IB · SL · Chemistry

6 hours 41 questions

Structured Questions

The Covalent Model

Covalent Bonds / Lewis Formulas / Multiple Bonds / Coordinate Bonds / Shapes of Molecules / Bond Polarity / Molecular Polarity / Giant Covalent Structures / Intermolecular Forces / Physical Properties of Covalent Substances / Chromatography

Easy (12 questions)	/100
Medium (16 questions)	/154
Hard (13 questions)	/122
Total Marks	**/376**

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Easy Questions

1 (a) Using Section 9 of the data booklet to state which of the following single covalent bonds is the most polar.

C-O   C-H   O-H

....

(1 mark)

(b) Using Section 11 of the data booklet, list the following molecules in order of increasing bond length between the carbon atoms.

C_2H_6 C_2H_4 C_2H_2

....

(1 mark)

(c) Using Section 12 of the data booklet, list the following molecules in order of decreasing bond strength between the carbon atoms.

C_2H_6 C_2H_4 C_2H_2

....

(1 mark)

2 (a) Calcium nitrate contains both covalent and ionic bonds.

State the formula of both ions present and the nature of the force between these ions.

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(2 marks)

(b) State the formula of the compound that boron forms with chlorine.

....

(1 mark)

(c) Draw the Lewis structure for boron chloride.

....

(1 mark)

3 (a) State the formula for benzene and draw the displayed structure.

....

....

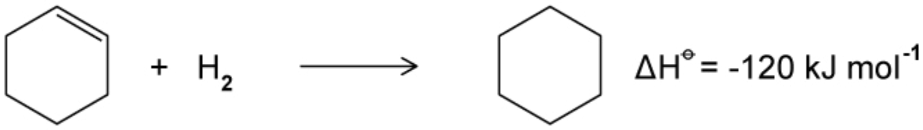
(2 marks)

(b) State the bond angle in the planar regular hexagon structure of benzene.

....

(1 mark)

(c) Cyclohexene is an unsaturated hydrocarbon and can undergo hydrogenation as shown below.



When benzene undergoes the same reaction with three hydrogen molecules the expected enthalpy change of the reaction is lower than expected.

State the expected value of the hydrogenation of benzene.

....

(1 mark)

(d) Explain why the enthalpy value for the hydrogenation of benzene is lower than expected.

....

....

(2 marks)

4 (a) Sulfur has no lone pairs when bonded to fluorines in SF_6. Predict the molecular geometry of sulfur hexafluoride, SF_6.

....

(1 mark)

(b) State the F-S-F bond angles in SF_6.

....

(1 mark)

(c) Phosphorus pentafluoride, PF_5, is also a molecule with an expanded octet around the central atom.

i) Draw a Lewis (electron dot) structure for PF_5

[1]

ii) Predict the molecular geometry of PF_5

[1]

iii) State the F-P-F bond angle(s)

[1]

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(3 marks)

5 (a) Although noble gases do not normally react, a few compounds are possible. One is xenon tetrafluoride.
Draw the Lewis structure (electron dot) for XeF_4.

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....

(2 marks)

(b) Predict the molecular geometry and electron domain geometry for the XeF_4 molecule.

....

....

(2 marks)

(c) Predict and explain the F-Xe-F bond angle in XeF_4

....

....

(2 marks)

6 (a) Draw a Lewis (electron dot) structure for carbon dioxide, CO_2.

....

....

(2 marks)

(b) Predict the molecular geometry and the O-C-O bond angle in carbon dioxide, CO_2.

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(2 marks)

7 (a) There are a number of different types of intermolecular force possible between molecules.

Which types of forces can be classified as 'van der Waals' forces?

(2 marks)

(b) Methanol, CH_3OH, is a small alcohol molecule that forms hydrogen bonds with water.

Sketch 2 different hydrogen bonding interactions between methanol and water.

(2 marks)

(c) Methanol, CH_3OH can be oxidised to methanal, CH_2O and then to methanoic acid, HCOOH.

