Organic Molecules

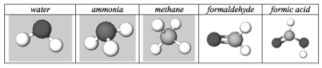
Functional Groups
Amino Acids - Proteins

Dr. Ron Rusay

https://www.youtube.com/watch?v=tJtAw61bzsM

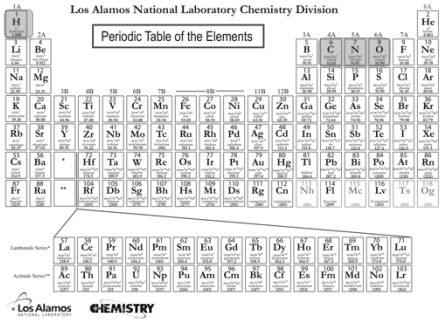
https://www.youtube.com/watch?v=qBRFIMcxZNM

Small Organic Molecules

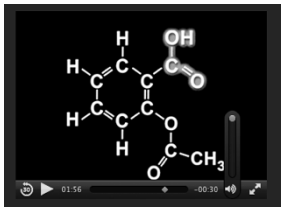


Water, Ammonia, Methane
molecular building blocks

Elemental building blocks for all organic molecules



Representing Organic Molecules

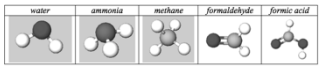


http://chemconnections.org/general/movies/Representations.MOV

Small Organic Molecules

Common Functional Groups

Name	General Formula
Alcohols	R−OH
Ethers	R−O−R′
Amines	$R-NH_2$
Carboxylic Acids	R-C(=O)-OH



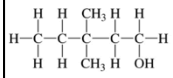
Small Organic Molecules

Common Functional Groups

Name	General Formula
Aldehydes	R-C(=O)-H
Ketones	R-C(=O)-R'
Carboxylic Acids	R-C(=O)-OH
Esters	R-C(=O)-OR'
Amides	R-C(=O)-N(R")R'

Organic Formulas: Kekulé / Condensed / Bond-Line Structures / Drawings

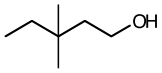
Molecular formula: $C_7H_{16}O$



Empirical Formula: $C_7H_{16}O$

$CH_3CH_2C(CH_3)_2CH_2CH_2OH$ or $CH_3CH_2\underset{\displaystyle CH_3}{\overset{\displaystyle CH_3}{C}}CH_2CH_2OH$

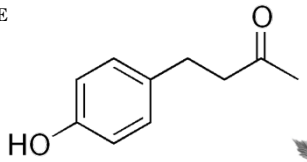
Bond-Line Structure:



QUESTION

A compound that smells like fresh raspberries, the following structure, $C_2H_2O_2$, matches its calculated molar mass which is 164 g/mol.

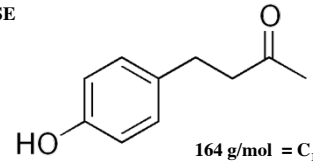
A) TRUE
B) FALSE



ANSWER

Based on your answers for the compound, which smells like fresh raspberries, in the previous two questions, the following structure matches its molecular formula.

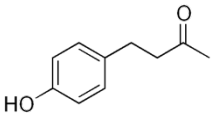
A) TRUE
B) FALSE



164 g/mol = $C_{10}H_{12}O_2$

QUESTION

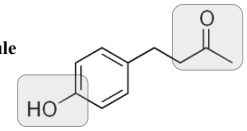
Select the function(s) in the molecule



	Alcohol	R−OH
	Ether	R−O−R′
	Amine	$R-NH_2$
	Aldehyde	
	Ketone	
	Carboxylic Acid	
	Ester	
	Amide	

Answer

Select the function(s) in the molecule



X	Alcohol	R−OH
	Ether	R−O−R′
	Amine	$R-NH_2$
	Aldehyde	
X	Ketone	
	Carboxylic Acid	
	Ester	
	Amide	

Large Organic Macromolecules

Genetics & Biological Polymers

RNA/DNA

Proteins/ Enzymes

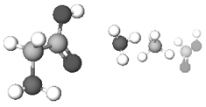
How are proteins & RNA/DNA related?
Amino Acids

https://www.youtube.com/watch?v=JQZQiEdOPJY

Amino Acids

Legos of Chemical Biology

Amino acids contain carbon, hydrogen, oxygen, and nitrogen, which resemble the following shapes & structural components



•20 different amino acids are encoded by the genetic code, which is archived in DNA.

