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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.

Excellence

TOTAL 21

QUESTION ONE

Sodium chloride, NaCl, is used as an antiseptic and antimicrobial agent. In analytical chemistry, it is often reacted with silver nitrate, $AgNO_3$, shown below.

$$NaCl(aq) + AgNO_3(aq) \rightarrow AgCl(s) + NaNO_3(aq)$$

(a) When silver nitrate, $AgNO_3$, 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(NaCl) = 58.4 g mol^{-1}

$n=\frac{m}{M}$

$n=\frac{73}{58.4}=1.25$

$\frac{81.8}{1.25}=65.4$ kJ

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

Zinc (Zn) **Ammonia (NH_3)** **Diamond (C)** **Sodium chloride (NaCl)**

Solid type	Melting point (°C)	Substance selected
3D Covalent Network	3550	Diamond (C)
Ionic	801	Sodium Chloride (NaCl)
Metallic	420	Zinc (Zn)
Molecular	–78	Ammonia (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.

Molecular solids are made up of molecule particles being held together by weak intermolecular forces. These weak forces do not require a lot of energy to break apart, which is why the melting point of Ammonia is so low at -78°C. Ionic solids are a 3D lattice of alternating ions, in the case of NaCl, alternating Na^+ and Cl^- ions. The ions are ~~on~~ bonded by strong ionic bonds. These strong bonds require a lot of energy to break, which is why the melting point of NaCl is very high at 801°C.

(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 3D covalent network which is a 3D lattice of Carbon atoms bonded to one another by strong covalent bonds. Because these covalent bonds are very strong and ~~[illegible]~~ directional, diamond can withstand high impact and is very hard.

Gold, Au, malleable and ductile: Gold is metallic solid which is a 3D lattice of Au cations being bonded to one another by metallic bonds These cations are surrounded in a sea of free moving electrons. Gold is malleable because the metallic bonds are non-directional, so when force is applied, the Au cations simply are pushed, creating dent where the force is applied.

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

$$N_2(g) + 3H_2(g) \rightarrow 2NH_3(g) \qquad \Delta_r H = -93.0 \text{ kJ mol}^{-1}$$

Calculate the average bond energy of the N≡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

N≡N	H−H	H−N−H | H

$\Delta_r H$ = bonds broken − bonds formed

~~$\Delta_r H = (N \equiv N + 3 \times 436 + 6 \times 391) -$~~

$\Delta_r H = (N \equiv N + 3 \times 436) - 6 \times 391 = -93$

$(N \equiv N + 1308) - 2346 = -93$

$N \equiv N + 1308 = 2253$

$N \equiv N = 2253 - 1308 = 945 \text{ kJ mol}^{-1}$

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The assessment continues on the following page.

QUESTION TWO

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

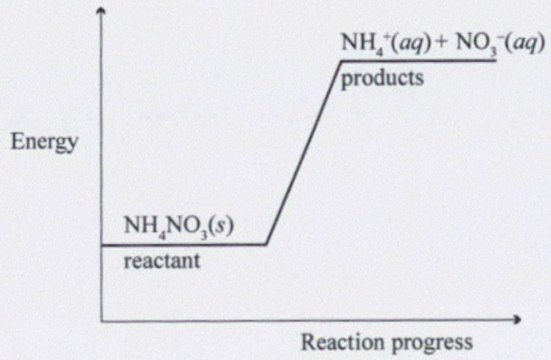
- The products have more energy than the reactants. **Endo / Exo**
- Energy is released to the surroundings. **Endo / Exo**
- The change in enthalpy (ΔH) for the reaction is positive. **Endo / Exo**

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

$H_2O(g) \rightarrow H_2O(\ell)$

~~It is endothe~~ It is exothermic. When a gaseous molecule, such as $H_2O_{(g)}$ here, is turned into a liquid, intermolecular forces are made between the molecules. This formation of these forces is exothermic, therefore $H_2O_{(g)} \rightarrow H_2O_{(l)}$ 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?

It is absorbing energy as $\Delta_r H$ is positive, therefore it is endothermic.

