EXAM PAPERS PRACTICE

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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

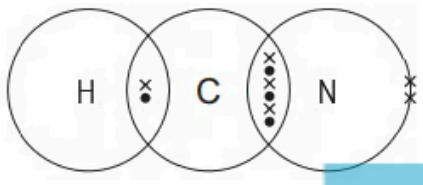
This to be used by all students studying CIE AS and A level Chemistry (9701) But students of other boards may find it useful

Mark Scheme

Answer 1.

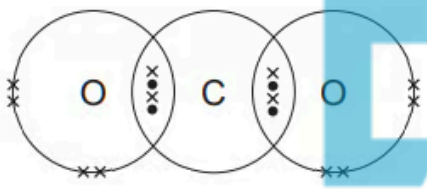
a) The dot-and-cross diagrams for the molecules are:

i) Hydrogen cyanide (HCN):

- 

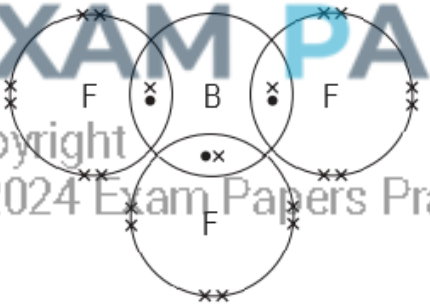
; [1 mark]

ii) Carbon dioxide (CO_2):

- 

; [1 mark]

iii) Boron trifluoride (BF_3):



; [1 mark]

[Total: 3 marks]

- To work out the dot-and-cross diagrams you need to follow these steps:
  - Count the total number of outer electrons
  - Use a pair of crosses or dot / cross to put an electron pair in each bond between the atoms
  - Add more electron pairs to complete the octets around the atoms (except H which has 2 electrons)
  - If there are insufficient electrons to complete the octets, form double / triple bonds
  - Check the total number of electrons in the finished structure is equal to the total number of outer electrons

b) The species from part **(a)** that is likely to form a coordinate bond is:

- Boron trifluoride (BF_3); [1 mark]

Explanation:

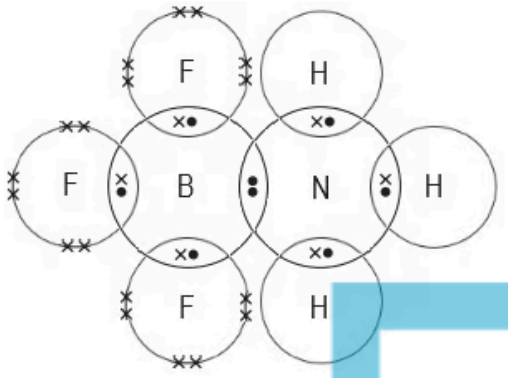
- (This is because) borons outer shell has space for two more electrons
  OR
  Boron only has six outer shell (valence) electrons
  OR
  Boron has an incomplete (unfilled) outer shell; [1 mark]

[Total: 2 marks]

- Boron trifluoride is the only one of the molecules in part **(a)**, which has a central atom with an incomplete outer shell
- In hydrogen cyanide and carbon dioxide, the central carbon has a complete outer shell so cannot accept a pair of electrons from another atom required to form a coordinate bond

c)

i) The dot-and-cross diagram for the product of boron trifluoride and ammonia is:

- 

; [1 mark]

ii) The bond between boron trifluoride and ammonia forms because:

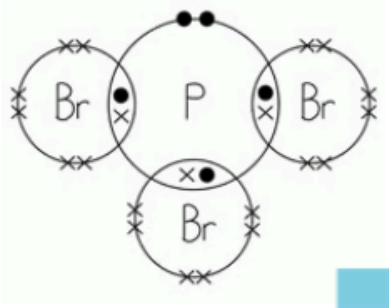
- Ammonia has a lone pair of electrons
  AND
  Boron trifluoride has an incomplete outer shell; [1 mark]

[Total: 2 marks]

- The pair of electrons between the B and N atoms **must** use the same symbols, i.e. both dots or both crosses
- NH_3 has a lone pair of electrons whilst BF_3 has space in its outer shell for two more electrons
  - This makes it possible for a coordinate bond to form between NH_3 and BF_3
  - The lone pair of electrons from the N in ammonia is donated to the B in BF_3

