Cambridge (CIE) A Level Chemistry

Your notes

Shapes of Organic Molecules; σ & π Bonds

Contents

- Shapes of Organic Molecules; σ & π Bonds
- Hybridisation in Organic Molecules
- Planarity of Organic Molecules

Your notes

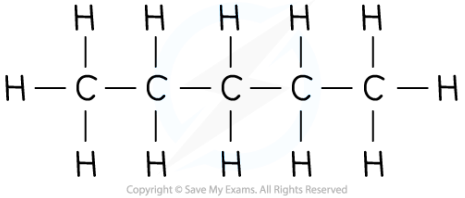
Straight, Branched & Cyclic Molecules

- Straight, branched and cyclic organic molecules are also called **aliphatic** compounds as long as they do not contain a **benzene ring**

Straight-chain

- **Straight-chain** organic molecules are those in which the carbon atoms are connected to each other in one continuous chain

A straight-chain organic molecule

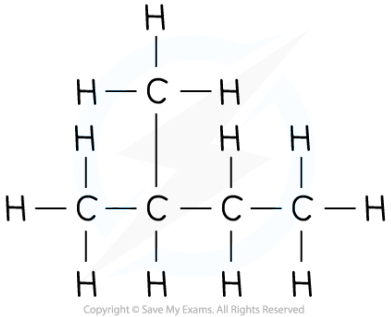


Pentane is a straight-chain organic molecule as the carbon atoms are connected in a straight line

Branched

- **Branched** organic molecules have side groups attached to the main chain of carbon atoms

A branched organic molecule

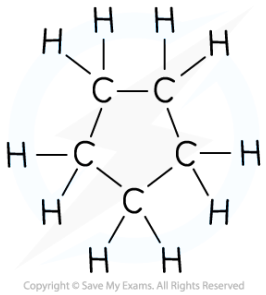


2-methylbutane is a branched organic molecule as the main chain (consisting of 4 carbon atoms) has a methyl branch

Cyclic

- **Cyclic** organic molecules are those in which the carbon atoms are connected to each other in a ring shape

A cyclic organic molecule



Cyclopentane is a cyclic organic molecule as the carbons are attached to each other in a ring structure

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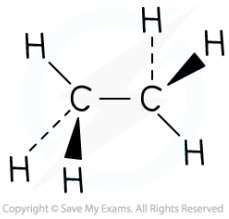
Hybridised Atoms: Shapes & Bond Angles in Molecules

- Each carbon atom has four electrons in its outer shell (**electronic configuration**: $1s^2 2s^2 2p^2$)
- Carbon atoms share these four electrons in four covalent bonds with other atoms to achieve a **full outer shell configuration**
- These electrons are found in orbitals within the respective atoms
- When forming a covalent bond, the orbitals overlap in such a way to form two types of bonds
  - Sigma bonds (σ)
  - Pi bonds (π)

Hybridisation: sp^3

- The electron pair in a σ bond is found in a region of space between the nuclei of the two atoms that are sharing the electrons
- The **electrostatic attraction** between the **electrons** (negatively charged) and the two **nuclei** (positively charged) holds the two atoms together
- Carbon atoms that form four σ bonds are said to be **sp^3 hybridised**
- The four pairs of electrons around each carbon repel each other forcing the molecule to adopt a configuration in which the bonding pairs of electrons are as far away from each other as possible
  - The molecule adopts a **tetrahedral** arrangement with bond angles of **109.5 °**

