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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.

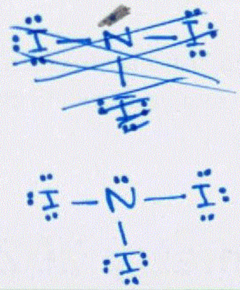
YOU MUST HAND THIS BOOKLET TO THE SUPERVISOR AT THE END OF THE EXAMINATION.

Excellence

TOTAL 21

QUESTION ONE

(a) Draw the Lewis structure for each of the two blank molecules, and name their shapes. 16e⁻

Molecule	NI_3 (nitrogen triiodide) 20e⁻	H_2S (hydrogen sulfide)	CS_2 (carbon disulfide)
Lewis structure		H–S̈–H	S̈=C=S̈
Name of shape	Trigonal pyramidal	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	H–Si–H with H above and below Tetrahedral 109.5°	H–N̈=Ö ~~Trigonal plane py.~~ Bent (3 regions). 120°

Silicon tetrahydride (~~SIH~~ SiH_4) has four regions of negative charge around the central Si atom. These regions maximise separation to minimise repulsion, forming a tetrahedral geometry with approximate bond angles of 109.5°. All four of these regions are bonding regions therefore the shape of SiH_4 is tetrahedral.

On the other hand,

Azanone (HNO) has three regions of negative charge around the central N atom. These regions maximise separation to minimise repulsion, forming a trigonal planar geometry, with approximate bond angles of 120°. Two of these regions are bonding regions and one of the regions ~~are~~ is a non-bonding region. Therefore the shape of HNO is bent (3 regions).

(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 $\overset{\delta+}{H}-\overset{\delta-}{\ddot{S}}-\overset{\delta+}{H}$

hydrogen cyanide $\overset{\delta+}{H}-\overset{\delta+}{C}\equiv\overset{\delta-}{N}:$

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

Polar **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 (H_2S) has 4 regions of negative charge around central S atom. Two of these regions are bonding and 2 are ~~bon~~ non-bonding. ~~or~~ They have approximate bond angle of 109.5° and a bent shape. H_2S has 2 polar H-S bonds, with S being the most electronegative. Electronegativity is the ability of an atom to attract electrons. Hydrogen cyanide (HCN) has a linear shape with bond angles of 180°. HCN also has polar bonds. A H-C polar bond and C≡N polar bond. Nitrogen (N) is the most electronegative. Both the molecules H_2S and HCN have an imbalance of electronegativity with S being most electronegative in ~~SH~~ H_2S and N being most electronegative is HCN. The molecular dipoles of both the molecules do not cancel out since they are assym~~etr~~ically arranged. Therefore, both H_2S and HCN are polar molecules.

(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.

Endo - exo

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

exo

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

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

Energy = 1890 KJ

$E = \frac{\Delta rH}{coef} \times n$

$M(CH_3NH_2) = 31.0$ g/mol

$\Delta rH = -158$ KJ/mol

$\frac{1890}{158} = \frac{158n}{158}$ $n = 11.96$ mol

n = ~~1mol~~ ? 11.96mol

m=?

