Revision Topic 3:
Chemical Bonding

1(a) What are the main features of the electron pair repulsion model that accounts for the shapes of molecules?

[2]

Electron pairs involved in forming either single, double or triple bonds around a central atom are termed as **bond pairs**. **[1/2]**

Electron pairs not involved in bond formation are termed as **lone pairs**. **[1/2]**

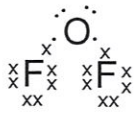
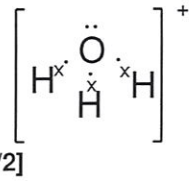
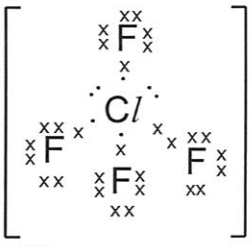
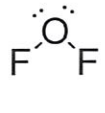
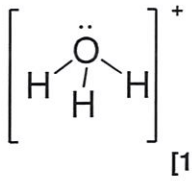
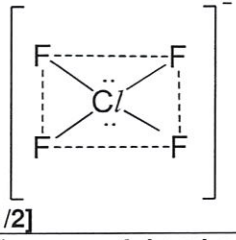
The electron pairs are arranged around the central atom **as far apart as possible** so as to **minimise repulsion** between them and **maximise stability**. **[1/2]**

Lone pair – lone pair repulsion > lone pair – bond pair repulsion > bond pair – bond repulsion. **[1/2]**

(b) By considering the number of lone pairs and bonding pairs of electrons, predict the general shapes of the following molecules or ions:

F_2O, H_3O^+, ClF_4^-

[9]

Species	F_2O	H_3O^+	ClF_4^-
Dot and Cross	 **[1/2]**	 **[1/2]**	 **[1/2]**
Structure	 **[1/2]**	 **[1/2]**	 **[1/2]**
Explanation	There are **2 bond pairs** and **2 lone pairs** around the O atom. **[1/2]** To **minimize repulsion**, the **4 electrons pairs** are directed to **corners of a regular tetrahedron** . **[1/2]**	There are **3 bond pairs** and **1 lone pair** around the O atom. **[1/2]** To **minimize repulsion**, the **4 electrons pairs** are directed to **corners of a regular tetrahedron**. **[1/2]**	There are **4 bond pairs** and **2 lone pairs** around the Cl atom. **[1/2]** To **minimize repulsion**, the **6 electrons pairs** are directed to **corners of a regular octahedron**. **[1/2]** Extent of repulsion between **lone pair – lone**

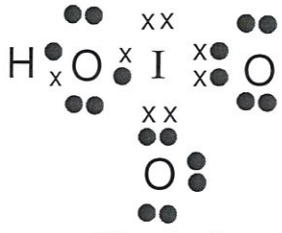
	Extent of repulsion between **lone pair – lone pair > lone pair – bond pair > bond pair – bond pair**. **[1/2]** Bond angle is compressed to 104.5° and hence F_2O is **bent** **[1/2]**	Extent of repulsion between **lone pair – bond pair > bond pair – bond pair**. **[1/2]** Bond angle is compressed to 104.5° and hence H_3O^+ is **trigonal pyramidal** **[1/2]**	**pair > lone pair – bond pair > bond pair – bond pair**. **[1/2]** Bond angle is compressed to 90° and hence ClF_3 is **square planar** **[1/2]**

[Total : 11 marks]

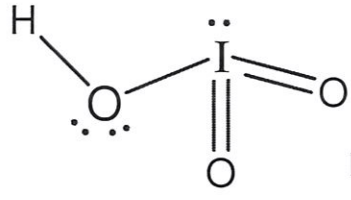
2 Iodine forms many compounds with different oxidation states. One of the compounds it can form is iodic acid, HIO_3.

Draw a dot-and-cross diagram and the structure for HIO_3. Using the VSEPR theory, describe the shape and predict the bond angle around the central atom in the HIO_3 molecule.

[3]



[1/2]



[1/2]

There are **3 bond pairs** and **1 lone pair** around **I atom.** **[1/2]**

To **minimize repulsion and maximize stability**, the **4 electron pairs** are directed to the corners of a **tetrahedron**. **[1/2]**

But **lone pair-bond pair repulsion** > **bond pair-bond pair repulsion**.

Thus, the **bond angle is compressed to 107°.** **[1/2]**

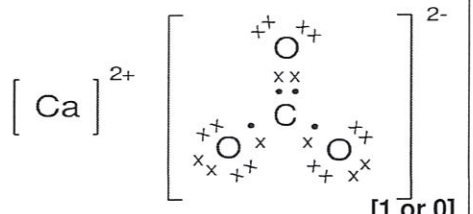
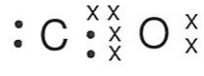
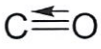
Thus the shape is **trigonal pyramidal around I atom.** **[1/2]**

[Total : 3 marks]

3(a) Draw the dot-and-cross diagram for the following species.