(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
H–C(H)(H)–OH	Cl–C(Cl)(Cl)–Cl	H–O–H

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

Bond dipoles are formed when the two atoms on each side of the bond have inequal electronegativity. In water, (for example) the electronegativity of oxygen is much higher than that of hydrogen, therefore the bonds in H_2O are polar - oxygen being δ negative and hydrogen being δ positive.

(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.

For a molecular with bond dipoles to be polar, the bond dipoles have to be symmetrically ~~opposite each other~~ organised for them to cancel each other out. For this to happen, the shape of the molecule has to be symmetrical. Tetrachloro methane has 4 areas of electron density, and because all areas are bonded, the shape is tetrahedral. This is a symmetrical shape, and because the polarity of all 4 bond dipoles is equal, as all 4 bonds are bonded to Cl, the bond dipoles cancel each other out and therefore makes this molecule non-polar. Methanol, though also being tetrahedral, is polar as it has only one OH bond while the other 3 are H, and therefore the bond diploes can not cancel each other. H_2O has ~~shaped~~ a bent shape, which is an assymetrical shape therefore H_2O ~~can not be~~ is 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.

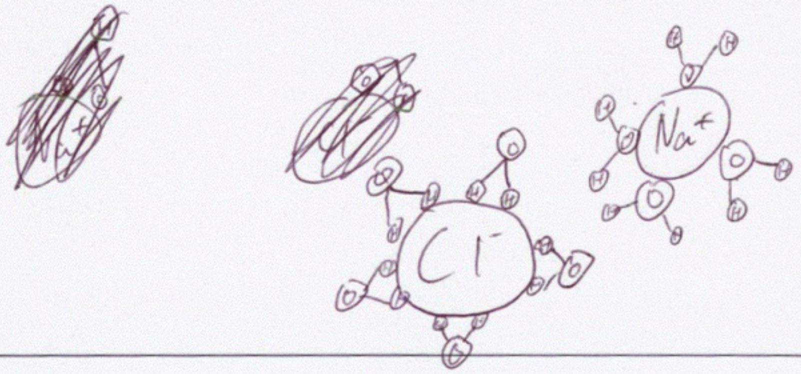
In your answer:

- 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.

For a ~~molecule to~~ substance to dissolve in a solvent, the solute-solvent attraction forces have to overcome the solute-solute and solvent-solvent attractions. ~~Water is a non-polar polar molecule, and so is NaCl. The~~ Water is a polar molecule as it has a bent shape whereas iodine is non-polar as it has a linear shape. ~~For the solute and solven solute-solvent bonds to form, the type of attraction~~ The difference in this bond type – the polar H_2O bonds and non-polar I_2 bonds – makes it so the solute-solvent attraction can not overcome/replace the already existing bonds. NaCl is an ionic compound, ~~and dissociates into Na^+ and Cl^- ions in water.~~ Made of Na^+ and Cl^- ions. As H_2O is polar, the oxygen area being partially negative and the hydrogen area being partially positive, ~~the areas~~ the partially negative area is attracted by the positive Na^+ ions and the partially positive area is attracted by the negative Cl^- ions. These attractions are strong enough to overcome the solute-solute and solvent-solvent ~~att~~ attractions, therefore

NaCl can dissolve in water.

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.

For a substance to ~~be~~ conduct electricity, it must have free moving charged particles. Diamond is a ~~3D lattice~~ 3D covalent network where carbons are bonded to each other by covalent bonds in a 3D lattice. Each carbon is bonded to 4 more carbons, therefore the carbons do not have any free valence electrons. This means there are no free moving charged particles in carbon, therefore ~~R~~ diamond is non-conductive.

