

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

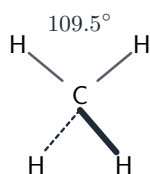
Build the skills to answer exam questions on **shapes of organic molecules – hybridisation** (sp , sp^2 , sp^3), **σ and π bonds**, and the term **planar**.

You must be able to:

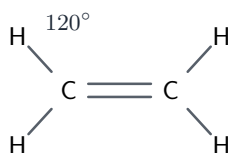
- describe organic molecules as straight-chained, branched or cyclic
- describe and explain the shape and bond angles at sp , sp^2 and sp^3 carbons
- describe the arrangement of σ and π bonds

1 Key knowledge and worked examples

■ Hybridisation and shape



sp^3 : 4 single bonds
tetrahedral

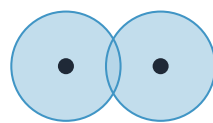


sp^2 : 1 double + 2 single
planar (flat)

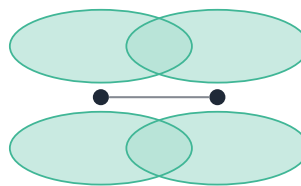


sp : 1 triple bond
linear

$sp^3 = \text{tetrahedral } (109.5^\circ)$; $sp^2 = \text{planar } (120^\circ)$; $sp = \text{linear } (180^\circ)$



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 .

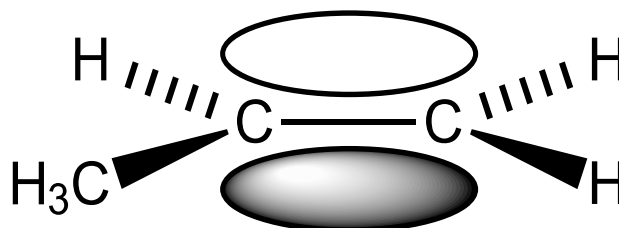
■ **Work locally, then count the whole molecule**

Original application: 9701/14 N25 Q6. In propyne, $\text{CH}_3\text{--C}\equiv\text{CH}$, 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, $\text{H}_2\text{C=O}$, 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 $\text{C}=\text{C}$ 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 $C=C$