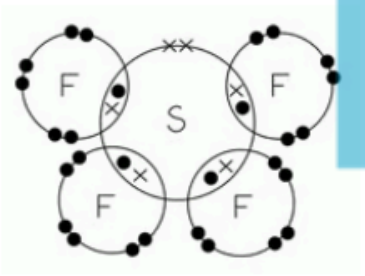
a) The diagrams to show the arrangement of outer electrons in both compounds are:

Phosphorus tribromide

- 

; [1 mark]

Sulfur tetrafluoride

- 

; [1 mark]

[Total: 2 marks]

- Phosphorus is in Group 15
  - It will have 5 outer / valence electrons
- Bromine is in Group 17
  - Each will have 7 outer / valence electrons
- Sulfur is in Group 16
  - It will have 6 outer / valence electrons
- Fluorine is in Group 17
  - Each will have outer / 7 valence electrons
- Students often lose marks from missing lone pairs on these questions so always double check!

b) The shape of the phosphorus tribromide molecule is:

- Pyramidal; [1 mark]

[Total: 1 mark]

- Phosphorous tribromide has 3 bonding and 1 lone pair of electrons
  - The lone pair - bonding pair repulsion is greater than bonding pair - bonding pair repulsion, resulting in a pyramidal shape

c) Phosphorus tribromide and sulfur tetrafluoride are both polar as:

- P–Br and S–F bonds are polar
  OR
  Bonds in both molecules are polar; [1 mark]
- Non-symmetrical distribution of electron cloud
  OR
  Polar bonds / dipoles do not cancel because of their non-symmetrical shape; [1 mark]

[Total: 2 marks]

- Both of the molecules have non-symmetrical shapes having one lone pair of electrons on the central atom
- The presence of a single lone pair of electrons on the central atom often results in the molecule being polar

Question 3.

a) The equation to show the formation of an ammonium ion from ammonia is:

- $NH_3 + H^+ \rightarrow NH_4^+$; [1 mark]

[Total: 1 mark]

- You should know that the ammonium ion is NH_4^+
- This is formed when ammonia accepts a proton

b) The shapes are:

Ammonia molecule:

- Pyramidal; [1 mark]

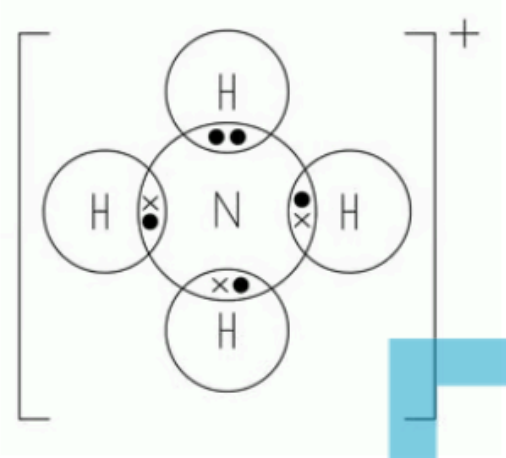
Ammonium ion:

- Tetrahedral; [1 mark]

[Total: 2 marks]

- You need to know the different shapes associated with various chemicals, so take the time to learn them

a) The dot-and-cross diagram to show the bonding in the ammonium ion is:



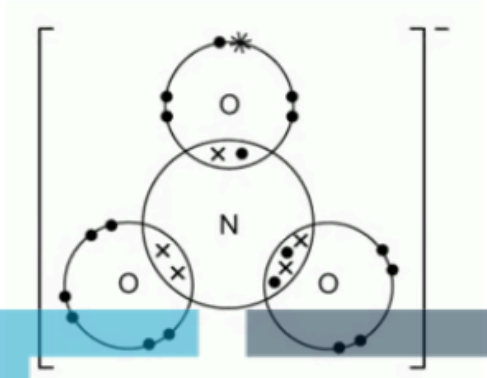
- 1 central nitrogen atom surrounded by 4 hydrogen atoms
  AND
  3 shared pairs of electrons
  AND
  1 pair of electrons donated from the nitrogen atom; [1 mark]
- Square brackets
  AND
  1+ charge; [1 mark]

