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 ACHIEVEMENT

TOTAL | 08

ASSESSOR'S USE ONLY

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

ASSESSOR'S USE ONLY

QUESTION ONE

(a) Complete the following table.

	Symbol	Electron configuration
34	Se	$1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^{10} 4p^2$
23	V	$1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^3$
20	V^{3+}	$1s^2 2s^2 2p^6 3s^2 3p^6$ ~~[illegible]~~ $4s^2$

Incorrect

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

(i)

Atom	Electronegativity
O	3.44
Se	2.55

~~As~~ the electronegativity values decrease ~~as~~ down a column. Electronegativity tells us how easy it is to attract ~~[illegible]~~ an ~~atom~~ electron to the atom. Se has lower electronegativity than O as it has more protons and more electrons. This causes shielding of the valence shell and there is less pull from the nucleus to the electron ∴ harder to attract an electron.

One valid point (shielding) contributes towards achievement.

(ii)

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

$Cl = 1s^2 2s^2 2p^6 3s^2 3p^5$
$Cl^- = 1s^2 2s^2 2p^6 3s^2 3p^6$

Cl^- has a bigger radius than Cl. This is because it has more electrons than Cl (as shown by the electron configurations above. Cl^-'s valence shell has 6 electrons while Cl's valence shell has 5. This results in Cl^-'s electron repelling each other more and becoming more far away from the nucleus so Cl^- is bigger than Cl

Two valid points contribute towards achievement.

Merit may have been given if they included reference to the same proton no.

ASSESSOR'S USE ONLY

(iii)

Atom	First ionisation energy/kJ mol^{-1}
Li	526
Cl	1 257

Provides evidence for Merit.

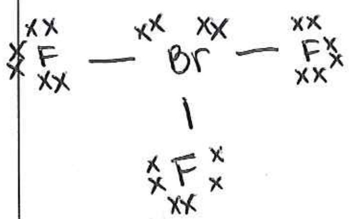
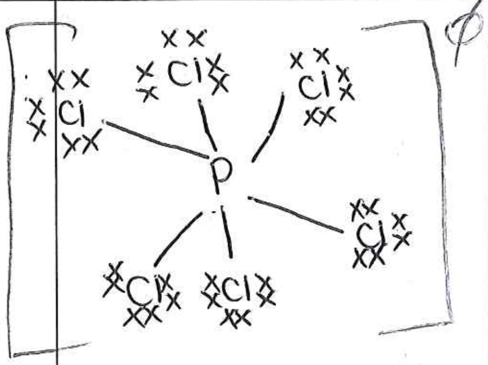
The Ionisation energy is the energy it takes to remove an electron from an atom. Cl has 17 protons while Li only has 3. This means that Cl has more protons than Li. This makes the proton-electron attraction of Cl larger and therefore it needs more energy (than Li) to break the proton-electron attraction, to remove the electron. So Cl has a larger Ionisation energy than Li

i

Insufficient evidence in (i) & (ii) for excellence.

(c) (i) Complete the following table.

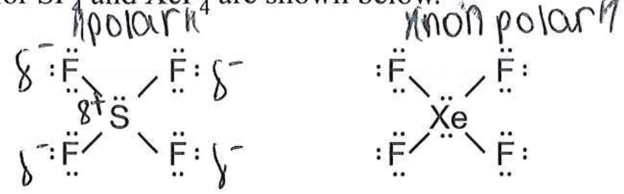
$7 \times 4 = 28$ $5 + 7 \times 6 = 47 + 1 = 48$

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

u

Evidence toward achievement.
If the charge outside the square brackets on PCl_6^- was given, then Merit would have been awarded.

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



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

~~SF4 is ... polar molecule ... and XeF4 are both non polar molecules~~

SF4 is a polar molecule. It has 5 areas of negative charge which consists of 4 bonded pairs of electrons and 1 lone pair of electron. These 5 areas allow for the shape of SF4 to be trigonal pyramid while the bonded pairs and lone pairs allow for the overall shape to be a trigonal ~~planar~~ bipyramidal. Because of the difference in electronegativity, the molecule is polar.
XeF4 is a non polar molecule. It has 6 areas of negative charge allowing for the shape of octahedral to form. However it has 4 bonded pairs of electrons and 2 bonded pairs and therefore the overall shape is a trigonal bipyramidal. The electronegativity difference makes the molecule non polar.
Due to the VSEPR theory, the electrons are undergoing maximum repulsion for both molecules and ∴ causes their respective shapes to form.

Evidence for achievement; correct polarities but insufficient reasoning. Incorrect shapes.