Bonding in ethane

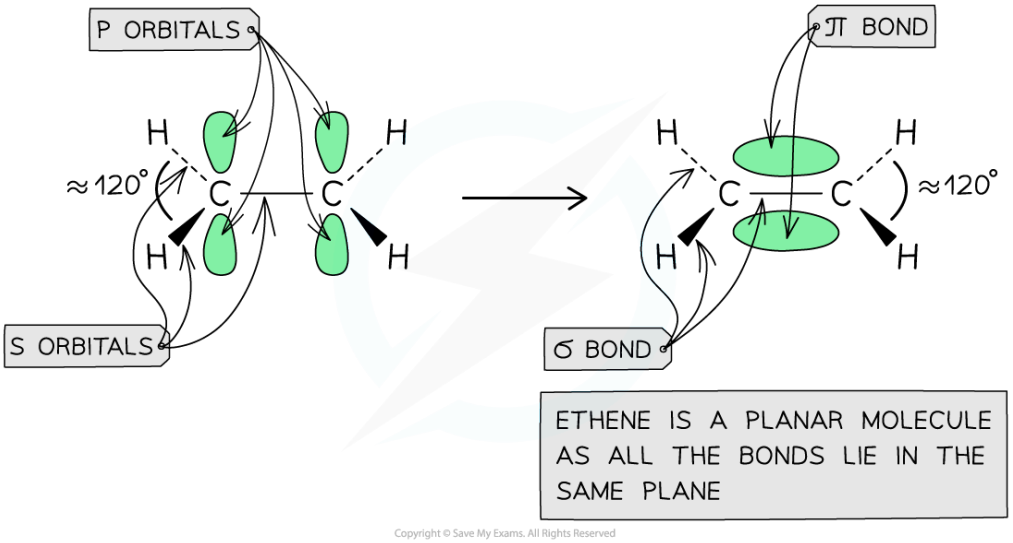


The diagram shows a molecule of ethane in which each carbon atom forms four σ bonds to adopt a tetrahedral configuration and minimise the repulsion between the bonding pairs of electrons

Hybridisation: sp^2

- When carbon atoms use only three of their electron pairs to form a σ bond, they are said to be **sp^2 hybridised**
  - Each carbon atom will have a p orbital which contains **one** spare electron
- When the p orbitals of two carbon atoms overlap with each other, a π bond is formed (the π bond contains two electrons)
- The two orbitals that form the π bond lie above and below the plane of the two carbon atoms to maximise bond overlap
- The three bonding pairs of electrons are in the plane of the molecule and repel each other
- The molecule adopts a **planar** arrangement with bond angles of **120 °**

Bonding in ethene



The overlap of the two p orbitals results in the formation of a π bond in ethene (sp2 hybridised molecule) in which the bonding pair of electrons repel each other to force the molecule into a planar configuration with bond angles of 120o

Hybridisation: sp

- Carbon atoms can also use only one of their electron pair to form a σ bond, in which case the carbon atoms are said to be **sp hybridised**
  - Each carbon atom will have **two** p orbitals with **one** spare electron each
- When the four p orbitals of the carbon atoms overlap with each other, **two** π bonds are formed (each π bond contains two electrons)
- The two orbitals that form the π bond lie above and below the plane of the carbon atoms
- The two orbitals of the **other** π bond lie in front and behind the plane of the atoms
  - This maximises the overlap of the four p orbitals

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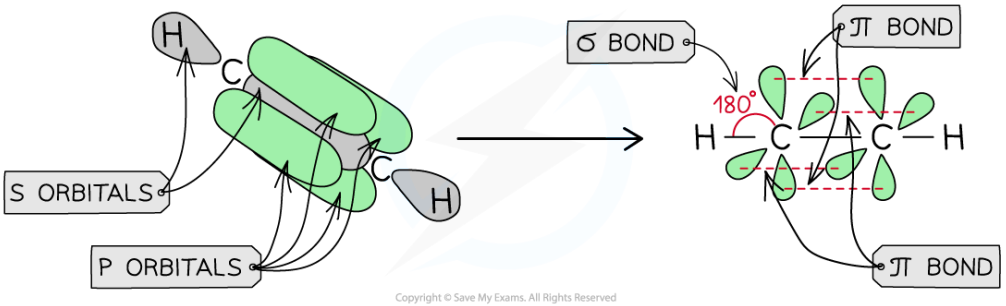
- The molecule adopts a **linear** arrangement with bond angles **180 °**

Bonding in ethyne



The overlap of the p orbitals results in the formation of two π bonds in ethyne (sp hybridised molecule) which adopts a linear arrangement with bond angles of 180o

Examiner Tips and Tricks

A **double bond** is a combination of a σ and π bond and a **triple bond** is a combination of one σ and two π bonds

The strength of the bonds increases as follows: **single < double < triple bond**

This is due to the increased electron density around the C-C atom, making the bond stronger and more difficult to break.

