



Mark Scheme (Results)

January 2020

Pearson International Advanced Subsidiary Level
In Chemistry (WCH11)
Paper 01 Structure, Bonding and Introduction
to Organic Chemistry

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General Marking Guidance

- All candidates must receive the same treatment. Examiners must mark the first candidate in exactly the same way as they mark the last.
- Mark schemes should be applied positively. Candidates must be rewarded for what they have shown they can do rather than penalised for omissions.
- Examiners should mark according to the mark scheme not according to their perception of where the grade boundaries may lie.
- There is no ceiling on achievement. All marks on the mark scheme should be used appropriately.
- All the marks on the mark scheme are designed to be awarded. Examiners should always award full marks if deserved, i.e. if the answer matches the mark scheme. Examiners should also be prepared to award zero marks if the candidate's response is not worthy of credit according to the mark scheme.
- Where some judgement is required, mark schemes will provide the principles by which marks will be awarded and exemplification may be limited.
- When examiners are in doubt regarding the application of the mark scheme to a candidate's response, the team leader must be consulted.
- Crossed out work should be marked UNLESS the candidate has replaced it with an alternative response.

Using the Mark Scheme

Examiners should look for qualities to reward rather than faults to penalise. This does NOT mean giving credit for incorrect or inadequate answers, but it does mean allowing candidates to be rewarded for answers showing correct application of principles and knowledge. Examiners should therefore read carefully and consider every response: even if it is not what is expected it may be worthy of credit.

The mark scheme gives examiners:

- an idea of the types of response expected
- how individual marks are to be awarded
- the total mark for each question
- examples of responses that should NOT receive credit.

/ means that the responses are alternatives and either answer should receive full credit.

() means that a phrase/word is not essential for the award of the mark, but helps the examiner to get the sense of the expected answer.

Phrases/words in **bold** indicate that the meaning of the phrase or the actual word is **essential** to the answer.

ecf/TE/cq (error carried forward) means that a wrong answer given in an earlier part of a question is used correctly in answer to a later part of the same question.

Candidates must make their meaning clear to the examiner to gain the mark. Make sure that the answer makes sense. Do not give credit for correct words/phrases which are put together in a meaningless manner. Answers must be in the correct context.

Section A

Question Number	Answer	Mark
1	<p>The only correct answer is C (17 protons, 20 neutrons, 18 electrons)</p> <p><i>A is incorrect because this shows the subatomic particles in $^{37}\text{Cl}^+$ ion</i></p> <p><i>B is incorrect because this is for a chlorine-37 atom</i></p> <p><i>D is incorrect because the proton and neutron numbers are reversed</i></p>	(1)
2	<p>The only correct answer is A (58.760)</p> <p><i>B is incorrect because this is the correct answer to 3 SF</i></p> <p><i>C is incorrect because a relative mass of 59 has been used for the first isotope and the answer is to 3 SF</i></p> <p><i>D is incorrect because a relative mass of 59 has been used for the first isotope</i></p>	(1)
3	<p>The only correct answer is D (14)</p> <p><i>A is incorrect because 3 is the number of quantum shells</i></p> <p><i>B is incorrect because 6 is the total number of subshells</i></p> <p><i>C is incorrect because 9 is the number of orbitals in the third quantum shell</i></p>	(1)

Question Number	Answer	Mark
4	<p>The only correct answer is B (carbon)</p> <p><i>A is incorrect because lithium is an s-block element with one unpaired electron</i></p> <p><i>C is incorrect because fluorine is a p-block element with one unpaired electron</i></p> <p><i>D is incorrect because titanium is a d-block element with two unpaired electrons</i></p>	(1)

Question Number	Answer	Mark
5	<p>The only correct answer is C (aluminium)</p> <p><i>A is incorrect because there would not be a large jump between the third and fourth ionisations</i></p> <p><i>B is incorrect because there would not be a large jump between the third and fourth ionisations</i></p> <p><i>D is incorrect because there would not be a large jump between the third and fourth ionisations</i></p>	(1)