•Hundreds of amino acids link together with amide (peptide) bonds to form proteins, which are the machinery for the chemistry of life.

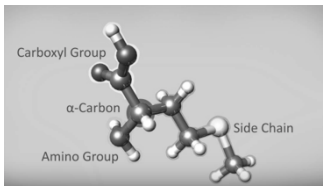
•There are less than 20,000 total proteins produced from humans' entire genome, each coded by a specific gene in DNA's ~3 billion genetic bases.

http://chem.libretexts.org/LibreTexts/Diablo_Valley_College/DVC_Chem_106%3A_Rusay/Amino_Acids

Amino Acids

Legos of Chemical Biology

Amino acid structural components can be divided into four parts that are illustrated below. Only the side chain varies among the alpha (α-) amino acids.

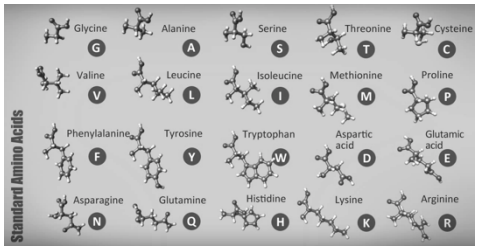


http://chem.libretexts.org/LibreTexts/Diablo_Valley_College/DVC_Chem_106%3A_Rusay/Amino_Acids

Amino Acids

Legos of Chemical Biology

All amino acids contain C, H, O, and N; two, C & M. also have sulfur.

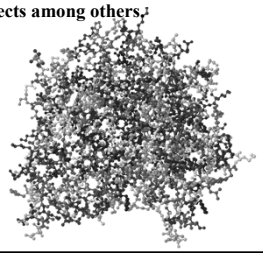


http://chem.libretexts.org/LibreTexts/Diablo_Valley_College/DVC_Chem_106%3A_Rusay/Amino_Acids

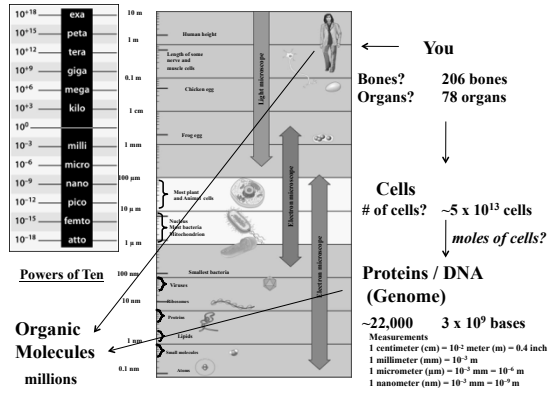
Proteins: Macromolecular Biopolymers

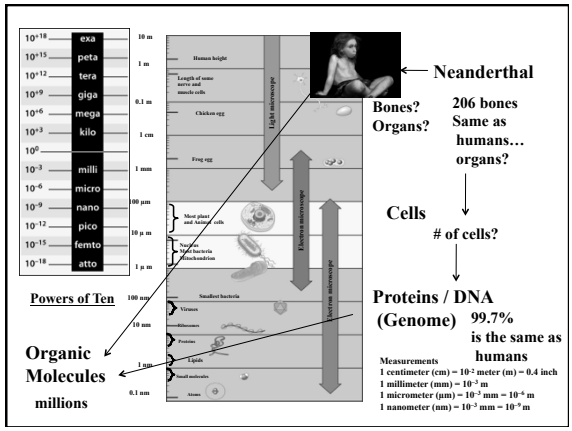
Acetylcholinesterase (ACE)

