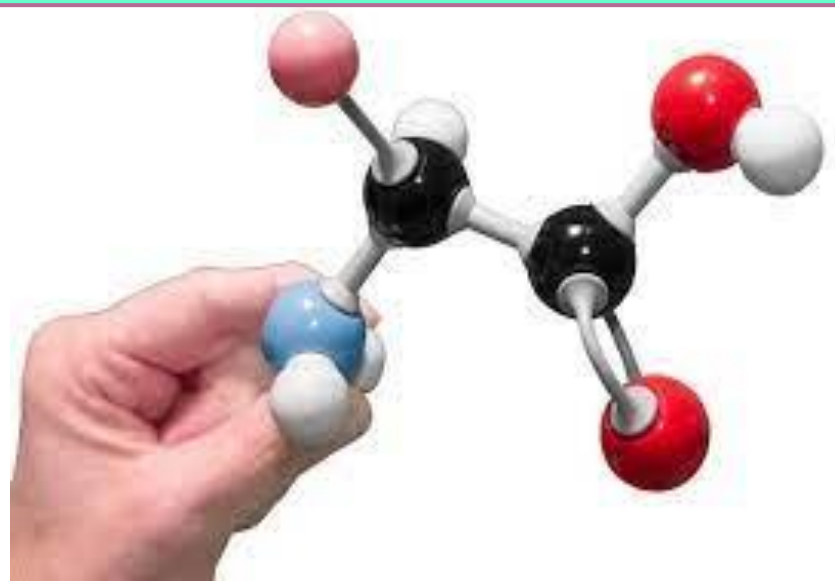
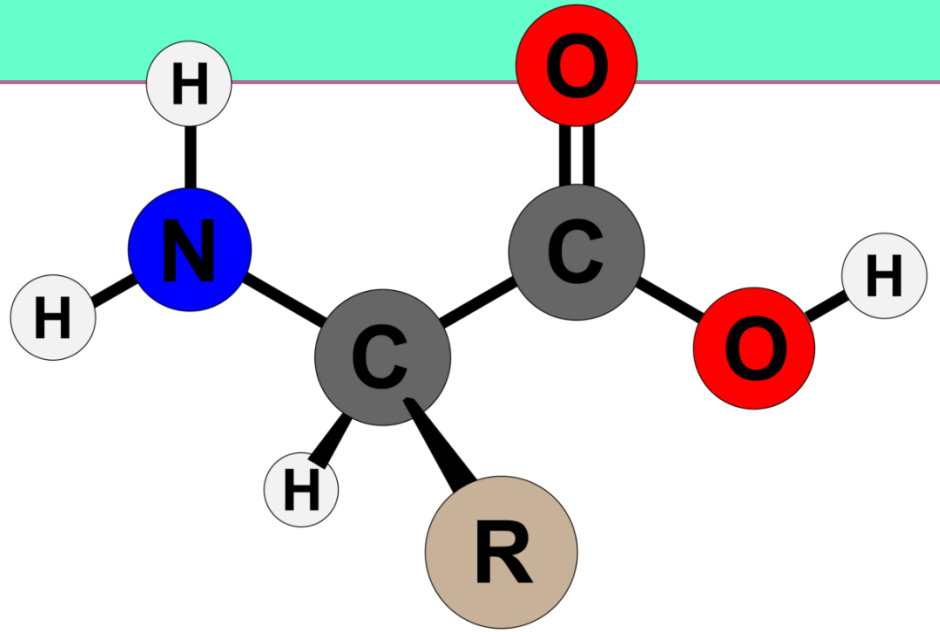
CHAPTER 12

AMINO ACIDS

12.1 INTRODUCTION TO AMINO ACIDS
12.2 CHEMICAL PROPERTIES





12.1 : INTRODUCTION TO AMINO ACIDS

Students should be able to:

a) Give the name for a given amino acid according to the IUPAC nomenclature (C2)

b) Give the general structure of α-amino acid in 12.1(a). (C2)

c) Define the terms: (C1)

i. zwitterion;

ii. Isoelectric point (pI).

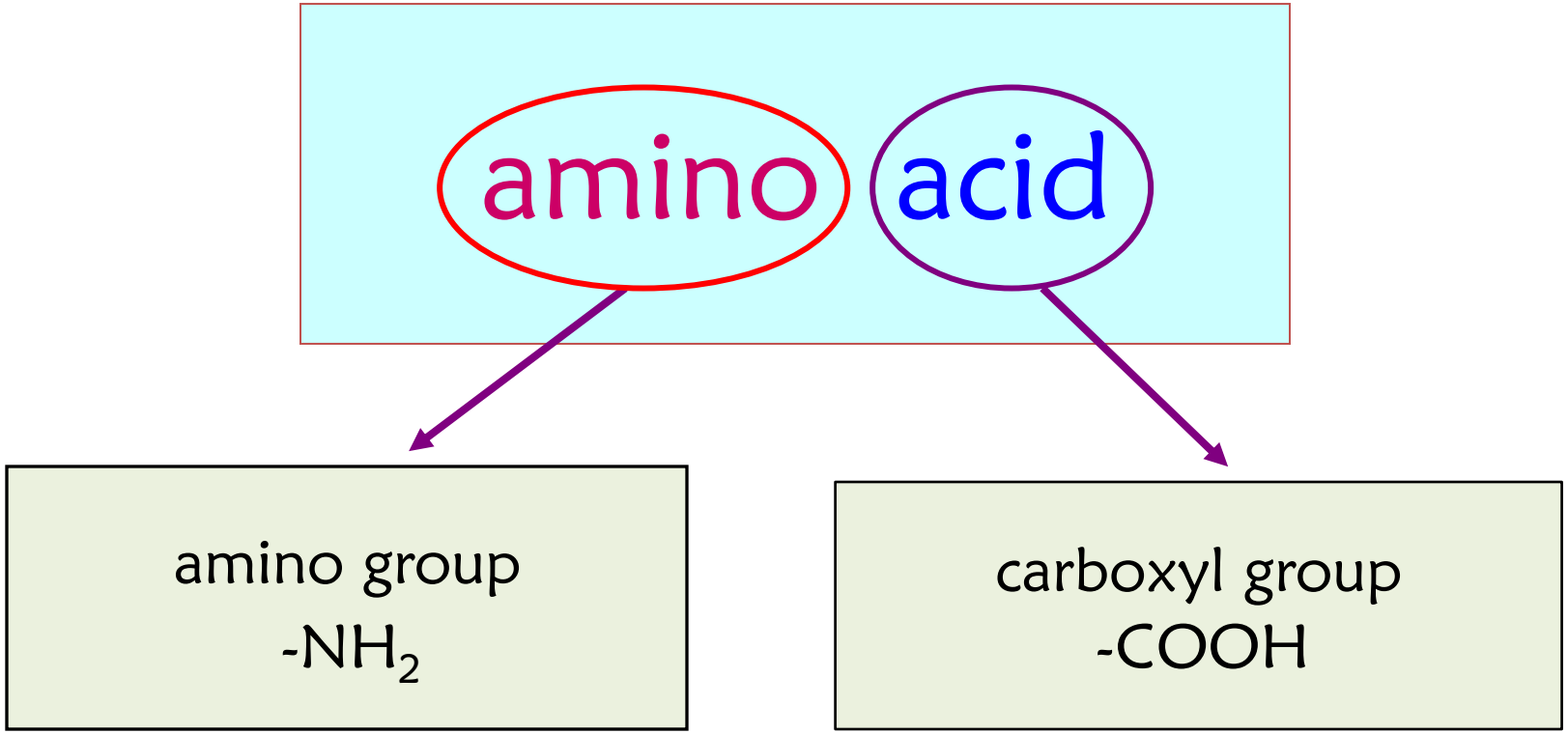
d) Predict the structure of a given amino acid, (C3)

i. in acidic medium

ii. in basic medium

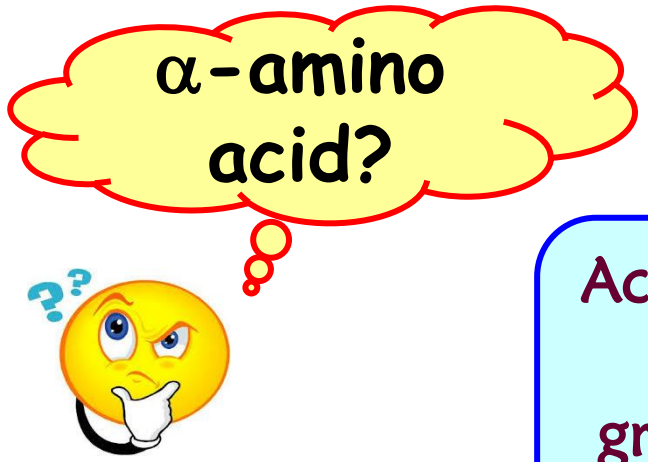
iii. at pI.

12.1 : INTRODUCTION TO AMINO ACIDS



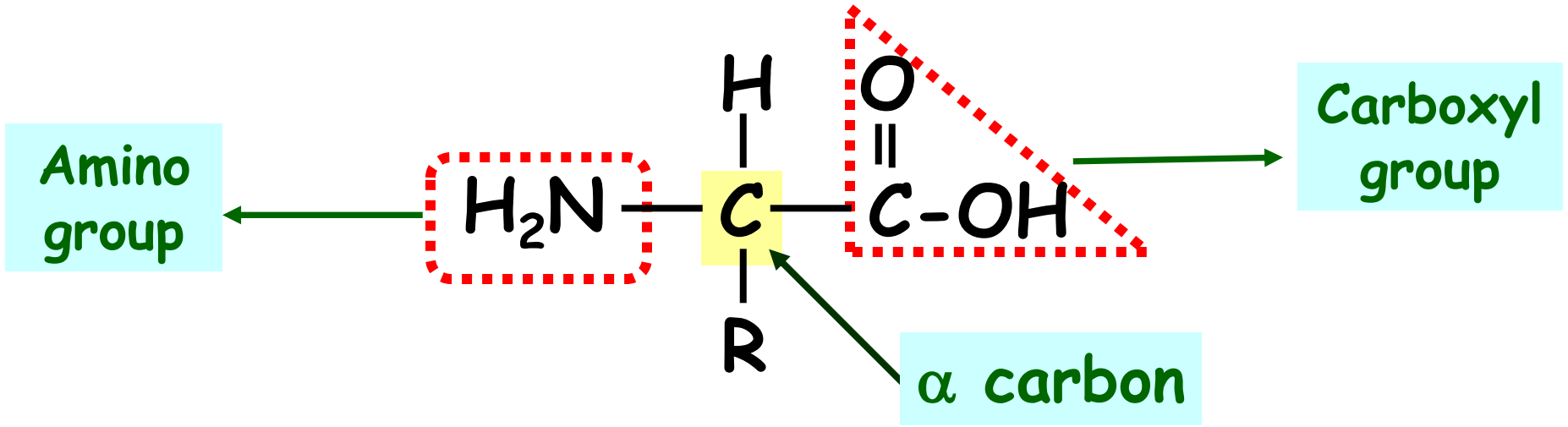
Amino acids are molecules with two functional groups:
amino group (-NH_2) and **carboxyl group (-COOH)**

Amino acid commonly found in proteins are **α-amino acid**

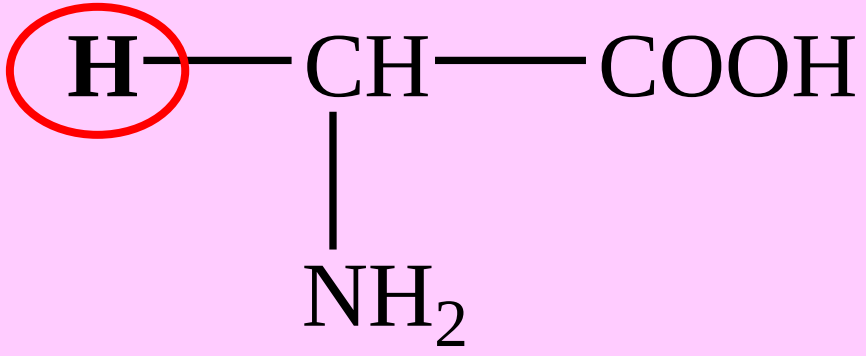
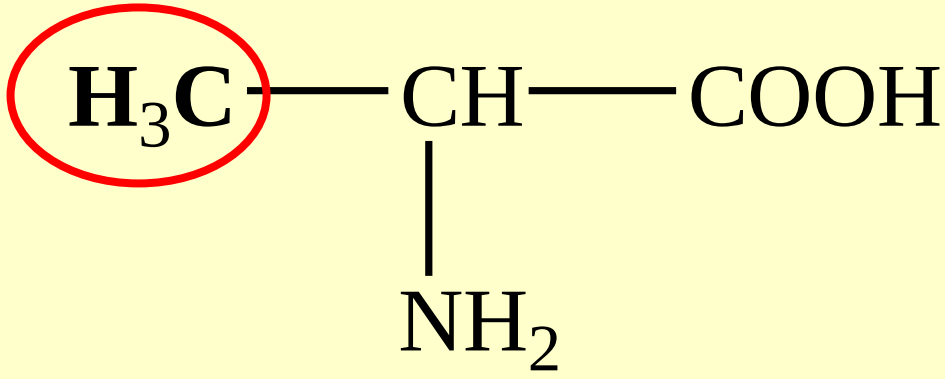


