Biomolecules

Question1

A linear octasaccharide (molar mass $= 1024 \mathrm{~g} \mathrm{~mol}^{-1}$) on complete hydrolysis produces three monosaccharides: ribose, 2-deoxyribose and glucose. The amount of 2-deoxyribose formed is $58.26\%(\mathrm{w}/\mathrm{w})$ of the total amount of the monosaccharides produced in the hydrolyzed products. The number of ribose unit(s) present in one molecule of octasaccharide is ________.

Use: Molar mass $\left(\right.$ in g $\left.\mathrm{mol}^{-1}\right)$: ribose $= 150$, 2-deoxyribose $= 134$, glucose $= 180$;

Atomic mass (in amu): $\mathrm{H}=1, \mathrm{O}=16$

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Options:

Answer: 2

Solution:

The problem involves determining the composition of an octasaccharide that, upon complete hydrolysis, yields three types of monosaccharides: ribose, 2-deoxyribose, and glucose.

First, consider the balanced chemical equation for the hydrolysis of the octasaccharide:

$\text{Octasaccharide} + 7\mathrm{H}_2\mathrm{O} \rightarrow \text{Ribose} + \text{2-deoxyribose} + \text{Glucose}$

The initial molar mass of the octasaccharide is $1024 \mathrm{~g/mol}$, and it requires 7 water molecules (each with a molar mass of $18 \mathrm{~g/mol}$, thus totaling $126 \mathrm{~g/mol}$) to undergo hydrolysis. Therefore, the total mass on the reactant side is:

$1024+126=1150 \mathrm{~g}$

According to the given data, the 2-deoxyribose formed constitutes 58.26% of the total mass of the monosaccharides. To find the mass of 2-deoxyribose, calculate:

$1150 \times \frac{58.26}{100}=669.99 \mathrm{~g} \approx 670 \mathrm{~g}$

The molar mass of 2-deoxyribose is $134 \mathrm{~g/mol}$, so the number of units produced is:

$\frac{670}{134}=5 \text{ units}$

Assuming there is one unit of glucose (molar mass $180 \mathrm{~g/mol}$), the remaining units in the octasaccharide must be ribose. Given five units of 2-deoxyribose and one unit of glucose, the potential number of ribose units can be calculated as the difference to reach a total of eight saccharide units, ensuring:

$5 \text{ (2-deoxyribose)} + 1 \text{ (glucose)} + x \text{ (ribose)} = 8$

Solving this gives:

$x = 8 - 5 - 1 = 2$

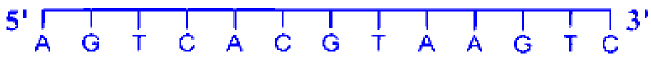
To verify the setup, the total mass of the hydrolysis products equals the mass at the reactant side:

$670\,(\text{2-deoxyribose}) + 180\,(\text{glucose}) + (2 \times 150\,(\text{ribose})) = 1150\,\text{g}$

Thus, the octasaccharide contains 2 ribose units. Therefore, the number of ribose units present in one molecule of the octasaccharide is 2.

Question2

For a double strand DNA, one strand is given below:



The amount of energy required to split the double strand DNA into two single strands is _______ kcal mol^{-1}.

[Given: Average energy per H-bond for A-T base pair $= 1.0\ \text{kcal mol}^{-1}$, G-C base pair $= 1.5\ \text{kcal mol}^{-1}$, and A-U base pair $= 1.25\ \text{kcal mol}^{-1}$. Ignore electrostatic repulsion between the phosphate groups.]

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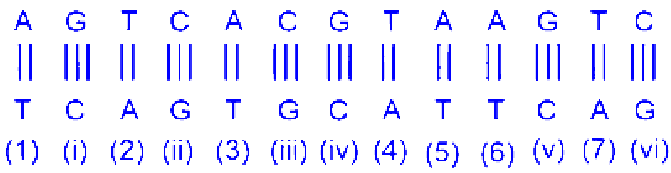
Options:

Answer: 41

Solution:



$\text{A} = \text{T} \quad \Rightarrow 2\text{H-bond}$

$\text{G} \equiv \text{C} \quad \Rightarrow 3\text{H-bond}$

Number of $\text{A} = \text{T}$ pair $= 7$

Number of $\text{G} \equiv \text{C}$ pair $= 6$

Number of H-bond involve in $\text{A} = \text{T} = 7 \times 2 = 14$

Number of H-bond involve in $\text{G} \equiv \text{C} = 6 \times 3 = 18$

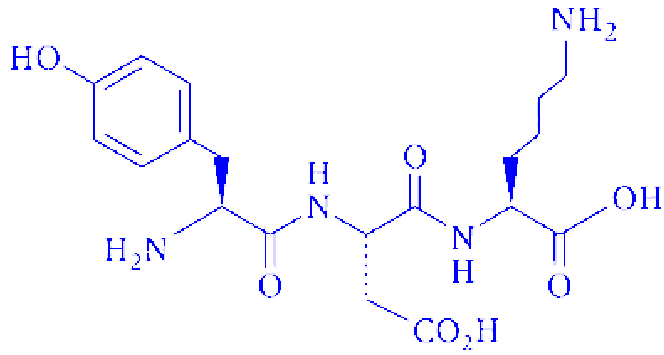
Energy required for $\text{A} = \text{T} = 14 \times 1 = 14$

Energy required for $\text{G} \equiv \text{C} = 18 \times 1.5 = 27$

Total energy required $14 + 27 = 41$

Question3

The structure of a peptide is given below.



If the absolute values of the net charge of the peptide at $\mathrm{pH}=2$, $\mathrm{pH}=6$, and $\mathrm{pH}=11$ are $|Z_1|$, $|Z_2|$, and $|Z_3|$, respectively, then what is $|Z_1|+|Z_2|+|Z_3|$?

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Options:

Answer: 5

Solution:

At pH = 2,

There are two $-NH_2$ group, and + 1 charge on each group because all amino groups exist in the form of $-NH_3^{\oplus}$.

Therefore, $|Z_1| = 2$.

At pH = 6,

NH_2 of lysine (+ 1) (pH = 9.47) and COOH (−1) of glutamic (pH = 3.08) acid, so because of dipolar ion exists, therefore $|Z_2| = 0$.

At pH = 11,

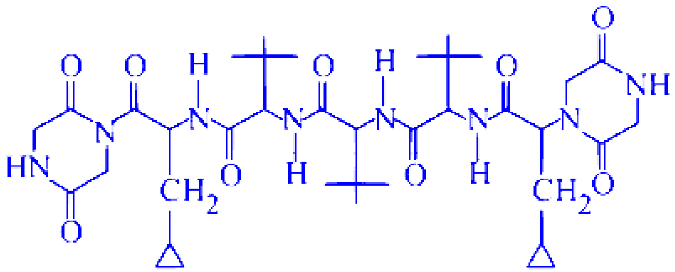
COOH of glutamic acid has (-1), COOH of lysine (-1) and OH of phenol (-1).

Therefore, $|Z_3| = |-3| = 3$ (All COOH and OH exist in the form of $-COO^-$ and $-O^-$).

