IB · DP · Chemistry

2 hours 13 questions

Structured Questions: Paper 2

14.1 More Structures & Shapes

Easy (4 questions)	/31
Medium (5 questions)	/45
Hard (4 questions)	/51
Total Marks	**/127**

Scan here to return to the course
or visit savemyexams.com

Easy Questions

1 (a) Two types of covalent bond are sigma and pi bonds.

i) Describe how a sigma (σ) bond is formed

[1]

ii) Describe how a pi (π) bond is formed

[1]

(2 marks)

(b) Describe the difference in the location of the electron dense regions in sigma (σ) and pi (π) bonds.

(2 marks)

(c) Deduce the number of sigma (σ) and pi (π) bonds in methane, CH_4.

(2 marks)

(d) Deduce the number of sigma (σ) and pi (π) bonds in oxygen, O_2.

(2 marks)

2 (a) Sulfur can form bonds with six fluorine atoms to form sulfur hexafluoride, SF_6.

i) How many electrons are in the outer shell of the sulfur in SF_6?

[1]

ii) State the minimum and maximum numbers of electrons possible in the outer shell of sulfur.

[1]

(2 marks)

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

(1 mark)

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

(1 mark)

(d) 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]

(3 marks)

3 (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.

....

....

(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)

(d) The formal charge on an atom can be calculated by the following:

FC = (Number of valence electrons) - ½(Number of bonding electrons) - (Number of non-bonding electrons)

Calculate the formal charge on the xenon and the fluorines in xenon tetrafluoride, XeF_4.

....

....

(2 marks)

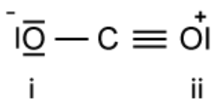
4 (a) Draw a Lewis (electron dot) structure for carbon dioxide, CO_2.

(2 marks)

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

(2 marks)

(c) An alternative way to draw the carbon dioxide molecule is:



Identify the formal charge on each of the oxygen atoms.

(2 marks)

(d) State which of the Lewis structures, that from part a) or part c), is preferable and explain your choice.

(2 marks)

Medium Questions

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

(2 marks)

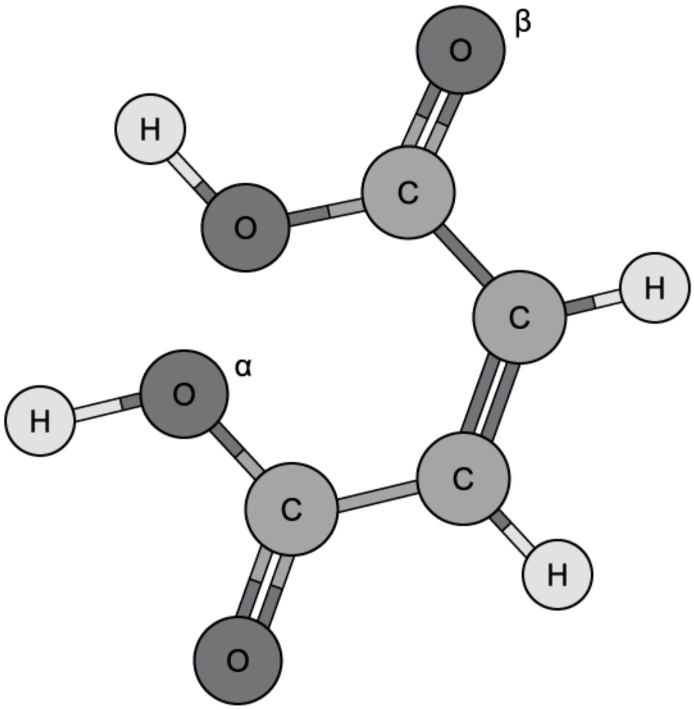
(c) c) Explain why both phosphorus tribromide and sulfur tetrafluoride are polar.

(2 marks)

(d) d) Compare the formation of a sigma (σ) and a pi (π) bond between two carbon atoms in a molecule.

(2 marks)

2 (a) a) But-2-ene-1,4-dioic acid exists as both cis and trans isomers. The cis isomer is shown below



Describe the type of covalent bond between carbon and hydrogen in the molecule shown above and how it is formed.

