IB · DP · Chemistry

3 hours | 13 questions

Structured Questions: Paper 2

4.2 Resonance, Shapes & Giant Structures

4.2.1 Resonance Structures / 4.2.2 Shapes of Molecules / 4.2.3 Predicting Molecular Shapes / 4.2.4 Molecular Polarity / 4.2.5 Giant Covalent Structures

Easy (4 questions)	/51
Medium (5 questions)	/61
Hard (4 questions)	/49
Total Marks	**/161**

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Easy Questions

1 (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]

(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]

(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 8 of the Data booklet.

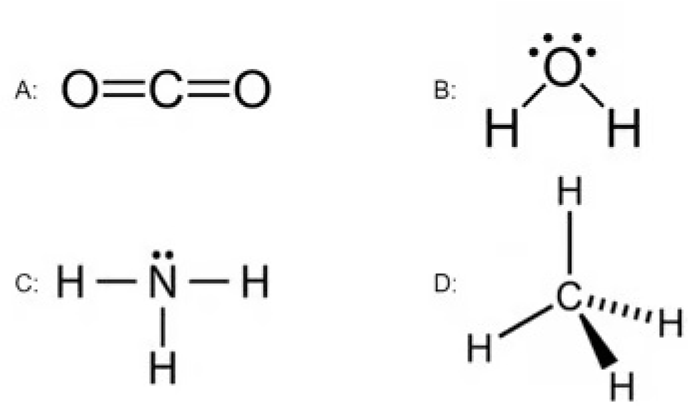
(4 marks)

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

Explain why PCl_4^+ is not a polar molecule.

(2 marks)

2 (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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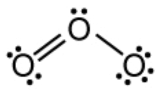
(3 marks)

(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)

3 (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.

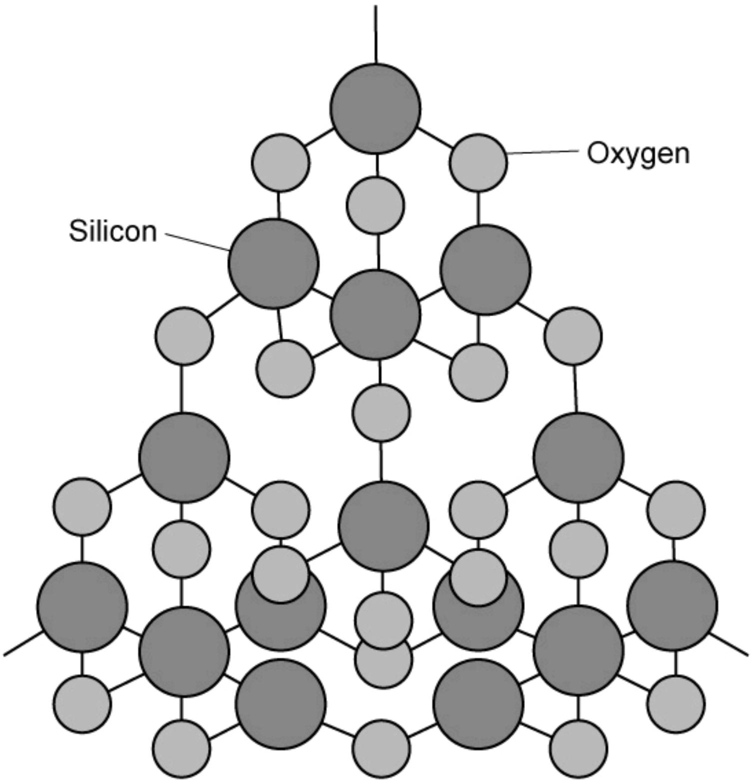
(4 marks)

(d) Graphene can be made from graphite.

Describe a similarity and difference between these two structures.

(2 marks)

4 (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 °C whilst carbon dioxide has a melting point of -78 °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) Draw the structure of silicon dioxide and state the type of bonding present.

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(2 marks)

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

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(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.

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(2 marks)

2 (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.

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(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.

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(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.

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

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(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)

3 (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.

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(3 marks)

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

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(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.

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(3 marks)

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

i) BF_3

ii) NBr_3

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(4 marks)

4 (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.

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(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.

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(2 marks)

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

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(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)

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

i) Methanoate, $HCOO^-$.

ii) Nitrate(III), NO_2^-.

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(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.

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(2 marks)

Hard Questions

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

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

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(2 marks)

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

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(6 marks)

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

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(4 marks)

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

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(3 marks)

2 (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.

(2 marks)

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

(5 marks)

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

Explain the difference in molecular polarity.

(4 marks)

3 (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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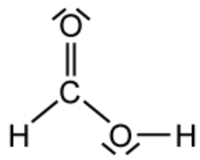
(3 marks)

(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)

4 (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) Predict the bond order in both diamond and graphite.

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(2 marks)

(c) 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)

(d) 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)