03 Chemical Bonding and Structure

Set B **Answer key**

A Competition questions

25 MARKS

1 **C** I and II only [1]

The attraction between ions is stronger when the charges are larger. Ca^{2+} and S^{2-} carry charges of 2, K^+ and Cl^- only 1, so I and II both explain it.

III is false: K^+ and Ca^{2+} have the same number of electrons, and Ca^{2+} has more protons, so Ca^{2+} is smaller.

2 **C** a giant lattice of oppositely charged ions [1]

A metal is a lattice of positive ions only, held together by the sea of delocalised electrons. There are no negative ions.

The other statements are correct.

3 **B** Both statements are correct but statement 2 does not explain statement 1. [1]

Both statements are true. Mobile electrons explain why metals conduct electricity.

Malleability comes from layers of ions sliding, and the high melting point from the strong metallic bonds, not from the electrons being mobile.

4 **B** WF_4 [1]

The sixth ionisation energy falls sharply from X to Y. For Y it is the last valence electron, so Y has 6 valence electrons. For X the sixth electron comes from an inner shell, so X has 5 valence electrons.

W is the element before X, with 4 valence electrons, and forms WF_4.

5 **A** bent, 110° [1]

Diazene is H–N=N–H. Each N has a single bond to H, a double bond to N (one region) and one lone pair: 2 bond pairs and 1 lone pair.

Three regions round each N point to the corners of a triangle, and the lone pair squeezes the angle below 120°, so the shape is bent at about 110°.

6 **B** T-shaped, trigonal pyramidal [1]

I has 7 valence electrons: 3 bond pairs and 2 lone pairs. The 5 pairs form a trigonal bipyramid with both lone pairs in the middle, so IF_3 is T-shaped.

P has 5 valence electrons: 3 bond pairs and 1 lone pair, so PF_3 is trigonal pyramidal.

7 **C** row C [1]

3 bond pairs and 1 lone pair give a trigonal pyramid with a bond angle of 107°, as in NH_3.

2 bond pairs and 1 lone pair give a bent shape just under 120°. 2 bond pairs and 2 lone pairs give about 104.5°. 3 bond pairs and 2 lone pairs give a T-shape with angles just under 90°.

8 **A** $POCl_3$ and CCl_4 [1]

$POCl_3$ has four regions round P (a P=O double bond and three P–Cl bonds) and no lone pairs, so it is tetrahedral, like CCl_4.

$AlCl_3$ is trigonal planar but NCl_3 is pyramidal. SO_2 is bent but CO_2 is linear. ClF_3 is T-shaped but SF_4 is see-saw.

9 **D** NH_3 and H_3O^+ [1]

NH_3 and H_3O^+ each have 3 bond pairs and 1 lone pair round the central atom: trigonal pyramidal, 107°.

CH_3^+ has 3 bond pairs and no lone pair (120°). H_2O and NH_2^- have 2 bond pairs and 2 lone pairs (about 104.5°).

10 **B** 180° [1]

The anion is attracted to the electron-deficient (slightly positive) region of the iodine atom.

That region lies directly opposite the X–I bond, so X, I and A^- lie in a straight line: 180°.

11 **C** row C [1]

Trichloromethane, $CHCl_3$, is tetrahedral round C, and the C–H and C–Cl dipoles do not cancel, so it is polar.

XeF_4 is square planar, SeF_6 is octahedral, and BCl_3 is trigonal planar but non-polar because its dipoles cancel.

12 **C** 3 only [1]

The number of electrons increases from CH_3CH_2Cl to CH_3CH_2I, so the instantaneous dipole–induced dipole attractions get stronger and the boiling point rises (3).

Electronegativity falls from Cl to I, so 1 and 2 are wrong. Statement 4 is true, but boiling does not break covalent bonds, so it does not explain the trend.

13 **A** CO_2 [1]

CO_2 molecules are non-polar, so only instantaneous dipole–induced dipole forces act between them.

Cu has metallic bonds, H_2O has hydrogen bonds as well, and SiO_2 is held by covalent bonds throughout.

14 **C** 3 and 4 only [1]

From ethane to butane the number of electrons rises, so the instantaneous dipole–induced dipole forces get stronger (4). Butane and 2-methylpropane have the same number of electrons, but the chain-shaped butane has more surface contact (3).