Hybridised Atoms: σ and π Bonds in Molecules

σ bonds

- Sigma bonds are formed from the end-on overlap of atomic orbitals
  - S orbitals overlap this way as well as p orbitals

Forming sigma bonds

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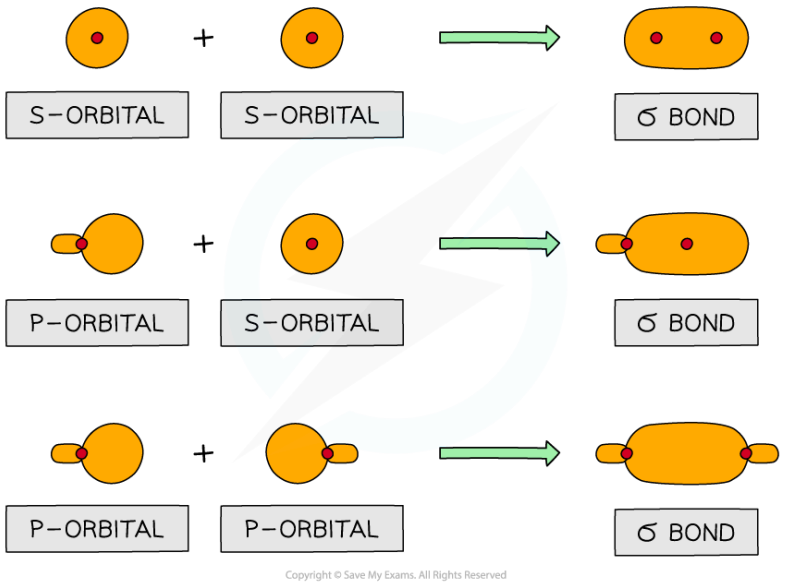

Sigma bonds can be formed from the end-on overlap of s or p orbitals

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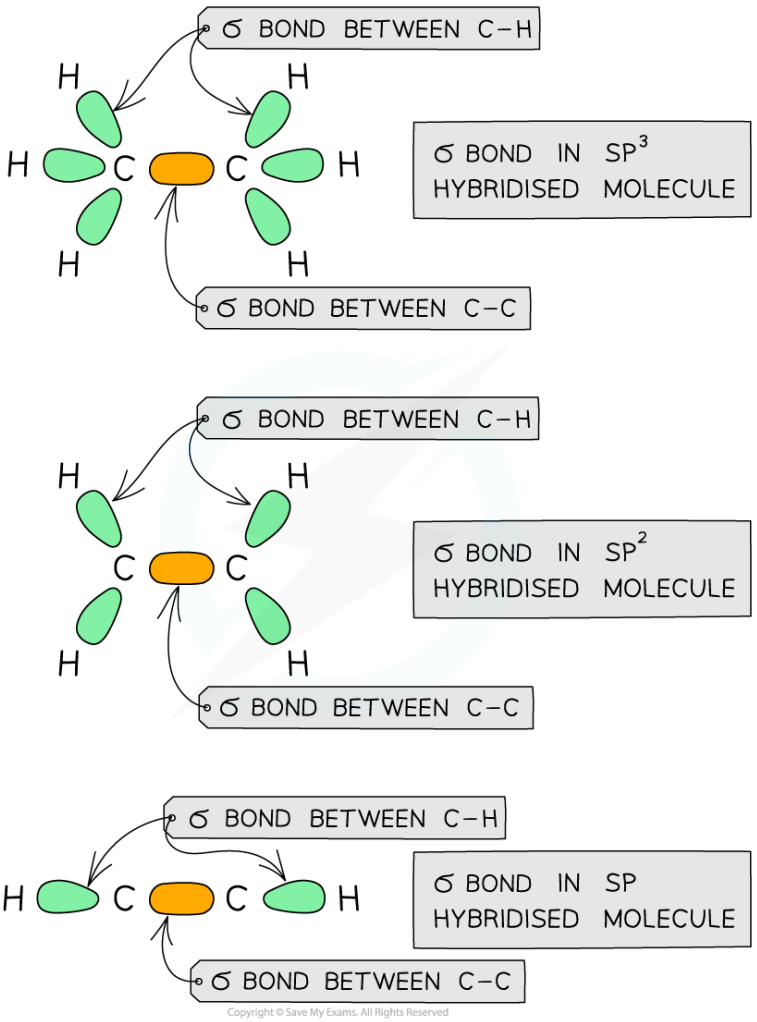
- The electron density in a σ bond is **symmetrical** about a line joining the nuclei of the atoms forming the bond
  - The pair of electrons is found between the nuclei of the two atoms
  - The electrostatic attraction between the electrons and nuclei bonds the atoms to each other

