3

SAMPLE PAPER

NZQA

NEW ZEALAND QUALIFICATIONS AUTHORITY
MANA TOHU MĀTAURANGA O AOTEAROA

Level 3 Chemistry

3.4: Demonstrate understanding of thermochemical principles and the properties of particles and substances

Credits: Five

Check that you have completed ALL parts of the box at the top of this page.

Check that you have been supplied with the resource sheet for Chemistry 3.4.

You should answer ALL parts of ALL questions in this booklet.

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

Check that this booklet has pages 2–11 in the correct order and that none of these pages is blank.

YOU MUST HAND THIS BOOKLET TO YOUR TEACHER AT THE END OF THE ALLOTTED TIME.

EXEMPLAR FOR LOW ACHIEVED

NOTE: These exemplars do not fully show Grade Score Marking (GSM) because of the small sample of student scripts involved, and the absence of a cut score meeting to determine grade boundaries. GSM can be seen in the level 1 and level 2 exemplars from the 2012 examinations, which will be published on the NZQA website when the assessment schedules are published.

You are advised to spend 60 minutes answering the questions in this booklet.

Assessor's use only

QUESTION ONE

(a) Write the electron configuration using *s*, *p*, *d* notation for:

Symbol	Electron configuration
Mg^{2+}	$1s^2\ 2s^2\ 2p^6$
As	$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2\ 3d^{10}\ 4p^3$
V^{3+}	$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2$

Two correct electron configurations.

(b) Give a justification for each of the following:

Identifies electron repulsion as the reason Cl^- is bigger than Cl.

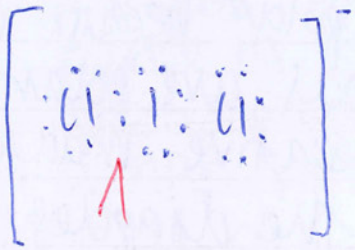
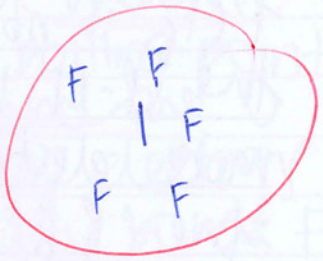
(i) A chloride ion, Cl^-, is larger than a chlorine atom, Cl, whereas a sodium ion, Na^+, is smaller than a sodium atom, Na.

An atom is made up of protons, neutrons and electrons. The protons and ~~electrons~~ neutrons are found in the nucleus and the electrons orbit around this nucleus. There are 2 forces occuring in the atom, the repulsive force of the electrons and the attractive force between the protons and electrons. In a chlorine atom there are the same amount of protons and ~~e~~ electrons, therefore the attractive forces make the radius smaller. In the chloride ion there is one ~~over~~ more electron than protons, which ~~repel each other~~ means the electrons repel each other making the radius bigger. In the Na^+ ~~atom~~ ion there is less electrons than protons, therefore all of the electrons are attracted to the protons. In the Na atom there is one more electron. This means there are more repulsive forces and the atoms radius is bigger than the Na^+ radius //

Assessor's use only

(ii) A chlorine atom has a greater first ionisation energy than a sodium atom.

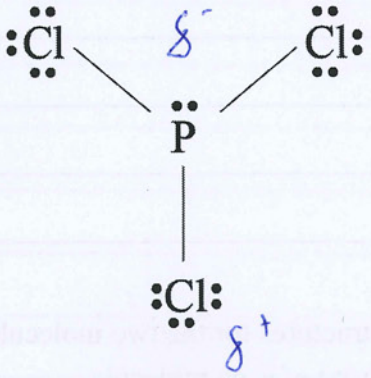
(c) (i) Complete the table below by drawing Lewis structures for the two molecules, drawing the shape of each molecule, and naming the shape of each molecule.