***ACE*, an enzyme, which catalyzes a key reaction in a repetitive biochemical cycle that is crucial to neurological and physiological functions in humans…. and insects among others.**



4,496 atoms;
4,404 bonds
574 amino acid residues

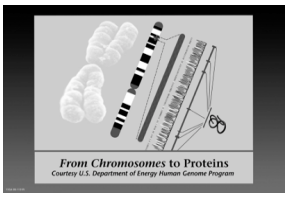


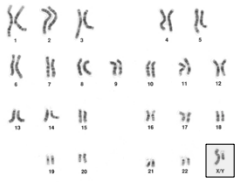


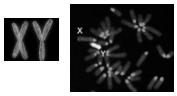
Genetic Controls

Chromosomes (DNA/RNA)

https://ghr.nlm.nih.gov/primer/basics/howmanychromosomes



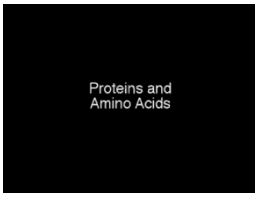


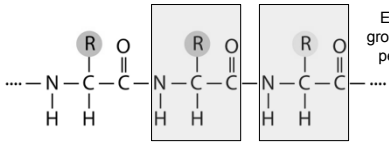


Male or female?

Amino Acids & Proteins

http://chemconnections.org/general/movies/Proteins-amino-acids.mov





Each amide group is called a peptide bond

Proteins (bio-polymers):

Polypeptides, Amides and Proteins

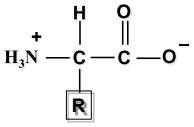
- **Proteins are polyamides, each amide group is called a peptide bond.**
- **Peptides are formed by condensation of the -COOH group of one amino acid and the $–NH_2$ group of another amino acid.**

The 20 Key Amino Acids (22 with Archaea)

- **Amino acids are compounds that contain a basic $—NH_2$ amine group and an acidic $—CO_2H$ carboxylic acid group.**
- **More than 700 amino acids occur naturally, but 20 (22?)of them are especially important.**
- **These 22 amino acids are the building blocks of proteins. All are α-amino acids.**
- **They differ in respect to the group attached to the α carbon.**

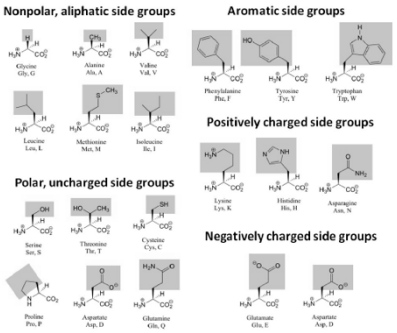
Amino Acids:

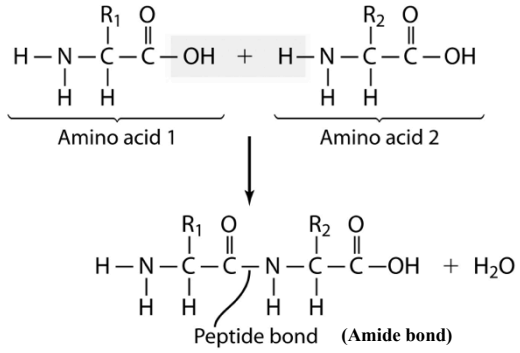
The basic amino group and acidic carboxylic acid group are actually present as $—NH_3^+$ and $—CO_2^-$ respectively.



