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Mana Tohu Mātauranga o Aotearoa
New Zealand Qualifications Authority

Level 2 Chemistry 2024

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 cross-hatched area. This area will be cut off when the booklet is marked.

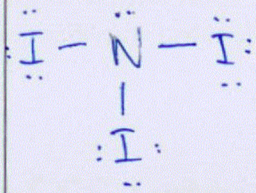
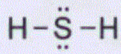
YOU MUST HAND THIS BOOKLET TO THE SUPERVISOR AT THE END OF THE EXAMINATION.

Merit

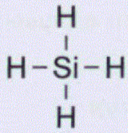
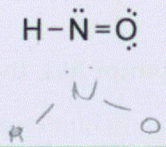
TOTAL 15

QUESTION ONE

(a) Draw the Lewis structure for each of the two blank molecules, and name their shapes.

Molecule	NI_3 (nitrogen triiodide)	H_2S (hydrogen sulfide)	CS_2 (carbon disulfide)
Lewis structure			
Name of shape	Trigonal pyramid	bent	linear
Approximate bond angle around central atom	109.5°	109.5°	180°

(b) Compare and contrast the shapes and bond angles of silicon tetrahydride, SiH_4, and azanone, HNO.

Molecule	SIH_4 (silicon tetrahydride)	HNO (azanone)
Lewis structure		

~~Silicon tetrahydride is a symmetrical tetrahedral shape, this i~~ Bond angle is determined by the number of electron densities there are on the central atom, all which are positioned to maximise seperation and minimise repulsion. The shape similarly, is determined by the no. of electron densities around the central atom, but conversly, also take into account whether these regions are bonding or non bonding → Non bonding regions contribute to the shape, but are not apart of it. Silicon tetrahydr is a symmetrical tetrahedral shape, this is because there are 4 regions of electron dencity around the central Si atom, ~~all of which are~~, thus these regions, are positioned to maximise seperation and minimise repulsion leaving a bond angle of 109.5°, and since all regions are bonding in has a tetrahedral shape (all regions contribute).

HNO is a ~~trigonal planar~~ Bent shape, this is because there are 3 regions of ED around the central ~~at~~ N atom, 1 which is non bonding and 2 which are bonding, hence the ND is not considered apart of the shape deeming it a bent shape. and all 3 regions impose a maximum seperation force and minimise repulsion leaving a bond angle of 120° (120.5°). ↳ as the lone pair of e⁻, exudes a greater repulsion force.

(c) Hydrogen sulfide, H_2S, and hydrogen cyanide, HCN, molecules have a different shape, but they both have the same polarity.

The Lewis structure of both of these molecules are shown below:

hydrogen sulfide H−S̈−H (with a lone pair above and below S)

hydrogen cyanide H−C≡N:

(i) Circle the word below which identifies the polarity of both H_2S and HCN.

Polar (circled) **Non-polar**

(ii) Justify your choice of polarity by:

- explaining the links between the bonding and structure of each substance, and
- relating this to how the polarity of a molecule is determined.

hydrogen sulfide is made up 2 polar S-H bonds, ~~that~~ (hence a dipole) this is because of the different electroneagtivies of S and H (and how they do not equate to eachother). H_2S has 4 regions of ED around the central sulfide atom, 2 which are bonding and 2 which are non bonding, hence this means it has a asymmetrical bent shape. Due to the asymmetrical shape, the 2 polar S-H bonds cannot cancel eachother out (as they are not positioned to fully oppose eachothers polar bonds), hence deeming the entire molecule polar. Hydrogen cyanide has 2 regions of electron density around the central C atom, both of which are bonding (thus they both contribute to the shape), therefore this leaves a symmetrical linear shape. There are also 2 polar bonds with HCN which is the (H-C) and the (C≡N) + this polar bond is also due to the differences in electronenatives between C, H & N. ~~then~~, Although this is a linear

(d) Methanamine, CH_3NH_2, is used widely in the production of pharmaceuticals, fungicides, insecticides, cleaning agents, and in the fabric industry.

