NZQA
NEW ZEALAND QUALIFICATIONS AUTHORITY
MANA TOHU MĀTAURANGA O AOTEAROA

EXEMPLAR

Level 3 Chemistry, 2013

91390 Demonstrate understanding of thermochemical principles and the properties of particles and substances

2.00 pm Tuesday 19 November 2013
Credits: Five

Achievement	Achievement with Merit	Achievement with Excellence
Demonstrate understanding of thermochemical principles and the properties of particles and substances.	Demonstrate in-depth understanding of thermochemical principles and the properties of particles and substances.	Demonstrate comprehensive understanding of thermochemical principles and the properties of particles and substances.

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 is provided on the Resource Sheet L3–CHEMR.

If you need more space for any answer, use the page(s) provided at the back of this booklet and clearly number the question.

Check that this booklet has pages 2–10 in the correct order and that none of these pages is blank.

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

LOW MERIT

TOTAL 13

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

ASSESS USE ON

QUESTION ONE

(a) Complete the following table.

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

Correct

Incorrect

Evidence not required as there is higher level evidence (merit or excellence) elsewhere within the question.

(b) Discuss the data for each of the following pairs of particles.

(i)

Atom	Electronegativity
O	3.44
Se	2.55

No evidence. Candidate confused electronegativity with ionisation energy.

Both O and Se have the same number of electrons at the most outter shell. However Se has a higher energy level as it has more electron orbitals. As it has more shells, the shielding effect increases and the effective nuclear charge decreases. So Se's most outter electron is easier to be removed thus lower electronegativity.

(ii)

Atom or ion	Radius/pm
Cl	99
Cl^-	181

Correct → merit.

Cl has an incomplete 3p orbital, yet Cl^- has a complete 3p orbital. As Cl^- has one more electron the electrons at the valence shell will repulse each other further. Thus the radius is larger.

While they have the same number of protons, equal positive charge,

(iii)

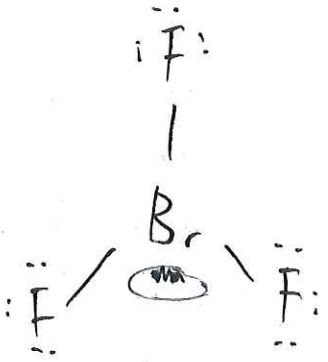
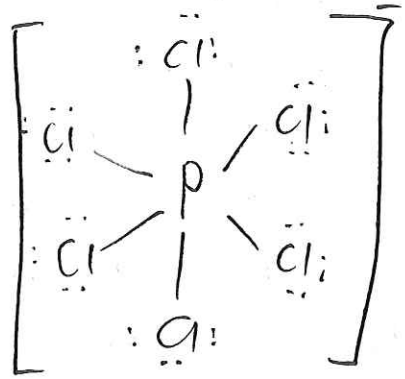
Atom	First ionisation energy/kJ mol^{-1}
Li	526
Cl	1257

Provides evidence towards achievement.

Li: $1s^2\ 2s^1$ Cl: $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^5$

First ionisation energy is when one electron is getting removed from the atom. ~~According to~~ ~~to~~ Li will have a stable orbital when one electron is removed. while Cl will gain sability when one ~~is~~ e is added. This means Cl will have high resistance against losing one electron. So, Li has lower ionisation energy than Cl.

(c) (i) Complete the following table.

Molecule	BrF_3	PCl_6^-
Lewis diagram		
Name of shape	~~Trigonal pyramid~~ planar	Octahedral

One correct shape and Lewis structure provides evidence towards achievement.

ASSESSOR'S USE ONLY

(ii) The Lewis diagrams for SF_4 and XeF_4 are shown below.

Compare and contrast the polarities and shapes of these two molecules.

In SF_4, S-F bond is ~~(polar)~~ polar as ~~it has~~ there is a difference of electronegativity. Around the central 'S' atom there are 5 electron clouds. 4 of them are bonding pair and one is a lone pair. The electron clouds arrange to a trigonal bipyramid, but as only bonding pairs contribute to shape the molecule is a see-saw. This shape is asymetrical so the dipoles do not cancel each other out. SF_4 is polar.

In XeF_4, Xe-F bond is also polar due to electronegative difference. Around the central 'Xe' atom there are 6 electron clouds. 4 of them are bonding pairs and 2 of them are lone pairs. As bonding pairs only contribute to shapes, ~~XeF_4 is a square pla~~ Although the electron cloud arrangment is an octahedral, ~~Each~~ the shape is a square plannar. A square plannar is symmetrical. The dipoles cancel out. Thus, the molecule is non-polar.

