Success criteria:	Relevant Tutorial question	What do you still struggle with? Write your queries here.
1. understand that all interatomic bonds and intermolecular forces of attraction are electrostatic in nature and energy is required to overcome them. Thus, the magnitude of the melting/boiling points reflects the strength of the different electrostatic forces of attraction. • describe metallic bond as the electrostatic attraction between a lattice of positive ions and delocalised electrons • describe the metallic lattice structure of a crystalline solid as in copper (see checkpt 5 on pg 18) • describe ionic bond as the electrostatic attraction between oppositely charged ions • describe the ionic lattice structure of a crystalline solid as in NaCl and MgO. See Figures 2.2 under section 2.2 on pg 8. • describe covalent bond as the electrostatic attraction between a shared pair of electrons and positively charged nuclei	Q1, Q2	
2. describe, interpret and/or predict the effect of different types of structure and bonding on the physical properties of substances.		
Refer to pg 12 - 18 of lecture notes		
3. describe co-ordinate (dative covalent) bonding where both electrons in the covalent bond comes from only one of the bonding atoms.	Q3a/ Q9d	
4. describe covalent bonding in terms of orbital overlap (use s and p orbitals only), giving σ and π bonds in **diatomic** molecules. 5. Understand that the **pair of orbitals** taking part in covalent bonding must **either** have one unpaired electron each (see section 3.3 on pg 16) **or** one orbital with lone pair while the other orbital is without electrons (see section 3.2). 6. Covalent bond strength increases with increase in shared electron density between 2 nuclei. See section 3.3 (sigma > pi) and 3.4. (a) bond order (b) effectiveness of orbital overlap. See checkpt 5.	Q3b Assess in chemical energetics/ organic chemistry	
7. Define the terms 'B*ond energy'* and 'B*ond length'*. 8. '*Bond energy'* and 'B*ond length'* are numerical values that help us compare covalent bond strength. 9. Compare covalent bond strength qualitatively by considering in decreasing order of priority (i) bond order (ii) effectiveness of orbital overlap. See checkpt 5.	Q 4 (iii)	

Refer to pg 19 - 21 of lecture notes		
10. describe the lattice structure of a crystalline solid of simple covalent molecule such as iodine and giant molecular lattice (giant covalent lattice) structure of a crystalline solid as in graphite and diamond (see figure 3.5b.1 and 3.5b.2.) see checkpt 6. 11. Able to use the concept of the number orbitals in the valence shell and electronegativity to explain why certain compounds can be formed with period 3 element but not period 2 element. See checkpt 7	Q1 Q6	
Refer to pg 22 - 23 of lecture notes for thinking process		
12. use of 'dot-and-cross' diagrams to describe covalent and ionic bonding	Q5 (1st column)	
Refer to pg 32 - 35, 39 - 40 of lecture notes for thinking process		
13. Able to use dot-and-cross diagram and Valence Shell Electron Pair Repulsion theory to identify the different electron geometry of atoms covalently bonded to each other. 14. Able to deduce and compare with reasoning, the shape (molecular geometry) and the bond angle by considering (i) the number of bonding and non-bonding pairs in the electron geometry and (ii) repulsive forces which increase with electron density of the electron pair nearer to the central atom.	Q5 (2nd column), Q7, Q8/ Q9	
15. explain and deduce bond polarity using the concept of electronegativity [quantitative treatment of electronegativity is **not** required] 16. deduce the polarity of a molecule using bond polarity and its molecular shape	Q 10	
Refer to pg 46 thinking processes		
17. Describe in words or using suitable diagrams to illustrate the formation of the following intermolecular forces (IMF) i. instantaneous dipole-induced dipole interactions. ii. permanent dipole-permanent dipole interactions between polar molecules. iii. hydrogen bonding between molecules with protonic hydrogen (H directly bonded to N,O and F). 18. For simple covalent molecules, only IMF are overcome during a physical change while interatomic covalent bonds are broken during a chemical change. 19. Strength of Hydrogen bonding > permanent dipole-permanent dipole > instantaneous dipole-induced dipole when molecules of similar M_r are being compared.	Q 5 (3rd column) Q 11/ Q12/ Q 14/ Q16	

