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 MERIT

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+}	1S2, 2S2, 2P6
As	1S2, 2S2, 2P6, 3S2, 3P6 4S2 3D10 ~~4S2~~ 4D3
V^{3+}	1S2 2S2 2P6 3S2 3P6

Correct electron configuration.

(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.

~~Na and Na+~~ The sodium ion has one less electron than the sodium atom but both have identical nuclei with the same number of protons. The positive attraction forces of the nuclei remain the same but the negative attraction forces are different. With less electrons, the other electrons* are pulled in more closely and thus have a smaller atomic radius than the sodium atom //

* in sodium ion

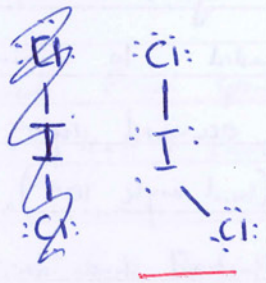
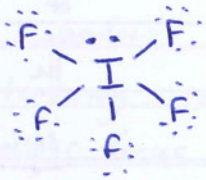
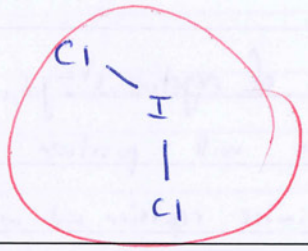
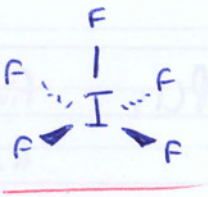
With the chlorine, again the nuclei of both contain the same number of protons but different electron numbers. With more electrons and thus more negative attraction forces compared to the Chlorine atom, the chlorine ion will have a larger atomic radius. //

Assessor's use only

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

Ionisation energy is the energy needed to remove an electron from the valence shell. Sodium has one valence electron and Chlorine has 7. With more valence electrons, Chlorine is the more stable atom, than sodium. Therefore more energy is required to remove the an electron (essentially destabilising it) than the sodium and thus has a greater ionisation energy ✓✓

(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.

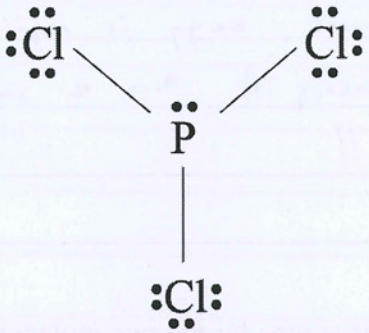
Molecule	ICl_2^-	IF_5
Lewis structures		
Diagram of shape		
Name of shape	bent	square based pyramid

Correct Lewis structure/shape for IF_5.

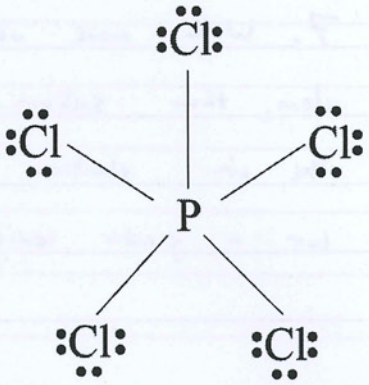
Assessor's use only

(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.

PCl_3



PCl_5



PCl_3: 4 regions of negative charge, with three occupied. The four regions will arrange themselves into the shape of tetrahedral to minimise repulsion and maximise stability. The three occupied regions will give the overall shape of trigonal pyramid (bond angle 109°). The P–Cl bonds are polar and the asymetrical shape does not result in cancellation ∴ overall polar molecule

PCl_5: Five regions of negative charge, all 5 occupied. The five regions will position themselves into a shape that will minimise repulsion and maximise stability. Will form a trigonal bipyramidal shape. Though the individual P–Cl bonds are polar the symetrical shape results in cancellation of these charges. The overall non-polar molecule

Clear explanation of shape/symmetry and polarity for both molecules.

Candidate omitted to attribute the polarity of P–Cl bond to the difference in electronegativity of P and Cl.

Four clear statements towards Achieved A4. Only one, (c) (ii), gives evidence towards Merit.

A4

This page has been deliberately left blank

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*).

$S + O_2 \Rightarrow SO_2$

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

Element states (S and O_2) have a zero $\Delta_f H$ value and both involve the same equation

$\therefore \Delta_c H = \Delta_f H$

(combustion) (formation)

Clearly states $\Delta_c H$(S) and $\Delta_f H$ refer to the same equation. Answer would be clearer if equations given in part (i).

