Remarks:

Directions: Decide whether each of the two statements is true or false: if both are true, then decide whether or not the second statement is a correct explanation of the first statement. Then select one option from A to D according to the following table:

A. Both statements are true and the 2nd statement is correct explanation of the Misstatement.

B. Both statements are true but the 2nd statement is NOT a correct explanation of the 1st statement.

C. The 1st statement is false but the 2nd statement is true.

D. Both statements are false.

SECTION 6 Microscopic World II

Multiple-Choice Questions

CE11_05

Hydrogen chloride has a low boiling point because

A. weak covalent bonds exist between hydrogen chloride molecules.

B. weak covalent bonds exist between hydrogen atoms and chlorine atoms.

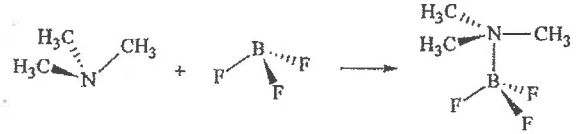
C. weak van der Waals' forces exist between hydrogen chloride molecules.

D. weak van der Waals' forces exist between hydrogen ions and chloride ions.

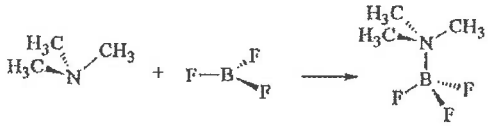
AL06(I)_03

Which of the following best represents the reaction of $(CH_3)_3N$ with BF_3 to form $(CH_3)_3NBF_3$?

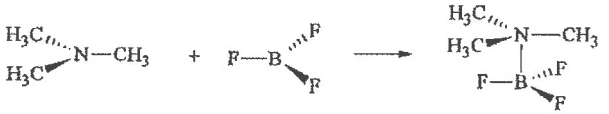
A.



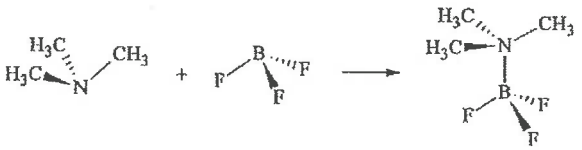
B.



C.



D.



ASL08(I)_05

Which one of the following molecules has a zero dipole moment?

A. BF_3 B. PH_3

C. SO_2 D. HCl

ASL12(I)_03

Which of the following species is NOT planar?

A. Boron trifluoride B. Nitrate(V) ion

C. Phosphorus trichloride D. Phenylethene

DSE12PP_02

Which of the species shown below does NOT follow the 'octet rule'?

A. Na_2O B. MgO
C. PCl_3 D. SCl_4

DSE12PP_16

Which of the following molecules is non-polar?

A. $BeCl_2$ B. NH_3
C. H_2O D. HCl

DSE12PP_17

Ammonia is very soluble in water. Which of the following statements best accounts for this phenomenon?

A. Both ammonia molecule and water molecule are polar.
B. Ammonia molecule and water molecule are of comparable sizes.
C. Ammonia undergoes ionization in water.
D. Ammonia forms hydrogen bond with water.

DSE12_05

Which of the following molecules is polar?

A. BF_3 B. C_{60}
C. NH_3 D. SF_6

DSE12_12

Which of the following molecules is planar?

A. BF_3 B. NH_3
C. CH_4 D. PCl_5

DSE13_23

To which of the following molecules is/are the 'octet rule' NOT applicable?

(1) OF_2
(2) NO_2
(3) CS_2

A. (1) only B. (2) only
C. (1) and (3) only D. (2) and (3) only

DSE13_24

1st statement	2nd statement
The boiling point of hydrogen chloride is higher than that of hydrogen fluoride.	The molecular size of hydrogen chloride is greater than that of hydrogen fluoride.

DSE14_22

Which of the following molecules have non-octet structures?

(1) NO_2
(2) PBr_3
(3) BCl_3

A. (1) and (2) only B. (1) and (3) only
C. (2) and (3) only D. (1), (2) and (3)

DSE14_23

When a negatively charged rod is placed near a jet of liquid running out from a burette, the jet of liquid deflects towards the rod. Which of the following may the liquid be?

(1) Water
(2) Hexane
(3) Trichloromethane

A. (1) and (2) only B. (1) and (3) only
C. (2) and (3) only D. (1), (2) and (3)

DSE14_24

1st statement	2nd statement
All acidic gases can react with CaO(s) to form salt and water only.	All acidic gases contain hydrogen as one of their constituent atoms.

DSE15_11

In the species below, the underlined atom is the central atom, and all non-central atoms have octet electronic arrangement. In which of them does the central atom NOT have octet electronic arrangement?

A. $\underline{S}F_2$ B. $\underline{C}F_2$
C. $\underline{C}S_2$ D. $\underline{N}Cl_3$

DSE15_24

1st statement	2nd statement
The boiling point of H_2O is lower than that of HF.	The electronegativity of oxygen is lower than that of fluorine.

DSE16_16

Which of the following compounds has the highest boiling point?

A. HF B. HCl
C. PH_3 D. H_2Se

DSE16_21

Which of the following molecules have a similar shape?

(1) BCl_3
(2) NH_3
(3) PF_3

A. (1) and (2) only
B. (1) and (3) only
C. (2) and (3) only
D. (1), (2) and (3)

DSE17_12

Which of the following molecules is polar?

A. CO_2
B. PCl_3
C. SiF_4
D. SF_6

DSE17_24 [OUT]

1st statement	2nd statement
Both buckminsterfullerence (C_{60}) and graphite are good conductors of electricity.	Buckminsterfullerence (C_{60}) and graphite are different forms of carbon.

DSE18_16

Which of the following molecules is/are nonpolar?

(1) BCl_3
(2) PCl_3
(3) $CHCl_3$

A. (1) only
B. (2) only
C. (1) and (3) only
D. (2) and (3) only

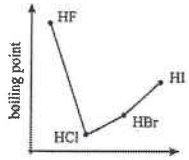
DSE19_13

Which of the following combinations is correct?

	Molecule	Molecular shape
A.	OF_2	Linear
B.	CS_2	V-shapd
C.	NCl_3	Trigonal planar
D.	PF_3	Trigonal pyramidal

DSE20_20

20. Refer to the sketch below :



Which of the following can explain the variation of the boiling points of the hydrogen halides ?

(1) The boiling point of HF is higher than that of HCl because the hydrogen bonds between HF molecules are stronger than the van der Waals' forces between HCl molecules.
(2) The boiling point of HI is higher than that of HBr because HI molecules are more polar than HBr molecules.
(3) HCl has the lowest boiling point because it has the smallest molecular size.

A. (1) only
B. (2) only
C. (1) and (3) only
D. (2) and (3) only

DSE20_22

22. Which of the following statements concerning ice and water at 0 °C are correct ?

(1) The density of ice is lower than that of water because ice has an open structure but water does not.
(2) In ice, the hydrogen bonds between the molecules are weaker than the covalent bonds in the molecules.
(3) In ice, each molecule links up with only two neighbouring molecules by hydrogen bonds.

A. (1) and (2) only
B. (1) and (3) only
C. (2) and (3) only
D. (1), (2) and (3)

DSE21_10

10. Which of the following processes involves the breaking of hydrogen bonds ?

A. $H_2(l) \rightarrow H_2(g)$
B. $HBr(l) \rightarrow HBr(g)$
C. $CH_3OH(l) \rightarrow CH_3OH(g)$
D. $CH_3CHO(l) \rightarrow CH_3CHO(g)$

Structural Questions

AL00(I)_01 (modified)

Explain why nitrogen forms only one chloride, NCl_3, whereas phosphorus forms two chlorides, PCl_3 and PCl_5.