Identify the strongest type of intermolecular force between:

i) Methanal molecules [1]

ii) Methanoic acid molecules [1]

iii) Water and methanal [1]

iv) Water and methanoic acid [1]

(4 marks)

(d) Methanoic acid reacts with sodium hydroxide to form sodium methanoate:

$$HCOOH + NaOH \rightarrow HCOONa + H_2O$$

Explain why sodium methanoate is a solid at room temperature and methanoic acid is a liquid.

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(3 marks)

8 (a) Group 17 of the Periodic Table contain non-metals that are often referred to as the halogens.

Iodine, I_2, is one of these halogens. At room temperature and pressure it exists as a grey-black solid.

Describe the bonding and forces present in I_2 in the solid state.

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....

(2 marks)

(b) The state of the halogens changes down the group, with fluorine being a gas and astatine being a solid.

Explain why the melting point of the halogens increases down the group.

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(2 marks)

(c) The halogens are all diatomic covalent molecules.

Predict the most probable physical properties shown by all of the elements in Group 17.

....

....

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(3 marks)

(d) The halogens can also form interhalogen compounds, such as iodine monochloride, ICl.

Predict the state of iodine monochloride at room temperature and pressure, and explain your answer with reference to the intermolecular forces present.

....

(3 marks)

9 (a) Yellow phosphorus reacts with chlorine to form phosphorus trichloride, PCl_3.

i) Draw the Lewis (electron dot) structure of phosphorus trichloride.

[1]

ii) Predict the Cl-P-Cl bond angle and molecular geometry of the phosphorus trichoride molecule.

[2]

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(3 marks)

(b) Phosphorus trichloride, PCl_3, can form a co-ordinate bond with a hydrogen ion to form $HPCl_3^+$.

i) Draw the Lewis (electron dot) structure of $HPCl_3^+$.

[2]

ii) Predict the bond angle and molecular geometry of $HPCl_3^+$.

[2]

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(4 marks)

(c) BCl_3 has three electron domains in a trigonal planar structure.

BCl_3 is not a polar molecule, but PCl_3 is.

Explain this difference using section 9 of the Data booklet.

....

....

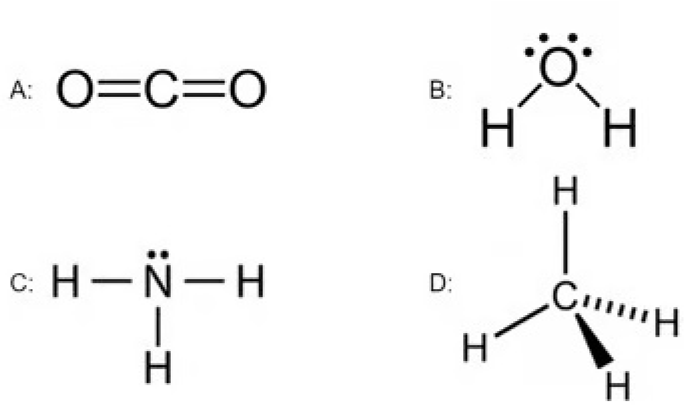
(4 marks)

(d) PCl_4^+ has the same electron domain geometry as $HPCl_3^+$.

Explain why PCl_4^+ is not a polar molecule.

(2 marks)

10 (a) This question is about the geometry of a number of common molecules.



i) Which molecule(s) has/ have tetrahedral structures with respect to the electron domain geometry?

[1]

ii) What is the molecular geometry of CO_2?

[1]

iii) Draw the 3D representation of ammonia, NH_3.

[1]

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(3 marks)

(b) Estimate the H-O-H bond angle in water, H_2O, using VSEPR theory.

Explain your answer.

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(3 marks)

(c) Suggest a way in which the bond angle in ammonia / NH_3 could become 109.5° and explain your answer.

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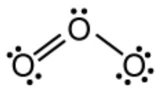
(3 marks)

(d) Ozone, O_3, is another simple molecule which has the following structure:



i) Estimate the O-O-O bond angle in ozone using VSEPR theory.

[1]

ii) Explain why the actual bond lengths present in ozone are equal.