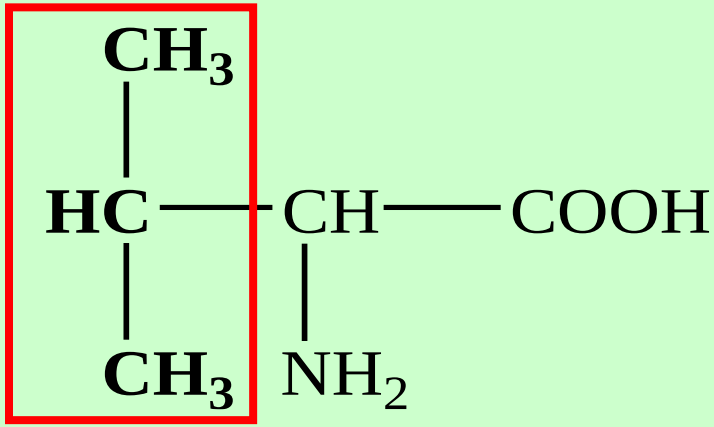
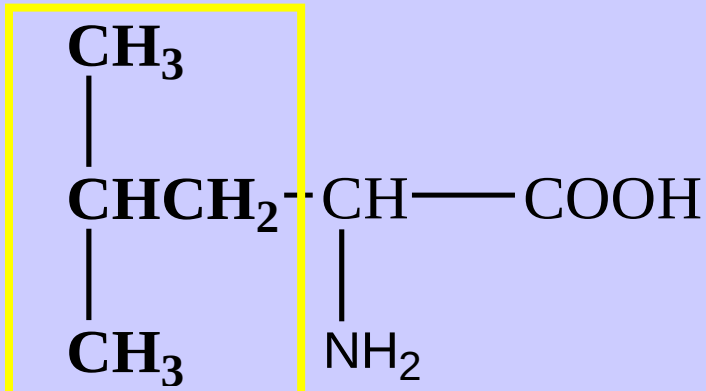
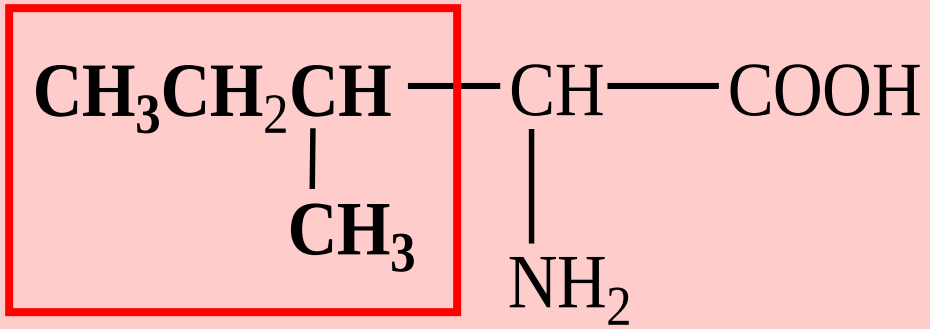
Acid amino on which both carboxyl and amino groups are bonded to the SAME CARBON atom.

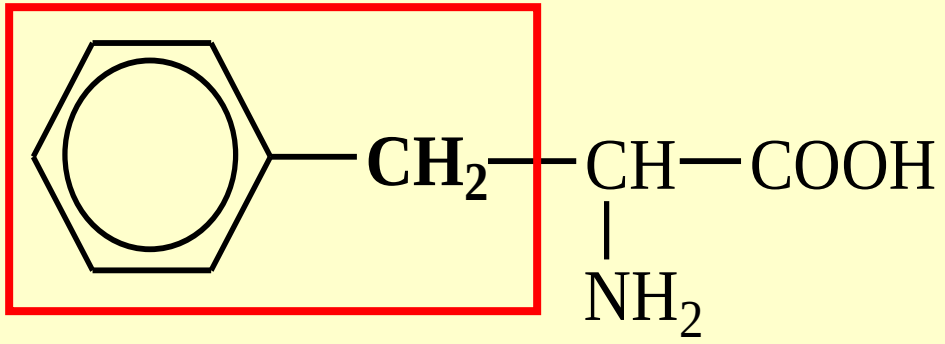
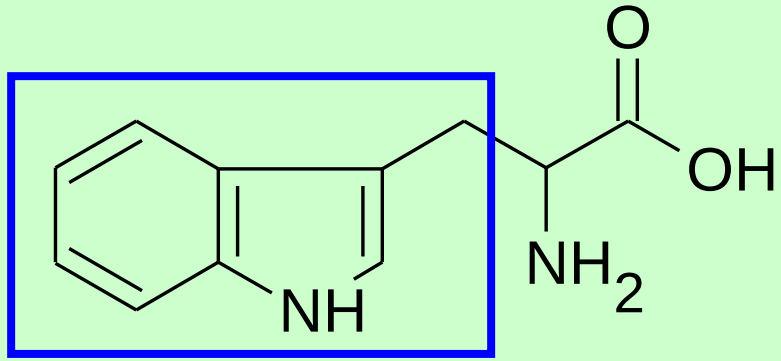
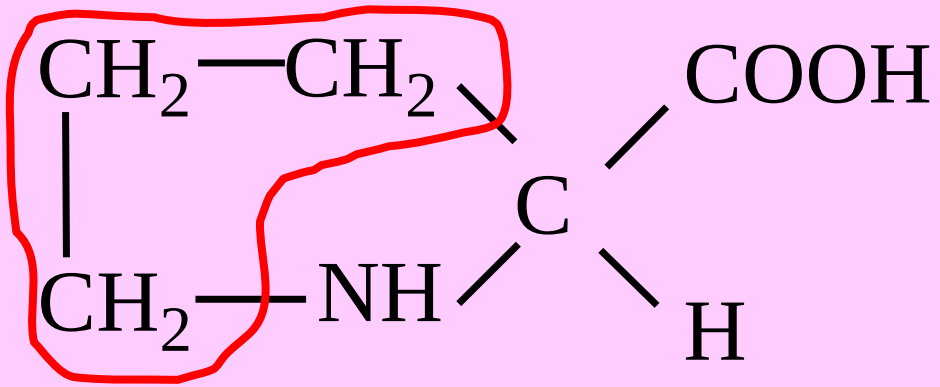
General structure of α-amino acid

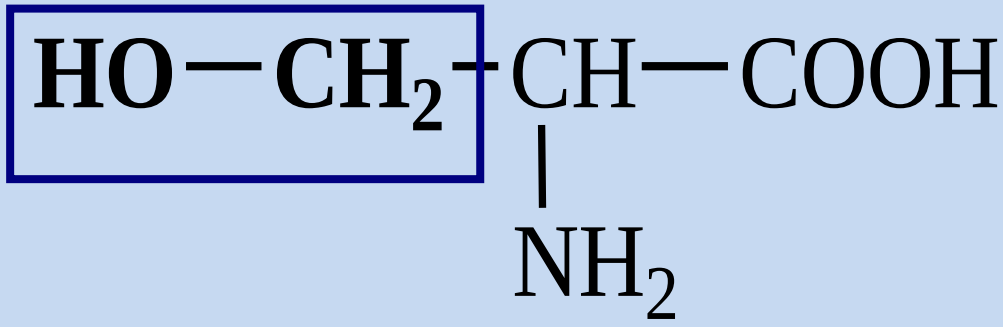
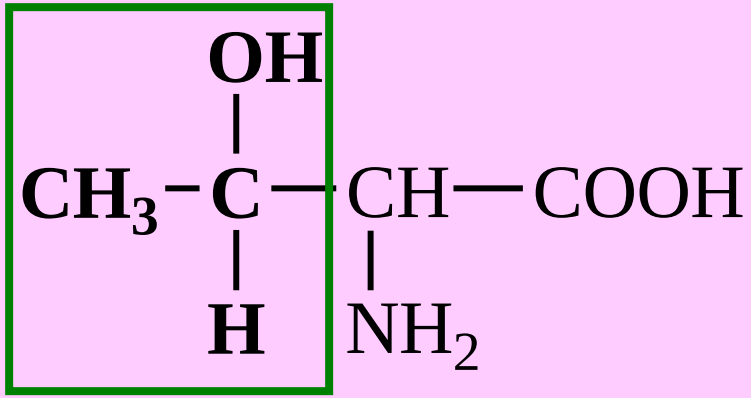
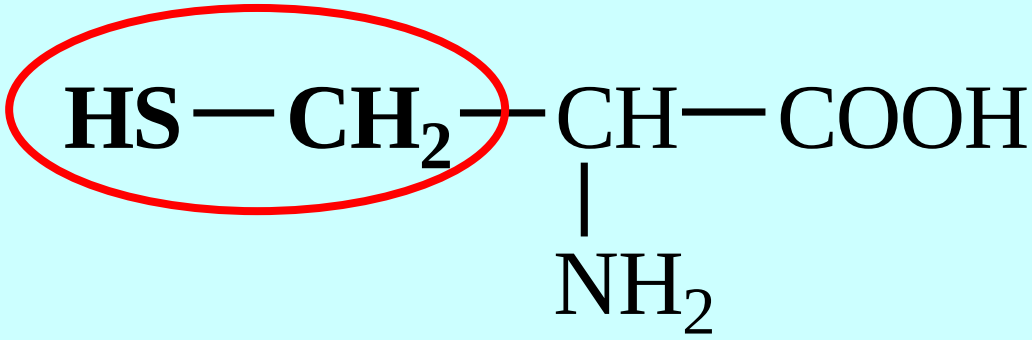


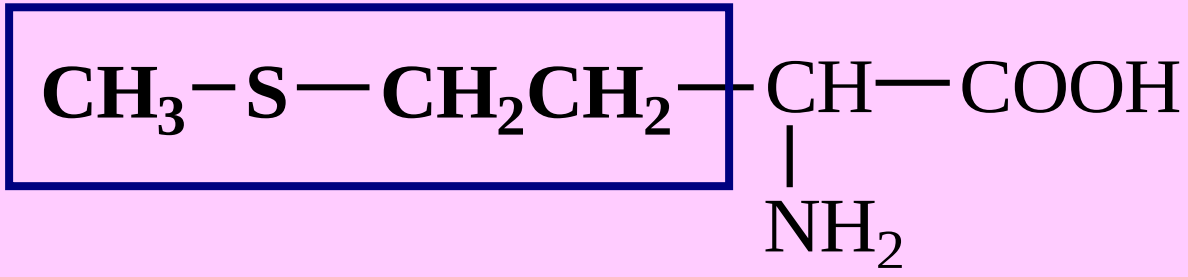
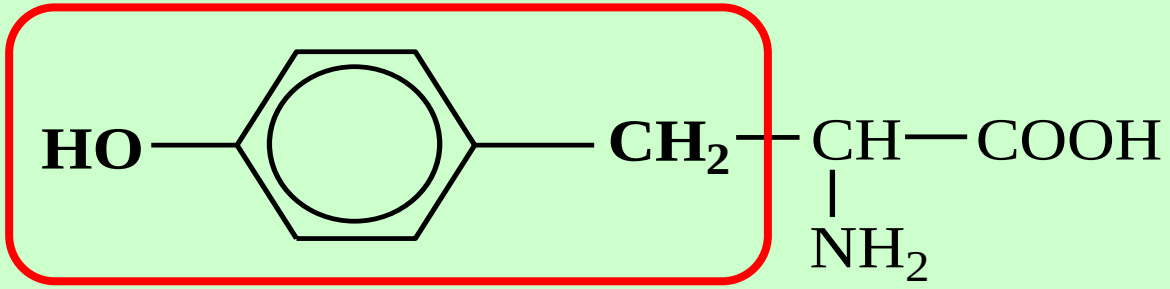
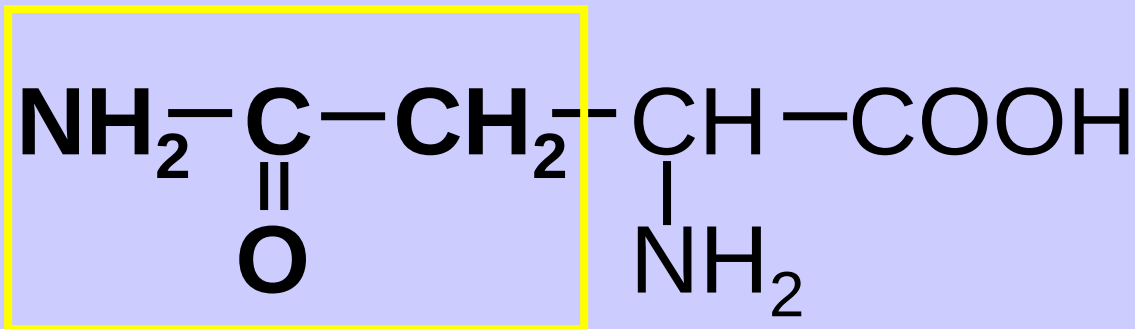
Classification of 20 amino acids in protein.