....

....

(2 marks)

(b) b) Identify how many sigma bonds and how many pi (π) bonds are present in cis but-2-ene-1,4-dioc acid.

....

....

(2 marks)

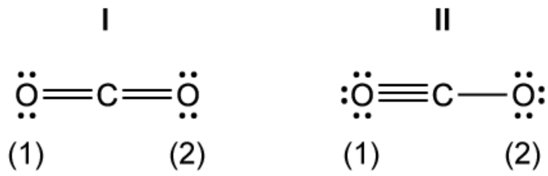
(c) c) Draw the Lewis structures, predict the shape and deduce the bond angles for xenon tetrafluoride.

(3 marks)

(d) d) Compare the polarity of xenon tetrafluoride with chlorine trifluoride.

(3 marks)

3 **(a)** a) Carbon dioxide can be represented by at least two resonance structures, **I** and **II**.



Calculate the formal charge on each oxygen atom in the two structures.

Structure	**I**	**II**
O atom labelled (1)		
O atom labelled (2)		

....

....

(2 marks)

(b) b) Deduce, giving a reason, the more likely resonance structure from part a)

....

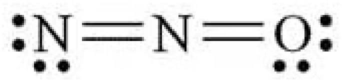
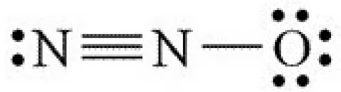
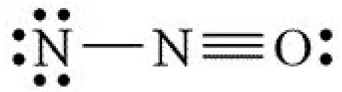
....

(2 marks)

(c) c) Nitrous oxide can be represented by different Lewis (electron dot) structures.

Deduce the formal charge (FC) of the nitrogen and oxygen atoms in three of these Lewis (electron dot) structures, **A**, **B** and **C**, represented below.

LHS: atom on the left-hand side; RHS: atom on the right-hand side

	Lewis (electron dot) structure	FC of O on LHS	FC of central N	FC of N on RHS
A				
B				
C				

(3 marks)

(d) d) Based on the formal charges assigned in part c), deduce which Lewis (electron dot) structure of N_2O (A, B, or C) is the preferred.

Explain another factor that also must be taken into account in determining the preferred structure.

(3 marks)

4 (a) a) Use the concept of formal charge to explain why BF_3 is an exception to the octet rule.

(2 marks)

(b) b) 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.

(2 marks)

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

(2 marks)

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

(2 marks)

5 **(a)** a) Draw two different Lewis (electron dot) structures for SO_4^{2-}, one of which obeys the octet rule for all its atoms, the other which has an octet for S expanded to 12 electrons.

....

....

(2 marks)

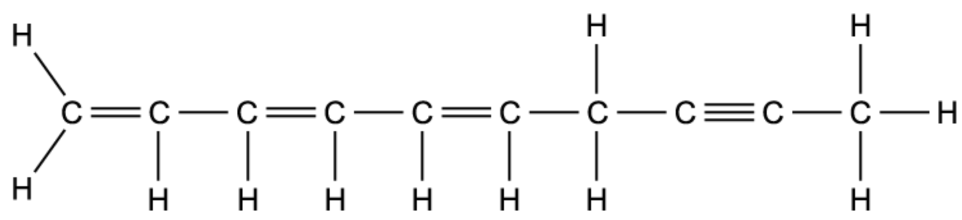
(b) b) Explain which of the two SO_4^{2-} structures is preferred using formal charges.

....

....

(2 marks)

(c) c) Consider the molecule shown below.



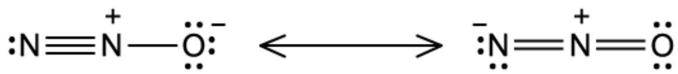
Identify the number of sigma and pi bonds in this molecule.

....

....

(2 marks)

(d) d) One of the intermediates in the reaction between nitrogen monoxide and hydrogen is dinitrogen monoxide, N_2O. This can be represented by the resonance structures below



Analyse the bonding in dinitrogen monoxide in terms of sigma and pi bonds.

(3 marks)

Hard Questions

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

Include the formal charges for each oxygen.

....