[2]

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(3 marks)

11 (a) Carbon has three naturally occurring allotropes; diamond, graphite and buckminsterfullerene, C_{60}.

State how many atoms each carbon is directly bonded to in each of the allotropes, explaining any differences.

(4 marks)

(b) Describe the differences in the structures of the three allotropes of carbon.

(3 marks)

(c) Describe and explain the differences in electrical conductivity between the three allotropes of carbon.

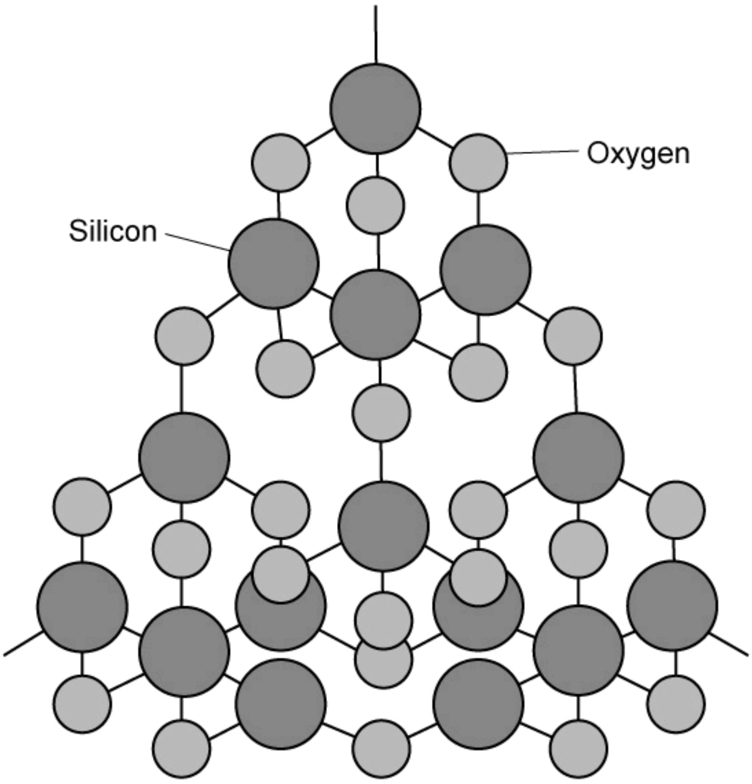
(4 marks)

(d) Graphene can be made from graphite.

Describe a similarity and difference between these two structures.

(2 marks)

12 (a) Silicon and carbon are in the same group of the Periodic Table. They both form covalent bonds.



$$O{=}C{=}O$$ (carbon dioxide)

Both silicon and carbon form dioxides, but silicon dioxide has a melting point of 1710 ^{o}C whilst carbon dioxide has a melting point of -78 ^{o}C.

Explain this difference with reference to the structure and bonding present in each dioxide.

....

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(4 marks)

(b) How many oxygen atoms are bonded to each carbon and to each silicon?

Explain how this links to the formula of each compound.

....

....

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(3 marks)

(c) Predict the O-C-O and O-Si-O bond angles respectively in CO_2 and in SiO_2.

....

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(2 marks)

Predict and explain the solubility of both SiO_2 and CO_2 in water.

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(d) **(4 marks)**

Medium Questions

1 (a) For each of the molecules below, draw the Lewis (electron dot) structure and use the valence shell electron pair repulsion theory (VSEPR) to predict the shape of each molecule.

Oxygen difluoride (OF_2), phosphorus trifluoride, (PF_3) and boron trichloride, (BCl_3).

(6 marks)

(b) Crystalline ionic compounds do not conduct electricity.

State and explain in which states ionic compounds conduct electricity.

(2 marks)

(c) The melting point of sodium chloride, NaCl, is 801° C.

Explain, with reference to structure and bonding, why sodium chloride melts at such a high temperature.

(3 marks)

(d) We can use electronegativity values to deduce whether a compound is likely to be ionic or covalent.

