Chapter 23: The Alkenes and The Alkynes

The Alkenes

The alkenes are a family of **unsaturated hydrocarbons.**

An unsaturated compound contains at least one double or triple bond between the atoms in the molecule.

- All alkenes contain a **carbon-carbon double bond (C=C).** This is the **functional group** of the alkenes.
- The general formula for alkenes is C_nH_{2n}.
- In a molecule of ethene the carbon atoms lie on the same plane – they are in planar geometry.

Naming alkenes

- Change 'ane' to 'ene',
- For alkenes containing more than three carbons, we must indicate the position of the double bond with a number, e.g. but-1-ene and but-2-ene.
- **The functional group determines the numbering system, not substituents.**

Step 1: Count the longest continuous chain of carbon atoms (that contains the C=C). This is the parent alkene.

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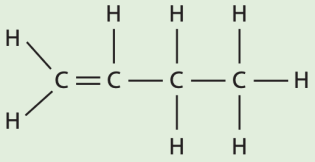
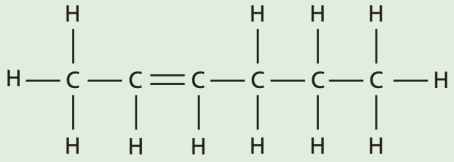
Step 2: Number the carbon chain, giving the lowest possible number to the carbon-carbon double bond (C=C). Insert this number before the 'ene'.

Step 4: Use prefixes and numbers to indicate the type and location of any substituents present.

Step 5: Write out the name as a single word

Representing alkenes

	But-1-ene	Hex-2-ene
Molecular formula	C_4H_8	C_6H_{12}
Expanded molecular structure		
Condensed structural formula	$CH_2{=}CHCH_2CH_3$	$CH_3CH{=}CHCH_2CH_2CH_3$

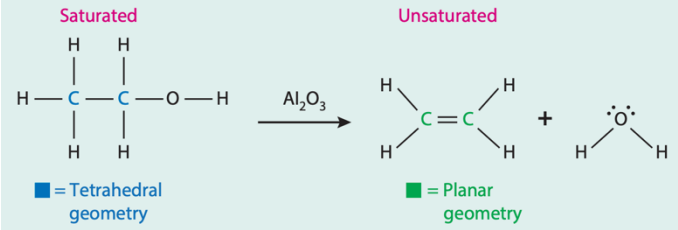
Structural isomers of alkenes

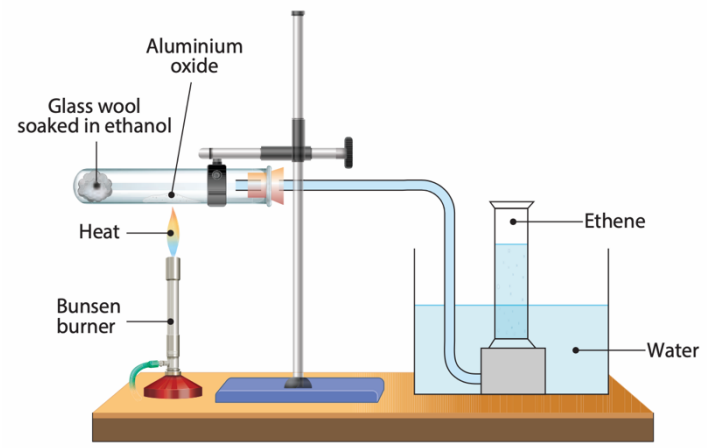
But-1-ene and but-2-ene (and 2-methylpropene) are **structural isomers**. They have the same molecular formula, C_4H_8, but different expanded molecular structures.

Experiment 22: Preparing ethene

- Ethanol (colourless liquid at room temperature) is dehydrated.
- Aluminium oxide (Al_2O_3), a white powder, is used as 1) a dehydrating agent, and 2) a catalyst.
- This is an elimination reaction.

$$C_2H_5OH \xrightarrow{Al_2O_3} C_2H_4 + H_2O$$





- The **glass wool is used to hold the ethanol in place**.
- As the ethanol is heated it vaporises (liquid → gas). As the ethanol vapour passes over the aluminium oxide it is dehydrated (water is removed) to form ethene.
- Note from the diagram that the ethanol is not heated directly (if it were heated directly it would evaporate very quickly and might not be properly dehydrated).
- Four-five test tubes of ethene are collected.
- The **first test tube collected is discarded as it contains mostly displaced air,** i.e. it does not contain pure ethene gas.
- **Avoid suck-back:** make sure to raise the apparatus so that the delivery tube is no longer dipping into the water **before** turning off the Bunsen burner. *(Turning off the Bunsen burner before raising the delivery tube causes the hot air in the boiling tube to cool and contract, drawing cold water back into the apparatus, potentially cracking the hot boiling tube).*

