Electrons, Bonding & Structure Multiple Choice

Model Answers 1

Level	A Level
Subject	Chemistry
Exam Board	OCR
Module	Foundations in Chemistry
Topic	Electrons, Bonding & Structure
Paper	Multiple Choice
Booklet	Model Answers 1

Time allowed: **18 minutes**

Score: **/13**

Percentage: **/100**

Grade Boundaries:

A*	A	B	C	D	E
>85%	73%	60%	47%	34%	21%

Question 1

Which statement best explains why nitrogen has a larger first ionisation energy than oxygen?

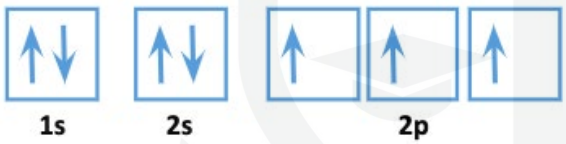
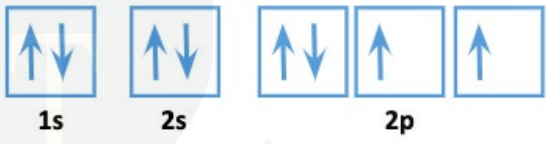
A. N atoms have less repulsion between p-orbital electrons than O atoms.

B. N atoms have a smaller nuclear charge than O atoms.

C. N atoms lose an electron from the 2s subshell, while O atoms lose an electron from the 2p subshell.

D. N atoms have an odd number of electrons, while O atoms have an even number. **[1]**

- The arrangement of electrons in nitrogen and oxygen are shown in the table below.

Nitrogen	Oxygen
	

- As you move from group 5 to group 6 you start to have to **double fill** the p subshell.
- The repulsion between the two electrons in the same subshell in oxygen means that the electron is easier to remove than it would otherwise be, so less energy is required.
- B is incorrect as the effect of a smaller nuclear charge is to decrease the first ionization energy, not increase it.
- C is incorrect as both atoms lose electrons from the 2p subshells.
- D is also incorrect as the number of electrons being odd or even is irrelevant.

Question 2

Which molecule is **not** planar?

A C_2H_4

B. C_2H_6

C. H_2CO

D. HCN

[1]

- A, C and D all contain either double or triple bonds which means the carbon atoms are unable to rotate around each other.
- Valence shell electron pair repulsion (VSEPR) theory places the atoms furthest apart to reduce repulsion which causes them to adopt a planar shape with **2D geometry**.
- This does not occur in molecule B which is ethane. The carbon carbon single bond allows for rotation and each carbon has three hydrogen bonds and one carbon-carbon bond, which arrange themselves in 3D formation to limit steric interference.

Question 3

Which element has induced dipole–dipole interactions (London forces) in its solid lattice?

A. boron

B. magnesium

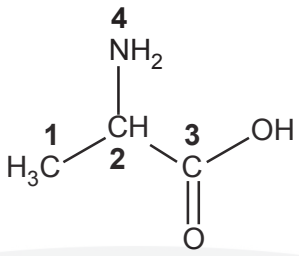
C. silicon

D. sulfur **[1]**

- Induced dipole-dipole interactions (London forces) exist in-between molecules of substances.
- Sulfur molecules form simple molecular structures, the most common of which consists of 8 S atoms in a cyclic shape held together by covalent bonding.
- Each S_8 molecule has a lot of electrons leading to strong London forces between adjacent molecules in the solid lattice structure.
- Mg, Si and B are not molecular substances hence there are no London forces present in these elements, hence A, B and C are incorrect.

Question 4

Four atoms, **1–4**, are labelled in the structure below.



Which atom has a trigonal planar arrangement of bonds around it?

A. Atom 1

B. Atom 2

C. Atom 3

D. Atom 4

[1]

- Carbon 3 forms a **trigonal planar** arrangement as it has **3 bonding pairs** and no lone pairs.
- Carbons 1 and 2 both adopt a **tetrahedral** arrangement.
- Group 4 is incorrect as the nitrogen has a lone pair of electrons hence it will form a **pyramidal s**hape.
- Hence A, B and D are incorrect.

Question 5

Which compound has polar molecules?

