IB · DP · Chemistry

2 hours 13 questions

Structured Questions: Paper 2

14.2 Further Aspects of Bonding

Easy (4 questions)	/32
Medium (5 questions)	/54
Hard (4 questions)	/50
Total Marks	**/136**

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Easy Questions

1 (a) State what is meant by the term delocalisation of electrons.

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(1 mark)

(b) Delocalisation is common in some types of organic molecule.

i) Identify whether ethanoic acid, CH_3COOH, has delocalised π electrons.

[1]

ii) Identify where the ethanoate ion, CH_3COO^-, has delocalised electrons.

[1]

iii) Give a reason for your choices.

[1]

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(3 marks)

(c) Draw two resonance structures for the ethanoate ion, CH_3COO^-.

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(2 marks)

(d) Deduce the bond order of the C-O bonds in the ethanoate ion.

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(1 mark)

2 (a) Benzene, C_6H_6, has two resonance structures. Draw skeletal formulae of these two structures.

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(1 mark)

(b) Benzene is commonly drawn in the following manner:

Explain what this represents and why this is a useful way to draw benzene.

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(2 marks)

(c) Some of the sigma bonds in benzene are formed from hybrid orbitals. The type of hybridisation present is sp^2.

State which orbitals hybridise to form sp^2 orbitals.

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(2 marks)

(d) The sp^2 hybridized orbitals form sigma bonds in the benzene molecule. The delocalised electrons from pi bonds.

i) Deduce the number of sigma (σ) bonds in benzene.

[1]

ii) Deduce the number of pi (π) bonds in benzene.

[1]

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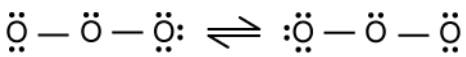
(2 marks)

3 (a) Ozone, O_3, forms two resonance structures, shown below:



i) Allocate formal charges to the oxygen atoms in the left-hand diagram.

[1]

ii) Deduce the bond order for the O-O bond in ozone.

[1]

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(2 marks)

(b) The bond order of oxygen, O_2, molecules is 2.

i) State which bonds are easier to break, those in oxygen or those in ozone.

[1]

ii) Compare the wavelengths of light needed to break the bonds in oxygen and ozone respectively

[1]

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(2 marks)

(c) Ozone, O_3, can react to form oxygen, O_2. Write an equation to show the overall equation for this depletion.

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(1 mark)

(d) A number of species can catalyse the depletion of ozone, O_3.

Write the molecular formulae for two catalysts of ozone depletion.

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(2 marks)

4 (a) Methane contains sp^3 hybridised orbitals.

i) Explain the formation of sp^3 hybridised orbitals.

[2]

ii) How many sp^3 hybridised orbitals are present in methane?

[1]

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(3 marks)

(b) Ethyne, C_2H_2, is another hydrocarbon, in this case containing sp hybrid orbitals.

i) Explain the formation of the sp hybrid orbitals in ethyne

[2]

ii) Deduce the number of sp hybrid orbitals in a molecule of ethyne.

[1]

iii) State if these sp hybrid bonds form sigma (σ) or pi (π) (bonds)

[1]

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(4 marks)

(c) Explain, using the concept of hybridisation, how the triple bond in ethyne, C_2H_2, forms.

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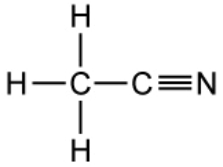
(2 marks)

(d) Ethanenitrile, CH_3CN, is an organic molecule with a tetrahedral molecular geometry around one carbon and a linear molecular geometry around the other carbon. The structure is shown below:



i) Identify how many sp^3 hybrid orbitals are present in this molecule.

[1]

ii) Identify how many sp hybrid orbitals are present in this molecule.

[1]

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(2 marks)

Medium Questions

1 (a) a) Harmful UV radiation from the Sun is absorbed by the ozone layer.

Explain how the bonding in O_2 and O_3 affects the wavelengths of UV light they absorb

(3 marks)

(b) b) The chemical balance of the stratosphere is disrupted by the presence of chlorofluorocarbons (CFCs) and other ozone-depleting compounds.

