IB · DP · Chemistry

2 hours 13 questions

Structured Questions: Paper 2

4.1 Ionic & Covalent Bonding

4.1.1 Forming Ions / 4.1.2 Ionic Compounds / 4.1.3 Formulae & Names of Ionic Compounds / 4.1.4 Covalent Bonds / 4.1.5 Bond Polarity / 4.1.6 Lewis Structures / 4.1.7 Resonance Structures / 4.1.8 Shapes of Molecules / 4.1.9 Predicting Molecular Shapes / 4.1.10 Molecular Polarity / 4.1.11 Giant Covalent Structures / 4.1.12 Types of Intermolecular Forces / 4.1.13 Deducing Intermolecular Forces / 4.1.14...

Easy (4 questions)	/21
Medium (5 questions)	/53
Hard (4 questions)	/40
Total Marks	**/114**

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Easy Questions

1 (a) Describe the nature of ionic bonding.

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(1 mark)

(b) State the type of bonding in potassium chloride which melts at 1043 K.

.....

(1 mark)

(c) Describe the structure and bonding in solid magnesium oxide.

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(2 marks)

(d) Outline why solid magnesium chloride does not conduct electricity.

.....

(1 mark)

2 (a) Predict whether phosphorus(V) oxide and sodium oxide conduct electricity in their solid and molten states. Complete the boxes with "yes" or "no".

	Phosphorus(V) oxide	**Sodium oxide**
Solid state		
Molten state		

(2 marks)

(b) State the formula of the compounds formed between the elements below.

i) Sodium and sulfur:

ii) Magnesium and phosphorus:

(2 marks)

(c) Describe the covalent bond present in a chlorine molecule and how it is formed.

(2 marks)

(d) Draw the Lewis (electron dot) structure of chloromethane.

(1 mark)

3 (a) Using section 8 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 10 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 11 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)

(d) CO contains three covalent bonds, one of which is a coordinate bond.

Describe how a coordinate bond arises in CO.

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(1 mark)

4 (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.

.....

.....

(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)

(d) Explain why boron trichloride is able to form coordinate (covalent) bonds with other molecules.

.....

(1 mark)

Medium Questions

1 (a) Calcium sulfide is an ionic solid that is phosphorescent and glows in the dark after a light source is removed.

i) Describe the nature of the bonding in calcium sulfide.

ii) State one physical property of calcium sulfide.

(2 marks)

(b) Suggest why the melting point of calcium sulfide is much higher than that of elemental calcium or sulfur.

(3 marks)

(c) Calcium sulfide has a lattice structure similar to sodium chloride.

Describe the lattice structure of calcium sulfide and draw a representative 3D diagram.

Label each ion and use different size spheres to distinguish between the different types of ions present.

(4 marks)

(d) State the formula of calcium phosphate and calcium hydroxide.

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.....

(2 marks)

2 (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.

(ii) Carbon dioxide.

(iii) Boron trifluoride.

.....

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(3 marks)

(c) Using your answer to part (b), identify and explain the species that is likely to form a coordinate covalent bond.

.....

.....

(2 marks)

(d) Using your answer to part (c), Explain, with the help of a diagram, the covalent bond formed between the species in part (c) and ammonia.

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(3 marks)

3 (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 Table 7 of the Data Booklet to state and explain whether each of the following compounds are ionic or covalent:

ICl

$SrCl_2$

RbI

HI

.....

.....

(2 marks)

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

$$\mathbf{(NCOOH)_2\,(g) \rightarrow N_2H_2\,(g) + 2CO_2\,(g)}$$

Another useful compound of nitrogen is hydrazine, N_2H_4.

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

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(2 marks)

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

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(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 Table 8 of the Data Booklet to predict which bond in each of the following pairs is more polar:

(i) C–H or C–Cl

(ii) Si–Li or Si–Cl

.....

.....

(2 marks)

5 (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.

(ii) A non-polar double bond.

(iii) A non-polar triple bond.

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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.

(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 Table 8 of the Data Booklet to state and explain whether each of the following covalent compounds are polar or non-polar:

H_2

HC*l*

CO

(2 marks)

Hard Questions

1 (a) Magnesium fluoride is a white crystalline salt that has a giant ionic lattice structure.

State whether the following substances conduct electricity when solid or molten, and explain your answers in terms of the particles involved:

- magnesium
- magnesium fluoride
- boron tribromide

(5 marks)

(b) Sodium chloride and iodine are both solids. Sodium chloride does not melt until it reaches a temperature of 1074 K yet iodine sublimes when heated gently, giving off purple vapours. Sodium chloride will conduct electricity when molten and iodine is a very poor conductor of electricity.

State the type of crystal structure for each of iodine and sodium chloride.

(2 marks)

(c) Explain why iodine vaporises easily.

(2 marks)

(d) Explain the differences in the electrical conductivity of sodium chloride and iodine.

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(3 marks)

2 (a) The nitrate (V) ion, NO_3^-, is a polyatomic ion, bonded by covalent bonds.

The three oxygen atoms are bonded by one single covalent bond, one double covalent bond and one dative covalent bond.

Draw the Lewis structure for NO_3^-.

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(2 marks)

(b) An ionic compound has the empirical formula $H_4N_2O_3$.

Suggest the formulae of the ions present in this compound.

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(2 marks)

(c) The compounds SO_2 and MgO are both oxides but with different melting points as shown below.

Compound	**Melting point / ℃**
SO_2	-72
MgO	2852

Describe the bonding in, and the structure of, SO_2 and MgO and explain the difference in their melting points.

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(4 marks)

(d) Ammonia, NH_3, has the same crystalline structure as SO_2 and yet its melting point is 2°C. Explain the difference in melting point between SO_2 and NH_3.

(2 marks)

3 (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.

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(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) Ammonia, NH_3, and boron trifluoride, BF_3, react together to form NH_3BF_3. Each of the molecules NH_3 and BF_3 have different features of its electronic structure which allows them to bond together. Explain how the two molecules bond together and what type of bond is formed between NH_3 and BF_3.

You may use a labelled diagram to help you.

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.....

(3 marks)

(d) 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)

4 (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.

.....

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(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 10 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.

.....

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(2 marks)

(d) Describe the bonding within the carbon monoxide molecule.

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(2 marks)