

Hydrocarbons and Naming Alkanes

What are hydrocarbons and how do you name alkanes?

●●● Intermediate

Organic Chemistry

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Before you start: it helps to understand [Ionic and Covalent Bonds](#) and [Molecular Shapes \(VSEPR\)](#).

What is it?

Organic chemistry is the chemistry of carbon compounds. Carbon is special because each carbon atom forms **four covalent bonds** and can bond to other carbon atoms, building chains, branches and rings of almost any size.

The simplest organic compounds are **hydrocarbons**, which contain **only carbon and hydrogen**. They form three families:

- **Alkanes:** only C–C **single** bonds. General formula C_nH_{2n+2} . Example: ethane, C_2H_6 .
- **Alkenes:** at least one C=C **double** bond. General formula C_nH_{2n} . Example: ethene, C_2H_4 .
- **Alkynes:** at least one C≡C **triple** bond. General formula C_nH_{2n-2} . Example: ethyne, C_2H_2 .

Alkanes are called **saturated**: each carbon holds as many hydrogen atoms as possible. Alkenes and alkynes are **unsaturated**.

KEY IDEA

Each family is a **homologous series**: a set of compounds with the same general formula and similar chemistry, in which each member differs from the next by one CH_2 unit. The name tells you the number of carbons (the stem) and the family (the ending: **-ane**, **-ene**, **-yne**).

Why does it matter?

- **Fuels.** Natural gas (methane), bottled gas (propane and butane), petrol (mostly C_5 to C_{10}) and diesel are hydrocarbons.
- **Materials.** Ethene and propene are the starting materials for the plastics polyethylene and polypropylene.
- **Language.** The alkane names are the foundation of every other organic name: ethanol, ethanoic acid and ethyl ethanoate all start from “eth-” (2 carbons).

How does it work?

1. The first ten stems

Carbons	Stem	Alkane
1	meth-	methane, CH ₄
2	eth-	ethane, C ₂ H ₆
3	prop-	propane, C ₃ H ₈
4	but-	butane, C ₄ H ₁₀
5	pent-	pentane, C ₅ H ₁₂
6	hex-	hexane, C ₆ H ₁₄
7	hept-	heptane, C ₇ H ₁₆
8	oct-	octane, C ₈ H ₁₈
9	non-	nonane, C ₉ H ₂₀
10	dec-	decane, C ₁₀ H ₂₂

2. Four ways to draw a molecule

Butane can be written as:

- **Molecular formula:** C₄H₁₀ (atoms only, no structure).
- **Structural formula:** every atom and every bond drawn out.
- **Condensed formula:** CH₃CH₂CH₂CH₃ (each carbon with its hydrogens, in order).
- **Skeletal formula:** a zigzag line. Each corner and line end is a carbon atom; hydrogen atoms on carbon are not drawn.

Around each carbon in an alkane the four bonds point to the corners of a tetrahedron (109.5°), which is why chains are zigzag, not straight.

3. Naming branched alkanes (IUPAC rules)

1. Find the **longest continuous carbon chain**. It gives the parent name (for example, 5 carbons: pentane). The chain may bend; it does not have to be the one written in a straight line.
2. **Number** the chain from the end that gives the branches the **lowest numbers** (locants).
3. Name each branch (**substituent**) from its number of carbons with the ending **-yl**: methyl, CH₃⁻; ethyl, C₂H₅⁻.
4. If a substituent appears more than once, use **di-**, **tri-**, **tetra-**, and give a locant for each one.
5. List different substituents in **alphabetical order** (ignore di-, tri-). Use commas between numbers and hyphens between numbers and words: **2,3-dimethylpentane**, **3-ethyl-2-**

methylhexane.

4. Structural isomers

Structural isomers have the same molecular formula but different arrangements of atoms. C_4H_{10} has two (butane and 2-methylpropane); C_5H_{12} has three (see the figure); C_6H_{14} has five. Isomers are different compounds with different properties: more branching makes molecules more compact, so their attractions are weaker and their boiling points lower.

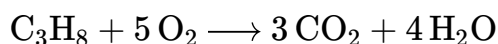
5. Alkenes and alkynes

Name them like alkanes, but the longest chain must contain the multiple bond, and you number it from the end that gives the double or triple bond the **lowest locant**. Write the locant of the first carbon of the double bond before the ending:

- $CH_2=CHCH_2CH_3$ is **but-1-ene**; $CH_3CH=CHCH_3$ is **but-2-ene**.

6. Combustion

In plenty of oxygen, hydrocarbons burn completely to carbon dioxide and water, releasing a lot of energy:



With too little oxygen, **incomplete combustion** also forms carbon monoxide (CO, a toxic gas) and soot (C).

∞ THINK OF IT LIKE THIS

An IUPAC name is like a postal address. The parent chain is the street (“pentane”), the locants are the house numbers (“2-”), and the substituents are what is at each house (“methyl”). Anyone who reads the address can find exactly one molecule, and every molecule has exactly one correct address.