Although hydrogen cyanide, HCN, is highly poisonous, it can be used to produce methanamine, as shown in the reaction below.

$$HCN(g) + 2H_2(g) \rightarrow CH_3NH_2(g) \quad \Delta_rH = -158 \text{ kJ mol}^{-1}$$

(i) Calculate the mass of methanamine formed when 1890 kJ of energy is released.

$M(CH_3NH_2) = 31.0 \text{ g mol}^{-1}$

$q = \frac{\Delta_r H}{\text{coefficient}} \times n \qquad 1890 = \frac{-158}{1} \times n$

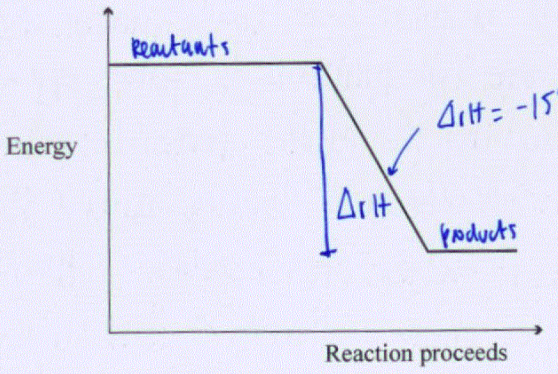
$n = -11.96 \rightarrow 11.96$

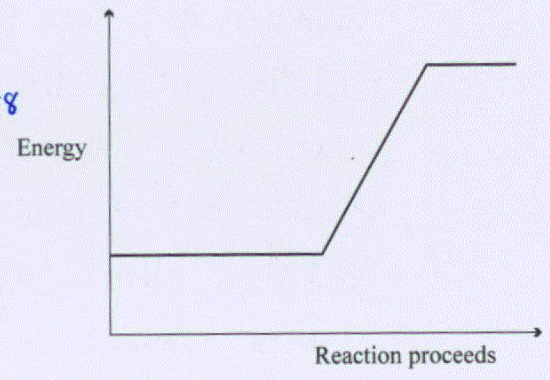
$n = m/M \rightarrow 11.96 = m/31.0$

$m = 11.96 \times 31$

$m = 370.8\ g\ (371\ g).$

(ii) Choose the correct energy diagram that represents the reaction above and label it with the information provided in the equation.





QUESTION TWO

(a) Complete the table below for each substance in their solid state.

Solid	Melting point (°C)	Type of solid	Type of particle	Attractive forces between particles
$SiO_2(s)$ (silicon dioxide)	1700	giant covalent network	atoms	covalent Bonding
$SiCl_4(s)$ (silicon tetrachloride)	–69	molecular	molecules	weak intermolecular forces / bonds
$CuCl_2(s)$ (copper (II) chloride)	620	ionic	ions (cation & Anion).	electrostatic attraction / ionic bonding
$Al(s)$ (aluminium)	660	metallaic	metal atoms / Atoms.	metalic bonding.

(b) Both SiO_2 and $SiCl_4$ contain silicon, but $SiCl_4$ has a considerably lower melting point. O=S=O

Explain why there is a difference in melting point for these substances.

$SiCl_4$ is a molecular solid, this means the molecules of Si & Cl are bonded through weak intermolecular bonds, which keep the solid together. These bonds require little / significantly smaller amount of energy than $SiCl_4$ to overcome, hence the melting point is low, as little heat (hence heat energy) is needed to break the van de groff forces in sich. SiO_2 is a giant covalent network which consists of Si and O_2 atoms covalently bonded together. Each oxygen atom is bonded to a silicone atom which is then again bonded to 4 other oxgen atoms. These bonds that are made up of the GCN, are strong covalent bonds, hence they need a lot of energy (heat energy) to over come. Therefore due to this SiO_2 has a very large ~~boiling~~ / melting point as a large amount of heat is required to break the bonds between it.

(c) Explain why silicon tetrachloride, $SiCl_4$, does not dissolve in water, but copper(II) chloride, $CuCl_2$, does.

