KSQUARE CAREER INSTITUTE

BIOMOLECULES

Class 12 Chemistry • Carbohydrates • NEET / JEE Notes

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Topics Covered

1. Introduction — biomolecules: carbohydrates, amino acids, nucleic acids, vitamins, enzymes, hormones
2. Carbohydrates — definition, classification (hydrolysis, reducing nature, number of carbons)
3. Glucose — preparation, structure, chemical reactions, cyclic structure, mutarotation
4. Fructose — open-chain & cyclic structure
5. Disaccharides (sucrose, maltose, lactose) & polysaccharides (starch, cellulose, glycogen)
6. 50+ practice questions with answers
7. Added: other biomolecules at a glance

CARBOHYDRATES

- **Hydrates of carbon** are called carbohydrates — general formula $\mathbf{C_x(H_2O)_y}$, e.g. $C_6(H_2O)_6 = C_6H_{12}O_6$ (glucose).
- **Exceptions:** $C_2(H_2O)_2 = C_2H_4O_2$ = **CH_3COOH (acetic acid)** fits the formula but is **not** a carbohydrate; **rhamnose ($C_6H_{12}O_5$)** is a carbohydrate but does **not** fit the formula.

Modern definition

Carbohydrates are **optically active polyhydroxy aldehydes or ketones**, or compounds which produce such units on hydrolysis.

- Carbohydrates which are **sweet** in taste are called **sugars**.
- Sugar used in our homes — **sucrose**; sugar present in milk — **lactose**.

CLASSIFICATION OF CARBOHYDRATES

1. Based on Hydrolysis

Class	Hydrolysis	Examples
Monosaccharides	Do **not** hydrolyse further (simple unit)	Glucose, fructose, galactose, ribose
Oligosaccharides	Give **2 to 10** monosaccharide units	Disaccharides (2): sucrose, maltose, lactose; Trisaccharide (3): **raffinose**; tetra- (4) … deca- (10)
Polysaccharides	Give a **large number (> 10)** of monosaccharide units	Starch, cellulose, glycogen, gums — **not sweet ⇒ non-sugars**

2. Reducing & Non-reducing Sugars

Reducing sugars	Non-reducing sugars
Reduce Tollens', Fehling's & Benedict's reagents (free aldehydic/ketonic group)	Do **not** reduce these reagents
All monosaccharides (glucose, fructose, galactose) and disaccharides like **maltose, lactose**	**Sucrose** (both reducing groups are tied up in the glycosidic bond)

3. Based on Number of Carbon Atoms

No. of C	Aldose	Ketose
3	Aldotriose	Ketotriose
4	Aldotetrose	Ketotetrose
5	Aldopentose	Ketopentose
6	**Aldohexose (glucose)**	**Ketohexose (fructose)**

GLUCOSE

Preparation

Methods

1. From sucrose (inversion of cane sugar): $C_{12}H_{22}O_{11} + H_2O \xrightarrow{-H^+ \text{ / invertase}} C_6H_{12}O_6$ (glucose, +) + $C_6H_{12}O_6$ (fructose, –)
2. From starch (commercial): $(C_6H_{10}O_5)_n + nH_2O \xrightarrow{-H^+,\ 393\ K,\ 2\text{–}3\ atm} n\ C_6H_{12}O_6$

Structure & Properties

- Glucose is also known as **dextrose (+)**; it is an **aldohexose**, $C_6H_{12}O_6$.
- Open-chain (Fischer projection) structure of D-(+)-glucose has **4 chiral carbons** (C2–C5).

Carbon	Left	Group	Right
C1		CHO	
C2	H	—	OH
C3	HO	—	H
C4	H	—	OH
C5	H	—	OH (D-series)
C6		CH_2OH	

Chemical Reactions of Glucose (Open-chain Evidence)

#	Reagent	Product	Inference
1	**HCN**	**Glucose cyanohydrin** (C1 becomes chiral ⇒ total 5 chiral C)	Presence of C=O group
2	**HI / red P** (prolonged heating)	**n-Hexane**	All 6 C in a **straight chain**
3	**NH_2OH**	**Glucose oxime** (CH=N–OH)	Carbonyl group present
4	**Acetic anhydride**	**Glucose pentaacetate**	**5 –OH groups**
5	**Br_2 water** (mild oxidant)	**Gluconic acid** (aldonic acid; –CHO → –COOH)	Carbonyl is an **aldehyde**
6	**Conc. HNO_3**	**Saccharic acid (glucaric acid)** (–CHO & –CH_2OH → –COOH)	Primary alcohol (–CH_2OH) present
7	**Na(Hg) / $NaBH_4$ / H_2 + catalyst**	**Sorbitol** (C=O → CH–OH)	Reduction of carbonyl

Reactions that Support the Cyclic Structure

1. Glucose does **not** give the **2,4-DNP** test
2. Glucose does **not** give **Schiff's test**
3. Glucose does **not** form the **hydrogensulphite ($NaHSO_3$) addition product**
4. **Glucose pentaacetate does not react with NH_2OH** — so free –CHO is absent

⇒ The –CHO group is tied up: C1 aldehyde reacts with **C5 –OH** to form a six-membered **hemiacetal (pyranose)** ring.

