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Examiners' Report
June 2015

IAL Chemistry WCH01 01

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Introduction

The ideas examined on this paper seemed accessible to the majority of candidates. There was little evidence of candidates not attempting questions, even towards the end of the paper. This suggests that time management was not an issue. Calculations seemed to be a particular strength. The mean mark for Section A was 12 marks out of 20. The most straightforward multiple-choice questions were 1, 12, 13, 16, 18 and 20. The most challenging multiple-choice questions were found to be 3, 5, 7 and 11. There was a feeling from those marking the examination that some common errors seen in previous series seemed less evident on this paper, suggesting that centres and candidates are making very effective use of past papers and mark schemes.

Question 21 (a) (iii)

(iii) Explain the term **structural isomers**, by reference to two molecules selected from the table in part (a).

(3)

structural isomers means it have same name, element. but difference ~~stur~~ structure

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Examiner Comments

This answer was awarded M3 only - for the idea that such isomers would have different structures. The isomers A and C were not identified, so marks M1 and M2 were not available.

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Examiner Tip

Always read the question carefully to ascertain fully what its requirements are.

(iii) Explain the term **structural isomers**, by reference to two molecules selected from the table in part (a).

(3)

Structural isomers are two molecules have same molecule number, but have different ~~sketal~~ skeletal formulas. For example, A and C are ~~same~~ isomers, but they have different skeletal formulas.

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Examiner Comments

Marks M1 and M3 were awarded. M2 was not awarded, as the term 'molecular formula' should have been used here instead of 'molecule number'.

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Examiner Tip

Learn key expressions and technical terms accurately.

Question 21 (c)

(ii) cracking and then reforming

(1)

D

(c) Suggest how engine performance is improved by using a fuel containing the molecule that you have identified in (b)(ii).

(1)

- No knocking sound.
- Pre ignition is avoided.

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Examiner Comments

This response scored the available mark - both statements were correct answers.

ResultsPlus
Examiner Tip

Use of 'bullet points' can add to the clarity of answers.

(ii) cracking and then reforming

(1)

C

(c) Suggest how engine performance is improved by using a fuel containing the molecule that you have identified in (b)(ii).

(1)

THERE IS MORE COMPLETE COMBUSTION SO THE ENGINE IS MORE ENERGY EFFICIENT AND LESS CARBON MONOXIDE IS PRODUCED

ResultsPlus
Examiner Comments

This answer scored the available mark for the idea of improved efficiency of combustion.

Question 21 (d)

(d) The **energy density** of a fuel is defined as the energy produced per kilogram of fuel.

Calculate the energy density of dodecane, $C_{12}H_{26}$, in kJ kg^{-1}. Give your answer to **two** significant figures.

The enthalpy change of combustion of dodecane is –8086 kJ mol^{-1}.

[Molar mass: $C_{12}H_{26}$ = 170 g mol^{-1}]

(3)

170g = 0.17kg $\frac{-8086}{0.17}$ = ~~476~~ −47564.7

≈ -4.8×10^{-4} kJ kg^{-1}

energy density = -4.8×10^{-4} kJ kg^{-1}

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Examiner Comments

This response scored marks M1 and M2 out of three. In standard form, the final answer should have been given as 4.8×10^{4} kJ kg^{-1}, not as written.

ResultsPlus
Examiner Tip

Check answers given in standard form carefully.

(d) The **energy density** of a fuel is defined as the energy produced per kilogram of fuel.

Calculate the energy density of dodecane, $C_{12}H_{26}$, in kJ kg^{-1}. Give your answer to **two** significant figures.

The enthalpy change of combustion of dodecane is −8086 kJ mol^{-1}.

[Molar mass: $C_{12}H_{26}$ = 170 g mol^{-1}]

(3)

1000 g - 1kg
170 g - x

$\frac{170}{1000} = 0.17\text{kg}$

0.17kg - -8086
1 kg - x

$\frac{-8086}{0.17} = -47564.7$

$= -48000 \text{ kjmol}^{-1}$

energy density = 48000 kJ kg^{-1}

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Examiner Comments

This well set-out answer earned all three available marks. Note that a minus sign was not essential here for the calculation of energy density. Note the requirement for the final answer to be given to two significant figures.

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Examiner Tip

Show all stages in your answer to a calculation question.

Question 22 (b) (i)

(b) The table below shows the energy changes that are needed to determine the lattice energy of strontium chloride, $SrCl_2$.

Energy change	ΔH / kJ mol^{-1}
enthalpy change of atomization of strontium	+164
first ionization energy of strontium	+550
second ionization energy of strontium	+1064
enthalpy change of atomization of chlorine, $\frac{1}{2}Cl_2$	+122
first electron affinity of chlorine	−349
enthalpy change of formation of strontium chloride	−829

(i) Define the term **lattice energy**.

(2)

It is the heat energy released when gaseous ions form from 1 mole of an ionic solid.