Question Number	Answer	Mark
6	<p>The only correct answer is D (315.3)</p> <p><i>A is incorrect because this is the relative formula mass of anhydrous barium hydroxide</i></p> <p><i>B is incorrect because the relative masses of 8H₂ and O have been added instead of 8H₂O</i></p> <p><i>C is incorrect because an M_r value of 16 has been used for water</i></p>	(1)

Question Number	Answer	Mark
7	<p>The only correct answer is C (1.1)</p> <p><i>A is incorrect because the volume has not been converted to dm³</i></p> <p><i>B is incorrect because the volume has been divided by the amount of sodium sulfate</i></p> <p><i>D is incorrect because the volume has not been converted to dm³ and the volume has been divided by the amount</i></p>	(1)

Question Number	Answer	Mark
8	<p>The only correct answer is B (MgO)</p> <p><i>A is incorrect because the ion charges are +1 and -1</i></p> <p><i>C is incorrect because the ion charges are +1 and -1 and the ionic radii are larger</i></p> <p><i>D is incorrect because the ionic radii are larger</i></p>	(1)

Question Number	Answer	Mark
9	<p>The only correct answer is B (MgI₂)</p> <p><i>A is incorrect because fluoride ions are not as easily polarised as iodide ions</i></p> <p><i>C is incorrect because barium ions are less polarising than magnesium and fluoride ions are not easily polarised</i></p> <p><i>D is incorrect because barium ions are less polarising than magnesium ions</i></p>	(1)

Question Number	Answer	Mark
10(a)	<p>The only correct answer is D (white precipitate)</p> <p><i>A is incorrect because the reactants are colourless</i></p> <p><i>B is incorrect because no gas is given off</i></p> <p><i>C is incorrect because a precipitate forms</i></p>	(1)

Question Number	Answer	Mark
10(b)	<p>The only correct answer is C ($\text{Ba}^{2+}(\text{aq}) + \text{SO}_4^{2-}(\text{aq}) \rightarrow \text{BaSO}_4(\text{s})$)</p> <p><i>A is incorrect because the ion charges are not +1 and -1</i></p> <p><i>B is incorrect because the equation does not represent the formation of a precipitate</i></p> <p><i>D is incorrect because the spectator ions have not been cancelled</i></p>	(1)

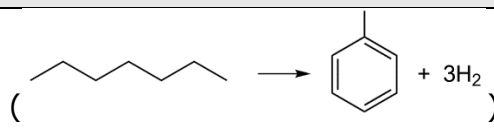
Question Number	Answer	Mark
10(c)	<p>The only correct answer is C (0.560 g)</p> <p><i>A is incorrect because the molar masses of barium chloride and barium sulfate have been reversed</i></p> <p><i>B is incorrect because the molar, and not the mass, ratio is 1:1</i></p> <p><i>D is incorrect because the M_r of Na_2SO_4 has been used instead of BaCl_2</i></p>	(1)

Question Number	Answer	Mark
10(d)	<p>The only correct answer is C (66.6%)</p> <p><i>A is incorrect because the total mass of reactants and products has been used</i></p> <p><i>B is incorrect because one mole of sodium sulfate has been used in place of two moles of sodium chloride</i></p> <p><i>D is incorrect because one mole of NaCl has been used in the equation</i></p>	(1)

Question Number	Answer	Mark
11	<p>The only correct answer is A (diamond)</p> <p><i>B is incorrect because C₆₀ fullerene contains delocalised electrons</i></p> <p><i>C is incorrect because graphene contains delocalised electrons</i></p> <p><i>D is incorrect because graphite contains delocalised electrons</i></p>	(1)

Question Number	Answer	Mark
12	<p>The only correct answer is A (OF₂)</p> <p><i>B is incorrect because BF₃ is trigonal planar and the bond dipoles cancel</i></p> <p><i>C is incorrect because CF₄ is tetrahedral and the bond dipoles cancel</i></p> <p><i>D is incorrect because PF₅ is trigonal bipyramidal and the bond dipoles cancel</i></p>	(1)

Question Number	Answer	Mark
13	<p>The only correct answer is A (CH₃⁺, trigonal planar, 120°)</p> <p><i>B is incorrect because the bond angle should be 107°</i></p> <p><i>C is incorrect because the shape should be tetrahedral and the bond angle should be 109.5°</i></p> <p><i>D is incorrect because the shape should be bent and the bond angle should be 104.5°</i></p>	(1)