(2 marks)

AL00(I)_01

Account for the order of boiling point for the two series of compounds below:

$H_2O > C_2H_5OH > C_2H_5OC_2H_5$

$H_2S < C_2H_5SH < C_2H_5SC_2H_5$

(3 marks)

AL00(I)_01

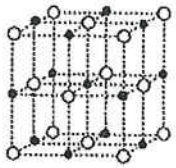
The diagrams below show the arrangement of atoms, ions or molecules in four crystalline substances: graphite, ice, iodine and sodium chloride.

(a) Write the name of the substance of each structure in the space provided.

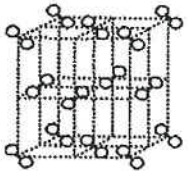
(b) Label, on the diagrams, the types of interactions that are present in these substances.

(i)

(ii)



(iii)



(iv)

(6 marks)

ASL00(II)_09

Silicon forms a hydride with formula SiH_4.

(a) Draw the three-dimensional structure of SiH_4.

(1 mark)

(b) The electronegativity values (Pauling's scale) of H and Si are 2.1 and 1.8 respectively. State, with explanation, whether or not SiH_4 is a polar molecule.

(2 marks)

(c) The boiling points of Si and SiH_4 are 2628 K and 161 K respectively. Explain why the boiling point of SiH_4 is much lower than that of Si.

(2 marks)

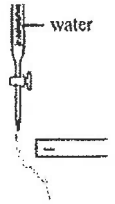
AL01(I)_01 [Same as DSE13_01]

Explain, in terms of structure and intermolecular force, why water is denser than ice.

(2 marks)

ASL01(I)_01

A negatively charged rod was brought near a jet of water running out from a burette. The jet of water was deflected as shown:



(a) With reference to the structure of water, explain why the jet of water was deflected.

(2 marks)

(b) State the effect on the jet of water if the negatively charged rod is replaced by a positively charged rod. Explain your answer.

(2 marks)

(c) If cyclohexane is used instead of water and a negatively charged rod is brought near the liquid jet, would the liquid jet be deflected? Explain your answer.

(2 marks)

AL02(I)_03

CO_2 and SiO_2 are oxides of Group IV elements. Account for the fact that CO_2 is a gas while SiO_2 is a high melting solid under room temperature and atmospheric pressure.

(2 marks)

ASL02(I)_04

For the substances below, sketch the variations of their boiling points and account for the variations.

Hydrides of Group VI elements, H_2O, H_2S, H_2Se and H_2Te

(4 marks)

AL02(II)_01

Ammonia (NH_3) and phosphine (PH_3) are hydrides of nitrogen and phosphorus respectively. Account for each of the following phenomena:

(a) The bond angle between two N–H bonds in NH_3 (about 107°) is greater than that between P–H bonds in PH_3 (about 94°).

(2 marks)

(b) NH_3 is very soluble in water but PH_3 is sparingly soluble.

(1 mark)

AL03(I)_01

Elemental oxygen exists in the atmosphere in two forms, O_2 and O_3.

(a) Draw the electronic structure of O_3.

(1 mark)

(b) Suggest why O_3 is more soluble in water than O_2.

(2 marks)

ASL03(I)_02

Arrange the following compounds in order of increasing boiling point. Explain your answer.

$CH_3(CH_2)_2CH_3$, $CH_3(CH_2)_3Cl$, $CH_3(CH_2)_3OH$, $CH_3(CH_2)_3CH_3$

(5 marks)

AL03(II)_03

The 'octet rule' is commonly used in elementary chemistry course to account for the formation of chemical bonds.

(a) What is the octet rule?

(1 mark)

(b) With appropriate examples, state two limitations of the octet rule.

(2 marks)

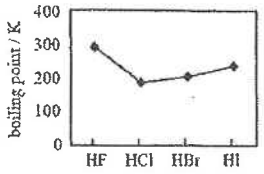
AL04(I)_02

Consider the noble gases, He, Ne, Ar Kr and Xe. Sketch a graph to show the variation of boiling point of these noble gases and account for the variation.

(2 marks)

ASL04(I)_03

The graph below shows the variation of boiling point of four hydrogen halides.



(a) Account for the variation of boiling point of HCl, HBr and HI.

(2 marks)

(b) Suggest why HF has the highest boiling point among the four hydrogen halides.
[Similar to DSE12_02]

(2 marks)

(c) Do you agree with the following statement? Explain your answer.
'H–F bond is more polar than H–I bond, therefore HF(aq) is a stronger acid than HI(aq).'

(2 marks)

AL04(II)_01 (modified)

A gaseous compound A has the following composition by mass:

N 21.6%, O 49.2% and F 29.2%

(a) Deduce the empirical formula of A.

(2 marks)

(b) If the molecular mass of A is in the range of 60 to 70 and hence deduce its molecular formula.

(2 marks)

(c) Draw all possible three-dimensional structures of A.

(3 marks)

AL05(I)_02

Nitrogen monoxide reacts with fluorine to form nitrosyl fluoride, FNO, according to the following equation:

$$2NO(g) + F_2(g) \longrightarrow 2FNO(g)$$

Draw the electronic structure of nitrosyl fluoride.

(1 mark)

ASL05(I)_02

(a) (i) Draw a three-dimensional structure for each of the following species:

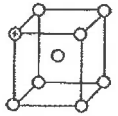
PH_3 and NH_4^+

(2 marks)

(ii) Which species in (i) has a larger bond angle? Explain.

(1 mark)

(b) The diagram below shows part of the lattice of caesium chloride with one caesium ion labelled with a positive (+) sign.



(i) In this diagram, mark all caesium ions with a positive (+) sign and all chloride ions with a negative (–) sign.

(1 mark)

(ii) What is the number of nearest chloride surrounding each caesium ion in caesium chloride crystal?

(1 mark)

(iii) Explain why caesium chloride is an insulator of electricity in the solid state, but it conducts electricity in the molten state.

(2 marks)

ASL05(I)_05

In a highly pressurized steam boiler, the oxygen dissolved in water can cause corrosion to the metallic parts of the boiler. The dissolved oxygen can be removed by adding hydrazine (N_2H_4) into the boiler.

(a) Draw the electronic diagram of a hydrazine molecule, showing electrons in the outermost shells only.

(1 mark)

(b) The reaction of hydrazine with oxygen gives nitrogen and water. Write the chemical equation for this reaction. Hence, suggest one advantage of using hydrazine as an anticorrosive agent in steam boilers.

(2 marks)

(c) A steam boiler contains 3.2×10^4 dm^3 of water. The dissolved oxygen in the water is 6.4 mg dm^{-3}. Calculate the mass of hydrazine required to remove all the oxygen present in the water.

(2 marks)

AL05(II)_02 (modified) [Similar to DSE13_02, DSE19_06]

Account for the following: "Sulphur dioxide possesses a overall molecular polarity while carbon dioxide does not."

(3 marks)

AL05(II)_03 [OUT]

Fullerences refer to the class of near spherical allotropes of carbon including C_{60}, C_{70} and C_{84}. They are made by electric arc discharge of graphite rods in an inert atmosphere. A sample is known to contain the above-mentioned fullerenes. Suggest an instrumental method to show the presence of these fullerenes in the sample and state the expected results.

(2 marks)

ASL05(II)_09

Arrange the following compounds **B**, **C** and **D** in order of increasing boiling point, and explain your answer.

$CH_3(CH_2)_3CH_3$	$CH_3(CH_2)_3OH$	$CH_3CH_2COCH_3$
B	**C**	**D**

AL06(I)_02a

Both diamond and graphite are allotropes of carbon.

(i) Give the meaning of the term 'allotrope'.

(1 mark)

(ii) Draw a diagram to show the three-dimensional arrangement of carbon atoms in graphite, and indicate the interactions between the carbon atoms.

(2 marks)

(iii) Given:

$$C(\text{diamond}) \longrightarrow C(\text{graphite}) \qquad \Delta H^\circ = -2\ kJ\ mol^{-1}$$

Explain why the conversion of diamond into graphite will not occur spontaneously under normal conditions.

(1 mark)

(iv) Name two allotropes of another element in Period 2, and draw the structures of these allotropes.