(i) $CaCO_3$
(ii) CO

[2]

Species	$CaCO_3$	CO
Dot-and-cross diagram	 **[1 or 0]**	 **[1 or 0]**
	When you draw Ca^{2+}, you need not to show the 8 inner shell electrons.	**Between C and O: 1 double bond and a dative bond:** 

(b) The melting points of $CaCO_3$ and CO are 825 °C and -205 °C respectively. Account for the difference in melting points in terms of their structures and chemical bonding.

[2]

Species	$CaCO_3$	CO
Melting Point Explanation	$CaCO_3$ has a **giant ionic lattice** structure. **[1/2]** **Large amount of energy** is required to **overcome the strong electrostatic attraction between the oppositely charged ions** **[1/2]** (Ca^{2+} and CO_3^{2-}) $\Rightarrow$ high melting point	CO has a **simple molecular** structure. **[1/2]** **Small amount of energy** is required to overcome the **weak van der Waals' forces of attraction between molecules.** **[1/2]** $\Rightarrow$ low melting point

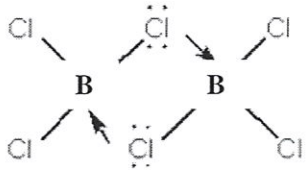
(c) $CaCO_3$ is soluble in water but CO is not. Account for the difference their solubility in water in terms of their structures and chemical bonding.

[2]

Species	$CaCO_3$	CO
Solubility in water explanation	**$CaCO_3$** is **soluble in water**. **[1/2]** The formation of **ion-solvent bonds/ interactions** **[1/2]** results in the **release of energy** that causes the **detachment of ions** **[1/2]** from the **crystal lattice for hydration** **[1/2]**	Hydrogen bonding between water molecules is **stronger** than the **weak van der Waals' forces of attraction** between hydride-hydride and hydride-water molecules. **[1/2]** These hydride molecules **cannot penetrate between the water molecules readily** and hence there is low solubility of these hydrides in water. **[1/2]**

[Total : 6 marks]

4(a) Under extreme conditions, boron chloride B_2Cl_6 can be formed via the dimerisation of BCl_3. Draw the shape of boron chloride, B_2Cl_6, indicating the likely bond angle. **[2]**



Indicate correct bond angle -- 109.5° [1]
Sketch correctly [1 or 0]

- Dative bond not shown [award 1 mark]
- Arrow point in wrong direction [0]
- Wrong shape but correct bonding [0]

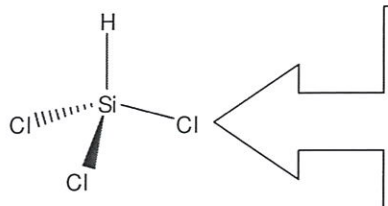
(b) State the nature of the chemical bond that leads to the formation of B_2Cl_6 and briefly describe its formation. **[2]**

- **B** in BCl_3 **is electron deficient (or only has 6 electrons around it) / B has the availability of empty orbital**[1/2] to **accept the lone pair of electrons from Cl** [1/2] **in another BCl_3 molecule**[1/2] via a **dative bond** to attain the **stable octet configuration**. **[1/2]**

[Total : 4 marks]

5(a) When a negatively charged rod is held near trichlorosilane, $SiHCl_3$, which is being released from a burette in a slow steady stream, the liquid stream is deflected.

(i) Account for the deflection that is observed.



Although the central atom, silicon, does not contain any lone pair of electrons, the net dipole moment does not cancel due to the fact that the surrounding atoms are not the same.

- $SiHCl_3$ is a **polar** molecule since its **net dipole moment is non-zero. [1/2]**
- There is **electrostatic forces of attraction** between the **charged poly(ethene) rod and the oppositely-charged end of the dipole** in $CHCl_3$ molecule, causing the $CHCl_3$ liquid stream to be deflected. **[1/2]**

(ii) Suggest, with reasoning in terms of their chemical structures and bonding, the relative boiling points of trichlorosilane and chlorosilane, SiH_3Cl.

$SiHCl_3$ has a **higher boiling point** than SiH_3Cl **[1/2]**

- Both have **simple molecular structures** with **intermolecular Van der Waals' forces of attraction [1/2]**
- **Size of electron cloud**: $SiHCl_3 > SiH_3Cl$ **[1/2]**
- **Extent of distortion of the electron cloud** : $SiHCl_3 > SiH_3Cl$ **[1/2]**
- **Extent of Van der Waal's attraction** : $SiHCl_3 > SiH_3Cl$ **[1/2]**
- **Energy requirement** to overcome van der Waal's attractions between molecules: $SiHCl_3 > SiH_3Cl$ **[1/2]** **[4]**

(b) Silicon carbide, with empirical formula SiC, is a ceramic material. Its chemical structure consists of alternating carbon and silicon atoms in a diamond-like structure.

