FREE EDITION · NOTES + 3 SAMPLE MCQS

CUET · CHEMISTRY · CLASS XI · CODE 306

Organic Chemistry - Some Basic Principles and Techniques

CUET unit: Organic Chemistry - Some Basic Principles and Techniques

By **UniDrill** · NCERT-grounded study material

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📌 Snapshot

- Establishes the founding vocabulary of organic chemistry: tetravalence of carbon, sp/sp²/sp³ hybridisation, structural formulas (complete, condensed, bond-line, wedge–dash) and 3-D shapes (NCERT §8.2–§8.3).
- Builds a complete classification tree (acyclic vs cyclic, alicyclic vs aromatic, homocyclic vs heterocyclic, benzenoid vs non-benzenoid) and introduces the concept of functional groups and homologous series (NCERT §8.4).
- Develops IUPAC nomenclature for alkanes (straight, branched, cyclic), alkenes, alkynes, substituted benzene and molecules carrying functional groups (NCERT §8.5).
- Lays the foundation for organic mechanism: homolytic vs heterolytic fission, free radicals, carbocations and carbanions, nucleophiles vs electrophiles, inductive, resonance, electromeric and hyperconjugation effects (NCERT §8.6–§8.7).
- Covers isomerism (chain, position, functional, metamerism, tautomerism, geometrical, optical) and the practical toolkit — purification (sublimation, crystallisation, distillation, differential extraction, chromatography) and detection/estimation of C, H, N, S, halogens, P (NCERT §8.6, §8.8–§8.10). CUET typically picks one item from each of these blocks every year.

📖 Detailed Notes

2.1 Core concepts

- Organic chemistry deals with carbon compounds; the unique property of carbon to form long chains, branched chains and rings by C–C bonding is called **catenation**, and explains the millions of organic compounds known. Carbon's small size, tetravalence and ability to form strong σ-bonds with itself and with H, N, O, S, halogens make catenation maximum among all elements (NCERT §8.1, p. 256).
- Wöhler's synthesis (1828) of urea by heating ammonium cyanate ($NH_4CNO \rightarrow NH_2CONH_2$) and Kolbe's synthesis of acetic acid (1845) disproved the vital-force theory and showed organic compounds can be made from inorganic ones — laying the basis for modern organic chemistry as a branch of structure-based science rather than "chemistry of living things" (NCERT §8.1, p. 256).

- Carbon is **tetravalent**; in saturated compounds it is sp^3 hybridised (tetrahedral, 109.5° bond angle, equivalent C–H bonds in CH_4), in alkenes/C=C it is sp^2 (trigonal planar, 120°, one π-bond), and in alkynes/C≡C and C≡N it is sp (linear, 180°, two π-bonds) (NCERT §8.2.1, p. 257).
- A C–C single bond is longer (≈154 pm) and weaker than C=C (≈134 pm) which in turn is longer than C≡C (≈120 pm); s-character increases $sp^3 < sp^2 < sp$, so bonds become shorter and stronger and the carbon becomes more electronegative (a vinyl/aryl/alkynyl carbon is more electronegative than alkyl) (NCERT §8.2.2, p. 257).
- Structural formulas have three forms: **complete** (every bond drawn, useful for showing all atoms), **condensed** (e.g. CH_3CH_2OH, $(CH_3)_2CHCH_3$, omits some C–H bonds) and **bond-line** (zig-zag, terminals are CH_3, vertices are carbons, H atoms implicit — quickest representation for complex skeletons) (NCERT §8.3.1, p. 258).
- Three-dimensional structure is shown by **wedge-dash** notation — solid wedge for a bond projecting towards the viewer, dashed/broken wedge for one going away, and ordinary line for bonds in the plane of the paper; equivalent to Newman, sawhorse and Fischer projections used elsewhere (NCERT §8.3.2, p. 260).
- Organic compounds are classified as **acyclic (open-chain or aliphatic)** or **cyclic (closed-chain)**; cyclic compounds split into **alicyclic** (cyclopropane, cyclohexane, tetrahydrofuran — properties resemble open-chain analogues) and **aromatic** (benzenoid like benzene/aniline/naphthalene/anthracene and non-benzenoid like tropone — show special π-electron stability, Hückel's 4n+2 rule) (NCERT §8.4, p. 261).
- Cyclic compounds with at least one heteroatom (O, N, S) in the ring are **heterocyclic** (furan O, thiophene S, pyridine N); these include both alicyclic (tetrahydrofuran THF) and aromatic (pyridine, furan, thiophene — all 6-π aromatic) types (NCERT §8.4, p. 262).
- A **functional group** (–OH, –CHO, >C=O, –COOH, $–NH_2$, $–NO_2$, –C≡N, halogen etc.) determines the chemical properties; compounds with the same functional group differing by $–CH_2–$ form a **homologous series** with regularly graded physical properties (e.g., alcohols methanol → ethanol → propanol show steady rise in bp) (NCERT §8.4.1–§8.4.2, p. 262).
- **IUPAC nomenclature** (1957, IUPAC) names a compound by combining a root word indicating number of carbons (meth-, eth-, prop-, but-, pent-, hex-, hept-, oct-, non-, dec-) with a primary suffix for saturation/unsaturation (-ane, -ene, -yne) and a secondary suffix/prefix for functional groups (NCERT §8.5, p. 263; Table 8.2 p. 263, Table 8.4 p. 267).
- For a branched alkane: select the **longest carbon chain** as the parent, number from the end that gives the **lowest set of locants** to substituents, name substituents alphabetically with locants and join (e.g. 2,5-dimethylhexane). Apply "first point of difference" rule when comparing two locant sets (NCERT §8.5.1, p. 263–264).