(2 marks)

AL06(II)_02

(a) Explain why ice is less dense than water. [Same as DSE13_02]

(3 marks)

(b) Explain why it is possible to skate smoothly on ice at temperature below 0 °C.

(2 marks)

AL06(II)_02

Ammonia and hydrogen azide (HN_3) are hydrides of nitrogen. Draw a possible electronic structure of hydrogen azide.

(1 mark)

AL07_Sample Paper [OUT]

A sample of soot obtained from an experiment was known to contain fullerenes. When the sample was treated with benzene, a red solution and a black residue were obtained. This solution, upon evaporation, left behind red crystals – a mixture containing mainly C_{60} and C_{70}.

(a) Suggest why C_{60} and C_{70} are soluble in benzene, while the residue is not.

(2 marks)

(b) Suggest a method to isolate C_{60} and C_{70} from the red crystals.

(2 marks)

(c) Both C_{60} and graphite are allotropes of carbon. With reference to their structures, compare the electrical conducting properties of C_{60} and graphite in solid state.

(2 marks)

ASL07(I)_01

Tetraethyl lead, $Pb(C_2H_5)_4$, was once widely used as an anti-knock agent in petrol. This anti-knocking function of $Pb(C_2H_5)_4$ is now commonly performed by methyl *t*-butyl ether (MTBE) instead.

(a) Draw the three-dimensional structure of $Pb(C_2H_5)_4$. (You are required to show only the stereochemistry of the central atom.)

(1 mark)

(b) Write the chemical equation for the complete combustion of $Pb(C_2H_5)_4$.

(1 mark)

(c) Based on environmental consideration, suggest *two* reasons why MTBE instead of $Pb(C_2H_5)_4$ is now used in petrol.

(2 marks)

AL07(I)_02

Write the Lewis structure of SO_4^{2-} and $S_2O_3^{2-}$ ions, and give the oxidation state of all sulphur atoms in each of these ions.

(4 marks)

AL08(I)_01

(a) Draw a 'dot-and-cross' diagram to show the arrangement of the outermost electrons in the species $NH_2^-(g)$, and predict the shape of this species

(2 marks)

(b) Arrange the H–N–H for the three species: $NH_2^-(g)$, $NH_3(g)$ and $NH_4^+(g)$. Explain your ordering.

(2 marks)

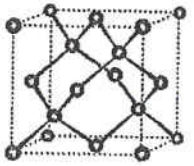
AL08(II)_01

Both sodium and chlorine are elements in Period 3 of the Periodic Table. At room temperature and atmospheric pressure, Na_2O is a solid with a very high melting point whereas Cl_2O is a gas. Account for this difference in property between Na_2O and Cl_2O.

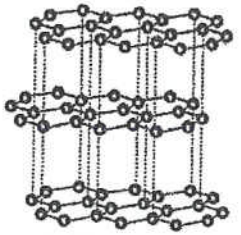
(2 marks)

AL08(II)_04

Both diamond and graphite are allotropes of carbon. A unit cell of diamond and a part of the structure of graphite are shown below:



a unit cell of diamond

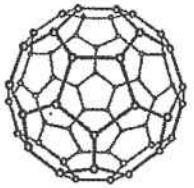


a part of the structure of graphite

(a) Diamond and graphite show a marked difference in electrical conductivity. Account for their difference in electrical conductivity in terms of bonding and structure. [Similar to DSE14_01]

(3 marks)

(b) Buckminsterfullerence (C_{60}) is another allotrope of carbon. [OUT]



structure of buckminsterfullerene

Suggest and explain how you would differentiate two samples of black powder, one of buckminsterfullerene and the other of graphite by

(i) a physical method, and

(2 marks)

(ii) a spectroscopic method.

(2 marks)

ASL09(I)_01 [Same as DSE13_02]

(a) Draw the respective electronic structure of BF_3 and NH_3. Hence, deduce the shape of each species.

(3 marks)

(b) Draw the three-dimensional structure of the product formed from the reaction of BF_3 with NH_3.

(1 mark)

AL09(I)_02

The compound $(CN)_2$ resembles the halogen in many ways and is often described as a "pseudohalogen"

(a) Draw the Lewis structure of $(CN)_2$.

(1 mark)

(b) Deduce the physical state of $(CN)_2$ at room temperature.

(1 mark)

ASL09(II)_04

The table below lists the melting points and boiling point of *cis*-1,2-dichloroethene and *trans*-1,2-dichloroethene.

Compound	Melting point / °C	Boiling point / °C
cis-1,2-dichloroethene	−80	60
trans-1,2-dichloroethene	−50	48

Explain why

(a) *cis*-1,2-dichloroethene has a higher boiling point, and

(2 marks)

(b) *trans*-1,2-dichloroethene has a higher melting point.

(2 marks)

ASL10(I)_04 (Modifieid)

Both nitrogen and phosphorus are Group V elements. Phosphorus forms two chlorides, PCl_3 and PCl_5, but nitrogen forms only one chloride, NCl_3.

(a) Suggest why NCl_5 does not exist.

(2 marks)

(b) Draw the three-dimensional structure of each of the following molecules: PCl_3 and PCl_5.

(2 marks)

(c) Suggest why phosphorus forms PI_3 but not PI_5.

(2 marks)

AL11(I)_01

(b) (i) For each of the following molecules, draw its three-dimensional structure:

OF_2 and SF_6

(2 marks)

(ii) Suggest why SF_6 exists while OF_6 does not.

(2 marks)

AL11(I)_03 [Similar to DSE14_02]

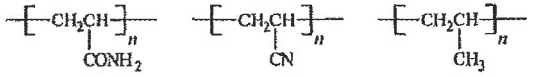
(b) Account for each of the following:

Ethanol is miscible with water, but ethoxyethane is not.

(2 marks)

ASL11(II)_08

Polyacrylamide, polyacrylonitrile and polypropene are three polymeric materials used as textile fabrics.



polyacrylamide polyacrylonitrile polypropene

Arrange these polymers in order of increasing tensile strength. Explain your arrangement.

(4 marks)

ASL12(I)_01

(a) Draw a Lewis structure for thiocyanate ion, SCN^-.

(1 mark)

ASL13(I)_01

Complete the table below for the three types of binary covalent compounds by giving ONE example and stating its molecular shape for each type.

Type	Example	Molecular shape
XY_2 (one lone pair on X)		
XY_2 (no lone pair on X)		
XY_3 (one lone pair on X)		

(3 marks)

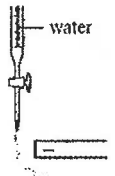
AL13(I)_01

(b) Arrange the hydrogen halide HF, HCl and HBr in increasing order of boiling point. Explain your arrangement.

(3 marks)

DSE11SP_06

A negatively charged rod was brought near a jet of water running out from a burette. The jet of water was deflected as shown:



(a) With reference to the structure of water, explain why the jet of water was deflected.

(2 marks)

(b) State the effect on the jet of water if the negatively charged rod is replaced by a positively charged rod. Explain your answer.

(2 marks)

(c) If hexane is used instead of water and a negatively charged rod is brought near the liquid jet, would the liquid jet be deflected? Explain your answer.

(2 marks)

DSE12PP_03

(b) Consider the nitrogen compound NCl_3.

(i) Draw the electron diagram of NCl_3, showing electrons in the outermost shells only.

(1 mark)

(ii) The shape of NCl_3 is similar to that of NH_3. Explain why this is so.

(2 marks)

DSE12PP_06

The table below lists some information about six hydroxy compounds, A, B, C, D, E and F.

Compound	Structural formula	Boiling point at 1 atm / °C	Density at 20 °C / g cm^{-3}
A	CH_3OH	65	0.7914
B	CH_3CH_2OH	78	0.7893
C	$CH_3CH_2CH_2OH$	97	0.8035
D	$CH_3CH(OH)CH_3$	82	0.7855
E	$HOCH_2CH_2CH_2OH$	213	1.0597
F	$HOCH_2CH(OH)CH_2OH$	290	1.2613

(a) Give the systematic name of **E**.