(i) Would you expect silicon carbide to have a high or low melting point? Explain your answer in terms of its chemical structure and bonding.

- SiC is expected to have a **very high melting point [1/2]**
- It has a **giant molecular structure [1/2]**
- **Large amount of energy [1/2]** required to **overcome the extensive covalent bonding between the atoms in a giant 3-dimensional structure. [1/2]**

(ii) Suggest why silicon carbide could be used as a coating for engineering components in terms of its physical property other than its high melting point.

- SiC is **extremely hard**
- It can **withstand considerable wear and tear**

} **either one [1/2]**

(iii) Silicon carbide is not suitable for use as a machinery lubricant. Explain why graphite might be suitable for this purpose in terms of its chemical structure and bonding.

- Graphite is **slippery [1/2]**
- It has a **giant molecular layered structure [1/2]**
- The adjacent layers are **held together by weak Van der Waals' forces of attraction** and can **easily slide over one another. [1/2]**

(iv) Silicon carbide is a non electrical conductor however rubidium is a electrical conductor. Account for the observation.

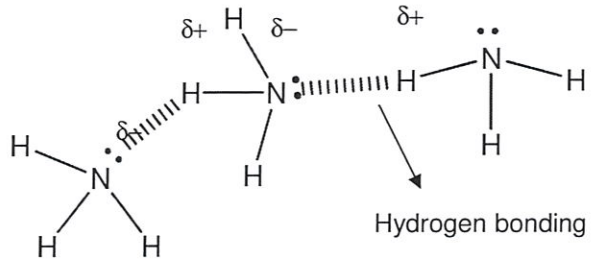
SiC	Rb
• SiC has a **giant molecular** structure. **[1/2]** • It is a non-conductor due to **the absence of delocalised electrons and free mobile ions** **[1/2]**	• Rb has a **giant metallic** structure. **[1/2]** • It is a good conductor due to the presence of **delocalised electrons.** **[1/2]**

[6]
[Total : 10 marks]

6 The table below gives the boiling points of the hydride of nitrogen and two other hydrides of Group V.

Compound	Boiling point / ° C
NH_3	- 33.4
PH_3	- 87.7
AsH_3	- 60 °C

(a) Explain with an aid of a suitable diagram why NH_3 has a higher boiling point than PH_3. **[3]**



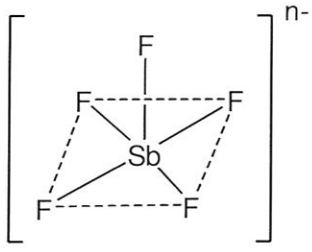
- Both NH_3 and PH_3 have **simple molecular structures**. **[1/2]**
- Since **hydrogen bonds are stronger** than the **Van der Waals' force, [1/2]**
- A larger amount of energy is required to overcome the hydrogen bonds between the NH_3 molecules compared to the weak van der Waals' forces between PH_3 molecules. **[1/2]**

(b) State and explain whether NH_3 has a smaller or larger bond angle than PH_3. **[2]**

- **NH_3** has a **larger bond angle** than PH_3. **[1/2]**
- **N is more electronegative** than P. **[1/2]**
- Therefore the **electrons pairs are drawn closer to N** compared to P. **[1/2]**
- Hence, the **bond pairs (N – H) experience greater repulsion** from one another in NH_3 compared to P – H bond in PH_3. **[1/2]**

[Total : 5 marks]

7 Antimony, Sb, is in Group V of the Periodic Table. It forms a series of salts which contain the SbF_5^{n-} anion, one of which is shown below.



Deduce the total number of electrons around the antimony atom, the value of n, and the oxidation number of Sb in this ion.
[2]

Since it is a **square-based pyramid**, the ion should consist of **5 bond pairs** and **1 lone pair** of electrons around the Sb atom. **[1/2]**

Total number of electrons around the central atom Sb = **12** **[1/2]**

To obtain the anion, electrons should be added to F since F is the more electronegative element.

Sb is in Group V ⇒ 2 electrons used for lone pair, and 3 bonding electrons available to bond with 3 F atoms

⇒ 2 other F atoms are dative-bonded to Sb have stable octet configuration

⇒ Each of the 2 other F atoms have accepted 1 electron each

∴ **n = 2** **[1/2]** (explanation not required)

Let the oxidation number of Sb in this ion be x.

$x + 5(-1) = -2$

$x =$ **+3** **[1/2]**

[Total : 2 marks]