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

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

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

$n(NH_3) = \frac{m}{M} = \frac{50\text{ g}}{17\text{ g mol}^{-1}}$

$= 2.9$

4 mol of NH_3 $\Rightarrow$ -1267 kJ mol^{-1}

2.9 mol of NH_3 $\Rightarrow$ $\left(\frac{-1267}{4} \times 2.9\right)$ kJ

$= -931.62$

$= -932\text{ kJ}$ (3SF)

Correct calculation.

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.

$-2 \times (N_2(g) + 3H_2(g) \rightarrow 2NH_3(g) \quad \Delta_r H = -92 \text{ kJ mol}^{-1})$

$3 \times (2H_2(g) + O_2(g) \rightarrow 2H_2O(g) \quad \Delta_r H = -484 \text{ kJ mol}^{-1})$

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

~~$(H_2O(l) \rightarrow H_2O(g) \quad \Delta_{vap} H = +41 \text{ kJ mol}^{-1})$~~

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

$6H_2 + 3O_2 \rightarrow 6H_2O \quad \Delta H = -1452 \text{ kJ mol}^{-1}$

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

$\therefore 4NH_3 + 5O_2 \rightarrow 4NO + 6H_2O \quad \Delta H = 184 - 1452 + 360$

$= -908 \text{ kJ mol}^{-1}$

Candidate fails to use $\Delta vap H$ in the calculation.

Two Merit opportunities gained M6.

M6

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 $Cl^-(aq)$.

disorder increases (more molecules) ∴ Entropy increases

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

disorder decreases (less molecules) ∴ Entropy decreases

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

disorder increases (more mol) ∴ Entropy increases

Entropy changes correct.

(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.

$\Delta G = \Delta H - \Delta TS$

entropy decreases and disorder lessens therefore $\Delta S < 0$. By looking at the free energy equation a negative entropy will reverse the sign of ΔTS to make $\Delta G = \Delta H + \Delta TS$, therefore ΔH value must be positive. All values positive (free energy) equates to spontaneous reaction. // ✓ //

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

Assessor's use only

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.

Water: Very strong intermolecular force through hydrogen bonding. Hydrogen from one molecule and an oxygen from another are attracted to one another through strong electronegativities ↑ covalent bond strength. This explains the high boiling point of water

Oxygen: temporary dipoles induced from spontaneous unevenness in distribution of electrons that causes temporary regions of charge. This is weak intermolecular forces explaining the low boiling point of Oxygen. //

Identifies H-bonding in water and temporary dipoles in O_2.

No comparison of molecules.

Three Achieved statements.

A4

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 HIGH MERIT

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
10 Mg^{2+}	$1s_2, 2s_2, 2p_6$
33 As	$1s_2, 2s_2, 2p_6, 3s_2, 3p_6, 3d_{10}, 4s_2, 4p_3$
20 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: atomic radi across rda

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

A chloride ion is larger than a chlorine atom, because it has a larger atomic radii. This is due to the added electrons ~~which~~ gave in the outer energy level, which create a larger distribution of the effective nuclear charge meaning the outer electrons are less ~~attra~~ close to the ~~nucl~~ than in a chlorine atom. Na^+ is a ~~ma~~ smaller nucleus atomic radii than a Na atom as it has less electrons in it's outer energy level thus there is less distribution of the effective nuclear charge and thus the outer electrons are attracted more strongly towards the nucleus, and are hence close to the nucleus creating a smaller atomic radii for the Na^+ cation than the Na atom. 11

rda rid
i i a idd

3

Explains the effect of increased protons on the first ionisation energy.

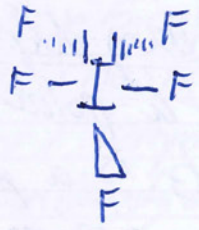
Assessor's use only

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

This is because moving across the periodic table from Na to Chlorine the number of protons in the nucleus of elements increase, as there are more protons attracting electrons in the same energy level in the Chlorine atom it has a higher first ionisation energy as more energy is required to separate an electron from the Cl atom as it is attracted more to the nucleus than an electron in Na as it has less protons. //

(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.

77

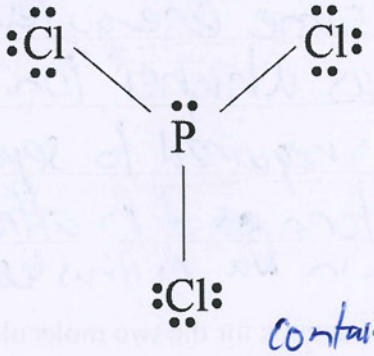
Molecule	ICl_2^-	IF_5
Lewis structures		
Diagram of shape		
Name of shape	linear	square pyramidal

Correct Lewis structures and shapes.