ASSESSOR'S USE ONLY

4

A3

QUESTION TWO

ASSESSOR'S USE ONLY

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

change in heat needed to turn a liquid into gas
$H_2O(l) \rightarrow H_2O(g)$ $\Delta vap H°$

Correct – achievement.

u

(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}

$\Delta f H°(H_2O(l)) = -242 - 44$
$= -286$ kJmol^{-1}

Correct – Merit.

i

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

Liquid water temperature does not change when it is heated at 100 °C because this is its maximum temperature. This means that this is the temperature where its particles cannot move any faster anymore

Answer does not refer to energy being used to break intermolecular forces.

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. NH_3Cl

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}

Δt = 6.50 °C ΔH = mts

= 50 × 6.5 × 4.18

= ~~679.25 J~~ ~~0.67925 kJ~~

= 1358.5 J ~~or 1.3585 kJmol⁻¹~~ or 1.3585 kJ

~~n = m/M =~~

n = m/M = 1.3585 / (3+7+17) = 0.050315 mol

ΔrH = ΔH / n = 1.3585 / 0.050315 = 27 kJmol⁻¹

Evidence for achievement, as only the first step is correct.

(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 'missing' value (ie: Theoretical value - obtained) is lost to heat. This could be minimised by making the experiment as accurate as possible.

ie: it becomes heat

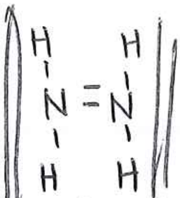
Suggestion as to how to minimise heat loss is insufficient.

A2

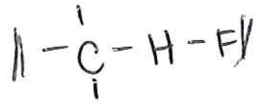
QUESTION THREE

(a)

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



hydrogen bond



non polar

~~hydrogen~~ polar

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.

Fluromethane has the lowest boiling point because due to its shape and electronegativity, ~~[illegible]~~ it has a symmetrical shape and is therefore a non polar molecule. Non polar molecules only have temporary dipoles which ~~are~~ have very weak intermolecular forces. This means that it does not need much energy to break its bonds. Hydrazine is a polar molecule. It has a high boiling point because due to its shape and electronegativity it has a asymmetrical shape and is ∴ polar. Polar molecules have permanent dipoles and their intermolecular forces are stronger than non polar's. It needs more energy to break its bonds. N_2H_4 also has hydrogen bonds in between the H-N and since N is very electronegative, it attracts ~~[illegible]~~ electrons well and you need a lot of energy to break the hydrogen bonds. Decane is a ~~non p~~ polar molecule and so has permanent dipoles. It is higher than Hydrazine as it has a longer molecule and ∴ has a stronger intermolecular force and it requires the most energy to remove / break these bonds.

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

ASSESSOR'S USE ONLY

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

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

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}

~~-393 + -286 - -250 =~~
~~(10 × -393) + (11 × -286) - (15.5 × -250)~~
~~= -3201~~

11(-393) + (-286) - (-250) = -429 kJmol^{-1}

Incorrect.

(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.

ASSESSOR'S USE ONLY

N2

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HIGH ACHIEVEMENT

TOTAL	12

ASSESSOR'S USE ONLY

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ASSESSOR'S USE ONLY

QUESTION ONE

1s 2s 2p 3s 3p 4s 3d 4p

(a) Complete the following table. 34

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+}	$1s^2 2s^2 2p^6 3s^2 3p^6 4s^0 3d^2$

Two lines correct – achievement.

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

(i)

Atom	Electronegativity
O	3.44
Se	2.55

the electronegativity is the atoms tendancy to attract other electrons. The data shows that oxygen has a higher electronegativety then Se, therefore a higher tendancy / ability to attract electrons. This is because Se has more electrons then Oxygen.

Answer lacks sufficient details for achievement

(ii)

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

← one more electron

This table shows that Cl^- has a larger radius than Cl. This is because with an extra electron the attractive force from the nucleus is reduced, because it now has to hold another electron in place. This means all the electrons are held less tightly, and therefore are further away from the nucleus, giving Cl^- a larger radius than Cl.

Answer lacks sufficient details for achievement.

(iii)

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

Sufficient evidence for Merit in part (iii), but given achievement as (i) + (ii) contain no evidence.

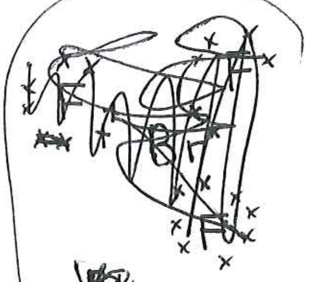
This table shows that Cl has a higher first ionisation energy then Li. This is because There are more protons and electrons in Cl, meaning it has a higher nuclear charge. There ~~etc~~ is higher attractive forces between protons and neutrons, Therefore more energy is required to remove the least tightly bound electron from Cl and in the process breaking the proton-to-electron bond!!