A. OCl_2

B. BCl_3

C. CCl_4

D. SCl_6 **[1]**

- Dichlorine monoxide is similar in shape and polarity to H_2O.
- The oxygen atom has two lone pairs of electrons which repel the chlorine atoms away from the central oxygen atom, decreasing the O-C*l* bond angles.
- Each O-C*l* has a permanent dipole and although each dipole acts in opposite directions, they do not exactly oppose each other as they are arranged asymmetrically.
- They are therefore unable to cancel each other out, so the molecule is overall polar.
- Molecules B, C and D are all nonpolar molecules due to their symmetrical arrangement of atoms.

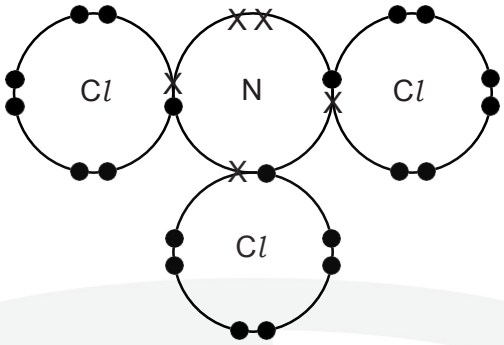
OCl_2 has a bent shape due to lone pair repulsion from the central oxygen atom on each Cl atom.

Exam Tip

For identifying polar/non-polar compounds, it is much easier to determine the symmetry of the compound by drawing out the structural formula, rather than from the molecular formula.

Question 6

A '*dot-and-cross*' diagram for nitrogen trichloride, NCl_3, is shown below.



Which row shows the correct shape and bond angle in a molecule of NCl_3?

	Name of shape	Bond angle
A	Pyramidal	104.5°
B	Pyramidal	107°
C	Tetrahedral	107°
D	Trigonal planar	120°

[1]

- There are three **bonding pairs** of electrons and one **lone pair** in nitrogen trichloride.
- That means there are a total of four pairs which make the molecule similar in shape to a tetrahedral.
- The **lone pair** of electrons on the nitrogen atom, however, repel the bonding pairs slightly and reduce the angle from a normal tetrahedral of 109^0 to 107^0 degrees.
- This angle and shape correspond to a pyramidal molecule.
- A, C and D are therefore incorrect.

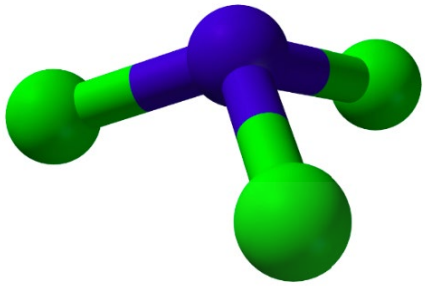


Image of NCl_3 showing lone pair repulsion on the N atom causing the N-H bonds to angle downwards

Exam Tip

Your first step in questions on shapes of molecules should be to identity the **bonding** and **non-bonding** pairs of electrons. This is easiest done using a dot-and-cross diagram, which you should draw if one is not given in the question.

Question 7

What is the shape around the carbon atoms in graphene?

A. linear

B. pyramidal

C. tetrahedral

D. trigonal planar

[1]

- In graphene each carbon atom is bonded to **three** others, forming a flat sheet.
- Each sheet is composed of carbon atoms that are **sp2 hybridized** which form **planar hexagonal** shapes.
- The three bonds in each carbon atom move as far apart from each other as possible to minimize electron pair repulsion, forming a triangle with bond angles of **120^0**.
- This geometry is called trigonal planar.
- A, B and C are thus incorrect.

Question 8

Electron configurations for atoms of different elements are shown below.

Which electron configuration represents the element with the largest first ionisation energy?

A $1s^2 2s^2$

B $1s^2 2s^2 2p^4$

C $1s^2 2s^2 2p^6$

D $1s^2 2s^2 2p^6 3s^2$

- Start this question by first identifying the elements in each option: **[1]**
  - Option A is beryllium
  - Option B is oxygen
  - Option C is neon
  - Option D is aluminium
- First ionization energies increase moving **across** the Periodic Table from left to right.
- Neon lies on the far right of the table, is a noble gas and has a full outer shell making it very stable and thus very difficult to ionize.
- It therefore has the highest first ionisation energy.
- A, B and D are thus incorrect.

Question 9

Which compound has non-polar molecules?