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Examiner Comments

This response scored one out of the two available marks. It implies that the definition of lattice energy refers to breaking up the lattice into gaseous ions when in fact the converse is true.

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Examiner Tip

Learn all definitions word-perfectly!

(b) The table below shows the energy changes that are needed to determine the lattice energy of strontium chloride, $SrCl_2$.

Energy change	ΔH / kJ mol^{-1}
enthalpy change of atomization of strontium	+164
first ionization energy of strontium	+550
second ionization energy of strontium	+1064
enthalpy change of atomization of chlorine, $\frac{1}{2}Cl_2$	+122
first electron affinity of chlorine	−349
enthalpy change of formation of strontium chloride	−829

(i) Define the term **lattice energy**.

(2)

It is the energy released when 1 mole of substance is formed from it's ions at thier gaseous state and it is exothermic.

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Examiner Comments

This answer scored both the available marks for the definition of lattice energy. It mentions both 'one mole' (of a substance) and the idea of formation from gaseous ions.

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Examiner Tip

Learn all definitions thoroughly.

Question 22 (b) (ii)

(ii) Calculate the lattice energy of strontium chloride, in kJ mol^{-1}. (2)

$\Delta H^\circ_f [SrCl_2] = \Delta H^\circ_2 + \Delta H^\circ_3 + \Delta H^\circ_4 + \Delta H^\circ_5 + \Delta H^\circ_6 + \Delta H^\circ_7$

$-829 = 164 + 550 + 1064 + 2(122) + 2(-349) + \Delta H^\circ_7$

$\Delta H^\circ_7 = -829$ ~~-2371 2720~~ -1324

$=$ ~~-30 3200~~ ~~-3544~~

~~-3544~~

lattice energy = ~~-3200~~ -2153 kJ mol^{-1}

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Examiner Comments

This response was awarded both the available marks for the correct numerical answer.

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Examiner Tip

Get plenty of practice working through Born-Haber cycle calculations.

(ii) Calculate the lattice energy of strontium chloride, in kJ mol^{-1}. (2)

$\Delta H_1 = \Delta H_2 + \Delta H_3 + \Delta H_4 + \Delta H_5 + \Delta H_6 + \Delta H_7$

$\Delta H_7 = \Delta H_1 - (\Delta H_2 + \Delta H_3 + \Delta H_4 + \Delta H_5 + \Delta H_6 \times 2)$

$\Delta H_7 = -829 - (164 + 550 + 1064 + 122 + 2(-349))$

$\Delta H_7 =$ ~~$-829 - (1202)$~~ $-829 - (1202)$

$=$ ~~$-2,031$~~ kJmol^{-1}

~~-1941~~

$= -2,031$

lattice energy = ~~$-2,031$~~ ~~-1944~~ $-2,031$ kJ mol^{-1}

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Examiner Comments

This response scored one out of the two available marks. The candidate has not doubled the value for the enthalpy change of atomization of chlorine (+122 kJ mol^{-1}) in order to account for the enthalpy change $Cl_2(g)$ □ $2Cl(g)$.

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Examiner Tip

Always check for the requirement for doubling values, where relevant, in a Born-Haber cycle.

Question 22 (c)

*(c) The lattice energies of sodium fluoride and magnesium fluoride are shown in the table below.

Compound	Lattice energy / kJ mol^{-1}
Sodium fluoride, NaF	−918
Magnesium fluoride, MgF_2	−2957

Explain, in terms of the sizes and charges of the ions involved, why the lattice energy of MgF_2 is more negative than that of NaF.
(exo) (more energy needed)

(3)

Mg^{2+} is smaller and greater charge than Na^+. F^- is more polarised by Mg^{2+}.

stronger attraction between Mg^{2+} and F^- ~~on~~ compare to Na^+ and F^-

more energy is needed to ~~break the~~ overcome the electrostatic attraction between MgF_2

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Examiner Comments

This response scored all three available marks. M1 for noting that the radius of the magnesium ion is smaller than that of the sodium ion. M2 was awarded for stating that the magnesium ion has a higher charge than the sodium ion. M3 was awarded for mentioning that the attraction between magnesium ions and fluoride ions is stronger than that between sodium ions and fluoride ions.

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Examiner Tip

Try to give three salient points when answering a question worth three marks - as is the case here.

*(c) The lattice energies of sodium fluoride and magnesium fluoride are shown in the table below.

Compound	Lattice energy / kJ mol^{-1}
Sodium fluoride, NaF	−918
Magnesium fluoride, MgF_2	−2957

Explain, in terms of the sizes and charges of the ions involved, why the lattice energy of MgF_2 is more negative than that of NaF.

(3)

Mg^{+2} ion is smaller in size than Na^{+1} due to less shells and sheilding electrons and less repulsion, Mg^{+2} has higher charge density than Na^{+1} therefore more electrostatic force of attraction between Mg^{+2} and F^{-1} more energy is needed to break bonds therefore more negative.