Q MORE PRECISELY

Hydrocarbon chains can also close into rings. **Cycloalkanes** such as cyclohexane, C_6H_{12} , have the general formula C_nH_{2n} , the same as alkenes, so a formula alone does not tell you the family. The boiling-point trend comes from **London dispersion forces**, which grow with the size and surface contact of the molecules: longer chains have higher boiling points, and branched isomers lower ones.

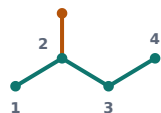
Visualise it

Three structural isomers of C₅H₁₂

Same molecular formula, different carbon skeletons.



pentane
 $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_3$
b.p. 36 °C (straight chain)



2-methylbutane
 $\text{CH}_3\text{CH}(\text{CH}_3)\text{CH}_2\text{CH}_3$
b.p. 28 °C (one branch)



2,2-dimethylpropane
 $\text{C}(\text{CH}_3)_4$
b.p. 10 °C (two branches)

● longest chain (numbered) ● methyl branch

Each dot is a C atom; H atoms are not drawn.

More branching: weaker attractions, lower boiling point.

Same formula, three compounds: the more branched the skeleton, the lower the boiling point.

Worked example

WORKED EXAMPLE: Naming a branched alkane

Question: Name $\text{CH}_3\text{CH}(\text{CH}_3)\text{CH}_2\text{CH}(\text{CH}_3)\text{CH}_3$.

- Step 1** Longest chain: the five carbons written in a row, so the parent is **pentane**.
- Step 2** Number the chain: the methyl groups are on carbons 2 and 4 from either end, so the locants are 2 and 4.
- Step 3** Two methyl groups: **dimethyl**.
- Step 4** Name: **2,4-dimethylpentane** (molecular formula C_7H_{16} , which fits $\text{C}_n\text{H}_{2n+2}$).

WORKED EXAMPLE: Finding the hidden longest chain

Question: A student names $\text{CH}_3\text{CH}(\text{C}_2\text{H}_5)\text{CH}_2\text{CH}_3$ as “2-ethylbutane”. Find the correct name.

- Step 1** Follow the chain through the ethyl group: CH_3 and CH_2 of the ethyl branch plus three more carbons give a chain of 5, not 4.
- Step 2** The parent is therefore **pentane**, with one CH_3 branch on carbon 3 (counting from either end).
- Step 3** Correct name: **3-methylpentane**. An ethyl group on carbon 2 is always a sign that the longest chain was missed.

 WORKED EXAMPLE: Mass of carbon dioxide from burning propane

Question: What mass of CO₂ forms when 11.0 g of propane burns completely? (C₃H₈ = 44.09 g/mol; CO₂ = 44.01 g/mol)

Step 1 Equation: C₃H₈ + 5 O₂ → 3 CO₂ + 4 H₂O

Step 2 $n(\text{C}_3\text{H}_8) = \frac{11.0 \text{ g}}{44.09 \text{ g/mol}} = 0.2495 \text{ mol}$

Step 3 $n(\text{CO}_2) = 0.2495 \text{ mol C}_3\text{H}_8 \times \frac{3 \text{ mol CO}_2}{1 \text{ mol C}_3\text{H}_8} = 0.7485 \text{ mol}$

Step 4 $m(\text{CO}_2) = 0.7485 \text{ mol} \times 44.01 \text{ g/mol} = 32.9 \text{ g}$

Common mistake

 COMMON MISTAKE: Not finding the longest chain

The longest chain is often bent on paper. Names such as “2-ethylbutane” or “1-methylbutane” are always wrong: a 2-ethyl or 1-methyl group means the chain could have been longer (3-methylpentane and pentane).

 COMMON MISTAKE: Numbering from the wrong end

CH₃CH₂CH₂CH(CH₃)CH₃ is **2-methylpentane**, not 4-methylpentane. Number from the end nearer the branch.

 COMMON MISTAKE: Ordering substituents by number instead of alphabet

Substituents are listed alphabetically, and di-, tri- do not count: **3-ethyl-2,3-dimethylpentane**, not 2,3-dimethyl-3-ethylpentane (“e” comes before “m”).

 NOTATION NOTE

- Current IUPAC names put the locant just before the ending (but-1-ene); older books write 1-butene. Both mean the same compound.
- In condensed formulas, a group in brackets is a branch on the carbon before it: CH₃CH(CH₃)CH₃ is 2-methylpropane.
- R stands for “the rest of the molecule”, a carbon chain of any length.

Remember this

REMEMBER THIS

- Alkanes C_nH_{2n+2} (single bonds), alkenes C_nH_{2n} ($C=C$), alkynes C_nH_{2n-2} ($C\equiv C$).
- Stems: meth 1, eth 2, prop 3, but 4, pent 5, hex 6, hept 7, oct 8, non 9, dec 10.
- Naming: longest chain → lowest locants → substituents (-yl) with di-/tri- → alphabetical order.
- Isomers: same molecular formula, different structure; more branching → lower boiling point.
- Complete combustion: hydrocarbon + $O_2 \rightarrow CO_2 + H_2O$.

References

1. Brown, T. L.; LeMay, H. E., Jr.; Bursten, B. E.; Murphy, C. J.; Woodward, P. M.; Stoltzfus, M. W. Chemistry: The Central Science, 15th ed.; Pearson, 2022.

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