$\therefore |Z_1| + |Z_2| + |Z_3| = 2 + 0 + 3 = 5$

Question4

The total number of distinct naturally occurring amino acids obtained by complete acidic hydrolysis of the peptide shown below is



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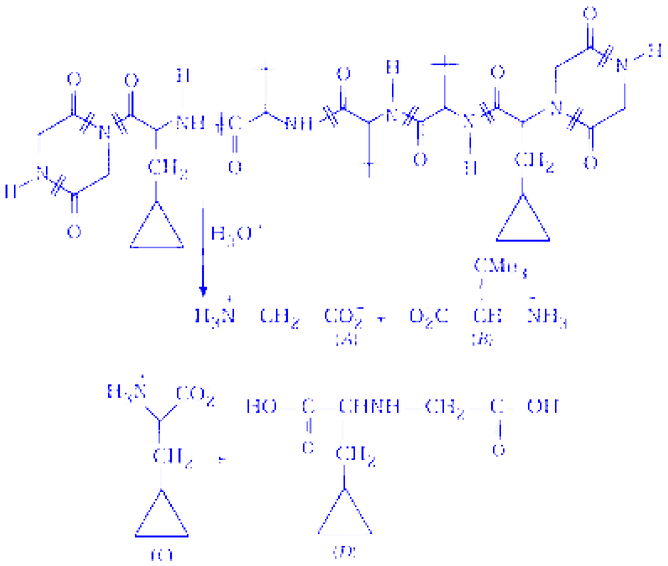
Options:

Answer: 1

Solution:

Chemical reaction and product formed after hydrolysis of given peptide can be represented as



(A) is glycine which is only naturally occurring amino acid. While (B), (C) and (D) are not the naturally occurring amino acids. Hence, correct integer is (1).

Question5

The total number of lone-pairs of electrons in melamine is

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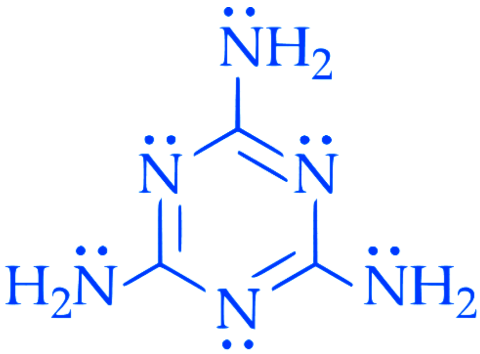
Options:

Answer: 6

Solution:

The structure of melamine is :



Each nitrogen has one lone pair of electrons. Number (no.) of nitrogen in a molecule = 6

Total no. of lone pairs in melamine

$=$ No. of nitrogen $\times$ lone pair

$= 6 \times 1 = 6$

Hence, total number of lone pair on nitrogen is 6.

Question6

A tetrapeptide has $-$COOH group on alanine. This produces glycine (Gly), valine (Val), phenyl alanine (Phe) and alanine (Ala), on complete hydrolysis. For this tetrapeptide, the number of possible sequences (primary structures) with $-NH_2$ group attached to a chiral center is _______.

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Options:

Answer: 4

Solution:

The possible combinations with C-terminal as alanine and N-terminal with chiral carbon (i.e. excluding glycine) are four.

Val$-$Phe$-$Gly$-$Ala

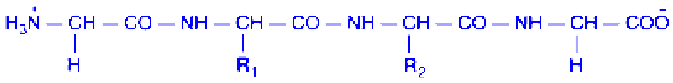
Val$-$Gly$-$Phe$-$Ala

Phe$-$Val$-$Gly$-$Ala

Phe$-$Gly$-$Val$-$Ala

Question7

The substituents R_1 and R_2 for nine peptides are listed in the table given below. How many of these peptides are positively charged at pH = 7.0 ?



Peptide	R_1	R_2
I	H	H
II	H	CH_3
III	CH_2COOH	H
IV	CH_2CONH_2	$(CH_2)_4NH_2$
V	CH_2CONH_2	CH_2CONH_2

Peptide	R_1	R_2
VI	$(CH_2)_4NH_2$	$(CH_2)_4NH_2$
VII	CH_2COOH	CH_2CONH_2
VIII	CH_2OH	$(CH_2)_4NH_2$
IX	$(CH_2)_4NH_2$	CH_3

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Options:

Answer: 4

Solution:

For basic amino acids with pH > 7, peptides will exist as cations. For example, when the substituents are basic, that is R_1 = CH_2CONH_2 and R_2 = $(CH_2)_4NH_2$ or when R_1 = $(CH_2)_4NH_2$ and R_2 = $(CH_2)_4NH_2$ or when R_1 = CH_2OH and R_2 = $(CH_2)_4NH_2$ or when R_1 = $(CH_2)_4NH_2$ and R_2 = CH_3.

Question8

A decapeptide (mol. wt. 796) on complete hydrolysis gives glycine (mol. wt. 75), alanine and phenylalanine. Glycine contributes 47.0% to the total weight of the hydrolysed products. The number of glycine units present in the decapeptide is __________.

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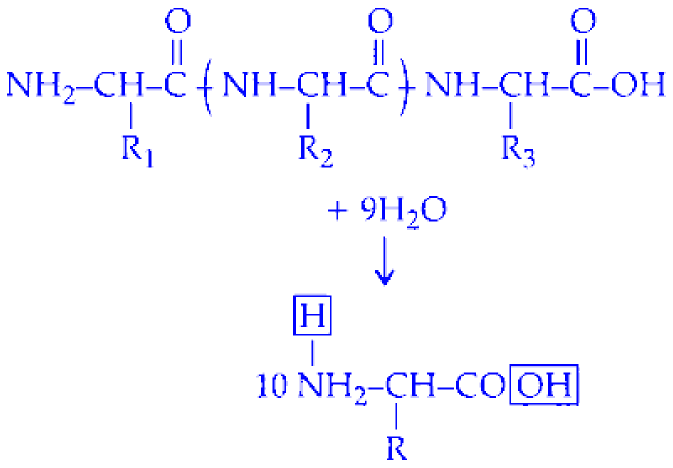
Options:

Answer: 6

Solution:

(i) A decapeptide has nine peptide bonds which hydrolyzes to give ten amino acids. Each peptide bond hydrolyses, to form one molecule of water. Hence, nine molecules of water are required to hydrolysis nine peptide bonds.

Decapeptide $\xrightarrow{\text{hydrolyse} \quad +9\,H_2O}$ Amino acids



(ii) On hydrolysis a molecule of water (equivalent to 18 g) is added across each amino acid.

Mass of hydrolysed decapeptide = Mass of decapeptide + 9 \times \text{mass of each water molecule}

$= 796 \text{ g mol}^{-1} + 9 \times 18 \text{ g mol}^{-1}$

$= (796 + 162) \text{ g mol}^{-1}$

$= 958 \text{ g mol}^{-1}$

Mass of glycine in hydrolysed decapeptide

$= \frac{47}{100} \times 958 \text{ g mol}^{-1}$

$= 450.26 \text{ g mol}^{-1}$

Mass of each glycine = 75 g mol^{-1}

Number of glycine units

$= \frac{\text{Mass of hydrolysed decapeptide}}{\text{Mass of each glycine}}$

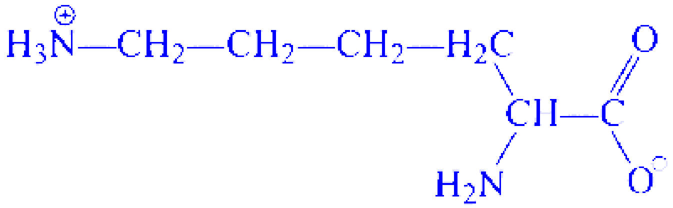
$n = \frac{450.26 \text{ g mol}^{-1}}{75 \text{ g mol}^{-1}}$

$n = 6.00$

Hence, there are six molecules of water in decapeptide.