Cyclic Forms & Mutarotation

- Glucose exists in **3 forms in solution**: **α-form (cyclic) ⇌ open chain ⇌ β-form (cyclic)**.
- Haworth forms: **α-D-(+)-glucopyranose** (–OH at C1 below the ring) and **β-D-(+)-glucopyranose** (–OH at C1 above).
- α and β forms differ only in configuration at **C1** (the **anomeric carbon**) ⇒ they are **anomers** (diastereomers).

Mutarotation

The spontaneous change in specific rotation due to interconversion of α and β forms in **acidic or basic medium** (possible because of the **hemiacetal**).

Form	Specific rotation	% at equilibrium
α-D-glucose	+112°	≈ 36%
β-D-glucose	+19°	≈ 64%
Equilibrium mixture	**+52.5°**	—

Remember

L-glucose is the mirror image (enantiomer) of D-glucose.

'D' and 'L' denote **configuration** (–OH on the lowest chiral C on right/left), **not** the sign of rotation; (+)/(–) denote rotation.

FRUCTOSE

- A **ketohexose** (C=O at C2); **laevorotatory (–)**; also called fruit sugar.
- Open chain: **3 chiral carbons**; cyclic (furanose, 5-membered ring formed between C2 and C5 –OH): **4 chiral carbons**.
- Forms **α- and β-D-fructofuranose** — **C2 anomers**.
- Reduces Tollens'/Fehling's reagent because in **basic medium it enolises** and converts into an aldose (glucose/mannose).

Important points

Glucose and fructose are distinguished by **bromine water** (only glucose reacts), **not** by Tollens', Fehling's or Benedict's reagents (both reduce them).

Glucose, fructose and mannose give the same osazone, because osazone formation involves only **C1 and C2**; osazone is stabilised by **intramolecular H-bonding**.

Glucose/fructose → **ethyl alcohol** by fermentation with the enzyme **zymase**.

Glucose & mannose are **C2 epimers**; glucose & galactose are **C4 epimers**.

DISACCHARIDES

Produce **two monosaccharide units** on hydrolysis; units are joined by an **oxide (glycosidic) linkage** (mono–O–mono).

Disaccharide	Units	Glycosidic linkage	Reducing?
Sucrose (cane sugar)	α-D-glucose + β-D-fructose	**C1 (glucose) – C2 (fructose)**	**Non-reducing**
Maltose (malt sugar)	α-D-glucose + α-D-glucose	**C1 – C4** (α)	Reducing
Lactose (milk sugar)	β-D-galactose + β-D-glucose	**C1 – C4** (β)	Reducing

*Note: the PDF slide lists maltose with a "C1 & C2" linkage and labels lactose as "β-D-galactose + β-D-galactose" — the correct facts are **maltose C1–C4** and **lactose = β-D-galactose + β-D-glucose**.*

▸ Inversion of Cane Sugar

- Sucrose is **dextrorotatory (+66.5°)**; on hydrolysis it gives an **equimolar mixture** of D-(+)-glucose (+52.5°) and D-(–)-fructose (–92.4°).
- The mixture is **laevorotatory** because fructose's laevo-rotation is larger ⇒ sign changes from (+) to (–) = **inversion**; the product is **invert sugar**.

POLYSACCHARIDES

Polysaccharide	Monomer	Linkage	Notes
Starch (plants)	α-D-glucose	Amylose: C1–C4 (α); Amylopectin: C1–C4 chain + **C1–C6 branches**	Main storage polysaccharide of plants
Cellulose (plants)	β-D-glucose	**C1–C4 (β)**, linear	Main structural component of plant cell wall
Glycogen (animals)	α-D-glucose	Like amylopectin but **more highly branched**	Animal starch — stored in **liver, muscles & brain**

▸ Amylose vs Amylopectin

Amylose	Amylopectin
Linear polymer	Branched polymer
15–20% of starch	80–85% of starch
Water-soluble	Water-insoluble
C1–C4 α-glycosidic linkage only	C1–C4 chain, branching at **C1–C6**

PRACTICE QUESTIONS — CARBOHYDRATES

Q1. Glycogen is a branched polymer of α-D-glucose (C1–C4 chain, C1–C6 branching). Its structure is similar to

(a) Amylose
(b) Amylopectin
(c) Cellulose
(d) Glucose

Answer: (b)

Q2. Which polymer is stored in the liver of animals?