The arrangement of the σ bond in sp^3, sp^2 and sp hybridised carbon atoms



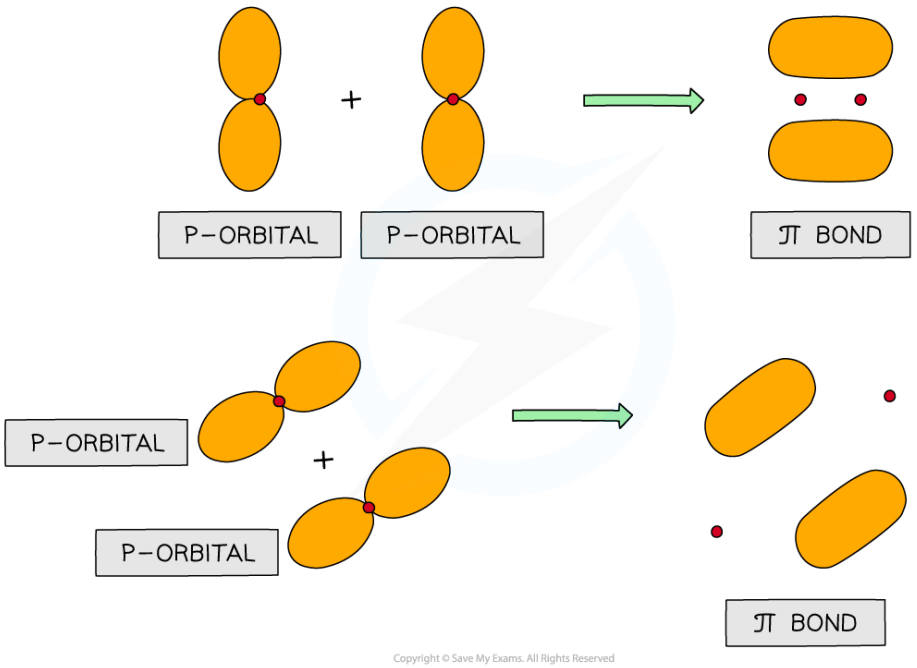
The σ orbitals are formed from the end-on overlap of the atomic orbitals resulting in symmetrical electron density on the atoms

π bonds

- Pi (π) bonds are formed from the sideways overlap of p orbitals
- The two lobes that make up the π bond lie above and below the plane of the atoms
  - This maximises the overlap of the p orbitals