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Examiner Comments

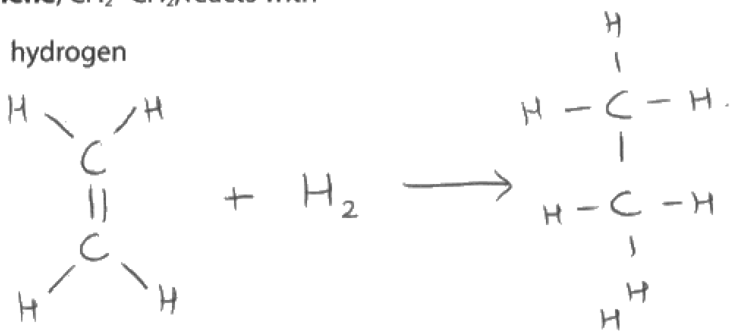
The first mark was negated due to incorrect chemistry when trying to justify the difference in ionic radius between the two cations. The second mark, M2, was awarded. The third mark was awarded, as per the Mark Scheme. There is no contradiction in the final sentence (as more energy would be needed to separate the ions in MgF_2 than in NaF).

Question 23 (b)

(b) Give the **structural** formula of the organic product formed when **ethene**, $CH_2{=}CH_2$, reacts with

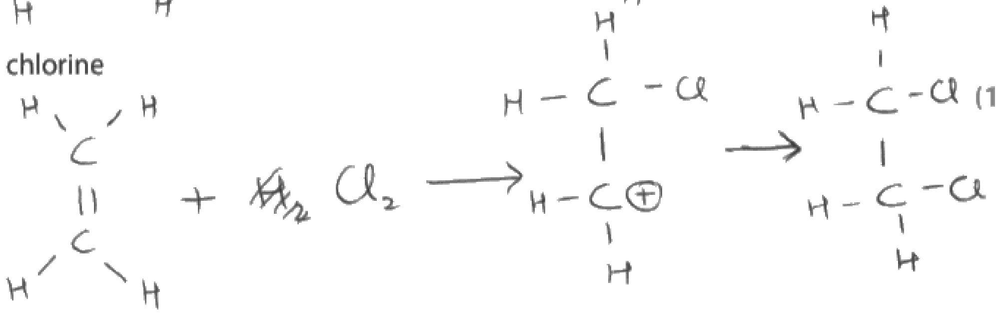
(i) hydrogen

(1)



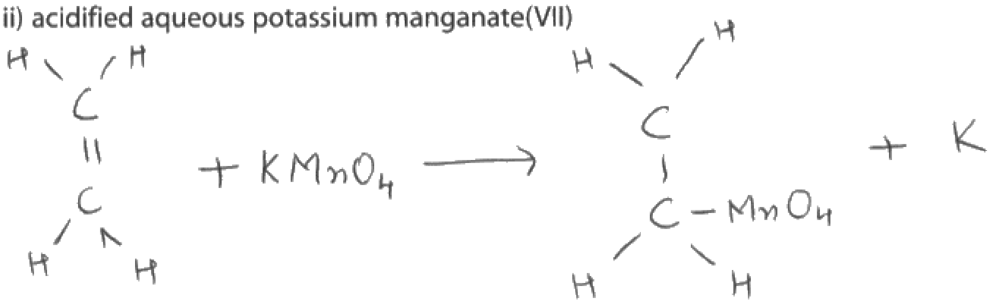
(ii) chlorine

(1)



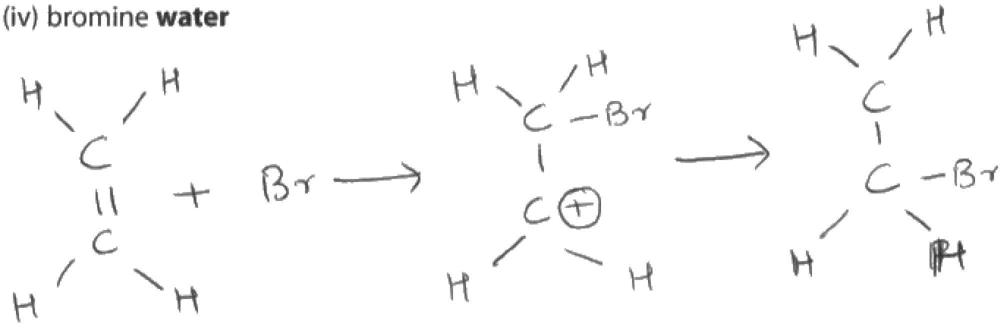
(iii) acidified aqueous potassium manganate(VII)

(1)



(iv) bromine **water**

(1)



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Examiner Comments

This response scored one mark each for parts (b)(i) and (b)(ii). A mechanism was not required for any of the answers and was ignored in (b)(ii). The products given in (b)(iii) and (b)(iv) were incorrect.

