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First, convert the temperatures to the Kelvin scale.

$T_i = (19 + 273) = 292\ K$

$T_f = (25 + 273) = 298\ K$

Following is the data table.

$V_i = 4.38\ dm^3$	$P_i = 101\ kPa$	$T_i = 292\ K$
$V_f = ?$	$P_f = 101\ kPa$	$T_f = 298\ K$

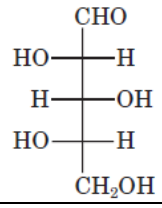
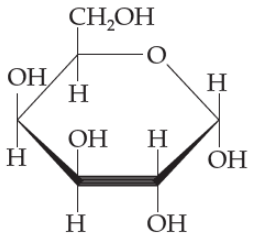
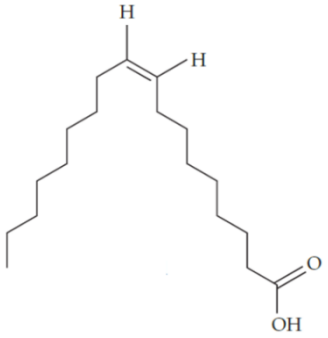
$\frac{V_i}{T_i} = \frac{V_f}{T_f}$

Apply Charles's law to obtain

$$V_f = V_i \times \frac{T_f}{T_i} = 4.38\ dm^3 \times \frac{298\ K}{292\ K} = 4.470 = 4.47\ dm^3$$

BIOCHEMISTRY

D. For each of the following statements answer TRUE or FALSE (0.5 point/each answer).

		TRUE	FALSE
1	Galactose is an aldose.	X	
2	This is a D-monosaccharide. 		X
3	This is β-D-glucose. 		X
4	This is trans- oleic acid. 		X
5	Amino acids used in protein synthesis are beta type		X

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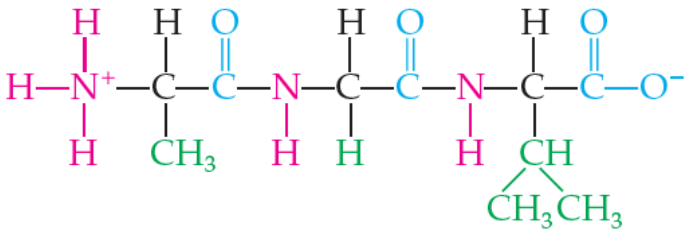
6	In this tripeptide, valine is present. 	**X**	
7	α- amilase is an enzyme able to catalyze the hydrolisis of cellulose.		**X**
8	Glycogen is synthesized in the liver and muscles.	**X**	

E. Each of the following questions has ONE correct answer. Identify the correct answer (ONE) for each of the following questions (0.5 point/each answer):

1. Which of the following is a reducing sugar?

A. Fructose.
B. Maltose.
C. Sucrose.

2. Which of the following fatty acids has the LOWEST melting point?

A. Linoleic acid.
B. Oleic acid.
C. α-Linolenic acid.

3. Which of the following lipoproteins has the HIGHEST content of cholesterol?

A. Chylomicrons.
B. LDL.
C. VLDL.

4. What is the biochemical nature of the immunochemical markers determining AB0 blood groups antigens:

A. Carbohydrates
B. Lipids
C. Proteins

5. Which of the following reactions is the MOST ENDOERGONIC?

A. Malate → fumarate + H_2O ($\Delta G'^\circ$ = 3.1 kJ/mol).
B. Fructose-6-phosphate → Glucose-6-phosphate ($\Delta G'^\circ$ = -1.7 kJ/mol).

C. lactose + H_2O → glucose + galactose ($\Delta G'^\circ$ = -15.9 kJ/mol).

6. What is the relationship between V_{max} and K_m in enzymatic kinetics?

A. V_{max} is the velocity when the substrate concentration is K_m.
B. $\frac{V_{max}}{2}$ is the velocity when the substrate concentration is K_m.
C. $K_m > V_{max}$

7. In a biochemical reaction, the presence of a NON COMPETITIVE inhibitor:

A. Decreases the Km.
B. Decreases the Vmax.
C. Increases the Km.

8. Which amino acid replaces Glu in the β chains of Hemoglobin S causing sickle cell anemia?

A. His.
B. Ala.
C. Val.

9. An allosteric inhibitor:

A. participates in feedback regulation
B. denatures the enzyme
C. decreases Km

10. Where does 2,3 BPG bind in hemoglobin?

A. On distal His.
B. On proximal His.
C. On the β–β subunit interface.

F. OPEN QUESTION (2 points)

Explain the major differences between myoglobin and hemoglobin. If possible mention examples or draw schemes/structures:

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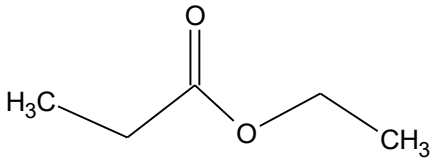
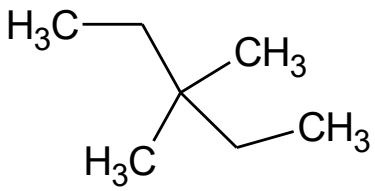
c) 

L. What is the correct IUPAC name of this structure? (0.5 point/correct answer)



a) 3,3-dimethylpentane

b) 2-ethyl-2-methylbutane

c) 2,2-diethylpropane

BIOCHEMISTRY (MODULE 2)

A. Each of the following questions has ONE or MORE correct answer. Identify the correct answer for each of the following questions (0.5 point/each answer):

1. Predict the spontaneity of a reaction that has ΔS<0 and ΔH>0 at 37°C:

A. spontaneous
B. nonspontaneous
C. spontaneity depends on temperature
D. None of the above

2. Which of the following are epimers?

A. D-glucose and D-ribose
B. D-glucose and D-mannose
C. D-glucose and D-fructose
D. None of the above

3. Phospholipids, the constituents of biological membranes, can have a skeleton constituted by:

A. glycerol only
B. sphingosine only
C. glycerol or sphingosine
D. None of the above

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4. An enzyme:

A. Doesn't change the rate of a biochemical reaction
B. Increases the Keq of a biochemical reaction
C. Decreases the ΔG of a biochemical reaction
D. None of the above

D. Identify the definition of each protein structure level (0.25 point/each correct answer).

A. Three dimensional folding of a polypeptide.
B. The sequence of the amino acids in the chain.
C. Association of two or more peptide chains to form a protein.
D. It refers to particularly stable arrangements of amino acid residues giving rise to recurring structural patterns (i.e. hydrogen bonding).

