Unit 9 · Organic Compounds

STUDY NOTES

Key terms

Organic compound: compound of carbon, mostly with hydrogen; others made by putting other atoms in place of some H. **Not organic**: CO, CO_2, H_2CO_3, carbonates, hydrogencarbonates, cyanides, carbides.

Hydrocarbon: only carbon and hydrogen.

Tetracovalency: forms four covalent bonds; valency 4.

Catenation: carbon atoms bond to each other in chains, branches, rings.

Multiple bonding: double (C=C, C=O), triple (C≡C, C≡N) bonds.

Saturated: only single C–C bonds. **Unsaturated**: a double or triple bond; could take on more H.

Alkyl group (R): alkane less one H; $C_nH_{2^n+1}$–; -ane → -yl.

Functional group: atom or group that decides chemical properties.

Homologous series: same functional group, each member differing from the next by $–CH_2–$. Members: **homologs**.

Isomers: same formula, different structures.

IUPAC: International Union of Pure and Applied Chemistry; system agreed at Geneva, 1892.

Formulas

Molecular mass from the general formula (C = 12, H = 1, O = 16):

$14n + 2$	alkane, $C_nH_{2^n+2}$ **Use:** ends -ane
$14n$	alkene, $C_nH_{2^n}$ **Use:** ends -ene
$14n - 2$	alkyne, $C_nH_{2^n-2}$ **Use:** ends -yne
$14n + 18$	alcohol $C_nH_{2^n+1}OH$; ether $C_nH_{2^n+2}O$ **Use:** same mass
$14n + 16$	aldehyde, ketone, $C_nH_{2^n}O$ **Use:** same mass
$14n + 32$	carboxylic acid, $C_nH_{2^n}O_2$ **Use:** n counts the –COOH carbon

- n = all the carbons, the –COOH or –CHO carbon too (in $C_nH_{2^n+1}COOH$, only R's); check by adding up: $C_4H_8O_2$ = 48 + 8 + 32 = 88

9.1 Organic compounds

- **Berzelius**: organic (from living things) vs inorganic; **vital force**, 1810
- **Wöhler**, 1828: heated ammonium cyanate → **urea**, "without the use of kidneys"; vital force faded over decades
- sources
  - plants
  - animals
  - coal
  - petroleum
  - natural gas
  - factories
- methane (biogas)
- propane + butane (LPG)
- ethanol (sanitizer)
- ethanoic acid (vinegar)
- methanal (formalin)
- propanone (nail polish remover)
- urea (fertilizer)
- polythene

Organic	Inorganic
carbon, nearly always H	any elements; most no carbon
covalent	many ionic
low m.p., b.p.	ionic: high
most insoluble in water, soluble in kerosene, alcohol, ether	many soluble in water, few in organic solvents
most burn; char without enough air	most don't burn
don't conduct	ionic conduct melted or dissolved
react slowly	ionic often at once
very many	far fewer

- low b.p.: atoms held strongly, molecules hardly pull on each other
- **a tendency**: sugar, ethanol, ethanoic acid, urea, propanone dissolve in water (–OH, C=O attract water); marble, sand don't
- **like dissolves like**; a black char = quick sign of organic

9.2 Unique properties of carbon

Tetracovalency

- 2, 4: C^{4+} or C^{4-} cost too much energy, so it **shares**; 8 electrons around it, each H 2
- bonds at the corners of a **tetrahedron**, **109.5**° (Kekulé, Couper 1858; van 't Hoff, Le Bel 1874)

Catenation

- C–C strong, 347 kJ/mol; C–H 413, C–O 358; stable in air; a flame starts burning
- N–N about 160, O–O about 146: chains fall apart
- Si–Si much weaker than Si–O (452): SiH_4 catches fire in air; silicon ends in sand
- polythene: tens of thousands of carbons
- isomers
  - C_4H_{10} 2
  - $C_{10}H_{22}$ 75
  - $C_{20}H_{42}$ 366,319

Multiple bonding

Bond	Pairs	Length	kJ/mol
C–C, ethane	1	154 pm	347
C=C, ethene	2	134 pm	614
C≡C, ethyne	3	120 pm	839

- more pairs: shorter, stronger; double isn't twice single (614, not 694), so the extra bond opens easily: unsaturated react more
- each carbon still 4 bonds: ethene 2 + 1 + 1; ethyne 3 + 1

9.3 Alkyl, functional group, series

Alkyl:

- CH_3– methyl

- C_2H_5– ethyl
- $CH_3CH_2CH_2$– propyl (end carbon)
- $(CH_3)_2CH$– isopropyl (middle carbon)
- C_4H_9– butyl

