

PAPER 3

Answer the following questions.

- 1 (a) Describe what is meant by the term *nucleon number*. [1]
- (b) State **two** ways in which the behaviour of electrons in an electric field differs from that of protons. [1]

(2010 P3 Q4a,b)

SECTION I PHYSICAL CHEMISTRY

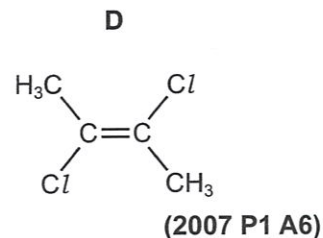
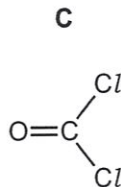
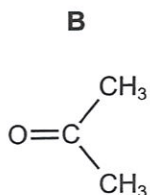
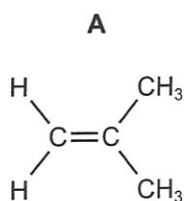
TOPIC 3 Chemical Bonding

PAPER 1

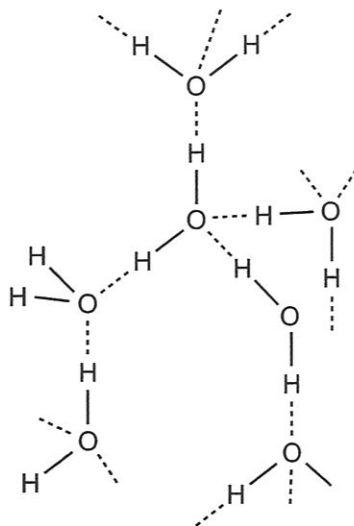
Section A

For each question there are four possible answers, A, B, C, and D. Choose the one you consider to be correct.

- 1 Which molecule has the largest dipole?



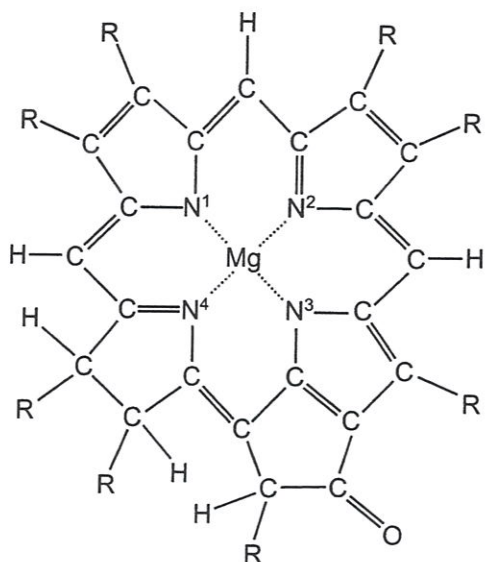
- 2 The diagram below shows the structure of part of a crystal of ice.



Which statement is correct?

- A** All the bond angles surrounding each oxygen atom are 120° .
- B** Four electrons from each oxygen are involved in forming hydrogen bonds.
- C** The hydrogen bonds, shown by the dotted lines, are stronger than the O–H covalent bonds.
- D** The open structure of ice causes ice to be denser than water. (2007 P1 A7)

- 3 Plants appear green due to the presence of chlorophyll. There are several closely related chlorophylls and the diagram shows a simplified version of one. The various different side-groups are all shown as R.



Note that the four N atoms and the Mg ion are planar.

Which of the descriptions of the bonds between Mg and the numbered N atoms is most likely to be correct?

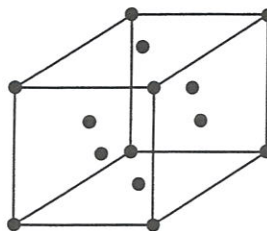
| | N atoms numbered | |
|---|------------------|-------------|
| | 1 and 3 | 2 and 4 |
| A | co-ordinate | ionic |
| B | co-ordinate | π |
| C | ionic | co-ordinate |
| D | π | co-ordinate |

(2008 P1 A6)

- 4 Copper and iodine are both shiny crystalline solids. The crystal structures of copper and iodine are both face-centred cubic. The diagram shows the arrangement of the particles in this type of crystal lattice.

