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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.

Excellence

TOTAL 21

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QUESTION ONE

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(a) Complete the following table.

Symbol	Electron configuration
Cl	$1s^2 2s^2 2p^6 3s^2 3p^5$
Zn	$[Ar] 4s^2 3d^{10}$
Cr^{3+}	$[Ar]$ ~~$4s$~~ $3d^3$

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(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

Both Cl and Cl^- have 17 protons in their nucleus. ~~an~~ and their valence electrons are situated in the 3rd energy level thus there is the same amount of electron shielding from the inner shells and the same electrostatic attraction on valence electrons. Because Cl^- has an extra electron there is greater repulsion between valence electrons therefore Cl^- has ~~there~~ ~~is~~ an increased radius of 181 pm in comparison ~~As the electrons as situated further away from the nucleus as the electrons repel for maxi~~ to Cl's radius of 99 pm.

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(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 of an atom to attract electrons within a covalent bond. The first ionisation energy is the energy required to remove one mole of electrons from one mole of atoms in the gaseous state. The trend in electronegativity is that it reduces down a group, similarly the first ionisation energy also decreases. Moving down a group, the number of electron energy levels increases causing there to be an increased atomic radii. There is also an increased number of protons in the nucleus, however because of the number of electrons and increase in number of shells, electron shielding causes that to have little effect as moving down a group atoms will have ~~the~~ effectively the same attraction to the nucleus however due to increased distance from the nucleus there is a smaller force on electrons. For electronegativity as

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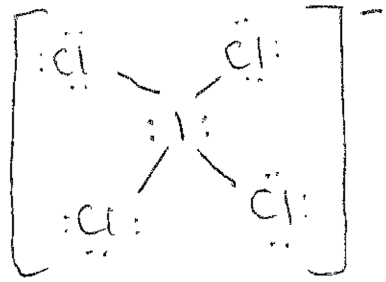
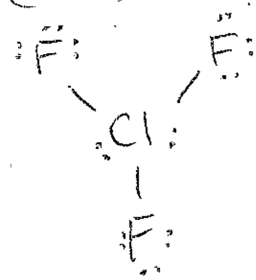
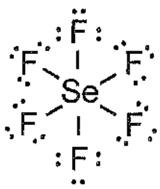
(c) (i) Complete the following table:

	ICl_4^-	ClF_3
Lewis diagram	$7 + (4 \times 7) + 1 = 36$ 	$7 + (3 \times 7) = 28$ 
Name of shape	Square Planar	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.

SeF_6 has 6 regions of negative charge around the central Se atom which repel for maximum separation into an octahedral shape with bond angles 90° As there are 6 bonding and no non bonding regions the shape is octahedral. There are 6 polar Se-F bonds with F being more electronegative creating a bond dipole. As SeF_6 is symmetrical the bond dipoles will cancel causing SeF_6 to have no net molecular dipole and is therefore non-polar. As water is a polar molecule and "like dissolves like" SeF_6 will not dissolve in water and is therefore insoluble.

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QUESTION TWO

The standard enthalpy of vaporisation, $\Delta_{vap}H^{\circ}$ (l → g), 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.

metal ionic salt

Compound	$\Delta_{vap}H^{\circ}$ / kJ mol^{-1}	Attractive forces
NaCl	194	Electrostatic ionic attraction
HCl	16.0	hydrogen bonding, permanent dipole, temporary dipole
CH_3Cl	22.0	permanent dipole, temporary dipole

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

NaCl is a metal salt which is ionically bonded. There is strong electrostatic (ionic) bonds that must be overcome for it to change state from liquid to solid. As this ~~intermolecular~~ attraction between particles is much stronger than the temp. dipole, permanent dipole & hydrogen bonding of HCl & CH_3Cl, more energy is required to break the bond hence the significantly higher $\Delta_{vap}H$ of 194 kJ mol^{-1}

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

Both CH_3Cl and HCl are able to form permant dipole-permanent dipole attractions and temporary dipole-temporary dipole attractions. CH_3Cl has a much greater molar mass of 50.5 compared to M(HCl) = 36.5 therefore CH_3Cl has a larger electron cloud allowing it to form stronger temporary dipole attractions. Although H-Cl is able to hydrogen bond the effect of the larger electron cloud of CH_3Cl & therefore its stronger temporary dipole attractions is greater causing it to have a higher $\Delta_{vap}H$ as more energy is required to overcome the stronger

(c) (i) Define $\Delta_{fus}H°(NaCl)$. $s \rightarrow l$

Enthalpy change when 1 mole of solid ~~atoms~~ is converted to 1 mole of liquid under standard conditions

(ii) Why is $\Delta_{vap}H°(NaCl)$ greater than $\Delta_{fus}H°(NaCl)$? $l \rightarrow g$ $s \rightarrow l$

~~Breaking bond~~ Δfus H involves breaking bonds within the solid and making weaker ~~liqu~~ bonds withins the liquid. As ΔH = bonds broken - bonds formed ΔH will be smaller as Δvap H does not invoke making any bonds as in a gas there are no interparticle attractions.

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

$NaCl(s) \rightarrow Na^+(aq) + Cl^-(aq)$ $\Delta_r H° = +3.90$ kJ mol^{-1}

Gibbs free energy states that a reaction will be spontaneous if ΔG is negative.
$\Delta G = \Delta H - t\Delta S$.
as ΔH is positive for this reaction $t\Delta S$ must be greater than 3.9.
ΔS (change in entropy (amount of disorder)) for this reaction is clearly positive as the number of moles of reactants is greater than the number of moles of reactants.
There is also a state change from solid, where there is very little disorder/entropy, to aqueous solution where there is greater entropy.
∴ This reaction occurs readily as the increase in entropy outweighs the decrease in enthalpy causing the reaction to be spontaneous.