(1 mark)

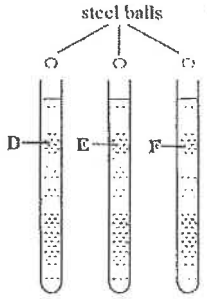
(b) Account for the variation in boiling points of **A**, **B** and **C**.

(2 marks)

(c) Explain why the density of **C** is greater than that of **D**.

(2 marks)

(d) Three identical steel balls are added separately to three identical vertical glass tubes each containing the same volume of **D**, **E** and **F** as shown in the diagram on the right.



In which tube will the steel ball take the longest time to reach the bottom? Explain your answer. (You are required to consider the intermolecular attraction forces involved.)

(3 marks + 1 mark)

DSE12_04 [Similar to ASL04(I)_03b]

With the aid of a diagram, explain the formation of hydrogen bonding in hydrogen fluoride.

(3 marks)

DSE13_01 [Same as AL06(II)_02]

Water is the most abundant compound on the Earth's surface. It is very important to life on Earth.

(c) Explain, for molecular level, why the density of ice is lower than that of water.

(3 marks)

DSE13_02 [Similar to AL05(II)_02, ASL09(I)_01, DSE19_06]

Both BF_3 and NH_3 exist as simple molecules.

(a) For each of these molecules, draw its three-dimensional structure.

(2 marks)

(b) For each of these molecules, explain whether or not it is polar.

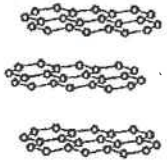
(2 marks)

(c) BF_3 reacts with NH_3 to give F_3BNH_3. Describe the bond formation between BF_3 and NH_3.

(2 marks)

DSE14_01 [Similar to AL08(II)_04(a)]

Graphite is a form of carbon and has a layer structure. Graphene is an individual single layer of graphite. Their structures are shown below:



graphite

graphene

(a) Thin sheets of graphene can be easily peeled off from graphite using adhesive tape.

(i) Explain why graphene can be easily peeled off.

(1 mark)

(ii) Explain whether graphene can conduct electricity.

(1 mark)

(iii) Draw the electron diagram for a molecule of the compound formed by complete combustion of graphene, showing *electrons in the outermost shells* only.

(1 mark)

(b) Based on the fact that graphene can be easily peeled off from graphite, a student concluded that graphite should have a low melting point due to its layer structure. Explain whether you agree with this conclusion.

(2 marks)

(c) Fullerene (such as C_{60}) is another form of carbon. Briefly describe the structure of C_{60}, and suggest why it is soluble in some organic solvents. [OUT]

(3 marks)

DSE14_02 [Similar to ASL11(I)_03b]

Draw the structure of ethane-1,2-diol, and suggest whether it is soluble in water.

(3 marks)

DSE16_04

Consider the molecules CO_2, CS_2 and CH_2Br_2.

(a) For each of the following molecules, draw its three-dimensional structure.

(i) CS_2

(1 mark)

(ii) CH_2Br_2

(1 mark)

(b) Identify, with explanation, the polar bond(s) in CH_2Br_2.

(2 marks)

(c) Suggest why, under room temperature and pressure, CO_2 is a gas but CS_2 is a liquid.

(2 marks)

DSE17_05

Explain the following increasing order of the boiling point of these substances:

$$H_2 < F_2 < HF$$

(3 marks)

DSE18_03 [Similar to AL13(I)_01]

(a) Explain whether $BaCl_2$ or OCl_2 would have a higher melting point.

(2 marks)

(b) Explain the following decreasing order of the boiling points of three substances:

$$NH_3 > PH_3 > CH_4$$

(3 marks)

(c) Draw a three-dimensional diagram to represent the molecular shape of SF_6.

(1 mark)

DSE19_06 [Similar to AL05(II)_02, DSE13_02]

Consider CH_2Cl_2 and CCl_4 molecules :

(a) Draw the three-dimensional structure of a CH_2Cl_2 molecule.

(1 mark)

(b) (i) Explain why CH_2Cl_2 is a polar molecule but CCl_4 is not.

(1 mark)

(ii) Explain why CCl_4 has a higher boiling point than CH_2Cl_2.

(2 marks)

3. (a) Draw a three-dimensional diagram to represent the shape of each of the following molecules :

(i) NH_3

(ii) BH_3

3. (b) (ii) Explain why H_3NBH_3 is a solid but ethane is a gas at room conditions.

2022

9. Consider the following three compounds :

X : $CH_3CH_2CH_2CH_2OH$ **Y** : $HOCH_2CH_2OH$ **Z** : CH_3COOCH_3

Which of the following shows the decreasing order of their solubilities in water ?

A. **X > Y > Z**
B. **Z > Y > X**
C. **Y > Z > X**
D. **Y > X > Z**

4 (c) (i) Draw the three-dimensional structure of a SF_6 molecule.

(c) (ii) Explain whether SF_6 is a polar molecule.

(2 marks)

(d) Explain the following increasing order of the boiling points of the three compounds :

$BF_3 < SF_6 < H_2O$

2022

Section A Industrial Chemistry

Answer **ALL** parts of the question.

1. (a) Answer the following short questions :

(i) Under certain conditions, ethanoic acid can be manufactured by the following reaction :

$$CH_3OH(l) + CO(g) \xrightarrow{Rh,\ HI} CH_3COOH(l)$$

(1) Suggest one reason why this reaction is considered to be green.

(2) Suggest one reason why this reaction is NOT considered to be green.

(2 marks)

Marking Scheme

MCQ

CE11_05	C (75%)	AL06(I)_03	B	ASL08(I)_05	A	ASL12(I)_03	C
DSE12PP_02	D	DSE12PP_16	A	DSE12PP_17	D	DSE12_05	C (82%)
DSE12_12	A (84%)	DSE13_23	B (61%)	DSE13_24	C (54%)	DSE14_22	B (62%)
DSE14_23	B (74%)	DSE14_24	D (51%)	DSE15_11	B (77%)	DSE15_24	C (59%)
DSE16_16	A (68%)	DSE16_21	C (72%)	DSE17_12	B (69%)	DSE17_24	C (77%)
DSE18_16	A (65%)	DSE19_13	D				

DSE20_20 A
DSE20_22 A

Structural Questions

AL00(I)_01 (modified)

Electronic arrangement of P is 2, 8, 5, and its outermost electron can hold maximum 18 electrons. Therefore, P can extend the octet structure and form 5 covalent bonds. [1]

In N, its outermost electron shell can only accept 3 electrons to complete its octet. ∴ It can form only 3 covalent bonds [1]

AL00(I)_01

$H_2O > C_2H_5OH > C_2H_5OC_2H_5$

Intermolecular attraction in water and in alkanols is mainly Hydrogen bond. **In H_2O, there are two hydrogen bond per molecule.** [½]

In C_2H_5OH, there is only one hydrogen bond per molecule. [½]

$C_2H_5OC_2H_5$ does not form hydrogen bond. The intermolecular attraction is mainly van der Waals' forces (much weaker than hydrogen bond). [½]

∴ b.p. : $H_2O > C_2H_5OH > C_2H_5OC_2H_5$

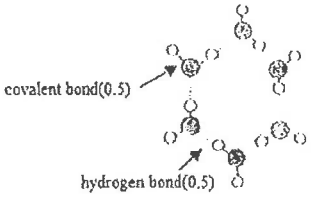
$H_2S < C_2H_5SH < C_2H_5SC_2H_5$

Intermolecular attraction **is van der Waals' forces.** [½]

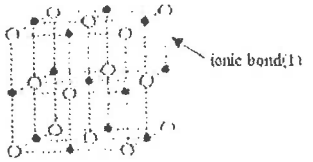
Strength of van der Waals' forces increases with no. of electron in a molecule / relative molecular size. [1]