Good discussion of shapes and polarities provides evidence towards Merit. If the answer had included the concept of repulsion between electron pairs, then excellence may have been awarded.

M5

QUESTION TWO

ASSESSOR'S USE ONLY

(a) (i) Explain what is meant by the term $\Delta_{vap}H°(H_2O(\ell))$.

$\Delta_{vap}H°(H_2O_{(\ell)})$ is the energy used to vaporise 1 mol of liquid water to gas state in a standard environment.

Suitable for achievement.

(ii) When gaseous hydrogen and oxygen are heated in a test tube, droplets of liquid water form on the sides of the test tube.

Calculate $\Delta_f H°(H_2O(\ell))$, given the following data:

$\Delta_f H°(H_2O(g)) = -242 \text{ kJ mol}^{-1}$

$\Delta_{vap}H°(H_2O(\ell)) = +44 \text{ kJ mol}^{-1}$

$\Delta_{vap}H°(H_2O_{(\ell)}) = \Delta_f H°(\text{product}) - \Delta_f H°(\text{reactant})$

$44 = -242 - a$

$a = -286 \text{ kJ mol}^{-1}$

Correct → Merit.

(iii) Explain why the temperature of liquid water does not change when it is heated at 100°C.

At 100°C water molecule have enough energy to be vapourised into gas. So further heat energy given is used to break the bond between molecules rather than exciting the molecules. Also at 100°C, water is vapourised. So liquid state of water and gaseous state of water both exist.

Correct → Merit.

ASSESSOR'S USE ONLY

(b) (i) When 25.0 mL of a 1.00 mol L^{-1} hydrochloric acid solution, HCl, is added to 25.0 mL of a 1.00 mol L^{-1} ammonia solution, NH_3, a temperature rise of 6.50°C is recorded, as a neutralisation reaction occurs to produce aqueous ammonium chloride and water.

Calculate $\Delta_r H°$ for this neutralisation reaction.

The mass of the mixture is 50.0 g.

Assume specific heat capacity of the aqueous ammonium chloride = 4.18 J g^{-1} $°C^{-1}$

$\Delta_r H°$ = ~~50 × 6.50g × 4.18~~

= 50.0g × 6.50 °C × 4.18 J g^{-1} $°C^{-1}$

= 1358.5 J mol^{-1}

First step of calculation is correct → achievement.

(ii) When the $\Delta_r H°$ for the neutralisation above was found experimentally in a school laboratory, the value obtained was lower than the theoretical value.

Account for the difference in values, and suggest how this difference could be minimised.

This difference maybe cause by the par experiment environment of the school. Heat may not be fully conducted and lost in its path of delivery. Thus the school can use experimental instruments with heat caps or any other methods to minimize the heat loss. Moreover, the standard experimental ~~environment~~ environment has to be secured.

Evidence not required as there is higher level evidence (M or E) elsewhere within the question.

M 5

QUESTION THREE

ASSESSOR'S USE ONLY

(a)

Molecule	Boiling point / °C
Hydrazine, N_2H_4	114
Fluoromethane, CH_3F	–78.4
Decane, $C_{10}H_{22}$	174

Use the information in the table above to compare and contrast the boiling points of hydrazine, fluoromethane, and decane in terms of the relative strengths of the attractive forces between the particles involved.

All three molecules have temporary dipoles. and ~~permanent~~ Hydrazine has a hydrogen bonding between molecules ✓, so it will have a higher boiling point than Fluoromethane. Therefore N_2H_4 needs more energy to separate each molecules compared to Fluoromethane which only has Van der Walls force.

Decane has a shape of a long chain. These long chains can be aligned ~~in~~ ~~across~~ in a very dense way. Even though all there is is induced dipole (Van der walls force), the shape causes the intermolecular force to be stronger. Therefore it has the highest boiling point among the three.

Provides evidence towards achievement as the answer relates boiling point to the strength of the intermolecular forces and identifies the correct intermolecular force for at least one molecule.