QUESTION THREE

ASSESSOR'S USE ONLY

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

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

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

$C_{(s)} + O_{2(g)} \rightarrow CO_{2(g)}$ $\Delta H = -394$

×2 $H_2 + \frac{1}{2}O_{2(g)} \rightarrow H_2O_{(l)}$ $\Delta H = -286$

$C_{(s)} + \frac{1}{2}O_{2(g)} + 2H_{2(g)} \rightarrow CH_3OH_{(l)}$ $\Delta H = -240$

$\cancel{C_{(s)}} + O_{2(g)} \rightarrow CO_{2(g)}$ $\Delta H = -394$

$\cancel{2H_2} + O_{2(g)} \rightarrow 2H_2O_{(l)}$ $\Delta H = 2(-286) = -572$

$CH_3OH_{(l)} \rightarrow \cancel{C_{(s)}} + \frac{1}{2}O_{2(g)} + \cancel{2H_{2(g)}}$ $\Delta H = 240$

$CH_3OH_{(l)} + \frac{3}{2}O_{2(g)} \rightarrow CO_{2(g)} + 2H_2O_{(l)}$

$\Delta_c(CH_3OH_{(l)}) = (-394) + (-572) + 240$
$= -726 \text{ kJmol}^{-1}$

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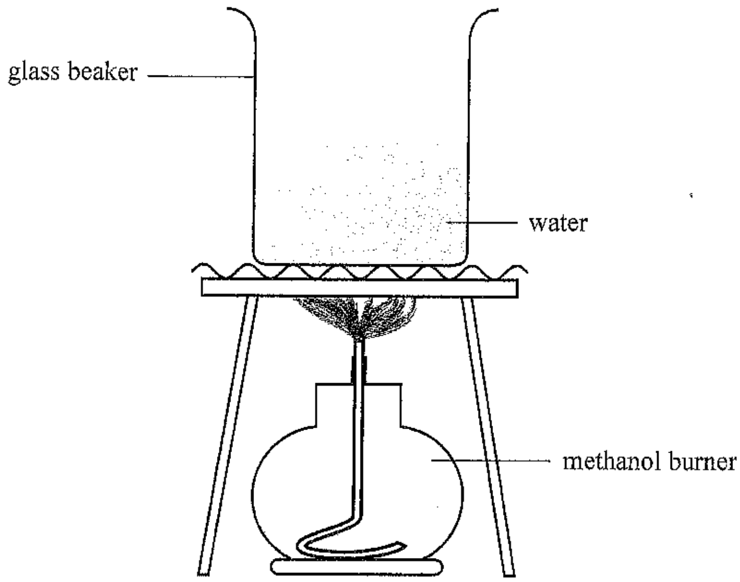
(b) The enthalpy of combustion of liquid methanol, $\Delta_c H°(CH_3OH(\ell))$, can also be determined by burning a known mass of methanol and measuring the temperature change in a known mass of water above the burning methanol.



(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}

$\Delta T = 34.5 - 21.2 = 13.3$

$Q = mc\Delta T$

$= \overset{0.5}{\cancel{500}} \times 4.18 \times 13.3$

$= 27.797$

$n = m/M = 2.56/32$

$= 0.08$

$\Delta_c H = -Q/n$

$= 27.797/0.08$

$= -347.4625$

(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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Because the experiment was possibly not under standard conditions & it was an open system so heat energy could be lost as well as mass or water as it evaporates //

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

$CH_3OH(\ell) \rightarrow CH_3OH(g)$ breaking bonds $\Delta H = +ve$ endo

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

As methanol is going from a liquid to a gas the entropy of the system is increasing as there is more random movement of particles ~~with~~ in gas form ~~thefor~~ therefore there will be more disorder & increased entropy in the system. Because changing state from liquid to gas involves breaking bonds ΔH will be positive & heat will be absorbed by the reaction & lost from the surroundings, this ~~redur~~ decrease in temperature reduces the random movement energy of particle in the surroundings causing there to be less disorder & a reduced entropy. //

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E7

Extra paper if required.
Write the question number(s) if applicable.

QUESTION NUMBER

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1.b ii. there will be a smaller force on covalently bonded electrons this means the electronegativity of the atom is less than those higher in the group. Likewise for first ionisation energy, due to the decreased force on electrons pulling them to the nucleus, ~~#~~ less energy is required to overcome that force to remove an electron therefore ionisation is also decreased down a group.

Excellence exemplar 2016

Subject:	Chemistry	Standard:	91390	Total score:	21

Q	Grade score	Annotation
1	E7	The Excellence was achieved through part (b)(ii) with a comprehensive understanding of ionisation energy and electronegativity trends. To achieve a grade score of E8, part (c)(ii) needed to have greater reference to the insolubility of SeF_6 than 'like dissolves like'.
2	E7	To achieve a grade score of E8, this candidate needed to understand that vaporisation required the breaking of all bonds as opposed to the breaking of some bonds for melting. Although the candidate understood that part (c)(ii) was an entropy question, they were not accurate enough in their communication to demonstrate comprehensive understanding.
3	E7	This candidate needed to be able to carry out the calorimetry calculation giving their answer to an appropriate number of significant figures to achieve a grade score of E8. All other parts of this question were answered comprehensively.