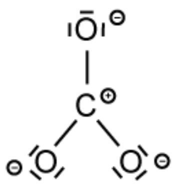
....

....

....

(4 marks)

(b) An alternative structure for the carbonate ion is proposed:



Explain why this structure is not accepted as another resonance structure for the carbonate ion.

....

....

(2 marks)

(c) Deduce the number of sigma (σ) and pi (π) bonds present in any of the resonance structures of the carbonate ions shown in part a).

....

....

(2 marks)

Deduce the bond order of the C-O bond in the carbonate ion, CO_3^{2-}.

(d) **(1 mark)**

2 (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) Carbon can form CCl_4 but cannot form CCl_6^{2-}. Explain why.

(3 marks)

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

(2 marks)

(d) Formal charge can be used to decide on the most stable, and therefore most likely, form a molecule can take. Resonance structures occur when more than one Lewis diagram describes a structure equally well.

i) Deduce the formal charge on the silicon and each chlorine within $SiCl_4$ and $SiCl_6^{2-}$ [2]

ii) Predict which will be the most stable molecule and explain your answer. [2]

iii) Predict if any resonance structures are possible for $SiCl_6^{2-}$ and explain your answer. [2]

....

....

....

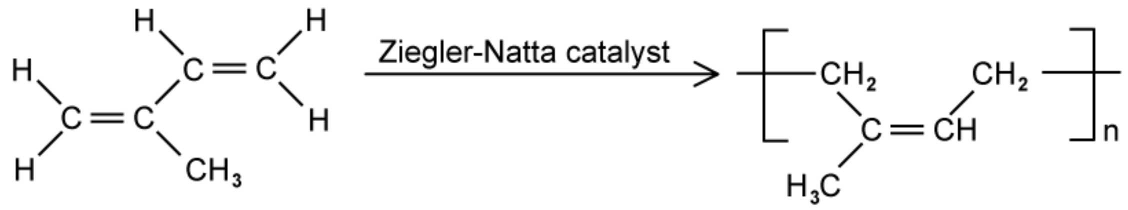
....

....

....

(6 marks)

3 (a) Natural rubber, polyisoprene, forms a flexible polymer in the following reaction:



Isoprene **Polyisoprene**

i) Deduce the number of sigma (σ) and pi (π) bonds in the monomer.

[2]

ii) Deduce the number of sigma (σ) and pi (π) bonds in the repeating unit.

[2]

....

....

....

....

(4 marks)

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

....

....

(2 marks)

(c) Polymer formation involves a radical intermediate to lengthen the polymer chain.

The radical in the formation of polyisoprene is shown below, where X represents the existing chain:

$$X\text{-}CH_2CCH_3CHCH_2$$

i) Identify the atom that is the radical in the structure shown.

[1]

ii) Deduce the formal charge on the radical atom.

[1]

iii) Use the information above, and your knowledge of structure and bonding, to predict if the structure is stable or not.

[2]

....

....

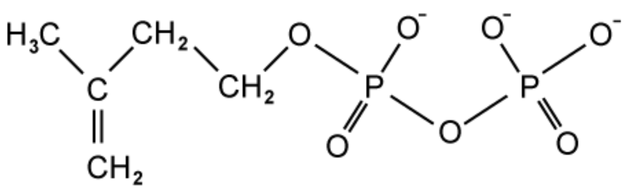
....

....

(4 marks)

(d) Isoprene is not produced directly by the rubber tree, but is the product of a series of biochemical reactions from the isopentenyl pyrophosphate molecules present in the tree.

The structure of isopentenyl pyrophosphate is shown below:



Deduce the number of sigma (σ) and pi(π) bonds present in one molecule of isopentenyl pyrophosphate.

(2 marks)

4 (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]

(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]

(4 marks)

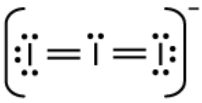
(c) Deduce the formal charge on each of the iodine atoms in the triiodide molecule, I_3^-.

....

....

(2 marks)

(d) An alternative Lewis structure for the triiodide ion, I_3^-, is suggested:



Deduce the formal charges and use them to suggest if the structure is stable and likely to occur.

....

....

....

(3 marks)