

Hybridization and Sigma and Pi Bonds

Answer key with explanations

A. Hybridization

1. Hybridization.

Hybridization is the mixing of an atom's valence orbitals into an equal number of identical hybrid orbitals. Carbon's 2s and 2p orbitals are different and the p orbitals are at 90°, yet methane has **four identical bonds at 109.5°**. Mixing one s and three p orbitals gives four identical **sp³** hybrids pointing to the corners of a tetrahedron.

2. Hybridization and angles.

(a) 4 domains: **sp³, 109.5°** (b) 3 domains, no lone pair: **sp², 120°** (c) 2 domains: **sp, 180°**
(d) 3 bonds + 1 lone pair: **sp³**, about 107° (ideal 109.5°) (e) 3 domains: **sp², 120°** (f) 2 domains: **sp, 180°**

B. Sigma and pi bonds

3. σ and π .

A **σ bond** forms by **head-on** overlap of orbitals along the line joining the nuclei; it allows rotation. A **π bond** forms by **side-on** overlap of two parallel p orbitals, with electron density above and below the line; it is weaker and prevents rotation.

4. Counting.

(a) 6 C-H + 1 C-C: **7 σ , 0 π** (b) 4 C-H + C=C: **5 σ , 1 π** (c) N $\equiv$ N: **1 σ , 2 π** (d) 6 C-H + C=C + C-C: **8 σ , 1 π** (e) two C=O: **2 σ , 2 π**

C. Carbon in organic molecules

5. Propyne.

C1 ($\equiv$ CH): 2 domains, **sp**, 180°. C2 ($-C\equiv$): 2 domains, **sp**, 180°. C3 (CH_3): 4 domains, **sp³**, 109.5°. So the H-C $\equiv$ C-C chain is linear.

6. Isomers.

The C=C contains a **π bond**, so rotation about it is not possible: the two Cl atoms can be fixed on the **same side** (*cis*) or **opposite sides** (*trans*), giving two different compounds. In 1,2-dichloroethane the C–C is only a **σ bond**, which rotates freely, so all arrangements interconvert and there is only one compound.

D. Lone pairs

7. Water and CO₂.

Oxygen in water has 2 bonds **and 2 lone pairs**: 4 domains, sp³, so the molecule is **bent** (about 104.5°). Carbon in CO₂ has 2 double bonds and **no lone pairs**: 2 domains, sp, so the molecule is **linear** (180°).

E. Challenge

8. Methanamide.

(a) C has 3 domains (H, O, N): **sp²**. O has 3 domains (the C and 2 lone pairs): **sp²**. (b) Bonds: C–H, C=O, C–N, 2 × N–H: **5 σ , 1 π** . (c) About **120°** (trigonal planar around C).