transfer reactions with compensating change in the amount of hydrogen and oxygen in the molecule Oxidase, peroxidase, oxygenase, reductase, dehydrogenase

2) **Transferases** (transfer a group) transaminase, transmethylase, transphosphatase - ATP, kinase

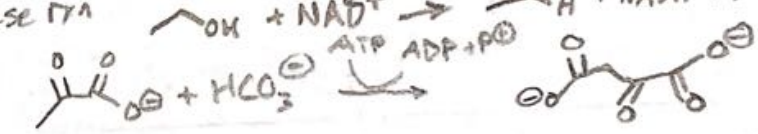
3) **Hydrolases** (hydrolysis) addition of H_2O reactions. Eg: phosphatase, esterase, protease

4) **Lyases** (splits substrate) non hydrolytic, non oxidative

5) **Isomerase** (Isomerize) racemize, create racemic mix

6) **Ligases** (Joins two peices) synthatase - "Tase" implies use of ATP

Oxoreductase rxn example:



Ligase rxn example:

4) Enzyme Kinetics - says something about mechanism

velocity of rxn: $V_0 = \frac{-\Delta[A]}{\Delta t} = \frac{\Delta[P]}{\Delta t}$, $\frac{\Delta[A]}{\Delta t} = K[A]^x$

[A] = substrate, [P] = product, t = time

reaction rate: $V_0 = K[A]^x$, K = rate constant

x = order of reaction, sum of exponents

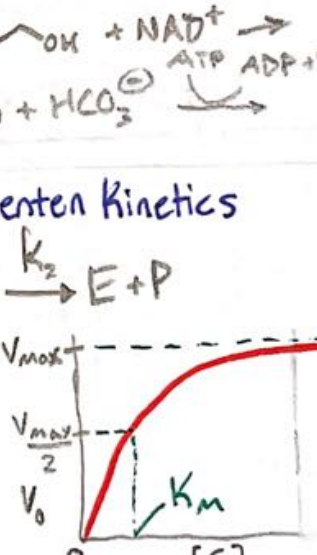
1st order = $[A]^1$, 2nd order = $[A]^1[B]^1$

Rate = $K[A]^1[H_2O]^1$ = first order, H_2O is constant

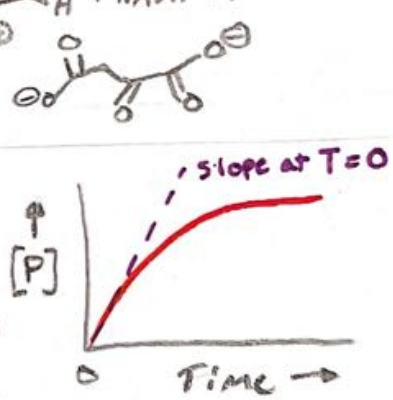
5) Mechaelis-Menten Kinetics

$$E + S \underset{k_{-1}}{\overset{k_1}{\rightleftharpoons}} ES \xrightarrow{k_2} E + P$$

$$V = \frac{V_{max}[S]}{[S] + K_m}$$



The smaller the K_M the tighter the complex



Hyperbolic curve, 1st order at Low [S], then 0 order under saturated condition

[S] = K_m then $V_0 = \frac{V_{max}}{2}$

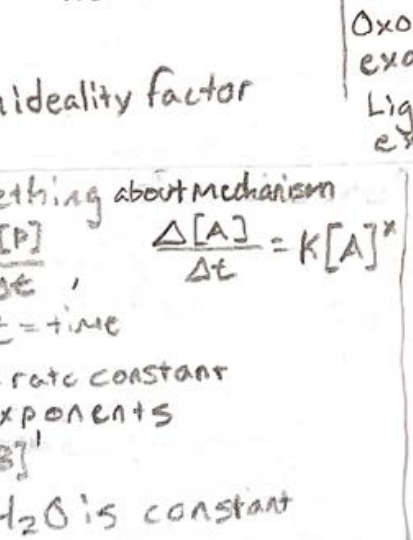
Lineweaver-Burk Kenetics

reciprocal of the Mechaelis-Menten Kinetics equation

Slope of the line = $\frac{K_M}{V_{max}}$

$\frac{1}{V_{max}}$ = y intercept $\frac{1}{K_M}$ = x intercept

$$\frac{1}{V_0} = \frac{K_M}{V_{max}}\left(\frac{1}{[S]}\right) + \frac{1}{V_{max}}$$



