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CHEMISTRY

Physical Chemistry

Level & Board	AQA (A-LEVEL)
TOPIC:	BONDING
PAPER TYPE:	SOLUTION -3
TOTAL QUESTIONS	10
TOTAL MARKS	53

Bonding

1.

(a)

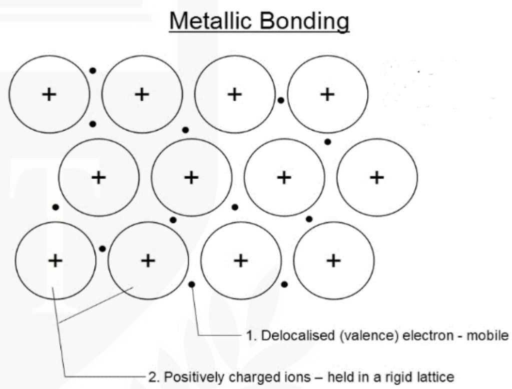
i.

Nickel Ni is located in the d-block (transition metals) of the Periodic Table.

(1)

ii. Nickel has a high melting point due to its strong metallic bonds formed by delocalized electrons moving freely between nickel atoms in a face-centered cubic crystal structure.

Breaking these strong bonds requires a significant amount of energy, resulting in the high melting point of nickel.

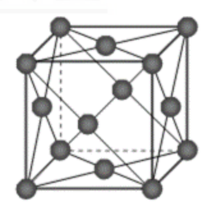


(2)

iii. **Nickel has face center cubic (FCC) crystal lattice**

The arrangement of particles in a crystal of nickel can be visualized as follows:

- Nickel atoms are located at each of the eight corners of the cube.
- There is one nickel atom at the center of each of the six faces of the cube.
- This arrangement forms a total of four atoms per unit cell in the FCC structure.

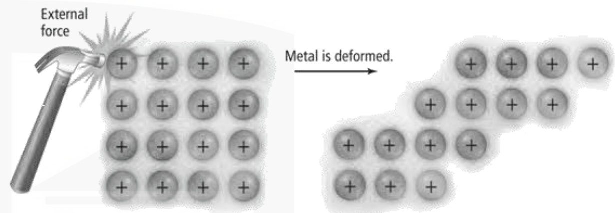


Cubic face centered (fcc)

The atoms in a nickel crystal are closely packed together, maintaining a regular and repeating pattern throughout the crystal lattice.

(2)

iv. Nickel's ductility, is due to its metallic bonding that allows atoms to slide over each other without breaking bonds. Its crystal structure enables easy movement of atoms when a force is applied, allowing the metal to be drawn into thin wires without breaking.



(1)

(b)

i. Ni^{2+} ion's electron configuration: $1s^2\ 2s^2\ 2p^6\ \ 3s^2\ 3p^6\ \ 3d^8$

The Ni^{2+} ion has lost the two electrons from its 4s orbital, leaving the $3d^8$ configuration.

(1)

ii.

$NiCl_2.6H_2O_{(s)}+6SOCl_{2(g)} \rightarrow NiCl_{2(s)}+6SO_{2(g)}+10HCl_{(g)}$

A substance that could react with both gaseous products, sulfur dioxide (SO_2) and hydrogen chloride (HCl), is a base such as sodium hydroxide ($NaOH$) or calcium oxide (CaO).
e.g.
$NaOH_{(s)}+SO_{2(g)} \rightarrow NaHSO_{3(s)}$
$NaOH_{(s)}+HCl_{(g)} \rightarrow NaCl_{(aq)}+H_2O_{(l)}$

(2)

2.
(a)
The repulsion between these lone pairs causes the O–O–H bond angle in hydrogen peroxide to be around 104.5^0.

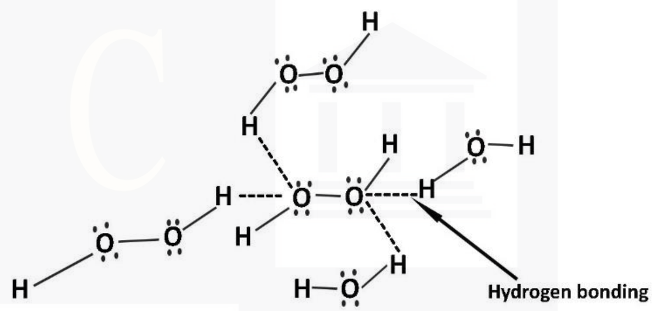
(1)

(b)

i. The strongest type of interaction between molecules of hydrogen peroxide (H_2O_2) and water (H_2O) is hydrogen bonding.