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Examiner Tip

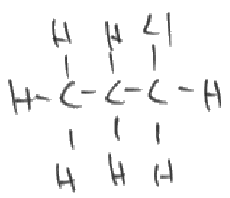
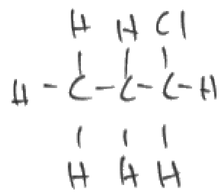
Learn all reagents and conditions for the organic reactions in the specification.

Question 23 (c)

(c) When **propene**, $CH_3CH{=}CH_2$, reacts with hydrogen chloride, there are **two** possible products, a major product and a minor product.

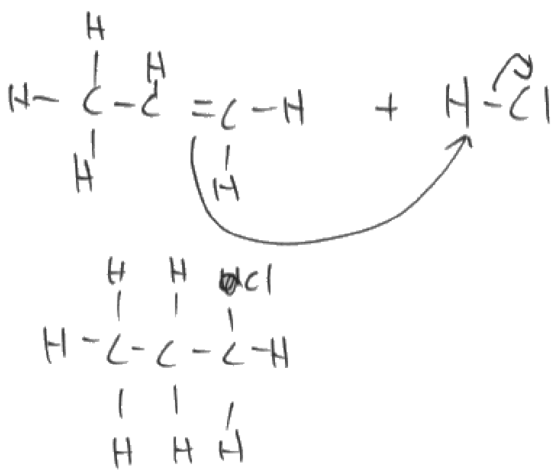
(i) Draw the **displayed** formulae of these products.

(2)

	
Major product	Minor product

(ii) Give the mechanism for the reaction of **propene** with hydrogen chloride which forms the major product.

(3)



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Examiner Comments

The answer to (c)(i) was awarded one mark out of two. Only the 'minor product' is correctly identified. In (c)(ii), only mark M1 was awarded for the mechanism. Neither the secondary carbocation intermediate has been shown, nor has the final attack by the chloride ion, Cl^-, on the carbocation intermediate, as was required for the award of M3.

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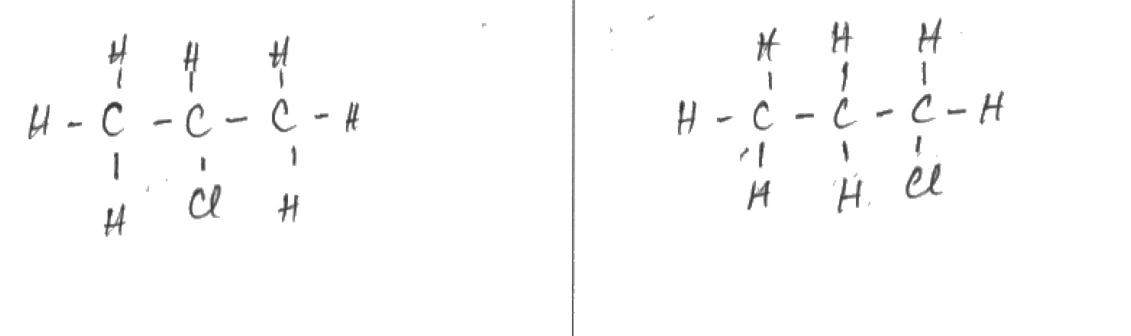
Examiner Tip

Get plenty of practice at drawing organic reaction mechanisms such as these.

(c) When **propene**, $CH_3CH{=}CH_2$, reacts with hydrogen chloride, there are **two** possible products, a major product and a minor product.

(i) Draw the **displayed** formulae of these products.

