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91164



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Mana Tohu Mātauranga o Aotearoa
New Zealand Qualifications Authority

Level 2 Chemistry 2025

91164 Demonstrate understanding of bonding, structure, properties and energy changes

Credits: Five

Achievement	Achievement with Merit	Achievement with Excellence
Demonstrate understanding of bonding, structure, properties and energy changes.	Demonstrate in-depth understanding of bonding, structure, properties and energy changes.	Demonstrate comprehensive understanding of bonding, structure, properties and energy changes.

Check that the National Student Number (NSN) on your admission slip is the same as the number at the top of this page.

You should attempt ALL the questions in this booklet.

A periodic table and other reference material are provided in the Resource Booklet L2-CHEMR.

If you need more room for any answer, use the extra space provided at the back of this booklet.

Check that this booklet has pages 2–16 in the correct order and that none of these pages is blank.

Do not write in any margins (✂/✂/✂). This area will be cut off when the booklet is marked.

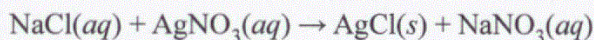
YOU MUST HAND THIS BOOKLET TO THE SUPERVISOR AT THE END OF THE EXAMINATION.

Merit

TOTAL 15

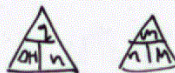
QUESTION ONE

Sodium chloride, NaCl, is used as an antiseptic and antimicrobial agent. In analytical chemistry, it is often reacted with silver nitrate, AgNO₃, shown below.



- (a) When silver nitrate, AgNO₃, is added to 73.0 g of sodium chloride, NaCl, 81.8 kJ of energy is released.

Calculate the $\Delta_r H$ for the above reaction.



$$M(\text{NaCl}) = 58.4 \text{ g mol}^{-1}$$

$\frac{m}{M} = n(\text{NaCl})$	$\Delta H = \frac{q}{n}$	$\Delta H = 65.44 \text{ kJ mol}^{-1}$
$\frac{73.0}{58.4} = 1.25 \text{ moles}$	$\Delta H = \frac{81.8}{1.25}$	$\Delta H = 65.4 \text{ kJ mol}^{-1} (3 \text{ s.f.})$

- (b) (i) Identify which substance below matches the information provided in the table by placing it into the correct row.

Zinc (Zn) Ammonia (NH₃) Diamond (C) Sodium chloride (NaCl)

Solid type	Melting point (°C)	Substance selected
3D Covalent Network	3550	Diamond
Ionic	801	NaCl
Metallic	420	Zinc
Molecular	-78	NH ₃

- (ii) Relate the bonding and structure in ionic and molecular solids to their relative melting points.

In your answer:

- describe the bonding and structure in ionic and molecular solids
- explain what the melting point of a solid indicates about the strength of forces between its particles
- link the strength of forces between the particles to their relative melting points.

Ionic solids are made up of a 3D lattice of ions, bonded together with strong ionic bonds.

These bonds require a lot of energy to be broken, meaning a large amount of heat is needed to get an ionic solid to melt. This ~~gives~~^{means} ionic solids generally have high melting points.

Molecular solids are made up of covalently bonded atoms (molecules), that are bonded to each other with weak intermolecular forces. Because these bonds are weak, they do not require much energy in order to be broken. This means little heat is needed to melt them, giving molecular solids generally low melting points.

The higher the melting point of a solid, the stronger the forces between its particles.

- (c) Diamond, C, and gold, Au, are both used frequently in jewellery making, but their properties are very different.

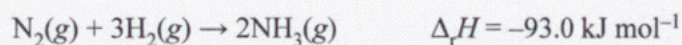
Diamond is very hard and can only be scratched by a substance equally as hard as itself. Gold, however, is malleable and ductile, and is used to craft intricate shapes and patterns.

Explain how the structure and bonding of each substance results in these properties.

Diamond, C, hardness: Diamond is a covalent network solid made of a 3D lattice of carbon atoms covalently bonded together. These bonds are strong, rigid and directional. Diamond is a very hard substance due to the very large number of strong covalent bonds it contains.

Gold, Au, malleable and ductile: Gold is a metallic solid. It is made of Au nuclei, metallicly bonded together and surrounded by delocalised electrons. If there is movement in a metallic solid, such as gold, the delocalised electrons and non-directional bonds allow the ~~metallic~~ electrons to simply align with new metal nuclei and the solid will remain intact. This is why gold is malleable and ductile.