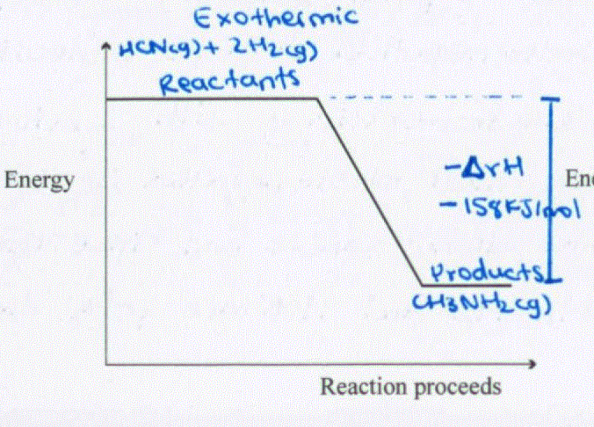
$\frac{m}{M} = n$

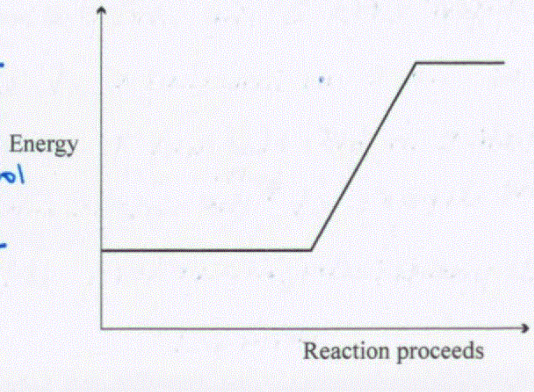
m= 370.82g or 371g

$\frac{m}{\cancel{31.0}} = 11.96 \times 31.0$

The mass of methanamine formed when 1890 KJ of energy is released is 371g

(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	covalent network	Atoms	strong covalent bonding.
$SiCl_4(s)$ (silicon tetrachloride)	–69	Molecular solid	Molecules	weak inter-molecular forces
Cl–Cu–Cl $CuCl_2(s)$ (copper (II) chloride)	620	Ionic solid	Ions	Ionic bonding
$Al(s)$ (aluminium)	660	Mettalic solid	cations in a sea of delocalised electrons	Non-directional strong mettalic bonding

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

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

$SiCl_4$ is a molecular solid made up of molecules held together by weak inter-molecular forces. Since ~~its~~ the molecules are bonded together by weak inter-molecular forces, less heat is required to break the bonds, therefore $SiCl_4$ melts at a lower temperature. SiO_2 on the other hand, is a covalent network, made up of Si and O atoms held together by strong covalent bonding. Since the atoms are held together by strong covalent bonding, lots of heat is required to break these bonds, thus SiO_2 melts at a higher temperature.

Although SiO_2 and $SiCl_4$ contain Si (silicon), they have a difference in melting points because they have a different~~es strengths~~ of strengths of bonding ~~which their atoms and molecules are bonded by~~. Therefore different temperatures overcome the bonding in the substances, melting them at different temperatures.

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

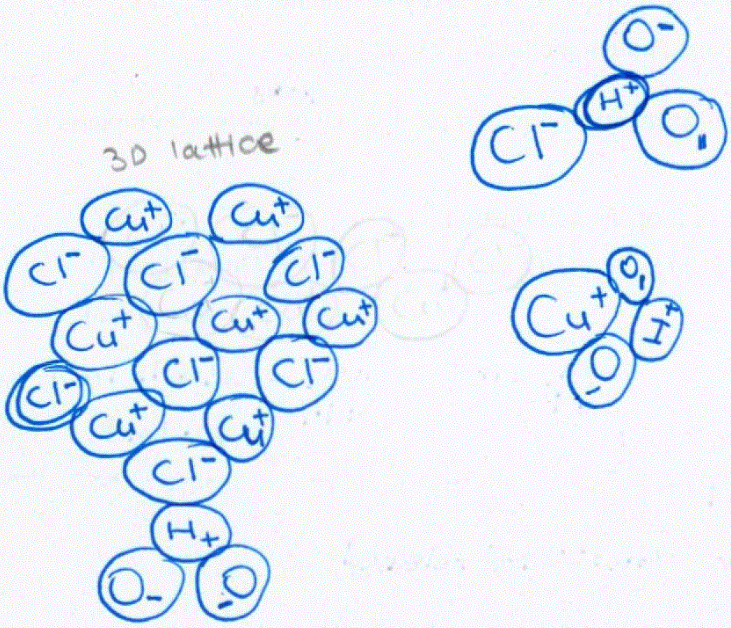
In your answer:

- 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 $CuCl_2$.

Silicon tetrachloride ($SiCl_4$) is a molecular substance, made up of molecules. $SiCl_4$ is also non-polar. Water is a polar substance. A substances ability to be soluble in a solvent is seen by them having charged ions. $SiCl_4$ does not have charged ions. Along with it, the attractive forces that forms between water molecules and $SiCl_4$ molecules is not enough to overcome the existing attractive forces in the solute and solvent substances. Therefore due to $SiCl_4$ ~~pot~~ non-polar nature, it is not able to to dissolve in polar water. However, $SiCl_4$ ~~can~~ will dissolve in cyclohexane which is non-polar. The attractive forces that form between $SiCl_4$ and cyclohexane molecules is enough to overcome the existing attractive forces in the solute and solvent. Thus, due to $SiCl_4$ ~~and~~ and cyclohexane's non-polar nature, $SiCl_4$ is soluble in cyclohexane.