Question9

The total number of basic groups in the following form of lysine is



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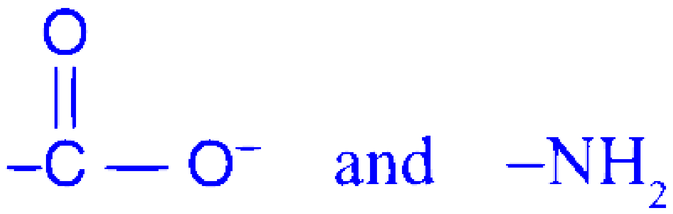
Options:

Answer: 2

Solution:

There are two basic groups in lysine



Question10

A disaccharide X cannot be oxidised by bromine water. The acid hydrolysis of X leads to a laevorotatory solution. The disaccharide X is :

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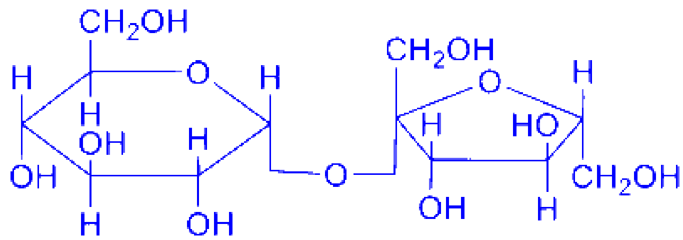
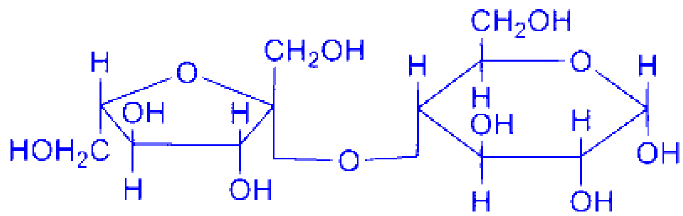
Options:

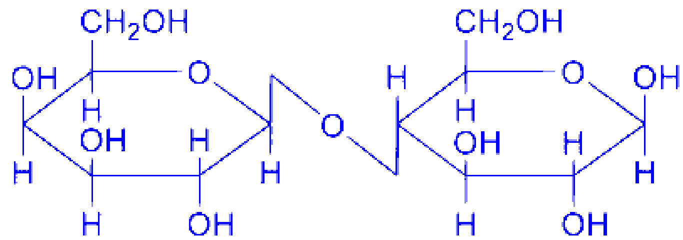
A.



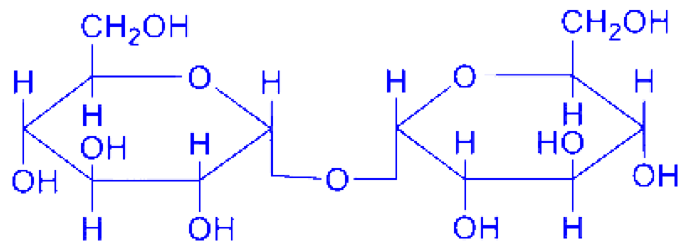
B.



C.



D.



Answer: A

Solution:

A and D cannot be oxidised by bromine water as they do not have hemiacetal linkage.

The acid hydrolysis of A leads to a laevorotatory solution.

A is sucrose which is dextrorotatory, on acid hydrolysis gives mixture of α-D-glucose and β-D-fructose, themixture is laevorotatory

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Question11

Treatment of D-glucose with aqueous NaOH **results in a mixture of monosaccharides, which are**

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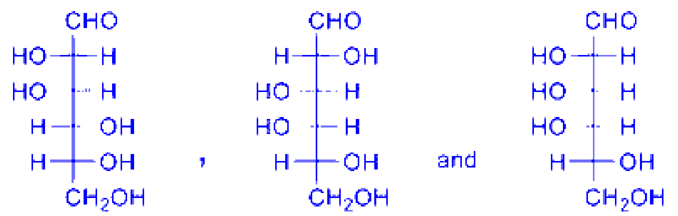
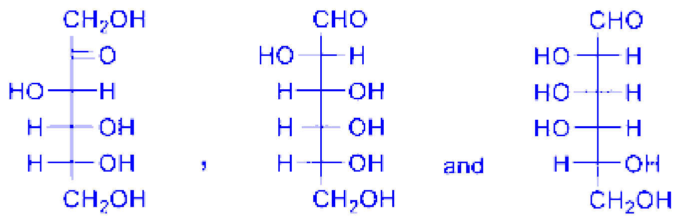
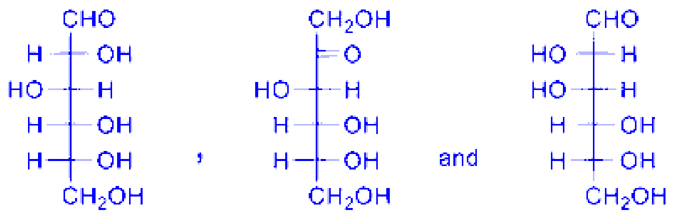
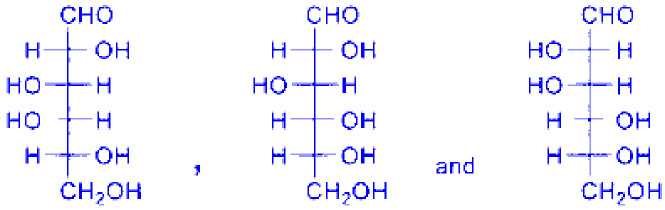
Options:

A. 

B. 

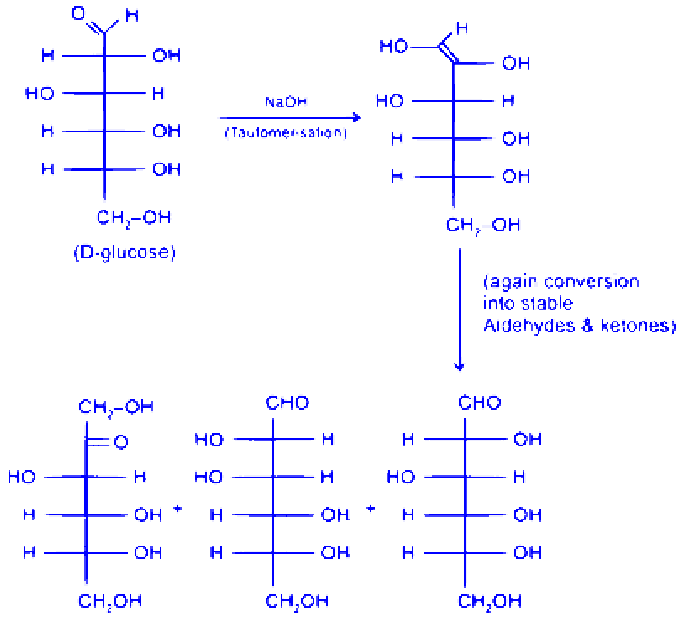
C. 