Forming pi bonds

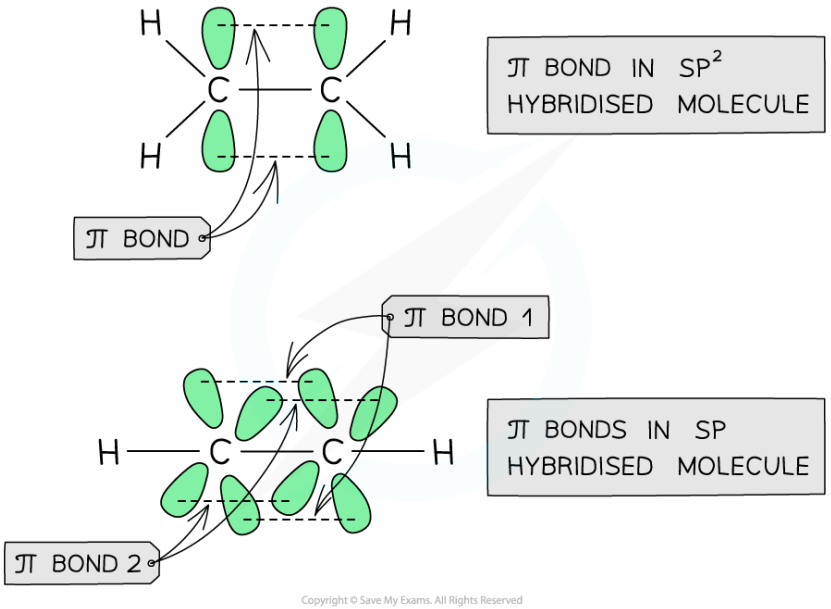
Your notes



π bonds can be formed from the end-on overlap of p orbitals

- In triple bonds, there is an additional overlap of p orbital
- The two lobes of the π bond lie in front of and behind the plane of the atoms in the molecule
  - This maximises the overlap of the p orbitals

The arrangement of the π bond in sp^3, sp^2 and sp hybridised carbon atoms



The π bonds are formed from the sideway overlap of the atomic orbitals

Your notes

Examiner Tips and Tricks

π bonds are drawn as two electron clouds, one arising from each lobe of the p orbitals

The two clouds of electrons in a π bond represent **one** bond consisting of **two** electrons (one from each orbital)

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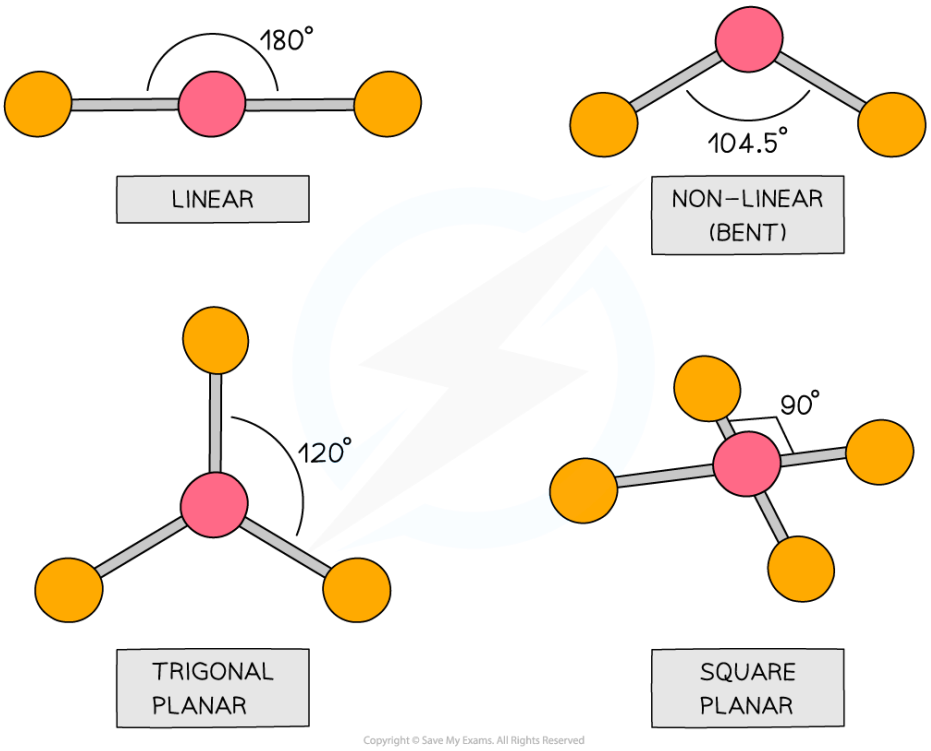
Planar Molecules