- For alkenes/alkynes, give the C=C/C≡C the lowest locant; cyclic compounds use the prefix **cyclo-** before the alkane/alkene root (cyclopropane, cyclohexene); compounds with both C=C and C≡C are "enynes" with C=C taking precedence in numbering (NCERT §8.5.2, p. 264–265).
- **Substituted benzenes** are named by giving the substituent locants the lowest set; for disubstituted benzenes, the prefixes ortho- (1,2-), meta- (1,3-), para- (1,4-) are also used. Some common (trivial) names — toluene, aniline, phenol, anisole — are retained by IUPAC (NCERT §8.5.4, p. 268–269).
- **Isomerism** — same molecular formula, different structure. **Structural isomerism** = chain, position, functional, metamerism, tautomerism; **stereoisomerism** = geometrical (cis-trans/E-Z) and optical (NCERT §8.6, p. 270; flowchart p. 270). Tautomerism is a dynamic interconversion (e.g., keto ⇌ enol).
- **Fission of a covalent bond: homolytic** (each fragment takes one electron, gives free radicals, shown by single-headed "fish-hook" arrow) vs **heterolytic** (one fragment takes both electrons, gives a cation + anion / carbocation + nucleophile, shown by double-headed arrow). Homolytic fission predominates in non-polar conditions (gas phase, $h\nu$, peroxides); heterolytic in polar conditions (NCERT §8.7.1, p. 271).
- **Carbocations** are sp^2 hybridised, planar, electron-deficient with an empty p-orbital; **carbanions** are sp^3, pyramidal with a lone pair; stability of carbocations follows 3° > 2° > 1° > methyl, opposite for carbanions (alkyl groups destabilise carbanion via +I effect) (NCERT §8.7.1, p. 271–272).
- **Nucleophiles** are electron-rich species (lone pair or –ve charge: OH^-, CN^-, RO^-, H_2O, NH_3, R_2NH) that attack electron-poor carbons; **electrophiles** are electron-deficient (carbocations, $AlCl_3$, BF_3, $^+NO_2$, $^+SO_3H$, ^+Cl) and attack electron-rich sites (alkenes, aromatics) (NCERT §8.7.2, p. 272–273).
- **Electron displacement effects** (NCERT §8.7.3):
- **Inductive (I) effect** — permanent, transmitted through σ-bonds, dies out beyond 3rd carbon. –I groups (–NO_2, –CN, –COOH, halogens, –OH, –NH_2⋯) withdraw electrons; +I groups (alkyl, –COO^-) push electrons (p. 274).
- **Resonance (M/R) effect** — π/lone-pair delocalisation; +R groups (–OH, –OR, –NH_2, –Cl) donate electrons by resonance, –R groups (–NO_2, –CN, –CHO, –COOH, –COR) withdraw (p. 275–276). On benzene, +R groups are o/p-directing; –R groups are m-directing.
- **Electromeric (E) effect** — temporary, occurs in presence of attacking reagent at a multiple bond; +E (alkenes towards H^+) and –E (towards CN^- etc.) (p. 277).
- **Hyperconjugation** — delocalisation of σ-electrons of a C–H bond α to an sp^2 carbon (alkene or carbocation) into the empty p / π^* orbital; explains stability order of carbocations (3° > 2° > 1° > methyl), Saytzeff orientation of alkene products, and the order of alkene stability (more α-H = more stable alkene) (p. 277–278).