Question Number	Answer	Mark
14	<p>The only correct answer is D </p> <p><i>A is incorrect because the equation represents a correctly balanced isomerisation</i></p> <p><i>B is incorrect because the equation is correctly balanced</i></p> <p><i>C is incorrect because the equation is correctly balanced</i></p>	(1)

Question Number	Answer	Mark
15	<p>The only correct answer is A (H₂)</p> <p><i>B is incorrect because H₂O is formed in the combustion of alkane fuels</i></p> <p><i>C is incorrect because CO is formed in the incomplete combustion of alkane fuels</i></p> <p><i>D is incorrect because CO₂ is formed by the combustion of alkane fuels</i></p>	(1)

Question Number	Answer	Mark
16	<p>The only correct answer is B (39 σ bonds, 3 π bonds)</p> <p>A is incorrect because 15 is the number of C-C σ bonds</p> <p>C is incorrect because 15 is the number of C-C σ bonds and 6 is twice the number of π bonds</p> <p>D is incorrect because 6 is twice the number of π bonds</p>	(1)

Question Number	Answer	Mark
17	<div style="text-align: center;"> $\begin{array}{cccc} \text{CH}_3 & \text{CH}_3 & \text{CH}_3 & \text{CH}_3 \\ & & & \\ -\text{C} & -\text{C} & -\text{C} & -\text{C}- \\ & & & \\ \text{H} & \text{H} & \text{H} & \text{H} \end{array}$ </div> <p>The only correct answer is D ()</p> <p>A is incorrect because this polymer is made from propene, which does not have E/Z isomers</p> <p>B is incorrect because this polymer is made from propene, which does not have E/Z isomers</p> <p>C is incorrect because this polymer is made from 2-methylpropene, which does not have E/Z isomers</p>	(1)

(Total for Section A = 20 marks)

Section B

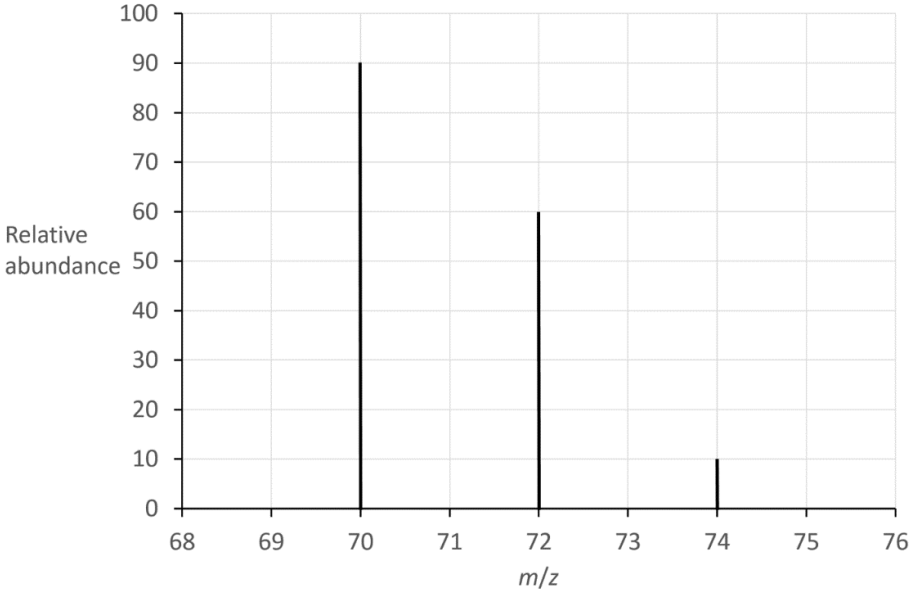
Question Number	Answer	Additional Guidance	Mark
18(a)	<ul style="list-style-type: none"> $1s^2 2s^2 2p^6 3s^2 3p^5$ 	Accept $2p_x^2 2p_y^2 2p_z^2$ for $2p^6$ etc Ignore [Ne] for $1s^2 2s^2 2p^6$	(1)