- **The amino acids in proteins differ in respect to R ("the side chain").**
- **The physical & chemical properties of the amino acid vary as the structure of R varies.**

The 20 Amino Acids in Animals/Humans





Proteins (Polypeptides)

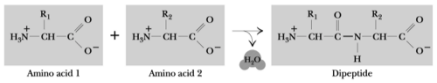
Polypeptides

- **Polypeptides are formed with a large number of amino acids (usually result in proteins with molecular weights between 6000 and 50 million amu).**

Protein Structure

- **Primary structure is the sequence of the amino acids in the protein.**
- **A change in one amino acid can alter the biochemical behavior of the protein. *Eg. Sickle Cell Anemia***

Proteins are Polymers of Amino Acids

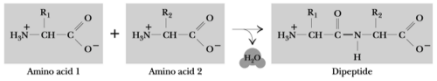


- **Peptides have various numbers of amino acids.**
- **Peptides are always written with the -NH_2 terminus on the left, -CO_2H on the right.**
- **Each amino acid unit is called a residue.**
- **2 residues = dipeptide,**
- **3 residues = tripeptide,**
- **12-20 residues = oligopeptide,**
- **Many residues = polypeptide.**

QUESTION

Proteins are made when amino acids form peptide bonds to link together. Which of the following contains the correct number and type of atoms that are necessary to define a peptide bond?

A. One carbon, two oxygen, one nitrogen
B. Two carbons, one oxygen, one nitrogen, one hydrogen
C. One carbon, two oxygen, one nitrogen, two hydrogen
D. One carbon, one oxygen, one nitrogen, one hydrogen



ANSWER

D

The carbon will contain a double bond to oxygen, a single bond to nitrogen that will also have a single bond to a hydrogen atom. Although not directly part of the peptide linkage, the carbon will have a single bond to some other atom as will the nitrogen atom.

Four Levels of Protein Structure

- **1º : (Primary) The linear sequence of amino acids and disulfide bonds. eg. ARDV:Ala-Arg-Asp-Val.**
- **2º : (Secondary) Local structures which include, folds, turns, ∝-helices and β -sheets held in place by hydrogen bonds. eg. hair curls, silk, denaturing egg albumin**
- **3º : (Tertiary) *3-D* arrangement of all atoms in a single polypeptide chain. eg. collagen**
- **4º : (Quaternary) Arrangement of polypeptide chains into a functional protein, eg. hemoglobin.**

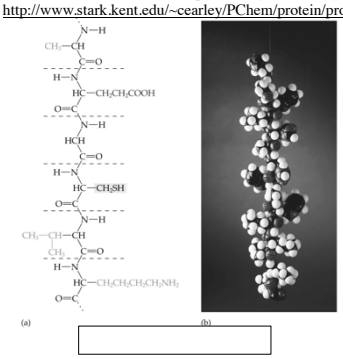
Different Protein Types -

- **Enzymes: *Glutamine synthetase* - 12 subunits of 468 residues each; total mol. wt. = 600,000 daltons**
- **Regulatory proteins: *Insulin* - α -alpha chain of 21 residues, β - beta chain of 30 residues; total mol. wt. of 5,733 amu**
- **Structural proteins: *Collagen***

  ***Connectin proteins*, β - MW of 2.1 million g/mol; length = 1000 nm; can stretch to 3000 nm.**
- **Transport proteins: *Hemoglobin***
- **Contractile proteins: *Actin, Myosin***
- **Specialized proteins: *Antifreeze in fish***

(A gene was first defined as: one piece of DNA that codes for one protein. The definition is being expanded beyond proteins to include certain types of RNA.)

Proteins: Size, Shape & Self Assembly
http://www.stark.kent.edu/~cearley/PChem/protein/protein.htm



Protein Structure

- **1º : The linear sequence of amino acids and disulfide bonds eg. ARDV:Ala-Arg-Asp-Val.**
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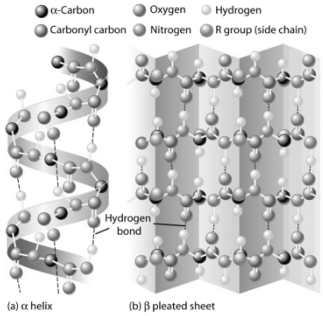
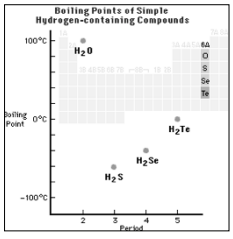
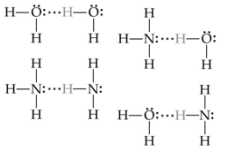


