Non-covalent bonding

Question Paper

Level	Pre U
Subject	Chemistry
Exam Board	Cambridge International Examinations
Topic	Non-covalent bonding-Chemical forces
Booklet	Question Paper

Time Allowed: **44 minutes**

Score: **/37**

Percentage: **/100**

Grade Boundaries:

1. **(a)** Fluorine forms simple molecular compounds with nearly all the non-metals.

(i) What is the name of the theory or model used to determine the shape of molecules?

.... [1]

(ii) Name the shape and give the bond angle in boron trifluoride.

name of shape ....

bond angle .... [2]

(b) Many non-metals form hypervalent compounds with fluorine.

(i) Explain what is meant by the term *hypervalent*.

....

.... [1]

(ii) IF_7 is a hypervalent compound.

Name the shape and give the bond angles in the molecule.

name of shape ....

bond angles .... and .... [3]

(iii) Unlike IF_7, BrF_7 is not known to exist. Suggest why IF_7 exists but BrF_7 does not.

....

.... [1]

(c) The trioxide of xenon, XeO_3, is simple molecular and hypervalent. It has three Xe=O double bonds and a lone pair on the xenon atom.

(i) Deduce and name the shape of an XeO_3 molecule.

.... [1]

(ii) In 2011 xenon dioxide, XeO_2, was synthesised for the first time (reported in the *Journal of the American Chemical Society*). Xenon dioxide exists as a polymer in which the oxygen atoms are bonded to xenon in a square planar arrangement.

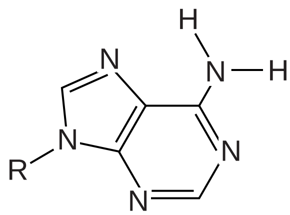
Work out the number of

- bonding electron pairs around each Xe atom, ...
- lone pairs around each Xe atom. .... [2]

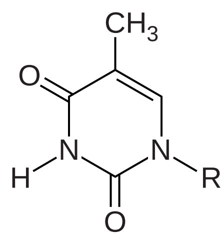
(d) Hydrogen-bonding is the interaction that holds the two strands of DNA together through its purine and pyrimidine bases.

(i) The structures of adenine and thymine are shown below (R indicates the DNA backbone).

Show both the hydrogen bonds linking these bases.



adenine

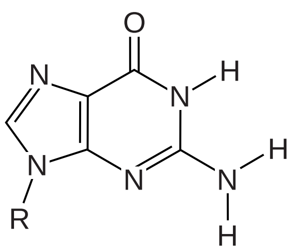


thymine

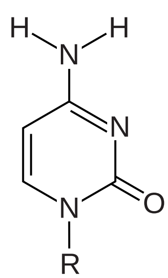
[2]

(ii) A Janus wedge is a molecule that can insert itself between a purine and a pyrimidine base in DNA using hydrogen-bonding interactions to each base. (It is named after the Roman god Janus who had two faces.)

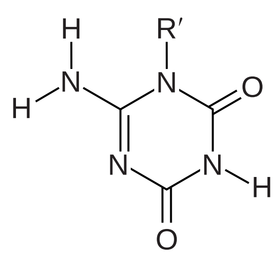
The structures of guanine, cytosine and a Janus wedge are shown. (R′ indicates the remainder of the Janus wedge structure.)



guanine



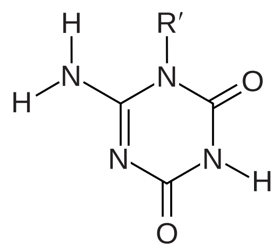
cytosine



Janus wedge

The guanine forms **three** hydrogen bonds with the Janus wedge, while the cytosine forms **two**.

Re-draw the guanine and cytosine on the next page, showing **all** the hydrogen bonds between the three molecules. The Janus wedge is drawn for you.



Janus
wedge

[3]

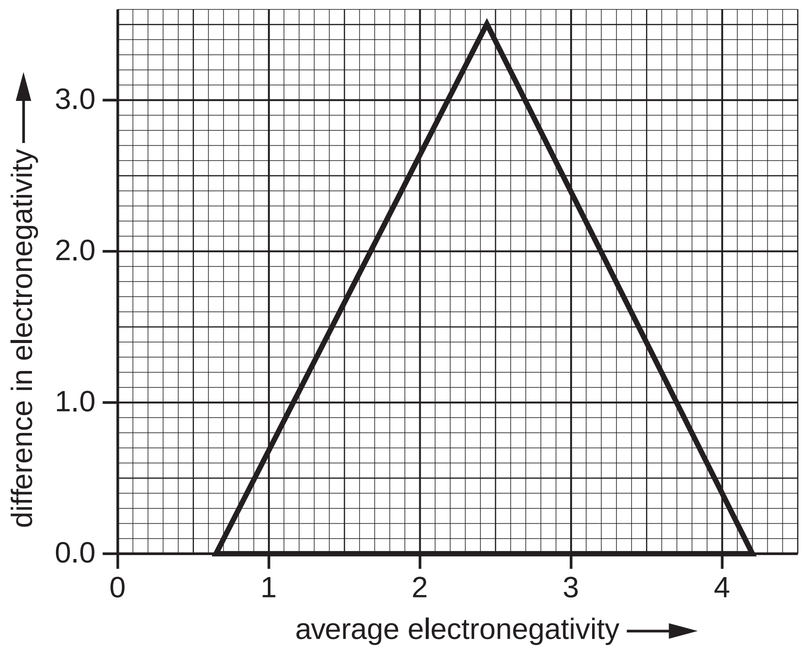
[Total: 16]

2. **(a)** Binary compounds such as cadmium sulfide, CdS, can be used to improve the efficiency of catalysts. The electronegativity values of cadmium and sulfur are shown in Table 3.1.