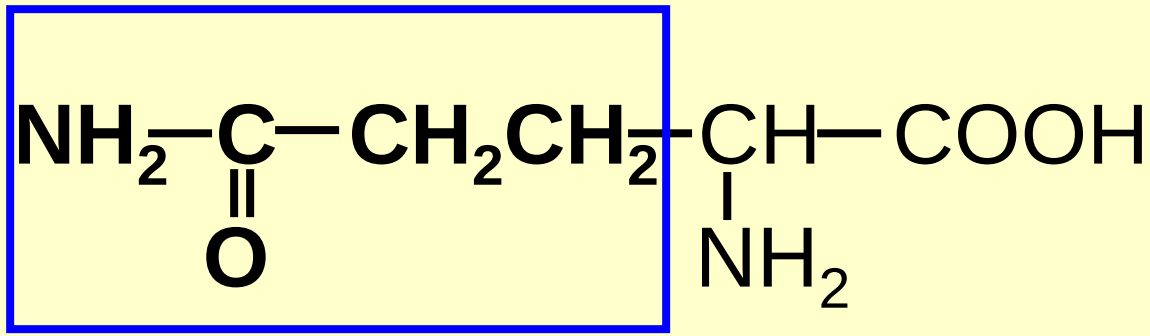
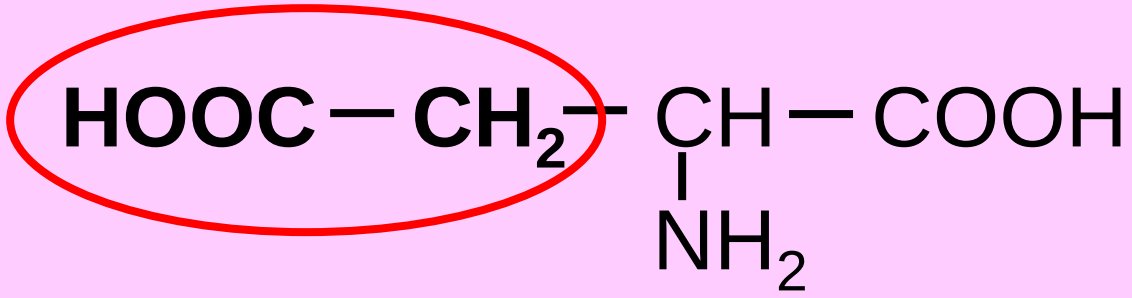
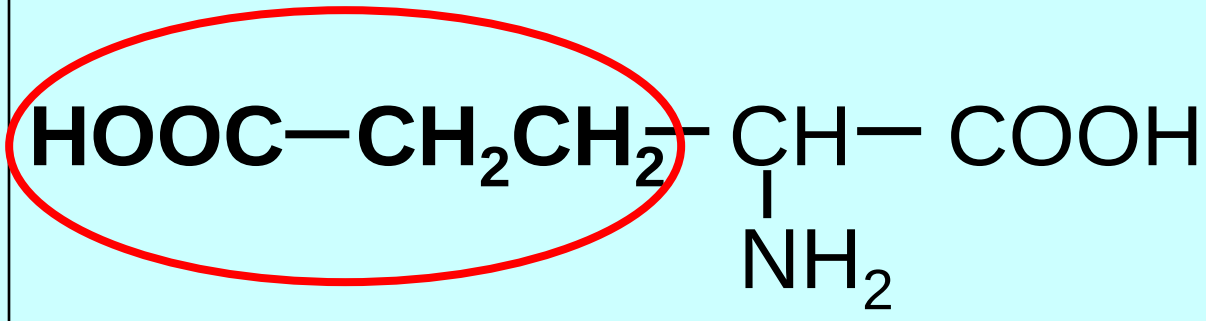
Name	Structure
Glycine (Gly)	
Alanine (Ala)	

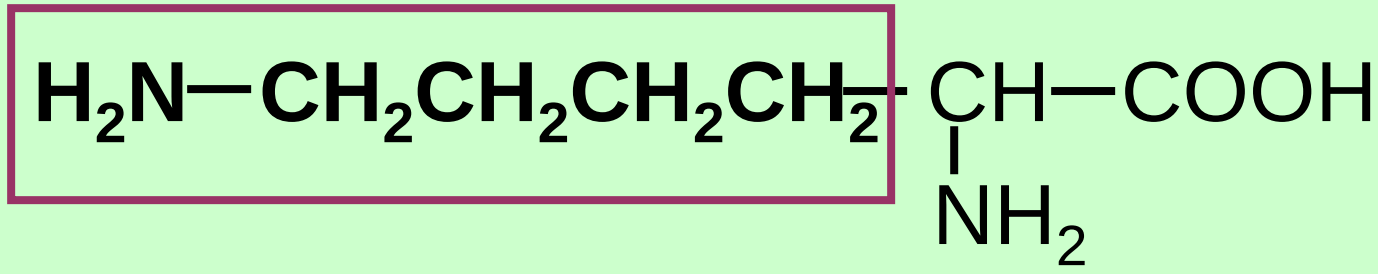
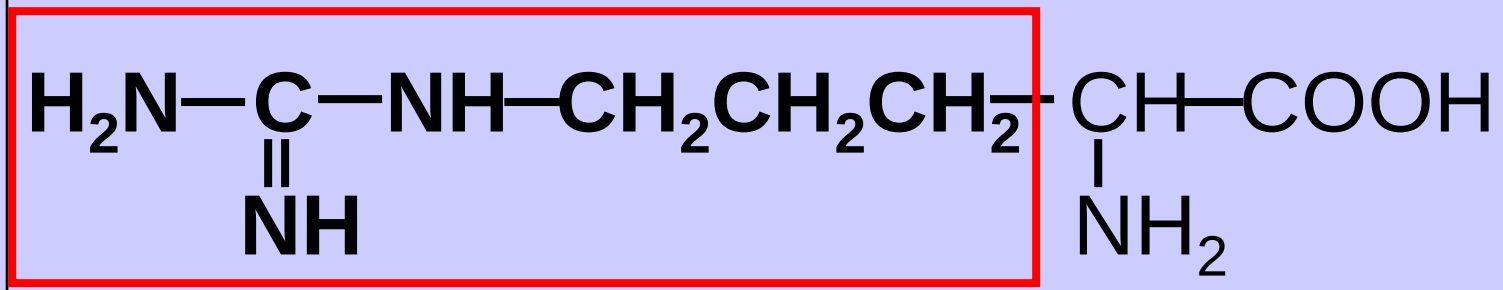
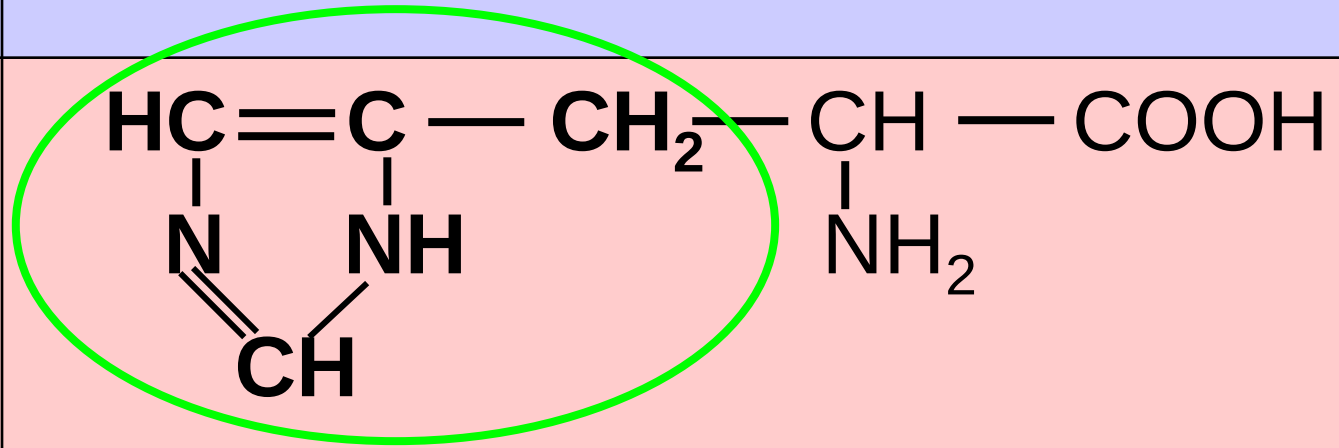
Valine (Val)	
Leucine (Leu)	
Isoleucine (Ile)	

Phenylalanine (Phe)	
Tryptophan (Trp)	
Proline (Pro)	

Serine (Ser)	
Threonine (Thr)	
Cysteine (Cys)	

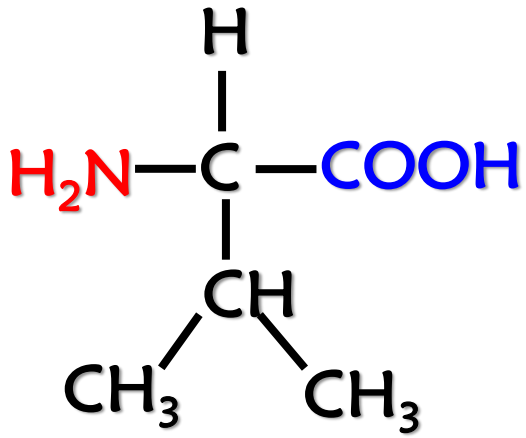
Methionine (Met)	
Tyrosine (Tyr)	
Asparagine (Asn)	

Glutamine (Gln)	
Aspartic acid (Asp)	
Glutamic acid (Glu)	

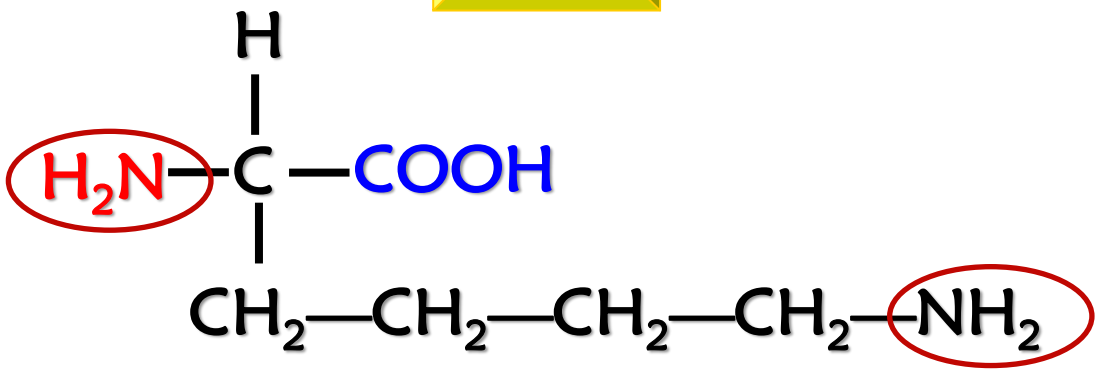
Lysine (Lys)	
Arginine (Arg)	
Histidine (His)	