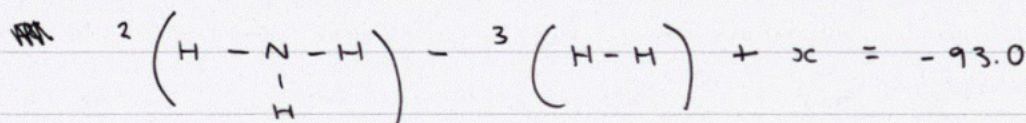
- (d) The development of the Haber-Bosch process, shown in the reaction below, is historically significant.



Calculate the average bond energy of the $\text{N}\equiv\text{N}$ bond in N_2 , using the average bond energies listed in the table below for this reaction between nitrogen, N_2 , and hydrogen, H_2 , that produces ammonia, NH_3 .

Bond	Bond energy (kJ mol^{-1})
H-H	436
N-H	391

$\text{N}\equiv\text{N}$	H-H	$\begin{array}{c} \text{H}-\text{N}-\text{H} \\ \\ \text{H} \end{array}$
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$$6(\text{N}-\text{H}) - 3(\text{H}-\text{H}) + x = -93.0$$

$$6(391) - 3(436) + x = -93.0$$

$$2346 - 1308 + x = -93.0$$

$$1038 + x = -93.0$$

$$-x = -1131$$

$$x = 1131$$

Average bond energy for $\text{N}\equiv\text{N} = 1131 \text{ kJ mol}^{-1}$

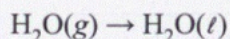
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QUESTION TWO

- (a) (i) Identify whether each of the statements apply to endothermic (Endo) or exothermic (Exo) reactions by circling the correct term only.

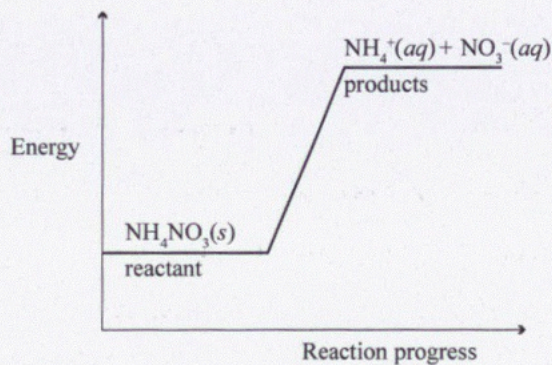
- The products have more energy than the reactants. (Endo) / Exo
- Energy is released to the surroundings. Endo / (Exo)
- The change in enthalpy (ΔH) for the reaction is positive. (Endo) / Exo

- (ii) State whether the following process is endothermic or exothermic, and give a reason for your choice.



In the process of H_2O going from a state of gas to a state of liquid, more bonds must be formed than broken. Forming bonds releases energy, heating up the surroundings, therefore this reaction is exothermic.

Ammonium nitrate, NH_4NO_3 , is used in first aid to treat injuries. The energy change in the reaction is shown in the diagram below.



- (iii) Is the reaction in the graph above absorbing energy from the surroundings or releasing energy to the surroundings?

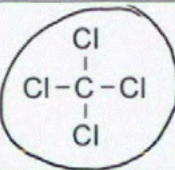
Absorbing energy from the surroundings.

- (iv) Circle the correct option for identification of the enthalpy change of this reaction ($\Delta_r H$):

$\Delta_r H < 0$, negative

($\Delta_r H > 0$, positive)

- (b) All three of the compounds given in the table below contain polar bonds, but only two of them are polar molecules.

Methanol	Tetrachloromethane	Water
$\begin{array}{c} \text{H} \\ \\ \text{H}-\text{C}-\text{OH} \\ \\ \text{H} \end{array}$		$\text{H}-\text{O}-\text{H}$

- (i) Define what makes a chemical bond polar, and give an example from one of the above compounds.

In order for a chemical bond to be considered polar, it must be between two atoms with different electronegativities. For example, the bonds between Oxygen and hydrogen in H_2O are polar because oxygen has a greater electronegativity than hydrogen*. This makes the bond itself polar, but doesn't always mean the molecule as a whole is polar as well.

* This gives the bond bond dipoles.

- (ii) Circle the compound in the table above that is the **non-polar** molecule.

- (iii) Use your understanding of structure and bonding to justify your choice of the molecule you circled above.