- **Types of organic reactions** — substitution (SN1/SN2 ; SE Ar in aromatics), addition (Markovnikov, anti-Markovnikov), elimination (E1/E2), rearrangement (Wagner-Meerwein); detailed treatment in Class XII (NCERT §8.7.10, p. 278).
- **Methods of purification** (NCERT §8.8, p. 278) match the property used: sublimation (solid ⇌ vapour, e.g. naphthalene, camphor, NH_4Cl, anthracene), crystallisation (different solubility in a solvent or solvent pair), distillation (different b.p.), differential extraction (different solubility in two immiscible solvents), chromatography (different adsorption or partition between phases).
- **Distillation variants** — **simple distillation** for liquids with appreciable b.p. difference (>25 K); **fractional distillation** (fractionating column with glass beads/ Vigreux) for liquids with close b.p. (industrial separation of petroleum); **steam distillation** for water-insoluble, steam-volatile compounds (e.g. aniline, o-nitrophenol, essential oils), works because P(total) = P(steam) + P(compound) reaches atmospheric below 100 °C; **distillation under reduced pressure** for liquids that decompose below their b.p. (e.g. glycerol, b.p. 290 °C) (NCERT §8.8.3, p. 279–281).
- **Chromatography** — separates by differential adsorption (adsorption chromatography: column on alumina/silica, TLC plate of glass coated with adsorbent); or differential partition (paper chromatography uses moisture as stationary phase). In **TLC**, retardation factor R_f = (distance moved by substance)/ (distance moved by solvent front) is always $\leqslant 1$ and characteristic of a compound under given conditions (NCERT §8.8.5, p. 282–284).
- **Detection of elements (qualitative)** — C and H by heating with dry CuO (gives CO_2 that turns lime water milky; H_2O that turns anhydrous $CuSO_4$ blue). N, S, halogens by **Lassaigne's test** (fuse organic with Na metal → covalent N, S, X become ionic NaCN, Na_2S, NaX, easy to detect) (NCERT §8.9, p. 284–285).
- N: Na fusion extract + $FeSO_4$ + dil H_2SO_4 → Prussian blue ($Fe_4[Fe(CN)_6]_3$).
- S: extract + sodium nitroprusside → violet ($Na_2[Fe(CN)_5NOS]$); or + lead acetate → black PbS.
- Halogens: extract + $AgNO_3$ → white AgCl (soluble in NH_3), pale-yellow AgBr (sparingly soluble in NH_3), yellow AgI (insoluble in NH_3) — the colour and solubility of AgX distinguishes Cl/Br/I.
- N + S together: violet/blood-red colouration from NaSCN + $FeCl_3$ → $Fe(SCN)_3$.
- **Quantitative estimation** (NCERT §8.10, p. 285):
- **C and H – Liebig's method**: known mass burnt in excess O_2 over hot CuO → CO_2 absorbed in KOH (mass gain measured), H_2O in anhydrous $CaCl_2$; % C = (12/44)×(mass CO_2/mass compound)×100, % H = (2/18)×(mass H_2O/mass compound)×100.
- **N – Dumas' method**: combustion with CuO in CO_2 atmosphere → N_2 collected over KOH (other gases absorbed); % N = (28/22400)×(V at STP/m)×100.