Molecule	ICl_2^-	IF_5
Lewis structures		
Diagram of shape		
Name of shape	linear	bipyrimidal planar

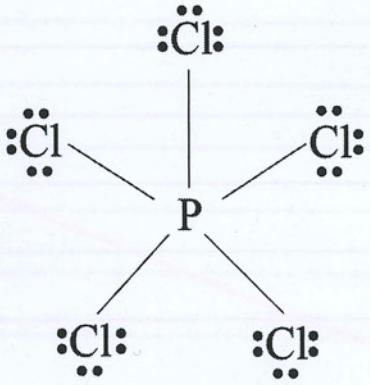
(ii) The Lewis structures for the two molecules PCl_3 and PCl_5 are shown below. Compare and contrast the shapes and the polarities of these two molecules.

Assessor's use only

PCl_3



PCl_5



Describes P-Cl bonds as polar.

PCl_3 is non polar. whereas PCl_5 is polar. PCl_5 is non polar because although each of the P-Cl bonds are polar (Cl bonds are more electronegative making the Cl δ⁻ and the P δ⁺) the diapoles cancel out to give PCl_5 an overall non polar status. the non bonding pairs on the Phosporous atom give the overall PCl_3 molecule a polar status. The electrons in these molecules will try and repel as far away from each other as possible. In PCl_3 there is 108° between each bond giving it a triagonal planar shape whereas in PCl_5 there is 90° between the bonds giving it a bypirimidal polar shape.

Identifies the overall polarity of molecules incorrectly in the first sentence.
Correctly explains the dipoles cancelling to give PCl_5 as a non-polar molecule.
Just Achieved.

A3

Overall three Achieved statements.

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QUESTION TWO

Assessor's use only

(a) (i) Write an equation for the reaction that represents the heat of combustion of sulfur $\Delta_c H$ (S, *s*).

$S_{(s)} + O_{2(g)} \rightarrow SO_{2(g)}$

Correct equation.

(ii) Explain why $\Delta_c H$ (S, *s*) and $\Delta_f H$ (SO_2, *g*) have the same value.

(b) Ammonia can be oxidised to produce nitrogen, N_2, and steam as shown in the equation below:

$4NH_3(g) + 3O_2(g) \rightarrow 2N_2(g) + 6H_2O(g) \quad \Delta_r H = -1267 \text{ kJ mol}^{-1}$

Calculate the energy produced when 50.0 g of ammonia reacts as shown in the equation above.

$m = nM = 68$

$\frac{-1267}{68} = -18.63$

-18.63×50

$= -931.62 \text{ kJ mol}^{-1}$.

Incorrect working. Incorrect units.

Assessor's use only

(c) Ammonia gas can be oxidised to produce nitrogen monoxide, NO, and water as shown in the equation below:

$$4NH_3(g) + 5O_2(g) \rightarrow 6H_2O(l) + 4NO(g)$$

Calculate the enthalpy change, $\Delta_r H$, for this reaction using the information given below.

$N_2(g)$	+	$3H_2(g)$	→	$2NH_3(g)$ $\quad \Delta_r H = -92$ kJ mol^{-1}
$2H_2(g)$	+	$O_2(g)$	→	$2H_2O(g)$ $\quad \Delta_r H = -484$ kJ mol^{-1}
$N_2(g)$	+	$O_2(g)$	→	$2NO(g)$ $\quad \Delta_r H = +180$ kJ mol^{-1}
		$H_2O(l)$	→	$H_2O(g)$ $\quad \Delta_{vap} H = +41$ kJ mol^{-1}

$4NH_3 \rightarrow 2N_2 + 6H_2$ $\quad \Delta_r H = +184$

$2H_2 + O_2 \rightarrow 2H_2O$ $\quad \Delta_r H =$

$4N_2 + 4O_2 \rightarrow 8NO$ $\quad \Delta_r H = +720$

$6H_2O_{(g)} \rightarrow 6H_2O_{(l)}$ $\quad \Delta_{vap} H = -246$

Some correct working but no answer calculated.

One correct statement for Achieved.

N2

QUESTION THREE

Assessor's use only

(a) Predict the entropy change for each of the following reactions by stating whether the entropy will increase OR decrease. Give a reason for each answer.

(i) Ammonium chloride solid $NH_4Cl(s)$ dissolves in water to form $NH_4^+(aq)$ and $Cl^-(aq)$.