D.



Answer: C

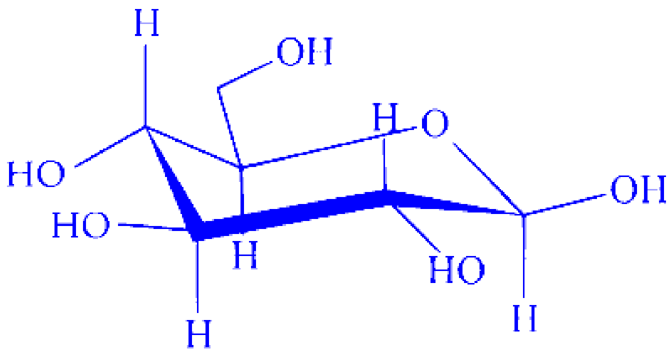
Solution:



[Mixture of 3 compounds will obtained]

Question12

The following carbohydrate is



IIT-JEE 2011 Paper 2 Offline

Options:

A. a ketohexose

B. an aldohexose

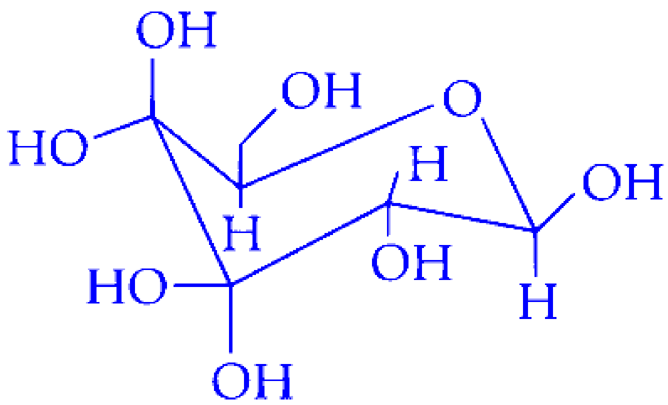
C. an α-furanose

D. an α-pyransose

Answer: B

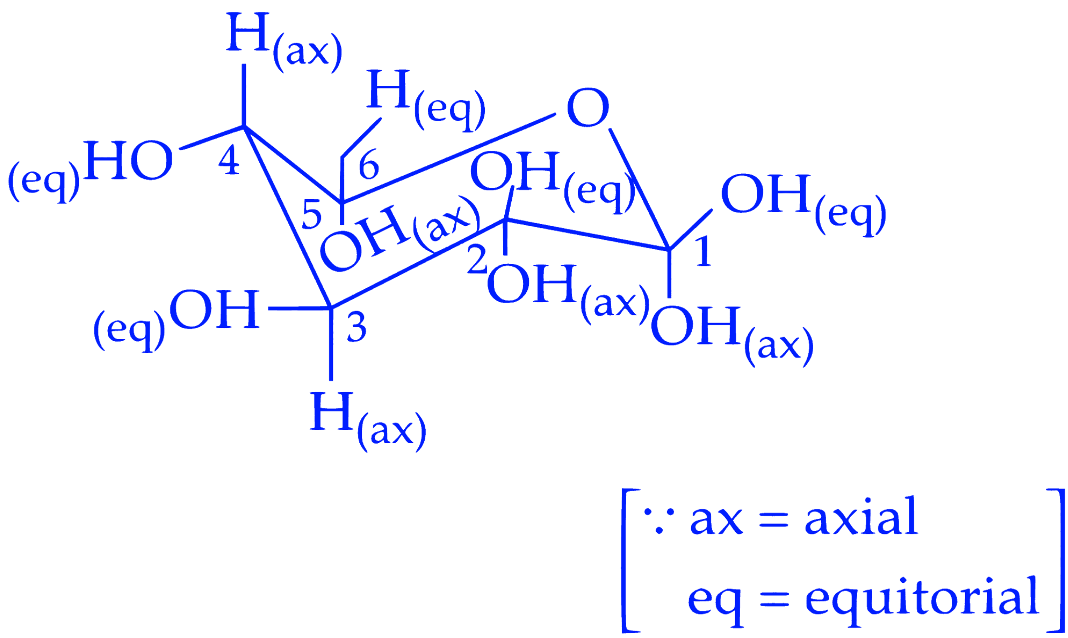
Solution:

(i) The cyclic structure of pyranose ring

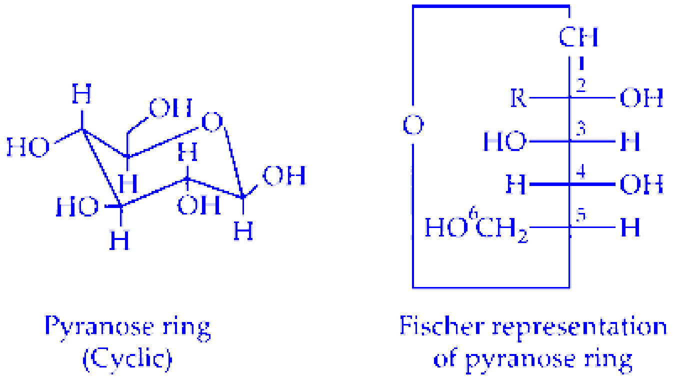


This is 3D structure of glucose formed as a result of cyclisation of an aldohexose.

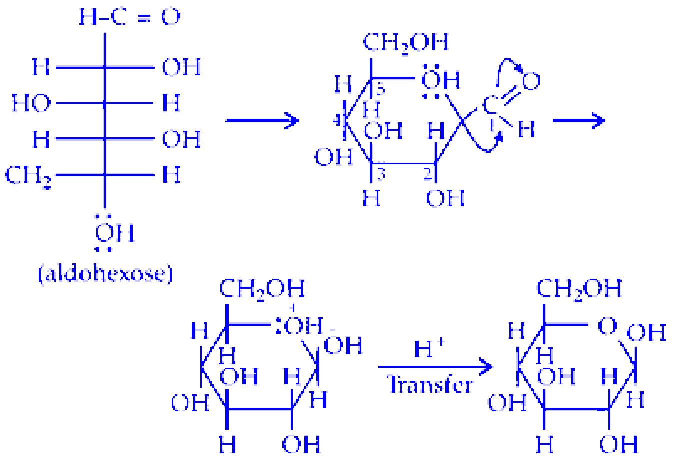
(ii) There are 2 types of groups in cyclic structure; groups that lie perpendicular to the plane of pyranose ring are axial and other are axial groups.



The fischer form of pyranose ring has groups above the ring on left and groups below the ring on right.

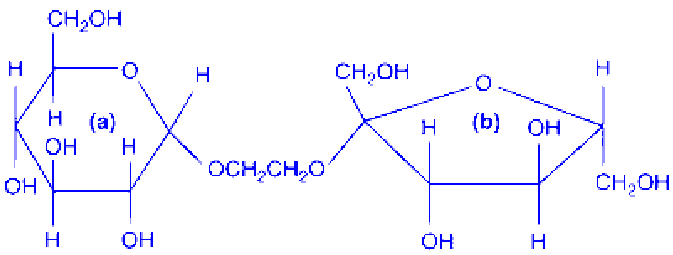


The cyclic form of pyranose ring is obtained as a result of reaction of hydroxyl group (–OH) at fifth carbon to the electropositive carbon of aldehydic group. The reaction happens as follows :



Question13

The correct statement about the following disaccharide is :



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Options:

A. Ring (a) is pyranonse with α-glycosidic link.

B. Ring (a) is furanonse with α-glycosidic link.

C. Ring (b) is furanonse with α-glycosidic link.

D. Ring (b) is pyranonse with α-glycosidic link.

Answer: A

Solution:

Pyranonse structure is a six-membered heterocyclic ring containing five carbon atoms and one oxygen atom. A glycosidic bond is formed between the hemiacetal group of a saccharide and the hydroxyl group of some organic compound such as an alcohol. C-1 of ring (a) has anα-glycosidic linkage.