(a) Amylose
(b) Cellulose
(c) Amylopectin
(d) Glycogen

Answer: (d)

Q3. One molecule of sucrose on hydrolysis gives

(a) 2 glucose
(b) 2 glucose + 1 fructose
(c) 1 glucose + 1 fructose
(d) 2 fructose

Answer: (c)

Q4. Which reaction of glucose can be explained only by its cyclic structure?

(a) Forms pentaacetate
(b) Forms oxime with NH_2OH
(c) Pentaacetate does not react with NH_2OH
(d) Oxidised by HNO_3

Answer: (c)

Q5. Sucrose is a
(a) Monosaccharide
(b) Disaccharide
(c) Non-reducing sugar
(d) Both (b) & (c)

Answer: (d)

Q6. Which carbohydrates are branched polymers of glucose?
(a) Amylose
(b) Amylopectin
(c) Glycogen
(d) Both (b) & (c)

Answer: (d)

Q7. A: D-(+)-glucose is dextrorotatory. **R:** 'D' represents its dextrorotatory nature.
(a) Both correct, R explains A
(b) Both wrong
(c) A correct, R wrong
(d) A wrong, R correct

Answer: (c) — 'D' is configuration; (+) is rotation.

Q8. A: β-glycosidic linkage is present in maltose. **R:** In maltose C1 of one glucose is linked to C4 of another.
(a) Both correct, R explains A
(b) Both wrong
(c) A correct, R wrong
(d) A wrong, R correct

Answer: (d) — Maltose has an α-linkage.

Q9. A: Oxidation of glucose by Br_2 water gives saccharic acid. **R:** Br_2 water oxidises –CHO and alcohol.
(a) Both correct, R explains A
(b) Both correct, R not explanation
(c) A correct, R wrong
(d) Both incorrect

Answer: (d) — Br_2 water gives gluconic acid (only –CHO oxidised).

Q10. A: Sucrose in water is dextrorotatory but becomes laevorotatory on hydrolysis with a little HCl. **R:** Hydrolysis gives unequal amounts of glucose and fructose.
(a) Both correct, R explains A
(b) Both correct, R not explanation
(c) A correct, R wrong
(d) Both incorrect

Answer: (c) — Equal amounts are formed; fructose is more strongly laevorotatory.

Q11. α-D-(+)-glucose and β-D-(+)-glucose are
(a) Conformers
(b) Epimers

(c) Anomers
(d) Enantiomers

Answer: (c)

Q12. A: Glucose and fructose give the same osazone. **R:** During osazone formation stereochemistry only at C1 and C2 is destroyed.

(a) Both correct, R explains A
(b) Both correct, R not explanation
(c) A correct, R wrong
(d) Both incorrect

Answer: (a)

Q13. Fructose on reduction gives a mixture of two alcohols (sorbitol & mannitol) which are related as

(a) Diastereomers
(b) Epimers
(c) Both (a) & (b)
(d) Anomers

Answer: (c) — New chiral centre at C2.

Q14. A: Sucrose is a non-reducing sugar. **R:** It has a peptide linkage.

(a) Both correct, R explains A
(b) Both correct, R not explanation
(c) A correct, R wrong
(d) Both incorrect

Answer: (c) — It has a glycosidic linkage.

Q15. A: Hydrolysis of sucrose is known as inversion of cane sugar. **R:** Sucrose is a disaccharide.

(a) Both correct, R explains A
(b) Both correct, R not explanation
(c) A correct, R wrong
(d) Both incorrect

Answer: (b)

Q16. Carbohydrates have

(a) –OH group
(b) –CHO group
(c) >C=O group
(d) All

Answer: (d)

Q17. Which does NOT show mutarotation?

(a) (–)-Fructose
(b) (+)-Lactose
(c) (+)-Maltose
(d) (+)-Sucrose

Answer: (d) — No free hemiacetal.

Q18. Ring structure of glucose is due to hemiacetal formation between

(a) C1 and C5
(b) C1 and C2
(c) C1 and C3
(d) C1 and C4

Answer: (a)

Q19. Glucose + Br_2/H_2O gives

(a) Glucaric acid
(b) Gluconic acid
(c) Hexanoic acid
(d) Bromohexane

Answer: (b)

Q20. Glucose does NOT react with

(a) $C_6H_5NHNH_2$
(b) NH_2OH
(c) HCN
(d) $NaHSO_3$

Answer: (d)

Q21. A carbohydrate which cannot be hydrolysed to simpler compounds is

(a) Monosaccharide
(b) Disaccharide
(c) Polysaccharide
(d) Oligosaccharide

Answer: (a)

Quick-fire practice (answers in bold)