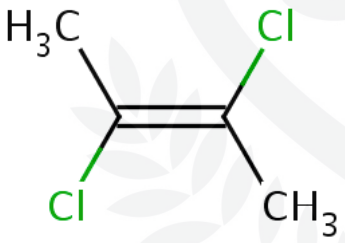
A *E*-1,2-dichlorobut-2-ene

B *E*-2,3-dichlorobut-2-ene

C *Z*-2,3-dichlorobut-2-ene

D *Z*-1,4-dichlorobut-2-ene **[1]**

- Draw out each molecule making sure that the E/Z notation and numbering is correct.
- It becomes clear that compound B, due to its symmetry, has non-polar molecules.
- This is as the polarity of the C*l* atoms acts in opposite directions which cancel each other.



The symmetrical shape of E-2,3-dichlorobut-2-ene renders the molecule non-polar

Exam Tip

For identifying polar/non-polar compounds, it is much easier to determine the symmetry of the compound by drawing out the structural formula, rather than from the molecular formula.

Question 10

Which molecule is non-polar?

A. SF_6

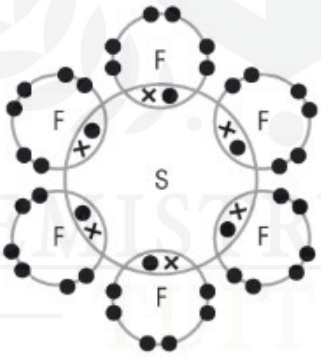
B. H_2S

C. PF_3

D. NH_3

[1]

- In SF_6 all 6 electrons in sulfur (Group 6) have been used in covalent bonds giving the sulfur atom **12 outer electrons**. Each fluorine atom has **8 electrons** in the outer shell.
- There are no non-bonding electrons hence the molecule is nonpolar.
- B is incorrect as in H_2S there are **two lone pairs** of electrons on the S atom.
- C is incorrect as in PF_3 there is one **lone pair** on the P atom.
- D is incorrect as in NH_3 there is one **lone pair** on the N atom.



Dot and cross diagram of SF_6

Question 11

Which substance contains hydrogen bonding in the liquid state?

A. $CH_3(CH_2)_4CH_3$

B. $CH_3(CH_2)_3CHFCH_3$

C. $CH_3(CH_2)_3COCH_3$

D. $CH_3(CH_2)_3CH(OH)CH_3$ **[1]**

- Hydrogen bonding occurs between **hydrogen** and **electronegative** atoms such as oxygen or a halogen.
- By drawing out the displayed formulae for each molecule, it's clear that only molecule D has a hydrogen atom that is **directly bonded** to an atom of high electronegativity, in this case oxygen.
- A is incorrect as this molecule is a **hydrocarbon**.
- B and C are incorrect as the F and O atoms are bonded to **carbons**, not **hydrogen**.

Question 12

The boiling point of hydrogen bromide is –67 ºC.
The boiling point of hydrogen iodide is –34 ºC.

The different boiling points can be explained in terms of the strength of bonds or interactions.

Which bonds or interactions are responsible for the higher boiling point of hydrogen iodide?

A covalent bonds

B hydrogen bonds

C permanent dipole–dipole interactions

D induced dipole–dipole interactions **[1]**

- Iodine sits below bromine in Group VII and thus has more electrons.
- This means there are stronger London forces in HI than in HBr hence the boiling point increases as more energy is required to break the intermolecular forces.
- A is incorrect as covalent bonds are not broken during boiling.
- B is incorrect as there is no hydrogen bonding is not involved in the process.
- C is incorrect as hydrogen bromide is more polar than hydrogen iodide as there is a greater difference in electronegativity in HBr.

Question 13

The boiling point of butan-1-ol is 118 °C. The boiling point of 2-methylpropan-2-ol is 82 °C.

Why is the boiling point of butan-1-ol higher than that of 2-methylpropan-2-ol?

A butan-1-ol has stronger induced dipole–dipole interactions because it has more electrons

B butan-1-ol has stronger induced dipole–dipole interactions because it has a straight-chain structure

C butan-1-ol can form hydrogen bonds while 2-methylpropan-2-ol cannot

D butan-1-ol is more stable because it is a primary alcohol **[1]**

- Butan-1-ol is a **straight chain structure** so there are no branches to disrupt the dipole-dipole interactions.
- 2-methylpropan-2-ol is branched hence the interactions are disrupted.
- A is incorrect as both molecules have the **same number** of electrons.
- C is incorrect as both molecules can hydrogen bond as both contain a hydroxyl group.
- D is incorrect as primary alcohols tend to be less stable due to there being less steric hindrance around the OH group.