Hydrocarbons have no H on F, O or N, so there is no hydrogen bonding, and boiling breaks no covalent bonds.

15 **D** NH_3 forms few hydrogen bonds on average and has the smallest bond dipole. [1]

NH_3 has only one lone pair, so it forms 1 hydrogen bond per molecule on average, and N–H is the least polar of the three bonds, so each hydrogen bond is the weakest.

HF and NH_3 both form 1 per molecule. H–F is more polar than H–O. Water boils highest because it forms 2 per molecule, not because it dimerises.

16 **C** There are, on average, more hydrogen bonds between water molecules. [1]

Water has 2 H atoms and 2 lone pairs, so it forms 2 hydrogen bonds per molecule on average. HF has only 1 H atom, so it forms 1.

H–F is more polar than H–O, so each hydrogen bond between HF molecules is actually stronger: the extent, not the strength, explains the result.

17 **C** II and III only [1]

H_2O has far fewer electrons than H_2Se, so its instantaneous dipole–induced dipole (temporary dipole) forces are weaker (II). O is more electronegative than S, so H_2O is more polar and has stronger permanent dipole–permanent dipole forces than H_2S (III).

I is wrong: H_2S is the more polar molecule. H_2Se boils higher because of its stronger instantaneous dipole–induced dipole forces from its larger number of electrons.

18 **B** IV and V [1]

Liquid–liquid extraction separates liquids that are immiscible, because they form two layers.

Hexane (IV) is non-polar and water (V) is polar, so they do not mix. The pairs in the other options mix: ethanol and hexane (A), acetone and hexane (C), and chloroform and ethanol (D).

19 **D** row D [1]

Simple molecular substances are separate molecules held to one another by weak intermolecular forces.

A giant molecular lattice is atoms, not molecules, joined by covalent bonds. Each ion attracts all the oppositely charged ions round it. Only the valence electrons of a metal are delocalised.

20 **B** a giant tetrahedral network of covalent bonds [1]

Hardness and a very high melting point mean many strong covalent bonds throughout the solid, as in diamond: each Si and C bonded to 4 others in a tetrahedral network.

Si and C are both non-metals, so they do not form ions. A layer structure would be soft, and a simple molecular structure would melt at a low temperature.

21 **C** ionic, simple molecular, giant molecular [1]

X melts high and conducts when molten: ionic. Y melts low and does not conduct: simple molecular.

Z melts very high but does not conduct when molten: giant molecular.

22 **C** row C [1]

Sodium sulfate is a lattice of Na^+ and SO_4^{2-} ions (ionic bonding), and the S and O atoms inside each sulfate ion are joined by covalent bonds.

Ice is simple molecular. Iodine is non-polar, so it has instantaneous dipole–induced dipole forces, not permanent dipoles. Copper has metallic bonding.

23 **B** bond length [1]

The atoms get larger down the group, so the distance between the two nuclei increases. Their larger, more diffuse orbitals overlap less effectively, so the bond energy falls: Cl–Cl 244, Br–Br 193 and I–I 151 kJ mol^{-1}.

The number of electrons increases, so the instantaneous dipole–induced dipole forces get stronger and the halogens get less volatile.

24 **D** A dative bond can be formed from the head-on overlap of orbitals. [1]

Once formed, a dative bond is identical to any other covalent bond, so it can be a σ bond.

A is false: π bonds are weaker than σ bonds, as sideways overlap is less effective than head-on overlap. B is false: when the number of shared pairs increases, the bond length usually decreases. C is false: some non-polar bonds are stronger than polar bonds, because the number of shared pairs and how well the orbitals overlap matter more.

25 **A** 1, 2 and 3 [1]

ICl_2^- is linear (2 bond pairs, 3 lone pairs), planar, 180°. ClF_3 is T-shaped (3 bond pairs, 2 lone pairs), planar, 90°. ClO_3^- is trigonal pyramidal (3 bond pairs, 1 lone pair), 107°.

1 is correct: the bond angles are $ClF_3 < ClO_3^- < ICl_2^-$. 2 is correct: ClF_3 and ClO_3^- have a net dipole moment, and only ICl_2^- is non-polar. 3 is correct: only ClO_3^- is not planar.