Boiling Points & Hydrogen Bonding



Hydrogen Bonding

- **Hydrogen bonds, a unique dipole-dipole attraction (10-40 kJ/mol).**

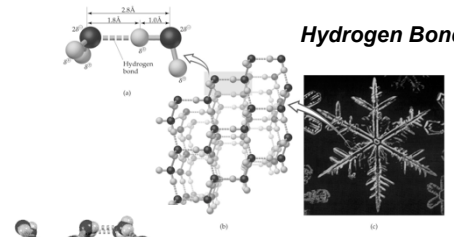


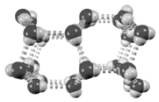
Hydrogen Bonding

http://chemconnections.org/general/movies/HydrogenBonding.MOV

Intermolecular Forces

Hydrogen Bonding





http://chemconnections.org/general/movies/ice-structure.MOV

QUESTION

Which pure substances will not form hydrogen bonds?

I) CH_3CH_2OH **II) CH_3OCH_3**

III) $H_3C{-}NH{-}CH_3$ **IV) CH_3F**

A) I and II **B) I and III** **C) II and III** **D) II and IV**

ANSWER

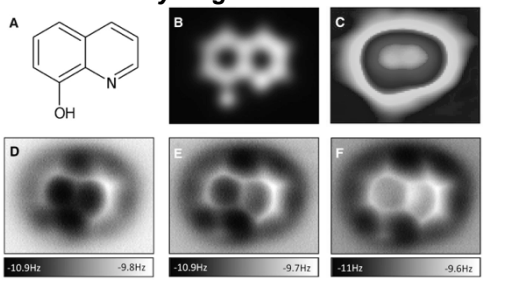
Which pure substances will not form hydrogen bonds?

I) CH_3CH_2OH **II) CH_3OCH_3**

III) $H_3C{-}NH{-}CH_3$ **IV) CH_3F**

A) I and II **B) I and III** **C) II and III** **D) II and IV**

Visualizing Intermolecular Hydrogen Bonds



J Zhang et al. Science 2013;342:611-614

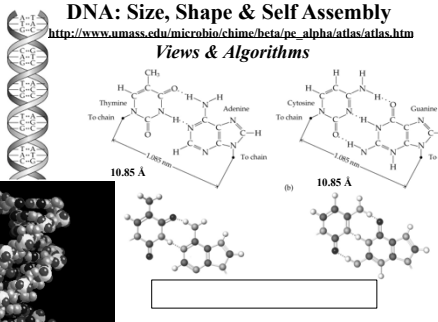
Fig. 1 STM and AFM measurements

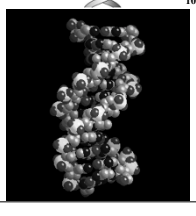
Published by AAAS

DNA: Size, Shape & Self Assembly

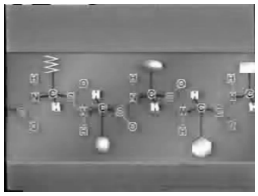
http://www.umass.edu/microbio/chime/beta/pe_alpha/atlas/atlas.htm

Views & Algorithms



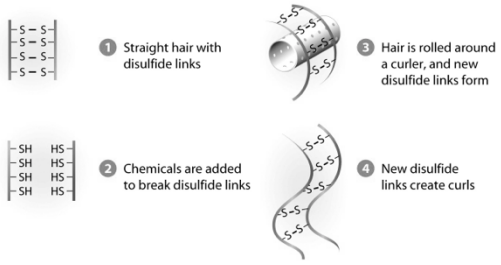


Hair: α-Helix
Annenberg World of Chemistry
#23 Proteins : http://www.learner.org/resources/series61.html



