

Predicting molecular shape, bond angles and polarity

Chemistry grades 11-12 (A Level · IB · Class 11-12) · Worksheet

Name: _____ Date: _____ Class: _____

These problems train you to count electron domains, predict molecular shapes and bond angles with VSEPR, compare bond polarity from electronegativity values, and decide when polar bonds give a polar molecule.

They suit A Level, IB Chemistry and CBSE Class 11-12. The first problems are recall, the middle ones apply the rules to molecules and ions, and the last five need reasoning about symmetry and dipoles.

Level: Chemistry grades 11-12 (A Level · IB · Class 11-12) · **Curriculum:** IB S2.2

Problem 1 Counting electron domains (easy)

Copy and complete for each molecule: number of bonding domains, lone pairs on the central atom, total domains.

1. CH₄
2. NH₃
3. H₂O
4. CO₂ (O=C=O)

Problem 2 Naming the shapes (easy)

Name the shape of each molecule.

1. BeCl₂ (2 domains, no lone pairs)
2. BF₃ (3 domains, no lone pairs)
3. CH₄
4. SF₆ (6 domains, no lone pairs)

Problem 3 Bond angles (easy)

State the bond angle in each molecule.

1. CH₄
2. BF₃
3. CO₂
4. SF₆

Problem 4 Electronegativity trends (easy)

Pauling values: H 2.2, C 2.6, N 3.0, O 3.4, F 4.0, Cl 3.2.

1. Name the most electronegative element in the list.
2. Arrange N, O, F in order of increasing electronegativity.
3. Explain why electronegativity increases from carbon to fluorine across period 2.

Problem 5 Polar or non-polar bond? (easy)

Use a difference of 0.4 as the dividing line between non-polar and polar covalent bonds.

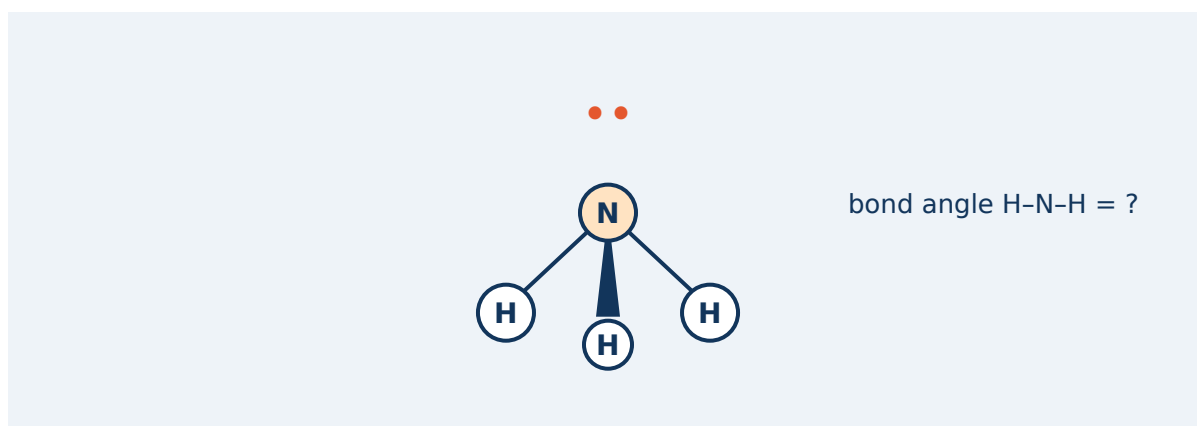
1. Classify H-H.
2. Classify C-H (C 2.6, H 2.2).
3. Classify H-Cl (Cl 3.2) and state which atom is $\delta+$.

Problem 6 What is a lone pair? (easy)

1. Define a lone pair.
2. Explain why a lone pair repels more strongly than a bonding pair.

Problem 7 Shape of ammonia (medium)

The diagram shows a model of ammonia.



A model of the ammonia molecule.

1. Name the shape.
2. Predict the approximate H-N-H angle.
3. Explain why the angle is not 109.5° .

Problem 8 The ammonium ion (medium)

When ammonia accepts H^+ it forms NH_4^+ .