What are the particles present in each lattice?

| | copper | iodine |
|---|---------|-----------|
| A | atoms | anions |
| B | atoms | atoms |
| C | cations | atoms |
| D | cations | molecules |



(2008 P1 A8)

- 5 Which feature is present in the ions carbonate, ethanoate, nitrate and phenoxide (phenate)?
- A all bond angles are 120°
 - B dative covalent bonds
 - C delocalised electrons
 - D hydrogen bonds
- (2009 P1 A5)
- 6 What is a property of a solution of dry hydrogen chloride in dry methylbenzene?
- A It has a pH less than 7.
 - B It is a non-conductor of electricity.
 - C It reacts with magnesium to give hydrogen.
 - D It reacts with anhydrous sodium carbonate to give carbon dioxide.
- (2009 P1 A6)
- 7 Predict the most likely bond angle at each nitrogen atom in di-imine, $\text{HN}=\text{NH}$.
- A 107°
 - B 118°
 - C 120°
 - D 180°
- (2009 P1 A19)
- 8 The gecko, a small lizard, can climb up a smooth glass window. The gecko has millions of microscopic hairs on its toes and each hair has thousands of pads at its tip. The result is that the molecules in the pads are extremely close to the glass surface on which the gecko is climbing.
- What is the attraction between the gecko's toe pads and the glass surface?
- A co-ordinate bonds
 - B covalent bonds
 - C ionic bonds
 - D van der Waals' forces
- (2010 P1 A4)
- 9 What value of the bond angles in the PH_3 molecule would the Valence Shell Electron Pair Repulsion theory predict?
- A 104°
 - B 107°
 - C 109°
 - D 120°
- (2010 P1 A5)

Section B

For each of the questions in this section, one or more of the three numbered statements 1 to 3 may be correct.

Decide whether each of the statements is or is not correct (you may find it helpful to put a tick against the statements that you consider to be correct).

The responses **A** to **D** should be selected on the basis of

| A | B | C | D |
|------------------------|--------------------------|--------------------------|-------------------|
| 1, 2 and 3 are correct | 1 and 2 only are correct | 2 and 3 only are correct | 1 only is correct |

No other combination of statements is used as a correct response.

13 Which systems contain delocalized electrons?

- 1 cyclohexene
- 2 graphite
- 3 sodium

(2007 P1 B31)

14 Carbon forms double bonds with each of the Group VI elements oxygen, sulphur and selenium. In each case, the double bond is polar.

In the molecules carbon dioxide (CO_2), carbonyl sulphide (COS) and carbonyl selenide (COSe), the polarities of these double bonds do not necessarily cancel.

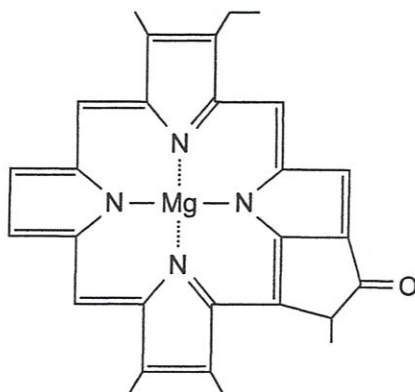
| | overall polarity of molecule |
|---------------|------------------------------|
| CO_2 | 0 |
| COS | 0.71 |
| COSe | 0.73 |

Which factors could account for these observations?

- 1 The C=S bond is more polar than the C=Se bond.
- 2 The C=O bond is more polar than the C=S bond.
- 3 The C=Se bond is more polar than the C=O bond.

(2008 P1 B31)

- 15 Which statements concerning the lattice structures of graphite and diamond are correct?
- 1 The C–C–C bond angle between nearest neighbours is smaller in diamond than in graphite.
 - 2 The shortest carbon-carbon bond occurs in diamond.
 - 3 All covalent bonds in diamond are of the same strength but those in graphite are not.
- (2009 P1 B32)
- 16 A simplified structure of a molecule of chlorophyll is shown.



The magnesium atom is situated in the centre of a planar arrangement of nitrogen atoms.

What does **this** structure suggest about the nature of the bonding around the magnesium atom?

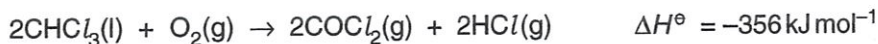
- 1 dative covalency
- 2 σ bonding
- 3 sp^3 hybridisation

(2010 P1 B32)

PAPER 2

Answer all the questions in the space provided.

- 1 Trichloromethane, CHCl_3 , formerly known as chloroform, was used as an anaesthetic in surgery. One reason for it not being used today is that it naturally oxidises to phosgene, COCl_2 , which is highly toxic.