Refer to pg 46 - 49 of lecture notes for the thinking process		
20. suggest the type of structure and bonding present in a substance from given information	Q4/ Q 13 Q18/ Q19	
Refer to pg 54 - 56 of lecture notes for thinking process		
21. Dissolution of a solute is **energetically favourable** if: energy released in the formation of solute-solvent interactions ≥ energy taken in to brea solute and solve interactio	Q15	
22. Able to illustrate ion dipole interaction with **one** water molecule using a labelled diagram.	Q16	
Refer to pg 57		
23. outline the importance of hydrogen bonding to the physical properties of substances, including ice and water	Q 17	

CHEMICAL BONDING TUTORIAL

Interatomic Bonding

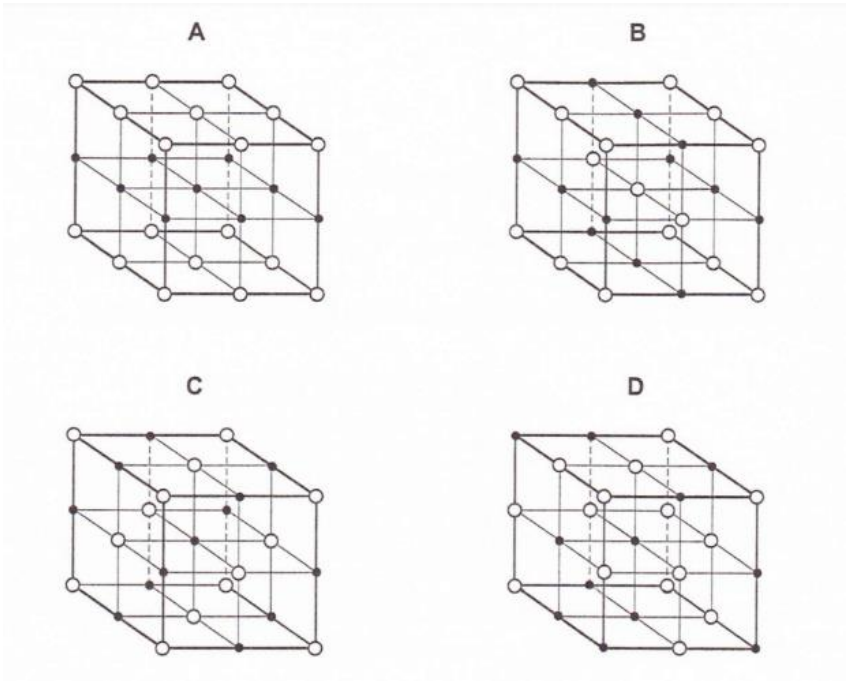
1(a) Fill in the following table by matching the following substances to their physical properties.

graphite, diamond, copper, iodine, sodium chloride

Properties	substance	structure	Describe bonding and relate it to the physical properties
(a) A hard and brittle solid.			
(b) A solid that conducts electricity and melts at 1085^{o}C.			
(c) A solid that cuts through metal and does not conduct electricity.			
(d) A substance that sublimates when heated.			
(e) A solid that can be used as a lubricant.			

2010 MCQ 6

1(b) Which diagram best represents the structure of solid magnesium oxide?



1(c) The melting point of calcium, 839°C, is much higher than the melting point of sodium, 98°C. Which statement is most relevant in explaining the difference?

A	The calcium atom is larger than the sodium atom.
B	The calcium atom is heavier than the sodium atom.
C	The calcium ion, Ca^{2+}, has a higher charge than the sodium ion, Na^{+}.
D	The calcium ion, Ca^{2+}, contains more electrons than the sodium ion, Na^{+}.

2 Which statement(s) are correct?

I HC*l* (aq) cannot conduct electricity.
II Covalent bond is a weak bond compared to ionic bond as boiling point of H_2O is lower than that of MgO.
III Ionic bonds and covalent bonds can both occur in the same compound.
IV Metals can be distinguished from ionic compounds by their electrical conductivity in the solid state.

A Statements **I** and **III** are correct.
B Statements **II** and **IV** are correct.
C Statement **III** and **IV** are correct.
D Statements **I, III** and **IV** are correct

3(a) Boron trifluoride and ammonia reacts in a 1:1 mole ratio to form a single compound. Describe the type of bond formed during this reaction.