PRIMARY	SECONDARY	TERTIARY	QUATERNARY
B	D	A	C

E. Link each type of enzyme inhibition to its definition (0.25 point/each correct answer).

A. Once the inhibitor is bound, the enzyme would be effectively dead, as the inhibitor could not be removed and no catalysis could occur.
B. When inhibitor binds, binding of the substrate is prevented.
C. When inhibitor binds, it cannot be overcome by increasing the substrate concentration.
D. The inhibitor generates a chemically reactive intermediate that inactivates the enzyme

COMPETITIVE INHIBITION	NONCOMPETITIVE INHIBITION	IRREVERSIBLE INHIBITION	SUICIDE INHIBITOR
B	C	A	D

F. The activity of pepsin was measured at various pH values. When the temperature and the concentrations of pepsin and substrate were held constant, the following activities were obtained (0.5 point/each correct answer):

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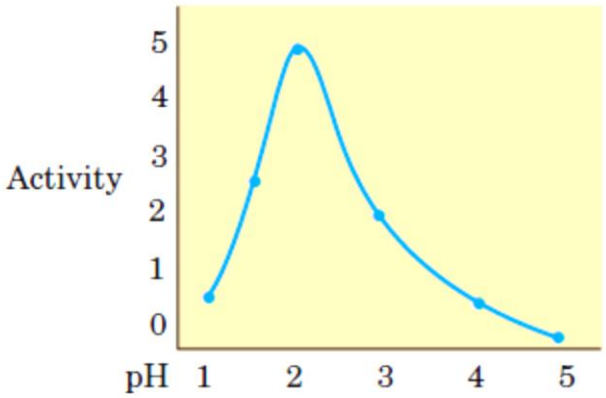
pH	Activity
1.0	0.5
1.5	2.6
2.0	4.8
3.0	2.0
4.0	0.4
5.0	0.0

(a) Plot the pH dependence of pepsin activity.



(b) What is the optimal pH 2

(c) Predict the activity of pepsin in the blood at pH 7.4. no activity

Answer to the following open questions (1.5 point/each answer). If possible mention examples or draw graphs/structures:

1. Why does myoglobin cannot function as an oxygen carrying protein?
2. What are the main differences between globular and fibrous proteins? Give some examples.

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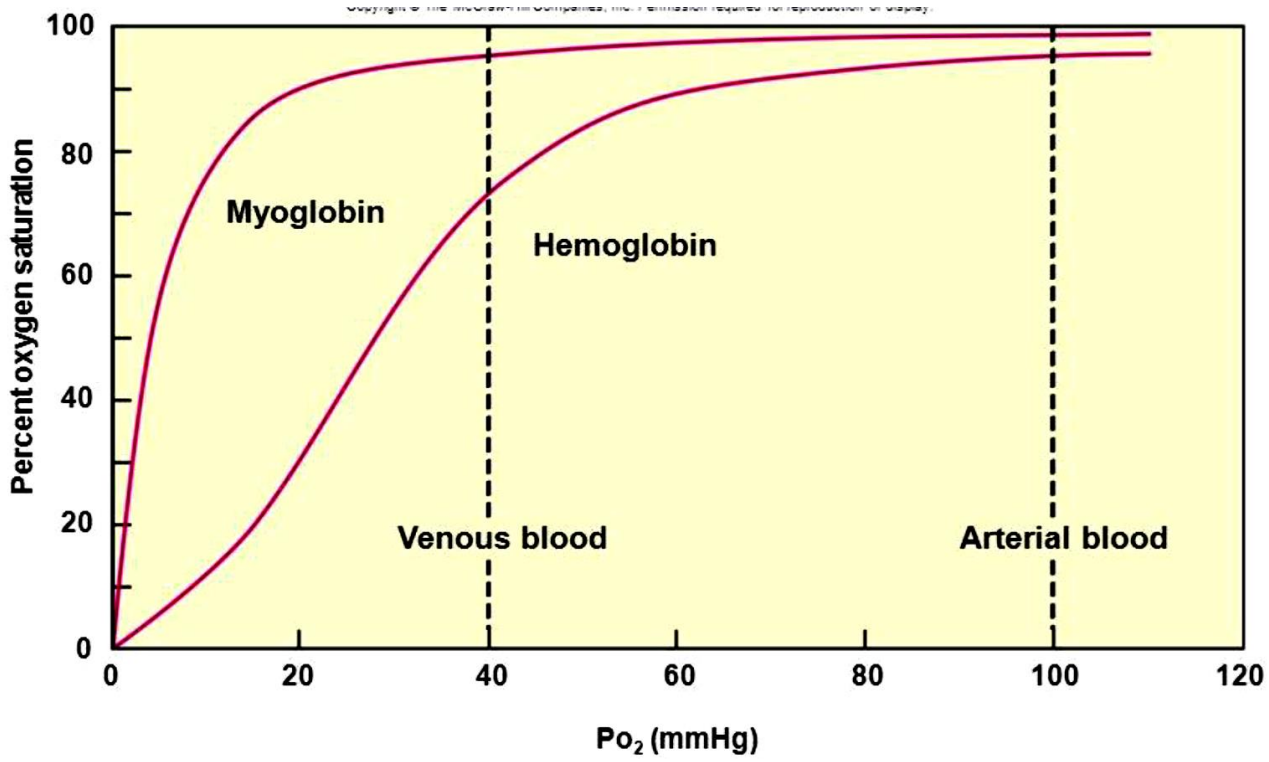
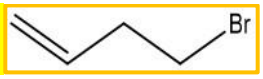
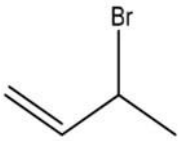