(b) Decane is a component of petrol. Carbon dioxide and water are formed when decane burns completely in oxygen.

$$C_{10}H_{22}(\ell) + 15.5O_2(g) \rightarrow 10CO_2(g) + 11H_2O(\ell)$$

Calculate $\Delta_c H°(C_{10}H_{22}(\ell))$, given the following data:

$\Delta_f H°(C_{10}H_{22}(\ell)) = -250$ kJ mol^{-1}
$\Delta_f H°(CO_2(g)) = -393$ kJ mol^{-1}
$\Delta_f H°(H_2O(\ell)) = -286$ kJ mol^{-1}

$\Delta_c H° = \Delta_f H°$ (products) $-$ $\Delta_f H°$ (reactants)
$= 10(-393) + (-286) - (-250)$
$= -3966.$

$\Delta_c H°(C_{10}H_{22}(\ell)) = -3966$ kJ mol^{-1}

Incorrect working and answer.

(c) Hydrazine is often used as a rocket fuel. When liquid hydrazine undergoes combustion, it forms nitrogen and water:

$$N_2H_4(\ell) + O_2(g) \rightarrow N_2(g) + 2H_2O(g) \qquad \Delta_c H°(N_2H_4(\ell)) = -624 \text{ kJ mol}^{-1}$$

Explain why liquid hydrazine readily burns in oxygen.

Your answer should consider both enthalpy and entropy changes.

As the $\Delta_c H°$ is negative the reaction is an exothermic reaction. Energy has been released. the enthalpy change is negative.
the Reactants have 2 mols while the products has 3 mols. As the number of total mol increased. The entropy also decreased.
There is less irregularity between atoms & molecules.

Suitable evidence for achievement.
If the answer stated that entropy increases they may have gained merit.

ASSESSOR'S USE ONLY

A3

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HIGH MERIT

TOTAL 18

ASSESSOR'S USE ONLY

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ASSESSOR USE ONLY

1s² 2s² 2p⁶ 3s² 3p⁶ 3d¹⁰ 4s² 4p⁶ 4d¹⁰ 4f¹⁴ 5s² 5p⁶ 5d¹⁰ 5f¹⁴

QUESTION ONE

(a) Complete the following table.

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

34 23 28

Correct. Incorrect.

Evidence not required as there is higher level evidence (merit or excellence) elsewhere in the question.

(b) Discuss the data for each of the following pairs of particles.

(i)

Atom	Electronegativity
O	3.44
Se	2.55

Suitable evidence for achievement. If more specific evidence was made to the attraction of bonding electrons, the response may have gained excellence.

Oxygen has a greater electronegativity value than Se because it is more electronegative. This means that in a molecule, it has a greater attraction towards the electrons than Se would. This is because there are less electron shells in an oxygen molecule and so a greater effective nuclear charge on the electrons / electrostatic attractions from the protons.

(ii)

Atom or ion	Radius/pm
Cl	99
Cl^-	181

Suitable evidence for achievement If reference was made to the same number of protons, the response may have gained excellence.

The chlorine ion has a greater radius than the chlorine atom because it has an extra electron in the same shell. This means that the effective nuclear charge is distributed across more electrons and that there is greater electron-electron repulsion, making the ion's radius larger.

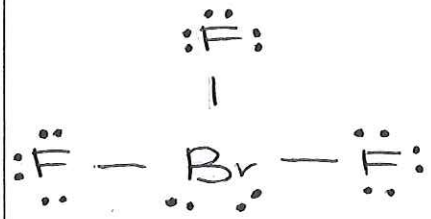
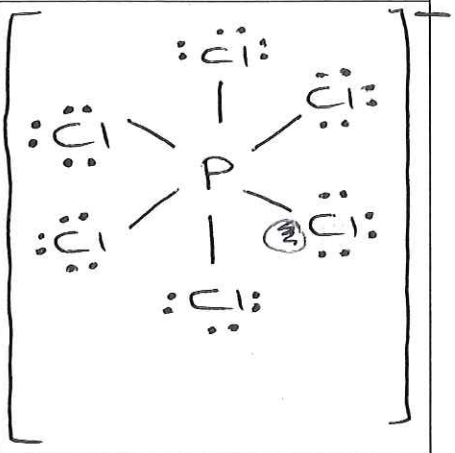
(iii)

Atom	First ionisation energy/kJ mol^{-1}
Li	526
Cl	1257

ASSESSOR'S USE ONLY

The first ionisation energy is the energy required to remove one electron from an atoms outermost electron shell. Chlorine requires more energy than lithium because it has a smaller radius than lithium. The effective nuclear charge is greater in chlorine, meaning the electrons are held more closely to the nucleus, and so more energy is required to remove the outermost electron. Correct → merit.