KEEP IN MIND

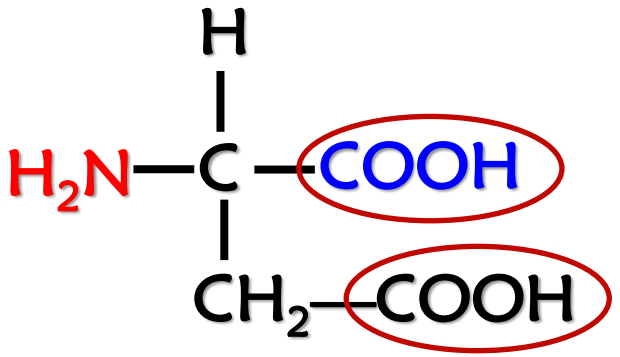
- Amino acids with an additional COOH group in the side chain - acidic amino acids
- Amino acids with an additional N atom in the side chain - basic amino acids
- Others are neutral amino acids



neutral



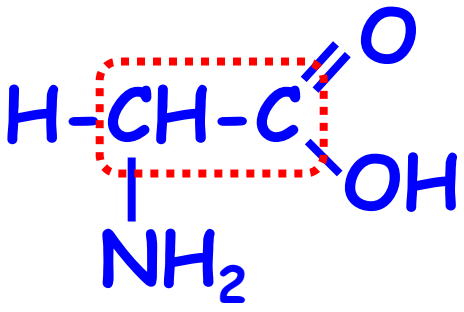
basic



acidic

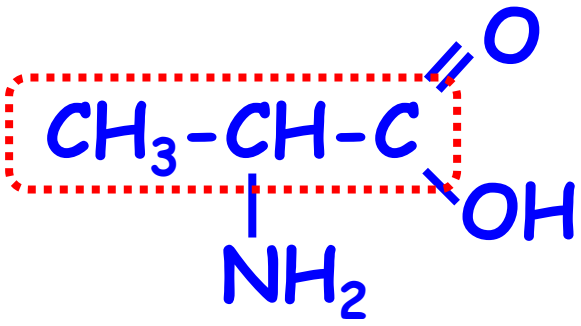
Nomenclature

- The names of α-amino acids given are common names.
- In IUPAC nomenclature, α-amino acids are named as **carboxyl group as the parent name** whereas **amino group as substituent group**.
- However, IUPAC names are not normally used for α-amino acids



aminoethanoic acid

(glycine)

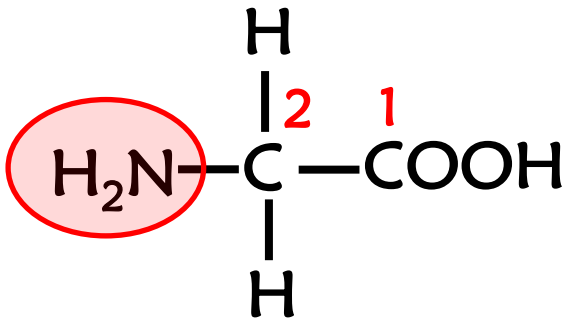


2-aminopropanoic acid

(alanine)

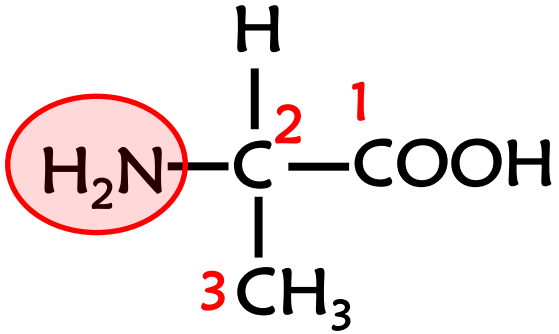
HOW TO NAME THESE AMINO ACID BASED ON IUPAC NOMENCLATURE?

a) glycine



aminoacetic acid / aminoethanoic acid

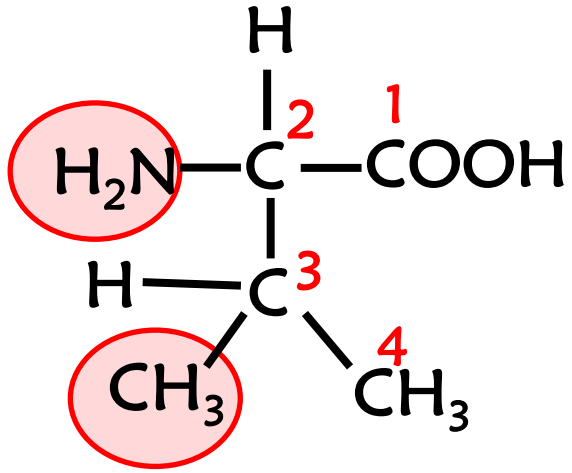
b) alanine



2–aminopropanoic acid

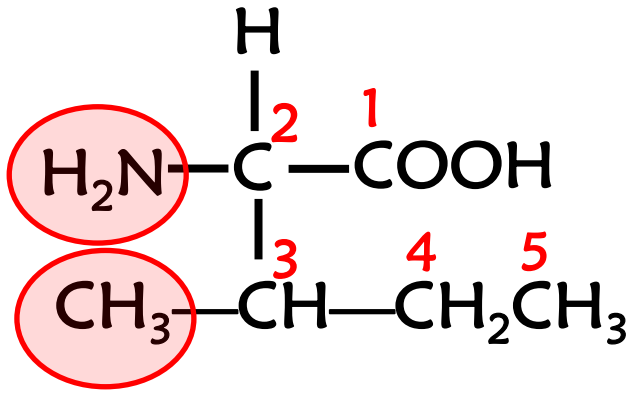
HOW TO NAME THESE AMINO ACID BASED ON IUPAC NOMENCLATURE?

c) valine



2–amino–3–methylbutanoic acid

d) isoleucine



2–amino–3–methypentanoic acid

Physical Properties

- Amino acids are white **crystalline solids** with **high melting points.**
- Amino acids such as glycine and alanine **dissolve in water** to form **neutral solution** but have low solubility in organic solvents.

This unique properties :

- ***High melting points***
- ***High solubility in water*** ***(****but low solubility in organic solvents)*

indicates that **amino acids exists as polar ions.**

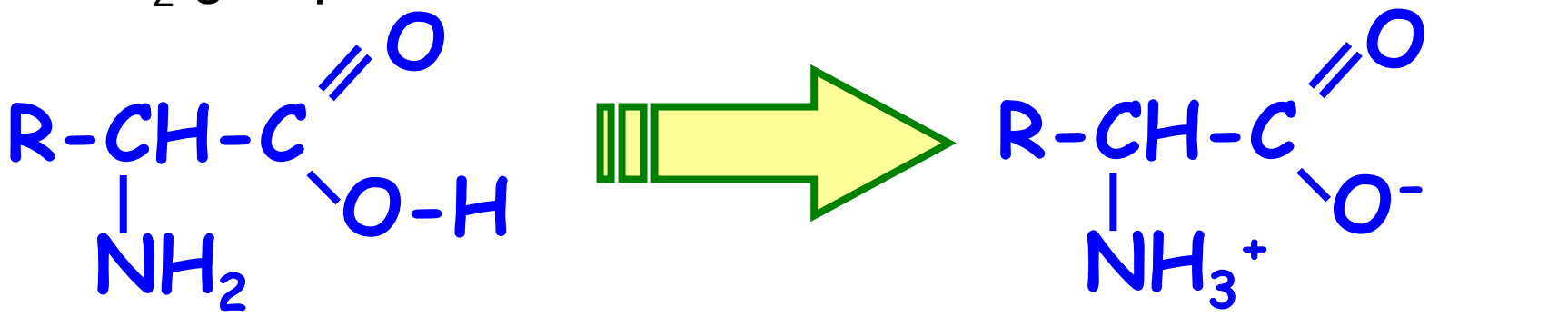
α-Amino acids are **dipolar ions**. The term used for dipolar ion is **zwitterion** .

Remarks!!

Dipolar ions = zwitterion

Zwitterion

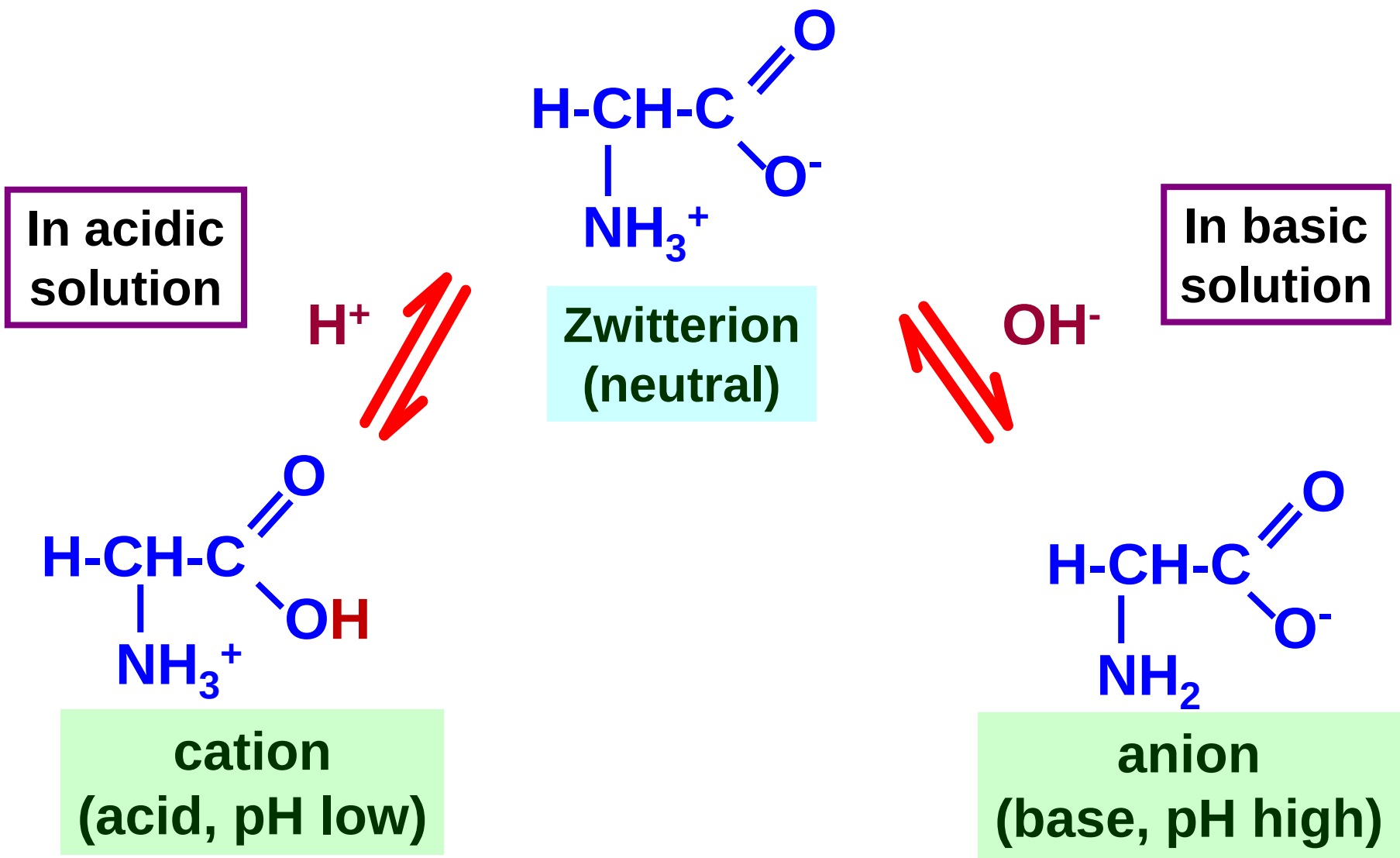
- **Zwitterion** is a molecule with an overall charge of zero which has a **positive charge at one part** and a **negative charge group** at another.
- In **neutral solution** and **in solid state**, amino acids exist as zwitterion.
- A zwitterion formed when a proton from the –COOH group is donated to the $–NH_2$ group of the same molecule.