- Planar molecules have all their atoms in the same plane
  - E.g. linear, bent, trigonal planar and square planar

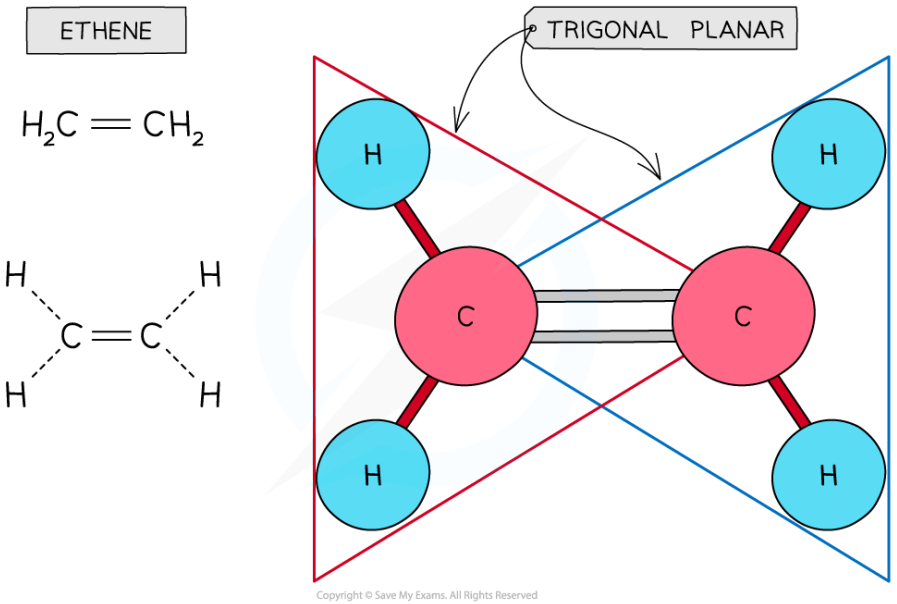
Examples of planar molecules



The diagram shows molecules which have all their atoms in the same plane with their name and the associated bond angle

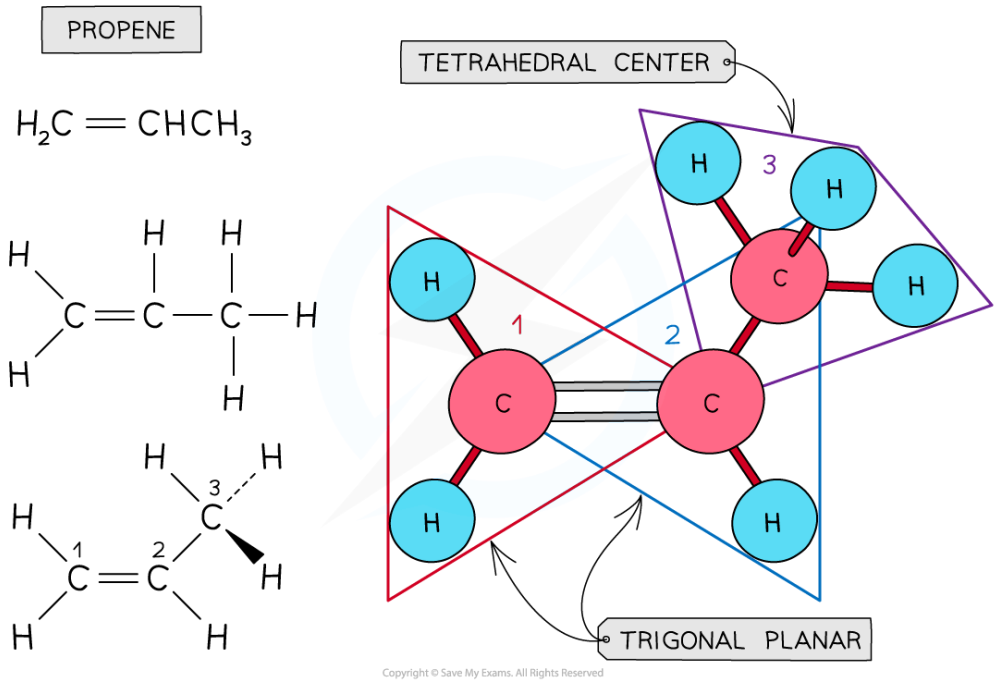
- The presence of an sp^2 hybridised carbon can force the molecule to adopt a planar configuration **(trigonal planar)**
- The 3 σ bonds position themselves in a trigonal planar position so that the bonding pair of electrons are as far away from each other and therefore minimise the repulsion between them