(c) (i) Complete the following table.

Molecule	BrF_3 28	PCl_6^- 48
Lewis diagram		
Name of shape	T-shape	octahedral

Correct → merit.

(ii) The Lewis diagrams for SF_4 and XeF_4 are shown below.

Compare and contrast the polarities and shapes of these two molecules.

SF_4 has a see saw shape. This is because VSEPR theory states that it has five areas of electron density and therefore an underlying trigonal bypyramid shape. Since one area is a non bonding electron pair, it has a see saw shape overall. Since flouvine atoms are more electronegative than sulfur atoms, polar bonds exist between the two. A negative dipole is set up on the flouvine atoms, and hence the molecule is polar overall, with the positive dipole at the top, and negative dipole at the bottom.

The VSEPR theory states that XeF_4 has six areas of electron density, giving it an underlying octahedral shape. Since two of these areas are non bonding pairs of electrons, the molecule has a square planar shape overall. Although F atoms are more electronegative than Xe atoms, and dipoles are set up, they all direct in opposite directions, effectively cancelling each other out and making the molecule non polar overall.

Full discussion → excellence.

ASSESSO USE ONI

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M6

QUESTION TWO

ASSESSOR'S USE ONLY

(a) (i) Explain what is meant by the term $\Delta_{vap}H°(H_2O(\ell))$.

The energy required to convert 1 mol of H_2O from liquid state to gaseous state under standard conditions

Suitable response for achievement.

(ii) When gaseous hydrogen and oxygen are heated in a test tube, droplets of liquid water form on the sides of the test tube.

Calculate $\Delta_f H°(H_2O(\ell))$, given the following data:

$\Delta_f H°(H_2O(g)) = -242$ kJ mol^{-1}

$\Delta_{vap}H°(H_2O(\ell)) = +44$ kJ mol^{-1} $H_2O(\ell) \rightarrow H_2O(g)$

$H_2(g) + \frac{1}{2}O_2(g) \rightarrow H_2O(g)$ -242 kJmol^{-1}

$H_2O(g) \rightarrow H_2O(\ell)$ -44 kJmol^{-1}

$(-242) + (-44) = -286$ kJmol^{-1}

$\Delta_f H° = -286$ kJmol^{-1}

Correct → merit.

(iii) Explain why the temperature of liquid water does not change when it is heated at 100°C.

The temperature of liquid water does not change when it is heated at 100°C because the heat energy here is going into breaking the intermolecular bonds, rather than causing the water molecules to speed up and gain kinetic energy (which causes a temperature increase)

Correct → merit.

ASSESSOR'S USE ONLY

(b) (i) When 25.0 mL of a 1.00 mol L^{-1} hydrochloric acid solution, HCl, is added to 25.0 mL of a 1.00 mol L^{-1} ammonia solution, NH_3, a temperature rise of 6.50°C is recorded, as a neutralisation reaction occurs to produce aqueous ammonium chloride and water.

Calculate $\Delta_r H°$ for this neutralisation reaction.

The mass of the mixture is 50.0 g.

Assume specific heat capacity of the aqueous ammonium chloride = 4.18 J g^{-1} $°C^{-1}$

$HCl + NH_3 \rightarrow NH_4Cl$

$n(HCl) = cV = (1.00)(0.025) = 2.5 \times 10^{-3}$ mol

$n(NH_3) = cV = (1.00)(0.025) = 2.5 \times 10^{-3}$ mol

$q = mc\Delta T$

$= (50.0)(4.18)(6.5)$

$= 1358.5$ J $= 1.36$ kJ (3sf)

Provides evidence for merit.

$\Delta_r H^\circ = \frac{q}{n}$

$= \frac{1.36}{2.5 \times 10^{-3}}$

543 kJ mol^{-1} (3sf)

If the negative sign was used & the decimal point was in the correct space, then excellence.

(ii) When the $\Delta_r H°$ for the neutralisation above was found experimentally in a school laboratory, the value obtained was lower than the theoretical value.

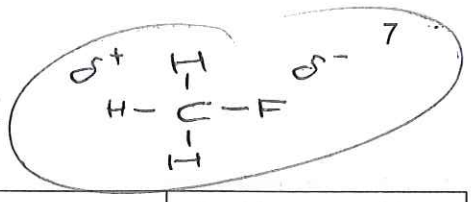
Account for the difference in values, and suggest how this difference could be minimised.