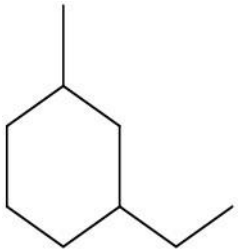
Student Number Name Surname

b) 

c) 

d) none of the above

L. What is the correct IUPAC name of this structure?



a) 1-ethyl-3-methylcyclohexane

b) 1-methyl-3-ethylcyclohexane

c) 1-methyl-2-ethylhexane

d) none of the above

BIOCHEMISTRY (MODULE 2)

A. Each of the following questions has ONE correct answer. Identify the correct answer for each of the following questions

1. Predict the spontaneity of a reaction that has ΔS<0 and ΔH<0 at 37°C:

A. spontaneous

B. nonspontaneous

C. spontaneity depends on temperature

D. None of the above

Student Number Name Surname

2. Peptide bond:

A. is responsible for the tertiary structure of proteins
B. behaves as partial doble bond
C. is not stable
D. None of the above

3. Scurvy is due to a lack of vitamin C, which causes a decreased synthesis of:

A. myoglobin
B. α-keratin
C. actin
D. None of the above

4. The secondary structure of proteins is mainly due to:

A. Ionic interactions
B. Hydrogen bonds
C. Disulfide bridges
D. None of the above

B. Identify the correct formula of each fatty acids

A. OLEIC ACID
B. LINOLEIC ACID
C. ARACHIDONIC ACID
D. STEARIC ACID

C18:2 $\Delta^{9,12}$	**C18:0**	**C18:1 Δ^{9}**	**C20:4 $\Delta^{5,8,11,14}$**
B	D	A	C

C. Indicate whether the side chains of each of the amino acids listed below is polar charged, polar but not charged or non polar

PROLINE	**ALANINE**	**CYSTEINE**	**ASPARTATE**
NON POLAR	NON POLAR	POLAR NOT CHARGED	POLAR CHARGED

D. Identify the correct formula of each fatty acids

A. PALMITIC ACID
B. α-LINOLENIC ACID
C. PALMITOLEIC ACID

C18:3 $\Delta^{9,12,15}$	**C16:0**	**C16:1 Δ9**
B	A	C

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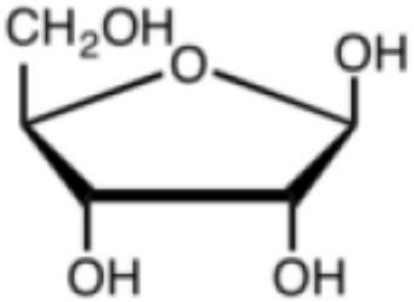
D. Indicate whether the side chains of each of the amino acids listed below is polar charged, polar but not charged or non polar.

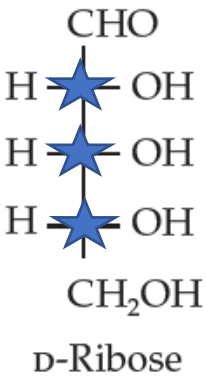
VALINE	SERINE	LYSINE
NON POLAR	POLAR NOT CHARGED	POLAR CHARGED

E. 1) Draw the open chain structures of D-ribose and L-ribose.
2) Indicate the position of chiral carbons in each structure.

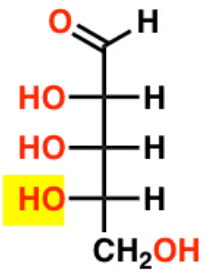
β-D-ribose



16.4



D-Ribose

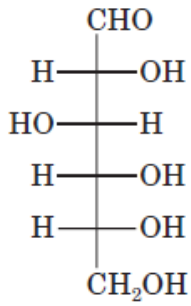


L-Ribose

F. Briefly answer to the following open questions. If possible mention examples or draw graphs/structures:

1. Explain the cooperative binding of oxygen with Hemoglobin.
2. Define competitive and non-competitive enzyme inhibition.

Identify how many chiral carbons are present in the following monosaccharide:



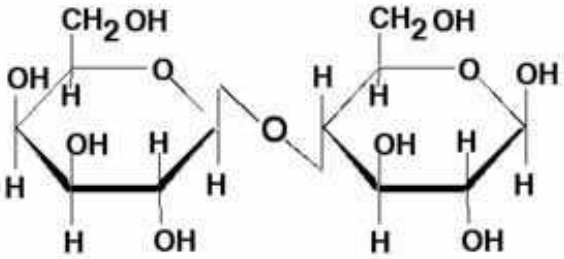
6

5

4

None of the above

Identify the two monosaccharide units in the disaccharide.



- D-galactose and D-glucose

- D-glucose and D-glucose

- D-glucose and D- fructose

- none of the above

Oleic acid has a melting point of 16°C. If you converted the cis double bond into a trans double bond, what would happen to the melting point?

- the melting point increases

- the melting point decreases

- the melting point doesn't change

- none of the above

Which of these compounds are NOT polar lipids ?

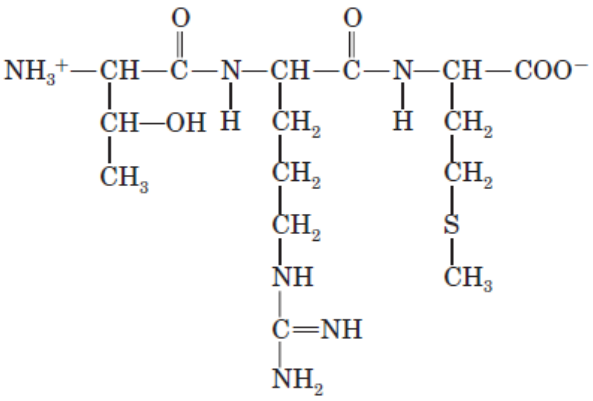
- waxes

- glycerophospholipids

- sphingolipids

- none of the above

Draw the structure of a tripeptide made of threonine, arginine, and methionine



Which of the following is a correct statement describing the induced-fit model of enzyme action?

