91390

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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.

Merit

TOTAL 17

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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~~ $3p^5$
Zn	$1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^{10}$
Cr^{3+}	$1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^1$

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 atom and the chlorine ion have the same number of shells and the same number of protons. However, Cl^- has a larger radius of 181pm because it contains an extra ~~atom~~ electron than Cl does (which has a radius of 99pm). The extra electron weakens the electrostatic force between the nucleus and the valence electrons as there is a higher ratio of electrons to protons. This causes an increase in the radius of the Cl^- atom. Because the ratio between protons is 1:1 in the Cl atom the electrostatic force is stronger than in Cl^-, thus pulling the valence electrons nearer the nucleus and giving it a smaller radius.

U

(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 measure of how closely an atom holds its valence electrons to its nucleus. First ionisation energy is the amount of energy required to remove one electron from a mole of an atom in a gaseous state. The value for electronegativity and the first ionisation energy decrease when going down a group. As the atoms gain more shells the effect of shielding grows. Thus, decreasing the electrostatic force between the nucleus and the valence electrons. As the radius gets bigger the electronegativity decreases because the electrons aren't held as closely to the nucleus. The first ionisation energy also decreases moving down a group because the electrostatic force weakens, meaning it requires less energy to remove the electron, from a mole of that atom. The trends for first ionisation energy and electronegativity are similar in the fact that as the radius increases their values decrease. The less electronegative an atom is the lower its first ionisation energy is.

(c) (i) Complete the following table:

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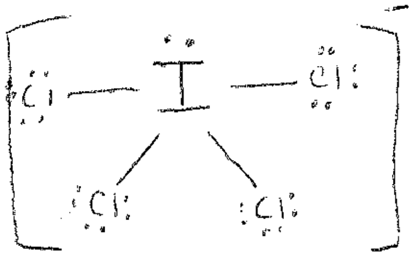
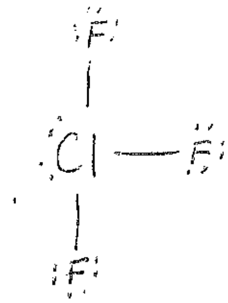
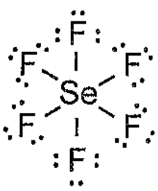
	ICl_4^-	ClF_3
Lewis diagram		
Name of shape	See-saw	T-shaped

i

(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.

SeF4 has six ~~regions of~~ negative regions. All six of these regions are taken up by bonds. To achieve maximum seperation, through electron-electron repulsion the bonds organise themselves in a Octahedral shape. Se and F have different electronegativities, F being the most electronegative, which means that there are diapoles. However, because the shape is symmetrical there is an even electron distubulion around the atom, which means the bond diapotes cancel out, making the molecule non-polar. Because it is non-polar it won't be soluble in a polar solvent such as water.

i

MS

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	Permanent diapole - diapole bonds Temporary diapole - diapole bonds
HCl	16.0	Permanent diapole - diapole bonds Temporary diapole - diapole bonds.
CH_3Cl	22.0	Permanent diapole - diapole bonds Temporary diapole - diapole bonds.

U

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

The difference in electronegativity between Na and Cl is so great that it requires 194 KJmol⁻¹ of energy to seperate them. Also NaCl is a very small straight chain molecule which means that the molecules can fit close together strengthening the temporary diapole-diapole bonds. The Permanent diapole-diapole bonds are very strong due to the large difference in electronegativities.

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

CH_3Cl has a much higher molar mass than HCl. This means that it takes more energy to seperate the intermolecular forces. HCl only has a molar mass of 36.5 gmol⁻¹. Thus, resulting in very little energy required to overcome its intermolecular forces compared to CH_3Cl.

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

ΔfusH° ~~is~~(NaCl) is the amount of energy required to turn one mole of solid NaCl into ~~one mole of liquid NaCl~~ a liquid.

u

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

ΔvapH° is greater because to turn NaCl into a gas all of the intermolecular forces must be broken whereas when going from a solid to a liquid these forces only need to be weakened not completely overcome ~~them~~. It takes more energy to completly overcome the intermolecular bonds.

u

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

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

The spontaneity of a reaction is determined by both the enthalpy and entropy of the system. This reaction is spontaneous although spontaneity favours exothermic reactions, because the entropy is increasing from 1 mole of reactants to 2 products. Also, the environment experiences a decrease in entropy as the reaction takes in heat energy. But within the system that is increasing the entropy. Heat is being taken in which is more disorded. The increase in entropy makes the reaction spontaneous.

u

M5

QUESTION THREE

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(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

$CH_3OH + \frac{3}{2}O_2 \rightarrow CO_2 + 2H_2O$

① $C + O_2 \rightarrow CO_2$ -394
② $H_2 + \frac{1}{2}O_2 \rightarrow H_2O$ -286
③ $C + 2H_2 + \frac{1}{2}O_2 \rightarrow CH_3OH$ -240

$CH_3OH \rightarrow C + 2H_2 + \frac{1}{2}O_2$ +240
$C + O_2 \rightarrow CO_2$ -394
$2H_2 + O_2 \rightarrow 2H_2O$ 2(-286)

$\Delta_c H° = 240 + (-394) + 2(-286)$
$\Delta_c H° = \underline{-726 \text{ kJmol}^{-1}}$

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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.