∴ b.p. : $H_2S < C_2H_5SH < C_2H_5SC_2H_5$

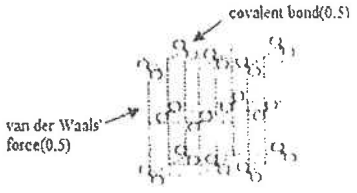
AL00(I)_01



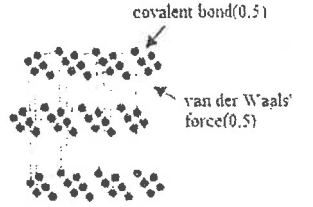
Ice



Sodium chloride [2] [1]

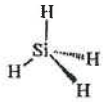


Iodine



Graphite [2] [1]

ASL00(II)_09

(a)  [1]

(b) The difference in electronegativties between Si and H = 2.1 – 1.8 = 0.3 [½]
Although each Si–H bond is polar, **four Si–H bonds are arranged tetrahedrally,** [1]
and all bond dipole moments of Si–H bond are cancelled out. Hence, SiH_4 is non-polar. [½]

(c) SiH_4 has a simple molecular structure and they are held by weak van der Waals' force, [1]
while Si has a giant covalent structure, and all Si atoms are bonded by strong covalent [1]
bond. Large amount of energy is needed to break Si–Si bond.

(d) (i) An atom of the same element with same number of proton, but different [1]
number of neutron.

(ii) **They have similar boiling point and chemical properties as SiH_4 and SiD_4** [1]
have the same type and strength of intermolecular force, and same bonding [½]
environment. [½]

AL01(I)_01

In ice and liquid water, the intermolecular attraction is **hydrogen bond.** [½]
Each H_2O molecule can form **a maximum of four hydrogen bonds with its neighbour / bond tetrahedrally with four H_2O molecules.** In ice, the molecules do not have translational motion. ∴ Ice as an **open structure.** [½]
In liquid water, translational motion of H_2O molecules brings the molecules close together. ∴ $H_2O(l)$ has a higher density. [½]

ASL01(I)_01

(a) The structure of water is non-liner. [1]
The dipole moments on the two O–H bonds cannot cancel each other / water has a net dipole moment. Hence water is a polar molecule and it would be attracted by the electric field. [1]

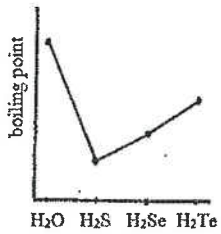
(b) The water jet will be attracted towards the rod. [1]
Water molecules will orientate themselves in alignment with the electric field so that they will be attracted. [1]

(c) The jet is not attracted. Only a weak dipole moment is induced in hexane molecules. [2]
The attraction between the induced diploe and the electric field is not strong enough to cause a deflection of the liquid jet.
OR, The liquid jet is attracted by the electric field. In the presence of an electric field, a diploe moment will be induced in the hexane molecule.

AL02(I)_03

CO_2 exists as simple molecules and the intermolecular attraction is van der Waals' forces. [1]
SiO_2 has a giant covalent network structure. Attraction between CO_2 molecules is weak, but attraction between Si and O atoms in $SiO_2(s)$ is strong. [1]

ASL02(I)_04



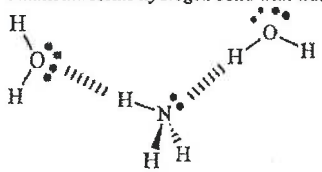
[1]

H_2O is a simple molecule and they are held by **strong hydrogen bond,** while other are only held by weak van der Waals' force. More energy is needed to break down strong hydrogen bond. Hence, the boiling point of H_2O are much higher than that of the rest. [1]
Other Group VI hydrides are simple molecule and they are held by **weak van der Waals'** forces. While the **strength of van der Waals' force increases with the molecular size.** Since the size of GroupVI hydrides increases down the group, hence the boiling point of hydrides also increases down the group. [1]

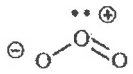
AL02(II)_01

(a) Both NH_3 and PH_3 have a pyramidal shape [1]

Electronegativity difference between N and H is greater than that between P and H. [½]
N–H bonds in NH_3 are more polar than P–H (almost non-polar) in PH_3.
Stronger repulsion between bond pairs in NH_3 than in PH_3 cause the bond angles in NH_3 to have a large value. [½]

(b) Ammonia forms hydrogen bond with water. [1]

P–H bonds in PH_3 are non-polar and lone pair on P is not readily donated. ∴ PH_3 is only sparingly soluble. [1]

AL03(I)_01

(a)  [1]

(b) O_2 is non-polar; O_3 has a v-shaped. [1]
The vector sum of the dipole moments of the O–O bonds in O_3 is non-zero.
∴ O_3 molecules has a net dipole moment / polar. H_2O molecule has a net dipole moment / polar. [½]
The electrostatic attraction between O_3 and H_2O is stronger than that between O_2 and H_2O (like dissolves like). [½]

ASL03(I)_02

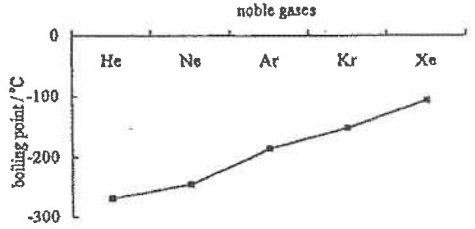
Boiling point increases in the order:
$CH_3(CH_2)_2CH_3$ < $CH_3(CH_2)_3CH_3$ < $CH_3(CH_2)_3Cl$ < $CH_3(CH_2)_3OH$ [1]
Both $CH_3(CH_2)_2CH_3$ and $CH_3(CH_2)_3CH_3$ are non-polar. Their intermolecular attraction is weak van der Waals' force. [1]
The strength of van der Waals' foces increases with their molecular size. [1]
∴ The boiling point of $CH_3(CH_2)_3CH_3$ is higher than the boiling point of $CH_3(CH_2)_2CH_3$.
$CH_3(CH_2)_3Cl$ has a net dipole moment. Its intermolecular attraction is stronger than that in alkanes but weaker than the intermolecular between the alcohol molecules. [1]
Stronger hydrogen-bond exist between the alcohol molecules. ∴ $CH_3(CH_2)_3OH$ has the highest boiling point. [1]

AL03(II)_03

(a) Octet rule – all atoms tend to attain the stable electronic configuration of a noble gas (in most case an "octet") by sharing or transfer of electrons. [1]

(b) Limitations of octet rule (any TWO of the following): [2]
1. some compound exists as radical (species with odd no. of electron) e.g. NO_2
2. some molecules contain atoms with electron no. greater than 8, e.g. PCl_5, SF_6
3. some molecules contain atoms with electron no. less than 8. e.g. BCl_3
4. elements for from the ends of a period fail to form ions with an octet structure, e.g. Fe forms Fe^{2+} and Fe^{3+}, Cu forms Cu^{2+}
5. not applicable for atoms which form a doublet structure e.g. H, Li, etc.

AL04(I)_02



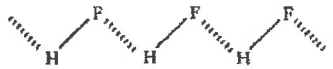
[1]

The intermolecular attraction between noble gas molecules is dispersion force / van der Waals' forces. [½] The strength of van der Waals' forces increases with the number of electrons / atomic size of the noble gas. [½] ∴ The boiling point of noble gas increases as the group is descended.

ASL04(I)_03

(a) The intermolecular attraction in HCl, HBr and HI is predominantly van der Waals' forces. [1] The strength of van der Waals' forces increases with increase in number of electrons (or molecular size). [1] ∴ boiling poing: HCl < HBr < HI

(b) F is highly electronegative and has a very small size. The H–F bond is strongly polarized. Hydrogen bonds are formed between H–F molecules. [1]



Extra energy is required to overcome the hydrogen bonds when HF(l) boils. [1]
∴ The boiling point of HF is exceptionally high as compared with the other hydrogen halides.