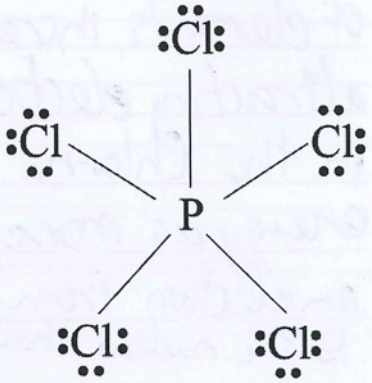
(ii) The Lewis structures for the two molecules PCl_3 and PCl_5 are shown below. Compare and contrast the shapes and the polarities of these two molecules.

Assessor's use only

PCl_3



PCl_5



Both molecules contain polar bonds due to the difference in electronegativity of P and Cl with Cl atoms attracting the electrons shared in the covalent bond between P and Cl atoms more. This sets up a permanent dipole with the Cl atoms becoming negatively charged and the P atom positively charged. Though the PCl_5 is not a polar molecule as it is symmetrical and it's bonding dipoles cancel each other out. PCl_5 is not a polar molecule but does contain polar bonds. PCl_3 is a polar molecule on the other hand as it is an assymetrical molecule with 4 regions of charge about the central atom, with 3 bonded. This means it's bonding dipoles do not cancel and hence the molecule is polar overall.

Correctly identifies and explains the polarity of the two molecules. Candidate omits discussion of the shape of the two molecules.

Three Merit answers for M6.

M6

This page has been deliberately left blank

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*).

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

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

because the combustion of Sulfur in a sufficient supply of oxygen forms SO_2 and hence both equations have the same value. //

Identifies $\Delta_c H$ and $\Delta_f H$ as the same reaction.

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

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

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

n
n M
n
V c

$n(NH_3) = 50.0 / M(NH_3) = 50/17 = 2.941$

$M(NH_3) = 14 + 3 = 17 \text{ gmol}^{-1}$

$\frac{2.94}{4} \times 1267 = 932$ kJ (3sf)

$= 932$ kJ released (3sf)

Correct calculation.

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.

$$N_2(g) + 3H_2(g) \rightarrow 2NH_3(g) \qquad \Delta_r H = -92 \text{ kJ mol}^{-1}$$

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

$$N_2(g) + O_2(g) \rightarrow 2NO(g) \qquad \Delta_r H = +180 \text{ kJ mol}^{-1}$$

$$H_2O(l) \rightarrow H_2O(g) \qquad \Delta_{vap} H = +41 \text{ kJ mol}^{-1}$$

One correct Merit answer.

M5

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 $Cl^-(aq)$.

Entropy will increase, less ordered (disorde

(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.

When steam condenses to form liquid water entropy decreases, as more order is created. This means the value given by Gibbs law is negative and hence the reaction is spontaneous

9

Correctly identifies and compares the intermolecular forces in all three molecules.

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 hydrogen bond	100	18.0
Oxygen, O_2 temporary induced dipol	–183	32.0
Hydrogen sulfide, H_2S permanent dipole Condon forces	–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.

Water has the highest boiling point of all these molecules due to the strength of its intermolecular forces. H_2O has hydrogen bonding which strengthens the molecule, the bond dipole from hydrogen bonding strengthens the intermolecular forces to that of approximately 1/10 of a covalent bond. This because the bond dipole created by Hydrogen bonding is so large that H_2O has such a high bp for such a low molar mass. Compared with a molecule such as O_2, one would expect O_2 to have a higher bp due to a larger molar mass this is not the case, because the strength of O_2 intermolecular forces is very weak as these forces are only temporarily induced dipoles (note H_2O has temporarily induced dipoles but their effect is not relevant). Temporary induced dipoles occur due to changes in electron density of the electrons shared in a covalent bond forming a temporary dipole at one atom which induced another dipole at another. These forces are weak. H_2S has a higher bp than O_2 as it has permanent dipoles due to electronegativity difference of H & S. These require more energy than the temporary induced dipoles to overcome hence H_2S has a higher Bp than O_2. Permanent dipoles are weaker intermolecular forces than hydrogen bonding hence H_2O has a higher bp than H_2S. /

Incorrectly refers to H-bonding 'strengthens the molecule'.

E7