(1)

ii. Diagram showing how one molecule of hydrogen peroxide interacts with one molecule of water is as:



Hydrogen bonding H_2O_2

(3)

(c)

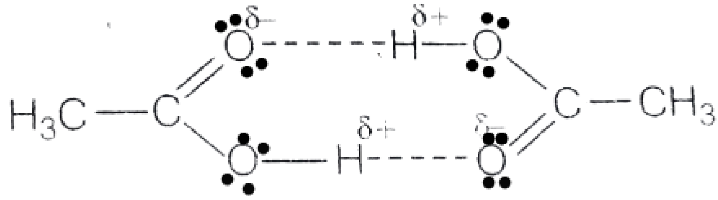
In H_2S_2 the central atoms are sulfur, which has a lower electronegativity than oxygen. Due to sulfur's lower electronegativity compared to oxygen, the S–H bond in H_2S_2 is less polar than the O–H bond in H_2O_2.
As a result, hydrogen bonding, which is stronger in H_2O_2 due to the higher polarity of the O–H bonds, is weaker in H_2S_2 because of the less polar S–H bonds.
The strength of hydrogen bonding directly affects the boiling point of a substance. So, H_2O_2 has a higher boiling point than H_2S_2 due to the stronger hydrogen bonding between its molecules.

(2)

3.

(a)

Hydrogen bonding in Acetic acid molecules as :



(3)

(b)

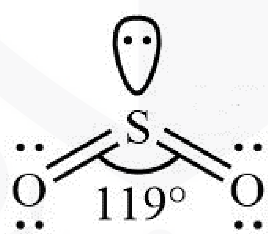
Acetic acid has a higher boiling point than dimethyl ether because it has stronger intermolecular forces, specifically hydrogen bonding, whereas dimethyl ether has only weaker van der Waals forces. The presence of hydrogen bonding in acetic acid requires more energy to break the bonds between molecules, resulting in a higher boiling point compared to dimethyl ether.

(3)

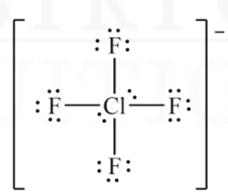
(c)

SO_2

Shape: trigonal planar

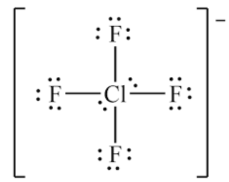


Shape of the ClF_4^-



The ClF_4^- ion consists of a central chlorine atom bonded to four fluorine atoms with two lone pairs on the central chlorine atom.

The ClF_4^- ion has a square planar molecular geometry due to its structure, with the four fluorine atoms and two lone pairs arranged around the central chlorine atom.
The lone pairs tend to repel more strongly than bonded pairs, resulting in a distortion from the ideal 90° and 180° angles in a perfect square planar structure.
Due to the repulsion between the lone pairs and the bonding pairs, the Cl-F-Cl bond angles in ClF_4^- are almost 90°.



(5)

4. (C)

(Total 1 mark)

5. (D)

(Total 1 mark)

6.

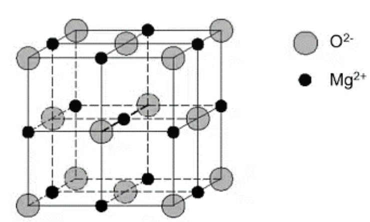
(a)

Magnesium ions (Mg^{2+}) and oxide ions (O^{2-}) both have the same electron configuration but differ in their number of protons.
When magnesium loses electrons to become an ion, it has a higher nuclear charge, making it smaller.
Oxygen gains electrons to form its ion, which increases electron-electron repulsion, causing the oxide ion to be larger than the magnesium ion despite their similar electron configurations.

(2)

(b)

MgO has a lattice structure formed by the strong ionic bonds between magnesium (Mg^{2+}) and oxygen (O^{2-}) ions.
Each magnesium ion is surrounded by six oxygen ions, and each oxygen ion is surrounded by six magnesium ions.
These ionic bonds are extremely strong due to the attraction between the oppositely charged ions.
Therefore, the high melting point of magnesium oxide is due to the strong ionic bonds.



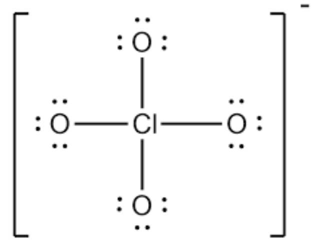
(2)

(c)

The shape of the ClO_4^- ion is tetrahedral.

