02 Chemical Bonding

Set A **Answer key**

A From the lesson

11 MARKS

1

Both have a giant metallic lattice structure. Both K^+ and Na^+ have a charge of +1 and each atom contributes one electron to the sea of delocalised electrons, but K^+ has a larger ionic radius, so K^+ has a lower charge density. [1]

Hence, less energy is needed to overcome the weaker electrostatic attraction between the K^+ cations and the sea of delocalised electrons. [1]

2

Both have a giant ionic lattice structure. F^- has a smaller ionic radius than Cl^- and the same charge, so the magnitude of the lattice energy of NaF is greater than that of NaCl. [1]

Hence, more energy is needed to overcome the stronger electrostatic attraction between Na^+ and F^- ions than between Na^+ and Cl^- ions. [1]

3

(a) 3 bond pairs and 1 lone pair: trigonal pyramidal, about 107° [1]

(b) 6 bond pairs and no lone pairs: octahedral, 90° [1]

(c) 4 bond pairs and 2 lone pairs, with the lone pairs opposite each other: square planar, 90° [1]

4

SiO_2 has a giant molecular structure, CO_2 has a simple molecular structure [1]

Hence, more energy is needed to overcome the stronger, extensive covalent bonds between Si and O atoms in SiO_2 than the weaker instantaneous dipole–induced dipole interactions between CO_2 molecules. [1]

5

It is linear, so the two bond dipoles cancel: no overall dipole moment. [1]

6

The hydrogen bonds in ice hold the molecules in an open structure, further apart than in the liquid, so ice is less dense. [1]

B Practice

24 MARKS

7 **C** There are, on average, more hydrogen bonds between water molecules than there are between HF molecules. [1]

Each H_2O can form two hydrogen bonds. HF tends to form fewer hydrogen bonds per molecule.

A Intermolecular hydrogen bonds for HF are stronger than those of H_2O. This is because F is more electronegative than O, hence the H–F bond is more polar than the H–O bond, resulting in stronger hydrogen bonding.

B The electron clouds of both are comparable and hence have similar strength of intermolecular instantaneous dipole–induced dipole.

D HF has the larger dipole, but dipole–dipole differences don't outweigh water's extensive hydrogen-bond network.

8 **B** giant covalent to giant metallic [1]

White tin must have a giant metallic structure as it conducts electricity in the solid and liquid state and it is malleable.

Grey tin cannot have a giant ionic structure as it does not conduct electricity in the liquid state, thus it has to be a giant covalent structure.

9 S is a Period 3 element and can expand its octet (i.e. have more than eight electrons) due to the presence of vacant and energetically accessible d orbitals, hence SF_6 can exist. [1]

However, O is in Period 2 and does not have vacant and energetically accessible d orbitals to accommodate more than eight electrons, hence OF_6 cannot be formed. [1]

NOTE Orbitals that are energetically accessible have low energies and can be used for bonding.

10 **(a)(i)** Instantaneous dipole–induced dipole interactions between Kr atoms held in a simple molecular structure. [1]

(ii) Metallic bonding, involving electrostatic attraction between Rb^+ cations and its sea of delocalised electrons. [1]

(b) A small amount of energy is required to overcome the weak instantaneous dipole–induced dipole interactions between Kr atoms, hence the low boiling point. [1]

A large amount of energy is required to overcome the strong electrostatic attraction between Rb^+ cations and its sea of delocalised electrons in Rb, hence the high boiling point. [1]

11 **(a)**

Halogens have simple molecular structures held by weak instantaneous dipole–induced dipole interactions.

The number of electrons of the halogens increases down the group, thus the polarisability of the electron cloud increases. [1]

A larger amount of energy is required to overcome the stronger instantaneous dipole–induced dipole interactions between molecules down the group. Hence, boiling point increases down the group. [1]

(b)

Both HF and HCl have simple molecular structures. [1]

More energy is required to overcome the stronger intermolecular hydrogen bonds in HF than the weaker permanent dipole–permanent dipole interactions between HCl molecules during boiling. Thus, HF has a higher boiling point than HCl. [1]

(c)

Both NH_3 and PH_3 have simple molecular structures. NH_3 molecules have stronger hydrogen bonding via the lone pair on N and the highly δ+ hydrogen of the N–H bond, while PH_3 molecules have weaker permanent dipole–permanent dipole interactions. [1]

Thus, more energy is needed to overcome the stronger hydrogen bonds and NH_3 has a higher boiling point. [1]

12 **(a)(i)**

Bond angle in a molecule of BF_3 = 120° [1]

(ii)

The bond angle in NH_3 is smaller than that in BF_3. There are three bond pairs and one lone pair around N in NH_3, so NH_3 has a trigonal pyramidal shape. Its bond angle is less than the tetrahedral angle of 109.5° because of the greater lone pair–bond pair repulsion compared with bond pair–bond pair repulsion. [1]

BF_3 has a trigonal planar shape as it has three bond pairs and no lone pairs around B, so its bond angle is 120°. [1]

(b)

CH_4 has a larger bond angle than NH_3. CH_4 has four bond pairs and no lone pairs around C, so the bond angle in CH_4 is the ideal bond angle of 109.5°. [1]

However, NH_3 has three bond pairs and one lone pair. Since the lone pair is closer to the nucleus of N, there is greater lone pair–bond pair repulsion than bond pair–bond pair repulsion, so the bond pairs are pushed closer together and the bond angle in NH_3 is smaller. [1]

13

Both have a giant ionic lattice structure, held together by strong electrostatic attractions between oppositely charged ions.

$$|\text{lattice energy}| \propto \frac{q_+ \times q_-}{r_+ + r_-}$$

Since Ca^{2+} and O^{2-} have smaller cationic and anionic radii than Na^+ and Cl^-, and they also have charges of higher magnitude, the magnitude of the lattice energy of CaO is higher than that of NaCl.

Hence, more energy is needed to overcome the stronger electrostatic attraction between Ca^{2+} and O^{2-} ions than between Na^+ and Cl^- ions, and CaO has a much higher melting point. [1] [1]

14 **(a)**

The Cl–C–Cl bond angle is larger than the H–C–H bond angle. Cl atoms are bigger and experience greater repulsion in their electron clouds. **[1]**

or The Cl–C–Cl bond angle is smaller than the H–C–H bond angle (actual data). Cl is more electronegative than H. Cl draws the C–Cl bond pair closer to itself. The C–Cl bond pair of electrons are thus further away from the nucleus of C and exert less repulsion than those in the C–H bond.

NOTE Either answer scores if it is justified. Stating that the Cl–C–Cl bond angle is larger because Cl is more electronegative is a contradiction.

(b)

Trigonal pyramidal **[1]**

3 bond pairs and 1 lone pair **[1]**