Ring (b) has5-members and hence is a furanose.

Question14

Cellulose upon acetylation with excess acetic anhydride/H_2SO_4 (catalytic) gives cellulose triacetate whose structure is :

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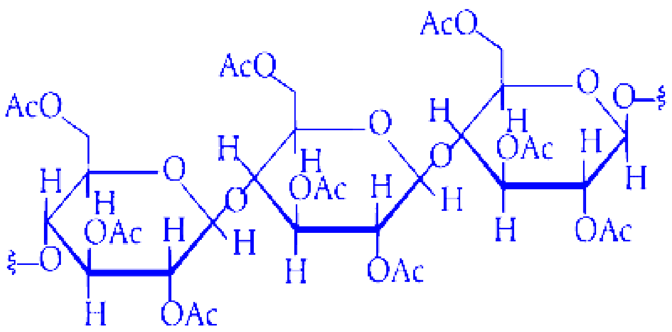
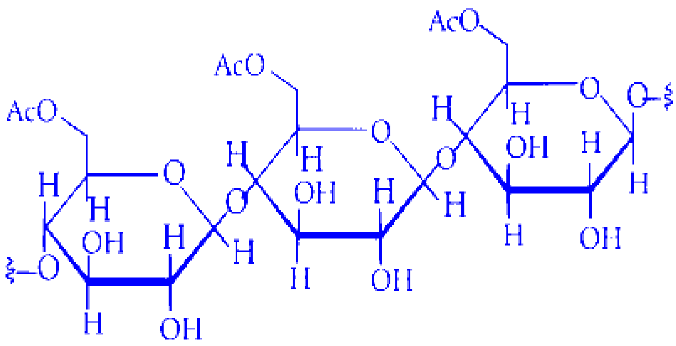
Options:

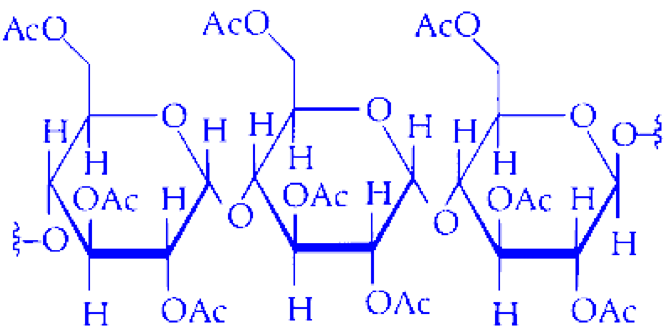
A.



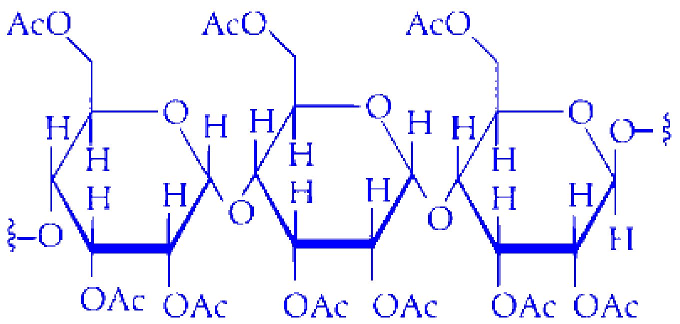
B.



C.



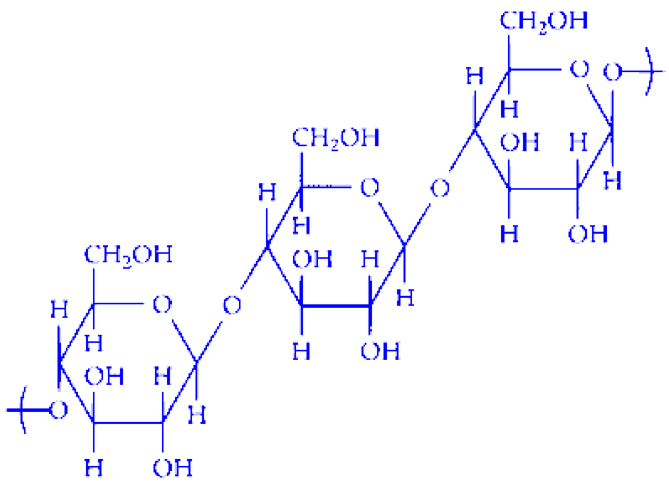
D.



Answer: A

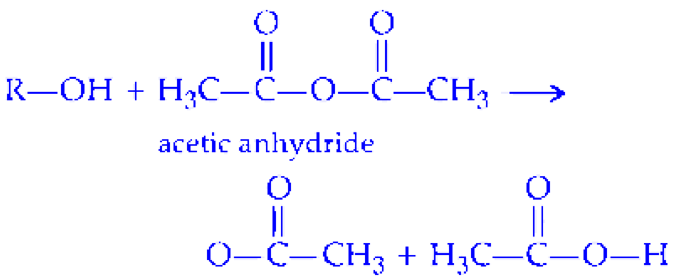
Solution:

Cellulose is linear chains of β-D-glucose molecules linked together by β-1, 4 glycosidic bonds. Cellulose has β-1, 4 linkage between β-D-glucose units. The cellulose is linear molecule.



CELLULOSE

A general reaction of alcohol with acetic anhydride is :



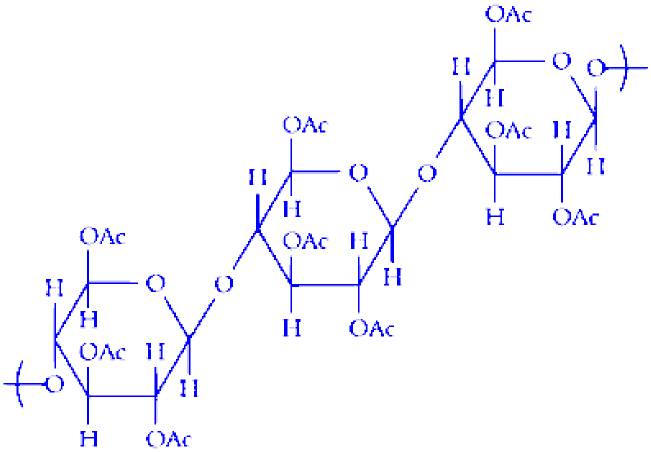
Acetic anhydride reacts with the alcoholic function group and converts the alcoholic function group into ester functional group. The $-$OH is known as an alcoholic functional group. The $-$OC(O)$-$ is known as an ester functional group.

During the conversion hydrogen of alcoholic group is replaced by CH_3CO- group of acetic anhydride. The above reaction is known as acetylation because acetyl group CH_3CO- is attaching with the reactant alcohol.