Uncharge structure **Zwitterion (dipolar ion)**

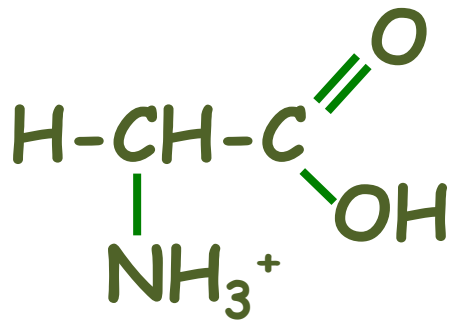
However, the molecules has no net charge

- Neutral amino acids are **amphoteric**.
- It can react as **acid** or **base** depending on the pH of the solution.



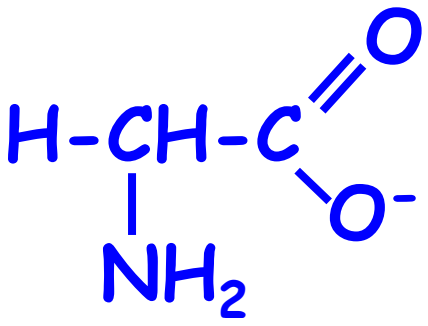
Amino acids can exists in 3 forms depending on the pH of the solution.

In ACIDIC
Cations are predominates



In NEUTRAL
Zwitterions are predominates

In BASIC
Anions are predominates



Isoelectric point, pI

- The pH whereby the concentration of zwitterion is **at maximum** and there is **equal concentration** of both anion and cation.

- At pI, **zwitterion has no net charge**.

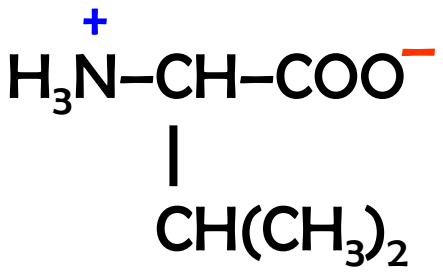
- Each amino acids has its **own specific pI.**

- For example: Alanine
  - ✓ Isoelectric point for Alanine is at pH 6.02
  - ✓ At this pH, Alanine exist as zwitterion

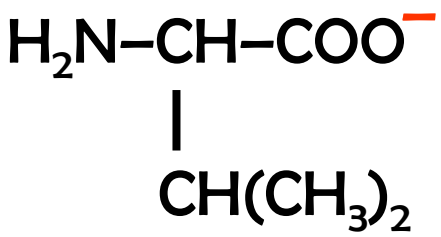
Example :

The isoelectric point of valine, 2-amino-3-methylbutanoic acid is 6.0. Predict the structural formula of valine at

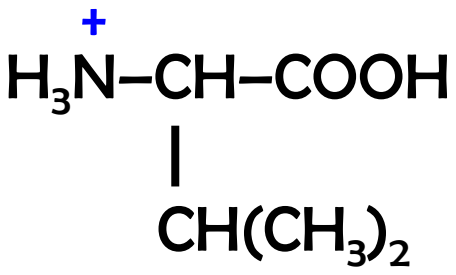
a) Isoelectric point, pI (pH 6)



b) pH 12



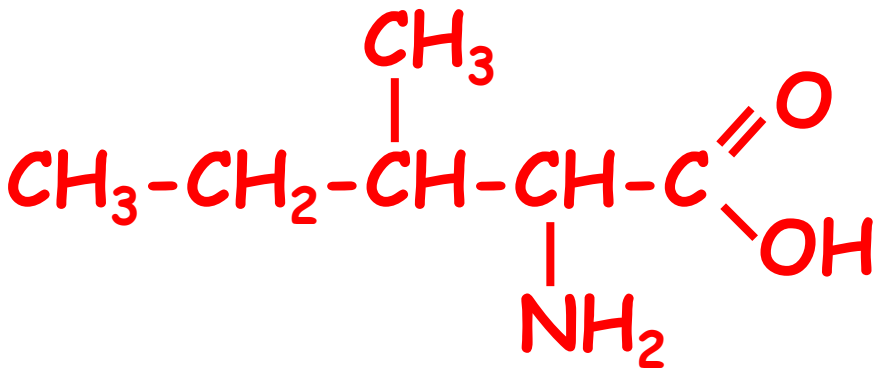
c) pH 1



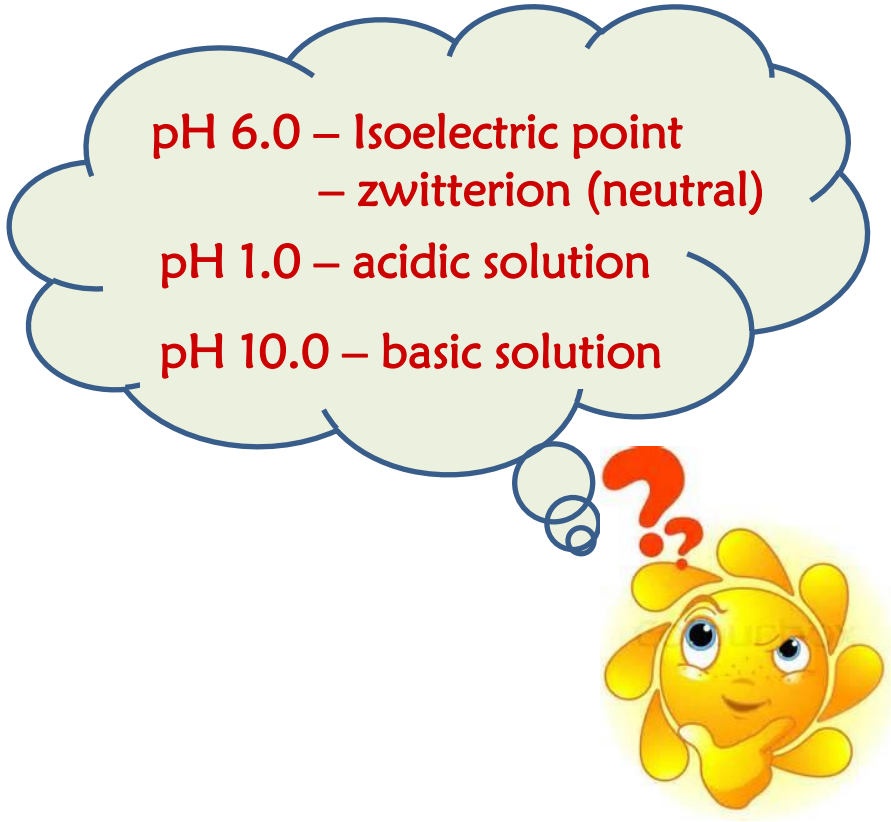
PAST YEARS QUESTIONS:

Isoleucine, 2-amino-3-methylpentanoic acid is a α-amino acid. Its isoelectric point is 6.0. Draw the structural formula of isoleucine at pH 1.0, pH 6.0 and pH 10.0.

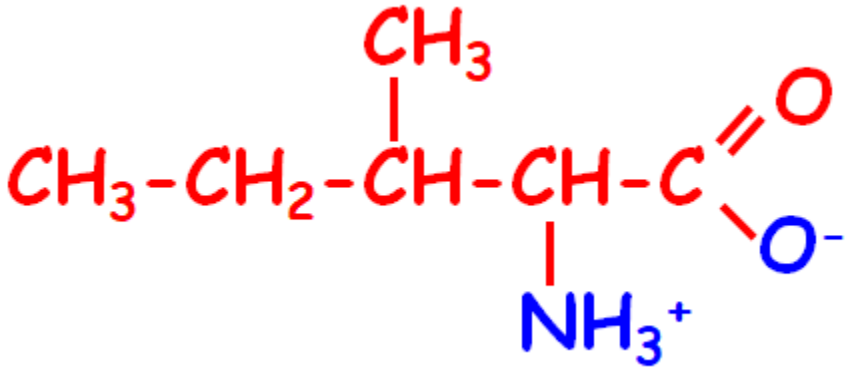
PROBLEM SOLVING:



2-amino-3-methylpentanoic acid

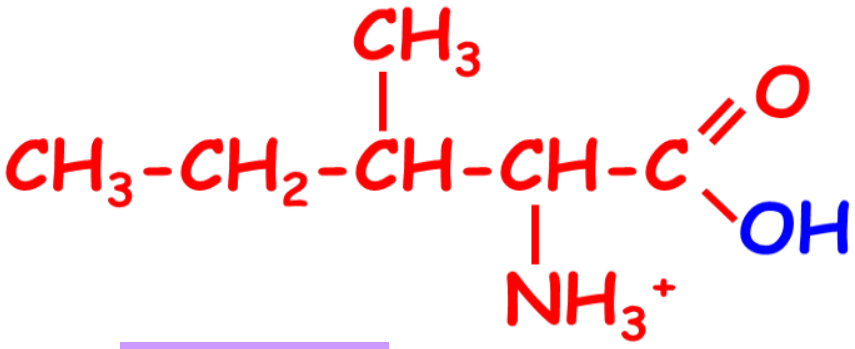


ANSWER:



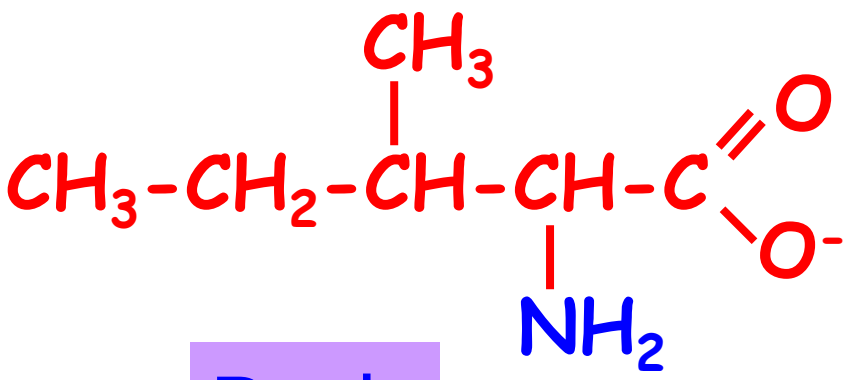
Zwitterion

pH 6.0



Acidic

pH 1.0



Basic

pH 10.0

12.2 : CHEMICAL PROPERTIES

Students should be able to:

a) Explain the reaction of amino acid with:
   i. hydrochloric acid
   ii. sodium hydroxide
   iii. nitrous acid
   iv. alcohols in the presence of an acid catalyst. (C3)

b) Explain the formation of peptide bond in dipeptides. (C3)

12.2: CHEMICAL PROPERTIES

Since amino acid have both **acidic (–COOH)** and **basic ($–NH_2$)** functional group, amino acids will undergo 2 main types of chemical reactions:

1. Reactions characteristic of the amino group

- ☑ Reaction with HCl
- ☑ Reaction with nitrous acid (HNO_2)

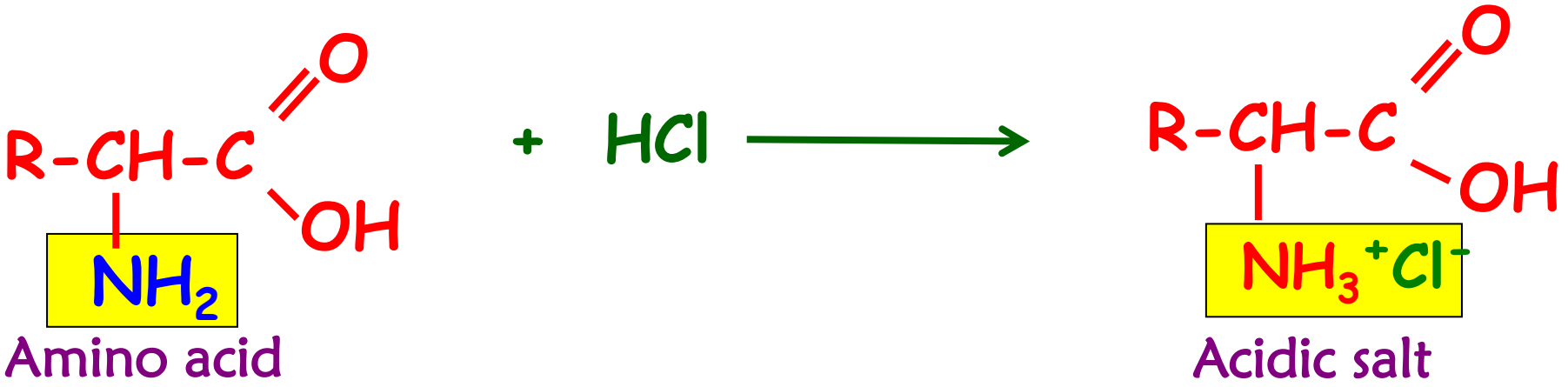
2. Reactions characteristic of the carboxyl group