Substrates fit into the active site:

(a) because both are exactly the same size and shape. F

(b) by changing their size and shape to match those of the active site. F

(c) by changing the size and shape of the active site upon binding. T

The correct answer is (c). Initially, the enzyme does not have exactly the right shape for strongly binding a substrate, but the shape of the active site changes to better accommodate the substrate molecule.

What are the main differences between starch and glycogen

Explain the cooperative binding of oxygen with Hemoglobin

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. The number of ions from each formula unit is i. Here,

$$i = 1 + 2 = 3$$

The boiling-point elevation is

$$\Delta T_b = K_b c_m = 3 \text{ x } \frac{0.512°C}{m} \text{ x } 0.050\, m = 0.07681 = 0.077°C$$

The boiling point of aqueous $MgCl_2$ is 100.077°C.

BIOCHEMISTRY (MODULE 2)

8 TRUE/FALSE QUESTIONS (0.5 point/each correct answer)

1) palmitic acid is an essential fatty acid F

2) The formation of a peptide bond between two amino acids is accompanied by water loss T

3) lactose can be considered as a reducing agent T

4) an allosteric enzyme follows the kinetics of Michaelis Menten F

5) a reversible competitive enzyme inhibitor lowers the Vmax of the reaction F

6) glutamate amino acid is not charged at physiological pH F

7) Galactose is an epimer of glucose V

8) Oleic acid is an unsaturated fatty acid V

10 SINGLE CHOICE QUESTIONS (0.5/each correct answer)

Each of the following questions has ONE correct answer. Identify the correct answer for each of the following questions (0.5 point/each answer):

1. **Which of the following reactions is the most exergonic?**
   A. Malate → fumarate + H_2O ($\Delta G'^\circ$ = 3.1 kJ/mol).
   B. Fructose-6-phosphate → Glucose-6-phosphate ($\Delta G'^\circ$ = -1.7 kJ/mol).
   C. Maltose + H_2O → 2 glucose ($\Delta G'^\circ$ = -15.5 kJ/mol).

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2. Which of the following is disaccharide?

A. Amylose.
B. Sucrose.
C. Galactose.

3. Which of the following fatty acids has the LOWEST melting point?

A. Oleic acid 18:1.
B. Stearic acid 18:0.
C. Linolenic acid 18:3.

4. Which of the following secondary structures is prevalent in α-keratins?

A. β-sheet.
B. α-helix.
C. Beta turn.

5. K_m indicates the affinity between an enzyme and a substrate. Which of the following substrates has the highest affinity for Hexokinase?

ATP (K_m = 0.4 mM).
D-glucose (K_m = 0.05 mM).
D-fructose (K_m = 1.5 mM).

6. The amino acids used in protein synthesis are of the following types:

a) alpha
b) beta
d) D

7. Which of the following are globular proteins

a) Keratin
b) Collagen
c) Hemoglobin

8. Myoglobin:

a) has a quaternary structure
b) has 2 heme groups
c) is a storage protein for oxygen in muscles

9. The secondary structure of a protein is maintained by:

(a) double bonds
b) hydrogen bonds
c) hydrophobic bonds

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10. Which of the following statements is correct:

a- Proteins composed of a single polypeptide can have a quaternary structure

b- Disulfide bond formation requires the two cysteines involved to be close together in the primary sequence of the protein

c- The primary structure determines the tertiary structure

1 OPEN QUESTION (2 point)

Answer to the following open questions (1.5 point/each answer). If possible mention examples or draw schemes/structures:

Explain the major differences between starch and glycogen

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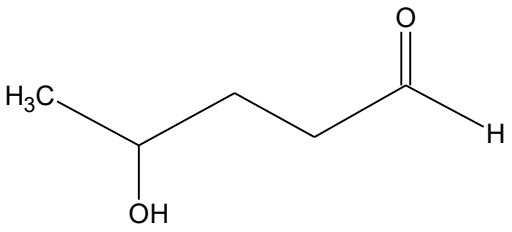

a) 4-hydroxypentanal

b) 1-oxo-4-hydroxypentane

c) 5-oxo-2-pentanol

BIOCHEMISTRY (MODULE 2)

A. Each of the following questions has ONE correct answer. Identify the correct answer for each of the following questions (0.5 point/each answer):

1. Which of the following reactions is the most exergonic?

A. Malate → fumarate + H_2O ($\Delta G'^\circ$ = 3.1 kJ/mol).
B. Fructose-6-phosphate → Glucose-6-phosphate ($\Delta G'^\circ$ = -1.7 kJ/mol).
C. Maltose + H_2O → 2 glucose ($\Delta G'^\circ$ = -15.5 kJ/mol).
D. Glucose-6-phosphate + H_2O → glucose + P_i ($\Delta G'^\circ$ = -13.8 kJ/mol).
E. Glycilglycine + H_2O → 2 glycine ($\Delta G'^\circ$ = -9.2 kJ/mol).

2. Which of the following is disaccharide?

A. Amylose.
B. Glycogen.
C. Cellulose.
D. Sucrose.
E. Galactose.

3. Which of the following fatty acids has the LOWEST melting point?

A. Linolenic acid 18:2.
B. Oleic acid 18:1.
C. Stearic acid 18:0.
D. Linolenic acid 18:3.
E. Palmitic acid 16:0.

4. Which of the following secondary structures is prevalent in α-keratins?

A. β-sheet.
B. α-helix.
C. Random structures.

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D. Y-helix.
E. Bends.