- **N – Kjeldahl's method**: digest with conc H_2SO_4 + K_2SO_4 + $CuSO_4$ catalyst → $(NH_4)_2SO_4$, distil with NaOH → NH_3 absorbed in known volume of standard H_2SO_4; the unused acid is back-titrated with NaOH; % N = (1.4 × N(acid) × V(acid used by NH_3))/ mass; **not applicable** to N in ring (pyridine), $–NO_2$ or azo compounds.
- **Halogen – Carius method**: heat with fuming HNO_3 and $AgNO_3$ in a sealed Carius tube → AgX is weighed; % X = (atomic mass X / mol mass AgX) × (mass AgX / mass compound) × 100.
- **Sulphur – Carius method**: oxidise with fuming HNO_3 → H_2SO_4, precipitate as $BaSO_4$; % S = (32/233) × (mass $BaSO_4$ / mass compound) × 100.
- **Phosphorus**: oxidise → H_3PO_4, precipitate as $MgNH_4PO_4$, ignite to $Mg_2P_2O_7$; % P = (62/222) × (mass $Mg_2P_2O_7$ / mass compound) × 100.
- **Oxygen**: usually obtained by difference, % O = 100 − Σ(% of all other elements).

2.2 Definitions to memorise

Term	Definition	Page
Catenation	Self-linking of carbon atoms by C–C covalent bonds to form long chains/rings	256
Hybridisation	Intermixing of atomic orbitals (s, p) to give equivalent hybrid orbitals (sp^3, sp^2, sp) on carbon	257
Bond-line formula	Skeletal representation where lines are bonds, vertices/ends are C, H atoms implicit	258
Wedge-dash notation	3-D representation: solid wedge = forward, dashed = back, line = in plane	260
Acyclic compound	Open-chain (aliphatic) compound	261
Cyclic compound	Closed-ring compound; can be alicyclic, aromatic, heterocyclic	261
Functional group	Atom or group that determines chemical properties (–OH, –CHO, –COOH, $–NH_2$, $–NO_2$⋯)	262
Homologous series	Series of compounds with same general formula and functional group, consecutive members differ by $–CH_2–$	263
IUPAC name	Systematic name = (locant)-(substituent prefixes)-root-(unsaturation suffix)-(functional-group suffix)	263–267
Isomerism	Phenomenon where compounds have the same molecular formula but different structures/spatial arrangement	270
Chain isomerism	Different arrangement of carbon skeleton (n-butane vs isobutane)	270
Position isomerism	Different position of functional group/substituent on same skeleton	270
Functional isomerism	Different functional groups for same molecular formula	270

Term	Definition	Page
Metamerism	Position isomerism arising from different alkyl groups on either side of a polyvalent atom (O, S, N) e.g. $C_2H_5OC_2H_5$ vs $CH_3OC_3H_7$	271
Tautomerism	Functional-isomerism in dynamic equilibrium (keto ⇌ enol)	271
Homolytic fission	Symmetrical bond breaking giving two free radicals (single-headed arrow)	271
Heterolytic fission	Unsymmetrical bond breaking giving a cation and an anion (double-headed arrow)	271
Free radical	Species with unpaired electron; sp^2-like geometry, electrically neutral	271
Carbocation	Positively charged sp^2 C with 6 valence electrons and an empty p-orbital	272
Carbanion	Negatively charged sp^3 C with a lone pair (pyramidal)	272
Nucleophile	Electron-rich reagent (OH^-, CN^-, RO^-, NH_3) that donates a pair of electrons to electron-poor carbon	273
Electrophile	Electron-deficient reagent (carbocation, $AlCl_3$, BF_3, $^+NO_2$) that accepts a pair of electrons	273
Inductive (I) effect	Permanent polarisation of σ-bonds due to electronegativity difference; dies out within 3 carbons	274
Resonance (M) effect	Permanent polarisation by π-electron / lone-pair delocalisation along conjugated systems	275–276
Electromeric effect	Temporary, reagent-induced shift of π electrons in a multiple bond	277
Hyperconjugation	Delocalisation of σ-electrons of α-C–H bond into adjacent empty p/π^* orbital (no-bond resonance)	277
Lassaigne's test	Sodium-fusion test that converts covalently bound N, S, X into ionic NaCN, Na_2S, NaX for qualitative detection	284–285

2.3 Diagrams / processes to remember

- **Fig. 8.1 — wedge/dash 3-D representation of CH_4 (p. 260):** central carbon, four sp^3 orbitals, two bonds in plane (lines), one solid wedge (toward viewer), one dashed wedge (away); explains tetrahedral geometry at a glance.
- **Fig. 8.2 — framework, ball-and-stick, space-filling models of methane (p. 260):** three complementary 3-D depictions showing increasing levels of detail; emphasises that all four H atoms are equivalent.
- **Classification flowchart of organic compounds (p. 261):** branching tree from "organic compounds" → acyclic/cyclic; cyclic → alicyclic/aromatic; aromatic → benzenoid/non-benzenoid; with examples at each leaf.