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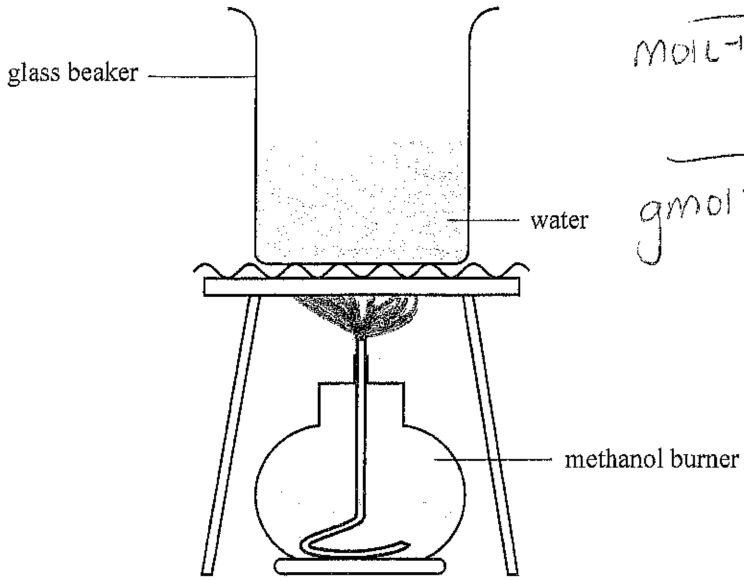

mol / molL⁻¹ | L

g / gmol⁻¹ | mol

(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

Q = mcΔt

Q = ~~2.56~~ 502.56 × 4.18 × 13.3

Q = ~~14232064~~ 27939

~~mol = concen mol L⁻¹ × L~~

mol = g / gmol

mol = 2.56 / 32

mol = 0.08 mol

ΔcH° = Q / n

ΔcH° = ~~14232064~~ 27939 / 0.08

ΔcH° = 349 J mol⁻¹

~~ΔcH° = 1779 J mol⁻¹~~

~~ΔcH° = 1.78 kJ mol⁻¹~~

ΔcH° = 349000 J mol⁻¹

ΔcH° = 349 kJ mol⁻¹

↑ This value is for the exothermic reaction.

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(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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Heat is lost to the environment through this ~~experiment which means~~ the value of the energy recorded will be less negative than what was calculated.

(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.

This is an endothermic reaction which has an increase in entropy. Transistioning from a liquid to a gas requires breaking all of the intermolecular bonds. Leaving ~~single~~ seperated molecules. This shows an increase in randomness and therefore an increase in entropy. For this reaction to happen there is a decrease in entropy for the surrounding environment as heat energy is taken in by the reaction ~~to~~ from the environment to break the intermolecular bonds.

C

E7

Merit exemplar 2016

Subject:	Chemistry	Standard:	91390	Total score:	17

Q	Grade score	Annotation
1	M5	In order to achieve a higher grade score, the candidate in part (b)(i) needed to refer to the electron-electron repulsion in the energy level through gaining an electron, rather than the electron : proton ratio causing the change in radius size. In part (b)(ii), there needed to be an understanding that electronegativity is related to the attraction for bonding electrons rather than for its own valence electrons. In part (c)(ii), the candidate needed to address the question which was asking if SeF_6 is soluble in water, so their answer was not comprehensively linked to the original question.
2	M5	The candidate needed to understand that NaCl is an ionic solid and therefore, its forces were electrostatic and very strong, thus requiring more energy to break. Although the candidate knew that CH_3Cl has a larger molar mass than HCl, they needed to link this to the increased temporary dipole-dipole attractions. Parts (c)(ii) and (c)(iii) needed to both be complete answers for an Excellence grade. In part (c)(ii), there needed to be no reference to intermolecular forces for NaCl and in part (c)(iii), there needed to be an understanding that the two moles of products were ions, as well as a more accurate reference to the spontaneity of the reaction with both enthalpy and entropy.
3	E7	This grade needed an accurate calorimetry calculation to achieve a grade score of E8. The inclusion of the alcohol used is not required to calculate the heat transferred (*q*). All other parts of this question were answered comprehensively.