1. Give the number of bonding pairs and lone pairs on nitrogen in NH_4^+ .
2. State the shape and the H-N-H angle.
3. Explain why the angle differs from that in NH_3 .

Problem 9 Sulfur dioxide (medium)

Sulfur dioxide, SO_2 , has $\text{S}=\text{O}$ double bonds and one lone pair on sulfur.

1. State the number of electron domains.
2. Name the shape and predict the angle (compared with 120°).
3. State and explain whether the molecule is polar.

Problem 10 Hydrogen sulfide (medium)

Hydrogen sulfide, H_2S , has two bonding pairs and two lone pairs on sulfur.

1. Name the shape.
2. Predict the angle compared with 109.5° .

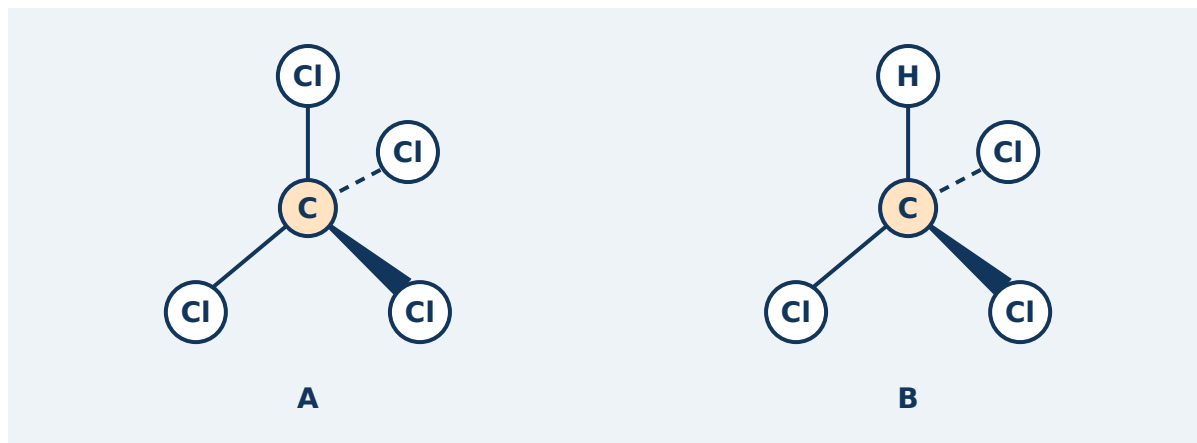
Problem 11 Phosphorus pentachloride (medium)

Gaseous PCl_5 has five bonding pairs and no lone pairs on phosphorus.

1. Name the shape.
2. State the two sets of bond angles.
3. Explain why PCl_5 is non-polar.

Problem 12 Carbon tetrachloride and chloroform (medium)

Compare molecule A, CCl_4 , with molecule B, CHCl_3 (C 2.6, H 2.2, Cl 3.2).



Two molecules, A and B, to compare.

1. Calculate the difference in electronegativity for C-Cl and C-H.
2. Explain why A is non-polar.
3. Explain why B is polar.

Problem 13 Boron trifluoride and ammonia (medium)

Both BF_3 and NH_3 have three polar bonds.