- **Functional-group table (Table 8.4, p. 267):** for every common class — alcohol, ether, aldehyde, ketone, carboxylic acid, ester, amide, amine, nitrile, nitro, halide — gives IUPAC prefix, suffix and example. Use this as the master nomenclature key.
- **Flowchart of isomerism: structural vs stereo (p. 270):** structural (chain, position, functional, metamerism, tautomerism) and stereo (geometrical, optical). Quick reference for MCQ identification.
- **Carbocation pyramid (sp^2, empty p) and carbanion (sp^3, lone pair) shapes (Figs. 8.3a/8.3b, p. 272):** carbocation drawn as planar trigonal with empty p-orbital perpendicular; carbanion as pyramidal sp^3 with lone pair in the fourth orbital — visually highlights why nucleophiles attack carbocation perpendicular to plane.
- **Orbital picture of hyperconjugation in $CH_3CH_2^+$ (Fig. 8.4(a), p. 277) and propene (Fig. 8.4(b), p. 277):** σ C–H orbital overlapping the empty p-orbital of the adjacent C^+ (or the π^* of C=C); shows the "no-bond resonance" canonical form (H^+ ... C=C–C–H...).
- **Fig. 8.5 — simple distillation apparatus (p. 279):** distillation flask, thermometer, condenser, receiver; for liquids with >25 K bp difference.
- **Fig. 8.6 — fractional distillation column (p. 280):** packed column above the flask provides many "plates" of repeated condensation/evaporation; needed for close-boiling liquids like petroleum fractions.
- **Fig. 8.7 — fractionating columns of different designs (p. 280):** Vigreux, glass-bead, plate columns.
- **Fig. 8.8 — distillation under reduced pressure (p. 281):** vacuum pump lowers boiling temperature, prevents decomposition of heat-sensitive liquids like glycerol.
- **Fig. 8.9 — steam distillation (p. 282):** steam generator + flask + condenser; principle: P(total) = P(steam) + P(compound) reaches atmospheric below 100 °C.
- **Fig. 8.10 — differential extraction in a separating funnel (p. 282):** aqueous + organic layers, repeated extractions move solute to organic phase.
- **Figs. 8.11–8.13 — column chromatography, TLC plate and developed chromatogram (p. 283–284):** column (gravity), TLC (capillary action), developed plate with separated spots and R_f calculation.
- **Fig. 8.14 — Liebig's combustion apparatus for C and H (p. 286):** O_2 flow, CuO furnace, anhydrous $CaCl_2$ tube (H_2O absorber), KOH tube (CO_2 absorber); mass gain measures each element.
- **Fig. 8.15 — Dumas' apparatus for N (p. 287):** combustion in CO_2 atmosphere; N_2 collected over KOH solution (KOH absorbs CO_2); volume of N_2 at STP gives % N.
- **Fig. 8.16 — Kjeldahl's apparatus (p. 288):** digestion flask + distillation set-up; NH_3 is steam-distilled into known H_2SO_4 and the excess back-titrated with NaOH.
- **Fig. 8.17 — Carius tube for halogens/sulphur (p. 289):** sealed glass tube heated in a Carius furnace with fuming HNO_3 + $AgNO_3$ (for X) or HNO_3 (for S); allows quantitative recovery as AgX or $BaSO_4$.