Bond angel: 109.5 °

In this structure:



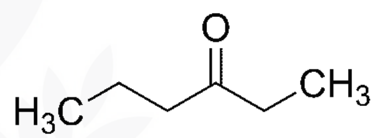
- *The central chlorine atom (Cl) is bonded to four oxygen atoms (O).*
- *Each oxygen atom has two lone pairs of electrons, but for clarity, only one lone pair is represented on each oxygen atom.*
- *The arrangement of the atoms around the central chlorine atom forms a tetrahedral shape.*

(4)

7.

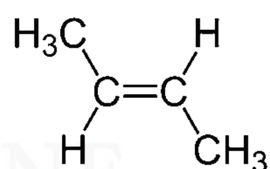
Hexan-3-one *molecules have dipole-dipole interactions and London dispersion forces between molecules. This is due to the presence of a polar carbonyl group (C=O) in the hexan-3-one molecule.*

The partially positive carbon of the carbonyl group and the partially negative oxygen create a permanent dipole, leading to stronger dipole-dipole interactions compared to the simple alkene structure of **but-1-ene**.



But-1-ene, is an alkene, *has weaker intermolecular forces because it has only London dispersion forces.*

Therefore, **the stronger intermolecular forces (dipole-dipole interactions) in hexan-3-one molecules result in a higher boiling point compared to but-1-ene, which has weaker intermolecular forces (London dispersion forces)**.

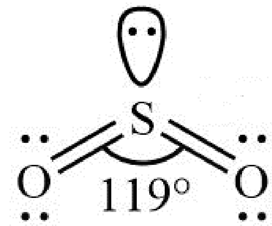


(3)

8.

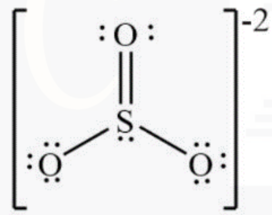
SO_2

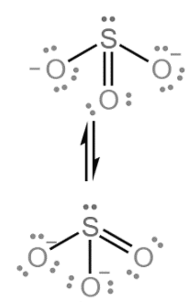
Shape: trigonal planar



SO_3^{2-}

Shape: trigonal pyramidal





The bond angle between the oxygen atoms in SO_3^{2-} is 109.5°. This bond angle is slightly less than the ideal 120° expected for a trigonal planar structure due to the presence of the lone pair on sulfur.
The lone pair repels more than bonded pairs, compressing the bond angles slightly and resulting in a bond angle smaller than the ideal value as in tetrahedral.

(Total 5 marks)

9. (A)

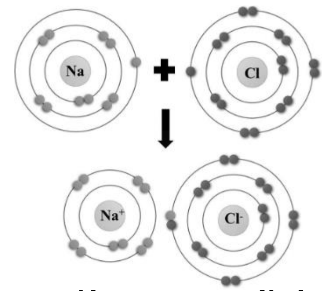
(Total 1 mark)

10.

Sodium chloride NaCl is an iconic example of an ionic compound, which forms through the bonding between sodium (Na) and chlorine (Cl) atoms.

Bonding in Sodium Chloride:

Ionic bonding is present between sodium and chlorine in NaCl.

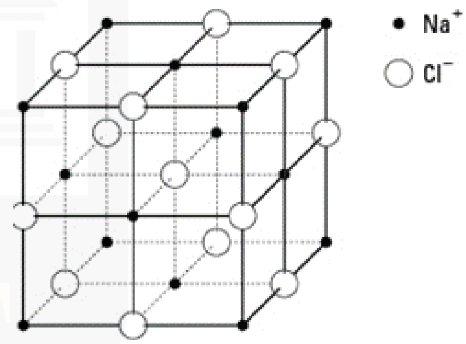


Sodium, a metal, has one valence electron in its outer shell, while chlorine, a nonmetal, has seven valence electrons. Sodium tends to lose one electron to achieve a stable electron configuration, forming a positively charged ion (Na^+), while chlorine tends to gain one electron to attain a stable configuration, forming a negatively charged ion (Cl^-).

The ionic bond in NaCl is the electrostatic attraction between these oppositely charged ions.

In the solid state, Na^+ and Cl^- ions arrange themselves in a three-dimensional lattice structure due to their attraction and repulsion forces.

Structure of Sodium Chloride:



The crystal structure of sodium chloride is a regular, repeating arrangement of sodium and chloride ions in a cubic lattice. In this lattice, each sodium ion is surrounded by six chloride ions, and each chloride ion is surrounded by six sodium ions. The ions are held together in a 3D array, forming a giant ionic structure.

The high melting point is a result of the strong electrostatic interactions between the ions within the crystal lattice.

As a result, a significant amount of heat energy is necessary to overcome these forces, hence the high melting point of sodium chloride.

(6)

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