Year 13 Science: Shapes, polarity and intermolecular forces

Name: _____ Date: _____

Try these without your notes first, then check the answer key.

Practice

1. XeF_2 has 2 bonding regions and 3 lone pairs on xenon. What is its shape?

2. What is the shape and bond angle of $SiCl_4$?

3. What is the shape of BrF_5?

4. Is PCl_5 polar or non-polar?

5. Which attractions act between CH_3Cl molecules?

6. Draw the Lewis structure of the ICl_4^- ion and name its shape.

7. Explain why the bond angle in NH_3 is about 107°, while in BF_3 it is 120°.

8. ClF_3 is polar but PCl_5 is non-polar. Explain why.

9. Ethanol, CH_3CH_2OH (46 g mol^{-1}), boils at 78 °C, methoxymethane, CH_3OCH_3 (46 g mol^{-1}), at −24 °C, and propane, C_3H_8 (44 g mol^{-1}), at −42 °C. Justify the order of boiling points.

Fix the mistake

10. Correct this statement: "XeF_4 has six regions, so its shape is octahedral."

11. Correct this statement: "When water boils, the O–H bonds break."

12. Correct this statement: "CH_3Cl contains a hydrogen atom and a chlorine atom, so it has hydrogen bonding."

13. Correct this statement: "XeF_4 has polar bonds, so it is a polar molecule."

Answer key (for parents and tutors)

1. XeF_2 has 2 bonding regions and 3 lone pairs on xenon. What is its shape?
   Linear: the 3 lone pairs take the equatorial positions of a trigonal bipyramid, leaving the two F atoms opposite each other at 180°.

2. What is the shape and bond angle of $SiCl_4$?
   Tetrahedral, 109.5°: 4 bonding regions and no lone pairs on Si.

3. What is the shape of BrF_5?
   Square pyramid: 6 regions, 5 bonding and 1 lone pair.

4. Is PCl_5 polar or non-polar?
   Non-polar: the P–Cl bonds are polar, but the trigonal bipyramid is symmetrical and the dipoles cancel.

5. Which attractions act between CH_3Cl molecules?
   Temporary dipole and permanent dipole attractions; no hydrogen bonding, because no H is bonded to N, O or F.

6. Draw the Lewis structure of the ICl_4^- ion and name its shape.
   Electrons: 7 + 4 × 7 + 1 = 36 (18 pairs); 4 I–Cl bonds, 3 lone pairs on each Cl, 2 lone pairs on I. Six regions in an octahedral arrangement with the lone pairs opposite, so the shape is square planar (Achieved for the structure or shape, Merit for both).

7. Explain why the bond angle in NH_3 is about 107°, while in BF_3 it is 120°.
   NH_3 has 4 regions (3 bonding pairs and 1 lone pair), which repel into a tetrahedral arrangement; the lone pair repels more strongly than bonding pairs, squeezing the angle from 109.5° to about 107°. BF_3 has only 3 bonding regions and no lone pair, so they spread to 120° in a trigonal planar shape (Excellence compares the number of regions and the effect of the lone pair).

8. ClF_3 is polar but PCl_5 is non-polar. Explain why.
   Both have polar bonds, as F and Cl are more electronegative than the central atoms. ClF_3 is T-shaped because two lone pairs occupy equatorial positions, so its three dipoles are not symmetrical and do not cancel; PCl_5 has no lone pairs and is a symmetrical trigonal bipyramid, so its five dipoles cancel.

9. Ethanol, CH_3CH_2OH (46 g mol^{-1}), boils at 78 °C, methoxymethane, CH_3OCH_3 (46 g mol^{-1}), at –24 °C, and propane, C_3H_8 (44 g mol^{-1}), at –42 °C. Justify the order of boiling points.
   The three molecules have similar numbers of electrons, so their TD attractions are similar. Propane is non-polar with TD attractions only, so it boils lowest. Methoxymethane has polar C–O bonds in a bent C–O–C, so it adds PD attractions and boils higher. Ethanol has an O–H group, so it also forms hydrogen bonds, the strongest attractions here, so far more energy is needed to separate its molecules and it boils highest, at 78 °C (Excellence links each attraction to its strength with the similar electron clouds as the control).

10. Correct this statement: "XeF_4 has six regions, so its shape is octahedral."
    The arrangement of regions is octahedral, but the shape names only the atoms: with two lone pairs, XeF_4 is square planar.

11. Correct this statement: "When water boils, the O–H bonds break."
    Boiling overcomes the hydrogen bonds between molecules; the covalent O–H bonds inside each molecule stay intact.

12. Correct this statement: "CH_3Cl contains a hydrogen atom and a chlorine atom, so it has hydrogen bonding."
    Hydrogen bonding needs H bonded directly to N, O or F; CH_3Cl has only TD and PD attractions.

13. Correct this statement: "XeF_4 has polar bonds, so it is a polar molecule."
    Its square planar shape is symmetrical, so the four equal Xe–F dipoles cancel out, giving a non-polar molecule.