- α-D-glucose and β-D-glucose differ w.r.t. one carbon's → **configuration (at C1)**
- Reagent for reduction of glucose to n-hexane → **HI (red P)**
- The letter 'D' in carbohydrates signifies → **its configuration**
- Which one is not a polysaccharide: sucrose, glycogen, starch, cellulose? → **Sucrose**
- A mixture of amylose and amylopectin is → **Starch**
- Sucrose is made up of → **α-glucopyranose + β-fructofuranose**
- Not a disaccharide: cane sugar, raffinose, lactose, maltose → **Raffinose (trisaccharide)**
- Lactose on hydrolysis gives → **Glucose + galactose**
- Hydrolysis of sucrose is called → **Inversion**
- Reagent to convert glucose to saccharic acid → **Nitric acid**
- Glucose + bromine water → major product → **Gluconic acid**
- Invert sugar is an equimolar mixture of → **D-glucose and D-fructose**
- Cellulose is a linear polymer of → **β-D-glucose**
- Correct about sucrose → **Non-reducing sugar**
- Glucose and mannose are → **Epimers (C2)**
- Lactose is made of → **β-D-galactose + β-D-glucose**
- Which is a disaccharide: glucose, fructose, sucrose, starch? → **Sucrose**
- Number of asymmetric carbons in (open-chain) fructose → **3**
- Sucrose is made of → **D-glucose + D-fructose**
- Rapid interconversion of α- and β-D-glucose in solution → **Mutarotation**
- Complete hydrolysis of starch gives → **Glucose only**
- Glucose and fructose are → **Functional isomers**

- Fructose reduces Tollens' reagent due to → **Enolisation followed by conversion to aldehyde in base**
- Pair forming the same osazone → **Glucose and fructose**
- Anomers of glucose differ in configuration at → **C-1**
- The glucose-type osazone can be obtained from → **D-glucose and D-mannose (also D-fructose)**
- Correctly matched pair → **Glucose : mutarotation**
- Match — sucrose, lactose, maltose, raffinose with hydrolysis products → **Sucrose–Glc + Fru; Lactose–Glc + Gal; Maltose–Glc + Glc; Raffinose–Glc + Fru + Gal**
- Match — sucrose, cellulose, starch, lactose with units → **Sucrose–α-Glc + β-Fru; Cellulose–β-Glc; Starch–α-Glc; Lactose–β-Gal + β-Glc**
- The 1,2-enediol (enol) form is common to → **D-glucose, D-mannose and D-fructose (all of these)**
- Fructose gives Fehling's test because → **the keto group changes into –CHO by enolisation in the basic medium**

OTHER BIOMOLECULES AT A GLANCE (ADDITIONAL TOPIC)

Biomolecule	Key facts
Amino acids & proteins	α-amino acids (–NH_2 and –COOH on same C); essential vs non-essential; joined by **peptide bonds (–CO–NH–)**; structures: primary, secondary (α-helix, β-pleated sheet), tertiary, quaternary; **denaturation** destroys 2°/3° structure (e.g. boiling egg)
Enzymes	Biological catalysts, mostly globular proteins; highly specific; e.g. invertase, maltase, zymase
Vitamins	Fat-soluble: A, D, E, K (stored in liver & adipose tissue); water-soluble: B-group & C (must be supplied regularly); deficiency diseases e.g. A–night blindness, C–scurvy, D–rickets
Nucleic acids	Polymers of nucleotides (base + pentose sugar + phosphate); DNA (deoxyribose; A, G, C, T; double helix) and RNA (ribose; A, G, C, U; single strand); nucleotides joined by **phosphodiester** linkages
Hormones	Chemical messengers: steroids (oestrogen, testosterone), polypeptides (insulin), amino-acid derivatives (thyroxine, adrenaline)

QUICK REVISION

- Carbohydrates = optically active polyhydroxy aldehydes/ketones; $C_x(H_2O)_y$ (exceptions: acetic acid, rhamnose).
- Mono (no hydrolysis), oligo (2–10), poly (> 10; non-sugars). Sucrose = non-reducing; maltose, lactose = reducing.
- Glucose: aldohexose, 4 chiral C; HI → n-hexane; Br_2 water → gluconic acid; HNO_3 → saccharic acid; Ac_2O → pentaacetate; $NaBH_4$ → sorbitol.
- Cyclic proof: no 2,4-DNP, Schiff's, $NaHSO_3$ reaction; pentaacetate + NH_2OH no reaction; ring C1–C5 (pyranose).
- α (+112°, 36%) ⇌ β (+19°, 64%); equilibrium +52.5° — mutarotation; anomers differ at C1.
- Sucrose: α-Glc C1–C2 β-Fru; maltose: α-Glc C1–C4 α-Glc; lactose: β-Gal C1–C4 β-Glc.

Notes revise 2 times — biomolecules is a scoring chapter!

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