CHEMICAL BONDING AND STRUCTURES MCQ PART 1

1 Which species contains a dative bond?

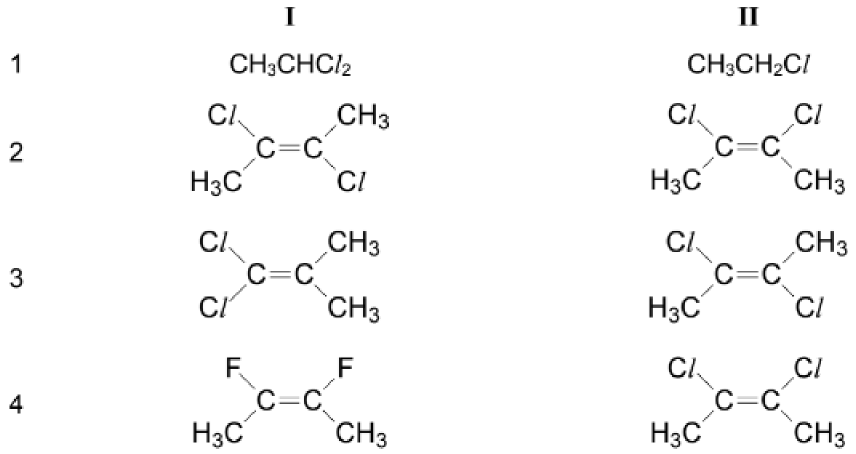
1 CO
2 NO_3^-
3 O_3

A 1, 2 and 3
B 1 and 2 only
C 1 and 3 only
D 2 only

2 Which row correctly describes the shape and polarity of the species?

	species	shape	polarity
A	$AlCl_3$	trigonal planar	polar
B	SiF_4	square planar	non-polar
C	BrF_3	trigonal pyramidal	polar
D	$BeCl_2$	linear	non-polar

3 Which pair of molecules have a greater permanent dipole in molecule **I** than in molecule **II**?



A 1 and 2 only
B 3 and 4 only
C 2, 3 and 4 only
D 1, 3 and 4 only

4 Four substances have the physical properties as shown.

Compound	**Melting point/°C**	**Electrical conductivity of solid**	**Electrical conductivity of molten substance**
E	-72	poor	poor
F	801	poor	good
G	842	good	good
H	1710	poor	poor

Which of the following shows the correct type of structures for each compound?

	E	F	G	H
A	simple molecular structure	giant ionic structure	giant metallic structure	giant molecular structure
B	giant molecular structure	giant metallic structure	giant ionic structure	giant molecular structure
C	giant molecular structure	simple molecular structure	giant metallic structure	giant ionic structure
D	simple molecular structure	giant ionic structure	giant molecular structure	giant metallic structure

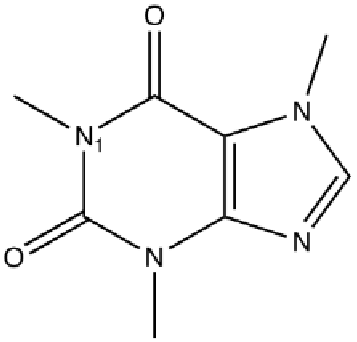
5 Which quantity would best indicate the relative strengths of the intermolecular forces of attraction between the molecules in liquid hydrogen halides?

A Bond dissociation energies
B Enthalpy changes of vapourisation
C Enthalpy changes of formation
D Enthalpy changes of atomisation

6 In which of the following sequences are the species quoted in order of decreasing boiling points?

A RbC*l*, KC*l*
B HF, HC*l*
C K, Ca
D CO, CO_2

7 People drink beverages containing caffeine to relieve or prevent drowsiness and to improve cognitive performance.



Caffeine

Which statement about caffeine is true?

A Caffeine molecule has a planar structure.
B The π bond in C=C is formed by sideways overlap of 2p orbitals.
C The nitrogen atom in caffeine, N_1 is basic.
D There are 16 sigma bonds in a caffeine molecule.

8 Which of the following substances conduct electricity due to delocalised electrons?

1 Graphite
2 Solid magnesium
3 Molten sodium chloride

A 1 only
B 1 and 2 only
C 2 and 3 only
D 1, 2 and 3

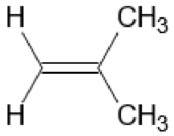
9 Which molecule does **not** have any 90° or 180° bond angles?

1 O_3
2 PF_5
3 $[PCl_4]^+$
4 SF_6

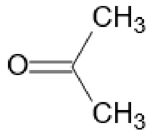
A 1 and 3 only
B 2 and 4 only
C 1, 2 and 4 only
D 3 only

10 Which molecule has the largest overall dipole moment?

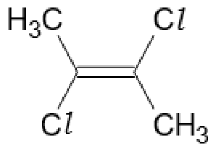
A



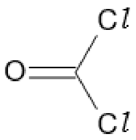
B



C



D



11 Bromine trifluoride is a liquid which undergoes auto-ionisation at room temperature as represented by the following equation:

$$2BrF_3 \rightarrow BrF_2^{+} + BrF_4^{-}$$

Which of the following is correct regarding BrF_3, BrF_2^{+} and BrF_4^{-}?

A BrF_3 is planar while BrF_4^{-} is non-planar.

B BrF_2^{+} is linear while BrF_4^{-} is tetrahedral in shape.

C The F–Br–F bond angle in BrF_3 is smaller than that in BrF_4^{-}

D There are more lone pairs of electrons around the Br atom in BrF_3 than that in BrF_2^{+}

12 Which observation **cannot** be explained by intermolecular hydrogen bonding?

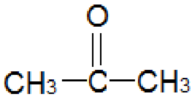
A Methanol dissolves readily in water.
B The boiling point of HBr is higher than that of HCl.
C The boiling point of 4-aminophenol is higher than that of 2-aminophenol.
D The relative molecular mass of ethanoic acid when dissolved in hexane is 120.

13 In which pairs of compounds does the first molecule have a smaller bond angle than that in the second molecule?

1	NF_3	CCl_4
2	H_2O	XeF_4
3	SF_6	CS_2

A 1, 2 and 3 **B** 1 and 2 only **C** 2 and 3 only **D** 1 and 3 only

14 Propanone and dichloromethane are common organic solvents used in the laboratory. Propanone is soluble in water but dichloromethane is not.



$CH_3-\overset{\overset{\displaystyle O}{\|}}{C}-CH_3$

propanone

CH_2Cl_2

dichloromethane

Which of the following statements best accounts for this?

A Propanone is a polar molecule but dichloromethane is non-polar.

B A hydrogen bond forms between the hydrogen in propanone and the oxygen of a water molecule.

C A hydrogen bond forms between the oxygen in propanone and the hydrogen of a water molecule.

D Propanone has a smaller relative molecular mass than dichloromethane.

15 Nitrogen oxides (NO_x) can be formed from the reaction of nitrogen with oxygen in car engines. It can dissolve in water to form nitric acid which causes acid rain. Which of the following statements are correct?