B. K_m indicates the affinity between an enzyme and a substrate. Which of the following substrates has the highest affinity for Hexokinase? (0.5 point/correct answer)

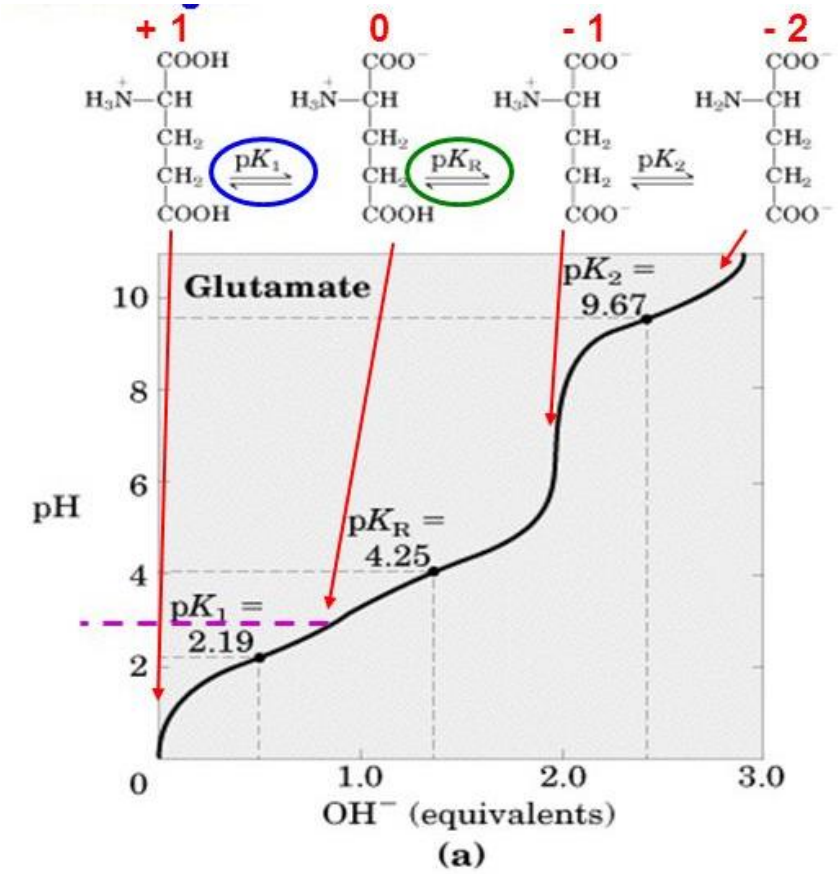
A. ATP (K_m = 0.4 mM).
B. D-glucose (K_m = 0.05 mM).
C. D-fructose (K_m = 1.5 mM).
D. D-mannose (K_m = 0.1 mM).
E. GTP (K_m = 0.8 mM).

C. Answer to the following open questions (1.5 point/each answer). If possible mention examples or draw schemes/structures:

1. Describe the classification of the 20 amino acids present in proteins.

2. Describe the titration curve of glutamate (pI = 3.22)

AS AN EXAMPLE FOR **QUESTION 2**, YOU CAN DRAW THE DIAGRAM ADDING THE RELATIVE IONIC STRUCTURE FOR EACH pKa AND THEN DEFINE THE ISOELECTRIC POINT (see the slides).



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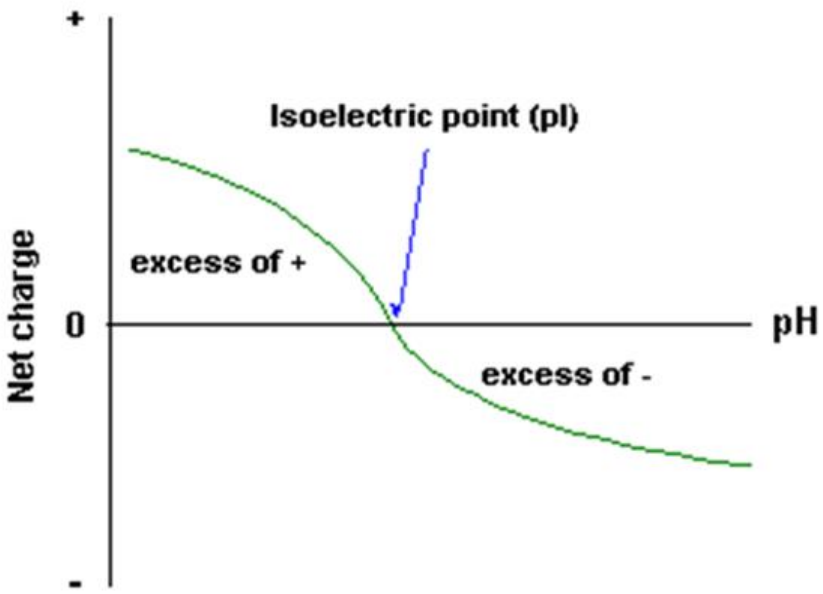

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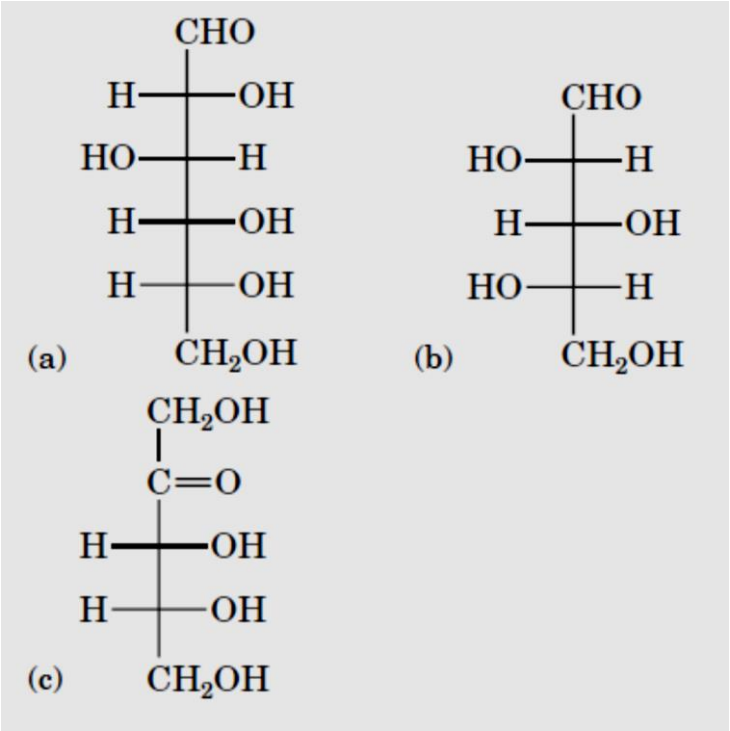
BIOCHEMISTRY (MODULE 2)