The planarity of ethene



Ethene is a planar molecule with two trigonal planar centres around the carbon atoms

The planarity of propene



Propene has two trigonal planar centres around the carbon-carbon double bond and one tetrahedral centre

- The presence of an sp hybridised carbon can also force the molecule to adopt a planar configuration (**linear**)
- The 2 σ bonds position themselves in a linear position to minimise the repulsion between the bonding pairs of electrons

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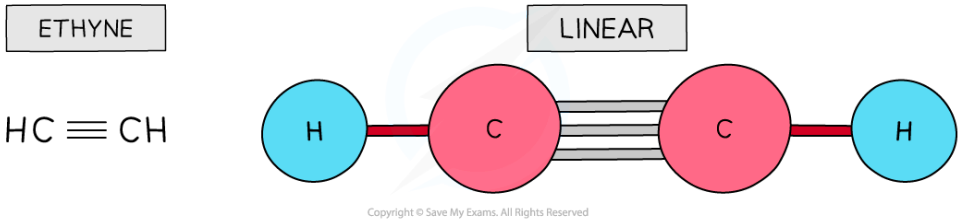
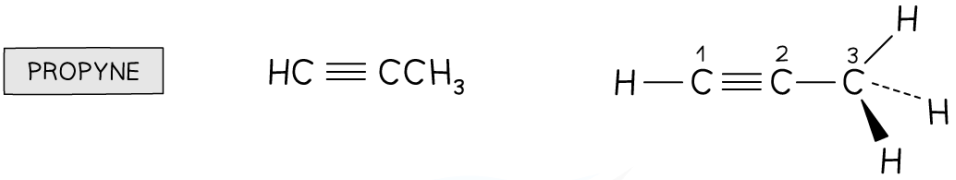
The planarity of ethyne

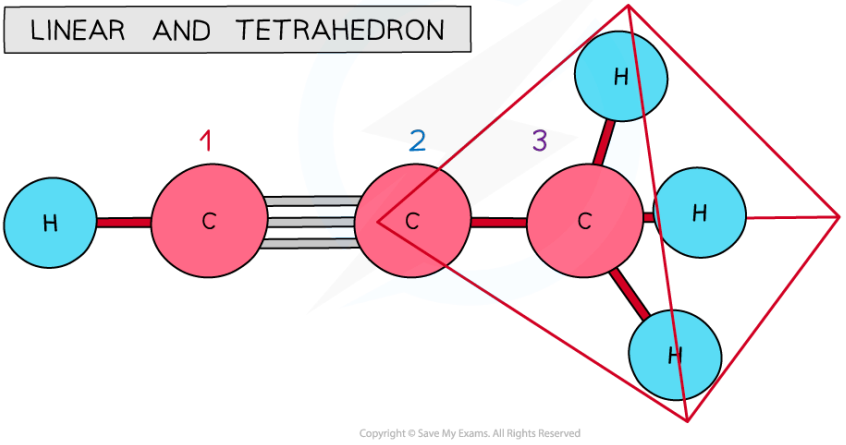
Your notes



Ethyne is a planar molecule with one planar centre: the molecule is linear

The planarity of propyne





Propyne has one planar centre around the carbon-carbon triple bond (linear) and one tetrahedral centre