Use Section 9 of the Data Booklet to state and explain whether each of the following compounds are ionic or covalent:

IC*l*

$SrCl_2$

RbI

HI

(2 marks)

2 (a) Diimide, N_2H_2, is a useful reagent in organic synthesis and can be made by the thermal decomposition of azodicarboxylic acid.

$$N(COOH)_2\,(g) \rightarrow N_2H_2\,(g) + 2CO_2\,(g)$$

Another useful compound of nitrogen is hydrazine, N_2H_4.

Draw Lewis (electron dot) structures for diimide and hydrazine.

....

....

(2 marks)

(b) Deduce the molecular geometry of diimide and estimate its H-N-N bond angle.

....

....

(2 marks)

(c) List, with an explanation, the three compounds in order of increasing carbon to oxygen bond length (shortest first).

H_3COCH_3 **CO** **CO_2**

....

....

....

(3 marks)

(d) Use Section 9 of the Data Booklet to predict which bond in each of the following pairs is more polar:

i) C–H or C–Cl

[1]

ii) Si–Li or Si–Cl

[1]

....

....

(2 marks)

3 (a) Three types of covalent bonds are present in the molecules in the following equation.

$$2C_2H_2\,(g) + 5O_2\,(g) \rightarrow 4CO_2\,(g) + 2H_2O\,(l)$$

Identify **one** bond in these molecules that is correctly described by the following:

i) A polar single bond.

[1]

ii) A non-polar double bond.

[1]

iii) A non-polar triple bond.

[1]

....

....

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(3 marks)

(b) Explain which of the bonds in part (a) is the shortest.

....

....

(2 marks)

(c) **Table 1** shows the carbon-carbon bond enthalpy values for three different hydrocarbons.

Table 1

Hydrocarbon	C_2H_6	C_2H_4	C_2H_2
Bond enthalpy / kJ mol^{-1}	346	614	839

Explain the difference in carbon-carbon bond enthalpy values for the three hydrocarbons.

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(3 marks)

(d) We can use electronegativity values to deduce whether a compound is likely to be pure covalent (non-polar) or polar covalent.

Use Section 9 of the Data Booklet to state and explain whether each of the following covalent compounds is polar or non-polar:

H_2 HCl CO

....

....

(2 marks)

4 (a) Ammonia, NH_3, is a chemical that is key in the manufacture of certain fertilisers and cleaning products.

An ammonia molecule will react with an H^+ ion, to form the ammonium ion, NH_4^+.

Draw a Lewis (electron dot) diagram to show the bonding in the ammonium ion and name the type of bond formed between the ammonia molecule and the hydrogen ion.

....

....

(2 marks)

(b) Lewis (electron dot diagrams) are used to show the electron arrangement in the valence shells of covalently bonded molecules.

Draw Lewis diagrams for the following molecules:

i) Hydrogen cyanide.

[1]

ii) Carbon dioxide.

[1]

iii) Boron trifluoride.

[1]

....

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(3 marks)

5 (a) Benzene is an aromatic hydrocarbon which is often drawn as **Figure 1**.

Discuss the physical evidence that justifies this structure for benzene.

Figure 1

....

....

(2 marks)

(b) Benzene and cyclohexene are both *unsaturated* molecules, but cyclohexene reacts with bromine water and benzene does not.

i) State the meaning of the terms *saturated* and *unsaturated* as applied to organic molecules.

[1]

ii) Explain this difference in reactivity and write an equation for the reaction between cyclohexene and bromine.

[2]

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....

(3 marks)

(c) **Table 1** below shows the enthalpy changes for the hydrogenation of cyclohexene, benzene, and the theoretical molecule 1,3,5-cyclohexatriene.

Table 1

Compound	Enthalpy of hydrogenation
Cyclohexene, C_6H_{10}	-120
Benzene, C_6H_6	-208
1,3,5-cyclohexatriene, C_6H_6	?

The equations for the hydrogenation reactions are:

Cyclohexene $C_6H_{10} + H_2 \quad C_6H_{12}$

Benzene $C_6H_6 + 3H_2 \quad C_6H_{12}$

i) Use the data in **Table 1** to determine the enthalpy of hydrogenation of the theoretical molecule 1,3,5-cyclohexatriene.