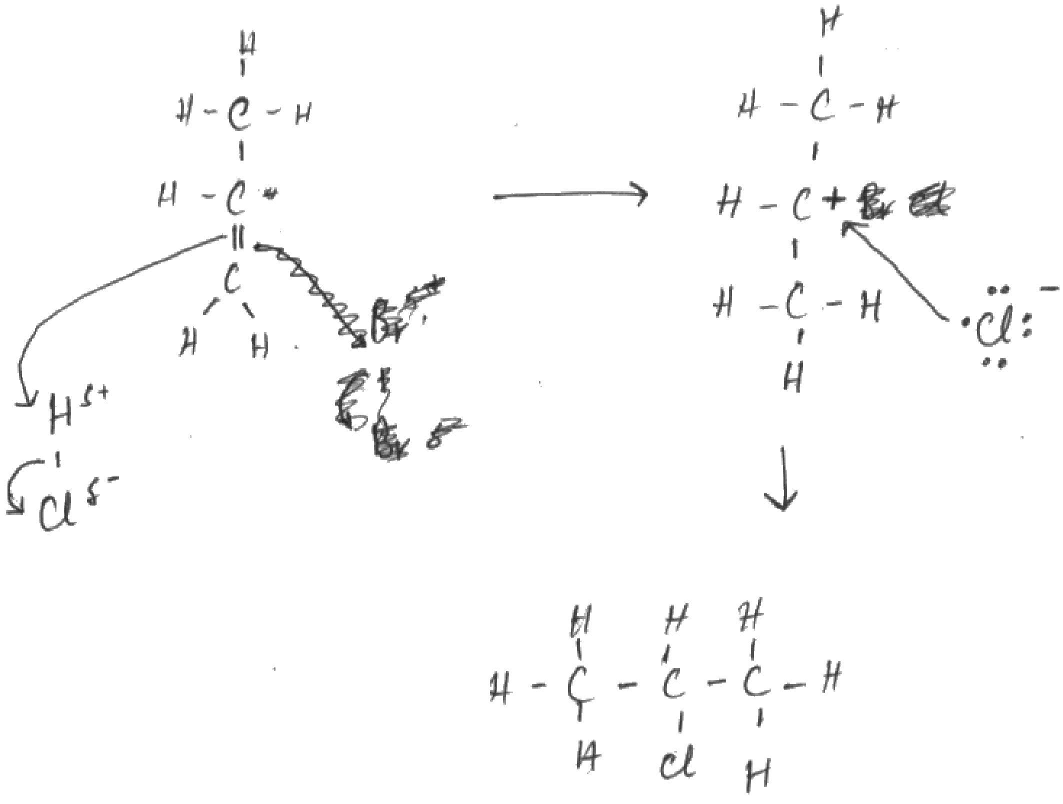
(2)



Major product	Minor product

(ii) Give the mechanism for the reaction of **propene** with hydrogen chloride which forms the major product.

(3)



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Examiner Comments

The answer to (c)(i) was awarded both marks. In (c)(ii), marks M1 and M2 were awarded for the mechanism. Note that the final attack by the chloride ion, Cl^-, is incorrectly shown as the electronic configuration of a free radical is shown on the anion.

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Examiner Tip

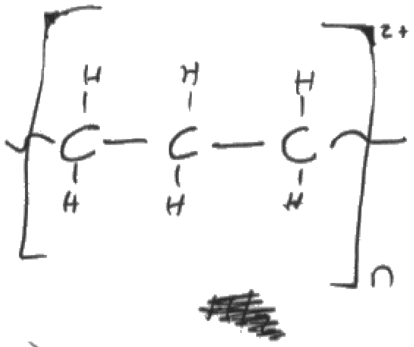
Practise plenty of 'curly arrow' reaction mechanisms, showing lone pairs of electrons and correct dipoles where you can.

Question 23 (d) (i)

(d) Propene can be polymerized.

(i) Write a balanced equation for the polymerization of propene to form poly(propene), drawing the **displayed** formula of the repeat unit of poly(propene).

(3)



$C_3H_6 \rightarrow (C_3H_6)_n$

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Examiner Comments

Only mark M3 was awarded, for displaying 'continuation bonds'.

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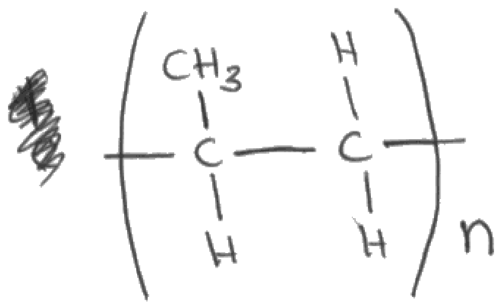
Examiner Tip

Practise writing equations, using displayed formulae, for the formation of addition polymers from the monomers encountered in the specification.

(d) Propene can be polymerized.

(i) Write a balanced equation for the polymerization of propene to form poly(propene), drawing the **displayed** formula of the repeat unit of poly(propene).

(3)



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Examiner Comments

This scored two out of the three available marks. The repeat unit, required for M2, and the 'continuation bonds', required for M3, are both shown. There is no left-hand side for the equation, so no M1 was awarded.

Question 23 (d) (ii)

(ii) State a problem associated with the disposal of waste poly(propene).

(1)

~~Difficult to~~

Requires a great area of land for disposal.

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Examiner Comments

This response identified a problem associated with the disposal of waste poly(propene).

Question 23 (e)

(e) Standard enthalpy changes of combustion can be used to calculate the standard enthalpy change of formation of propene.