- ☑ Reaction with NaOH
- ☑ Reaction with alcohols in the presence of an acid catalyst (esterification)

Reaction of amino group (-NH_2)

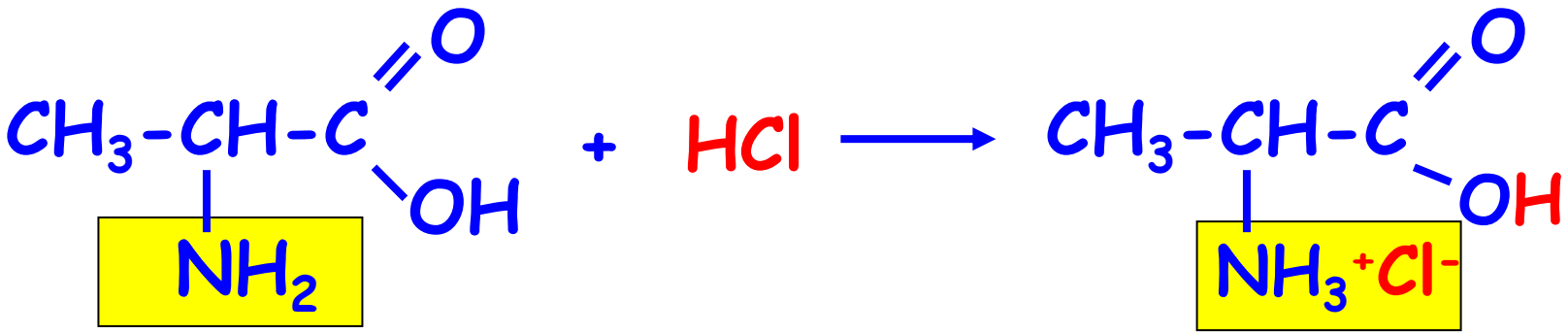
1 Reaction with HCl

- Amino group is basic, so it react with HCl to form salt.
- General equation:



Example:

Reaction of Alanine with HCl



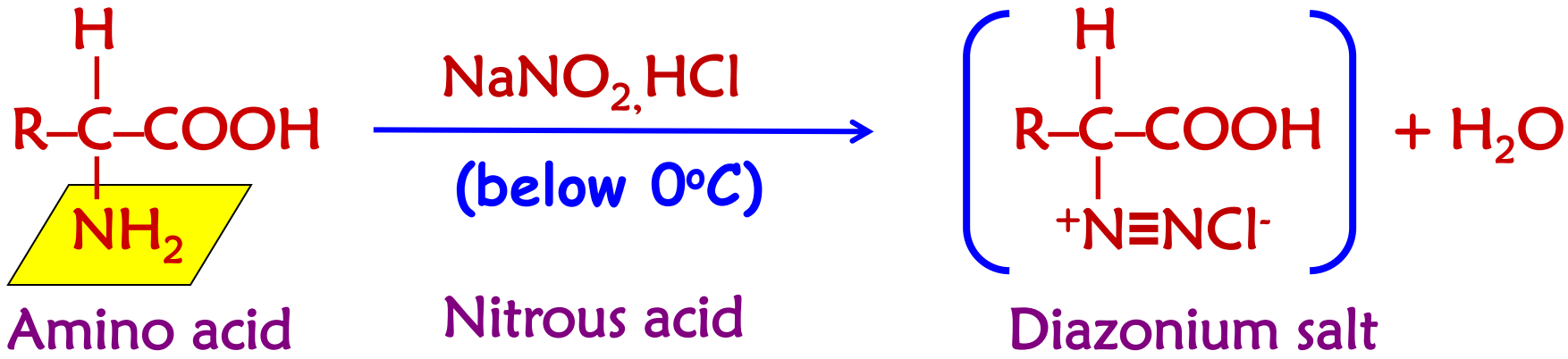
Alanine

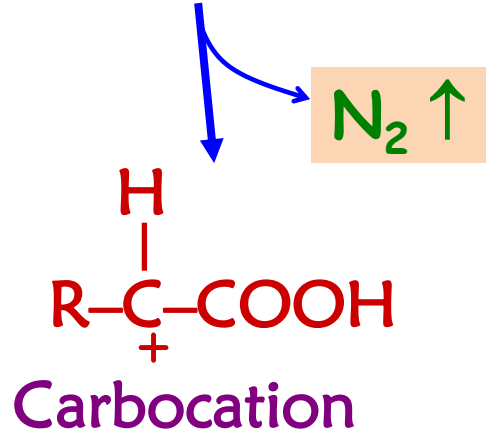
② Reaction with Nitrous Acid (HNO_2)

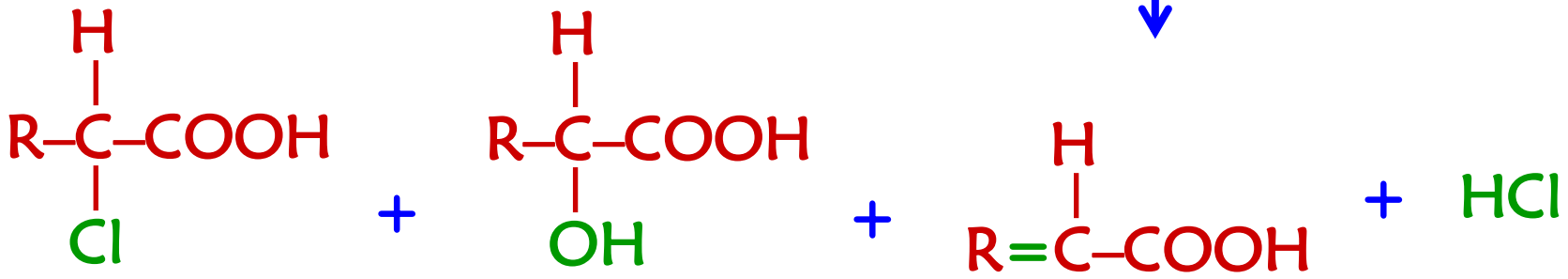
- Nitrous acid are prepared ***in situ*** from **$NaNO_2$ + HCl**
- Amino group react with HNO_2 at 0^oC to form **diazonium salt** as intermediate product
- This salt decompose easily by losing N_2 to form **carbocation.**
- The carbocation react with nucleophile to form a mixture of products such as alcohol, alkene, haloalkanes and HCl

Same reaction that we learn in 1^o aliphatic amine with nitrous acid

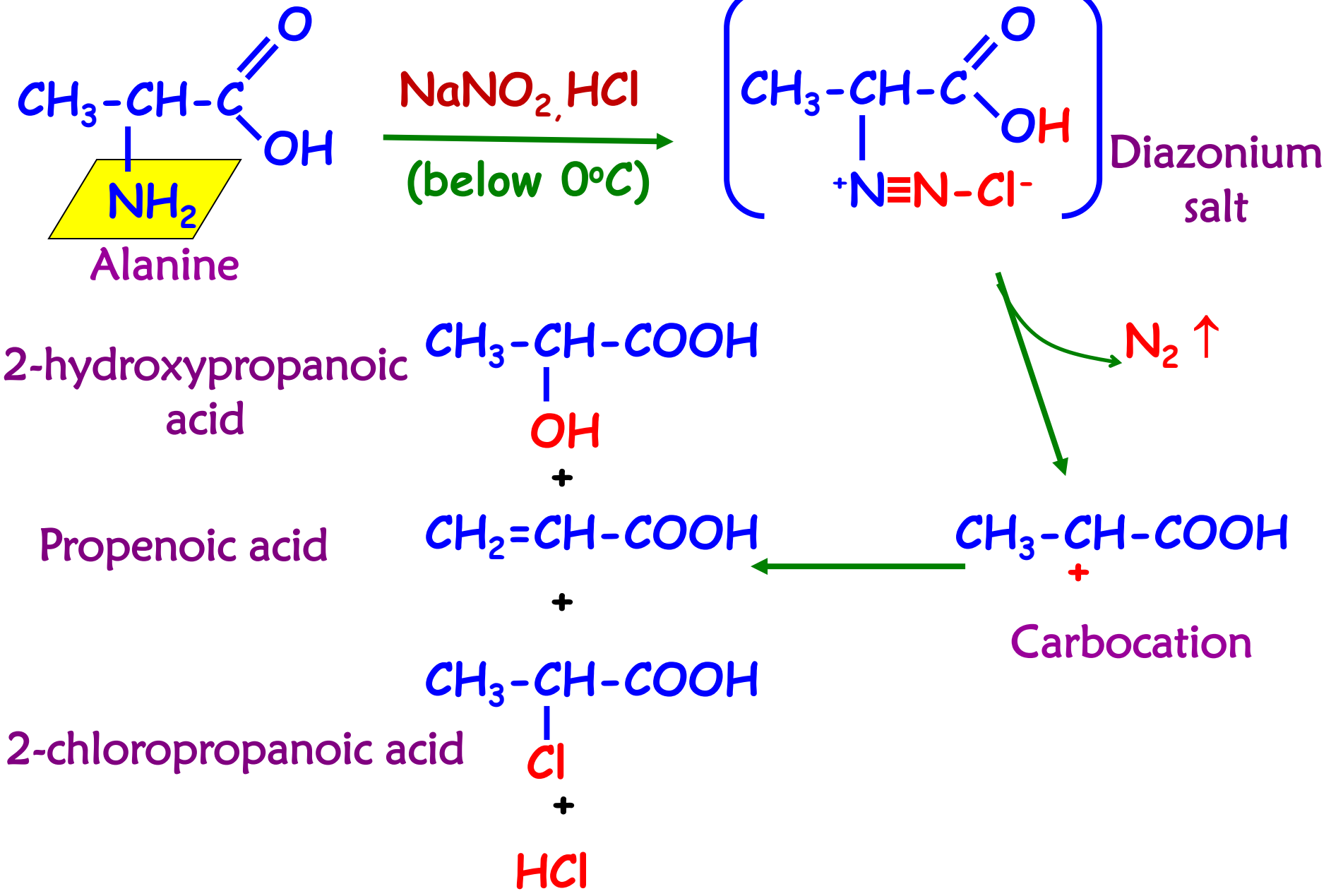
- General Equation:







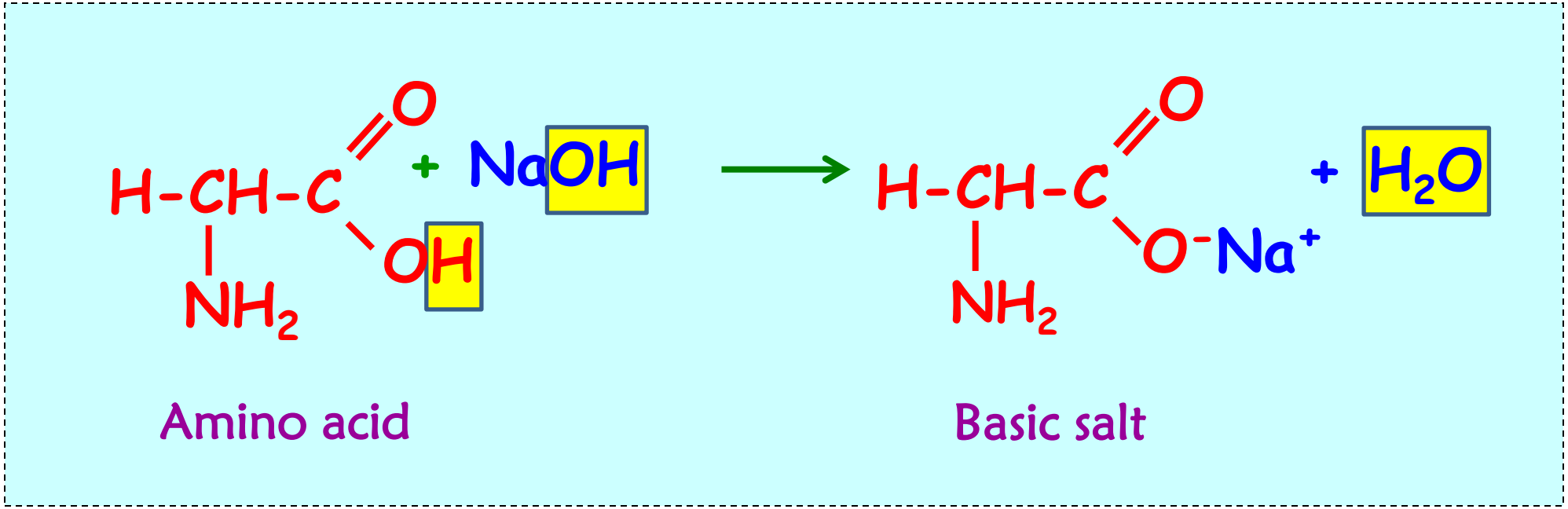
Example: Alanine



Reaction of Carboxyl group (-COOH)

