EXAM PAPERS PRACTICE

- Boost your performance and confidence with these topic-based exam questions
- Practice questions created by actual examiners and assessment experts
- Detailed mark scheme
- Suitable for all boards
- Designed to test your ability and thoroughly prepare you

Level: CIE AS and A Level (9701)
Subject: Chemistry
Topic: CIE Chemistry
Type: Mark Scheme

Chemistry CIE AS & A Level
To be used for all exam preparation for 2025+

CHEMISTRY AS and A

This to be used by all students studying CIE AS and A level Chemistry (9701) But students of other boards may find it useful

Mark Scheme

Answer 1.

a)

i) The number of electrons in the outer shell of sulfur in SF_6 is:

- Twelve; [1 mark]

ii) The maximum and minimum electrons possible in the outer shell of sulfur are:

- Minimum of 8 (electrons)
  AND
  Maximum of 18 (electrons); [1 mark]

[Total: 2 marks]

- Sulfur is in Period 3, so it can use the empty d-orbitals to allow more electrons than the standard octet, up to a maximum of 18 to form an expanded octet

b) The shape of a molecule of SF_6 is:

- Octahedral; [1 mark]

[Total: 1 mark]

- There are six electron domains around the sulfur, one single bond with each fluorine, which means an octahedral shape for the molecule

c) The F-S-F bond angles in SF_6 are:

- 90°; [1 mark]

[Total: 1 mark]

- All bond angles in octahedral molecules are 90°, as this is the furthest away from each other that the electron domains can get before they are getting closer again!

d)

i) Predicting the polarity of the S-F bond:

- (The S-F bond) is polar; [1 mark]

ii) Predicting the polarity of SF_6:

- SF_6 is not polar/ is a non-polar molecule; [1 mark]
- As it has no overall dipole/ the distribution of electrons is even across the molecule as a whole; [1 mark]

[Total: 3 marks]

- Bonds are polar when there is a sufficient difference in electronegativity, generally treated as a difference of 0.5 or more between the values for the different atoms
- Fluorine is the most electronegative element that can form bonds and forms polar bonds with all other elements except itself
- Molecules are polar when they have an uneven distribution of electrons across the molecule in any direction; this can be the result of unsymmetrical polar bonds or non-polar bonds

Answer 2.

The bond angle in BH_3 is 120° as:

- Boron (B) has 3 bonding pairs of electrons; [1 mark]
- Which repel each other equally / as much as possible to take up positions as far apart as possible; [1 mark]

[Total: 2 marks]

- The shape of a simple molecule can be predicted by the valence-shell electron-pair repulsion (**VSEPR**) theory
- This theory states that the shape of a molecule depends on the number of **bonding pairs** and **lone pairs** of electrons
- Bonding pairs of electrons: electrons that are involved in bonding
- Lone pairs of electrons: electrons that are **not** involved in bonding (also called non-bonding pairs of electrons)
- The bonding pairs and lone pairs of electrons in the outer shell of atoms are **charge clouds** that repel each other
- They will arrange themselves as far apart as possible to minimise repulsion
- Lone pair-lone pair repulsion > lone pair-bonding pair repulsion > bonding pair-bonding pair repulsion
- Boron (B) is a Group 3 element and has, therefore, **three** electrons in its outer shell
- Each electron is used to form a bond with a hydrogen (H) atom
- Since there are three H atoms in BH_3, all three outer shell electrons are **bonding pairs of electrons** that will repel each other **equally**
- Since BH_3 has a **planar shape/arrangement,** the sum of the angles is 360°
- As all bonding pairs of electrons in BH_3 repel each other equally, each bond angle will be 120° (360 ÷ 3)
- **Note** that the angles in BH_3 are 120° due to repulsion between the bonding pairs of electrons and **not** due to repulsion between the hydrogen atoms

The bond angle in NH_3 will be smaller than the bond angle in BH_3; [1 mark]

[Total: 1 mark]

- Nitrogen (N) is a Group 5 element and so has **five** outer shell electrons
- Since there are three hydrogen (H) atoms in NH_3, only **three** of these outer shell electrons are used to form covalent bonds with hydrogen atoms
- There are, therefore:
- **Three** bonding pairs of electrons
- **One** lone pair of electrons
- The repulsion between the lone pairs of electrons and three bonding pairs of electrons is **greater than** the repulsion between the three bonding pairs of electrons with each other
- This effect squeezes the hydrogen atoms together, reducing the N-H angles
- In BH_3 there are no lone pairs of electrons, so all three bonding pairs of electrons repel each other equally
- **Note** that unlike BH_3, the NH_3 molecule is **not planar,** but has a **3D arrangement** so the sum of the angles can be more than 360°