(ii) $3O_2(g) \rightarrow 2O_3(g)$

(iii) $N_2O_4(g) \rightarrow 2NO_2(g)$

(b) At room temperature, 25°C, steam condenses to water as shown in the equation below. This reaction occurs spontaneously.

$$H_2O(g) \rightarrow H_2O(l)$$

Explain why this reaction is spontaneous by considering the entropy changes when steam condenses.

ionic covalent. intermolecular.

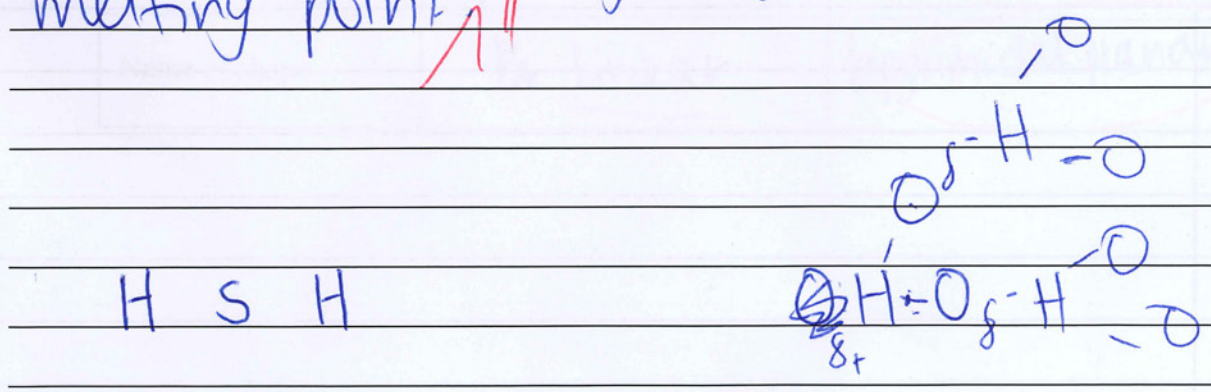
Assessor's use only

(c) Use the information in the table to answer the following question.

Molecule	Boiling point °C	Molar mass/g mol^{-1}
Water, H_2O	100	18.0
Oxygen, O_2	–183	32.0
Hydrogen sulfide, H_2S	–62	34

Compare and contrast the boiling points of water, oxygen, and hydrogen sulfide in terms of the similarities and differences in the relative strengths of the attractive forces present between particles.

The hydrogen bonds in H_2O are very strong giving it a high boiling point. Also the bigger the molar mass the stronger the bonds in the molecule. Because O_2 is made up of weak covalent bonds, hence its low boiling point. The water molecule is polar and the O atoms have lots of non bonding electrons which means that it will easily bonds to the H atom of other water molecules. The bonds are hard to break. With H_2S there are not many non bonding electrons so only weak intermolecular bonds are made, giving it a low melting point.



Identifies hydrogen bonds in H_2O.
One correct statement for Achieved.

N2

3

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EXEMPLAR FOR HIGH ACHIEVED

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You are advised to spend 60 minutes answering the questions in this booklet.

Assessor's use only

QUESTION ONE

(a) Write the electron configuration using *s*, *p*, *d* notation for:

Symbol	Electron configuration
Mg^{2+}	$1s^2, 2s^2, 2p^6$, ~~3s~~
As	Ar $4s^2, 3d^{10}, 4p^3$
V^{3+}	Ar $4s^2$

Two correct electron configurations.

(b) Give a justification for each of the following:

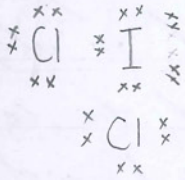
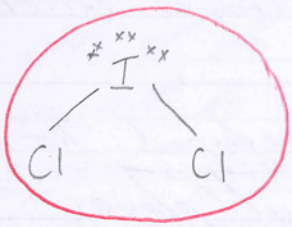
(i) A chloride ion, Cl^-, is larger than a chlorine atom, Cl, whereas a sodium ion, Na^+, is smaller than a sodium atom, Na.