1 N atom in NO_3^- is sp^2 hybridised.
2 NO and NO_2 contain an unpaired electron.
3 NO and NO_2 have no net dipole moment.

A 1 only
B 1 and 2
C 2 and 3
D 1, 2 and 3

16 Which species has the most number of unpaired electrons?

A Co^{2+}
B N
C Fe
D S

17 Rubidium and bromine form ions that are isoelectronic.

1 Ionic radius of rubidium is smaller than its atomic radius.

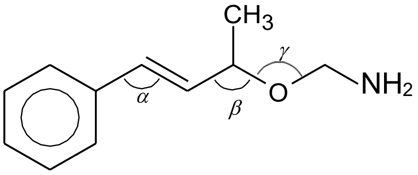
2 Ionic radius of bromine is larger than its atomic radius.

3 Ionic radius of bromine is smaller than that of rubidium.

Which statements are correct?

A 1, 2 and 3 **B** 1 and 2 only **C** 1 and 3 only **D** 2 and 3 only

18 Which row correctly shows the bond angles for α, β, γ in the molecule below?



	α	β	γ
A	109.5°	120°	109.5°
B	120°	109.5°	107°
C	120°	107°	105°
D	120°	109.5°	105°

19 In which pair is the melting point of the **second** species higher than that of the **first** species?

A C and Si

B K and Rb

C NaC*l* and NaBr

D SiC*l*$_4$ and SiO$_2$

20 When liquid N_2F_4 is heated, it decomposes into a single product, **B**.

Which statements are correct?

1 N–F bonds are broken during this decomposition.

2 The enthalpy change when N_2F_4 decomposes into **B** is approximately +160 kJ mol$^{-1.}$

3 Molecules of **B** are non-linear.

A 1, 2 and 3 **B** 1 and 2 only **C** 2 and 3 only **D** 1 only

21 In which row does G have a smaller overall dipole moment than H?

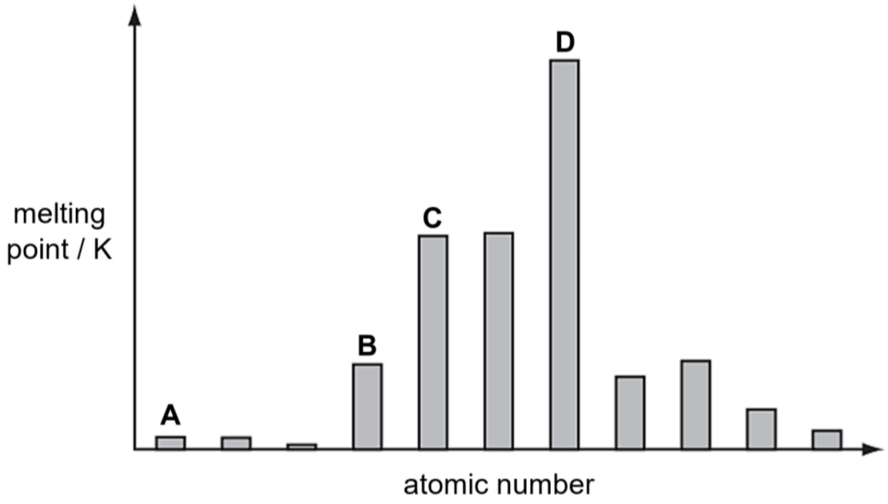
	G	H
A	COS	CS_2
B	PCl_3	PF_3
C	IF	BrC*l*
D	XeF_4	PCl_5

22 Which compound has the greatest covalent character?

A MgO
B MgS
C CaO
D CaS

23 The bar chart shows the melting points of a series of consecutive elements arranged in order of increasing atomic number. The elements sodium to chlorine form part of this series.

Which bar represents sodium?



24 Which statement about the element astatine is correct?

A Silver astatide is insoluble in aqueous ammonia.
B Astatine is a liquid at room temperature and pressure.
C The bond energy of hydrogen astatide is larger than that of hydrogen iodide.
D Astatine is not a product of the reaction between sodium astatide and bromine.

CHEMICAL BONDING AND STRUCTURES STRUCTURED QUESTIONS PART 1

1 The carbon family consists of the elements of Group 14. The elements at the top of the group, carbon to germanium, have very different properties from those at the bottom, tin and lead. For instance, Group 14 elements tend to adopt oxidation states of +4, whereas the heavier elements, such as tin and lead, exhibit the +2 oxidation state due to the inert pair effect.

(a) State the valence shell configuration of Group 14 elements.

.... [1]

(b) One of the contributing factors to the inert pair effect is the unexpected increase in the ionisation energies, after lead, down the group.

Explain why the 1st ionisation energies are expected to decrease down the group.

....

....

....

....

.... [2]

(c) Carbon forms carbide anion, C_2^{2-} in calcium carbide while silicon mostly forms Si^{4+} ions.

(i) Draw the dot-and-cross diagram of the carbide anion, C_2^{2-}.

[1]

(ii) In a particular experimental set-up, a beam of ${}^{28}Si^{4+}$ ions was deflected by an angle of +4.2°. Assuming an identical set of conditions, by what angle will the ${}^{12}C^{2-}$ ions to be depleted?

[1]

(d) Table 1.1 shows that the melting points of the elements of Group 14.

Table 1.1

element	C	Si	Ge	Sn	Pb
melting point / °C	>3550	1410	937	232	327

Carbon, silicon and germanium each form a solid with the same type of structure. Using bonding and structure, suggest why the melting points of these elements decrease from carbon to germanium.

....

....

....

....

.... [2]

(e) Carbon forms many allotropes such as graphite and diamond. Recent scientific research has found that replacing the graphite electrodes with graphene in lithium-ion batteries can extend battery life.

(i) Graphene is a **single, one atom thick** layer of graphite. Describe the hybridisation of the orbitals in, and the bonds between, the carbon atoms within graphene.

....

....

....

....

.... [2]

(ii) Using your answer from **(e)(i)**, explain why graphene can conduct electricity along the plane.

....

....

....

.... [1]

(iii) State and explain how you would expect the bond strength of carbon-carbon bonds in graphene to differ when compared with that in diamond.

....

....

....

....

.... [2]

(f) Diamond and graphite are allotropes of carbon. Fig. 1.1 gives the structure of diamond and graphite. Diamond is an important abrasive while graphite is used as a lubricant.