The bond angle in NH_3 is different from the bond angle in BH_3 as:

- The lone pair of electrons on nitrogen in NH_3 has a greater repulsion / repels more than the bonding pairs of electrons; [1 mark]

- So the pairs of electrons arrange themselves as far apart as possible to minimise repulsion; [1 mark]

[Total: 2 marks]

- Boron (B) has **three bonding pairs of electrons**
- These bonding pairs of electrons repel each other **equally** and arrange themselves in a planar arrangement to minimise repulsion
- Nitrogen has:
  - Three **bonding pairs of electrons**
  - One **lone pair of electrons**
- These bonding pairs and lone pair of electrons do **not** repel each other **equally** as:
- Lone pair-bonding pair repulsion > bonding pair-bonding pair repulsion
- This effect squeezes the hydrogen atoms together, reducing the N-H angles
- As a result, the bond angles in NH_3 are **smaller** than in BH_3

Answer 3.

a) The main features of the VSEPR theory for predicting the shapes of molecules are:

- Pairs of electrons in the valence/ outer shell; [1 mark]
- Repel one another; [1 mark]
- (And so) take up positions in space to minimise these repulsions; [1 mark]

[Total: 3 marks]

- Molecules frequently contain multiple pairs of shared electrons, and these behave as a single unit in terms of repulsion because they are orientated together. So a better, more inclusive, term than electron pair is electron domain
- This includes all electron locations in the valence shell, be they occupied by lone pairs, single, double, or triple bonded pairs
- What matters in determining shape is the total number of electron domains, and this can be determined from the Lewis structure
- Non-bonding pairs (lone pairs) have a higher concentration of charge than a bonding pair because they are not shared between two atoms, and so cause slightly more repulsion than bonding pairs. The repulsion decreases in the following order:
  - lone pair–lone pair > lone pair–bonding pair > bonding pair–bonding pair
- As a result, molecules with lone pairs on the central atom have some distortions in their structure that reduce the angle between the bonded atoms

b) The bond angle F-O-F in OF_2 is:

- (Any bond angle) in the range 97° to 109°; [1 mark]
- This angle is due to four electron domains (where two of them are lone pairs)
  OR
  A tetrahedral arrangement of electron pairs; [1 mark]
- The lone pairs repel more than the bonding pairs
  AND
  The F-O-F bond angle is slightly smaller than 109.5°; [1 mark]

[Total: 3 marks]

- You need to learn the bond angles for the three basic electron domain shapes
  - **2** domains = **180°**
  - **3** domains = **120°**
  - **4** domains = **5°**
- Lone pairs of electrons are pulled more closely to the central atom (since they are not shared between two atoms) and cause greater repulsion towards the bonding pairs of electrons
  - This results in the bond angle being slightly smaller if lone pairs are present
  - The rough rule of thumb is that the bond angle is reduced by around 2.5° for every lone pair

d) The shape and bond angles in the following molecules would be:

i) For BF_3:

- Trigonal planar
  AND
  3 electron domains; [1 mark]

- 120°; [1 mark]

ii) For NBr_3 :

- Trigonal pyramid(al)
  AND
  4 electron domains and 1 lone pair; [1 mark]

- 107°; [1 mark]

[Total: 4 marks]

- It can often be helpful to draw the Lewis structure before attempting to deduce the shape and bond angle as you could easily miss some lone pairs
- BF_3 has the following Lewis structure:
  - 

- NBr_3 has the following Lewis structure:
  - 

- The electron domain shape for a molecule is as follows
  - **3** domains = **triangular or trigonal planar**
  - **4** domains = **tetrahedral**
- We do not count the lone pairs when naming the shape of the molecule, so
  - **4** domains, where 1 domain is a lone pair = **trigonal/triangular pyramid**
  - **4** domains, where 2 domains are lone pairs = **bent linear/ angular/ V-shaped**

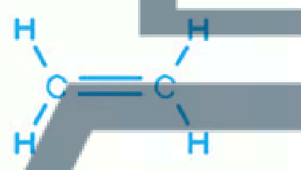
Answer 4.

a) The H—C—H bond angle in ethene and the H—N—H bond angle in hydrazine would be:

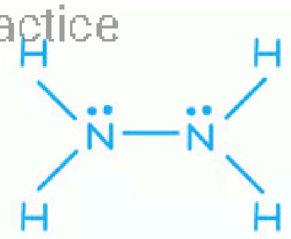
- (H—C—H would be) any angle between 118° and 122°; [1 mark]
- (due to) three electron domains; [1 mark]
- (H—N—H would be) any angle between 104 and 108°; [1 mark]
- (due to) four electron domains; [1 mark]
- The extra repulsion is due to the lone electron pairs; [1 mark]

[Total: 5 marks]

- It can often be helpful to draw the Lewis structure before attempting to deduce the shape and bond angle as you could easily miss some lone pairs
- The Lewis structure for ethene is:



- Each carbon atom has 4 bond pairs of electrons but only 3 electron domains due to the carbon-carbon double bond
    - 3 electron domains give an approx angle of 120°
- The Lewis structure for hydrazine is:



- Each nitrogen atom has 3 bond pairs and 1 lone pair of electrons so has 4 electron domains
    - 4 electron domains give an approx angle of 109°

b) The molecular geometry and the H–N–N bond angle of diimide is:

- Planar molecule

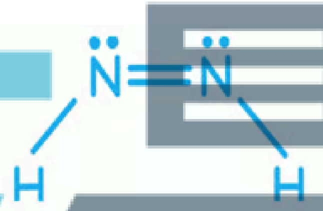
  OR

  Bent linear / angular / V shape around each N atom; [1 mark]
- The H–N–N bond angle is between 115° and 120°; [1 mark]

(The answer **must** be less than 120° to consider the lone pair on the middle N)

[Total: 2 marks]

- The Lewis diagram for diimide shows that around each nitrogen atom are three electron domains



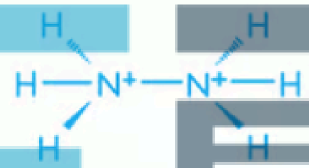
- One of the domains is a lone pair, so we do not count it in naming the shape
- The result is a bent linear/ angular / V shape around the N
- The two bent linear N atoms joined together would make the whole molecular planar

c) The H–N–H bond angle in $N_2H_6^{2+}$ is:

- 109°; [1 mark]

[Total: 1 mark]

- Each nitrogen in hydrazine accepts a proton similar to ammonia, NH_3, forming an ammonium ion NH_4^+
- The structure of $H_2N_6^{2+}$ is:



- Each nitrogen has 4 bond pairs in 4 electron domains.
  - 4 electron domains, with no lone pairs, give an approximate angle of 109°

Answer 5.

b) The bond angles in $HCONH_2$ are:

H-C-N:

- Any angle between 117° and 120°; [1 mark]
- Due to three bonded regions / 2 single bonds and 1 double bond (and no lone pairs); [1 mark]
- That repel each other equally; [1 mark]

C-N-H:

- Any angle between 104° and 108°; [1 mark]
- Due to 3 electron / bonded pairs and 1 lone pair; [1 mark]
- Greater repulsion between the unbonded pair / lone pair (on nitrogen) than between unbonded pairs; [1 mark]

[Total: 6 marks]

- **Remember:** Only the atoms that are surrounded by other atoms are 'central' as they need to have at least two different atoms attached in order to have a bond angle
- The bond angle is based on the number of regions of electron density, so includes lone pairs, not just the number of bonded atoms
- Bond angles are reduced by the presence of unbonded electron pairs
- The bond angle that results between four bonded pairs of electrons is 109.5°
- The C-N-H bond angle is predicted to be 107° as the lone pair present pushes the bonded pairs of electrons closer, reducing the bond angle by 2.5°
- In VSEPR, the repulsion between a multiple bond and a single bond is assumed to be the same as the repulsion that occurs between single bonds
- This would give the H-C-N bond angle to be 120°
- In reality, the multiple bond will provide extra repulsion and reduce this bond angle, hence any angle between 117° and 120° is accepted

c) The shapes around the C and N in $HCONH_2$ are:

Around the carbon:

- Trigonal planar; [1 mark]

Around the nitrogen:

- Pyramidal; [1 mark]

[Total: 2 marks]

- The shape around each atom is determined by the number of regions of electron density around the atom and it is the basis for working out bond angles
- Different bond angles give rise to different shapes, common bond angles and shapes that you need to know are:
  - Trigonal planar: 120°
  - Linear: 180°
  - Tetrahedral: 109.5°
  - Pyramidal, 107°
  - Non-linear: 104.5°
  - Octahedral: 90°
  - Trigonal bipyramidal: 90° and 120°