Describe, using equations, how CFCs contribute to ozone depletion using dichlorodifluoromethane and explain the initial step by reference to the bonds in the CFC.

(4 marks)

(c) c) Although the use of harmful CFCs is being phased out, suggest why these compounds are expected to remain in the atmosphere for the next 80 – 100 years.

(2 marks)

(d) d) Formulate two equations to show how nitrogen(II) oxide, NO, catalyses the destruction of ozone.

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(2 marks)

2 (a) a) Cyclohexane C_6H_{12} has a puckered, non-planar shape whereas benzene C_6H_6 is planar.

Explain this difference by making reference to the C–C–C bond angles and the type of hybridisation of carbon in each molecule.

(4 marks)

(b) b) Urea, $CO(NH_2)_2$, is present in solution in animal urine.

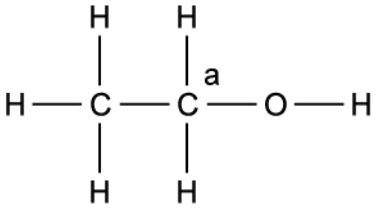
What is the hybridisation of C and N in the molecule, and what are the approximate bond angles?

(4 marks)

(c) c) Describe the hybridisation of the carbon atom in methane and explain how the concept of hybridisation can be used to explain the shape of the methane molecule

(4 marks)

(d) d) A molecule of ethanol is shown below.



Deduce the hybridisation of the carbon atom marked in the diagram below.

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(1 mark)

3 (a) 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.

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(1 mark)

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

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(3 marks)

(c) 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)

(d) d) Identify and explain the bond order of the carbonate ion.

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(2 marks)

4 (a) a) Explain how the concept of hybridisation can be used to explain the triple bond present in propyne.

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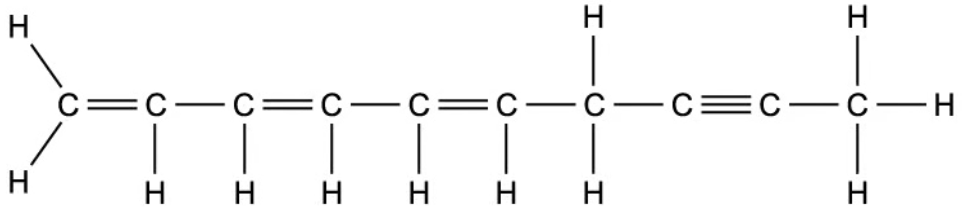
(3 marks)

(b) b) Consider the molecule below which contains both sigma and pi bonds.



How many carbon atoms exhibit sp^2 hybridisation in this molecule.

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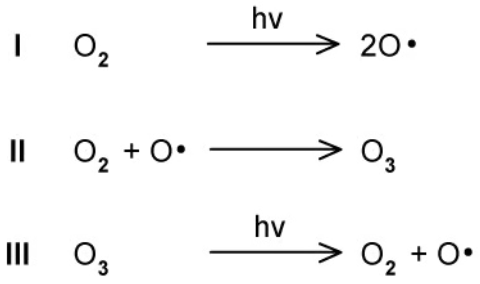
(1 mark)

(c) c) The concentration of ozone in the upper atmosphere is maintained by the following three reactions, **I**, **II** and **III**



Explain which reaction requires the most energy

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(4 marks)

(d) d) Deduce the hybridisation shown by the nitrogen atoms in NF_4^+, N_2H_2 and N_2H_4.

	NF_4^+	N_2H_2	N_2H_4
Hybridisation			

(3 marks)

5 (a) a) Sea spray is generated by the breaking of waves and releases bromine into the atmosphere.

Write two balanced equations to show how a bromine radical could cause the destruction of ozone.

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(2 marks)

(b) b) Explain why ozone can be dissociated by light with a longer wavelength than required to decompose oxygen.

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(3 marks)

(c) c) The two oxygen-oxygen bonds in ozone are in fact of equal length. Deduce why this is the case and how the length of these would compare to oxygen-oxygen bond lengths in hydrogen peroxide, H_2O_2, and in the oxygen molecule, O_2

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(2 marks)

(d) d) One CFC, Freon-13 (chlorotrifluoromethane), which can be used as a refrigerant, has been phased out by the Montreal Protocol.

