

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.

EXCELLENCE

TOTAL

23

ASSESSOR'S USE ONLY

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

QUESTION ONE

(a) Complete the following table.

Symbol	Electron configuration
$^{34}_{16}$ Se	$1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^2 4p^4$
$^{23}_{23}$ V	$1s^2 2s^2 2p^6 3s^2 3p^6 3d^3 4s^2$
$^{23}_{20} V^{3+}$	$1s^2 2s^2 2p^6 3s^2 3p^6 3d^2$

All correct

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

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

(i)

Atom	Electronegativity
O	3.44 smaller
Se	2.55

Suitable answer for achievement. Answer could have been improved by outlining 'shielding'.

Electronegativity refers to the ability of nucleus to attract the shared bonded pair of e^- .

$^8_8 O$ $1s^2 2s^2 2p^4$ 2nd Energy level

$^{34}_{16} Se$ $1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^2 4p^4$ e^- in the 4th energy level.

e^- in O atoms are closer than e^- in Se, therefore despite the smaller number of protons (i.e. less nuclear charge)

e^- are held more tightly by O nucleus. \therefore O atom is smaller ~~in size and~~ hence higher electronegativity for O

(ii)

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

Correct \rightarrow merit.

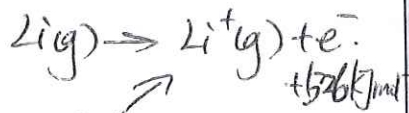
$^{17}_{17} Cl$ $1s^2 2s^2 2p^6 3s^2 3p^5$ e^- in the 3rd Energy level.

$^{17}_{17} Cl^-$ $1s^2 2s^2 2p^6 3s^2 3p^6$.

Both Cl and Cl^- have the same number of protons and hence same nuclear charge. There is 1 more electron for Cl^- , so \therefore greater e^- and e^- repulsion for Cl^- . Therefore, e^- are least tightly held by nucleus in Cl^- . \therefore Cl^- is larger in radius than Cl.

(iii)

Atom	First ionisation energy/kJ mol ⁻¹
Li	526
Cl	1257 smaller



First ionisation energy is the energy required to remove the least tightly bound e⁻ from 1 mol of atoms in its gaseous state.

³Li 1s²2s¹ 2nd energy level, e⁻ are closer to nucleus

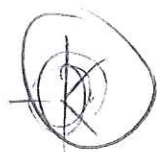
¹⁷Cl 1s²2s²2p⁶3s²3p⁵ 3rd energy level, e⁻ are further away from nucleus.

But Cl has got more protons than Li, so greater nuclear charge for Cl atoms, therefore, e⁻ are held more tightly by Cl atoms. ~~Cl atoms are smaller than Li~~, ∴ Cl has a higher 1st ionisation energy, as greater amount of energy is needed.

Full discussion provided evidence for excellence.

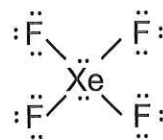
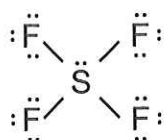
(c) (i) Complete the following table.

Molecule	BrF ₃ = 28.	PCl ₆ ⁻ 5+6x7+1=48
Lewis diagram		
Name of shape	T shape	octahedral.



Achievement only as the Lewis structure for PCl₆⁻ lacks brackets and a charge.

(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 . $\text{S}^{\delta+} - \text{F}^{\delta-}$ S and F have different electronegativities, e^- are pulled towards F. \therefore S-F is a polar bond.

There are 5 regions of e^- density around central atom S, they repel and move as far apart as possible. They are arranged in the corners of trigonal bi-pyramid. (Bond angle is 109.5°)

There is 4 bonded ~~atom~~ atoms and 1 non bonded pair of electrons around the S, so the shape is see saw. There is an uneven distribution of charge. \therefore bond dipoles do not cancel.

\therefore SF_4 is polar.

XeF_4 . $\text{Xe}^{\delta+} - \text{F}^{\delta-}$ Xe and F have different electronegativities, e^- are pulled towards F. \therefore Xe-F is a polar bond.

There are 6 regions of e^- density around the central atom Xe, they repel and move as far apart as possible. They are arranged in the corners of an octahedron. (Bond angle 90°). There are

4 bonded atoms and 2 non-bonded pair of electrons around Xe. \therefore Shape is square planar. There is an even distribution of charge. Bond dipoles cancel. \therefore XeF_4 is non-polar.

Full Discussion

\rightarrow excellence.

QUESTION TWO

- (a) (i) Explain what is meant by the term
- $\Delta_{\text{vap}}H^\circ(\text{H}_2\text{O}(\ell))$
- .

The enthalpy change of 1 mol of H_2O to vaporize at its boiling point under standard conditions (pressure).

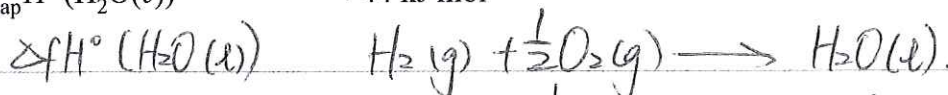
Suitable evidence for achievement.

- (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 $\Delta_f H^\circ(\text{H}_2\text{O}(\ell))$, given the following data:

$$\Delta_f H^\circ(\text{H}_2\text{O}(\text{g})) = -242 \text{ kJ mol}^{-1}$$

$$\Delta_{\text{vap}} H^\circ(\text{H}_2\text{O}(\ell)) = +44 \text{ kJ mol}^{-1}$$



$$\Delta_f H^\circ(\text{H}_2\text{O}(\ell)) = -242 - 44 \quad \text{H}_2\text{O}(\text{g}) \rightarrow \text{H}_2\text{O}(\ell) \quad -44 \text{ kJ mol}^{-1}$$

$$= -286 \text{ kJ mol}^{-1} \quad \text{Correct} \rightarrow \text{Merit.}$$

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

Between H_2O molecules, there is temporary dipole attractions (All molecules have temporary dipole attractions between them, which, as the molar mass increases, size of e⁻ cloud increases, strength of temporary dipole attractions increases).