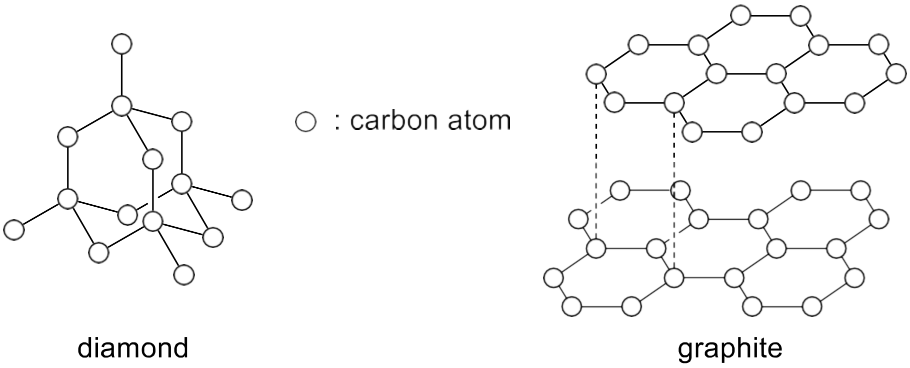


Fig. 1.1

(i) Explain why the sign of the entropy change for the conversion of diamond to graphite is positive.

....

....

....

....

....

.... [2]

(ii) The standard enthalpy change of reaction for the conversion of diamond to graphite is exothermic. Explain whether the conversion of diamond to graphite is spontaneous at all temperatures.

....

....

....

.... [2]

(iii) In daily life, we do not observe diamond converting to graphite readily. Explain why this is so.

....

....

.... [1]

(g) A three-membered ring cycloalkane, C_5H_{10}, gives only two mono-brominated products with Br_2 under uv light. Only one of the two mono-brominated product is chiral. Give the structural formulae of the cycloalkane and the two mono-brominated products formed. State the ratio in which the two mono-brominated products will be formed.

[3]

[Total: 20]

2 **(a)** Figure 1.1 shows the **third** ionisation energies of eight consecutive elements **A** to **H,** in the Periodic Table.
[Note that letters **A** to **H** are not the atomic symbols of the elements concerned.]

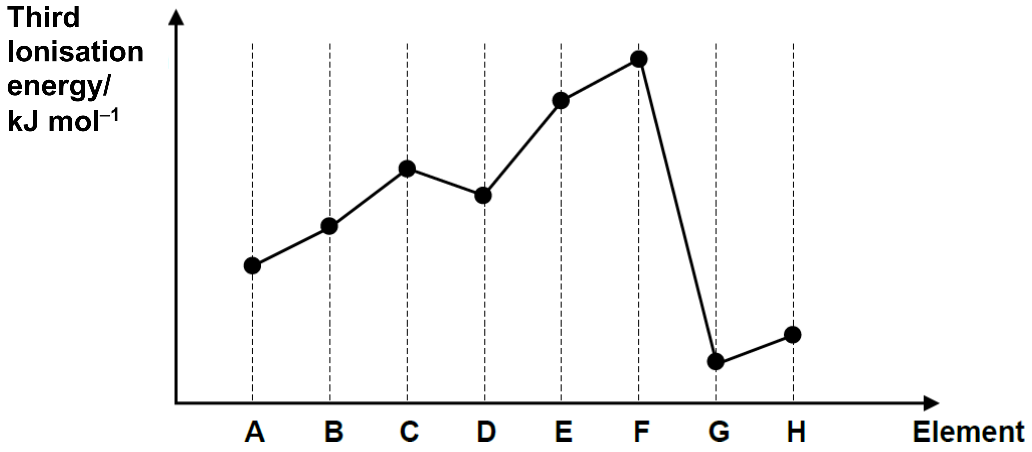


Figure 1.1

(a) Write an equation, including state symbols, to represent the *third ionisation energy* of element **A**.

……………………………………………………………………………………

…………………………………………………………………………………… [1]

(b) From Figure 1.1, suggest the identity of **B**. Explain how you arrived at your answer.

……………………………………………………………………………………

……………………………………………………………………………………

……………………………………………………………………………………

……………………………………………………………………………………

…………………………………………………………………………………… [2]

(c) Explain why the third ionisation energy of element **D** is slightly lower than that of element **C**.

……………………………………………………………………………………

……………………………………………………………………………………

…………………………………………………………………………………… [1]

(b) Nitrogen and phosphorus are elements of Group 15 in the Periodic Table. Nitrogen exists naturally as gaseous diatomic N≡N molecules whereas phosphorus is a solid and exists as P_4 molecules comprising of P-P single bonds.

(i) Account for the difference in their physical states in terms of structure and bonding.

………………………………………………………………………………………

………………………………………………………………………………………

………………………………………………………………………………………

………………………………………………………………………………………

……………………………………………………………………………………… [2]

(ii) Suggest why phosphorus does **not** occur naturally as P≡P molecules.

…………………………………………………………………………………………

…………………………………………………………………………………………

………………………………………………………………………………………… [1]

(iii) Nitrate, NO_3^-, and phosphate, PO_4^{3-}, are oxoanions of nitrogen and phosphorus respectively.

Draw a dot-and-cross diagram to show the bonding PO_4^{3-}, deducing the shape and the bond angle around the phosphorous atom.

Hence explain why it is not possible for nitrogen to form an oxoanion with formula of NO_4^{3-}.

[3]

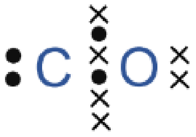
[Total: 10]

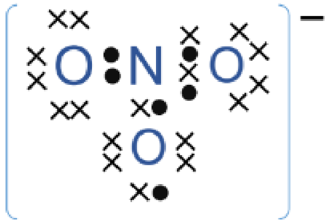
ANSWERS FOR CHEMICAL BONDING AND STRUCTURES MCQ PART 1

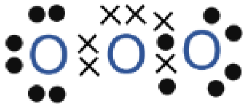
1 Which species contains a dative bond?

1 CO
2 NO_3^-
3 O_3

A 1, 2 and 3
B 1 and 2 only
C 1 and 3 only
D 2 only





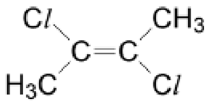
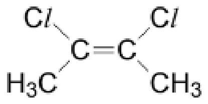
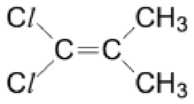
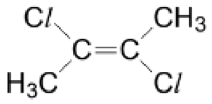
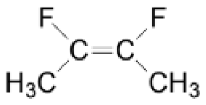
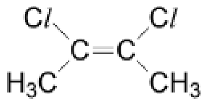


2 Which row correctly describes the shape and polarity of the species?

	species	shape	polarity
A	$AlCl_3$	trigonal planar	polar
B	SiF_4	square planar	non-polar
C	BrF_3	trigonal pyramidal	polar
D	$BeCl_2$	linear	non-polar

	species	shape	polarity
A	$AlCl_3$	trigonal planar (3 b.p.)	non-polar
B	SiF_4	tetrahedral (4 b.p.)	non-polar
C	BrF_3	T shaped (3 b.p. + 2 l.p.)	polar
D	$BeCl_2$	Linear (2 b.p.)	non-polar

3 Which pair of molecules have a greater permanent dipole in molecule **I** than in molecule **II**?

	I	**II**
1	CH_3CHCl_2	CH_3CH_2Cl
2		
3		
4		

A 1 and 2 only

B 3 and 4 only

C 2, 3 and 4 only

D 1, 3 and 4 only

1: C-C*l* bond is polar and there are 2 C*l* bonds in molecule I, thus it is more polar than molecule II.