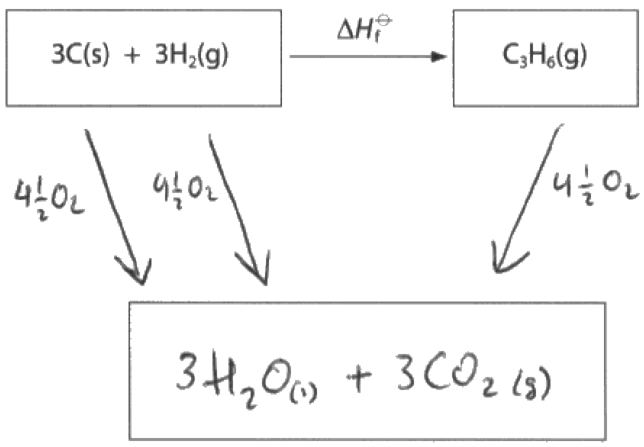
$$3C(s) + 3H_2(g) \longrightarrow C_3H_6(g)$$

Values for some standard enthalpy changes of combustion, $\Delta H_c^\ominus$, are shown in the table below.

Substance	$\Delta H_c^\ominus$ / kJ mol^{-1}
C(s)	−394
$H_2(g)$	−286
$C_3H_6(g)$	−2058

(i) Complete the Hess cycle below to enable you to calculate $\Delta H_f^\ominus$ from combustion data.

(1)



(ii) Calculate $\Delta H_f^\ominus$, in kJ mol^{-1}.

(2)

$= 3(-394) + 3(-286) - (-2058)$

$= 18$ kJmol^{-1}

standard enthalpy change of formation of propene = + 18 kJ mol^{-1}

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Examiner Comments

In (e)(i), both arrows have been correctly added to the cycle, as have the appropriate number of moles of both carbon dioxide and water. The calculation has been correctly answered in (e)(ii).

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Examiner Tip

Get plenty of practice of Hess cycle type calculations.

(e) Standard enthalpy changes of combustion can be used to calculate the standard enthalpy change of formation of propene.

$$3C(s) + 3H_2(g) \longrightarrow C_3H_6(g)$$

Values for some standard enthalpy changes of combustion, $\Delta H_c^\ominus$, are shown in the table below.

Substance	$\Delta H_c^\ominus$ / kJ mol^{-1}
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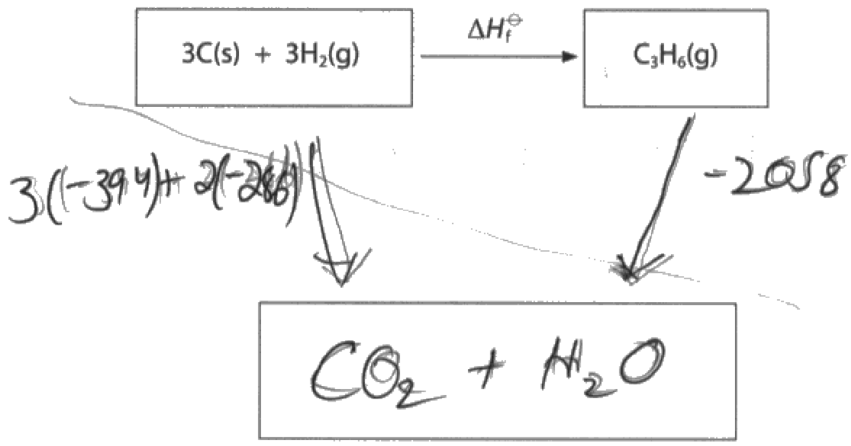
(i) Complete the Hess cycle below to enable you to calculate $\Delta H_f^\ominus$ from combustion data.

(1)



(ii) Calculate $\Delta H_f^\ominus$, in kJ mol^{-1}.

(2)

$\Delta H_f^\ominus = 3(-394) + 2(-286) + 2058$

standard enthalpy change of formation of propene = 304 kJ mol^{-1}

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Examiner Comments

Part (e)(i) was not awarded the mark. Although both arrows were correctly drawn, the moles of both carbon dioxide and of water were incorrect ($3CO_2$ and $3H_2O$ were required). For (e)(ii), one mark was awarded for a transferred error. There has been one mistake: the value of the enthalpy change of combustion of hydrogen, -286 kJ mol^{-1}, should have been multiplied by 3, rather than by 2.

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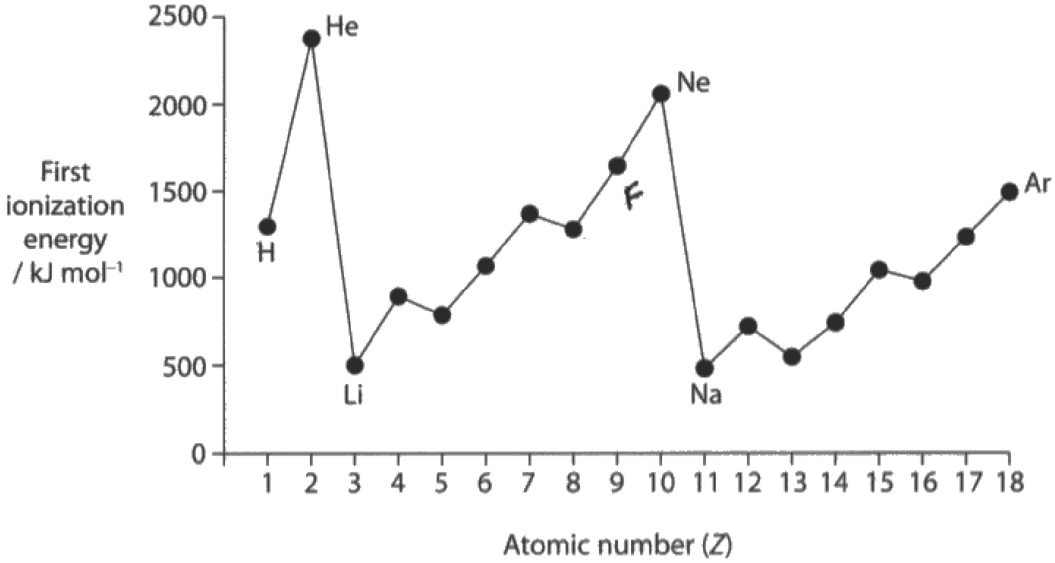
Examiner Tip