Question Number	Answer	Additional Guidance	Mark
18(b)	<ul style="list-style-type: none"> species and balancing (1) state symbols (1) 	Example of equation: $Cl(g) \rightarrow Cl^+(g) + e^-$ or $Cl(g) - e^- \rightarrow Cl^+(g)$ Do not award multiples M2 dependent on M1 or neutral Cl/Cl ₂ on one side of equation and charged Cl ⁺ /Cl ₂ ⁺ /Cl ⁻ /Cl ₂ ⁻ on the other Ignore state symbol on electron	(2)

Question Number	Answer	Additional Guidance	Mark
18(c)	<p>An explanation that makes reference to the following points:</p> <p>chlorine is higher</p> <p>and</p> <p>any three of the following qualifying statements:</p> <ul style="list-style-type: none"> • (although) the nuclear charge / number of protons is lower • the (outer) electron is in a lower (principal) energy level / orbital of lower energy • the (outer) electron is closer to the nucleus / smaller (atomic) radius • (the outer electron experiences) less shielding 	<p>Accept reverse arguments throughout</p> <p>This can be implied through correct reference to attraction between nucleus and (outer) electron / amount of energy required to remove (outer) electron</p> <p>If bromine identified as higher, or it is not implied which element has the higher ionisation energy, penalise once only</p> <p>Ignore effective nuclear charge</p> <p>Allow (outer) electron is lower in energy Allow 3p lower in energy than 4p</p> <p>Allow just smaller atom Do not award smaller ionic radius Allow just fewer shells Ignore just fewer sub-shells / electrons</p> <p>Accept less repulsion from inner / core electrons Ignore just less repulsion between electrons Do not award less repulsion between paired electrons within an orbital</p>	(3)

Question Number	Answer	Additional Guidance	Mark
18(d)	<ul style="list-style-type: none"> correct dot-and-cross diagram 	<p>Example of dot-and-cross diagram:</p> <pre> •• ×× •• ×× :Cl:×Cl:× •• ×× •• ×× </pre> <p>Allow any combination of dots, crosses or other symbols for electrons</p> <p>Allow indication of shells by overlapping circles</p> <p>Allow correctly filled inner shells</p>	(1)

Question Number	Answer	Additional Guidance	Mark
18(e)	<p>An explanation that makes reference to the following points: (chlorine is a simple molecule with)</p> <ul style="list-style-type: none"> weak forces between the molecules little energy required to overcome these forces 	<p>(1) Accept weak London / instantaneous dipole-induced dipole / van der Waals / VdW forces</p> <p>Allow weak intermolecular bonds / weak bonds between molecules</p> <p>Do not award if implied that intermolecular forces are within a chlorine molecule</p> <p>(1) M2 dependent on M1 Do not award just bond for forces unless clear that the bond is intermolecular</p> <p>Allow as relatively few electrons / small contact surface area</p>	(2)

Question Number	Answer	Additional Guidance	Mark
18(f)(i)	<ul style="list-style-type: none"> • lines at 70 and 72 and 74 only (1) • relative abundances 90:60:10 (1) respectively 	<p>Mark M1 and M2 independently</p>  <p>Accept relative abundances 100:67:11 / 54:36:6</p> <p>Allow relative abundances in ratio close to 9:6:1, eg 100:65:11 / 55:40:6</p> <p>If neither M1 nor M2 awarded, two peaks at correct <i>m/z</i> and in correct ratio scores (1), eg peaks at 70 and 74 in 9:1 ratio</p>	(2)

Question Number	Answer	Additional Guidance	Mark
18(f)(ii)	<p>An answer that makes reference to the following points:</p> <ul style="list-style-type: none"> • (peak is due to) $^{35}\text{Cl}-^{37}\text{Cl}$ (molecular ion) (1) • (with a charge of) $2+$ (1) 	<p>Mark M1 and M2 independently</p> <p>Allow any indication that peak is due to combination of (chlorine-)35 and (chlorine-)37, eg $(35+37)/2 = 36$</p> <p>Do not award chlorine-36 isotope</p> <p>Allow (molecular ion has) lost two electrons</p> <p>Just $(^{35}\text{Cl}-^{37}\text{Cl})^{2+}$ or $(35-37)^{2+}$ scores (2)</p>	(2)