A. Which of the following compounds are D- monosaccharides, and which are L-monosaccharides? (0.5 point/each correct answer): 1.5

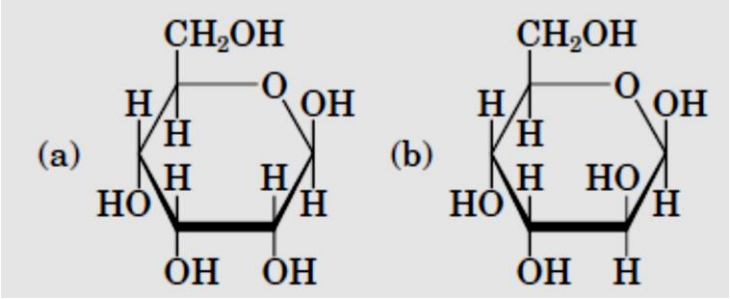


a	b	c
D	L	D

Compounds (a) and (c) are D-monosaccharides.

Compound (b) is an L-monosaccharide.

B. Convert each of the following Haworth projections to an open-chain form and to a Fischer projection (0.5 point/each correct answer). 2



Student Number Name Surname

C. Oleic acid has a melting point of 16°C. If you converted the cis double bond into a trans double bond, what would happen to the melting point? (1 point/ correct answer).1

The melting point would increase. The *trans* double bonds would fit more in the packing of the long hydrophobic tails, creating more order and therefore more interaction between chains. This would require more energy to disrupt, and hence a higher melting point.

D. Identify the primary, secondary, and tertiary structures in the numbered boxes (0.25 point/each correct answer): 1.25

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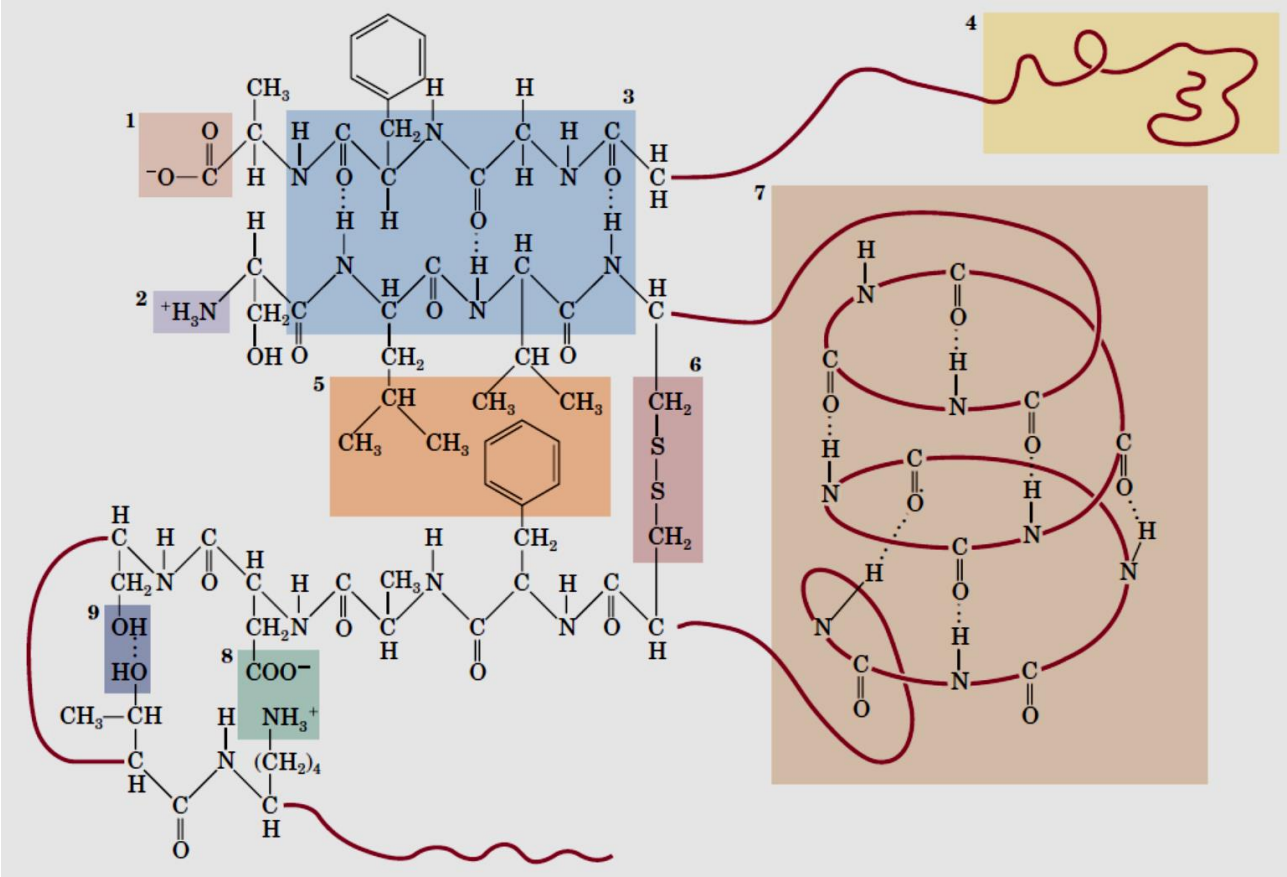