In phosgene, the carbon atom is in the centre of the molecule and is attached to both chlorine atoms and to the oxygen atom.

- (a) Draw a 'dot-and-cross' diagram of the phosgene molecule.

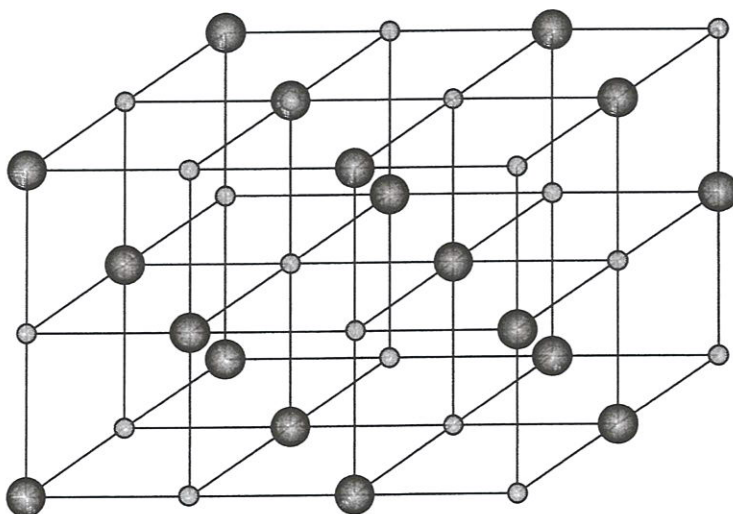
- (b) Suggest the size of the $\text{Cl}-\text{C}-\text{Cl}$ bond angle in the COCl_2 molecule.

.....

[3]

(2007 P2 Q4c)

- 2 In the crystal lattice of sodium and potassium chlorides, the co-ordination number of each ion is 6. In the crystal lattice of caesium chloride, CsCl , the co-ordination number has a different value.



Crystal lattice of sodium chloride

- (a) Suggest what is meant by the term *co-ordination number* when used to refer to a crystal lattice.

.....
.....

- (b) Suggest an explanation for the co-ordination number in the CsCl lattice being different from those in NaCl and KCl .

.....
.....
.....

[3]

(2009 P2 Q1d)

- 3 Phosphorus(V) chloride dissolves in some polar solvents without reaction and such solutions conduct electricity. This is due to the presence of the two ions $[\text{PCl}_4]^+$ and $[\text{PCl}_6]^-$.

Draw the structure and suggest the shape of **each** of these ions.



[3]

(2011 P2 Q2b)

PAPER 3

Answer the following questions.

- 1 (a) Describe the requirements needed for two molecules to form a hydrogen bond between them, illustrating your answer with a suitable example.
- (b) The first four members of the series of carboxylic acids represented by the general formula $\text{H}-(\text{CH}_2)_n-\text{CO}_2\text{H}$ ($n = 0, 1, 2, 3\dots$) are fully soluble in water, but as the value of n increases from 4 upwards, the acids become increasingly insoluble.

By considering the relevant interactions between the molecules of the carboxylic acids with each other, and also with the solvent, suggest reasons for this decreasing solubility.

[6]

(2007 P3 Q5a)

- 2 (a) Draw dot-and-cross diagrams to show the bonding in the molecules of NO_2 and O_3 .

Each molecule contains a dative covalent bond.

In the NO_2 molecule the central atom is nitrogen.

In each case you should distinguish carefully between electrons originating from the central atom and those from the two outermost atoms.

Include all lone pairs in your diagrams.

- (b) Suggest a value for the bond angle in each of the above two molecules, giving reasons for your choice.
- (c) The compound FO_2 does not exist, but ClO_2 does.

By considering the possible types of bonding in the two compounds, suggest reasons for this difference. (Assume that the halogen atom occupies a central position in each of these molecules.)

[6]

(2010 P3 Q4c)

- 3 The halogens form many interhalogen compounds and ions, in which a halogen atom lower down the group is surrounded by atoms of halogens higher in the group. Two such species are the compound ClF_5 and the ion ICl_4^- .

Draw 'dot-and-cross' diagrams showing the electrons (outer shells only) in ClF_5 and ICl_4^- , and use the VSEPR (valence shell electron pair repulsion) theory to predict their shapes. You may find both a written description and a 3-dimensional sketch useful in your answer.

[4]

(2011 P3 Q1b)