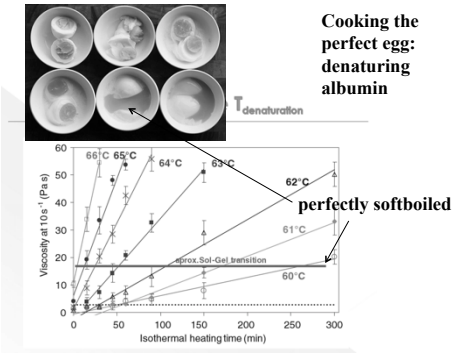
http://chemconnections.org/general/movies/protein-hair-2.mov

Hair: α-Helix



Silk: β-Sheets

http://chemconnections.org/general/movies/proteins-silk-2.mov

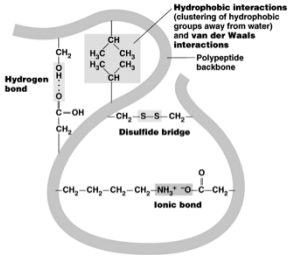


http://chemconnections.org/general/chem106/Tech%20Prep/Protein%20Activity%20I-2016.html

Protein Structure

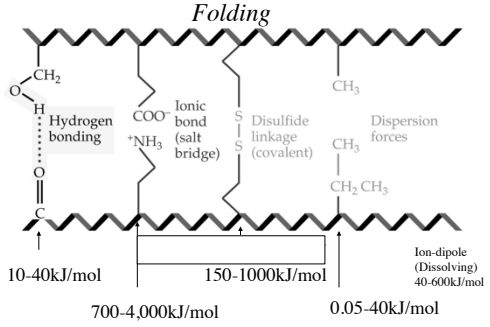
- **1º : The linear sequence of amino acids and disulfide bonds eg. ARDV:Ala-Arg-Asp-Val.**
- **2º : Local structures which include, folds, turns, ∝-helices and β -sheets held in place by hydrogen bonds.**
- **3º : *3-D* arrangement of all atoms in a single polypeptide chain.**
- **4º : Arrangement of polypeptide chains into a functional protein, eg. hemoglobin.**

- ***Tertiary structure* is determined by the interactions among and between R groups and the polypeptide backbone.**



- **While these three interactions are relatively weak, disulfide bridges, strong covalent bonds between the sulfhydryl groups (SH) of cysteine monomers, stabilize the structure.**

Protein Shape: Forces, Bonds, Self Assembly, Folding

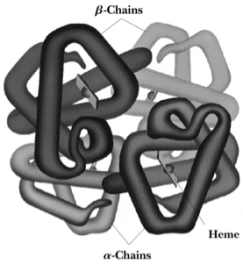


Protein Structure

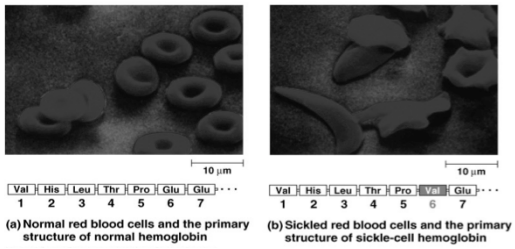
- **1º : The linear sequence of amino acids and disulfide bonds eg. ARDV:Ala-Arg-Asp-Val.**
- **2º : Local structures which include, folds, turns, ∝-helices and β -sheets held in place by hydrogen bonds.**
- **3º : *3-D* arrangement of all atoms in a single polypeptide chain.**
- **4º : Arrangement of polypeptide chains into a functional protein, eg. hemoglobin.**

The quaternary structure of hemoglobin, Hb

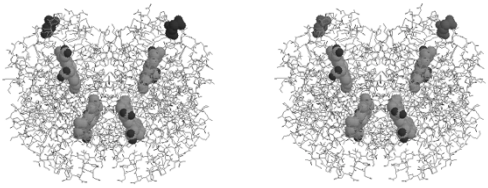
(A tetramer)



Hb: two alpha units of 141 residues, 2 beta units of 146



Normal hemoglobin vs sickle cell hemoglobin



Valine replaces Glutamate

http://chemconnections.org/Presentations/Columbia/slide8-3.html

Firefox to listen

Summary