[Total: 2 marks]

- NH_3 has a lone pair of electrons
  - This makes it possible for the dative bond to form between NH_3 and a proton (H^+)
  - The lone pair of electrons from the N in ammonia is donated to the H^+ ion

Question 4.

a) The dot-and-cross diagram for the NO_3^- ion is:



- Dot and cross correct around N atom showing double, single and a coordinate bond; [1 mark]
- Correct number of electrons for each atom
  AND
  Extra electron for O^-; [1 mark]

[Total: 2 marks]

- **Careful:** Read the question, as it explains the three types of covalent bonds that are in a NO_3^- ion
- As it is a polyatomic ion you need to include [ ] and the negative charge on the outside
- Use your displayed formula to help guide your dot and cross diagram:
- Start by drawing your N atom as normal with 5 electrons in the outer shell
- Then take each type of covalent bond at a time and draw either the single, double or dative covalent bond with the correct number of electrons
  - The single bond will have one electron from the N atom and one from an O atom
    - This O atom needs an extra electron to complete the shell and this is the electron that causes the ion to have a 1– charge
  - The coordinate bond will have two electrons from the N atom
  - The double bond will have two electrons from the N atom and two electrons from an O atom

b) The formulae of the ions present in $H_4N_2O_3$ are:

- NH_4^+; [1 mark]
- NO_3^-; [1 mark]

[Total: 2 marks]

- Empirical formula - simplest whole-number ratio of atoms of elements in a compound
- You need to learn all of your polyatomic ion formulae and know them from memory, as they won't be given in the exam
- In this instance, the empirical formula is also the molecular formula and NH_4^+ and NO_3^- make up $H_4N_2O_3$
- Don't forget the correct charges on the ions in your answer as well

c) The dot-and-cross structure for a CN^- ion is:

- Correct bonding shown; [1 mark]
- Rest of the structure correct, including charge; [1 mark]

[Total: 2 marks]

- To deduce the dot-and-cross diagram for the CN^- ion, you need to consider the number of outer electrons of each atom and the overall charge of the ion:
  - Carbon has 4 outer electrons
  - Nitrogen has 5 outer electrons
  - +1 extra outer electron as it is the CN^- ion with a 1– charge
- Carbon and nitrogen must bond together to **form a triple bond** for nitrogen to have a full outer shell of 8 outer electrons
  - As it is a CN^- ion, there must also be an extra electron in the carbon atoms' outer shell for carbon to have a full outer shell of 8 outer electrons
- Don't forget your [ ] and negative charge on the outside of the brackets

d)

i) The average bond enthalpy of the C-N bond in the cyanide ion compared to the C-N bond in the methylamine molecule:

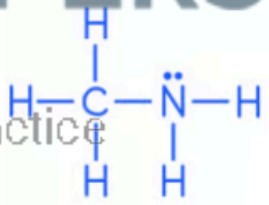
- Average bond enthalpy for the C-N (triple) bond in the cyanide ion is greater / average bond enthalpy of the C-N (single) bond in methylamine is lower; [1 mark]
- Triple bonds are stronger than single and double bonds so require more energy to break; [1 mark]

ii) The C-N bond length in the cyanide ion is shorter than in methylamine because:

- There is a larger negative charge density / electron density between the (carbon and nitrogen) nuclei; [1 mark]
- The greater forces of attraction between electrons and the nuclei pull the nuclei closer together; [1 mark]

[Total: 4 marks]

- To do this question you need to know, or work out, the structure of methylamine first and establish that the C-N bond is a single bond



- Where the covalent bond is between the same two atoms, in this case carbon and nitrogen, the single bond is always the weakest and the triple bond is the strongest
- The bond length is the internuclear distance between two covalently bonded atoms
- The C-N triple bond in the cyanide ion has 6 electrons between the carbon and nitrogen atom, compared with 2 electrons in the C-N single bond in methylamine
- There is a much greater attraction between the negative electrons and the positive nuclei in the cyanide ion, which pulls the atoms closer, decreasing the bond length