So, upon acetylation of cellulose with excess acetic anhydride/H_2SO_4 (catalytic) all the $-$OH group will convert into acetyl group.

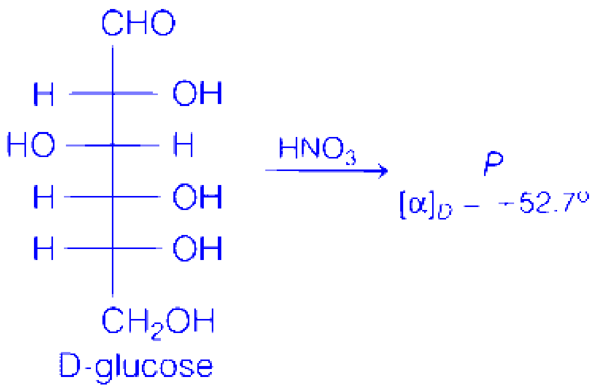
As the cellulose contains a large number of glucose units but our product is triacetate. It means the alcohol group of three glucose units of cellulose is converted into acetyl group. As the acetic anhydride is in excess, all alcoholic groups of three glucose units of cellulose will convert into acetyl groups.

So, the structure of the product is



Question15

Given :



The compound(s), which on reaction with HNO_3 will give the product having degree of rotation, $[\alpha]_D = -52.7°$ is (are)

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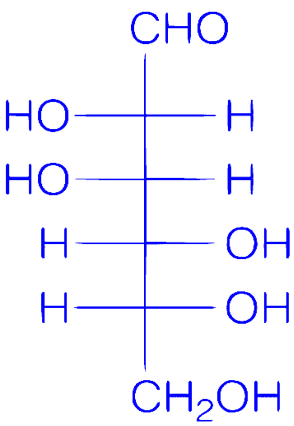
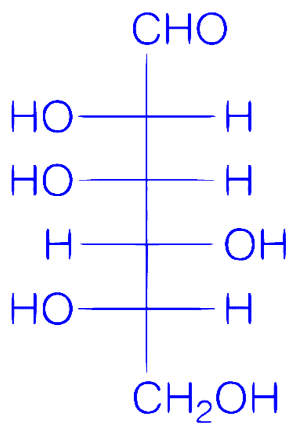
Options:

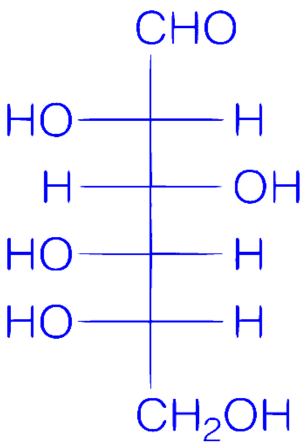
A.



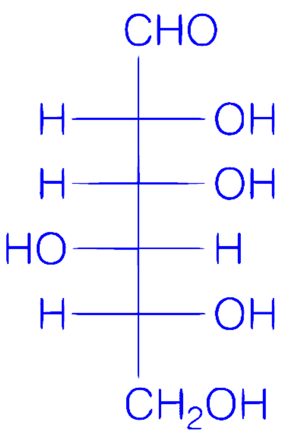
B.



C.



D.

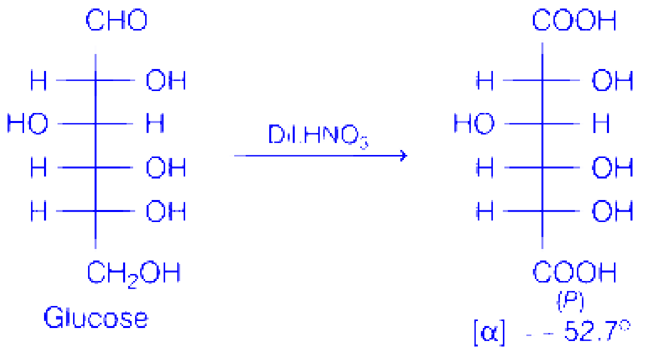


Answer: C

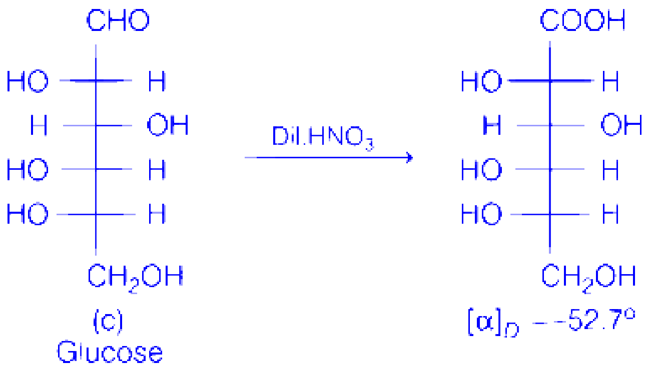
Solution:

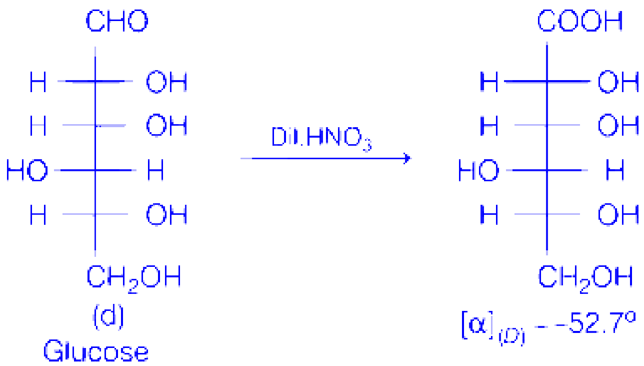
Monosaccharide oxidises on reacting with HNO_3toform carboxylic acids. Primary alcohols also oxidise tocarboxylic acid alongwith aldehyde.

Complete reaction is as follows :



The enantiomer of product (P) has rotation -52.7^{o} . The twoenantiomers (c and d) with their reactions are as follows :





Question16

Which of the following statement(s) is(are) true?

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Options:

A.

The two six-membered cyclic hemiacetal forms of D-(+)- glucose are called anomers.

B.

Oxidation of glucose with bromine water gives glutamic acid

C.

Monosaccharides cannot be hydrolysed to given polyhydroxy aldehydes and ketones

D.