Table 3.1

element	electronegativity
cadmium	1.52
sulfur	2.59

(i) Plot the position of CdS on the van Arkel triangle below.



[1]

(ii) Circle the option that best describes the bonding in CdS.

ionic **covalent** **met**

intermediate ionic-metallic **covalent-ionic**

intermediate covalent-metallic **covalent-ionic-metallic**

[1]

(b) Some bacteria can oxidise methane to carbon dioxide in the absence of oxygen. It has recently been reported that the mechanism involves a reaction between methane and nitrite ions in acidic conditions (reported in *Nature*, 2010).

The half-equation for the oxidation of methane is:

$$CH_4 + 2H_2O \rightarrow CO_2 + 8H^+ + 8e^-$$

(i) Write a half-equation for the reduction of NO_2^- in acidic conditions to give N_2.

.... [2]

(ii) By combining the half-equations, or otherwise, balance the overall equation shown below.

......CH_4 + ...NO_2^- + ...H^+ $\rightarrow$ ......CO_2 + ...N_2 + ...H_2O [1]

(iii) The oxidation of methane by nitrite ions is thermodynamically favourable but will not occur under standard laboratory conditions. Suggest briefly the role of bacteria in this reaction.

....

.... [1]

(c) Molybdenum can form many complex oxy-ions. It has been reported that a complex molybdenum oxyanion can self-assemble to a large doughnut-shaped structure with a 3.6 nm diameter (reported in *Science*, 2010). The oxyanion unit has the formula $[Mo_{36}O_{112}(H_2O)_{16}]^{8-}$.

(i) Calculate the oxidation state of molybdenum in this oxyanion unit.

[1]

(ii) Give the empirical formula of the oxyanion unit.

.... [1]

[Total: 8]

3 The compound whose bonding most resembles pure ionic bonding is caesium fluoride.

(a) Write down the formula of caesium fluoride.

.... [1]

(b) Draw a dot-cross diagram to show the bonding in caesium fluoride. Show outer electrons only.

[2]

(c) Explain why caesium fluoride is the compound whose bonding most closely resembles pure ionic.

....

.... [1]

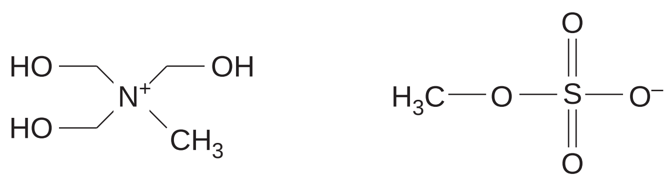
(d) Virtually all ionic compounds are solids at room temperature and pressure. However, researchers have designed ionic compounds whose ionic bonding is so weak that they are liquids under these conditions. Ionic liquids are often easy to handle as solvents as they are non-volatile; they have also recently found use in solar cells for this reason.

Explain what is meant by *non-volatile*.

.... [1]

(e) In the pure ionic bonding model, the ionic bond energy is proportional to the charge on each ion and inversely proportional to the distance between the charges, which are considered to be located at the centre of ions.

The structure of an ionic substance which is a liquid at room temperature and has been used in thermometers (reported in *Green Chemistry*, 2008) is shown below.



Suggest two features of these ions that account for the compound having such a low melting point.

1. ....

2. .... [1]

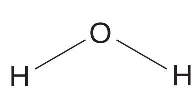
(f) Hydrogen-bonding is weaker than ionic or covalent bonding, but accounts for many important intermolecular attractions.

State two anomalous properties of water that are the result of hydrogen-bonding.

1. ....

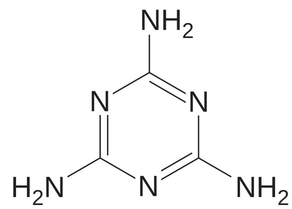
2. .... [2]

(g) Draw a second molecule of water and a hydrogen-bond between the two molecules. Indicate the bond angle around the hydrogen atom involved in the hydrogen-bond. Include all relevant lone pairs and dipoles.

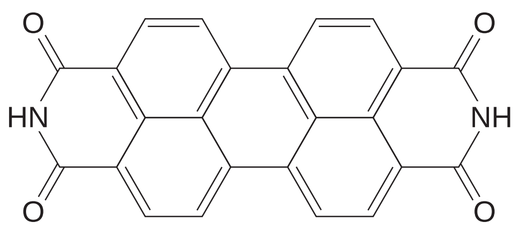


[3]

(h) Hydrogen-bonding is directional (i.e. a specific link between two atoms can be drawn) and has many applications in linking together molecules in an organised way. This linking has been put to use recently by researchers designing self-assembling surface networks for applications in nanotechnology (reported in *Nature*, 2008).



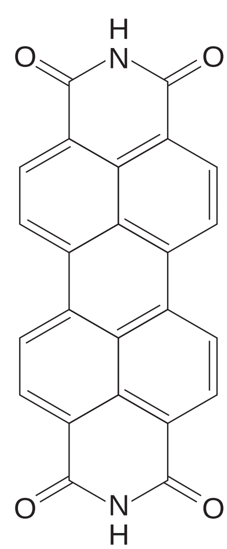
1,3,5-triazine-2,4,6-triamine (melamine)



perylene-3,4,9,10-tetracarboxylic diimide (PTCDI)

Fig. 3.1

The two molecules in Fig. 3.1 were chosen for the self-assembling network. A molecule of melamine and a molecule of PTCDI attach together strongly via three hydrogen bonds. Suggest where these **three** hydrogen-bonds form by drawing the melamine below in the correct orientation, with the hydrogen-bonds connecting the relevant atoms.



[2]

[Total: 13]