Physical properties

- Ethene is a **colourless, flammable gas** with a slightly sweet smell.
- Ethene **burns with a luminous yellow, slightly smoky flame**. (After burning the test tube of ethene, limewater should be added and the test tube stoppered and shaken. The limewater turns milky, indicating that carbon dioxide is present).
- It is **non-polar** & less dense than water – allows ethene to be collected over water.

Chemical properties

- Ethene will decolourise dilute bromine water from **yellow → colourless.**
- Ethene will decolourise acidified $KMnO_4$ from **purple → colourless.**
- These are both **tests for unsaturation** (i.e. a test to see if a compound contains a double or triple bond).
- Ethene is used to make polythene (plastic).

Properties of alkenes

The alkenes have very similar properties to the alkanes.

Identifying features	Unsaturated hydrocarbon, functional group C=C
Carbon-carbon bonds	Carbon-carbon double bond (one sigma bond and one pi bond). Any other single bonds are sigma bonds.
Intramolecular bonds	Pure (non-polar) covalent bonds *(electronegativity difference of 0.35)*
Type of molecule	Non-polar
Intermolecular forces	London dispersion forces
Melting and boiling points	Relatively low* Increases as the size of the molecules increases
State of matter (at room temperature)	C_2-C_4 are gases, C_5–C_{14} are liquids, C_{15} onwards are solids
Combustion	Like alkanes, alkenes burn in excess oxygen to produce carbon dioxide and water vapour.
Solubility in water	Insoluble Like dissolves like
Solubility in non-polar substances	Soluble Like dissolves like
Reactivity	Reactive due to double bond (region of high electron density)

Reactivity

- More reactive than alkanes because of their **double bond**, which is a region of **high electron density**.
- **Alkenes tend to undergo addition reactions**, where two or more molecules combine to form a single product.

Comparing properties of straight chain alkenes

The trend in boiling points for alkenes is similar to that of alkanes; as the chain length of straight chain alkenes increases, so too does their boiling point.

The Alkynes

- **Unsaturated hydrocarbons**.
- Alkynes contain **carbon-carbon triple bonds** (functional group)
- The general formula for alkynes is C_nH_{2n-2}.

Naming of alkynes

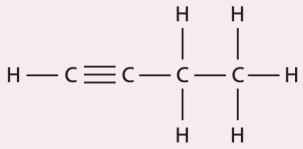
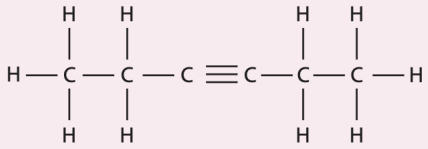
Step 1: Count the longest continuous chain of carbon atoms (that contains the C≡C). This is the parent alkyne.

Step 2: Number the carbon chain, giving the lowest possible number to the carbon- carbon triple bond (C≡C). Insert this number before the 'yne'.

Step 3: Use prefixes and numbers to indicate the type and location of any substituents present.

Step 4: Write out the name as a single word

Representing alkynes

	But-1-yne	Hex-3-yne
Molecular formula	C_4H_6	C_6H_{10}
Expanded molecular structure		
Condensed structural formula	$HC{\equiv}CCH_2CH_3$	$CH_3CH_2C{\equiv}CCH_2CH_3$