2: The dipole moments associated with the polar C-C*l* bond is canceled out in the trans molecule. Thus, the cis isomer is more polar.

3: The dipole moments associated with the polar C-C*l* bond is canceled out in the trans molecule. Thus, molecule I is more polar.

4: C-F bond is more polar than C-Cl bond. Thus, molecule I is more polar.

4 Four substances have the physical properties as shown.

Compound	**Melting point/°C**	**Electrical conductivity of solid**	**Electrical conductivity of molten substance**
E	-72	poor	poor
F	801	poor	good
G	842	good	good
H	1710	poor	poor

Which of the following shows the correct type of structures for each compound?

	E	F	G	H
A	simple molecular structure	giant ionic structure	giant metallic structure	giant molecular structure
B	giant molecular structure	giant metallic structure	giant ionic structure	giant molecular structure
C	giant molecular structure	simple molecular structure	giant metallic structure	giant ionic structure
D	simple molecular structure	giant ionic structure	giant molecular structure	giant metallic structure

E has simple molecular structure with low m.p because little amount of energy is needed to overcome the weak intermolecular forces of attraction. It is unable to conduct electricity in any state due to absence of mobile charge carriers.

F has giant ionic lattice structure with high m.p because large amount of energy is needed to overcome the strong electrostatic forces of attraction between the oppositely charged ions. It conducts electricity in aqueous and molten state due to the presence of mobile ions.

G has giant metallic lattice structure with high m.p because large amount of energy is needed to overcome the strong metallic bonds. It conducts electricity in solid and molten state due to the presence of delocalised electrons.

H is SiO_2. It has giant molecular structure with high m.p because large amount of energy is needed to overcome the strong and extensive covalent bonds between the atoms. It cannot conducts electricity in solid state because there is no mobile charge carriers.

5 Which quantity would best indicate the relative strengths of the intermolecular forces of attraction between the molecules in liquid hydrogen halides?

A Bond dissociation energies
B Enthalpy changes of vapourisation
C Enthalpy changes of formation
D Enthalpy changes of atomisation

During vapourisation, molecules need to overcome intermolecular forces of attraction to move further apart to convert to gaseous states.
Atomisation is to convert molecules into atoms and that would need to break strong covalent bonds within molecules instead

6 In which of the following sequences are the species quoted in order of decreasing boiling points?

A $\mathrm{RbC}l$, $\mathrm{KC}l$

B HF, $\mathrm{HC}l$

C K, Ca

D CO, CO_2

Concept: Boiling points

Option A: Both of them have giant ionic lattice structure with strong electrostatic forces of attractions between cations and anions. The strength of ionic bonding α $\left|\frac{q_+ \cdot q_-}{r_+ + r_-}\right|$

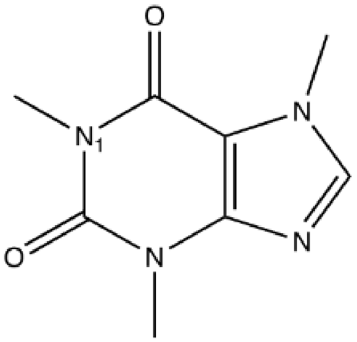
Rb^+ has larger cationic size than K^+, hence RbC*l* has weaker ionic bonding than KC*l*.

Option B: HF has a higher boiling point than HC*l* as it has stronger intermolecular hydrogen bonding while HC*l* has weaker permanent dipole-permanent dipole between its molecules.

Option C: Both K and Ca have giant metallic lattice structure with strong electrostatic forces of attractions between cations and sea of delocalised electrons. The strength of metallic bonding α the number of valence electrons involved in the delocalisation.
K: $4s^1$
Ca: $4s^2$
Ca has higher boiling point than K because it has more valence electrons than K involved in the delocalisation.

Option D: Both of them have simple molecular structure. CO_2 has larger electron cloud size compared to CO. CO_2 has higher boiling point as it has stronger intermolecular instantaneous dipole-induced dipole attractions between its molecules compared to the weaker intermolecular permanent dipole-permanent dipole between CO molecules.

7 People drink beverages containing caffeine to relieve or prevent drowsiness and to improve cognitive performance.



Caffeine

Which statement about caffeine is true?

A Caffeine molecule has a planar structure.
B The π bond in C=C is formed by sideways overlap of 2p orbitals.
C The nitrogen atom in caffeine, N_1 is basic.
D There are 16 sigma bonds in a caffeine molecule.

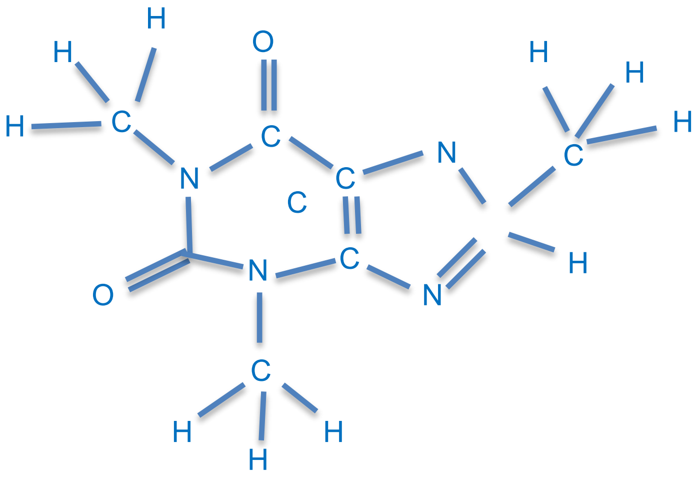
Concept: Chemical Bonding

Option A is wrong. There are sp^3 carbon atoms which have tetrahedral geometry.

Option B is correct. The pi bond is formed by sideways overlap of parallel unhybridised p orbitals.

Option C is wrong. The lone pair of electrons in the unhybridised p orbital of N_1 has overlapped sideways with the adjacent π electron cloud of C=O bond resulting in the delocalisation of lone pair of electrons. Hence, lone pair of electrons is unavailable for protonation.

Option D is wrong. There are 25 σ bonds in a caffeine molecule. There is one σ bond and one π bond in a double bond.



8 Which of the following substances conduct electricity due to delocalised electrons?

1 Graphite
2 Solid magnesium
3 Molten sodium chloride

A 1 only
B 1 and 2 only
C 2 and 3 only
D 1, 2 and 3

Concept: Physical properties of compounds

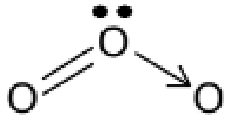
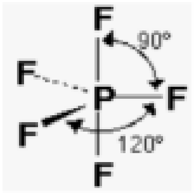
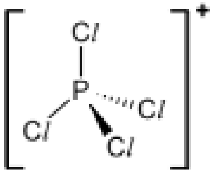
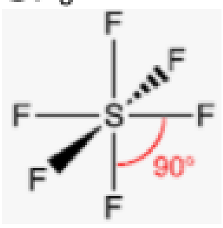
Answer: B

Molten sodium chloride conducts electricity due to the presence of free mobile ions.