The theoretical value for the reaction is much higher because when the experiment is carried out, heat is lost to the surrounding area, is not recorded as a part of the energy change ($\Delta_r H^\circ$). A way to minimise this difference is to ensure the reaction is being carried out in a closed system where heat cannot be lost to the surroundings.

Evidence not required as there is higher level evidence (M or E) elsewhere in the question.

M 6

QUESTION THREE



7

ASSESSOR'S USE ONLY

(a)

Molecule	Boiling point/ °C
Hydrazine, N_2H_4	114
Fluoromethane, CH_3F	–78.4
Decane, $C_{10}H_{22}$	174

molar mass
32
34
142

Use the information in the table above to compare and contrast the boiling points of hydrazine, fluoromethane, and decane in terms of the relative strengths of the attractive forces between the particles involved.

Boiling points of molecules are dependant upon two variables: the molar mass of the molecule and the intermolecular forces between the molecules. Decane has ~~the largest~~ (a significantly larger) molecular mass in comparison to Fluoromethane and Hydrazine and therefore the largest boiling point. Hydrazine has a relatively high boiling point due to the hydrogen bonding that exists due to the high ~~electro~~ difference between electronegativity ~~of nitrogen and hydrogen~~ Nitrogen and hydrogen and the consequent polar bonds that exist. Hydrogen bonds are very strong - about 10% the strength of chemical bonds - and so require a lot of energy to break. Fluoromethane does not have a very high boiling point in comparison. This is because polar bonds between the C-F make the molecule polar and hence there is dipole-dipole interaction. Compared to hydrogen bonding, this does not require as much energy to break and so ~~the molecule is polar~~ the boiling point is low.

Evidence given for Merit. If reference was made to the presence of temporary dipoles in all three molecules and their particular importance for decane, the excellence may have been awarded.

ASSESSOR'S USE ONLY

(b) Decane is a component of petrol. Carbon dioxide and water are formed when decane burns completely in oxygen.

$$C_{10}H_{22}(\ell) + 15.5O_2(g) \rightarrow 10CO_2(g) + 11H_2O(\ell)$$

$15.5 = 3\frac{1}{2}$

Calculate $\Delta_c H°(C_{10}H_{22}(\ell))$, given the following data:

$\Delta_f H°(C_{10}H_{22}(\ell)) = -250$ kJ mol^{-1}
$\Delta_f H°(CO_2(g)) = -393$ kJ mol^{-1}
$\Delta_f H°(H_2O(\ell)) = -286$ kJ mol^{-1}

$10C + 11H_2 \leftarrow C_{10}H_{22}(\ell)$ $+250$ kJ mol^{-1}

$\times 10$ $C + O_2 \rightarrow CO_2(g)$ -393 kJ mol^{-1}

$\times 11$ $H_2 + \frac{1}{2}O_2 \rightarrow H_2O(\ell)$ -286 kJ mol^{-1}

$C_{10}H_{22}(\ell) + 10O_2 + 10C + 11H_2 + \frac{31}{2}O_2 \rightarrow$

$10C + 11H_2 + 10CO_2 + 11H_2O$

$+250 + 10(-393) + 11(-286) = -6826$

$\Delta_c H° = -6830$ kJ mol^{-1} (3sf)

Correct → merit

(c) Hydrazine is often used as a rocket fuel. When liquid hydrazine undergoes combustion, it forms nitrogen and water:

$$N_2H_4(\ell) + O_2(g) \rightarrow N_2(g) + 2H_2O(g) \qquad \Delta_c H°(N_2H_4(\ell)) = -624 \text{ kJ mol}^{-1}$$

Explain why liquid hydrazine readily burns in oxygen.

Your answer should consider both enthalpy and entropy changes.

Burning hydrazine in oxygen is a negative enthalpy change. That means the bonds formed in the products release more energy than the energy required to break the bonds from the reactants. This means that energy is not required in the reaction where hydrazine reacts with oxygen/combusts. When hydrazine combusts, it goes from a state of ion entropy to a state of higher entropy. This is because one mole of $N_2H_4(\ell)$ and 1 mole of oxygen has been burned to form 1 mole

of nitrogen gas and two moles of water vapour. The entropy of the system has increased due to the production of more moles in gaseous state.

Provide evidence towards Merit.
If there was a clearer link between exothermic reactions and spontaneity, the response may have gained excellence.

ASSESSOR'S USE ONLY

M 6