(Total for Question 18 = 13 marks)

Question Number	Answer	Additional Guidance	Mark
19(a)(i)	An answer that makes reference to the following points: <ul style="list-style-type: none"> (incorrectly plotted metal is) aluminium / Al (1) (incorrectly plotted non-metal is) argon / Ar (1) 	Credit can be awarded from annotations to the graph Ignore classification of elements as metallic / non-metallic, even if incorrect	(2)

Question Number	Answer	Additional Guidance	Mark
19(a)(ii)	An answer that makes reference to the following points: <ul style="list-style-type: none"> (silicon has a) giant (lattice/molecular structure) (1) and covalent (bonds) (many) strong (covalent) bonds (between silicon atoms) (1) or each (silicon) atom bonded to four others (1) requiring a large amount of energy to break (1) 	Mark all points independently Accept macromolecular Ignore large molecule Accept electrostatic attraction between nuclei and shared pair of electrons Allow strong electrostatic attraction between (silicon) atoms Do not award strong ionic/metallic bonds Do not award strong intermolecular forces Ignore three bonds between (silicon) atoms Do not award any other elements / number of bonds Allow overcome for break	(3)

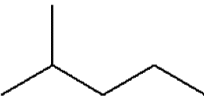
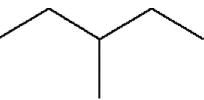

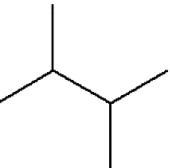
Question Number	Answer	Additional Guidance	Mark
19(b)(i)	<p>A description that makes reference to the following points:</p> <ul style="list-style-type: none"> (metals contain) delocalised electrons (1) (which can) flow / move (freely through the structure when a potential difference is applied) (1) 	<p>Allow delocalised electron Allow sea of electron(s) Ignore just free electrons Ignore charge carriers</p> <p>M2 dependent on M1</p> <p>Ignore reference to physical state</p>	(2)

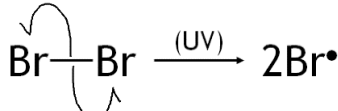
Question Number	Answer	Additional Guidance	Mark
19(b)(ii)	<p>A description that makes reference to the following points:</p> <ul style="list-style-type: none"> Aluminium has more delocalised electrons (than sodium per atom / ion) <p>or</p> <p>Aluminium has three delocalised electrons whereas sodium has one (per atom / ion)</p>	<p>Accept reverse argument</p> <p>Allow just more delocalised electrons</p> <p>Do not award incorrect numbers of delocalised electrons (per atom / ion)</p>	(1)

Question Number	Answer	Additional Guidance	Mark
19(c)(i)	Dot-and-cross diagram showing the following: <ul style="list-style-type: none"> <li data-bbox="427 448 1144 512">• 0 electrons on outer shell of aluminium and 8 electrons on outer shell of oxide (1) <li data-bbox="427 663 1144 727">• two aluminium (ions) and three oxide (ions) (1) <li data-bbox="427 839 1144 903">• 3+ charge on aluminium ion and 2- charge on oxide ion (1) 	Example of dot-and-cross diagram: $2[Al]^{3+} \quad 3[:\overset{\times\times}{O}{}_{\times\times}]^{2-}$ <p>M1 dependent on some indication of ionic structure Allow 8 electrons on outer shell of Al Allow correctly filled inner shells Allow any combination of dots or crosses for electrons Allow circles to indicate outer shells</p> <p>Accept any unambiguous indication of the correct number of ions Allow any indication that formula is Al₂O₃, even if covalent dot-and-cross diagram shown</p> <p>Allow +3 and -2 Ignore missing square brackets</p> <p>If no other mark awarded, a correct dot-and-cross diagram for either an Al³⁺ ion or O²⁻ ion scores (1)</p>	(3)

Question Number	Answer	Additional Guidance	Mark
19(c)(ii)	<ul style="list-style-type: none"> ions must be mobile / free to move (to allow a current to flow) 	<p>Allow reverse argument (eg ions cannot move in the solid)</p> <p>Allow ions can flow</p> <p>Ignore just ions must be free</p> <p>Ignore charge carriers / charged particles</p> <p>Ignore reference to aqueous solutions</p> <p>Ignore just ions must be delocalised / dissociated</p> <p>Ignore reference to (lack of) delocalised electrons in the solid state</p> <p>Do not award reference to (presence of) delocalised electrons in the liquid/molten state</p>	(1)