9 Which molecule does **not** have any 90° or 180° bond angles?

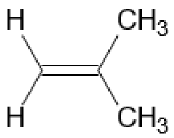
1	O_3
2	PF_5
3	$[PCl_4]^+$
4	SF_6

A 1 and 3 only
B 2 and 4 only
C 1, 2 and 4 only
D 3 only

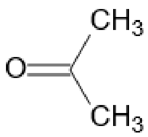
✓	**1**	O_3  Bond angle <120°
✗	**2**	PF_5  Bond angles 90°, 120°
✓	**3**	$[PCl_4]^+$  Bond angle 109.5°
✗	**4**	SF_6  Bond angle 90°

10 Which molecule has the largest overall dipole moment?

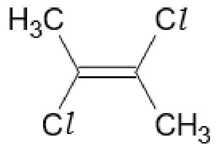
A



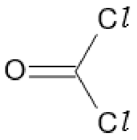
B

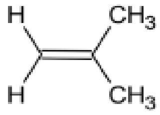
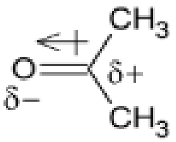
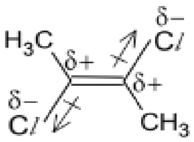
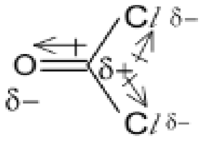


C



D



x	A	 This hydrocarbon is a non-polar molecule
√	B	 The C=O bond has a relatively large dipole moment (due to the large difference in the electronegativities of carbon and oxygen) and there are no other significantly polar bonds to offset the dipole moment of the C=O bond Thus, the molecule has the largest overall dipole moment among the four options.
√	C	 C-C/ bond is polar but the dipole moments cancel out.
√	D	 C=O bond is more polar than C-C/bond as O is more electronegative than C/ but since both bonds are polar, there will be some degree of offset of dipole moments of the bonds, hence this molecule does not have the largest overall dipole moment among the four options.

11 Bromine trifluoride is a liquid which undergoes auto-ionisation at room temperature as represented by the following equation:

$$2BrF_3 \rightarrow BrF_2^+ + BrF_4^-$$

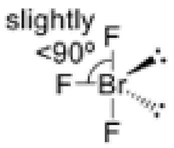
Which of the following is correct regarding BrF_3, BrF_2^+ and BrF_4^-?

A BrF_3 is planar while BrF_4^- is non-planar.

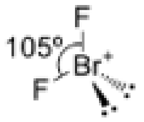
B BrF_2^+ is linear while BrF_4^- is tetrahedral in shape.

C The F–Br–F bond angle in BrF_3 is smaller than that in BrF_4^-

D There are more lone pairs of electrons around the Br atom in BrF_3 than that in BrF_2^+



3 σ bond, 2 lone pairs
=> T-shaped (planar)



2 σ bond, 2 lone pairs
=> bent

4 σ bond, 2 lone pairs
=> square planar

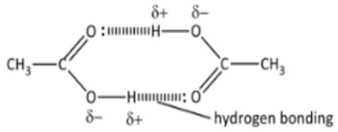
12 Which observation **cannot** be explained by intermolecular hydrogen bonding?

A Methanol dissolves readily in water.

B The boiling point of HBr is higher than that of HC*l*.

C The boiling point of 4-aminophenol is higher than that of 2-aminophenol.

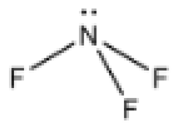
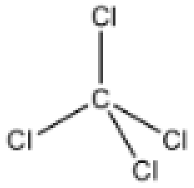
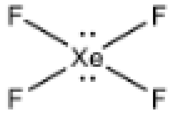
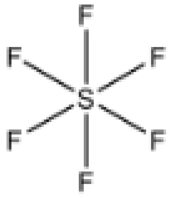
D The relative molecular mass of ethanoic acid when dissolved in hexane is 120.

A	Methanol forms favourable hydrogen bonding between its -OH group and that in water.
B	The hydrogen atom is not bonded to F, O or N atom, hence there is no intermolecular hydrogen bonding for HBr and HCl.
C	For 2-aminophenol, the -NH2 and the -OH groups are in close proximity which allows for intramolecular hydrogen bonding. Hence there is less extensive intermolecular hydrogen bonding for 2- aminophenol and less energy is required to overcome the intermolecular forces, leading to a lower boiling point.
D	When ethanoic acid, CH3CO2H (Mr =60), is dissolved in a non-polar solvent (hexane), the molecules form hydrogen-bonded dimers. 

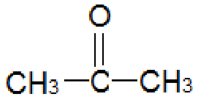
13 In which pairs of compounds does the first molecule have a smaller bond angle than that in the second molecule?

1	NF_3	CCl_4
2	H_2O	XeF_4
3	SF_6	CS_2

A 1, 2 and 3 **B** 1 and 2 only **C** 2 and 3 only **D** 1 and 3 only

Option	Explanation	
1	 about 107°	 109.5°
2	 about 104.5°	 90°
3	 90°	$S{=}C{=}S$ 180°

14 Propanone and dichloromethane are common organic solvents used in the laboratory. Propanone is soluble in water but dichloromethane is not.



$CH_3-\overset{\overset{O}{\|}}{C}-CH_3$

propanone

CH_2Cl_2

dichloromethane

Which of the following statements best accounts for this?

A Propanone is a polar molecule but dichloromethane is non-polar.

B A hydrogen bond forms between the hydrogen in propanone and the oxygen of a water molecule.

C A hydrogen bond forms between the oxygen in propanone and the hydrogen of a water molecule.

D Propanone has a smaller relative molecular mass than dichloromethane.

15 Nitrogen oxides (NO_x) can be formed from the reaction of nitrogen with oxygen in car engines. It can dissolve in water to form nitric acid which causes acid rain. Which of the following statements are correct?

1 N atom in NO_3^- is sp^2 hybridised.
2 NO and NO_2 contain an unpaired electron.
3 NO and NO_2 have no net dipole moment.

A 1 only
B 1 and 2
C 2 and 3
D 1, 2 and 3

16 Which species has the most number of unpaired electrons?

A Co^{2+}
B N
C Fe
D S

	electronic configuration	unpaired electrons	box diagram
Co^{2+}	$1s^2 2s^2 2p^6 3s^2 3p^6 3d^7$	3	3d ↑↓ ↑↓ ↑ ↑ ↑
N	$1s^2 2s^2 2p^3$	3	2p ↑ ↑ ↑
Fe	$1s^2 2s^2 2p^6 3s^2 3p^6 3d^6 4s^2$	4	3d ↑↓ ↑ ↑ ↑ ↑
S	$1s^2 2s^2 2p^4$	2	2p ↑↓ ↑ ↑

17 Rubidium and bromine form ions that are isoelectronic.

1 Ionic radius of rubidium is smaller than its atomic radius.

2 Ionic radius of bromine is larger than its atomic radius.

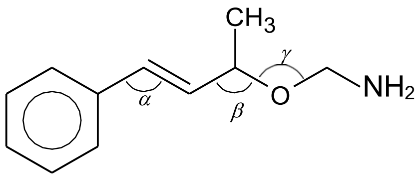
3 Ionic radius of bromine is smaller than that of rubidium.