The sodium atom Na will become the sodium ion Na^+ after losing an electron from its outer shell (so ~~#~~ Na^+ electron configuration will be $1s^2, 2s^2, 2p^6$). This means that the positively charged nucleus of the ~~sodium~~ atom due to its protons will be greater than the negative charge of the electrons orbiting it. This causes the electrons to be pulled closer to the nucleus and thus making Na^+ smaller than Na. However, for Cl, it needs to gain an electron in order to complete its outer shell and form the ion Cl^- (electron configuration will become $1s^2, 2s^2, 2p^6, 3s^2, 3p^6$). This means that the negative charge of the electrons will be greater than the positively charged protons. This causes the electrons of Cl^- to repel each other more therefore making Cl^- bigger in size than Cl.

Assessor's use only

(ii) A chlorine atom has a greater first ionisation energy than a sodium atom.

(c) (i) Complete the table below by drawing Lewis structures for the two molecules, drawing the shape of each molecule, and naming the shape of each molecule.

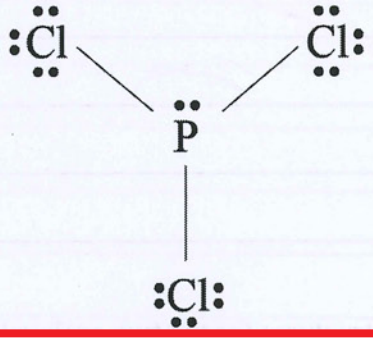
Molecule	ICl_2^-	IF_5
Lewis structures	I: 7 Cl: 14 + 1 = 22. 	I: 7 F: 35 7 = 47 
Diagram of shape		
Name of shape	Bent	

Two correct Lewis structures ICl_2^-
Missing brackets and charge.

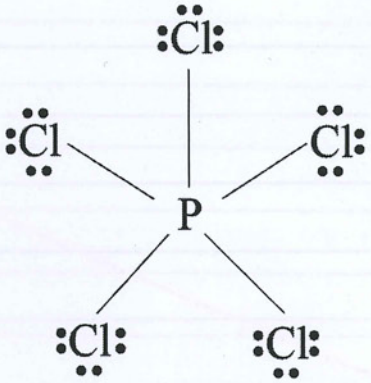
(ii) The Lewis structures for the two molecules PCl_3 and PCl_5 are shown below. Compare and contrast the shapes and the polarities of these two molecules.

Assessor's use only

PCl_3



PCl_5



Correctly identifies polarity of P-Cl bond due to greater electronegativity of Cl.

The bond between Cl and P is polar due to Chlorine's larger electronegativity. However, PCl_5 is a non polar molecule as the charges a symmetrical. PCl_5 is trigonal ~~bipyramidal~~ bipyramidal in shape. The concentration of negative charge is at the centre of the molecule (where the P atom is) and that is also where there is a concentration of positive charge. Because of this, the two charges cancel which is why PCl_5 is ~~not~~ non-polar.

PCl_3 is ~~not~~ asymmetrical. The shape of the PCl_3 molecule is trigonal planar. The lone pair of electrons has a greater charge than the Cl atoms and so the concentration of negative charge will be ~~above~~ slightly above the atom P whereas the concentration of positive charge is still at the centre. This causes a permanent dipole to form as one side is slightly more negative causing the molecule to be polar.

Correctly identifies shape of PCl_5, but not PCl_3.

Total of three Achieved statements.

A3

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QUESTION TWO

Assessor's use only

(a) (i) Write an equation for the reaction that represents the heat of combustion of sulfur $\Delta_c H$ (S, *s*).

$S_{(s)} + O_{2(g)} \rightarrow SO_{2(g)}$ $\Delta_c H$

Correct equation.

(ii) Explain why $\Delta_c H$ (S, *s*) and $\Delta_f H$ (SO_2, *g*) have the same value.

(b) Ammonia can be oxidised to produce nitrogen, N_2, and steam as shown in the equation below:

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Calculate the energy produced when 50.0 g of ammonia reacts as shown in the equation above.

Assessor's use only

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Calculate the enthalpy change, $\Delta_r H$, for this reaction using the information given below.