Graphite is also a 3D covalent network, a 3D lattice of carbons bonded to each other by covalent bonds. Unlike diamond, ~~graq~~ carbon atoms in graphite only bond to 3 other carbons, forming thin, 2D sheets. These sheets are stacked on top of each other to form graphite. Because each carbon only has 3 bonds, 1 valence electron is left. This valence electron is free moving within the layers, ~~there A~~ therefore it is a free moving charged particle, allowing graphite 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.

$$C_2H_5OH(\ell) + 3O_2(g) \rightarrow 2CO_2(g) + 3H_2O(\ell) \qquad \Delta_rH = -1370 \text{ kJ mol}^{-1}$$

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

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

$\frac{17500}{1370} = 12.77372263$

~~A=~~ $n = \frac{m}{M}$, $m = nM$

$m = 12.77372263 \times 46.7$

$m =$ ~~596~~ 597g (3 s.f)

(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.

$$2Zn(s) + O_2(g) \rightarrow 2ZnO(s) \qquad \Delta_rH = -696 \text{ kJ mol}^{-1}$$

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

$\frac{696}{2} = 348$

~~[illegible]~~

$n = \frac{m}{M}$

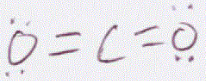
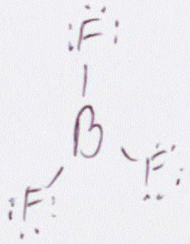
$n = \frac{187}{81.4} = 2.297297297$

~~ΔH=n×~~

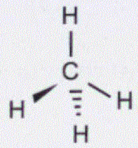
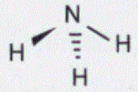
$2.297297297 \times$ ~~[illegible]~~ $348 = 799$ kJmol^{-1} (3s.f)

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_2O**	**BF_3**
Lewis structure			
Name of shape	Linear	Bent	Trigonal Planar

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

Solid name	**Methane**	**Ammonia**
Shape diagram		
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.

Molecular shape is determined by the number of electron density and how many of them are bonds.
Both methane and ammonia have 4 areas of electron density. ~~Methane~~ ~~Of the~~ In methane, all 4 are bonds meaning it is tetrahedral, but in ammonia, only 3 are bonds while one is a lone electron pair. This makes ammonia have a trigonal pyramidal shape. Bond angles, or how the areas of electron density is arranged around the central atom, is determined only by the number of electron density. Both molecules have 4

areas of electron density, so the bond angles are equal at ~~109~~ 109.5°. It is this angle due to VESPR theory, which states that areas of electron density ~~arrange themselves to~~ repel each other and arrange themselves to maximise the space between each area. In molecules with 4 areas, this maximum angle is 109.5°, hence both molecules here have bond angles of 109.5°.

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

QUESTION NUMBER

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QUESTION NUMBER

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Write the question number(s) if applicable.

QUESTION NUMBER

Excellence

Subject: L2 Chemistry

Standard: 91164

Total score: 21

Q	Grade score	Marker commentary
One	E7	The candidate was awarded E7. They correctly calculated the enthalpy change for the given reaction, but failed to assign correct units and sign. Types of solids were correctly identified from given data, and the relationship between melting point and forces between particles fully discussed, with correct details of particle types and structure. In part (c), they lacked detail when describing the hardness of diamond, and implied that cations were pushing rather than sliding when discussing the malleability of gold. Part (d) had no calculation errors and correct units and earned an excellence point.
Two	E7	The candidate identified exothermic and endothermic statements and correctly identified that bonds were made and that condensation is an exothermic reaction, but failed to mention that energy is released. They were awarded an achieved 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, symmetry, and the size of the dipoles – an excellence point was awarded here. All of three solubility options were selected correctly in part (c), and in part (d) they recognised that attractions (or lack of them) were required for a solute to dissolve in water, with a correct hydrated ion diagram. The discussion was robust in terms of specific solute-solvent forces overcoming solute-solute and solvent-solvent for NaCl, but lacked a description of the type of forces overcome for iodine. This was counted as a minor excellence error, resulting in a score of E7.
Three	E7	The candidate was awarded E7 as they comprehensively compared and contrasted the conductivity of both allotropes with reference to the inherent structure and bonding. An excellence point was awarded here. A merit point was awarded for part (b), as they correctly calculated the mass with correct units from the first calculation, but had incorrect units and a missing minus sign for the second calculation. All Lewis diagrams and shapes were correct in part (c). In part (d), the shape and bond angle of methane and ammonia were correctly discussed and compared concisely using VSEPR theory. The second excellence point was awarded here.