2015 MCQ 2

3(b) Which row about sigma (σ) bonds and pi (π) bonds in hydrocarbons is correct?

	(σ) bonds	(π) bonds
A	Can be formed by either s or p orbitals	Can be formed by either s or p orbitals
B	Can be formed by either s or p orbitals	Can be formed by p orbitals but not s orbitals
C	Can be formed by p orbitals but not s orbitals	Can be formed by either s orbitals but not p orbitals
D	Can be formed by s orbitals but not p orbitals	Can be formed by p orbitals but not s orbitals

4 Explain the following observations.

i. Magnesium oxide is used in making bricks for lining high temperature furnaces; while sodium chloride cannot be used for this purpose. Explain this observation in terms of structure and bonding.

ii. At room temperature and pressure, CO_2 is a gas, while SiO_2 is a solid of high melting temperature.

iii. SiC has a higher melting point (2730 °C) than SiGe (1176 °C)

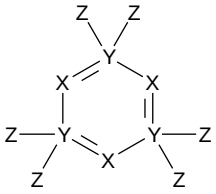
Dot-and-Cross Diagram and VSEPR

5 Fill up the table below for the following compounds:

compound	'dot-and-cross' diagram	(i) **Draw** the **Lewis structure** and **name** the shape wrt central atom (ii) Indicate the **bond angle** in the diagram	Bonds or intermolecular forces broken during melting or boiling process
(i) Al_2O_3 (m.p. 2072°C)			
(ii) $AlCl_3$ (m.p. 192°C)			
(iii) PCl_3 (l)			
(iv) CH_2Cl_2(l)			
(v) PCl_5(s)			
(vi) HCN			

compound	'dot-and-cross' diagram	(i) **Draw** the **Lewis structure** and **name** the shape wrt central atom (ii) Indicate the **bond angle** in the diagram	Bonds or intermolecular forces broken during melting or boiling process
(vii) XeF_4			
(viii) H_2O_2			
(ix) Na_2O_2			
(x) $(NH_4)_2SO_4$ Salt formed from H_2SO_4 and NH_3.			

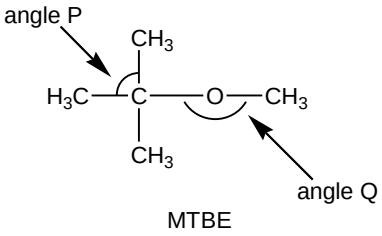
6 A stable molecule containing atoms of the elements, X, Y and Z has the following structure.



Which option is a possible combination of the elements?

	X	**Y**	**Z**
A	N	P	C*l*
B	O	S	C*l*
C	B	N	H
D	P	O	F

7 MTBE is a constituent of petrol.
What are the values of angle P and angle Q in a molecule of MTBE?



MTBE

	angle P	angle Q
A	90°	105°
B	90°	180°
C	109°	105°
D	109°	180°

8 Using VSEPR theory, predict which compound in each of the following pair of molecules has a larger bond angle.

(a) BCl_3 and NCl_3

(b) H_2S and PH_3

9 [N10/III/4c]

(a) Draw 'dot-and-cross' diagrams to show the bonding in the molecules of NO_2, O_3 and BF_3.

In the molecule NO_2, the central atom is nitrogen. In each case you should distinguish carefully between electrons originating from the central atom and those from the two outermost atoms. Include all lone pairs in your diagrams.

(b) Suggest a value for the bond angles in each of the three molecules, giving reasons for your choice.

(c) The compound FO_2 does not exist but ClO_2 does.
By considering the possible types of bonding in the two compounds suggest reasons for this difference. (Assume the halogen atom occupies the central position in each of these molecules.)

(d) Modified from 2016 P3 Q1 (b)
Carbon monoxide reacts with boron hydride, BH_3, at high pressure to give one product **W**.

(i) Give the dot-and-cross diagram of CO and BH_3. Hence draw dot-cross diagram showing the bonding in the product **W**, clearly indicating any coordination bond (dative covalent) bonds it contains.

(ii) Use a Lewis diagram, indicate the bond angles with respect to each central atom in **W**.

Polarity and Intermolecular Forces

10 **(a)** Draw the Lewis structure of the following molecules and indicate for each one the polarity of each of the bonds it contains, and the overall polarity of the molecule.
Hence classify the following molecules as polar or non-polar.