[1]

ii) Discuss the difference between the enthalpy of hydrogenation of benzene and of 1,3,5-cyclohexatriene.

[2]

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(3 marks)

(d) An unknown aromatic compound has the molecular formula $C_8H_8O_2$.

Deduce the structural formula of **two** isomers of this compound which contain an ester group.

....

....

(2 marks)

6 (a) Phosphorus tribromide and sulfur tetrafluoride are two colourless compounds which both react with water to form toxic products.

Deduce the Lewis (electron dot) structure of both molecules.

....

....

(2 marks)

(b) Predict the shapes of the two molecules of phosphorus tribromide and sulfur tetrafluoride

....

....

(2 marks)

(c) Explain why both phosphorus tribromide and sulfur tetrafluoride are polar.

....

....

(2 marks)

Draw the Lewis structures, predict the shape and deduce the bond angles for xenon tetrafluoride.

7 (a) **(3 marks)**

Compare the polarity of xenon tetrafluoride with chlorine trifluoride.

(b) **(3 marks)**

8 (a) Compounds containing two different halogen atoms bonded together are called interhalogen compounds. They are interesting because they contain halogen atoms in unusual oxidation states. One such compound is BrF_3.

Deduce the electron domain geometry and molecular geometry of BrF_3.

....

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(2 marks)

(b) Give the approximate bond angle(s) and a valid Lewis (electron dot) structure for BrF_3.

....

....

(2 marks)

(c) Explain why bromine trifluoride, BrF_3 has its lone pairs of electrons located in equatorial positions.

....

....

(2 marks)

9 (a) Based on the type of intermolecular force present, explain why butan-1-ol has a higher boiling point than butanal.

....

....

(2 marks)

(b) Ethane, C_2H_6, and disilane, Si_2H_6, are both hydrides of Group 4 elements with similar structures but different chemical properties.

Explain why disilane has a higher boiling point than ethane.

....

....

(2 marks)

(c) Put the following molecules in order of increasing boiling point and explain your choice:

CH_3CHO CH_3CH_2OH $CH_3CH_2CH_3$

....

....

....

(3 marks)

(d) Based on the type of intermolecular force present, explain the difference in solubility in water between ethane and ethanol.

....

....

....

....

(4 marks)

10 (a) The melting points of some Group 1 elements are listed in **Table 1.**

Table 1

	Na	**K**	**Rb**
Melting point / °C	98	63	

Predict, with a reason, the melting point of Rb.

....

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(3 marks)

(b) Explain why ammonia, NH_3, is a gas at room temperature.

....

....

(2 marks)

(c) Phosphine (IUPAC name phosphane) is a hydride of phosphorus, with the formula PH_3. Phosphine has a much greater molar mass than ammonia.

Explain why phosphine has a significantly lower boiling point than ammonia.

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(3 marks)

(d) Identify the type of interaction that must be overcome when liquid hydrazine, N_2H_4, vaporizes. Suggest, with a reason, whether hydrazine has a lower or higher boiling point than diimide, N_2H_2.

....

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(2 marks)

11 (a) Carbonation is the process of increasing the concentration of carbonate ions in water to produce carbonated drinks.

Identify the hybridisation of the central carbon atom.

....

(1 mark)

(b) Explain, with the use of diagrams, how there are three valid structures for the carbonate ion.

....

....

....

(3 marks)

(c) Describe the distribution of pi (π) electrons and explain how this can account for the structure and stability of the carbonate ion, CO_3^{2-}.

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(3 marks)

12 (a) Draw the structure of silicon dioxide and state the type of bonding present.

....

....

(2 marks)

(b) Describe the similarities and differences you would expect in the properties of silicon and diamond.

....

....

....

(3 marks)

(c) The boiling point of diamond is 3550 ℃, but for carbon dioxide it is -78.5 ℃. Both are covalent substances.

Explain this difference with reference to structure and bonding.

