91390

3

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Level 3 Chemistry, 2016

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

2.00 p.m. Monday 21 November 2016
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 in the Resource Sheet L3–CHEMR.

If you need more room for any answer, use the extra space provided at the back of this booklet and clearly number the question.

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 THE SUPERVISOR AT THE END OF THE EXAMINATION.

Achievement

TOTAL 11

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QUESTION ONE

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(a) Complete the following table.

Symbol	Electron configuration
Cl 17	~~Zn~~ $1s^2, 2s^2, 2p^6, 3s^2, 3p^5$
Zn 30	$1s^2, 2s^2, 2p^6, 3s^2, 3p^6, 4s^2, 3d^{10}$
Cr^{3+} ~~27-3~~ ~~=24~~ 24-3 = 21	$1s^2, 2s^2, 2p^6, 3s^2, 3p^6, 3d^{3}$

Cr 24 -2 = 22 $4s^2$

U

(b) (i) Explain why the radius of the Cl atom and the radius of the Cl^- ion are different.

	Radius (pm)
Cl atom	99
Cl^- ion	181

~~The Chlorine ion has a~~ Cl^- ion radius > Cl atom radius. The Cl^- ion has gained an extra electron and ~~and~~ the number of protons has remained the same. This provides more electron-electron repulsion between the electrons in the energy levels so the electrons are moved further away from the nucleus, and therefore the radius is bigger than a Cl atom.

I

(ii) Explain the factors influencing the trends in electronegativity and first ionisation energy down a group of the periodic table.

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In your answer you should:

- define both electronegativity and first ionisation energy
- explain the trend in both electronegativity and first ionisation energy down a group
- compare the trend in electronegativity and first ionisation energy down a group.

Electronegativity is the ability to attract an electron, ~~to~~ and ~~ion~~ first ionisation energy is the energy needed for ~~a~~ ~~gas~~ one ~~mole~~ gaseous mole of an element to ~~gain~~ lose an electron. As you go down a group the electronegativity of an atom decreases as there are more electron shells preventing the positive nuclei to attract an electron due to shielding of inner shells and the electron-electron repulsion between the shells. As you go down a group the first ionisation energy increases as because of ~~this~~ the shielding from the positive nuclei, and the electron-electron repulsion between inner shells, it is easier for an atom to lose an electron to ~~p~~ become positive. So as you go down a group the electronegativity ~~inc~~ decreases but the first ionisation energy increases.

C

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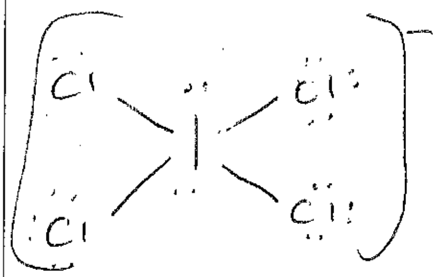
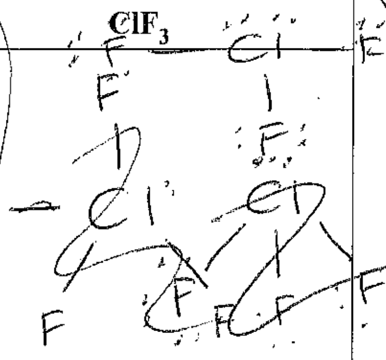
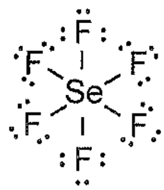
(c) (i) Complete the following table:

	ICl_4^-	ClF_3
Lewis diagram		
Name of shape	square planar	~~trigonal pyramid~~ T-shaped

(ii) The Lewis diagram for SeF_6 is shown below.



Would you expect SeF_6 to be soluble in water?

Yes **No**

Explain your answer in terms of the shape and polarity of SeF_6.

There are six region of negative space around the central Se atom. These separate at a 90° angle for maximum separation. There are six polar Se-F bonds and no free pairs of electrons. This gives a shape of octrahedral. Because ~~o~~ the shape is symmetrical the dipoles cancel out and SeF_6 is non-polar. Water is a polar solvent, and only polar ~~to~~ molecules can dissolve in ~~water~~ polar solvents. Therefore SeF_4 is not soluble in water.

i

i

Mb

QUESTION TWO

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The standard enthalpy of vaporisation, $\Delta_{vap}H°$, of sodium chloride, NaCl, hydrogen chloride, HCl, and chloromethane, CH_3Cl, are given in the table below.