(c) No.
The strength of an acid H–X depends on the extent of the equilibrium [1]
$H–X(aq) \rightleftharpoons H^+(aq) + X^-(aq)$
rather thant he polarity of H–X bond.
In HF(aq), $H^+(aq)$ and $F^-(aq)$ form tight ion-pairs. Thus the concentration of $H^+(aq)$ [1] is lower than expected.

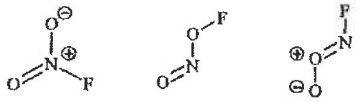
AL04(II)_01 (modifield)

(a) Mole ratio of N : O : F = $\frac{21.6}{14} : \frac{49.2}{16} : \frac{29.2}{19}$ [½]
= 1.543 : 3.075 : 1.537 = 1 : 2 : 1 [½]
∴ empirical formula: NO_2F [1]

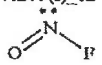
(b) Molecular formula of A : $(NO_2F)_n$
$60 < (14.0 + 16.0 \times 2 + 19.0)n < 70$ [1]
$0.923 < n < 1.077$, $n = 1$ (n must be an integer)

Molecular formula: NO_2F [1]

(c) [3]



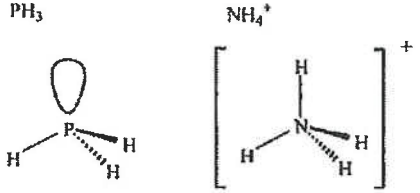
AL05(I)_02



[1]

ASL05(I)_02

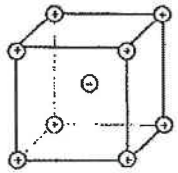
(a) (i) [2]



(ii) NH_4^+

In NH_4^+ all four electron pairs are bond pairs, but in PH_3 there are one lone pair and three bond pairs. The repulsion between lone pair and bond pair is stronger than that between bond pair and bond pair. ∴ The bond angles in PH_3 are squeezed to a value less than 109°28'. [1]

(b) (i)



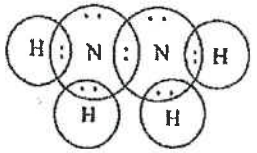
[1]

(ii) 8 [1]

(iii) In solid state, the ions have no translational motion. ∴ CsCl(s) is an electrical insulator. In molten state, the cations and anions can move under the influence of an electric field. [1]

ASL05(I)_05

(a)



[1]

(b) $N_2H_4 + O_2 \longrightarrow N_2 + 2H_2O$ [1]

The products H_2O and N_2 are non-corrosive. [1]

OR, $N_2(g)$ formed will be released ∴ No other materials will be introduced into the water.

(c)

$$\text{Moles of } N_2H_4 = \text{moles of } O_2 \text{ present} = \frac{3.2 \times 10^4 \times 6.4 \times 10^{-3}}{16 \times 2} \quad [1]$$

$$\text{Mass of hydrazine required} = \frac{3.2 \times 10^4 \times 6.4 \times 10^{-3}}{16 \times 2} \times 32 = 204.8\ \text{g} \quad [1]$$

AL05(II)_02 (modified)

SO_2 is of V-shape  [1]

CO_2 is liner, O=C=O [1]

In SO_2, the vector sum of two S=O bond polarity is non-zero. In CO_2, the vector sum of the two C=O bond bond polarity is zero. [1]

AL05(II)_03

Mass spectrometry [1]

Peaks of m/z ratios 720, 840 and 1008 can be found in the mass spectrum [1]

ASL05(II)_09

Boiling point: B < D < C [1]

The boiling point of a compound depends on its intermolecular attraction.

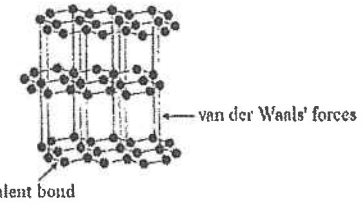
The intermolecular attraction of B is van der Waals' forces. This attraction force is weakest among the three. [1]

The attraction between molecules of C is hydrogen bond which is the strongest among the three. ∴C has the highest boiling point. [1]

AL06(I)_02a

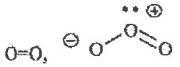
(i) Allotrope: one of the several possible forms of an element, which are significantly different in physical or chemical properties / which have different structures. [1]

(ii) Diagram + labels of interatomic attractions: 2 marks [2]



(iii) The conversion of diamond to graphite has very high activation energy. The reaction is very slow under normal conditions. [1]

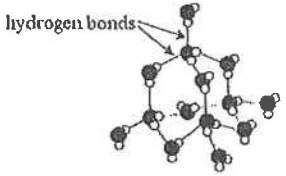
(iv) Oxygen and ozone [1]



[1]

AL06(II)_02

(a) The intermolecular attraction in both ice and liquid water is hydrogen-bond [1]
The directional character of hydrogen bond makes the water molecules in ice to arrange tetrahedrally to form an open structure. [½] [½]

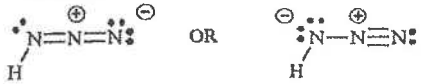


When ice melts, the open structure collapses. Molecules can be packed more closely together in liquid water than in ice. ∴ Ice has a smaller density than water. [1]

(b) $H_2O(s)$ ⟷ $H_2O(l)$
Lower density Higher density

The blade of the skate exerts a high pressure on ice. The position of the above equilibrium shifts to the right, ice melts. [1]
The water formed can help reduce the friction between blade of the skate and ice. [1]

AL06(II)_02



[1]

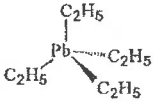
AL07_Sample Paper [OUT]

(a) **The residue consists of inorganic components like graphite that is insoluble in benzene, whereas C_{60} and C_{70} are nonpolar molecules held by dispersion forces (van der Waals' force) and thus are soluble in nonpolar benzene.** [1] [1]

(b) **Heat the red crystals in vacuum or in an atmosphere of noble gas.** [1]
C_{60} and C_{70} will sublime out at a temperature of 400 –500 °C, depositing to form a brown or grayish layer of powdery molecular crystals. [½] [½]

(c) Like graphite, fullerenes can conduct electricity. [1]
due to the presence of delocalized electrons. [1]

ASL07(I)_01

(a)

[1]

(b) Any ONE of the following: [1]
$2Pb(C_2H_5)_4 + 27O_2 \longrightarrow 2PbO + 16CO_2 + 20H_2O$
$3Pb(C_2H_5)_4 + 41O_2 \longrightarrow Pb_3O_4 + 24CO_2 + 30H_2O$
$Pb(C_2H_5)_4 + 14O_2 \longrightarrow PbO_2 + 8CO_2 + 10H_2O$

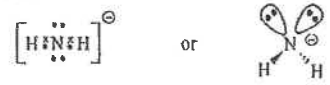
(c) Any TWO of the following: [2]
Combustion of tetraethyl lead(TEL) gives lead compounds which are highly toxic.
Leaded petrol cannot be used in cars equipped with catalytic converter.
MTBE is an oxygen-containing compound. It can enhance the complete combustion of petrol.

AL07(I)_02


[2]

SO_4^{2-}: O.S. of S = +6 [1]
$S_2O_3^{2-}$: O.S. of central S atom = +4; [½]
O.S. of the other S atom = 0 [¼]

AL08(I)_01

(a)


[1]

v-shaped [1]

(b) Bond angle: $NH_4^+(g) > NH_3(g) > NH_2^-(g)$ [1]
In the outermost electron shell of the N atom in the three species, the numbers of lone-pairs and bond-pairs are as follow:

Species	No. of bond-pairs	No. of lone-pairs

$NH_4^+(g)$	4	0
$NH_3(g)$	3	1
$NH_2^-(g)$	2	2

[½]

In each of the three species, the electron pairs in the outermost shell of N are arranged tetrahedrally.