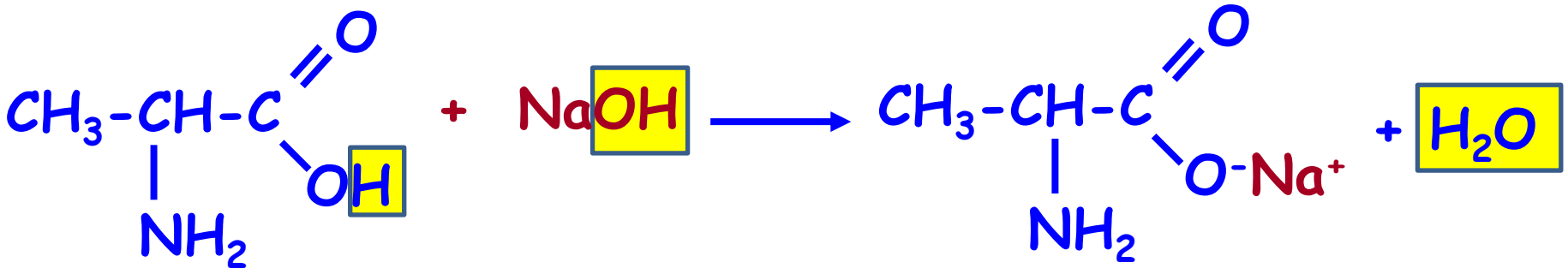
① Reaction with Sodium Hydroxide (NaOH)

- Carboxyl group is acidic, so it react with NaOH to form salt.
- **General equation:**



Example:

Reaction of Alanine with NaOH



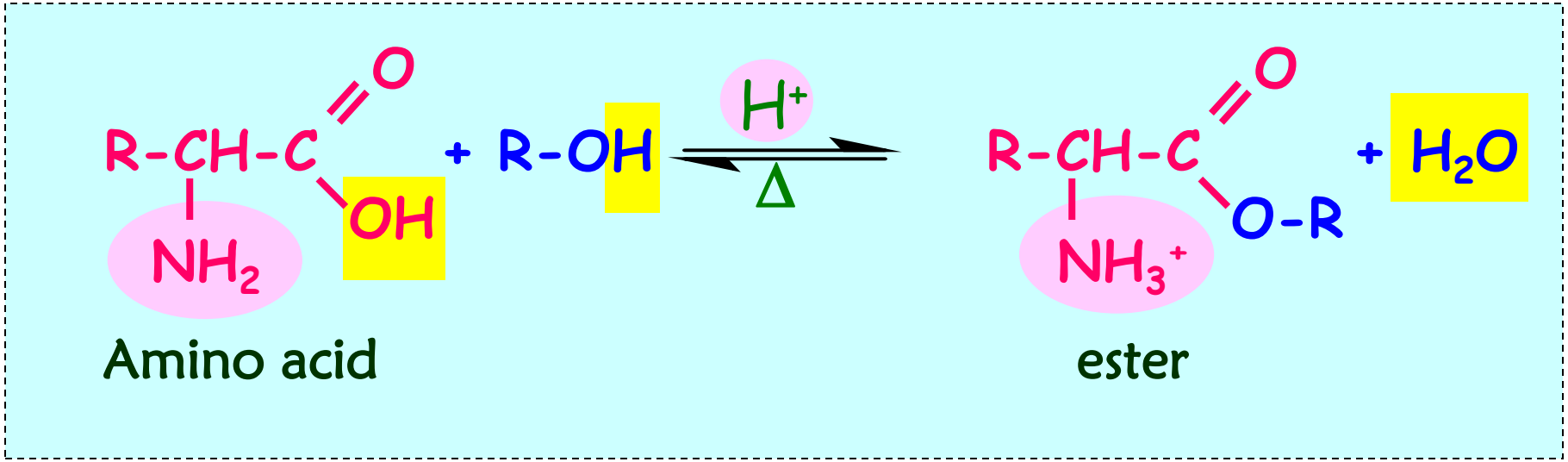
2-aminopropanoic acid

sodium 2-aminopropanoic acid

② Reaction with alcohol (esterification)

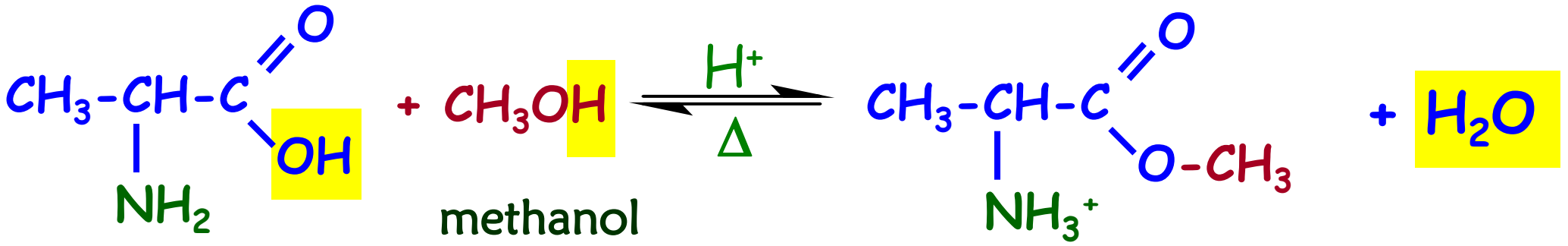
- Amino acid reacts with alcohol in presence of an acid (normally HCl/H_2SO_4) as a catalyst to form ester and water

- **General equation:**



Example:

Alanine reacts with methanol in presence of HCl



2-aminopropanoic acid

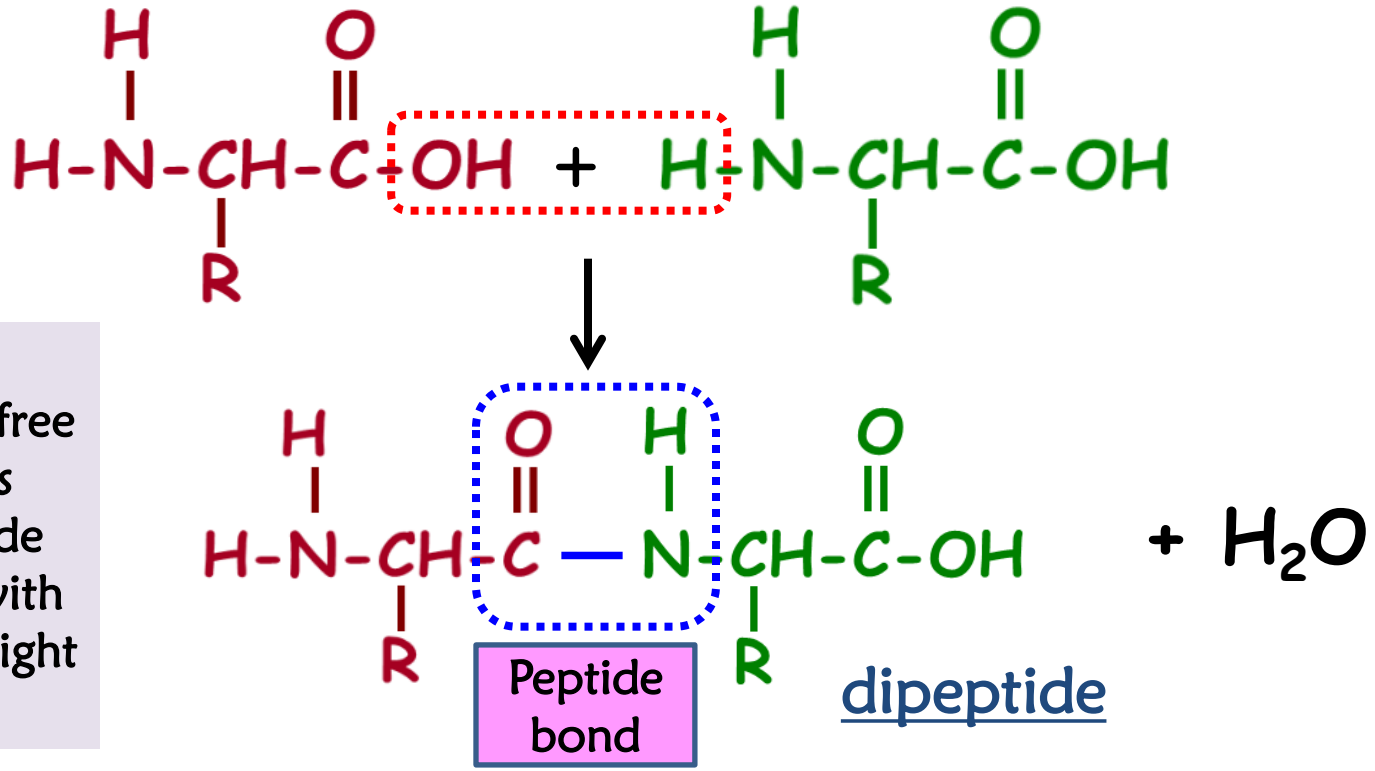
methanol

ester

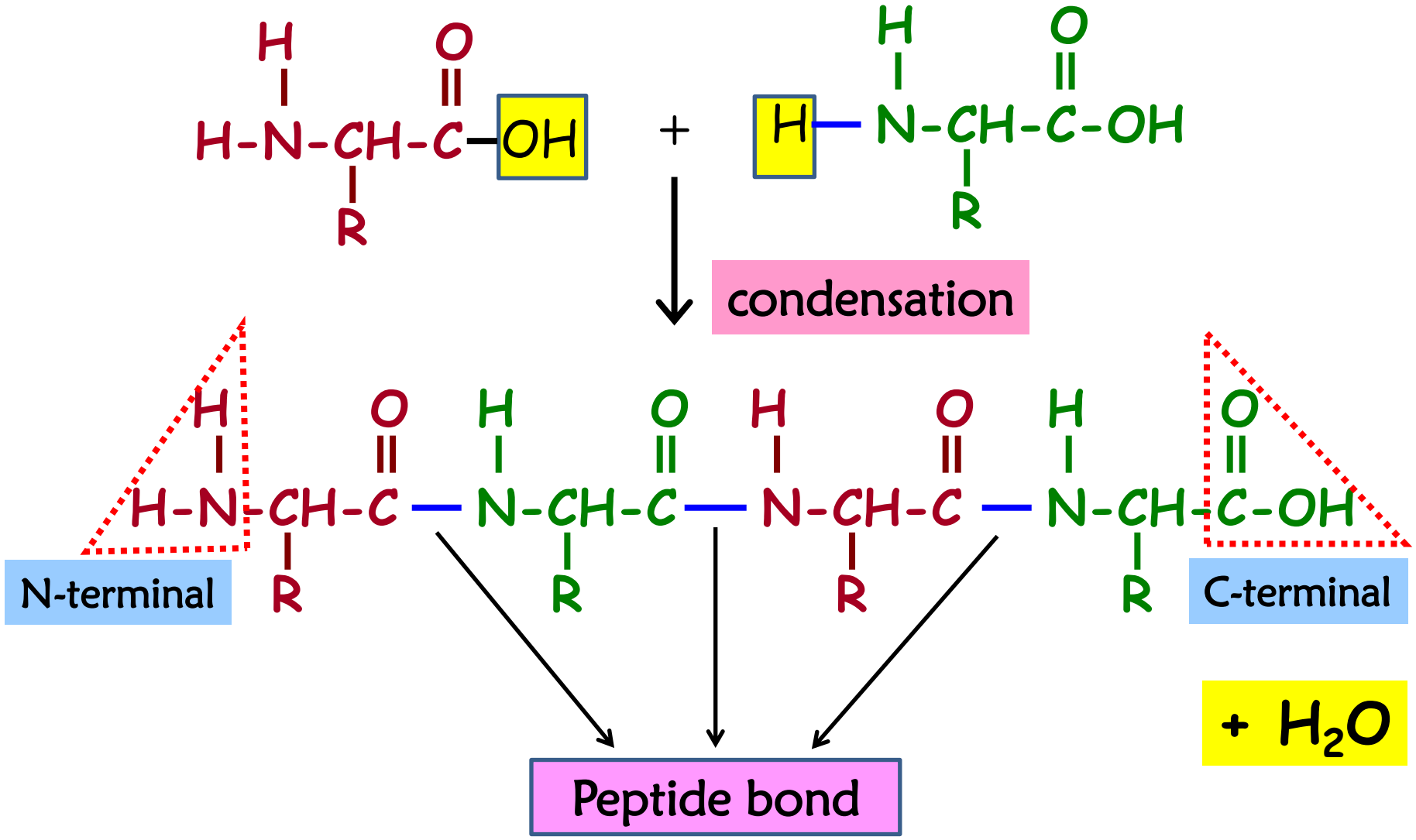
Formation of peptide bonds

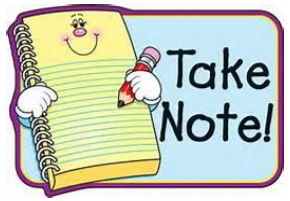
- **Peptide bond** is a linkage between two amino acid residue.