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(4 marks)

(d) Silicon dioxide has a similar name to carbon dioxide, but its boiling point is 2230 ℃.

Briefly outline the reason for this difference.

....

....

(2 marks)

13 (a) In 1996 the Nobel prize in Chemistry was awarded for the discovery of a new carbon allotrope, known as fullerenes.

Outline the structure of buckminsterfullerene.

(2 marks)

(b) Like carbon dioxide, graphite is also a covalent substance, but it is a solid at room temperature. Graphite has a melting point of around 3600 ^{o}C.

Describe the structure and bonding of graphite and explain why it has such a high melting point.

(5 marks)

(c) Graphite is made purely of carbon, a non-metal, yet it conducts electricity. Diamond, which is also made purely of carbon, cannot conduct electricity.

i) Explain this difference in electrical conductivity between graphite and diamond.

[3]

ii) Give one other difference in the properties of graphite and diamond.

[1]

(4 marks)

(d) Graphite is soft and so is used as a lubricant, whereas diamond is hard and so is used in many cutting tools. Both are giant covalent structures.

Explain this difference with reference to structure and bonding.

(4 marks)

14 (a) The Valence Shell Electron Pair Repulsion Theory (VSEPR) is used to predict the shapes of many chemical molecules.

Describe the main features of the VSEPR theory for predicting shapes of molecules.

(3 marks)

(b) State and explain the bond angle F-O-F in OF_2.

(3 marks)

(c) Deduce whether each of the three molecules oxygen difluoride, OF_2, phosphorus trifluoride, PF_3, and boron trichloride, BCl_3, are polar or non-polar.

Give a reason in each case.

(3 marks)

(d) Predict and explain the shapes and bond angles of the following molecules:

i) BF_3

[2]

ii) NBr_3

[2]

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(4 marks)

15 (a) Ethene, C_2H_4, and hydrazine, N_2H_4, are hydrides of adjacent elements in the periodic table.

State and explain the H C H bond angle in ethene and the H N H bond angle in hydrazine.

(5 marks)

(b) Hydrazine can be oxidised to form diimide, which is a useful compound used in organic synthesis.

Deduce the molecular geometry of diimide, N_2H_2, and estimate its H–N–N bond angle.

(2 marks)

(c) Explain whether ethene and hydrazine are polar or non-polar.

(4 marks)

(d) Hydrazine forms a cation with an ethane-like structure called hydrazinediium, $N_2H_6^{2+}$.

Predict the value of the H–N–H bond angle in $N_2H_6^{2+}$.

(1 mark)

16 (a) Draw the resonance structures for the following ions:

i) Methanoate, $HCOO^-$.

[1]

ii) Nitrate(III), NO_2^-.

[1]

....

....

(2 marks)

(b) Deduce the resonance structures of the carbonate ion, giving the shape and the oxygen-carbon-oxygen bond angle.

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(3 marks)

(c) In December 2010, researchers in Sweden announced the synthesis of N,N–dinitronitramide, $N(NO_2)_3$. They speculated that this compound, more commonly called trinitramide, may have significant potential as an environmentally friendly rocket fuel oxidant.

Deduce the N–N–N bond angle in trinitramide and explain your reasoning.

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(3 marks)

(d) Predict, with an explanation, the polarity of the trinitramide molecule.

(2 marks)

Hard Questions

1 (a) Silver chloride, AgCl, is a chloride compound that has uses in photography films as well as having antiseptic properties.

Silver chloride has a high melting point and a structure similar to sodium fluoride.

Explain why, with reference to structure and bonding, why silver chloride has such a high melting point.

(3 marks)

(b) Cyanide is a fast-acting chemical, which can be found in various forms and can have toxic effects on the body.

Draw the Lewis structure for a CN^- ion.

Show the outer electrons only.

(1 mark)

(c) Aluminium chloride, Al_2Cl_6, does not conduct electricity when molten but aluminium oxide, Al_2O_3, does.

Explain this in terms of the structure and bonding of the two compounds.

(4 marks)

2 (a) State why magnesium and oxygen form an ionic compound while carbon and oxygen form a covalent compound.