1. State the shape of each molecule.
2. Explain why BF_3 is non-polar but NH_3 is polar.

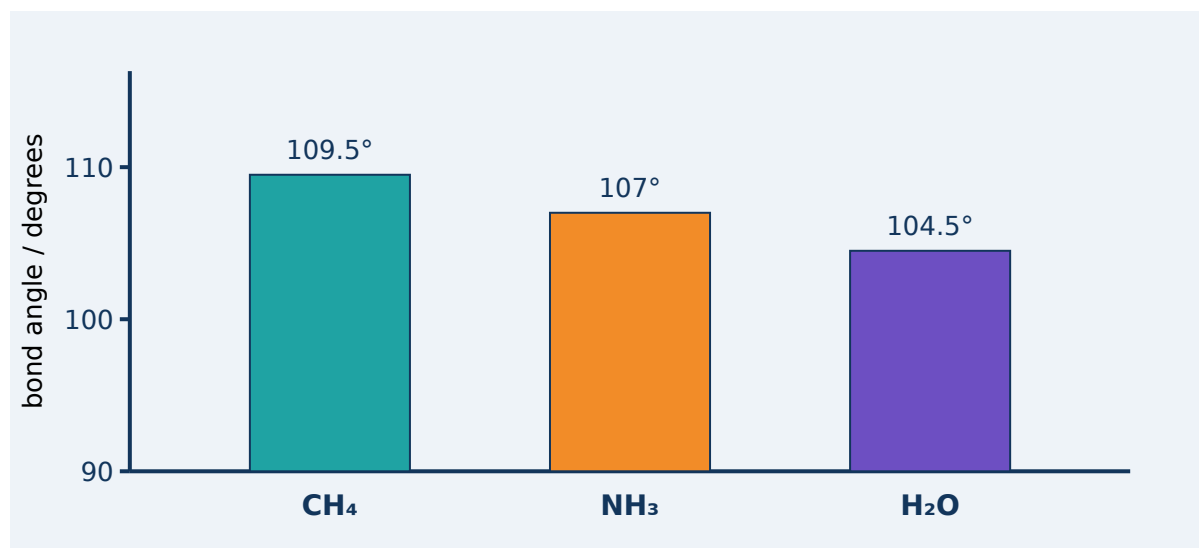
Problem 14 Partial charges (medium)

Electronegativities: H 2.2, Cl 3.2, Na 0.9.

1. Calculate the difference in H-Cl and in Na-Cl.
2. Classify each bond as non-polar, polar covalent or ionic (ionic above 1.8).
3. Mark $\delta+$ and $\delta-$ on H-Cl.

Problem 15 Trend in bond angles (medium)

The chart shows bond angles of three molecules, each with four electron domains.



Measured bond angles of three hydrides (axis starts at 90°).

1. Describe the trend.
2. Explain it in terms of lone pairs.
3. Predict whether the angle in NH_2^- (two lone pairs) is larger or smaller than in NH_3 .

Problem 16 Xenon tetrafluoride (hard)

XeF_4 has four bonding pairs and two lone pairs on xenon.

1. State the number of electron domains and their arrangement.
2. Explain why the lone pairs lie opposite each other.
3. Name the shape and the F-Xe-F angle.
4. Explain why XeF_4 is non-polar.

Problem 17 Chlorine trifluoride (hard)

ClF_3 has three bonding pairs and two lone pairs on chlorine.

1. State the number of electron domains and the arrangement.
2. Explain why the two lone pairs occupy equatorial positions.
3. Name the shape.
4. State whether the molecule is polar and why.

Problem 18 Ammonia against nitrogen trifluoride (hard)

Both NH_3 and NF_3 are pyramidal. The dipole moment of NH_3 is 1.47 D but that of NF_3 is only 0.24 D (N 3.0, H 2.2, F 4.0).

1. State the direction (toward which atom) of the N-H and N-F bond dipoles.
2. Explain why the dipole of the lone pair adds to the bond dipoles in NH_3 but opposes them in NF_3 .
3. Explain the much smaller dipole of NF_3 .

Problem 19 Cis and trans isomers (hard)

1,2-dichloroethene, ClHC=CHCl , exists as cis (both Cl on the same side) and trans (Cl on opposite sides) isomers. The C=C is planar with angles of about 120° .

1. Draw the two isomers and show the C-Cl bond dipoles as arrows.
2. Deduce which isomer is polar.
3. Explain your answer.

Problem 20 Shapes of ions (hard)

1. Predict the shapes of NO_3^- , ClO_3^- and SO_4^{2-} , stating the number of lone pairs on the central atom in each. (Treat double bonds as one domain.)
2. State the approximate O-Cl-O angle in ClO_3^- compared with 109.5° .
3. Explain why ClO_3^- and NO_3^- have different shapes though both have three oxygen atoms.