Properties of alkynes

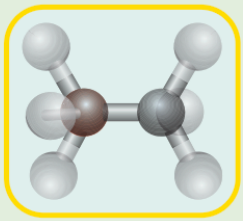
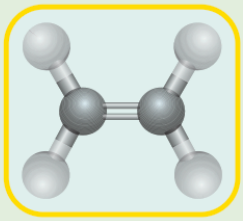
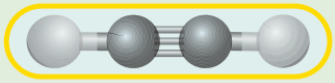
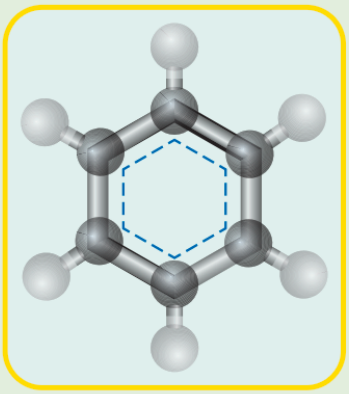
Identifying features	Unsaturated hydrocarbon, functional group C≡C
Carbon-carbon bonds	Carbon-carbon triple bond (one sigma bond and two pi bonds). All other single bonds are sigma bonds.
Intramolecular bonds	Pure or non-polar covalent bonds (electronegativity difference of 0.35)
Type of molecule	Non-polar
Intermolecular forces	London dispersion forces
Melting and boiling point	Relatively low Increase as the size of the molecules increase
State of matter at room temperature	C_2-C_4 are gases, C_5-C_{15} are liquids, C_{15} above are generally solids
Combustion	Alkynes are fuels and burn in excess oxygen to produce carbon dioxide and water vapour. However, alkynes are more likely than alkanes or alkenes to undergo incomplete combustion; resulting in a soot and a smoky flame.
Solubility in water	Insoluble Like dissolves like

Solubility in non-polar substances	Soluble Like dissolves like
Reactivity	Very reactive (due to carbon-carbon triple bond)

Reactivity of alkynes

- Alkynes are very reactive because of their **triple bond**, which is a region of **high electron density**.
- **Alkynes tend to undergo addition reactions**, where two or more molecules combine to form a single product.

Comparing ethane, ethene, ethyne and benzene

	Diagram	Carbon–carbon bonds	Sigma bonds	Pi bonds	Geometry of carbon atoms	Bond angle
Ethane	 Figure 23.21	Single	7	0	Tetrahedral	109.5°
Ethene	 Figure 23.22	Double	5	1	Planar	120°
Ethyne	 Figure 23.23	Triple	3	2	Linear	180°
Benzene	 Figure 23.24	6 (of inter-mediate length) carbon–carbon bonds	12	Delocalised pi-bonding system	Planar	120°

Geometric isomerism

Geometric isomerism occurs when two compounds have the same molecular formula, but different spatial arrangements of their atoms.

- Single bonds have 360° rotation, meaning alkanes cannot display geometric isomerism.
- However, in contrast to single bonds, there is **no rotation** around a double bond due to the side-on overlap of orbitals in the pi bond.
- Alkenes, therefore, can display geometric isomerism.
- **Only molecules with restricted rotation will have geo-isomers**.

Cis-trans isomerism

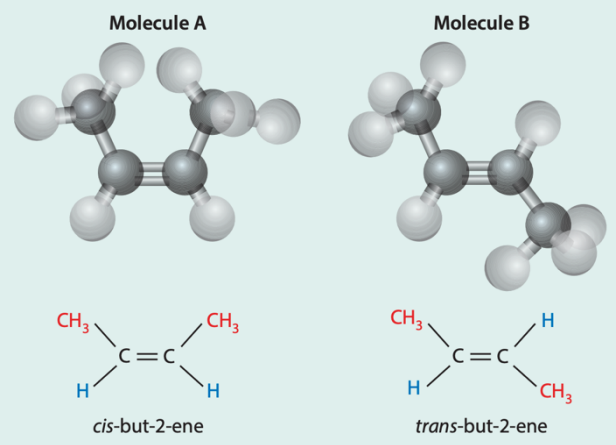
'Cis' isomer = 'cis' meaning 'on the same side'
'Trans' = 'on opposite sides' (*think of transatlantic)*

Since there is no rotation around a double bond, we cannot simply 'twist' this molecule.

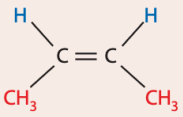
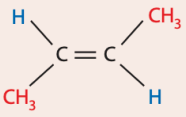
Cis-but-2-ene:
Two methyl groups are on the **same side** of the C=C double bond

T**rans**-but-2-ene:
Two methyl groups are **on either side** of the C=C double bond

Be careful not to mix up structural and geometric isomers. **Structural isomers differ in the way the atoms are connected to each other, but geometric isomers differ in the way atoms are arranged in space.**



Comparing properties that are due to isomerism

	Cis-but-2-ene	*Trans*-but-2-ene
Expanded molecular structure		
Placement of methyl groups	Same side of double bond	Different sides of double bond
Polarity	Very slightly polar	Not polar
Intermolecular forces	Stronger	Weaker
Boiling point	Higher	Lower
Symmetry	Not symmetrical	Symmetrical
Molecules are...	Less tightly packed	More tightly packed
Melting point	Lower	Higher
Stability	Less stable	More stable