Year 12 Science: Lewis structures, shapes and polarity

Name: _____ Date: _____

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

Practice

1. How many valence electrons are shown in the Lewis structure of HCN?

2. Give the shape and bond angle of methanal, H2CO (C in the middle, double bonded to O).

3. What is the bond angle in silane, SiH4?

4. Name the shape of oxygen difluoride, OF2.

5. Is dichloromethane, CH2Cl2, polar or non-polar?

Exam-style question: BCl3 and PCl3

Boron trichloride, BCl3, and phosphorus trichloride, PCl3, are both used to make other chemicals in industry. Each has three Cl atoms bonded to a central atom.

6. Give the total number of valence electrons in the Lewis structure of each molecule.

7. Name the shape of each molecule and give its bond angle.

8. Explain why the two molecules have different shapes.

9. Both molecules contain polar bonds. Discuss why BCl3 is non-polar but PCl3 is polar.

Fix the mistake

10. Correct this statement: "CO2 is bent like water, because it has three atoms."

11. Correct this statement: "A double bond counts as two regions of electron density."

12. Correct this statement: "CCl4 has polar bonds, so it must be a polar molecule."

13. Correct this statement: "In a Lewis structure of PCl3 only the bonds and the P lone pair need drawing."

Answer key (for parents and tutors)

1. How many valence electrons are shown in the Lewis structure of HCN?
   1 + 4 + 5 = 10 electrons (5 pairs: H–C≡N with one lone pair on N).
2. Give the shape and bond angle of methanal, H2CO (C in the middle, double bonded to O).
   C has three regions (two C–H and one C=O) and no lone pairs, so it is trigonal planar with angles of 120°.
3. What is the bond angle in silane, SiH4?
   Si has four bonding regions and no lone pairs, so it is tetrahedral, 109.5°.
4. Name the shape of oxygen difluoride, OF2.
   O has 2 bonds and 2 lone pairs (20 electrons in all), so four regions give a bent shape.
5. Is dichloromethane, CH2Cl2, polar or non-polar?
   Polar: it is tetrahedral, but the C–Cl dipoles are bigger than the C–H dipoles, so they do not cancel.
6. Give the total number of valence electrons in the Lewis structure of each molecule.
   BCl3: 3 + (3 × 7) = 24 electrons, 12 pairs: three B–Cl bonds and three lone pairs on each Cl; B has only 6 electrons.
   PCl3: 5 + (3 × 7) = 26 electrons, 13 pairs: three P–Cl bonds, three lone pairs on each Cl and one lone pair on P (Achieved for a correct Lewis structure).
7. Name the shape of each molecule and give its bond angle.
   BCl3 is trigonal planar, 120°; PCl3 is a trigonal pyramid, about 109.5° (Achieved for both).
8. Explain why the two molecules have different shapes.
   Merit: B has three regions of electron density, all bonded, which repel to maximum separation in a flat triangle at 120°. P has four regions (three bonds and a lone pair), which repel into a tetrahedral arrangement at 109.5°; only three are bonded, so the shape is a trigonal pyramid. Excellence links the lone pair on P to both the different arrangement and the different shape.
9. Both molecules contain polar bonds. Discuss why BCl3 is non-polar but PCl3 is polar.
   Excellence: B–Cl (3.16 – 2.04) and P–Cl (3.16 – 2.19) are both polar, with Cl δ–. In BCl3 the three equal dipoles are arranged symmetrically in a plane, so they cancel and the molecule is non-polar. In PCl3 the lone pair makes the shape a pyramid, which is not symmetrical, so the three dipoles do not cancel and the molecule is polar.
10. Correct this statement: "CO2 is bent like water, because it has three atoms."
    C in CO2 has two double-bond regions and no lone pairs, so the regions sit 180° apart and the molecule is linear.
11. Correct this statement: "A double bond counts as two regions of electron density."
    A double or triple bond is one region, because all its electrons sit between the same two atoms.
12. Correct this statement: "CCl4 has polar bonds, so it must be a polar molecule."
    Its four equal C–Cl dipoles are arranged symmetrically, so they cancel and CCl4 is non-polar.
13. Correct this statement: "In a Lewis structure of PCl3 only the bonds and the P lone pair need drawing."
    Every valence electron is shown: each Cl also has three lone pairs, making 13 pairs (26 electrons) in total.