The repulsion between the electron pairs is in the order:

Lone pair-lone pair repulsion > Lone pair-bond pair repulsion > bond pair - bond pair repulsion [½]

Bond angles in the species are: NH_4^+ 109.5 °, NH_3 107.5°, NH_2^- 104.5°

AL08(II)_01

Na_2O is an ionic solid in giant ionic structure. The strong attraction between the cations and anions makes it a high melting point solid. [1]

Cl_2O exists as simple molecules. The intermolecular attraction is weak van der Waals' force. It is much weaker than ionic bond in Na_2O. [1]

AL08(II)_04

(a) Diamond is covalent crystal. Each carbon form four (single) bonds and the electrons are localized / no delocalized electrons. [½] [½]

∴ Diamond is a poor conductor / insulator of electricity.

In graphite, each carbon atom is covalently bonded to only three other carbon atoms in its layer, one outer electron of each carbon is free / delocalized. These [½] [½]

"free" electrons are delocalized and moved in the direction of an electric field / within the layers. ∴ Graphite is an electrical conductor. [1]

(b) (i) Adding an organic solvent (e.g. benzene), C_{60} is soluble but graphite powder is not. [1]

Explanation: C_{60} exists as simple molecules and is non-polar. It is soluble in non-polar solvents. Graphite is a covalent crystal. It is not soluble in most solvents. [1]

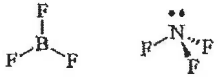
OR Packing of powder to form a solid mass. Graphite conducts electricity but the other does not.

OR Check m.p. / b.p. C_{60} sublimes but the other does not.

(ii) Mass spectrometry: C_{60} gives a peak of m/z = 720 for the molecular ion. [1]

Explanation: C_{60} exists as simple molecules and its relative molecular mass is 720. [1]

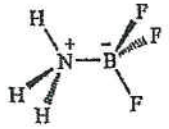
ASL09(I)_01

(a)  [½]

 [½]

For BF_3, there are 3 bond-pair (no lone-pair) in the outermost shell of B. To minimize electronic repulsion, the 3 bond-pairs in BF_3 will be arranged in a trigonal planar shape. [1]

For NF_3, there are 3 bond-pairs and 1 lone-pair in the outermost shell in N. The electron pairs in NF_3 will also be arranged tetrahedrally. The molecule is trigonal pyramidal in shape. The bond angle < 109° as repulsion between lone-pair and bond-pair is stronger than that between bond-pair and bond-pair. [1]

(b)  [1]

AL09 (I)_02

(a) ⋮N≡C—C≡N⋮ [1]

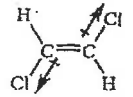
(b) $(CN)_2$ exists as simple molecules. Its relative molecular mass is smaller than that of Cl_2. [½]

$(CN)_2$ is a gas. [½]

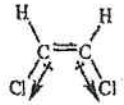
ASL09(II)_04

(a) The boiling point of a compound depends on its intermolecular attraction. [1]

For *trans*-isomer, the dipole moments of the C–Cl bonds cancel each other, thus resulting in weak intermolecular attraction. [½]



For *cis*-isomer, the vector sum of the two dipole moments gives rise to a net dipole moment. The intermolecular attraction is stronger.

 [½]

(b) In addition to intermolecular attraction, the melting point of a compound depends also on the degree of compactness of molecules in the solid state. [1]

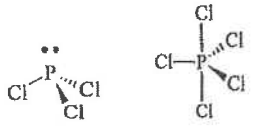
The *cis*-isomer has a lower symmetry. It fits into a crystalline lattice relatively poorly and therefore has a lower melting point. [1]

ASL10(I)_04 (Modified)

(a) Electronic configuration of N: 2, 5 [1]

In N, its outermost electron shell can only accept 3 electrons to complete its octet. ∴ It can form only 3 covalent bonds. [1]

(b)



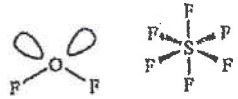
[2]

(c) The size of I is much smaller than that of Cl. [1]

The repulsion between P–I bonds is greater than that of P–Cl bonds, and destabilize the PI_3 structure. [1]

ASL11(I)_01

(b) (i)



[2]

(ii) S is a Period 3 element. It can expand its octet structure by using the 3rd electron shell. [1]

O is a Period 2 element. Its 2nd electron shell cannot expand its octet structure. [1]

ASL11(I)_03

(b) For water, the intermolecular attraction is hydrogen bond. [½]

Ethoxyethane molecules are weakly polar, and the intermolecular attraction is van der Waals' force. [½]

Ethanol has an –OH group which enables its molecules to form hydrogen bond with water. [1]

Ethanol molecule interact strongly with water molecules, but ethoxyethane molecules do not.

OR, The interaction between propane and water molecules is so weak that it cannot overcome the hydrogen bond between water molecules.

ASL11(II)_08

Tensile strength: polypropene < polyacrylonitrile < polyacrylamide

Explanation:

Polyacrylamide contains both C=O group and NH_2 group. The attraction between polymer chains in predominately hydrogen bond. [1]

Polyacrylonitrile contains polar C≡N group. The attraction between polymer chains is van der Waals' force which is weaker than hydrogen bond. [1]

Polypropene is non-polar and the attraction between polymer chains in PP is van der Waals' force which is the weakest. [1]

ASL12(I)_01

(a)

[1]

ASL13(I)_01

Type	Example	Molecular shape	
XY_2 (one lone par on X)	SO_2 / $SnCl_2$	V-shape / bent	[1]
XY_2 (no lone par on X)	CO_2 / $BeCl_2$	Linear	[1]
XY_3 (one lone par on X)	BF_3 / SO_3	Trigonal planar	[1]

AL13(I)_01

(a) Boiling point: HCl < HBr < HF [1]

All three hydrogen halides are polar molecules.

In HBr and HCl, the intermolecular attraction force is van der Waals' force, while van der Waals' force is stronger for molecules with more electrons / larger molecular size. [1]

∴ b.p. of HBr > b.p. of HCl

F has a very small size and is highly electronegative.

Hydrogen bonds are formed between HF molecules, and hydrogen bond is stronger than van der Waals' force. [1]

∴ HF as the highest b.p.

DSE11SP_06

(a) The structure of water is non-liner. [1]

The dipole moments on the two O–H bonds cannot cancel each other / water has a net dipole moment. Hence water is a polar molecule and it would be attracted by the electric field. [1]

(b) The water jet will be attracted towards the rod. [1]

Water molecules will orientate themselves in alignment with the electric field so that they will be attracted. [1]

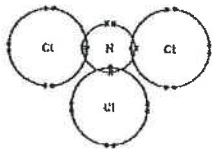
(c) The jet is not attracted. Only a weak dipole moment is induced in hexane molecules. [2]

The attraction between the induced diploe and the electric field is not strong enough to cause a deflection of the liquid jet.

OR, The liquid jet is attracted by the electric field. In the presence of an electric field, a diploe moment will be induced in the hexane molecule.

DSE12PP_03

(b) (i)



[1]

(ii) The nitrogen in NCl_3 and that in NH_3 both have the same number of electron bond-pairs and lone electron pairs / have three electron-pairs and one lone electron pair in their outermost shells. [1]

The repulsion between these electron pairs causes both NCl_3 and NH_3 to adopt a trigonal pyramidal shape. [1]

DSE12PP_06

(a) Propane-1,3-diol / 1,3-propanediol [1]

(b) All three compounds have a hydroxyl group / are monohydric alcohols. The boiling point of these compounds depends on the strength of van der Waals' forces between molecules. [1]

The strength of van der Waals' forces in alcohol increases with the carbon chain length / molecular size. Boiling point increases in the order: **A < B < C** [1]

(c) For isomeric compounds with the same functional group, the strength of intermolecular force is affected by the shape of the molecules. [1]

The structure of $CH_3CH_2CH_2OH$ allows the molecules to have a greater area of contact than those of $CH_3CH(OH)CH_3$. ∴ $CH_3CH_2CH_2OH$ has a greater density. [1]

OR, The structure of $CH_3CH(OH)CH_3$ makes the formation of Hydrogen bonds less effective. ∴ $CH_3CH(OH)CH_3$ has a smaller density.