Which statements are correct?

A 1, 2 and 3 **B** 1 and 2 only **C** 1 and 3 only **D** 2 and 3 only

	Proton number	Ion	
Rb	37	Rb$^+$	For Rb vs Rb$^+$, since the same nuclear charge is attracting less electrons for the ion, the outermost electrons are more tightly held in Rb$^+$ Ionic radius is smaller. Option 1 is true.
Br	35	Br$^-$	For Br vs Br$^-$, since the same nuclear charge is attracting more electrons for the ion, the outermost electrons are less tightly held in Br$^-$ Ionic radius is larger. Option 2 is true.
			For Br$^-$ vs Rb$^+$, there are less nuclear charge (less protons) attracting the same number of electrons in Br$^-$ than in Rb$^+$, the outermost electrons are less tightly held by nucleus in Br$^-$. Ionic radius of Br$^-$ is larger. Option 3 is not true.

18 Which row correctly shows the bond angles for α, β, γ in the molecule below?



	α	β	γ
A	109.5°	120°	109.5°
B	120°	109.5°	107°
C	120°	107°	105°
D	120°	109.5°	105°

α: 3 Bond pairs (1 C=C, 1 C-C and 1 C-H) – Bond Angle of 120° β: 4 bond pairs (3 C-C and 1 C–H) – Bond Angle of 109.5°

γ: 2 lone pairs & 2 bond pairs (2 C–O) – Bond Angle of 105°

19 In which pair is the melting point of the **second** species higher than that of the **first** species?

A C and Si

B K and Rb

C NaC*l* and NaBr

D $SiCl_4$ and SiO_2

C and Si are both giant covalent structure and atoms held by covalent bonds. C atoms have a smaller orbital size than Si and hence greater degree of orbital overlap leader to stronger covalent bonds in C than Si. More energy is needed to break the stronger covalent bonds in C than Si. Hence, C has a higher melting point than Si.

K and Rb are both metallic lattices. Both K and Rb contribute the same number of electrons to the sea of mobile electrons. K^+ has a larger charge to size ratio than Rb^+ due to having a smaller ionic radius. More energy is needed to break the stronger metallic bonds in K than in Rb. Hence, K has a higher melting point than Si.

NaC*l* and NaBr are both giant ionic lattices. The product of the charges are the same for both NaC*l* and NaBr, however, the interionic distance for NaC*l* is smaller than NaBr. Since L.E $\propto \left|\frac{q_+ \times q_-}{r_+ + r_-}\right|$, more energy is needed to break the stronger ionic bonds in NaC*l* than NaBr. Hence, NaC*l* has a higher melting point than NaBr.

$SiCl_4$ is simple molecular structure and SiO_2 is giant covalent lattice structure. More energy is needed to overcome the covalent bonds in SiO_2 than the weak id-id in $SiCl_4$. Hence, SiO_2 has a higher melting point than $SiCl_4$.

20 When liquid N_2F_4 is heated, it decomposes into a single product, **B**.

Which statements are correct?

1 N–F bonds are broken during this decomposition.

2 The enthalpy change when N_2F_4 decomposes into **B** is approximately +160 kJ mol^{-1}.

3 Molecules of **B** are non-linear.

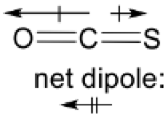
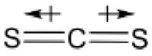
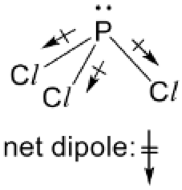
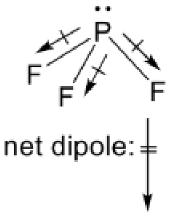
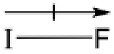
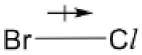
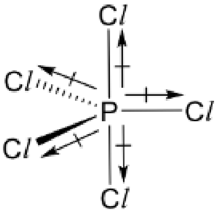
A 1, 2 and 3 **B** 1 and 2 only **C** 2 and 3 only **D** 1 only

$N_2F_4 \rightarrow 2NF_2$

From the equation, can see that only N-N bonds are broken. Hence statement 1 is incorrect. Based on Data Booklet, N–N bond is +160 kJ mol^{-1}, so statement 2 is correct because that is the only bond broken in the reaction.
Statement 3 is correct because there are lone pair(s) on N of NF_2 molecule, so it has to be non-linear.

21 In which row does G have a smaller overall dipole moment than H?

	G	H
A	COS	CS_2
B	PCl_3	PF_3
C	IF	BrC*l*
D	XeF_4	PCl_5

	G	H	Remarks
A	 net dipole:	 no net dipole	G has a greater net dipole than H.
B	 net dipole:	 net dipole:	P-F bond is more polar than P-C*l* bond. G has a smaller net dipole than H.
C			I-F bond is more polar than Br-C*l* bond. G has a greater net dipole than H.
D	 no net dipole	 no net dipole	Both G and H do not have a net dipole.

22 Which compound has the greatest covalent character?

A MgO
B MgS
C CaO
D CaS

For ionic compounds, the extent of polarisation/distortion of the electron cloud of the anion and hence the degree of covalent character increases with:

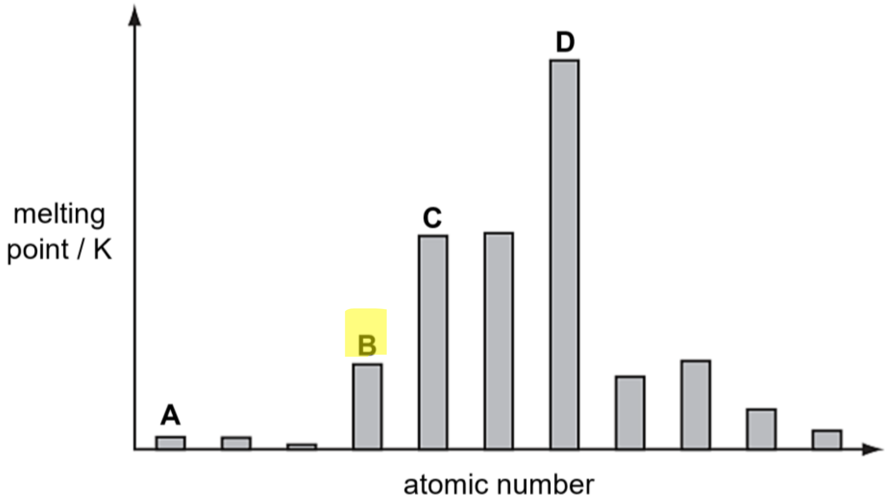
- higher polarising power of the cation
- higher polarisability of the anion

Compared to Ca^{2+}, Mg^{2+} has a smaller ionic radius and hence a higher charge density and polarising power. Mg^{2+} is able to distort the electron cloud of the anion to a greater extent.