Always check Hess cycles carefully - both for species and for balancing!

Question 24 (a)

24 The diagram below shows the pattern in the first ionization energies of the first 18 elements.



(a) Give the equation, including state symbols, for the first ionization energy of fluorine.

(2)

$\frac{1}{2}F_{2(g)} \rightarrow F^{+}_{(g)} + e^{-}$

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Examiner Comments

The correct equation was F(g) □ F⁺(g) + e⁻. The correct definition refers to gaseous atoms rather than to gaseous molecules. The award of the mark, M2, for correct state symbols, was dependent on M1 having been awarded.

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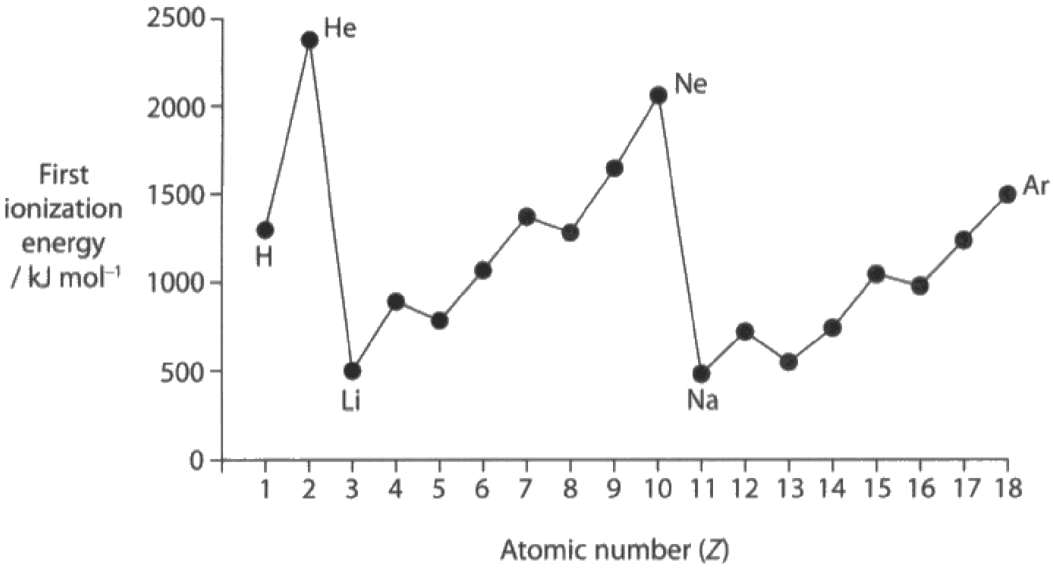
Examiner Tip

Learn all key definitions, including relevant equations, thoroughly.

24 The diagram below shows the pattern in the first ionization energies of the first 18 elements.



(a) Give the equation, including state symbols, for the first ionization energy of fluorine.

(2)

$F_{(g)} \longrightarrow F^{+}_{(g)} + e^{-}$

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Examiner Comments

This answer is fully correct, as per the Mark Scheme.

Question 24 (b)

*(b) Explain why there is a **general** increase in the first ionization energies from sodium to argon.

(3)

As we go from sodium to argon across the period ~~the nuclear c~~

- the nuclear charge increases.
- Electrons are being added to the same shell.
- Shielding effect remains the same.
- The outer electrons are more forcefully attracted by the nucleus.
- More energy is required to remove the electrons.

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Examiner Comments

A well-structured answer, awarded all three available marks.

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Examiner Tip

A well-structured answer often involves 'bullet points' and contains short sentences.

*(b) Explain why there is a **general** increase in the first ionization energies from sodium to argon.