$CuCl_2$ is an ionic substance in a 3D lattice structure made up of positively charge copper cations and negatively charged chloride anions. When $CuCl_2$ is in water, the positive head of water (H^+) will be attracted to the negative chloride anions. The negative head of water (O^-) will be attracted to the positive copper cations, pulling the ions from the 3D lattice structure. The attractive forces forming between water molecules and $CuCl_2$ ions will be enough to overcome the existing forces in the solute and solvent. Thus the 3D lattice structure of $CuCl_2$ will break and the ions/~~with~~ $CuCl_2$ will dissolve in water.

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 (1000g) of propane compared to 1.00 kg of butane.

(i) Energy released by 1.00 kg of propane combustion

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

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

$E = \frac{\Delta r H}{coef} \times n$ | $\frac{m}{M} = n$ $\frac{1000}{44.1} = 22.6757$ mol or 22.7 mol

$= 2044 \times 22.6757$

$= 46349.21$ kJ or 46,300 kJ released

(ii) Energy released by 1.00 kg of butane combustion

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

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

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

$\frac{1000}{58.1} = 17.21$ mol or 17.2 mol

$E = \frac{\Delta r H}{coef} \times n$

$= \frac{2877}{2} \times 17.2117$

$= 1438.5 \times 17.2117$

$= 24,759$ kJ or 24,800 kJ released

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

Propane = 46,300 kJ $46300 - 24800 = 21,500$ kJ

Butane = 24,800 kJ

1.00 kg of propane released 21,500 kJ more than 1.00 kg of butane.

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

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

H–H	O=O	H–O–H
H_2	O_2	H_2O

2(O–H O–H)

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

ΔrH = Bonds broken − Bonds made

−484 = 2 H–H + O=O − 4 O–H

−484 = 2(436) + 498 − 4(O–H)

−484 = +1370 − 4(O–H)

−484 − 1370 = −4 O–H

$\frac{-1854}{-4} = \frac{-4\,O\text{–}H}{-4}$

O–H = 463.5 kJ/mol

The average bond energy of the ~~H~~ O–H bond is 463.5 kJ/mol

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?

Galvorn must have delocalised electrons present, so that the electrons can carry charge and conduct electricity

(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: Aluminium is a 3D metallic solid, made up of cations in a sea of delocalised electrons, held together by strong non-directional metallic bonding. Due to the presence of delocalised electrons in Aluminium, it can conduct electricity. The delocalised electrons can carry charge from a positive to negative terminal, thus is used extentisely in overhead power lines and in smart-phones and laptops

Malleable: Aluminium has non-directional metallic bonding. This means that the particles in the metal can slide past each in the lattice structure when force is applied to it, without breaking the structure. ~~Th~~ Hence Aluminium can be pressed into shapes due to non-directional ~~bo~~ metallic bond and is used as wires in power lines and shells in smart phone & laptops.

Excellence

Subject: Chemistry

Standard: 91164

Total score: 21

Q	Grade score	Marker commentary
One	E7	The candidate was awarded E7 as linked comprehensively and compared the number of bonded and unbonded areas of electron density around a central atom repel to form parent and 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 failed to discuss the symmetrical nature of a linear shape. In part d the mass calculation was correctly rounded, and the enthalpy diagram was fully labelled.
Two	E7	The candidate was awarded M5 as they were able to state the particle type and attractive forces for all solid types and compared and contrasted the difference between the melting point of two solids linking their particle type and strength of forces. In part c they linked attractions between a solute and solvent overcoming existing attractions and polarity and attractive forces for both the ionic and a non-polar substances solubility in water but incorrectly drew water molecules as O_2H so were not awarded the second excellence opportunity for this part of 2c.
Three	E7	The candidate was awarded E7 as they correctly calculated how much more energy was released from propane with correct units (rounding not required in part a). In part b they did not round their final answer so were only awarded a merit grade here. Correct descriptions of metallic bonding in were given in part c for conductivity and malleability with clear links to uses.