Describe, using equations, the mechanism of the catalysis of ozone depletion by this particular CFC.

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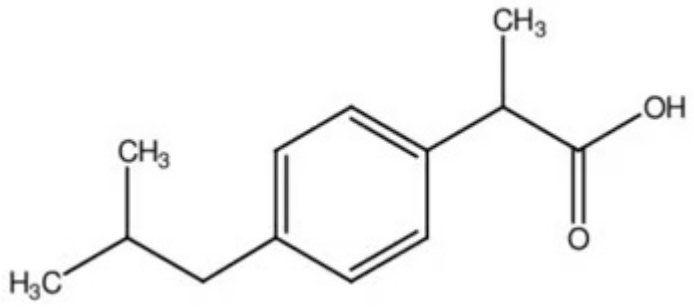
(3 marks)

Hard Questions

1 (a) 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)

(b) Deduce the number of:

i) Sigma (σ) bonds in ibuprofen

[1]

ii) Pi (π) electrons in ibuprofen

[1]

.....

.....

(2 marks)

(c) The ibuprofen molecule contains both sp^3 and sp^2 hybridised orbitals.

i) Identify how many sp^3 hybrid orbitals are present.

[1]

ii) Identify how many sp^2 hybrid orbitals are present.

[1]

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(2 marks)

(d) Explain why the benzene ring is a regular, planar hexagon.

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(3 marks)

2 (a) 2-hydroxypropanenitrile, $CH_3CHOHCN$, is a hydroxynitrile that can be formed from ethanal in a nucleophilic addition reaction.

Deduce the number of sigma (σ) and pi (π) bonds in a molecule of 2-hydroxypropanenitrile.

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(2 marks)

(b) Deduce the number of sp^3, sp^2 and sp hybrid orbitals in a molecule of 2-hydroxypropanenitrile.

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(3 marks)

(c) Describe how the concept of hybridisation can be used to explain the formation of the triple bond and C-C-N bond angle in 2-hydroxypropanenitrile.

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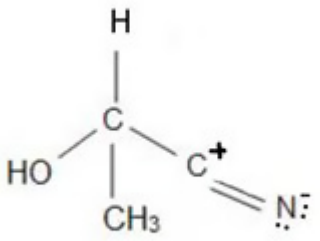
(5 marks)

(d) Explain why, despite the high electron density in the triple bond, the triple bonded nitrile group is a more stable structure than the following alternative Lewis structure:



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(3 marks)

3 (a) Predict whether ozone, O_3, is a polar or non-polar molecule. Explain your choice.

(4 marks)

(b) Ozone can be both formed and depleted by reactions with an oxygen radical, which is an oxygen atom.

Draw a diagram to support an explanation of why an oxygen atom is a radical.

(2 marks)

(c) Ozone can be made and depleted in reactions involving other forms of oxygen only.

i) Write one equation to show the natural formation of ozone in the atmosphere.

[1]

ii) Write two equations to show the steps in the natural depletion of ozone in the atmosphere.

[2]

(3 marks)

(d) For each of the equations in part c), deduce whether the reaction is endothermic or exothermic and explain your choices.

(6 marks)

4 (a) Trichlorofluoromethane is a banned CFC, as it can lead to accelerated ozone depletion.

Write equations to show the mechanism of catalysis of ozone depletion by trichlorofluoromethane.

(3 marks)

(b) It is possible for the chlorine radical to undergo a termination reaction where it joins with another organic radical available, and can reform the original molecule:

$$Cl^{\bullet}(g) + CCl_2F^{\bullet}(g) \rightarrow CCl_3F(g)$$

Explain why this is not a solution to the depletion of ozone.

(4 marks)

(c) CFCs have been replaced by other inert compounds, including FCs, which are fluorocarbons.

Explain why these do not pose a threat to ozone depletion.

(3 marks)

(d) Compounds containing iodine and carbon are usually broken down lower in the atmosphere, beneath the ozone layer. Suggest why iodocarbons are not popular alternatives to CFCs.

(4 marks)