$N_2(g)$	+	$3H_2(g)$	→	$2NH_3(g)$	$\Delta_r H = -92$ kJ mol^{-1}
$2H_2(g)$	+	$O_2(g)$	→	$2H_2O(g)$	$\Delta_r H = -484$ kJ mol^{-1}
$N_2(g)$	+	$O_2(g)$	→	$2NO(g)$	$\Delta_r H = +180$ kJ mol^{-1}
		$H_2O(l)$	→	$H_2O(g)$	$\Delta_{vap} H = +41$ kJ mol^{-1}

$2NH_3 \rightarrow 3H_2 + N_2 \quad \Delta_r H = +92\ kJ\ mol^{-1}$ A

$4NH_3 \rightarrow 6H_2 + 2N_2 \quad \Delta_r H = +184\ kJ\ mol^{-1}$ A

$N_2 + O_2 \rightarrow 2NO \quad \Delta_r H = +180\ kJ\ mol^{-1}$

$2N_2 + 2O_2 \rightarrow 4NO \quad \Delta_r H = +360\ kJ\ mol^{-1}$ A

$6H_2 + 3O_2 \rightarrow 6H_2O(g) \quad \Delta_r H = -1452\ kJ\ mol^{-1}$ A

$6H_2O(g) \rightarrow 6H_2O(l) \quad \Delta_{vap} H = +246\ kJ\ mol^{-1}$ A

$\therefore 4NH_3 \rightarrow 6H_2 + 2N_2$

$2N_2 + 2O_2 \rightarrow 4NO$

$6H_2 + 3O_2 \rightarrow 6H_2O(g)$

$6H_2O(g) \rightarrow 6H_2O(l)$

$\therefore 4NH_3 + 5O_2 \rightarrow 4NO + 6H_2O(l)$

$\Delta_r H = -662\ kJ\ mol^{-1}$

Attempts calculation with a correct method. Incorrectly uses positive value for ΔvapH = +41. Sign should be reversed.

Two Achieved statements.

A3

QUESTION THREE

Assessor's use only

(a) Predict the entropy change for each of the following reactions by stating whether the entropy will increase OR decrease. Give a reason for each answer.

(i) Ammonium chloride solid $NH_4Cl(s)$ dissolves in water to form $NH_4^+(aq)$ and $Cl^-(aq)$.

(ii) $3O_2(g) \rightarrow 2O_3(g)$

(iii) $N_2O_4(g) \rightarrow 2NO_2(g)$

(b) At room temperature, 25°C, steam condenses to water as shown in the equation below. This reaction occurs spontaneously.

$$H_2O(g) \rightarrow H_2O(l)$$

Explain why this reaction is spontaneous by considering the entropy changes when steam condenses.

Assessor's use only

(c) Use the information in the table to answer the following question.

Molecule	Boiling point °C	Molar mass/g mol^{-1}
Water, H_2O	100	18.0
Oxygen, O_2	–183	32.0
Hydrogen sulfide, H_2S	–62	34

Compare and contrast the boiling points of water, oxygen, and hydrogen sulfide in terms of the similarities and differences in the relative strengths of the attractive forces present between particles.

The boiling point of water is very high due to the hydrogen bonds present in the molecule. Hydrogen bonds are formed due to the large electronegativity difference between H and either N, O or F. Therefore this causes the bonds to be very strong and thus, extremely hard to break requiring a lot of energy which is why water has a very high boiling point.

(1)

Oxygen however has a very low boiling point despite its large molar mass. The forces between each molecule is very weak as they can only be formed through dispersion. This causes a temporary dipole as at some point, one side of the oxygen will have more electrons and so will be slightly negative but this is very spontaneous. Because these forces are so weak, O_2 has a low boiling point.

(2)

H_2S has permanent dipoles and so the forces holding molecules together will be relatively stronger than that of O_2. The bond between H-S is polar due to the difference in electronegativity and so permanent dipoles are formed because these are relatively stronger than the dispersion forces between O_2 molecules H_2S will have a slightly higher boiling point.

(3)

M5

See comments on next page.

(1) Incorrectly refers to bonds within the molecule.

(2) Correctly identifies temporary dipole-attractive forces between oxygen molecules.

(3) Correctly identifies permanent dipole-attractive forces between hydrogen sulfide molecules. Compares O_2 and H_2.