....

(1 mark)

(b) Explain why the melting point of phosphorus(V) oxide is lower than that of sodium oxide in terms of their bonding and structure.

....

....

(2 marks)

(c) N, N–dinitronitramide $N(NO_2)_3$, also known as trinitramide, has been identified as a potentially more environmentally friendly rocket fuel oxidant.

Using Section 11 of the data booklet, outline how the length of the bond between nitrogen atoms in trinitramide compares with the bond between nitrogen atoms in nitrogen gas, N_2.

....

....

(2 marks)

3 (a) Draw a diagram to show the resonance structure in a molecule of benzene.

....

....

(2 marks)

(b) The energy change for hydrogenation of cyclohexene is -120 kJ mol^{-1}. However, when benzene undergoes hydrogenation, the energy change is 152 kJ mol^{-1} less than expected.

Use this data to explain the relative stabilities of benzene and the theoretical cyclohexa-1,3,5-triene molecule.

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(3 marks)

With reference to bonding and hybridisation, describe the structure of benzene.

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(c) **(4 marks)**

4 (a) Silicon can form silicon tetrachloride $SiCl_4$ and also silicon hexachloride, $SiCl_6^{2-}$.

i) Draw the Lewis structure for $SiCl_4$ and $SiCl_6^{2-}$.

[2]

ii) Use VSEPR theory to deduce the Cl-Si-Cl bond angles in both the $SiCl_4$ and $SiCl_6^{2-}$ molecules.

[2]

iii) Predict the molecular geometry of each molecule.

[2]

(6 marks)

(b) Deduce which, if any, of $SiCl_4$ and $SiCl_6^{2-}$, are polar molecules and explain your choice.

(2 marks)

5 Deduce the number of carbons with a tetrahedral geometry in both the monomer, isoprene, and the repeating unit of the polymer, polyisoprene.

(2 marks)

6 (a) One interhalogen compound is IF_5.

i) Draw the Lewis structure for IF_5.

[1]

ii) Use VSEPR theory to deduce the bond angles in IF_5.

[1]

iii) Predict whether IF_5 will be a polar molecule and explain your choice.

[2]

....

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....

(4 marks)

(b) Iodine can also form the triiodide ion, I_3^-.

i) Draw the Lewis structure for I_3^-.

[1]

ii) Use VSEPR theory to deduce the bond angles in I_3^-.

[1]

iii) Explain the position of the lone pairs on the central iodine.

[2]

....

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(4 marks)

7 (a) Explain why methanol is soluble in water.

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(3 marks)

(b) Methanol, ethanol and propan-1-ol are all primary alcohols. Describe and explain the trend in their melting points shown below.

Alcohol	Methanol CH_3OH	Ethanol C_2H_5OH	Propan-1-ol C_3H_7OH
Melting point / °C	-97	-114	-126

....

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(4 marks)

(c) These longer primary alcohols have the following melting points:

Alcohol	C_4H_9OH	$C_5H_{11}OH$	$C_6H_{13}OH$	$C_7H_{15}OH$	$C_8H_{17}OH$	$C_9H_{19}OH$	$C_{10}H_{21}OH$
Melting point / °C	-90	-79	-52	-34	-16	-6	6

Describe and explain this trend.

(4 marks)

(d) Predict, with a reason, whether ethanol or ethane-1,2-diol will have the higher melting point?

(2 marks)

8 (a) C_2H_6, C_4H_{10} and C_3H_8 are alkanes.

i) Put them in order of increasing boiling point and explain your answer. [3]

ii) Put them in order of increasing volatility and explain your answer. [3]

(6 marks)

Predict, with a reason, whether the alkanes are soluble in water and propanone.

