13.3 Shapes of organic molecules; sigma and pi bonds

Name: _____ Class: _____ Date: _____ **Total: 12 marks**

KEY WORDS planar • cyclic • hybridisation • pi bond π

Objective

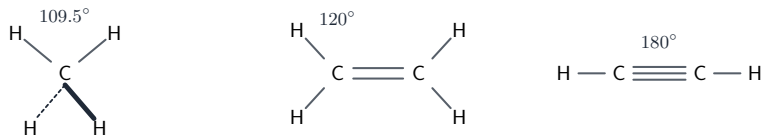
Build the skills to answer exam questions on **shapes of organic molecules** – **hybridisation** (sp, sp^2, sp^3), **σ and π bonds**, and the term **planar** .

You must be able to:

- describe organic molecules as straight-chained, branched or cyclic
- describe and explain the shape and bond angles at sp, sp^2 and sp^3 carbons
- describe the arrangement of σ and π bonds

1 Key knowledge and worked examples

Hybridisation and shape



sp^3: 4 single bonds tetrahedral

sp^2: 1 double + 2 single planar (flat)

sp: 1 triple bond linear

sp^3 = tetrahedral (109.5°); sp^2 = planar (120°); sp = linear (180°)

σ bond: head-on overlap

π bond: sideways overlap of p orbitals

Hybridisation builds sigma and pi bonds

hybridisation	bonds	shape	angle
sp^3	4 single	tetrahedral	109.5°
sp^2	1 double + 2 single	planar	120°
sp	1 triple	linear	180°

Every single bond is a **σ bond** (direct overlap); a double bond is one σ + one **π bond** (sideways p-orbital overlap). Ethene is **planar** because its carbons are sp^2.

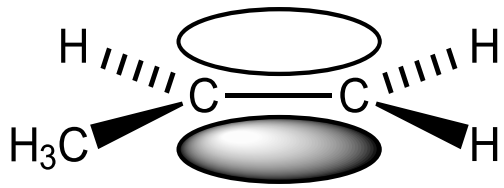
Work locally, then count the whole molecule

Original application: 9701/14 N25 Q6. In propyne, CH_3–C ≡ CH, the methyl carbon has four bonding regions: sp^3, tetrahedral, 109.5°. Each triple-bond carbon has two regions: sp, linear, 180°. A multiple bond counts as one region for shape. The molecule therefore contains sp and sp^3 carbons, not sp^2.

For bond counts, each bonded atom pair contributes one σ bond. A double bond adds one π; a triple bond adds two π bonds. Methane has four σ and no π bonds. Ethene has **five** σ (four C–H and one C–C) and **one** π. Ethyne has three σ and two π bonds. Include the C–H bonds when counting the whole molecule.

Original application: 9701/12 N25 Q25. Methanal, $H_2C{=}O$, has three bonding regions around carbon: sp^2, trigonal planar, approximately 120°. All four atoms are in a plane. It has three σ bonds (two C–H and one C–O) plus one π bond. Both original statements are correct: answer A.

Orbital drawing: 9701/24 N25 Q3(a)(iv). The original scheme shows the π overlap above and below the propene framework:



Sideways overlap of parallel p orbitals forms one pi bond with two regions of density; the regions are not separate pi bonds.

Transfer to a non-organic molecule: 9701/12 N25 Q5. The question states that each N in N_2 is sp hybridised. Of its two sp orbitals, one holds a lone pair and one forms a head-on sp–sp σ overlap. The two remaining p orbitals form two π bonds by sideways overlap. The original answer is B.

2 Practice

2.1 State the shape and bond angle around an sp^3 carbon. [2]

2.2 State how many σ and π bonds make up a C=C double bond. [2]

3 Exam-style questions

3.1 The carbon atoms in ethene, C_2H_4, are: [1]

- ☐ **A** sp hybridised, linear
- **B** sp^2 hybridised, planar
- **C** sp^3 hybridised, tetrahedral
- **D** sp^3 hybridised, planar

3.2 The bond angle around the carbon in methane is: [1]

- ☐ **A** 90°
- **B** 104.5°
- **C** 109.5°
- **D** 120°

3.3 (a) State the shape and bond angle around each carbon in ethyne, C_2H_2. [2]

(b) Explain why ethene is a planar molecule. [2]

3.4 Describe the σ and π bonds present in a molecule of ethene, C_2H_4. [2]

Solutions

Each answer shows the steps, then the **result**.

2.1

- tetrahedral; 109.5°

2.2

- 1 σ bond and 1 π bond

3.1 B

- Ethene's carbons are sp^2 hybridised and the molecule is planar

3.2 C

- Methane's bond angle is 109.5°

3.3

(a)

- linear; 180°

(b)

- the carbons are sp^2 hybridised with 120° bond angles; all the atoms lie in one plane around the C=C double bond, so it is planar

3.4

- five σ bonds (4 C–H and 1 C–C) formed by direct overlap; one π bond from sideways overlap of p orbitals above and below the C=C