Chemical Bonding

(Past Year Topical Questions 2010-2015)

May/June 2010 (21)

1 Elements and compounds which have small molecules usually exist as gases or liquids.

(a) Chlorine, Cl_2, is a gas at room temperature whereas bromine, Br_2, is a liquid under the same conditions.

Explain these observations.

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..... [2]

(b) The gases nitrogen, N_2, and carbon monoxide, CO, are isoelectronic, that is they have the same number of electrons in their molecules.

Suggest why N_2 has a lower boiling point than CO.

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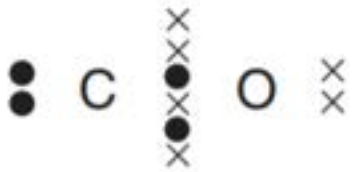
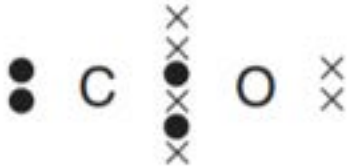
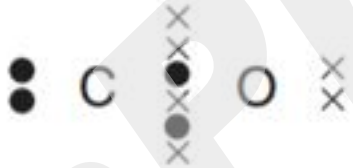
..... [2]

(c) A 'dot-and-cross' diagram of a CO molecule is shown below. Only electrons from outer shells are represented.



In the table below, there are three copies of this structure.
On the structures, draw a circle round a pair of electrons that is associated with **each** of the following.

(i) a co-ordinate bond	**(ii)** a covalent bond	(iii) a lone pair
		

[3]

(d) Hydrogen cyanide, HCN, is a gas which is also isoelectronic with N_2 and with CO. Each molecule contains a strong triple bond with the following bond energies.

bond	bond energy / kJ mol^{-1}
−C≡N in HCN	890
N≡N	994
C≡O	1078

Although each compound contains the same number of electrons and a strong triple bond in its molecule, CO and HCN are both very reactive whereas N_2 is not.

Suggest a reason for this.

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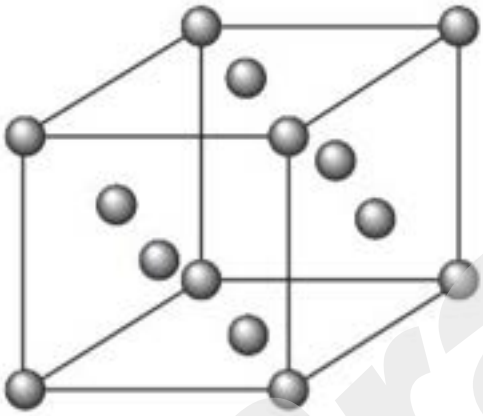
..... [1]

May/June 2010 (22)

2 Copper, proton number 29, and argon, proton number 18, are elements which have different physical and chemical properties.
In the solid state, each element has the same face-centred cubic crystal structure which is shown below.



The particles present in such a crystal may be atoms, molecules, anions or cations. In the diagram above, the particles present are represented by ●.

(a) Which types of particle are present in the copper and argon crystals?
In each case, give their formula.

element	particle	formula
copper		
argon		

[2]

At room temperature, copper is a solid while argon is a gas.

(b) Explain these observations in terms of the forces present in **each** solid structure.

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..... [4]

Although copper is a relatively unreactive element, when it is heated to a high temperature in an excess of chlorine, copper(II) chloride is formed.

When a mixture of argon and chlorine is heated to a high temperature, no reaction occurs.

(c) **(i)** How does chlorine behave in its reaction with copper?

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(ii) Suggest a reason for the lack of a reaction between argon and chlorine.

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[2]

The melting points of the noble gases neon to xenon are given below.

	Ne	Ar	Kr	Xe
melting point/K	25	84	116	161

(d) Explain why there is an increase in melting point from neon to xenon.

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..... [2]

May/June 2010 (23)/Q1

Hydrazine reacts with oxygen according to the following equation.

$$N_2H_4(l) + O_2(g) \rightarrow N_2(g) + 2H_2O(g)$$

(c) The bonding in hydrazine is similar to that in ammonia.

(i) Showing outer-shell electrons only, draw a 'dot-and-cross' diagram of an ammonia molecule.