Compared to O^{2-}, S^{2-} has a larger and more polarisable electron cloud. Hence, MgS has the greatest covalent character

23 The bar chart shows the melting points of a series of consecutive elements arranged in order of increasing atomic number. The elements sodium to chlorine form part of this series.

Which bar represents sodium?



Element **D** is silicon as it has the highest melting point. Since the elements are consecutively arranged, **B** is sodium.

24 Which statement about the element astatine is correct?

A Silver astatide is insoluble in aqueous ammonia.
B Astatine is a liquid at room temperature and pressure.
C The bond energy of hydrogen astatide is larger than that of hydrogen iodide.
D Astatine is not a product of the reaction between sodium astatide and bromine.

Option **A** is correct. The solubility of silver halides in aqueous ammonia decreases down the group (due to decreasing K_{sp} values). Since silver iodide is insoluble in aqueous ammonia, silver astatide is expected to be also insoluble in aqueous ammonia.

Option **B** is incorrect. The melting and boiling points of halogens increase down the group. Since iodine is a solid, astatine is expected to be also a solid at room temperature and pressure.

Option **C** is incorrect. H-X bond energy decreases down the group due to decreasing effectiveness of the valence orbital overlap. Hence the bond energy of HAt is expected to be smaller than that of HI.

Option **D** is incorrect. Oxidising power of halogens decreases down the group. Hence, a halogen can oxidise a halide below (but not above) it. Bromine is expected to be able to oxidise sodium astatide to give astatine.

ANSWERS FOR CHEMICAL BONDING AND STRUCTURES STRUCTURED QUESTIONS PART 1

1 The carbon family consists of the elements of Group 14. The elements at the top of the group, carbon to germanium, have very different properties from those at the bottom, tin and lead. For instance, Group 14 elements tend to adopt oxidation states of +4, whereas the heavier elements, such as tin and lead, exhibit the +2 oxidation state due to the inert pair effect.

(a) State the valence shell configuration of Group 14 elements.

$ns^2\ np^2$ .... [1]

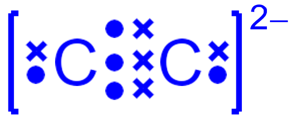
(b) One of the contributing factors to the inert pair effect is the unexpected increase in the ionisation energies, after lead, down the group.

Explain why the 1st ionisation energies are expected to decrease down the group.

Down the group, **nuclear charge increases** and **shielding effect increases..** Valence electrons are **further away from the nucleus** **and this leads to decrease ...in electrostatic forces of attraction between the nucleus and the valence electron.** Less energy needed to remove the valence electron, resulting in decrease in 1st I.E. down the group [2]

(c) Carbon forms carbide anion, C^{2-}_2in calcium carbide while silicon mostly forms Si^{4+} ions.

(i) Draw the dot-and-cross diagram of the carbide anion, C^{2-}_2



[1]

(ii) In a particular experimental set-up, a beam of $^{28}Si^{4+}$ ions was deflected by an angle of +4.2º. Assuming an identical set of conditions, by what angle will the $^{12}C^{2-}$ ions to be depleted?

$^{28}Si^{4+}$ whose $\frac{q}{m}=\frac{+4}{28}=+\frac{1}{7}$ gives an angle of deflection, θ, of +4.2º

$$\theta = k\left(\frac{q}{m}\right) \Rightarrow +4.2^\circ = k\left(+\frac{1}{7}\right) \Rightarrow k = 29.4$$

For $^{12}C_2^{2-}$ whose $\frac{q}{m}=\frac{-2}{24}=-\frac{1}{12}$,

[1]

angle of deflection, $\theta = 29.4\times\left(-\frac{1}{12}\right) = \underline{\mathbf{-2.45^\circ}}$

(d) Table 1.1 shows that the melting points of the elements of Group 14.

Table 1.1

element	C	Si	Ge	Sn	Pb
melting point / °C	>3550	1410	937	232	327

Carbon, silicon and germanium each form a solid with the same type of structure. Using bonding and structure, suggest why the melting points of these elements decrease from carbon to germanium.

Carbon, silicon and germanium are of **giant covalent structure**. To melt these elements, strong **covalent bonds** between the atoms have to be broken. **From C to Ge, the orbitals become bigger and more diffuse.** The **overlap of the orbitals becomes less effective.** Bond strength decreases and hence less energy is required for melting

[2]

(e) Carbon forms many allotropes such as graphite and diamond. Recent scientific research has found that replacing the graphite electrodes with graphene in lithium-ion batteries can extend battery life.

(i) Graphene is a **single, one atom thick** layer of graphite. Describe the hybridisation of the orbitals in, and the bonds between, the carbon atoms within graphene.

Each carbon atom is **sp^2 hybridised,** and forms **3 σ bonds via head-on overlap between sp^2 hybrid orbital** from an adjacent C atom. The π **bond is formed through sideways overlap of the unhybridised p orbitals** from an adjacent C atom

[2]

(ii) Using your answer from **(e)(i)**, explain why graphene can conduct electricity along the plane.

The remaining **2p electron on each carbon atom can delocalise along the plane** when a potential difference is applied.

[1]

(iii) State and explain how you would expect the bond strength of carbon-carbon bonds in graphene to differ when compared with that in diamond.

The carbon-carbon bond in graphene is **stronger** than that in diamond. This is due to the **presence of both σ and π bonds / partial double bond character in the C–C bond in graphene, while there are only σ bonds present in diamond.**

[2]

(f) Diamond and graphite are allotropes of carbon. Fig. 1.1 gives the structure of diamond and graphite. Diamond is an important abrasive while graphite is used as a lubricant.

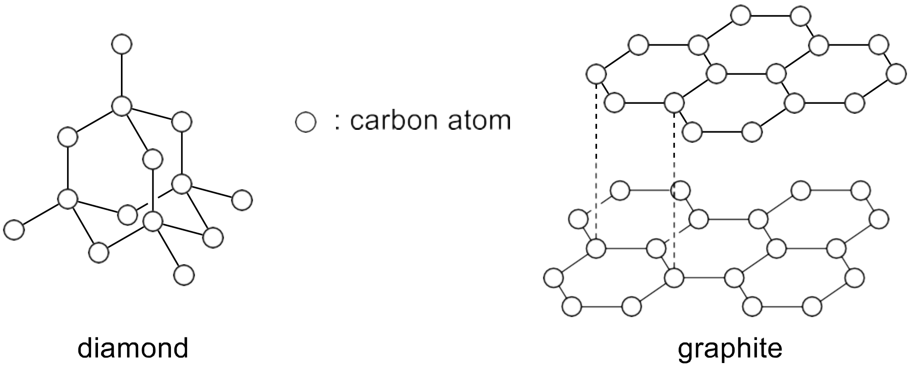


Fig. 1.1

(i) Explain why the sign of the entropy change for the conversion of diamond to graphite is positive.