M

6 x 8 48

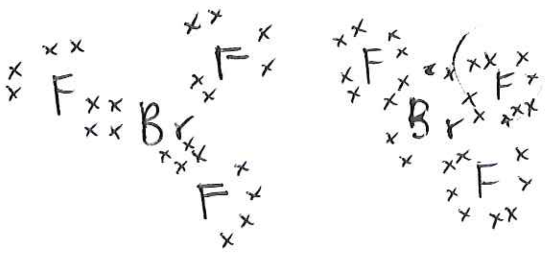
12 12 12 12

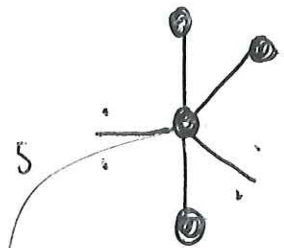
(c) (i) Complete the following table.

Molecule	22 BrF_3 6 6 6 6 24	PCl_6^- 1 minus
Lewis diagram	 (extra pages	
Name of shape	T-shaped ~~tetrahedral~~	octahedral

M

tetrahedral





6 x 7 = 42

47

-1

= 46

28

12 22

18 4

Achievement evidence only as PCl_6^- is missing a pair of electrons.

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

1 square planar

1 see saw

ASSESSOR'S USE ONLY

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

11 SF_4 is the see saw shape, whereas XeF_4 is the square planar shape. 11

M

Two shapes correct → achievement.

A4

ASSESSOR'S USE ONLY

QUESTION TWO

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

// Δvap is the energy required to change one mol of liquid water (H_2O) to H_2O gas at boiling point //

Must state 'standard conditions' to gain 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: endo

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

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

ΔfH° (H2O(g)) → ΔvapH°(H2O(l))

products - reactants

44 kJmol - (-242 kJmol)

286 kJmol⁻¹

Incorrect method.

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

100°C is the boiling point of water, however at this temperature, energy is required to break the intermolecular bonds thus turning it into gas, rather then raising the temperature of liquid water. so the temperature of liquid water will not increase further then 100°C, rather it will be turned into gas.//

Correct → Merit.

$C = n/V \therefore n = CV$

(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}

$n = CV$
$n = mM$
$Q = m \times t \times c$
$Q = \frac{n}{M}$

$n = CV \rightarrow 25 \times 1.00 = 25 \text{ mol L}^{-1}$

$Q = m \times t \times c$
$Q = 50 \times 6.50 \times 4.18 = 1358.5 J$

Only first step is correct → achievement.

$M = n/m \rightarrow 25/50 = 0.5 \text{ mols}$

$\Delta_r H° = Q/M \rightarrow 1358.5/0.5 = \Delta_r H°$
$\therefore \Delta_r H° = 2717 J$
$\therefore 2.72 kJ$

(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.

at the school the equipment may have been less accurate then that used in the results used from theoretical value. e.g lower concentration of solutions. However most likely reason is system is not closed so heat escapes meaning less increase of temperature in solutions. Because $Q = m \times t \times c$, if t (temperature) is reduced then this will have a domino effect and reduce the calculations of enthalpy change, which is the reason for lower then expected results

Suitable evidence for achievement.

ASSESSOR'S USE ONLY

A3

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.

We can observe that Fluoromethane has the lowest boiling point, Hydrazine has the next highest boiling point, and Decane has the highest boiling point. boiling point indicates the strength of bonds and intermolecular forces in a molecule. From this we can deduce that Decane has the strongest bonds and intermolecular forces, followed by Hydrazine, and then Fluoromethane.

M

Provides evidence towards achievement as the answer relates the boiling point to the strength of the intermolecular forces.

ASSESSOR'S USE ONLY

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

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

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

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

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

to find energy change (Σ products)−(Σ reactants)

$(10 \times -393) + (11 \times -286) - (-250)$
$= (-7076) - (-250)$
$= -6826\ kJ\ mol^{-1}$

Correct → Merit.

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

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

Explain why liquid hydrazine readily burns in oxygen.

Your answer should consider both enthalpy and entropy changes.

the $\Delta_cH°$ is the energy change when one mole of a substance is completely burnt, with all products and reactants in their standard states. The combustion of hydrazine releases 624 kJ mol⁻¹ of energy, therefore the process is exothermic. The substance goes from liquid in the form of fuel to gas. Because the particles go from a more ordered state in liquid, to a less ordered state in gas, this is an increase in entropy. The hydrazine goes from a less probable state to a more probable one with no energy input, the exposure to oxygen is what initiates the combustion.

Provides evidence towards merit.
If the candidate had link exothermic reactions to spontaneity more clearly then excellence would have been awarded.

ASSESSOR'S USE ONLY

M5