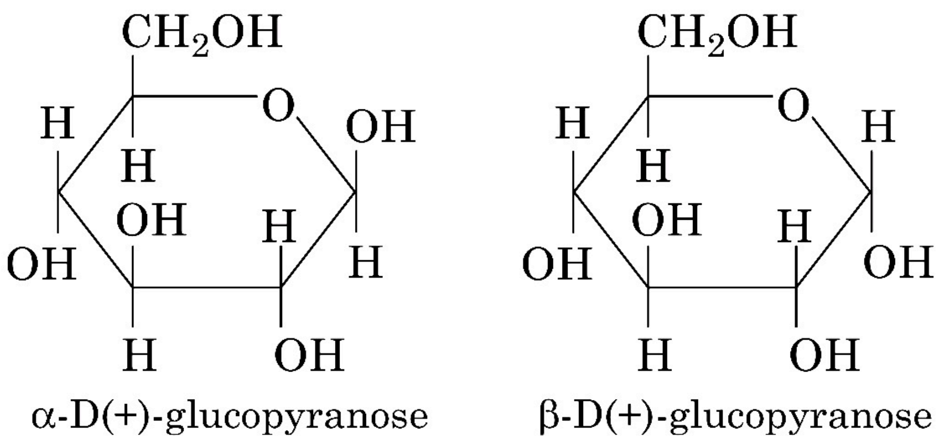
Hydrolysis of sucrose gives dextrorotatory glucose and laevorotatory fructose

Answer: A

Solution:

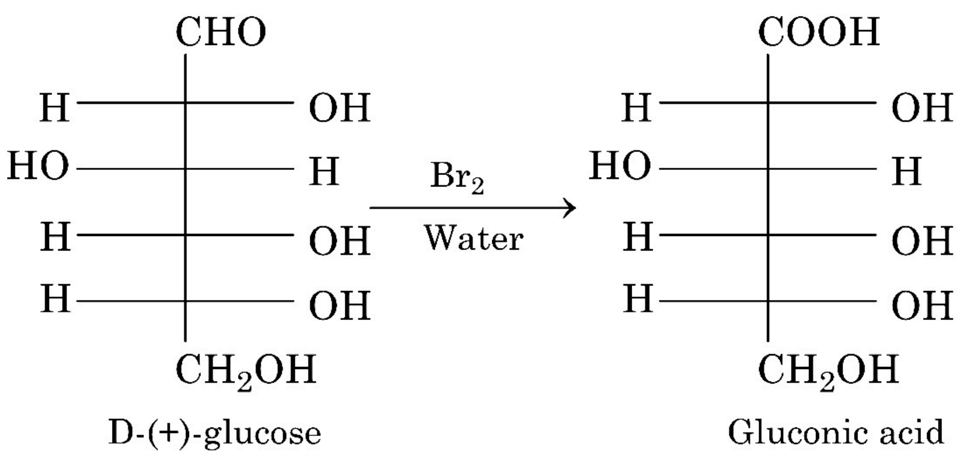
The explanation of given statements are as follows :

(a) Two six membered cyclic hemiacetal form of D-(+)- glucose are called anomers.



Both are anomers.

(b) Oxidation of glucose in presence of Br_2 water gives gluconic acid.



(c) Monosaccharides can not be hydrolysed into polyhydroxy aldehydes and ketones.

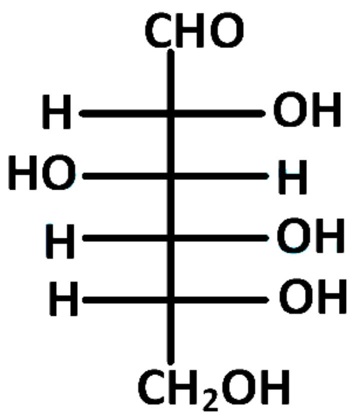
(d) Hydrolysis of sucrose gives D-glucose and L-fructose.

$$C_{12}H_{22}O_{11} + H_2O \xrightarrow{\text{Invertase}} \underset{\substack{\text{D-glucose} \\ \text{or dextrorotatory}}}{C_6H_{12}O_6} + \underset{\substack{\text{L-fructose} \\ \text{or laevorotatory}}}{C_6H_{12}O_6}$$

Hence, options (a, c, d) are correct.

Question17

The Fischer presentation of *D*-glucose is given below.



D-glucose

The correct structure(s) of β-L-glucopyranose is (are) :

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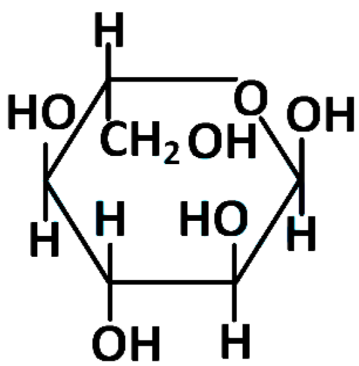
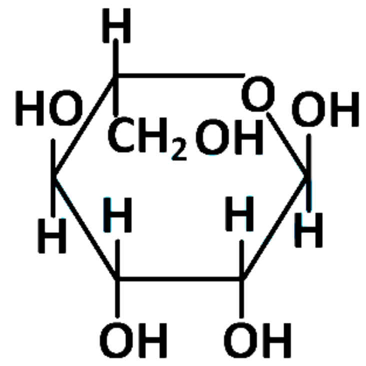
Options:

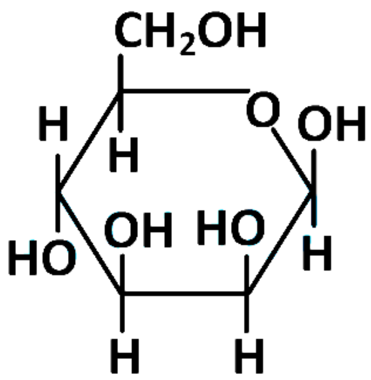
A.



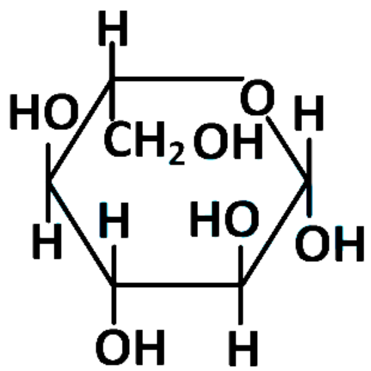
B.



C.



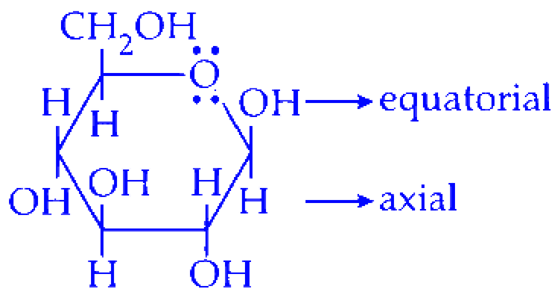
D.



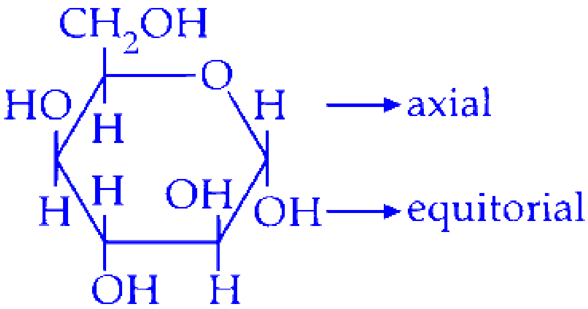
Answer: D

Solution:

When we move from β-(D)-glucopyranose (obtained from D-glucose) groups it axial position becomes equatorial and at equatorial becomes axial.



β-(D) Glucopyranose (from D-glucose)



β-(L) Glucopyranose (from L-glucose)

Question18

For "invert sugar", the correct statement(s) is(are)

(Given : specific rotations of (+)-sucrose, (+)-maltose, L-(−)-glucose and L-(+)-fructose in aqueous solution are +66°, +140°, −52° and +92°, respectively.)

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Options:

A.

"invert sugar" is prepared by acid catalyzed hydrolysis of maltose.

B.

"invert sugar" is an equimolar mixture of D-(+)-glucose and D-(−)-fructose.

C.

specific rotation of "invert sugar" is −20°.