(a) Identify all the attractive forces between particles of the following compounds in their liquid state.

Compound	$\Delta_{vap}H°$ / kJ mol^{-1}	Attractive forces
NaCl	194	Ionic bond Permanent dipole attraction
HCl	16.0	hydrogen bonding covalent bond tempory dipole attraction
CH_3Cl	22.0	Covalent bond ~~hydrogen bonding~~ ~~permanent dipole attraction~~

U

(b) (i) Explain why $\Delta_{vap}H°(NaCl)$ is significantly higher than both $\Delta_{vap}H°(HCl)$ and $\Delta_{vap}H°(CH_3Cl)$.

NaCl ~~are~~ have an ionic bond, which is the strongest bond that a compound can have, as this is caused by ~~the~~ a great difference in electronegabuity. that an atom can pull an electron off another ~~to~~ form an electrostatic attraction so more energy is required to break the intermolecular forces ~~seperate the molecules compound~~ between NaCl compounds compared to HCl and CH_3Cl.

U

(ii) Explain why $\Delta_{vap}H°(CH_3Cl)$ is greater than $\Delta_{vap}H°(HCl)$.

~~CH_3Cl have a greater entropy~~ $\Delta vapH°$ for CH_3Cl is greater because it has three hydrogens bonded to the central ~~c~~ carbon atom so ~~it~~ more energy is needed to break the intermolecular forces between the hydrogens.

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(c) (i) Define $\Delta_{fus}H^\circ(NaCl)$.

This is the energy required to form ~~Na~~ ~~sodium~~ NaCl (s)

(ii) Why is $\Delta_{vap}H^\circ(NaCl)$ greater than $\Delta_{fus}H^\circ(NaCl)$?

~~Attract~~ to To form NaCl, less energy is required as the electrostatic attraction is strong between Na^+ and Cl^- ~~that~~ so it's easier to compared to breaking the ~~n~~ intermolecular forces between them as the electrostatic attraction is so strong

(iii) Why does NaCl readily dissolve in water, even though the process is slightly endothermic?

$$NaCl(s) \rightarrow Na^+(aq) + Cl^-(aq) \qquad \Delta_rH^\circ = +3.90 \text{ kJ mol}^{-1}$$

The reaction itself is spontaneous as the ~~Na+~~ water molecules are able to attract the ~~Na+ and Cl-~~ NaCl into its separate ions.

N2

QUESTION THREE

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(a) The equation for the combustion of liquid methanol is:

$$CH_3OH(\ell) + \tfrac{3}{2}O_2(g) \rightarrow CO_2(g) + 2H_2O(\ell)$$

Calculate the standard enthalpy of combustion of liquid methanol, $\Delta_c H°(CH_3OH(\ell))$, using the information in the table below.

Compound	kJ mol^{-1}
$\Delta_c H°(C(s))$	–394
$\Delta_c H°(H_2(g))$	–286
$\Delta_f H°(CH_3OH(\ell))$	–240

$C + O_2 \rightarrow$

$C_{(s)} + O_{2(g)} \longrightarrow CO_{2(g)}$ -394 kJ mol^{-1}

$H_{2(g)} + \frac{1}{2}O_{2(g)} \longrightarrow H_2O_{(l)}$ -286 kJ mol^{-1}

~~CH~~ $C_{(s)} + 2H_{2(g)} + \frac{1}{2}O_{2(g)} \longrightarrow CH_3OH_{(l)}$ -240 kJ mol^{-1}

$2\cancel{H_2}_{(g)} + \frac{1}{2}O_{2(g)} \longrightarrow 2H_2O_{(l)}$ $2(-286) = -572$ kJ mol^{-1}

$CH_3OH_{(l)} \longrightarrow \cancel{C}_{(s)} + 2\cancel{H_2}_{(g)} + \frac{1}{2}O_{2(g)}$

~~$C_{(s)} + O_2 \longrightarrow$~~ $\rightarrow$ $+240$ kJ mol^{-1}

$\cancel{C}_{(s)} + O_{2(g)} \longrightarrow CO_{2(g)}$ $= -394$ kJ mol^{-1}

$-572 + +240 + -394 = -726$

$\Delta_c H°(CH_3OH_{(l)}) = \underline{-726 \text{ kJ mol}^{-1}}$

C

(b) The enthalpy of combustion of liquid methanol, $\Delta_c H°(CH_3OH(\ell))$, can also be determined by burning a known mass of methanol and measuring the temperature change in a known mass of water above the burning methanol.