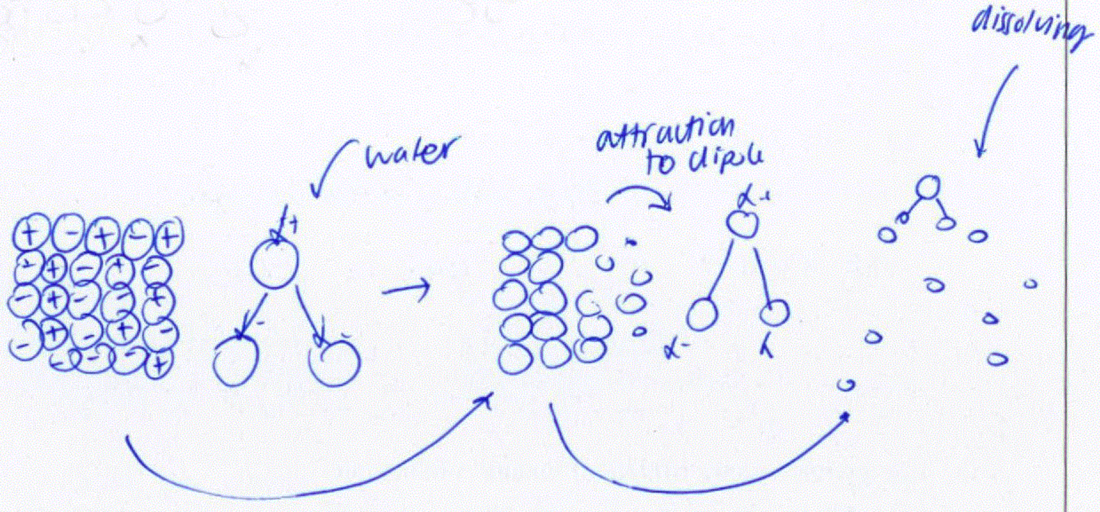
In your answer:

- link to their structure and bonding
- include the type of solvent that $SiCl_4$ will dissolve in, and why
- include a diagram to support your answer for $CuCl_2$.

Copper Chloride is an ionic substance which consists of a 3D alternate lattice structure, of postive Copper ions (cations) and negative Cl ions (Anions). The structure is held up by the electrostatic attraction between the Anions and cations ~~are~~ as ✓ oppositly charged ions attract. (this is also known as ionic bonding). when placed in water the attraction of the ions to the polar ends (dipole) of the water molecules are greater than the ~~a~~ attraction within the ~~so~~ ionic solid itself. Hence, $CuCl_2$ is able to dissolve in water, and is water solvable. $SiCl_4$ is a non polar molecular substance, due to its non polar nature (as the tetrahedral shape with 4 regions of ED cancel out the dipoles), the forces of attraction to the polar water molecules are not great enough to overcome the bonds within themselves (Si and Cl_4), however, $SiCl_4$ will dissolve in a polar solvent, as this will iniate a force of attraction between the solid and the solvent, which is great enough to overcome the bonds within the solid / structure.

known as ionic bonding

Diagram to show $CuCl_2$ dissolving in water.



QUESTION THREE

Bottled gas supply in New Zealand is a 60% propane, C_3H_8, and 40% butane, C_4H_{10}, mix.

The combustion reactions for both propane and butane fuels are given below.

(a) Show by calculation how much more energy is released per 1.00 kg of propane compared to 1.00 kg of butane.

(i) Energy released by 1.00 kg of propane combustion

$$C_3H_8(g) + 5O_2(g) \rightarrow 3CO_2(g) + 4H_2O(g) \qquad \Delta_rH = -2044 \text{ kJ mol}^{-1}$$

$M(C_3H_8) = 44.1 \text{ g mol}^{-1}$

q = -2044 × 22.67

q = -46349.206 (-46300 kJ mol⁻¹)

n = m/M → n = 1000 / 44.1 = 22.67

(ii) Energy released by 1.00 kg of butane combustion

$$2C_4H_{10}(g) + 13O_2(g) \rightarrow 8CO_2(g) + 10H_2O(g) \qquad \Delta_rH = -2877 \text{ kJ mol}^{-1}$$

$M(C_4H_{10}) = 58.1 \text{ g mol}^{-1}$

q = -2877 × 17.212

q = 49518.07 (49500 kJ mol⁻¹)

n = m/M → n = 1000 / 58.1

n = 17.212

(iii) Calculate how much more energy is released by 1.00 kg of propane than 1.00 kg of butane.

propane = -46349.206

butane = 49518.07

difference = 3168.86 kJ mol⁻¹

(b) The reaction of a hydrogen fuel cell is shown below. Hydrogen reacts with oxygen to produce water.