(ii) Draw a diagram to show the three-dimensional shape of an ammonia molecule.

(iii) Draw a diagram to show the shape of a hydrazine molecule.
Show clearly which atom is joined to which and show clearly the value of **one** bond angle.

[4]

(d) Deduce the oxidation state of nitrogen in hydrazine.

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[1]

3 Astronomers using modern spectroscopic techniques of various types have found evidence of many molecules, ions and free radicals in the dust clouds in Space. Many of the species concerned have also been produced in laboratories on Earth.

Two such species are the dicarbon monoxide molecule, C_2O, and the amino free radical, NH_2.

(a) (i) Dicarbon monoxide can be produced in a laboratory and analysis of it shows that the sequence of atoms in this molecule is carbon-carbon-oxygen and there are no unpaired electrons, but one of the atoms is only surrounded by six electrons.

Draw a 'dot-and-cross' diagram of C_2O and suggest the shape of the molecule.

shape .....

(ii) What is meant by the term *free radical*?

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(iii) Explain why NH_2 is described as a 'free radical'.

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.....[5]

May/June 2011 (21)/Q2

One of the sulfur-containing compounds present in crude oil is ethanethiol, C_2H_5SH, the sulfur-containing equivalent of ethanol. Ethanethiol is toxic and is regarded as one of the smelliest compounds in existence.

(b) The boiling point of ethanol, C_2H_5OH, is higher than that of C_2H_5SH. Suggest a reason for this difference.

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May/June 2011 (22)/Q2

A greenhouse gas which is present in very small amounts in the atmosphere is sulfur hexafluoride, SF_6, which is used in high voltage electrical switchgear.

(e) What shape is the SF_6 molecule?

..... [1]

May/June 2011 (23)/Q2

(f) The boiling points of these two compounds are given below.

compound	bp/K
CH_3CH_3	184.5
CH_3F	194.7

Suggest explanations for the following.

(i) the close similarity of the boiling points of the two compounds

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(ii) the slightly higher boiling point of CH_3F

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[2]

May/June 2012 (21)/Q1

(f) Another sulfur compound which is present in the Earth's atmosphere is carbonyl sulfide, OCS. The sequence of atoms in the molecule is oxygen-carbon-sulfur and the molecule is **not** cyclic.

(i) Draw a 'dot-and-cross' diagram of the OCS molecule.
Show outer electrons only.

(ii) Suggest a value for the O–C–S bond angle.

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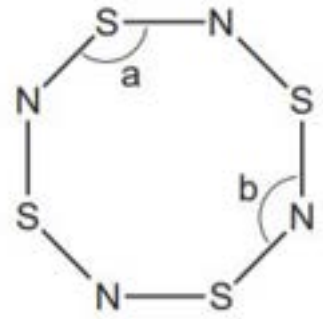
[2]

May/June 2012 (22)/Q1

(c) Sulfur forms the compound S_4N_4 with nitrogen. The structure of S_4N_4 is shown below. Assume all bonds shown are single bonds.



(i) Determine the number of lone pairs of electrons around a nitrogen atom and a sulfur atom in S_4N_4.

nitrogen atom .....

sulfur atom .....

(ii) Which bond angle, a or b, in the S_4N_4 molecule will be smaller? Explain your answer.

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[2]

May/June 2012 (23)

3 With the prospect that fossil fuels will become increasingly scarce in the future, many compounds are being considered for use in internal combustion engines. One of these is DME or dimethyl ether, CH_3OCH_3. DME is a gas which can be synthesised from methanol. Methanol can be obtained from biomass, such as plant waste from agriculture.

(d) DME is a gas at room temperature while ethanol is a liquid.

(i) Which intermolecular force exists between ethanol molecules, which causes ethanol to be a liquid at room temperature?

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(ii) Draw a diagram that clearly shows this intermolecular force.
Your diagram should show any lone pairs or dipoles present that you consider to be important. You should represent at least two molecules in your diagram.

[4]

May/June 2013 (23)

1 Carbon disulfide, CS_2, is a volatile, flammable liquid which is produced in small quantities in volcanoes.

(a) The sequence of atoms in the CS_2 molecule is sulfur to carbon to sulfur.