H-bonding between H_2O molecules, too. which is relatively strong.

Therefore, at 100°C , all the heat taken in by water are used to overcome the intermolecular

forces between H_2O molecules, so that H_2O molecules are free to move as gas, rather than having only restricted movements in the liquid form.

∴ Temperature does not change. Correct → Merit.

- (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, NH₃, a temperature rise of 6.50°C is recorded, as a neutralisation reaction occurs to produce aqueous ammonium chloride and water.

Calculate $\Delta_r H^\circ$ 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



$$q = mc\Delta T = 50 \times 4.18 \times 6.5 = 1358.5 \text{ J}$$

$$= 1.3585 \text{ kJ}$$

$$\Delta_r H^\circ = \frac{-q}{n} = \frac{-1.3585}{0.025 \times 1}$$

$$= -54.3 \text{ kJ mol}^{-1} \quad // \quad n = cV$$

Correct → excellence.

- (ii) When the $\Delta_r H^\circ$ 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.

It could be due to heat lost to surroundings. So temperature measured is lower. Could carry out experiment in some form of containment to provide insulation.

Or could be experiment not done under standard conditions, i.e. 25°C and 1 atm pressure. Could adjust the condition to standard conditions for a result closer to the theoretical value. // Correct answer

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

QUESTION THREE

(a)

Molecule	Boiling point/°C
Hydrazine, N_2H_4 32 g mol^{-1}	114
Fluoromethane, CH_3F 34 g mol^{-1}	-78.4
Decane, $C_{10}H_{22}$ 142 g mol^{-1}	174

M - molar mass.

Full Discussion
→ excellence.

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 point is the temperature at which substance vapourises. The stronger intermolecular forces, the higher the boiling point.

<p>temporary dipole attractions. All molecules.</p> <p>$M(C_{10}H_{22}) > M(CH_3F) > M(N_2H_4)$</p> <p>$\therefore C_{10}H_{22}$ has the largest e^- cloud</p> <p>$\therefore C_{10}H_{22}$ has the strongest temporary dipole attractions.</p> <p>CH_3F and N_2H_4 have similar strength of temporary dipole attractions.</p>	<p>permanent dipoles attractions</p> <p>Polar molecules.</p> <p>$C_{10}H_{22}$ is non polar as C-H have atoms of similar electronegativities</p> <p>\therefore C-H is non polar.</p> <p>$\therefore C_{10}H_{22}$ doesn't have permanent dipole attractions.</p> <p>$C-F$ have atoms of different electronegativities.</p> <p>\therefore C-F is polar</p> <p>CH_3F is tetrahedral shaped</p> <p>\therefore Bond dipoles do not cancel</p> <p>$\therefore CH_3F$ is polar</p> <p>$\therefore CH_3F$ has permanent dipole attractions.</p>	<p>H bonding.</p> <p>Molecules have OH or NH or FH bonds.</p> <p>N_2H_4 is able to form H bonding between molecules.</p> <p>\therefore H-bonding is relatively stronger than permanent dipole attractions.</p>
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Overall, boiling point. $C_{10}H_{22} > N_2H_4 > CH_3F$.

\therefore Size of intermolecular forces $C_{10}H_{22} > N_2H_4 > CH_3F$.

\therefore In this case, temporary dipole attractions is the most significant in determining the relative strengths of attractive forces for $C_{10}H_{22}$, and between N_2H_4 and CH_3F , H-bonding is the most significant.

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



Calculate $\Delta_c H^\circ(\text{C}_{10}\text{H}_{22}(\ell))$, given the following data:

$$R \Delta_f H^\circ(\text{C}_{10}\text{H}_{22}(\ell)) = -250 \text{ kJ mol}^{-1}$$

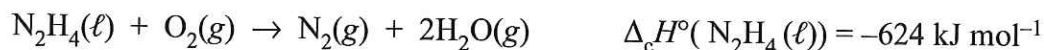
$$P \Delta_f H^\circ(\text{CO}_2(\text{g})) = -393 \text{ kJ mol}^{-1}$$

$$P \Delta_f H^\circ(\text{H}_2\text{O}(\ell)) = -286 \text{ kJ mol}^{-1}$$

$$\begin{aligned} \Delta_c H^\circ(\text{C}_{10}\text{H}_{22}(\ell)) &= \sum f H^\circ_{\text{products}} - \sum f H^\circ_{\text{reactants}} \\ &= \cancel{0} - 393 \times 10 - 286 \times 11 + 250 \\ &= -6830 \text{ kJ mol}^{-1} \end{aligned}$$

Correct \rightarrow merit.

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



Explain why liquid hydrazine readily burns in oxygen.

Your answer should consider both enthalpy and entropy changes.

$\Delta G = \Delta H - T\Delta S$. For a reaction to be spontaneous, ΔG must be ~~small~~ negative.

ΔH - negative, exothermic reaction.

ΔS - positive. \therefore there is 1 mol of liquid and 1 mol of gas on the reactants side and there is 3 mols of gases on the product side. Gases are more random than liquids and also ~~the~~ the increase in the number of mols of gases indicate an increase in the level of motion (and randomness) and energy. \therefore the level of disorder in the system (S) increases.

At any temperature, reaction B will be spontaneous, as ΔG will always be negative. For a negative ΔH

and a positive. ΔS

Provides evidence towards merit.
Further links between exothermic
reactions and spontaneity would
have taken the answer up to
excellence, and E8 for the question.

-ve - positive.