Family	Group	Ending	First member
alkane	none	-ane	methane, CH_4
alkene	C=C	-ene	ethene, $CH_2=CH_2$
alkyne	C≡C	-yne	ethyne, CH≡CH
alcohol	–OH	-ol	methanol, CH_3OH
ether	–O–	alkoxyalkane	methoxymethane, CH_3OCH_3
aldehyde	–CHO	-al	methanal, HCHO
ketone	C=O inside chain	-one	propanone, CH_3COCH_3
acid	–COOH	-oic acid	methanoic acid, HCOOH

- **aldehyde**: C=O at the end, H on it; **ketone**: carbon on both sides
- **acid**: C=O and –OH on one carbon, one new group; R may be H in an aldehyde and an acid

Homologous series

1. same functional group, similar chemical properties
2. one general formula
3. neighbors differ by CH_2: mass **14**
4. physical properties change gradually (b.p., m.p., density rise; small alcohols and acids mix with water, large don't)
5. similar methods of making

- group decides how it **reacts**; chain length decides how it **looks physically**
- b.p. climbs by less each time: methane → ethane 73 °C, nonane → decane 23 °C; first four alkanes gases at 25 °C
- ethanol (46) 78 °C, propane (44) −42 °C: –OH holds molecules together; acids higher still

9.4 Formulas and IUPAC names

- **Molecular** C_4H_{10}: how many; can fit several compounds
- **Structural**: every bond drawn. **Condensed** $CH_3CH_2CH_2CH_3$; branch in brackets: $CH_3CH(CH_3)CH_3$; double, triple bond always shown

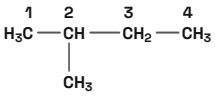
prefix (branches) + word root + -ane/-ene/-yne + suffix (group)

1	2	3	4	5	6	7	8	9	10
meth	eth	prop	but	pent	hex	hept	oct	non	dec

Rules

1. longest continuous chain, round corners; must hold the group's carbon and the multiple bond
2. number for the lowest: **group, then multiple bond, then branches**
3. branches as alkyl with a number; di-, tri-, a number each: 2,2-dimethyl
4. alphabetical, ignoring di-, tri-: ethyl before methyl
5. one word (except "acid"); commas between numbers, hyphens between number and letter
6. first point of difference: 2,2,4 is lower than 2,4,4

- number just before the part it numbers: but-2-ene, propan-2-ol (older: 2-butene); left out where only one place: propene, propanone, butanone
- final "e" dropped before a vowel: propane + ol = propanol



Lower number wins: 2-methylbutane.

Families in use

- **alkanes** (paraffins)
  - react with little except oxygen and, in sunlight, chlorine
  - biogas, LPG, petrol, kerosene, wax
  - Same formula, different b.p.: butane −0.5 °C, 2-methylpropane −12 °C
- **octane number**
  - isooctane (2,2,4-trimethylpentane) 100
  - heptane 0
  - 91 knocks like 91% isooctane
- **alkenes**: number the first carbon of C=C. Ethene → polythene; ripens fruit
- **alkynes**: ethyne torch over 3,000 °C; CaC_2 + water gives ethyne
- **alcohols**
  - –OH covalent, **not alkaline**
  - first three mix with water
  - **Methanol** poisonous: blindness, death
  - Ethanol: drinks, sanitizer (at least 60%)
  - Propan-2-ol: swabs
- **ethers**
  - longer side the alkane
  - CH_3O– methoxy, C_2H_5O– ethoxy
  - Ethanol 78 °C, methoxymethane −25 °C, both C_2H_6O
  - Ethoxyethane: first public surgery under ether (Morton, 16 Oct 1846); b.p. 35 °C
- **aldehydes**: –CHO always carbon 1, no number. Formalin: 37–40% methanal
- **ketones**: from 3 carbons. Pentan-2-one ≠ pentan-3-one
- **acids**
  - –COOH carbon is carbon 1
  - weak: sour, blue litmus red, fizz with carbonates
  - Methanoic: ants
  - Vinegar: 4–8% ethanoic; glacial, freezes at 17 °C
  - Butanoic: rancid butter
  - Long chains + alkali → soap

COMMON MISTAKES

✗ CO_2, $CaCO_3$ are organic
✓ counted as inorganic, though they hold carbon.

✗ all organic compounds are insoluble
✓ *most*; sugar and ethanol dissolve.

✗ –COH
✓ **–CHO**: C first.

✗ 2-ethylpropane
✓ the ethyl lengthens the chain: 2-methylbutane.

✗ 2-methylpent-4-ene
✓ multiple bond before branch: 4-methylpent-1-ene.

✗ 2,2-methyl
✓ 2,2-**di**methyl.

✗ leaving the –COOH carbon out of the count
✓ it counts: CH_3COOH is **ethanoic**.