Saturation Kenetics

1) Initial Rate kenetics
2) Dependance of V_0 on [substrate]
3) Propose a stepwise mechanism

Assumptions

① $V_0 = K_2 \cdot [ES]$

② K_2 = is the rds

③ $\frac{d[ES]}{\partial x} \approx 0$ steady state, fast equilibrium

2 Perameters

1) How fast will the rxn go when saturated completely with substrate?
2) Gauge sensitivity, $\frac{1}{2}V_{max}$ and find [S]

[S] at $\frac{1}{2}V_M = K_M$

7) Inhibition Kenetics

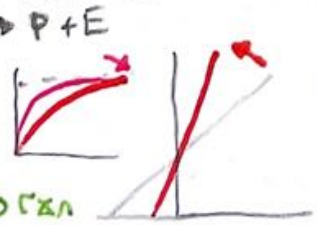
1) Competitive Inhibitors

Inhibitor binds to the enzyme and creates EI complex. This then reduces the reaction

$E + S \rightleftharpoons ES \longrightarrow P + E$

\+ K_M: ↑, V_M: NC

\+ S → no rxn



2) noncompetitive Inhibitors

Binds to both E and ES results in E bending into shape that can't react to form product.

$E + S \rightleftharpoons ES \longrightarrow P + E$

\+ I ↓↑ K_M: NC, V_M: ↓

\+ I ↓↑

$EI + S \rightleftharpoons ESI$ → no rxn

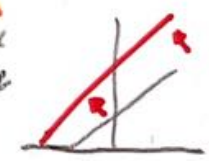
3) Uncompetitive Inhibition

I binds to the ES complex in is a type of noncompetitive

$E + S \rightleftharpoons ES \longrightarrow P + E$

\+ I ↓↑ K_M: ↓, V_M: ↓

ESI



Mechanistic Effects of Catalysis

1) **Surface Effect** - holding the molecule
2) **Transition state stabalization**
Stabalizes the highest energy state
holds the transition state in a lower E state
3) **Acid/Base Catalysis**
aids in acid/Base catalysis
4) **Cofactors (metal ions) Coenzymes**
5) **Covalent intermediate**

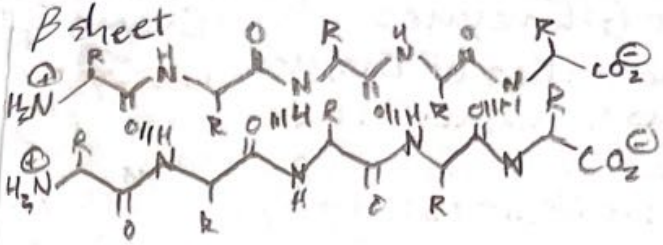
MM Calculations

$$[S] = \frac{V_0 K_m}{V_m - V_0}, \quad V_0 = \frac{V_m[S]}{[S] + k_m}$$

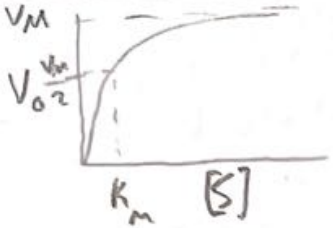
Variables = $[S]$, V_0, K_m, V_m

$$\frac{1}{V_0} = \frac{k_m}{V_m}\left(\frac{1}{[S]}\right) + \frac{1}{V_m}$$

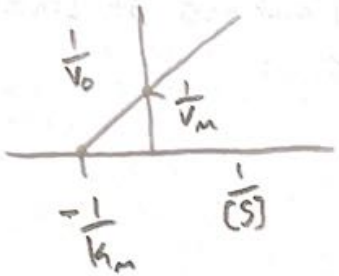
β sheet



$$V_0 = \frac{V_m[S]}{[S] + K_m}$$



$$\frac{1}{V_0} = \frac{K_m}{V_m}\left(\frac{1}{[S]}\right) + \frac{1}{V_m}$$



$$\Delta G = \Delta G^\circ + RT \ln Q$$

$$\Delta G^\circ = -RT \ln k$$

$$[S] = \frac{V_0 k_m}{V_m - V_0}$$

Competitive: K_M ↑ V_M NC

Un competitive: ↓ ↓

non competitive: NC ↓