3	4	6	7
Pleated sheet (secondary)	Random coil (secondary)	Disulfide brigde (tertiary)	Alfa helix (secondary)

(1) C-terminal end (2) N-terminal end
(3) pleated sheet (4) random coil
(5) hydrophobic interaction (6) disulfide bridge
(7) a-helix (8) salt bridge (9) hydrogen bonds

E. Which of the following is a correct statement describing the induced-fit model of enzyme action? (0.75 point/correct answer)

Substrates fit into the active site:
(a) because both are exactly the same size and shape.
(b) by changing their size and shape to match those of the active site.
(c) by changing the size and shape of the active site upon binding.

The correct answer is (c). Initially, the enzyme does not have exactly the right shape for strongly binding a substrate, but the shape of the active site changes to better accommodate the substrate molecule.

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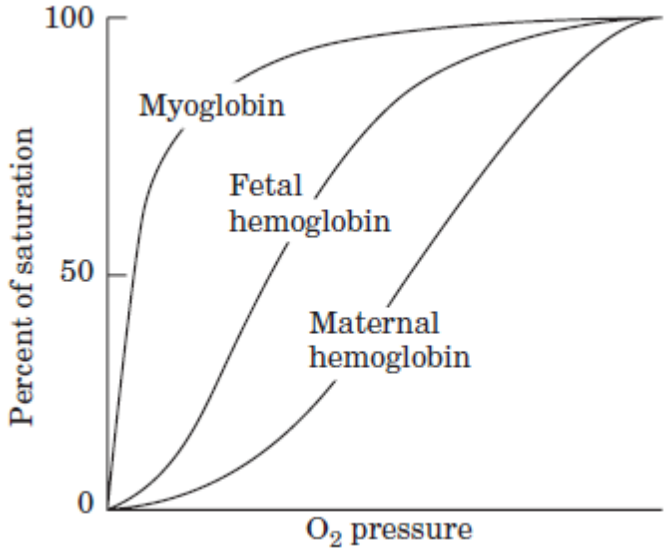
F. Which can carry more oxygen between fetal hemoglobin and adult hemoglobin ? (0.5 point/correct answer)

(b) Fetal hemoglobin has a higher affinity for oxygen. Fetal hemoglobin has an oxygen saturation curve that is in between myoglobin and maternal hemoglobin, so the graph would look like the figure below:



G. Answer to the following open questions (1.5 point/each answer). If possible mention examples or draw graphs:

1. Explain the difference between an irreversible inhibitor and a reversible, competitive inhibitor.

Competitive inhibition

• Inhibitor has a structure similar to the substrate thus it can bind to the same active site

•The enzyme can hardly differentiate between the two compounds

• When inhibitor binds, binding of the substrate is prevented

• The inhibitor can be displaced by increasing substrate Concentration

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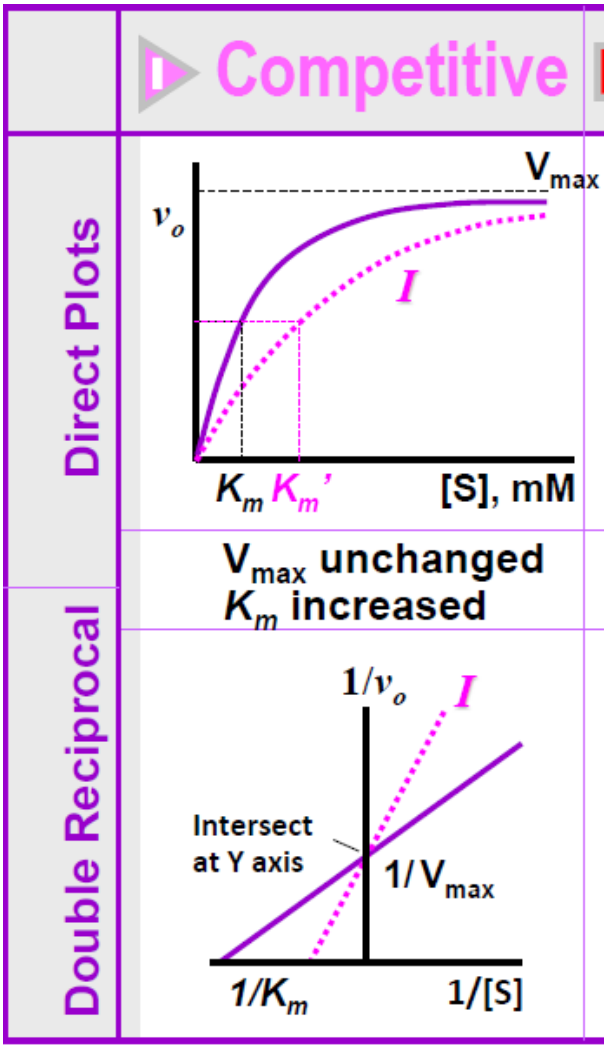