2.4 Common confusions / NTA trap points

- "Lowest locant" rule confused with "lowest first locant": apply the **first point of difference** rule on the whole set, not just the smallest number (NCERT §8.5.1, p. 263–264). For two possible sets {2,5,6} vs {3,4,5}, choose {2,5,6} because 2 < 3.
- Carbocation vs carbanion **shape**: carbocation is sp^2 **planar**; carbanion is sp^3 **pyramidal** with a lone pair (p. 272). NTA often swaps these.
- **Order of carbocation stability** (3° > 2° > 1° > methyl) is the opposite of carbanion stability (methyl > 1° > 2° > 3°) — students invert.
- **Inductive (–I) vs resonance (–M)**: $–NH_2$, –OH are –I but **+M** on benzene ring; NTA likes to ask the net effect (typically activating, ortho/para-directing on benzene despite –I).
- **Halogens are −I AND +M on the ring**, but they are weakly deactivating overall while still ortho/para-directing — a unique combination that catches students.
- **Steam distillation** works because vapour pressure of the mixture reaches atmospheric **below** 100 °C; common error is to say the compound's b.p. is below 100 °C (p. 281). What is true is that the **combined** pressure reaches atmospheric below 100 °C.
- **Kjeldahl** does **not** work for N in pyridine ring, nitro groups ($–NO_2$) or azo compounds (–N=N–) because these are not converted to $(NH_4)_2SO_4$ under digestion (p. 288).
- **Sodium fusion extract** must be made **alkaline** before testing for halogens with $AgNO_3$ — and any cyanide/sulphide must be removed by boiling with dil HNO_3, else they precipitate with Ag^+ and give false positives (p. 285).
- **R_f value** is always $\leqslant 1$; it is the ratio of distance moved by substance to distance moved by solvent front, not by the spot from the bottom of the plate (p. 284). R_f depends on the solvent and adsorbent used.
- **Hyperconjugation** is also called no-bond resonance and requires **α-C–H** bonds — vinyl/aryl cations show no hyperconjugation because the p-orbital is on a C that has no sp^3 C–H next to it (p. 277).
- **Lassaigne's test** does NOT detect oxygen — there is no specific qualitative test for O; it is found by difference in mass.
- **Resonance ≠ tautomerism**: resonance is delocalisation in a SINGLE structure (canonical forms have only π/lone-pair shifts, atoms don't move); tautomerism is two different structures in equilibrium (atoms move, usually H).
- **Functional isomers** can interconvert (e.g., propanone $\rightleftharpoons$ prop-1-en-2-ol via keto-enol tautomerism); chain and position isomers cannot interconvert without C–C bond breaking.

🎯 Practice MCQs

Q1. The hybridisation of the carbon atoms in $CH_3–CH=CH–C\equiv N$, from left to right, is

A. sp^3, sp^2, sp^2, sp

B. sp^3, sp^2, sp, sp

C. sp^2, sp^2, sp^2, sp

D. sp^3, sp^3, sp^2, sp

Q2. Which of the following statements about a carbocation (R_3C^+) is correct?

A. It is sp^3 hybridised and pyramidal with a lone pair on carbon.

B. It is sp^2 hybridised and trigonal planar with an empty p-orbital on carbon.

C. It is sp hybridised and linear with two lone pairs on carbon.

D. It is sp^3 hybridised and tetrahedral with eight valence electrons.

Q3. The IUPAC name of the compound $(CH_3)_2CH–CH_2–CH(C_2H_5)–CH_2–CH_3$ is

A. 2-methyl-4-ethylhexane

B. 5-ethyl-2-methylhexane

C. 3-ethyl-5-methylhexane

D. 3-ethyl-5-methylheptane

📊 PYQ Alignment

This chapter is the single highest-yielding chapter from the Class XI organic block in CUET; roughly 8–10 MCQs every year are drawn from it, most often on (i) hybridisation/ shape of given carbons, (ii) IUPAC names of branched alkanes, alkenes, substituted benzenes or compounds with functional groups, (iii) comparing stability of carbocations/ free radicals via inductive, resonance and hyperconjugation, (iv) identifying –I/+I, +M/–M

groups, and (v) calculations from Liebig/Dumas/Kjeldahl/Carius data plus the property exploited by each purification technique.

CUET 2023 — Actual PYQs from this chapter

Q.48 (CUET 2023) The IUPAC name of the compound shown is:

- A) 1-Methyl-2-phenyl ethanol B) 1-Methyl-1-phenyl ethanol C) 2-Phenylpropan-2-ol D) 1,1-Dimethyl-1-phenyl methanol

Tests: IUPAC nomenclature organic Answer: Not in extracted key