(d) F [1]

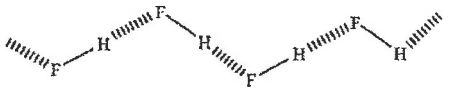
The rate at which the steel balls drop depends on the viscosity of the liquid / the resistance (frictional force) experienced by the ball. This is related to the intermolecular attraction of the liquids. [1]

In the three compounds, the intermolecular attraction is predominately hydrogen bonds. The no. of hydrogen bonds former per molecule is 1 in D 2 in E and 3 in F. F forms the greatest number of hydrogen bonds per molecule. ∴ F is the most viscos and the ball will drop most slowly. [1]

OR, F has the highest boiling point among the three compounds. Its intermolecular attraction is strongest. ∴ The ball will drop most slowly in F.

Effective communication (Award 1 mark if candidates can express their ideas clearly.) [1]

DSE12_04



✓ The drawing should show at least TWO HF molecules. [1]
✓ Should show complete HF molecules.
✓ Should indicate the hydrogen bonds by dashed lines.
✓ Each H atom can only form one hydrogen bond.
✓ F–H–F angle not necessary be drawn as 180° in the drawing.

Fluorine / F is a highly electronegative element. [1]

The H–F covalent bond is very /highly polar / The H–F molecule is highly polarized. [1]

DSE13_01

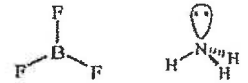
(c) The attraction between water molecules is predominately hydrogen bond. [1]

Hydrogen bond is directional. In ice, the H_2O molecules have a tetrahedral arrangement / are packed in an open structure. [1]

In liquid water, the H_2O molecules have relative motion and this leads to the collapse of the open structure. The molecules become more closely packed. ∴ liquid water has higher density than ice. [1]

DSE13_02

(a) BF_3 NH_3



[2]

(b) BF_3 is a non-polar molecule. The three polar B–F bonds are symmetrically arranged on the same plane / dipole moments cancel out / net dipole moment is 0. [1]

NH_3 is a polar molecule. The molecule has a lone pair in its outermost shell and thus the three polar N–H bonds are not on the same plane / diploe moments cannot cancel out / net dipole moment is not 0. [1]

(c) In BF_3, there are three (bond) electron pairs / there is a vacant site / 6 electrons only / electron deficient in the outermost shell of the B atom. [1]

By accepting the lone pair of electrons from the nitrogen atom of NH_3 / forming dative bond with N, boron attains the stable electronic configuration of neon (a noble gas). [1]

DSE14_01

(a) (i) Layers of graphite are held together by van der Waals' forces / weak intermolecular forces only. [1]

(ii) Yes, graphene has delocalized electrons / electrons in graphene are not localized / mobile electrons / electrons will flow. [1]

(iii)  (Accept any symbols of electrons, ignore shape) [1]

Not accepted: Showing electrons in the inner shells.

(b) No. Graphene layers are made up of a giant covalent structure. [1]

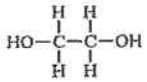
A large amount of energy is needed during melting to destroy the large amount of strong covalent bonds between atoms. [1]

(c) C_{60} has a spherical shape (ball) / and with strong covalent bonds between atoms. [1]

C_{60} has a simple molecular structure. [1]

The van der Waals' forces / attractive forces between C_{60} molecules are of comparable / similar strength as those in organic solvent. [1]

DSE14_02

  $HOCH_2CH_2OH$ [1]

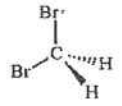
(Accept condensed or skeletal structural formula)

It has a smaller molecular size. / It is a small molecule. / It has a short carbon chain. [1]

The hydroxyl groups in it can form hydrogen bonds with water. [1]

DSE16_04

(a) (i)  [1]

(ii)  [1]

(b) C—H and C—Br bonds are polar. [1]

(Accept if only either one of C-H or C-Br bond is mentioned)

C and H / C and Br have different electronegativities. [1]

C is more electron-withdrawing than H / Br is more electron-withdrawing than C.

(Accept if only either C / H or C / Br is mentioned)

(c) The intermolecular forces between CS_2, CO_2 molecules are van der Waals' forces. [1]

As CS_2 has greater molecular size than CO_2, the van der Waals' forces between CS_2 molecules are stronger than those between CO_2 molecules. [1]

DSE17_05

Both molecules of H_2 and F_2 are held by weak van der Waals' forces. [1]

The van der Waals' forces between F_2 are stronger that those between H_2 because larger

size of F_2 than H_2. (Accept: F_2 molecule has more electrons than H_2 molecule; Not Accept: F_2 has a higher molecular mass than H_2) [1]

Hydrogen bond exists among HF molecules and hydrogen bond is stronger than van der Waals' forces.

DSE18_03

(a) The electrostatic attraction between Ba^{2+} and Cl^- in $BaCl_2$ is ionic bond, while intermolecular attraction between OCl_2 molecules are van der Waals' forces. [1]

OR, $BaCl_2$ is an ionic compound, while OCl_2 has a simple molecular structure. [1]

As ionic bond is much stronger than van der Waals' forces / intermolecular forces between OCl_2 molecules, $BaCl_2$ would have a higher melting point than OCl_2.

(b) Both molecules of PH_3 and CH_4 are held by van der Waals' forces / intermolecular forces. [1]

The van der Waals' forces between PH_3 are stronger than those between CH_4 because of the larger molecular size of PH_3 than CH_4. [1]

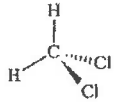
(Accept: PH_3 molecule has more electrons than CH_4)

OR, Intermolecular forces between PH_3 molecules are stronger than that between CH_4 molecules as PH_3 is polar while CH_4 is non-polar.

Hydrogen bond exists among NH_3 molecules that is stronger than van der Waals' forces. [1]

(c)  [1]

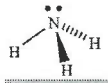
DSE19_06

(a)  [1]

(b) (i) The polarities of bonds in CCl_4 cancel out each other while those in CH_2Cl_2 do not. [1]

(Accept drawings with suitable annotations.)

(ii) CCl_4 has a larger molecular size than CH_2Cl_2, therefore it has larger van der Waals' forces between molecules / intermolecular forces, and hence it has a higher boiling point. [1]

3. (a) (i)  1

(Accept answer without showing the lone-pair electrons)

(ii)  1

(b) (i) • B–N is the dative covalent bond. 1

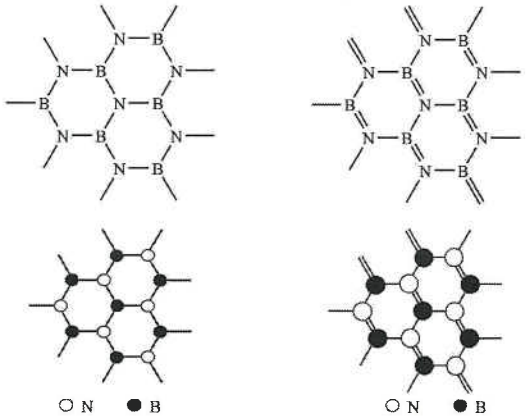
• The lone electron pair on nitrogen atom of NH_3 is donated to form a dative covalent bond with the boron atom of BH_3. 1

(ii) • Both are van der Waals' forces between their respective molecules. 1

• As H_3NBH_3 is polar but ethane is not, the van der Waals' forces between H_3NBH_3 molecules are stronger than those between ethane molecules. 1

(Only the 2nd mark will be given if the candidate answered in terms of "intermolecular forces" instead of van der Waals' forces)
(2nd mark not accept comparison of molecular size)

(iii) 2



(1 mark for showing the fused hexagonal structure, need to show at least 2 fused rings)
(1 mark for showing alternating N and B atoms)
(Ignore the double bonds in the structure)