(i) Draw a 'dot-and-cross' diagram of the carbon disulfide molecule.
Show outer electrons only.

(ii) Suggest the shape of the molecule and state the bond angle.

shape .....

bond angle .....

[3]

Oct/Nov 2013 (21)

1 Valence Shell Electron Pair Repulsion theory (VSEPR) is a model of electron-pair repulsion (including lone pairs) that can be used to deduce the shapes of, and bond angles in, simple molecules.

(a) Complete the table below by using simple hydrogen-containing compounds. One example has been included.

number of bond pairs	number of lone pairs	shape of molecule	formula of a molecule with this shape
3	0	trigonal planar	BH_3
4	0		
3	1		
2	2		

[3]

(b) Tellurium, Te, proton number 52, is used in photovoltaic cells.

When fluorine gas is passed over tellurium at 150 °C, the colourless gas TeF_6 is formed.

(i) Draw a 'dot-and-cross' diagram of the TeF_6 molecule, showing outer electrons only.

(ii) What will be the shape of the TeF_6 molecule?

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(iii) What is the F–Te–F bond angle in TeF_6?

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[3]

Oct/Nov 2013 (23)

1 Ammonia, NH_3, and methane, CH_4, are the hydrides of elements which are next to one another in the Periodic Table.

(a) In the boxes below, draw the 'dot-and-cross' diagram of a molecule of **each** of these compounds. Show outer electrons only.
State the shape of **each** molecule.

NH_3	CH_4
shape	shape

[3]

(b) Ammonia is polar whereas methane is non-polar. The physical properties of the two compounds are different.

(i) Explain, using ammonia as the example, the meaning of the term *bond polarity*.

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(ii) Explain why the ammonia molecule is polar.

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(iii) State **one** physical property of ammonia which is caused by its polarity.

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[4]

(c) When ammonia gas is mixed with hydrogen chloride, white, solid ammonium chloride is formed.

State **each type** of bond that is present in one formula unit of ammonium chloride and how many of each type are present.
You may draw diagrams.

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..... [3]

May/June 2014 (21)/Q1

(e) Sulfur reacts with fluorine to form SF_6. State the shape and bond angle of SF_6.

shape of SF_6 .....

bond angle of SF_6 .....

[2]

Oct/Nov 2014 (21)/Q2

(c) (i) Sulfur dioxide and sulfur trioxide both contain only S=O double bonds.

Draw labelled diagrams to show the shapes of these two molecules.

SO_2 SO_3

[2]

(ii) For your diagrams in **(i)**, name the shapes and suggest the bond angles.

SO_2 shape ..... SO_3 shape .....

SO_2 bond angle ..... SO_3 bond angle .....

[2]

Oct/Nov 2014 (23)/Q2

(c) Draw a three-dimensional diagram to show the shape of an ammonia molecule. Name this shape and state the bond angle.

shape ..... bond angle ..... [3]

May/June 2015 (23)/Q1

(e) Neon and argon can both be obtained by fractional distillation of liquid air as they have different boiling points.

Neon has a boiling point of 27.3K. The boiling point of argon is 87.4K.

(i) Name the force that has to be overcome in order to boil neon or argon and explain what causes it.

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..... [3]

(ii) Explain why argon has a higher boiling point than neon.

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..... [2]

Oct/Nov 2015 (22)/Q1

(b) One of the factors that determines the type of bonding present between the particles of a substance is the relative electronegativities of the bonded particles.

(i) Explain the meaning of the term *electronegativity*.

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(ii) Name and describe the type of bonding you would expect to find between particles with equal electronegativities.

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..... [2]

(iii) Name and describe the type of bonding you would expect to find between particles with very different electronegativities.

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..... [2]

(c) The boiling points of some molecules with equal numbers of electrons are given.

substance	fluorine	argon	hydrogen chloride	methanol
formula	F_2	Ar	HC*l*	CH_3OH
boiling point/K	85	87	188	338

(i) Explain why the boiling points of fluorine and argon are so similar.

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(ii) Explain why the boiling point of hydrogen chloride is higher than that of fluorine.

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(iii) Explain why methanol has the highest boiling point of all these molecules.

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