Tetrachloromethane has 4 regions of electronegativity, which repel to get give a maximum separation of 109.5° (4 regions, tetrahedral configuration). As it has 4 bonding regions, and 0 non-bonding regions, its shape is tetrahedral.

Tetra~~meth~~chloromethane contains polar bonds between carbon and chlorine, due to their difference in electronegativity. However, due to the shape of the molecule, the bond dipoles are arranged symmetrically so they cancel. This makes the tetrachloromethane molecule as a whole non-polar.

- (c) Predict the solubility of the following combinations of solutes and solvents by adding a tick (✓) to the correct column for each combination.

Solute and solvent combination	Soluble?	Insoluble?
Tetrachloromethane, CCl_4 , in water, H_2O		✓
Magnesium bromide, MgBr_2 in hexane, C_6H_{14}	✓	
Bromine, Br_2 , in hexane, C_6H_{14}		✓

- (d) What makes sodium chloride, NaCl , soluble in water, but iodine, I_2 , insoluble in water.

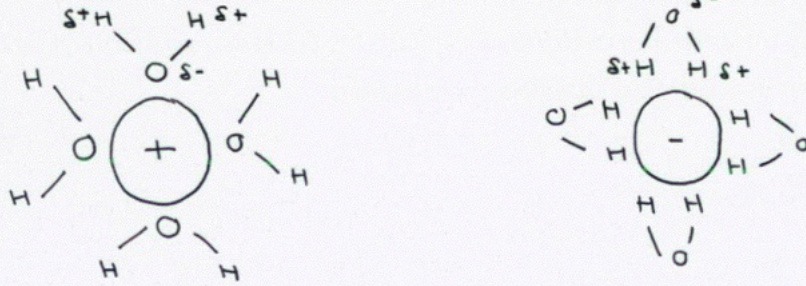
In your answer:

- refer to the structure and bonding of each substance
- explain how the substance interacts with water molecules
- include a diagram showing the dissolving of NaCl in water.

NaCl is an ionic solid, ~~made~~ made of a 3D lattice of ions, bonded with strong ionic bonds. When added to water, NaCl dissolves because the ions are attracted to the bond dipoles of the water molecules, more than they are attracted to each other.

I_2 is a molecular substance, made of ~~the~~ individual molecules ~~are~~ bonded to each other with weak ~~intermolecular~~ intermolecular forces. Molecules that are polar will dissolve in polar solvents, and molecules that are non-polar will dissolve in non-polar solvents. I_2 is a non-polar molecule as it doesn't contain any polar bonds. As water is a polar solvent, I_2 doesn't dissolve in water as its attraction to itself is stronger than its attraction to the solvent.

Diagram to show NaCl dissolving in water:



QUESTION THREE

- (a) Different forms (allotropes) of carbon have different electrical conductivities. Diamond does not conduct electricity, but graphite is a very good electrical conductor.

Compare and contrast the structure and bonding of these two carbon compounds.

In your answer:

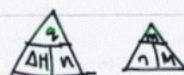
- explain the structure and bonding of diamond and graphite
- define electrical conductivity in solids
- justify the difference in electrical conductivity between diamond and graphite.

You may include a diagram to support your answer.

In order to conduct electricity, a solid needs to have both charged and freely moving particles.

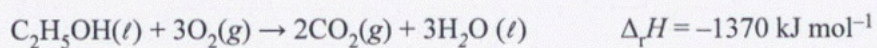
Diamond is a covalent network solid, made of a 3D lattice of carbon atoms covalently bonded together. These covalent bonds are strong, rigid and directional. Diamond does not contain any freely moving charged particles, preventing it from conducting electricity.

Graphite is also a covalent network solid, but it is made of 2D ~~layers~~^{sheets} of covalently bonded carbon atoms, separated by layers of delocalised electrons. Because these electrons are both freely moving AND charged particles, graphite is able to conduct electricity.



- (b) Combustion is a chemical reaction in which a substance combines with oxygen and produces heat.

When ethanol, C_2H_5OH , is combusted with oxygen, O_2 , carbon dioxide, CO_2 , and water, H_2O , are produced.