(Total for Question 19 = 12 marks)

Question Number	Answer	Additional Guidance	Mark
20(a)	Correct structures of: <ul style="list-style-type: none"> • 2-methylpentane • 3-methylpentane • 2,2-dimethylbutane • 2,3-dimethylbutane 	Allow displayed, structural, skeletal formulae or any combination of these If more than one type of formula is given for an isomer all must be correct Penalise missing hydrogens from displayed formulae once only Ignore bond angles and bond lengths Ignore names even if incorrect Example of correct structures: <div style="display: flex; flex-direction: column; align-items: flex-end; margin-top: 10px;"> <div style="display: flex; align-items: center; margin-bottom: 10px;">  <div style="margin-left: 20px;">(2-methylpentane)</div> </div> <div style="display: flex; align-items: center; margin-bottom: 10px;">  <div style="margin-left: 20px;">(3-methylpentane)</div> </div> <div style="display: flex; align-items: center; margin-bottom: 10px;">  <div style="margin-left: 20px;">(2,2-dimethylbutane)</div> </div> <div style="display: flex; align-items: center;">  <div style="margin-left: 20px;">(2,3-dimethylbutane)</div> </div> </div>	(4)

Question Number	Answer	Additional Guidance	Mark
20(b)(i)	Mechanism / equation showing: <ul style="list-style-type: none"> • homolytic fission of Br–Br bond with curly half-arrows (1) • (producing) two bromine radicals (1) 	Example of mechanism: $\text{Br}-\text{Br} \xrightarrow{\text{(UV)}} 2\text{Br}\cdot$  <p>Allow curly half-arrows on same side of the bond Do not award arrows that are not half-headed</p> <p>Do not award missing •</p> <p>Use of Cl for Br in otherwise fully correct equation scores (1)</p>	(2)

Question Number	Answer	Additional Guidance	Mark
20(b)(ii)	<ul style="list-style-type: none"> • $\text{C}_6\text{H}_{14} + \text{Br}\cdot \rightarrow \text{C}_6\text{H}_{13}\cdot + \text{HBr}$ (1) • $\text{C}_6\text{H}_{13}\cdot + \text{Br}_2 \rightarrow \text{C}_6\text{H}_{13}\text{Br} + \text{Br}\cdot$ (1) 	<p>Allow equations in either order</p> <p>Penalise missing • in (b)(i) and (b)(ii) once only</p>	(2)

Question Number	Answer	Additional Guidance	Mark
20(b)(iii)	<ul style="list-style-type: none"> • $\text{C}_{12}\text{H}_{26}$ 	Allow $\text{H}_{26}\text{C}_{12}$	(1)

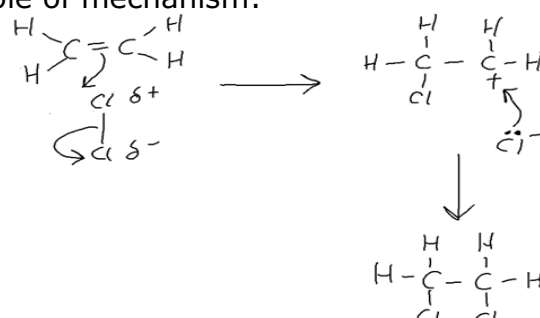
Question Number	Answer	Additional Guidance	Mark
20(b)(iv)	<ul style="list-style-type: none"> <li data-bbox="443 304 1173 371">• evidence of C₆Br₁₄ (identified as heaviest possible product) (1) <li data-bbox="443 411 1173 448">• calculation of molar mass (1) <li data-bbox="443 555 1173 622">• calculation of percentage by mass of bromine (1) 	<p data-bbox="1200 268 1547 300">Example of calculation:</p> <p data-bbox="1200 411 1962 515">14 × 79.9 + 6 × 12.0 (= 1190.6) TE on any compound of formula C₆H_(14-n)Br_n (where 2 ≤ n < 14) or C₆Br₁₂</p> <p data-bbox="1200 555 1973 659">%Br = (14 × 79.9) / (14 × 79.9 + 6 × 12.0) × 100 = 93.953 % = 94.0 %</p> <p data-bbox="1200 667 1895 730">TE on any compound of formula C₆H_(14-n)Br_n or C₆H_(12-n)Br_n</p> <p data-bbox="1200 770 1966 802">Allow use of 80 for relative atomic mass of bromine</p> <p data-bbox="1200 842 1536 874">Ignore SF except 1 SF</p>	(3)