- When 2 amino acids react together, H_2O is eliminated, and a compound formed is known as **dipeptide**



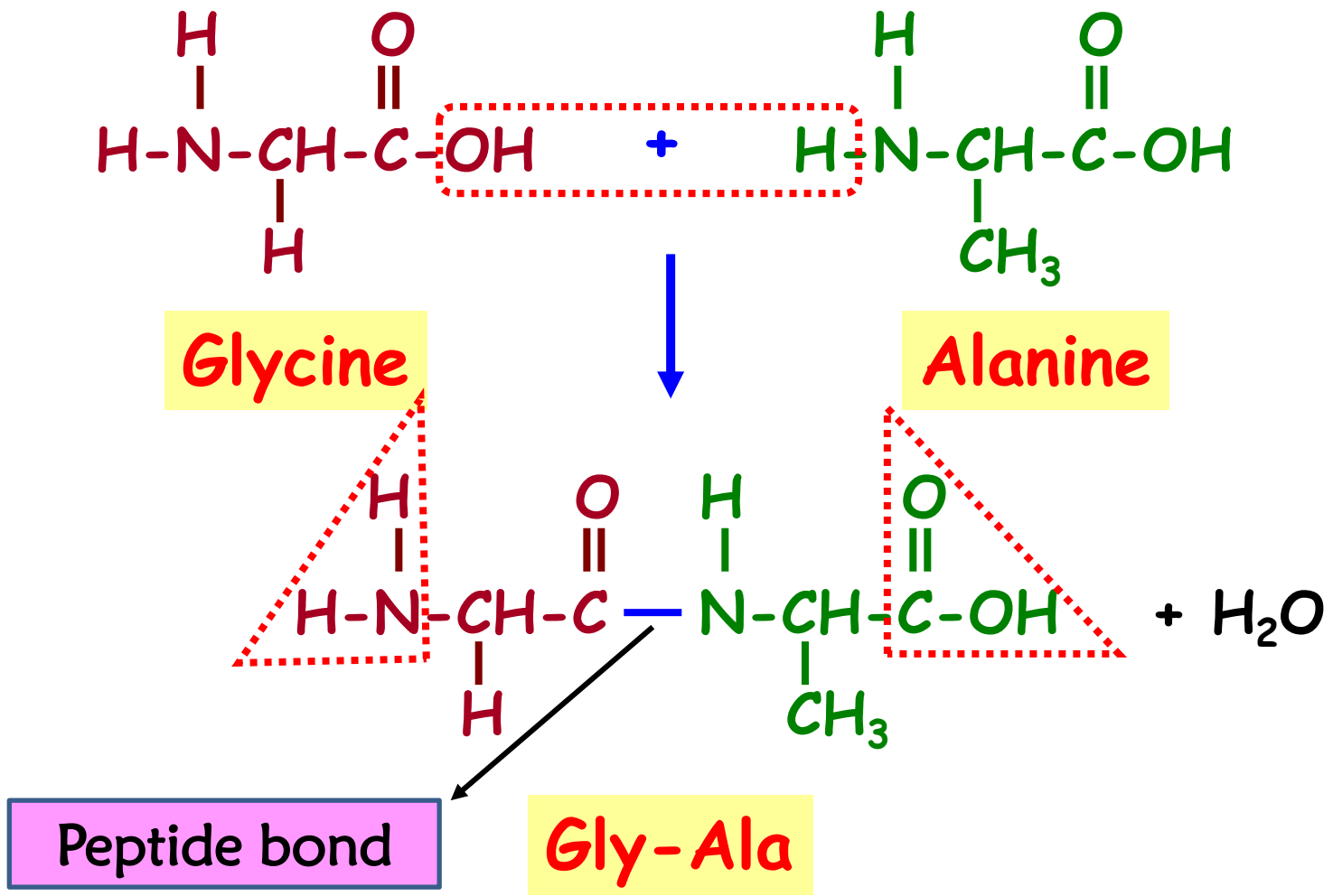
NOTES:
N- terminal (with free $-NH_2$) is always written on left side and C-terminal (with free –COOH) on right side

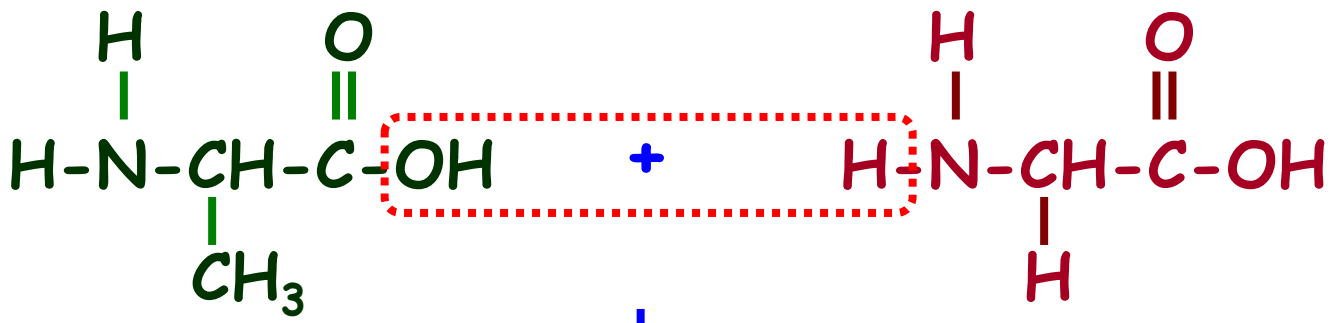

condensation
N-terminal
C-terminal
Peptide bond
+ H2O



- 2 amino acids = **dipeptide**
- 3 amino acids = **tripeptide**
- 15-30 amino acids = **oligopeptide**
- > 30 amino acids = **polypeptide**

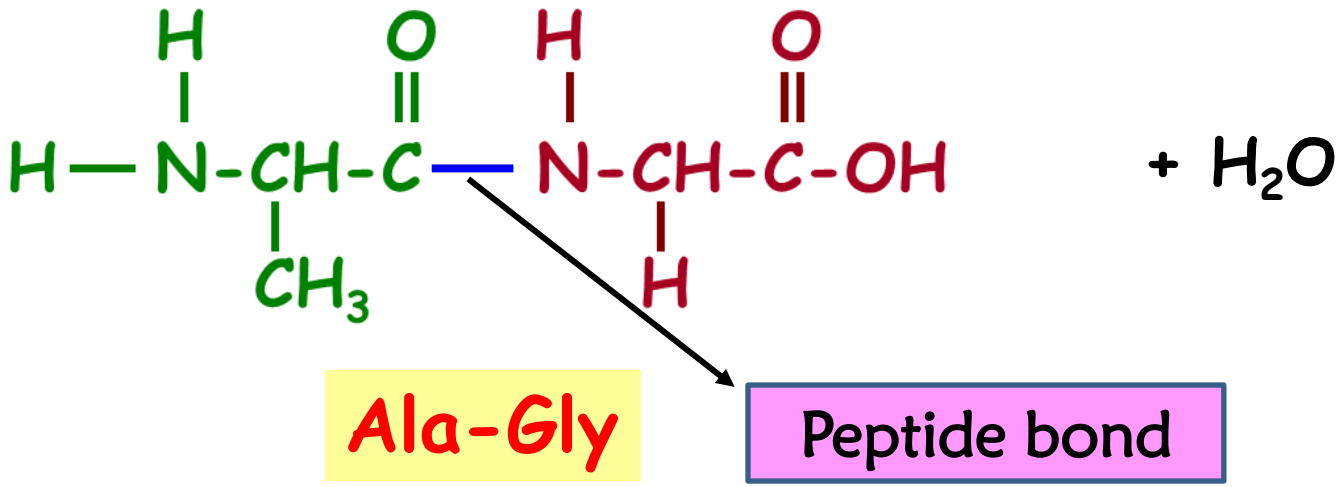
- Example: Formation of two dipeptides from Glycine (Gly) and Alanine (Ala)
- The name of the dipeptides are glycylalanine (Gly-Ala) and alanylglycine (Ala-Gly)





Alanine

Glycine

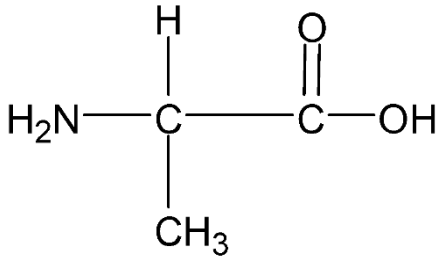


Ala-Gly

Peptide bond

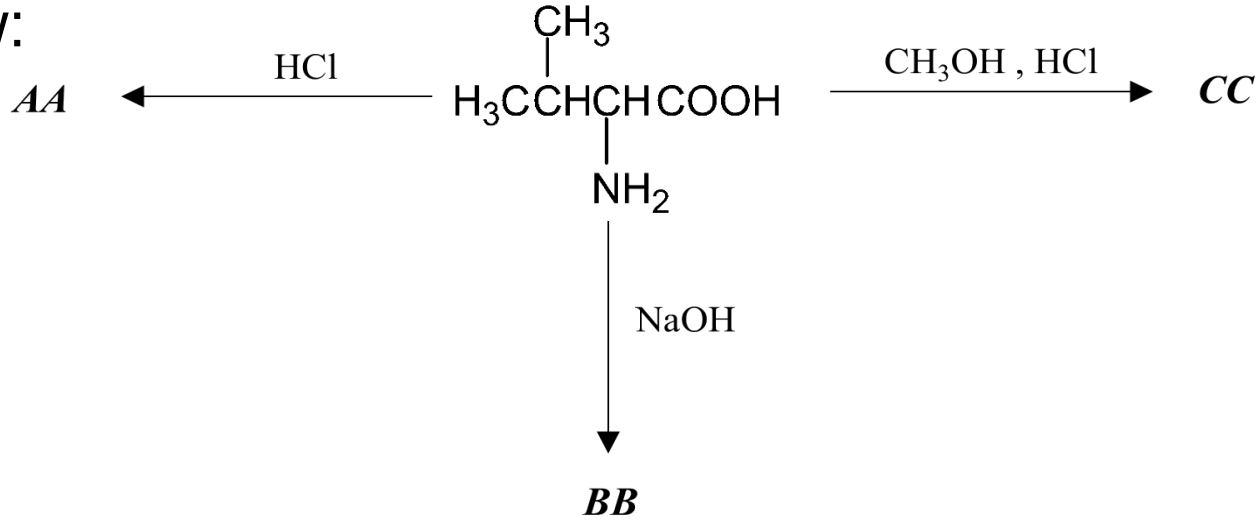
Exercise:

(a) The structure of Alanine is given as below:



Draw the structure of Alanine as zwitterion. [1 mark]

(b) Reaction of valine with several reagents are shown below:



Draw the structures of products **AA**, **BB** and **CC**. [3 marks]