$2H_2(g) + O_2(g) \rightarrow 2H_2O(g)$ $\Delta_r H = -484 \text{ kJ mol}^{-1}$

H–H	O=O	H–O–H
H_2	O_2	H_2O

Use the bond energies listed in the table, and the change in enthalpy (–484 kJ mol^{-1}) provided for the reaction, to calculate the average bond energy of the O–H bond.

Bond	Bond energy (kJ mol^{-1})
H–H	436
O=O	498

OI = break – formed

4(H-H) = 4 × 436 = 1744
(O=O) = 498 = 498
total = 2242 kJ mol⁻¹.

formed
= 4(O-H) = 4x

-484 = 2242 - 4x
-4x = -2726
x = 681.5 kJ mol⁻¹.
O-H = 682 kJ mol⁻¹. (3 sf).

Question Three continues on the next page.

(c) 'Galvorn' is a newly developed form of carbon that is strong, light, and has good conductivity. With its clean manufacturing process and wide range of applications, it is anticipated that Galvorn could reduce the reliance on standard metals that are energy intensive to produce.

(i) As with graphite, Galvorn conducts electricity.

What requirement must Galvorn have to allow it to conduct electricity?

There must be free flowing charge / charged particle (electrons) within galvorn.

(ii) Aluminium, Al, is also a good conductor of electricity, and it is malleable (can be pressed into shapes). These properties enable it to be used extensively in overhead power lines and for components and shells in smartphones and laptops.

Explain why aluminium, Al, has these properties, and link it to the uses stated.

Refer to its structure and bonding.

Conducts electricity: Aluminum is a metal solid, which consists of a 3D lattice structure in which loosely held valence electrons are attracted to neighbouring ions (~~Al~~ Aluminium cations in a sea of delocalized electrons), this is known as metallic bonding. due to the delocalized electrons, ~~being at~~ contributing to metallic bonding they are free to go throughout the substance in both solid and molten states, hence this means that aluminium / metal is a good conductor, (as the charged particles flow throughout the structure).

Malleable: As metal / Aluminum consists of ~~[illegible]~~ metal cations in a sea of delocalized electrons, the ~~&~~ bonds / forces of attraction in Aluminum are non directional, meaning you can distort / change its shape, ~~and~~ without disrupting the metallic bonding ~~of the~~ ~~[illegible]~~ between the particles. here they can move past one another, and are ~~also~~ can be 'pulled' out into wires (ductile) and controted into different shape / is malleable.

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

QUESTION NUMBER

Q c(ii) Symmetrical shape, there strengths between the polar C-H bond is different to the polar C≡N bond. Hence they cannot cancel, eachother out, deeming the molecule polar. (dipoles cannot cancel)

Merit

Subject: Chemistry

Standard: 91164

Total score: 15

Q	Grade score	Marker commentary
One	M5	The candidate was awarded M5 as they correctly drew and named the shapes of Lewis diagrams and were recognised that the number of bonded and unbonded areas of electron density around a central atom repel to form final shapes with specific bond angles. In part c they identified that the electronegativity difference between atoms and symmetry of shape influences a molecules polarity but mistakenly had polar bonds cancelling for one molecule. In part d the mass calculation was correctly calculated but not rounded and the enthalpy diagram was only partially labelled.
Two	M5	The candidate was awarded M5 as they were able to state the particle type and attractive forces for all solid types and explained the difference between the melting point of two solids linking their particle type and strength of forces but did not compare and contrast. In part c they recognised that attractions between a solute and solvent must overcome existing attractions for the solubility of both the ionic and a non-polar substance in water but incorrectly labelled the dipoles on a water molecule so was not awarded the second merit opportunity for this part of 2c.
Three	M5	The candidate was awarded M5 as they correctly calculated the energy released from one fuel in part a. In part b they mistakenly doubled the number of bonds broken in one reactant so were only awarded an achieved grade here. The description of metallic bonding in part c was good for conductivity and malleability but there was no link to uses.