NH_3, SF_6, $CH_2{=}CH_2$, CH_3OH, ClF_3, CH_3OCH_3 , N_2H_4

(b) Hence, classify the molecules in **(a)** according to the main type of intermolecular forces present.

2018 P2 Q1(b)

(c) Table 1.2 shows the electronegativity values of the atoms in phosgene, $Cl_2C{=}O$.

Table 1.2

atom	electronegativity
carbon	2.5
chlorine	3.0
oxygen	3.5

(i) Explain what is meant by the term *electronegativity*. [2]

(ii) Predict all possible intermolecular forces which could exist between phosgene molecules. Explain how these forces arise. [3]

Structure and Physical Properties

11 The boiling points of four compounds are given in the table below.

Compound	Boiling point/ °C
H_2O	100
CH_3OH	65
SiH_4	–107
CH_4	−164

Explain the differences in boiling point between

(a) CH_4 and SiH_4

(b) H_2O and CH_3OH

12 The boiling points of three organic compounds are given in the table below.

Compound	Molecular formula	M_r
A	$CH_3CH_2OCH_2CH_3$	74
B	$CH_3CH_2CH_2CH_2OH$	74
C	$(CH_3)_3COH$	74

Explain, in the following pairs, why the first compound is more volatile than the second compound

(a) **A** and **B**

(b) **C** and **B**

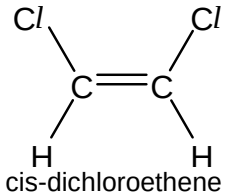
13 Referring to table in question **5**, explain the following observations.

(i) Al_2O_3 conducts electricity in molten state while $AlCl_3$ in molten state does not.

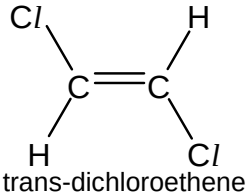
(ii) Difference in physical state of PCl_3 and PCl_5.

14 Explain why the following pairs of molecules differ in their boiling point despite having the same M_r and functional groups.

(a) The boiling point of cis-dichloroethene is 333 K, whereas that of trans-dichloroethene is 321 K.

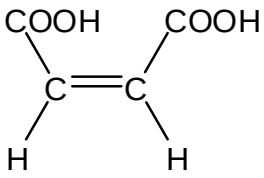


cis-dichloroethene

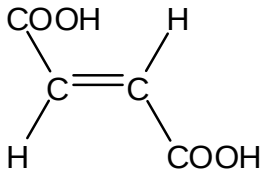


trans-dichloroethene

(b) The boiling point of **R** is higher than **Q**.



Q



R

Solubility

15 Predict with explanations whether or not the following solute is soluble in the given solvent

(a) Solute: CH_3CH_2OH / Solvent: H_2O

(b) Solute: NH_4NO_3 / Solvent: benzene, C_6H_6.

16 Ammonia and hydrogen chloride gases are soluble in water because they interact with the solvent.

$$HCl(g) + aq \rightarrow H^+(aq) + Cl^-(aq)$$
$$NH_3(g) + aq \rightarrow NH_3(aq)$$

Use suitable diagrams to illustrate all the possible interactions between the dissolved gas and **a water molecule**.

Application questions

17 Provide an explanation for the following observations.

(a) Ice is less dense than water.

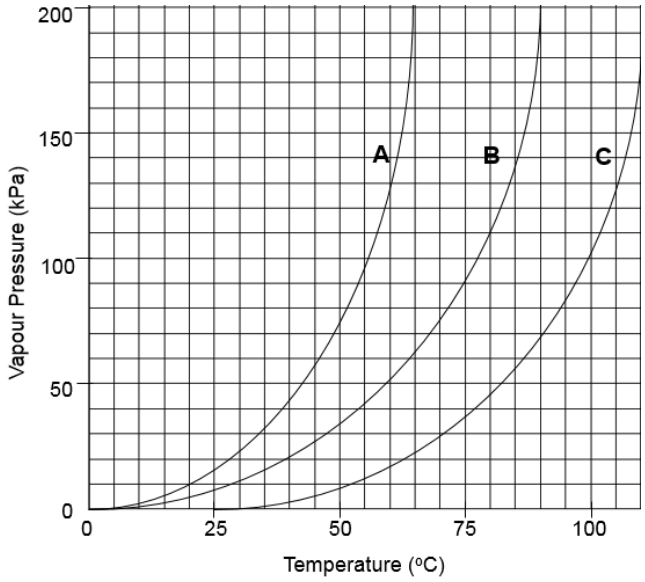
(b) The relative molecular mass of ethanoic acid is 120 in benzene, C_6H_6.