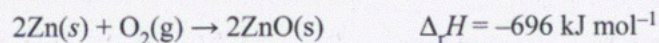


- (i) Calculate the mass of ethanol, C_2H_5OH , that must react to release 17 500 kJ of energy.

$$M(C_2H_5OH) = 46.7 \text{ g mol}^{-1}$$

$n = 2$	$n = -12.77372263 \text{ moles}$	$m(C_2H_5OH) = 597 \text{ g (3 s.f.)}$
ΔH	$n \times M = m$	
$n = \frac{17500}{-1370}$	$m = 596.5328$	

- (ii) Calculate the energy change when 187 g of zinc oxide, ZnO , is produced in the reaction below between zinc, Zn , and oxygen, O_2 .



$$M(ZnO) = 81.4 \text{ g mol}^{-1}$$

Question Three continues on the next page.

- (c) Draw the Lewis structure (electron dot diagram) for each of the following molecules, and give their shapes.

Molecule	CO ₂	Cl ₂ O	BF ₃
Lewis structure	$\ddot{\text{O}}=\text{C}=\ddot{\text{O}}$	$\ddot{\text{Cl}}-\ddot{\text{O}}-\ddot{\text{Cl}}$	$\begin{array}{c} \ddot{\text{F}} \\ \\ \ddot{\text{F}}-\text{B}-\ddot{\text{F}} \\ \\ \ddot{\text{F}} \end{array}$
Name of shape	linear	trigonal pyramidal	trigonal planar

- (d) The table gives information relating to the shape of each molecular substance.

Solid name	Methane	Ammonia
Shape diagram	$\begin{array}{c} \text{H} \\ \\ \text{C} \\ / \quad \backslash \\ \text{H} \quad \text{H} \\ \\ \text{H} \end{array}$	$\begin{array}{c} \text{N} \\ / \quad \backslash \\ \text{H} \quad \text{H} \\ \\ \text{H} \end{array}$
Bond angle	109.5°	109.5°
Molecular shape	Tetrahedral	Trigonal pyramid

Compare the two shapes and explain the factors that contribute to:

- arrangement around the central atom
- molecular shape.

CH₄ has 4 regions of electron ^{density}, which repel to give a maximum separation of 109.5° (4 regions, tetrahedral configuration). As it has 4 ~~regions~~ ^{bonding} regions and 0 non-bonding regions, its shape is tetrahedral.

NH₃ has 4 regions of electron density, which repel to give a maximum separation of 109.5° (4 regions, tetrahedral configuration). As NH₃ has 3 bonding regions and 1 non-bonding region, its shape is trigonal pyramid.

Although both molecules have 4 regions of electron density, they are ~~and~~ different shapes and arrangements around their central atoms due to their number of non-bonding regions.

Extra space if required.
Write the question number(s) if applicable.

QUESTION
NUMBER

linear	X	X
trigonal planar	bent	X
tetrahedral	trigonal pyramidal	bent

Merit

Subject: L2 Chemistry

Standard: 91164

Total score: 15

Q	Grade score	Marker commentary
One	M5	The candidate was awarded M5. They correctly calculated the enthalpy change for the given reaction, but failed to signify that it was an exothermic reaction. They correctly identified types of solids when given data, and fully discussed the relationship between melting point and forces between particles with correct details of particle types and structure. An excellence point was awarded here. In part (c), they lacked detail when describing the hardness of diamond, and implied that the non-directional bond and delocalised electrons were responsible for the malleability of gold, rather than cations sliding. An error in subtraction led to a merit grade being awarded for part (d).
Two	M5	The candidate was awarded M5 as they were able to identify exothermic and endothermic statements, and correctly identified that bonds were made and that condensation is an exothermic reaction with energy is released. They were awarded a merit point for part (a). In part (b), tetrachloromethane is correctly identified as a non-polar molecule, and electronegativity is explained appropriately. The explanation in part (b)(iii) discussed bond dipole cancellation and symmetry, but failed to mention the size of the dipoles. Merit was awarded here. None of three solubility options were selected correctly in part (c), and in part (d), the candidate recognised that attractions (or lack of them) were required for a solute to dissolve in water, with a correct hydrated ion diagram, but could not be awarded a merit point as the discussion lacked detail of specific solute-solvent forces overcoming solute-solute and solvent-solvent.
Three	M5	The candidate was awarded M5. They were awarded an achieved point for part (a), as they lacked detail of structure of either allotrope with regard to the number of bonded carbon atoms, but did identify that mobile charged particles were needed for conductivity. A merit point was awarded for part (b), as they correctly calculated the mass with correct units from the first calculation. All Lewis diagrams were correct in part (c), and two the shapes were correct. In part (d), the shape and bond angle of methane and ammonia were correctly discussed and compared succinctly using VSEPR theory. An excellence point was awarded here.