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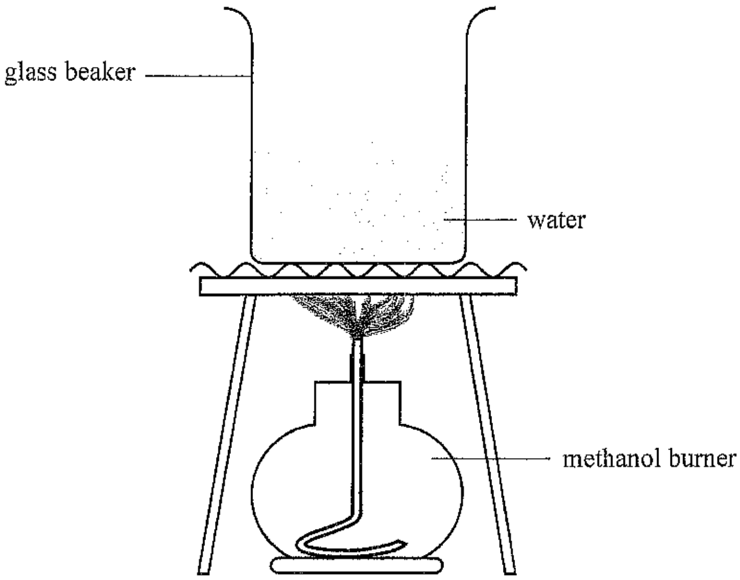

(i) If 2.56 g of methanol is burned, the temperature of 500 g water increases from 21.2°C to 34.5°C.

Using these results, calculate the experimental value of $\Delta_c H°(CH_3OH(\ell))$.

The specific heat capacity of water is 4.18 J °C^{-1} g^{-1}.

$M(CH_3OH) = 32.0$ g mol^{-1}

$\Delta_c H° = \Delta Hm$

$\Delta H = mc\Delta t$ $\quad$ 21.2 − 34.5 ($\cancel{34.5 - 21.2}$)

$4.18 \times 2.56 \times 34.5$

$= -142$ KJ mole^{-1}

(ii) Why is the experimental value obtained in part (b)(i) less negative than the theoretical value determined in part (a)?

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This is because some of the heat energy from the methanol burned is ~~getting~~ not all moving ~~lost in the~~ towards the water but is getting lost to the atmosphere instead so not of the heat energy ~~it~~ being produced is being used in the experiment.

u

(iii) The equation for the evaporation of liquid methanol is:

$CH_3OH(\ell) \rightarrow CH_3OH(g)$

Explain the entropy changes of the system and surroundings for the evaporation of methanol.

Entropy is the amount of disorder in a ~~che~~ substance or chemical system. As the $CH_3OH_{(l)}$ evaporates into $CH_3OH_{(g)}$, entropy increases as there are more ways for the particles to be disordered as there is more space between them to move in their surroundings as they change state.

u

A3

Achieved exemplar 2016

Subject:	Chemistry	Standard:	91390	Total score:	11

Q	Grade score	Annotation
1	M6	To gain excellence, the candidate needed to show an understanding that electronegativity is the attraction for bonding electrons. They also needed to explain why the Se-F bond is polar and link their answer more fully to the original question of why SeF_6 is insoluble in water.
2	N2	The candidate needed to show an understanding of the difference between molecules and compounds as well as the implications of the size of a molecule on the amount of energy required to break the various forces. Defining terms is a valuable means of gaining some credit. In part (c)(ii), it was important to be able to communicate the difference between melting and evaporation through the number of bonds being broken rather than reiterating the amount of energy needed.
3	A3	This candidate was unable to complete a calorimetry calculation. There was an understanding that heat energy would be lost to the surroundings but there was a need to link this to the water temperature not being as high, therefore a less negative enthalpy or to the need to insulate to ensure the heat energy was not lost. This candidate understood that entropy was related to disorder in a system but was not able to link this information sufficiently for a merit level answer.