(b) **(5 marks)**

(c) Pentane can exist as isomers, including pentane, $CH_3CH_2CH_2CH_2CH_3$ and 2,2-dimethylpropane, $CH_3C(CH_3)_2CH_3$.

i) Draw skeletal formula for each isomer shown above. [2]

ii) Predict and explain which isomer of pentane would have the greater volatility. [3]

(5 marks)

(d) There are two isomers possible with the molecular formula C_2H_6O.

i) Draw the skeletal formulae of both isomers

[2]

ii) Identify the strongest type of intermolecular force present in each isomer

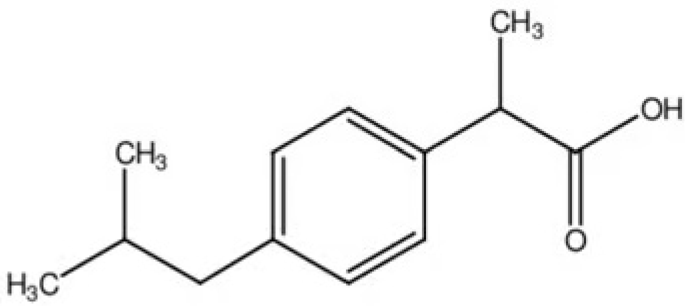
[2]

iii) Predict which isomer would have the higher melting point

[1]

(5 marks)

9 Ibuprofen is a common non-steroidal anti-inflammatory drug (NSAID). It contains a benzene ring and a carboxylic acid at the end of one of the branches.



Deduce the number of resonance structures possible in the deprotonated form of ibuprofen.

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(1 mark)

10 (a) A simple amide is $HCONH_2$.

Draw the Lewis (electron dot) structure for this molecule.

(2 marks)

(b) Predict and explain the bond angle around the C and N atoms.

(6 marks)

(c) Predict the molecular geometry and the electron domain geometry around the C and N in $HCONH_2$.

(4 marks)

(d) State, with a reason, whether $HCONH_2$ is a polar molecule.

(3 marks)

11 (a) Tetrafluoroethene, C_2F_4, and tetrafluorohydrazine, N_2F_4, are fluorides of adjacent elements in the Periodic Table.

Draw the Lewis (electron dot) structures for C_2F_4 and N_2F_4 showing all valance electrons.

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(2 marks)

(b) Predict and explain the F-C-F bond angle in tetrafluoroethene and the F-N-F bond angle in tetrafluorohydrazine.

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(5 marks)

(c) Tetrafluorohydrazine is a polar molecule but tetrafluoroethene is not.

Explain the difference in molecular polarity.

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(4 marks)

12 (a) Draw the Lewis (electron dot) structure of the carbonate ion, CO_3^{2-}.

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(3 marks)

(b) Deduce the number of possible resonance structures for the carbonate ion, CO_3^{2-}, and draw two of them.

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(3 marks)

(c) Discuss how the bonding in the carbonate ion, CO_3^{2-}, evidences the presence of the resonance structures.

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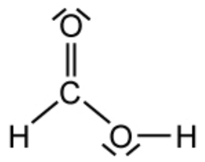
(3 marks)

(d) Organic molecules can also show resonance. The methanoate ion, $HCOO^-$, shows similar resonance forms to the carbonate ion, CO_3^{2-}.

The corresponding organic acid, methanoic acid, also has resonance structures.



Draw another resonance structure of methanoic acid.

(2 marks)

13 (a) Some of the physical and structural properties of diamond and graphite are shown below:

Property	Diamond	Graphite
Melting Point at 1 atmosphere / K	4200	4300
Density / g cm^{-3}	3.51	2.26
Average bond length / nm	0.155	0.142
Delocalisation	No	Yes
Hybridisation	sp^3	sp^2
Electron mobility / cm^2 V^{-1} s^{-1}	1000 - 2000	15000 - 200000

Suggest why the melting point of graphite is higher than that of diamond, using the information in the table.

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(2 marks)

(b) Graphene has the structure of a single layer of graphite.

Suggest, giving a reason, the electron mobility of graphene compared to graphite.

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(2 marks)

(c) Graphite is a layered giant structure, containing London dispersion forces between the layers, whereas diamond has covalent bonds across all planes.

Describe and explain, based on structure and bonding, the differences expected when each of graphite and diamond are moved across a paper surface.

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(6 marks)