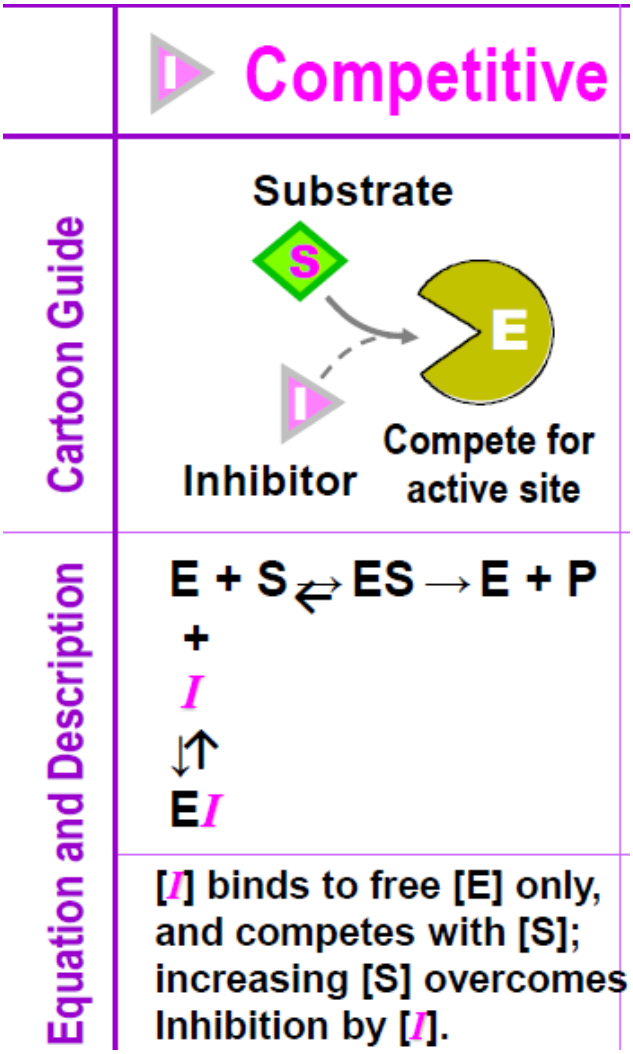

Irreversible Inhibitors

•Irreversible inhibitors generally result in the MODIFICATION of an essential amino acid required for enzyme activity

•They covalently bind or destroy a functional group on an enzyme that is essential for the enzyme's activity

•These types of inhibitors range from fairly simple, broadly reacting chemical modifying reagents (like iodoacetamide that reacts with cysteines) to complex inhibitors that interact specifically and irreversibly with active site amino acids (termed suicide inhibitors)

• Use of suicide inhibitors have proven to be very clinically effective

TYPES

• group specific reagents

• substrate analogs

•suicide inhibitors (compounds relatively unreactive until they bind to the active site of a specific enzyme)

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2. What is meant by a coupled reaction?

A coupled reaction is one that can be thought of as a twostep process. In a coupled reaction, two reactions occur simultaneously. Frequently, one of the reactions releases the energy that drives the second, energy-requiring reaction.

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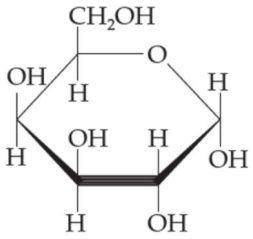
University of Bologna
CdL Medicine and Surgery

GENERAL BIOCHEMISTRY – January 26th 2026

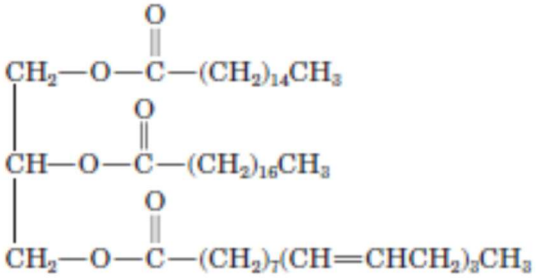
1. **For each statement, answer TRUE or FALSE (0.4 point/correct answer).**

		TRUE	FALSE
1	Galactose is an aldopentose.		x
2	The covalent backbone of RNA is subject to nonenzymatic hydrolysis of the phosphodiester bonds in alkaline conditions	x	
3	This is ß-D-glucose. 		X
4	Replication of DNA requires RNA primers	X	
5	The side products of the action of primase in forming primers are pyrophosphate groups	x	
6	The leading strand of DNA molecule is synthesised continuously in 5'-3' direction	x	
7	The Michaelis-Menten constant, KM, corresponds to the [S] required to reach Vmax		x
8	A competitive inhibitor reduces the Km.		x

2. **Each of the following questions has ONE correct answer. Identify the correct answer for each of the following questions (0.85 point/each answer):**

1. **How many stereocenters are present in mannose?**
   A. 2
   B. 3
   C. 4

2. **Which fatty acid is NOT present in this triglyceride?**



   A. Palmitic acid
   B. Palmitoleic acid

C. Stearic acid

3. Which is the most stable structure of DNA under physiological conditions?
   A. B form
   B. Z form
   C. A form

4. **Which of the following amino acids is ALIPHATIC NON POLAR:**
   A. Threonine
   B. Leucine
   C. Phenylalanine

5. **What kind of lipid do you obtain following esterification reactions of sphingosine with one fatty acid molecule and a phosphate group linked with an amino alcohol?**
   A. A polyunsaturated fatty acid
   B. A sphingophospholipid
   C. A glycerophospholipid

6. **Which bases are most often METHYLATED in DNA?**
   A. Thymine and Cytosine
   B. Uracil and Adenine
   C. Adenine and Cytosine

7. **Which of the following are NOT a globular protein?**
   A. Myoglobin
   B. Hemoglobin
   C. Collagen

8. **The DNA polymerase III in E. Coli:**
   A. has the Nick translation activity
   B. is involved in the elongation process of the new strand
   C. unwounds the DNA

9. **Which of the following states of hemoglobin (Hb) has the highest affinity for oxygen:**
   A. Hb
   B. $Hb(O_2)$
   C. $Hb(O_2)_3$

10. **The Shine-Dalgarno sequence pairs with:**
    A. A purine-rich sequence near the 3'-end of the 16S rRNA of the 30S subunit.
    B. A purine-rich sequence near the 5'-end of the 16S rRNA of the 30S subunit.
    C. A pyrimidine-rich sequence near the 3'-end of the 16S rRNA of the 30S subunit.

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C. Answer the following open question (2 points).

1. Explain the major differences between A, B, AB, and o Blood types.

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D. Answer the following open questions (2.8 points). If possible mention examples or draw schemes/structures:
Briefly describe the the biochemical reactions involved in the mRNA maturation process.