There is greater disorderliness as the **layers of graphite are loosely held by weak instantantaneous dipole-induced dipole interactions** as compared to the carbon atoms being held in the 3-dimensional lattice in diamond. This results in **greater spread of energies and more ways to arrange the particles in graphite compared to diamond**.

[2]

(ii) The standard enthalpy change of reaction for the conversion of diamond to graphite is exothermic. Explain whether the conversion of diamond to graphite is spontaneous at all temperatures.

Since **$\Delta S > 0$, $-T\Delta S$ is always negative at all temperatures.**

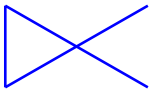
and **$\Delta H < 0$** (given in question). **Hence $\Delta G = \Delta H - T\Delta S \Rightarrow \Delta G < 0$ is spontaneous at all temperatures.**

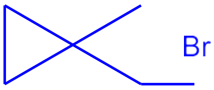
[2]

(iii) In daily life, we do not observe diamond converting to graphite readily. Explain why this is so.

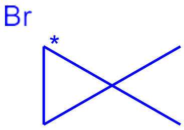
Although the reaction is spontaneous, it has a **high activation energy and it takes place at a very slow rate** [1]

(g) A three-membered ring cycloalkane, C_5H_{10}, gives only two mono-brominated products with Br_2 under uv light. Only one of the two mono-brominated product is chiral. Give the structural formulae of the cycloalkane and the two mono-brominated products formed. State the ratio in which the two mono-brominated products will be formed.





bromoalkane A



bromoalkane B

ratio of the products A : B = 6 : 4 = **3 : 2**

[3]

[Total: 20]

2 **(a)** Figure 1.1 shows the **third** ionisation energies of eight consecutive elements **A** to **H,** in the Periodic Table.
[Note that letters **A** to **H** are not the atomic symbols of the elements concerned.]

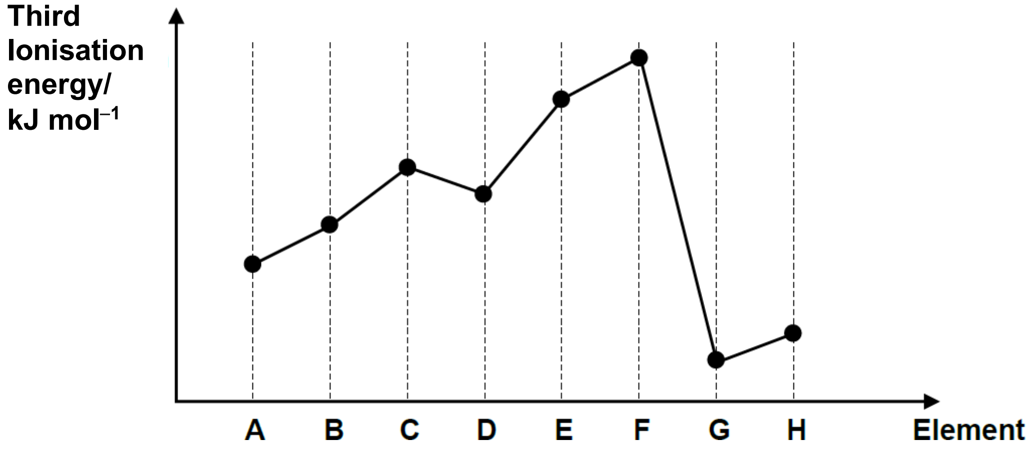


Figure 1.1

(a) Write an equation, including state symbols, to represent the *third ionization energy* of element **A**.

$A^{2+}(g) \longrightarrow A^{3+}(g) + e^-$ [1]

(b) From Figure 1.1, suggest the identity of **B**. Explain how you arrived at your answer.

The large decrease in 3rd IE from F to G implies that G^{2+} has 1 more quantum shell of electrons than F^{2+} / 3rd electron to be removed from F is from the inner quantum shell.

The valence shell configuration of G^{2+} is ns^1 and hence, the valence shell configuration of G is $ns^2\ np^1$ (*i.e.* A*l*).
OR
This also implies that the valence shell configuration of B^{2+} is $(n\text{-}1)s^2\ np^2$ and hence, the valence shell configuration of B is $ns^2\ np^4$.

OR
F is in group 2 / G is in group 13

Hence, B is oxygen.
Cannot accept sulfur. [2]

(c) Explain why the third ionisation energy of element **D** is slightly lower than that of element **C**.

C^{2+}: $1s^2 2s^2 2p^3$ D^{2+}: $1s^2 2s^2 2p^4$

The inter–electronic repulsion / repulsion between the paired 2p electrons in D^{2+} makes it easier to remove a paired electron than an unpaired 2p electron of C^{2+} which do not experience such repulsion.

Hence, the 3rd IE of D is lower than that of element C.

[1]

(b) Nitrogen and phosphorus are elements of Group 15 in the Periodic Table. Nitrogen exists naturally as gaseous diatomic N≡N molecules whereas phosphorus is a solid and exists as P_4 molecules comprising of P-P single bonds.

(i) Account for the difference in their physical states in terms of structure and bonding.

Both N_2 and P_4 have simple molecular structures.

As P_4 has larger number of electrons/ bigger electron cloud to be polarised, more energy is required to overcome the stronger instantaneous dipole-induced dipole interactions/attractions between the P_4 molecules.

This results in higher melting point in P_4, hence P_4 exists as solid. [2]

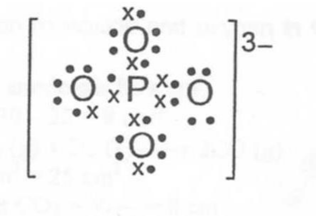
(ii) Suggest why phosphorus does **not** occur naturally as P≡P molecules.

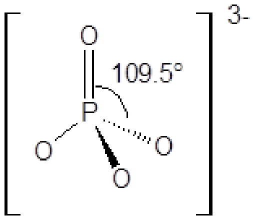
Phosphorus is a relatively big atom with diffused orbitals, side-on overlap of its p orbitals to form π bonds is much less effective than head-on overlap to form sigma bond. [1]

(iii) Nitrate, NO_3^-, and phosphate, PO_4^{3-}, are oxoanions of nitrogen and phosphorus respectively.

Draw a dot-and-cross diagram to show the bonding PO_4^{3-}, deducing the shape and the bond angle around the phosphorous atom.

Hence explain why it is not possible for nitrogen to form an oxoanion with formula of NO_4^{3-}.





[3]

[Total: 10]

4 bond pairs around central atom P

Shape of PO_4^{3-} is tetrahedral, angle O—P—O: 109.5°

To form NO_4^{3-}, N must be able to accommodate 10 electrons in its valence shell. Since N is in Period 2, it has no energetically accessible/low lying d orbital to expand its octet.