D.

on reaction with Br_2 water, "invert sugar" forms saccharic acid as one of the products.

Answer: B

Solution:

Invert sugar is prepared by acid catalyzed hydrolysis of sucrose.

$$C_{12}H_{22}O_{11} + H_2O \xrightarrow{HCl} \underbrace{\underset{D-(+)-Glu\cos e}{C_6H_{12}O_6} + \underset{D-(-)-Fructose}{C_6H_{12}O_6}}_{Invert\ sugar}$$

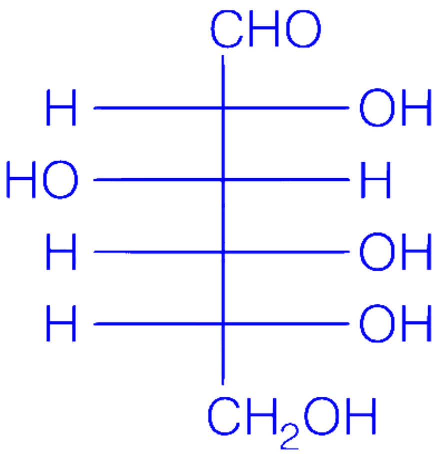
Specific rotation of invert sugar is

$[\alpha]_{mix} = 0.5 \times (+52) + 0.5 \times (-92) = +26 - 46 = -20°$

On reaction with Br_2 water, invert sugar forms gluconic acid as one of the products. Br_2 water oxidises glucose into gluconic acid and fructose is not oxidised by it.

Question19

The structure of D-(+)-glucose is



The structure of L-(−)-glucose is

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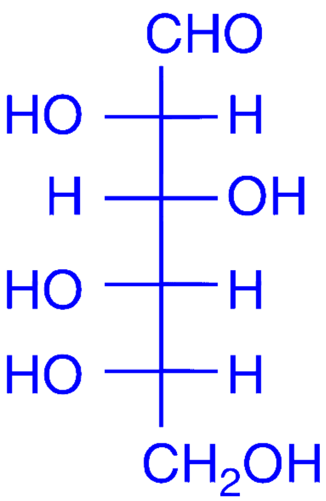
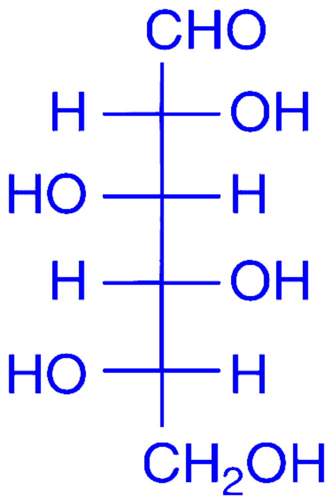
Options:

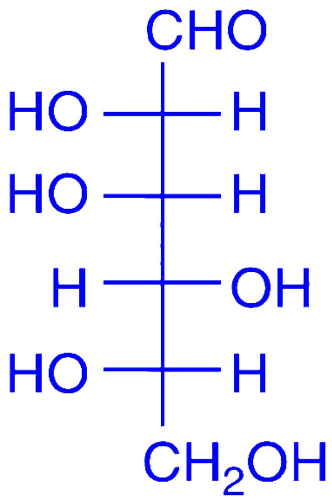
A.



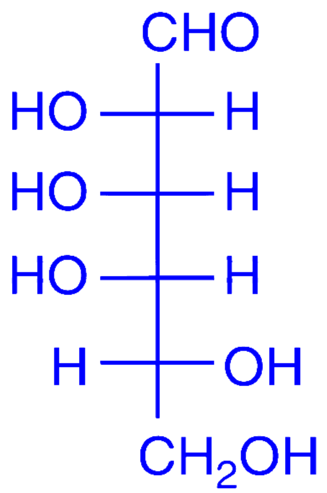
B.



C.



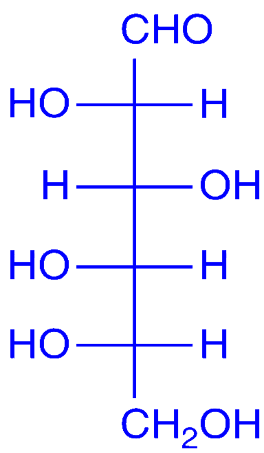
D.



Answer: A

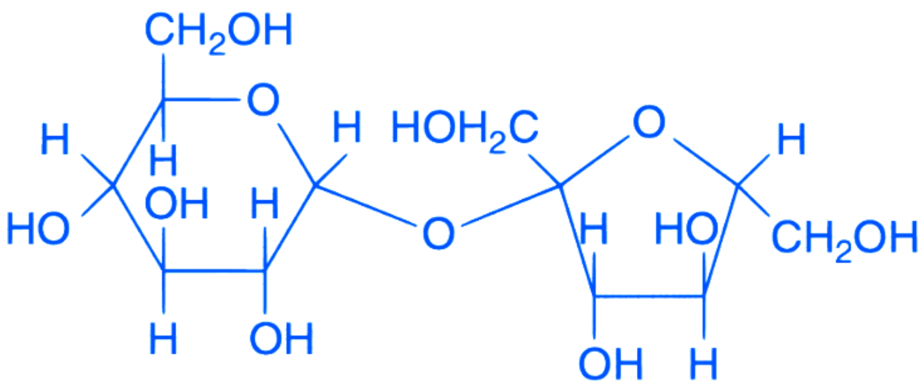
Solution:

In D-(+)-glucose the OH group attached to the last stereocentre is on the right hand side while in L-(−)-glucose it is on left hand side. The structure of L-(−)-glucose is

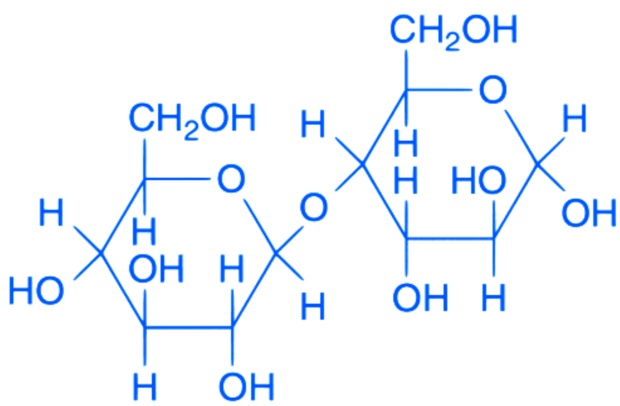


Question20

The correct statement(s) about the following sugar X and Y is(are)



X



Y

IIT-JEE 2009 Paper 2 Offline

Options:

A.

X is a reducing sugar and Y is a non-reducing sugar.

B.

X is a non-reducing sugar and Y is a reducing sugar.

C.

The glucosidic linkages in X and Y are α and β, respectively.

D.

The glucosidic linkages in X and Y are β and α, respectively.

Answer: B

Solution:

Reducing sugars contain cyclic hemiacetal or hemiketal groups in equilibrium with the open chain from having a free $-$CHO or $-$C = O group. Non-reducing sugars contain stable acetal or ketal structures their cyclic structures cannot be opened into an open chain form having a free carbonyl group. In X the glyco-sidic linkage is in between two anomeric carbon atoms while in Y it is only with one anomeric carbon, the other one is free. So, X is non-reducing while Y is reducing.