(3)

This is because the size of the ~~size~~ atom decrease, so the is less or same sheilding effect, the nuclear charge increases, since the size decrease the force of attraction increase hence there is an increase in the first ionization energy

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Examiner Comments

This response scored M1 for the idea of increasing nuclear charge (from sodium to argon). The second scoring point was negated by the mention of 'less shielding'. No third mark was credited as there is no mention of the increase in attraction between the nucleus and the (outermost) electron (from sodium to argon).

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Examiner Tip

Try to include all salient points in a clear and logical form in your answer.

Question 24 (c) (i)

$1s^2\ 2s^2\ 2p^6\ 3s^2$ $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^1$

(c) *(i) Explain why the first ionization energy of aluminium ($Z = 13$) is less than that of magnesium ($Z = 12$).

(2)

In Aluminium there is one electron in the 3p ~~orb~~ orbital. This electron is easily removed due to shielding from inner subshells. Magnesium has a full 3s subshell so is harder to lose an electron.

$1s^2\ 2s^2\ 2p^6\ 3^2\ \ p^4$

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Examiner Comments

The first scoring point was awarded for recognition that the electron is lost from a 3p-orbital. The second mark was awarded for mention of shielding by the inner 3s sub-shell.

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Examiner Tip

Be aware of the reasons for the observed trend in first ionization energy across a period.

Question 24 (c) (ii)

*(ii) Explain why the first ionization energy of sulfur ($Z = 16$) is less than that of phosphorus ($Z = 15$).

(2)

The electron in sulfur is an a sub-shell that already has an electron in it so it will experience repulsion, making the ionization energy lower.

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Examiner Comments

The first scoring point was not awarded as the term 'sub-shell' has been used where the term 'orbital' should have been mentioned instead. The idea of increased repulsion secured the award of M2 as per the Mark Scheme.

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Examiner Tip

Think carefully about when to use the terms: 'shell', 'sub-shell' and 'orbital'. They are not interchangeable!

Question 24 (e)

(e) In an experiment, 2.76 g of sodium completely reacted with water to form 500 cm^3 of aqueous sodium hydroxide.

$$2Na(s) + 2H_2O(l) \rightarrow 2NaOH(aq) + H_2(g)$$

(i) Calculate the number of moles of sodium that reacted. **(1)**

$\frac{2.76g}{23g\ mol^{-1}} = 0.12\ mol$

(ii) Calculate the maximum volume, in dm^3, of hydrogen that can be formed at room temperature and pressure.

[1 mol of any gas occupies 24 dm^3 at room temperature and pressure.] **(2)**

$24\ dm^3\ mol^{-1} \times 0.12\ mol = 2.88\ dm^3$

(iii) Calculate the concentration, in mol dm^{-3}, of the sodium hydroxide solution, NaOH(aq), formed in the experiment. **(2)**

$0.12\ mol / 500\ cm^3$

$0.24\ mol\ dm^{-3}$

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Examiner Comments

Part (e)(i) was answered correctly. In (e)(ii), M1 was not awarded as the moles of sodium, Na, were not divided by 2. M2 was awarded, for the resultant transferred error. Part (e)(iii) is correct.

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Examiner Tip

Check mole ratios from equations carefully when answering calculation questions.

(e) In an experiment, 2.76 g of sodium completely reacted with water to form 500 cm^3 of aqueous sodium hydroxide.

$$2Na(s) + 2H_2O(l) \rightarrow 2NaOH(aq) + H_2(g)$$

(i) Calculate the number of moles of sodium that reacted.

(1)

$\frac{2.76}{23} = 0.12$

0.12 mol

(ii) Calculate the maximum volume, in dm^3, of hydrogen that can be formed at room temperature and pressure.

[1 mol of any gas occupies 24 dm^3 at room temperature and pressure.]

(2)

~~0.12 × 24 = 2.88 dm^3~~

$\frac{0.12}{2} = 0.06$ $\quad$ $0.06 \times 24 = 1.44\ dm^3$

(iii) Calculate the concentration, in mol dm^{-3}, of the sodium hydroxide solution, NaOH(aq), formed in the experiment.

(2)

$\frac{0.12}{500 \times 1000} = 0.24$

ResultsPlus
Examiner Comments

This answer is fully correct.

ResultsPlus
Examiner Tip

Check all reacting ratios carefully. Here, the candidate has realised that the moles of hydrogen gas produced are half that of the sodium metal reacting.

Paper Summary

Practise constructing Hess's Law cycles and applying these to find enthalpy changes.

Terms such as 'shell', 'sub-shell' and 'orbital' are not interchangeable!

Make sure you can write equations for the formation of polymers, as well as draw the repeat unit in full.

Remember that equations for the first ionisation energy always apply to gaseous atoms losing electrons, regardless of the nature of the element.

Make sure you read all the questions very carefully. This is for two reasons. Firstly, to make sure that you are clear that you understand what is being asked of you and, secondly, to identify useful information in the question that may help you to structure your answer appropriately.

Grade Boundaries

Grade boundaries for this, and all other papers, can be found on the website on this link:

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