18 Vaporization occurs when some molecules in a liquid possesses enough kinetic energy to escape from the surface of the liquid at a given temperature.

Saturated vapour pressure is the pressure on the walls of the container exerted by the gas molecules vaporized from the surface of the liquid in a closed container when the rates of condensation and evaporation are equal.

Boiling occurs when the vapour pressure is equal to the external pressure which is usually the atmospheric pressure (101 kPa).

The graph below shows the vapour pressures of three liquids at varying temperatures.



(a) The identities for liquids **A** and **B** could be ethanol (CH_3CH_2OH) and propanone (CH_3COCH_3). Based on the graph, identify liquids **A** and **B** and explain your reasoning. [4]

(b) Suggest a possible identity for **C**.

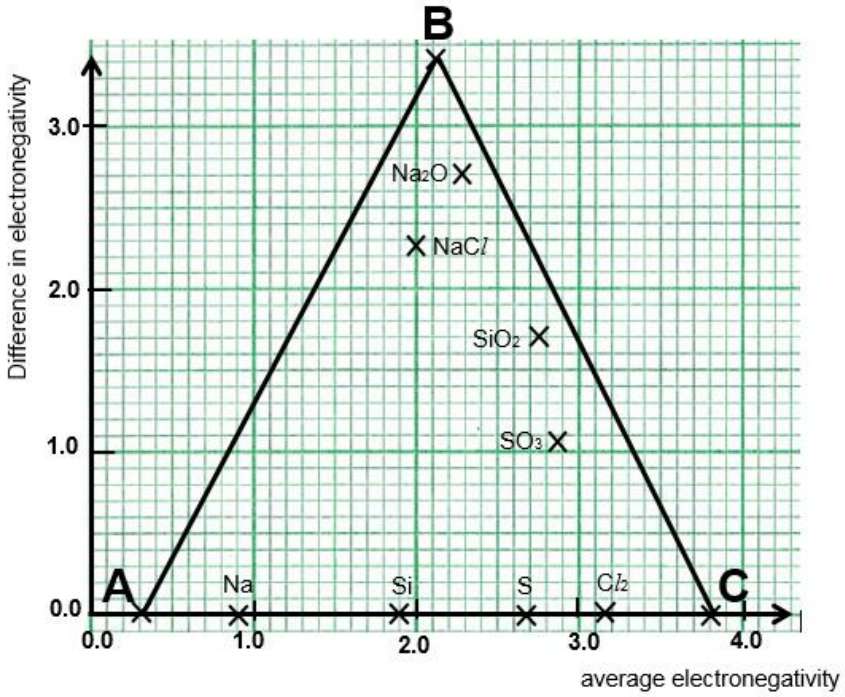
19 The type of bonding (covalent, ionic or metallic) present in a substance can be determined and predicted using the van Arkel triangle based on the values of electronegativity of the element.

Difference in electronegativity between the element(s) is plotted along the *y–axis* and the average electronegativity of the element(s) is plotted along the *x–axis*.

The electronegativity data for oxygen and germanium, Ge, and some selected elements from Period 3 of the Periodic Table are given below.

element	Na	A*l*	Si	Ge	S	C*l*	O
electronegativity	0.93	1.61	1.90	2.01	2.58	3.16	3.61

In addition, some of the Period 3 elements and their compounds have been plotted on the van Arkel triangle given below.



(i) Using your knowledge of the Period 3 elements and their compounds plotted above, state *the type of bonding* present at each of these bonding extremes, labelled as **A**, **B** and **C**, on the triangle. [3]

(ii) Germanium oxide has a giant molecular structure. On the van Arkel triangle above, **plot the point** corresponding to the oxide of germanium. Hence explain if the melting point of the oxide of germanium would be lower or higher than that of the oxide of silicon. [3]