(Total for Question 20 = 12 marks)

Question Number	Answer	Additional Guidance	Mark
21(a)	<ul style="list-style-type: none"> <li data-bbox="394 339 1196 371">• calculation of moles of ethene (1) <li data-bbox="394 443 1196 475">• calculation of number of ethene molecules (1) 	<p data-bbox="1223 268 1568 300">Example of calculation:</p> $\text{mols} = \frac{1.50 \times 10^{14}}{28.0} = 5.3571 \times 10^{12}$ $\text{molecules} = 5.3571 \times 10^{12} \times 6.02 \times 10^{23} = 3.225 \times 10^{36}$ <p data-bbox="1223 555 1935 622">TE on moles of ethene (calculated by dividing a mass by a molar mass)</p> <p data-bbox="1223 662 1554 694">Ignore SF except 1 SF</p> <p data-bbox="1223 730 1783 762">$(3.225 / 3.23 / 3.2) \times 10^{36}$ scores (2)</p>	(2)

Question Number	Answer	Additional Guidance	Mark
21(b)	<p>M1: conversion of temperature to K (1)</p> <p>M2: rearrangement of ideal gas equation (1)</p> <p>M3: evaluation to give moles of gas (1)</p> <p>M4: use of mixing ratio to calculate moles of ethene (1)</p> <p>M5: answer to 2 or 3SF – standalone (1)</p>	<p>Example of calculation:</p> <p>(T = 21 + 273 =) 294 (K)</p> $n = \frac{pV}{RT}$ <p>or</p> $n = \frac{1.01 \times 10^5 \times 220}{8.31 \times 294}$ <p>n = 9094.9 Ignore SF except 1 SF TE on M1 No TE on incorrect volume</p> <p>moles = $\frac{100}{10^6} \times 9094.9$ = 0.90949 Ignore SF except 1 SF TE on M3</p> <p>0.91 / 0.909 (moles) Do not award incorrect units</p> <p>Max (3) for calculations using 24 dm³ mol⁻¹ as the molar gas volume (ie no M1 or M2) eg 0.92 scores (3), 0.916667 scores (2)</p>	

	<p>Alternative route to M2, M3 and M4</p> <ul style="list-style-type: none"> • use of mixing ratio to calculate volume occupied by ethene (1) • rearrangement of ideal gas equation (1) • evaluation to give moles of ethene (1) 	<p> $V = \frac{100}{10^6} \times 220$ $= 0.022 \text{ (m}^3\text{)}$ Do not award 0.02 </p> <p> $n = \frac{pV}{RT}$ or </p> <p> $n = \frac{1.01 \times 10^5 \times 0.022}{8.31 \times 294}$ </p> <p> $n = 0.90949$ Ignore SF except 1 SF TE on M1 No TE on incorrect volume </p>	(5)
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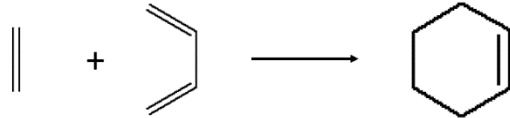
Question Number	Answer	Additional Guidance	Mark
21(c)(i)	<p>Mechanism showing:</p> <ul style="list-style-type: none"> • induced dipole on chlorine (1) and • correct product • curly arrow from C=C bond to Cl(δ^+) (1) and • curly arrow from Cl-Cl bond to Cl(δ^-) (1) • correct carbocation intermediate (1) • lone pair and negative charge on chloride (1) and • curly arrow from lone pair to C($^+$) (1) 	<p>Example of mechanism:</p>  <p>Mark all points independently</p> <p>Penalise use of HCl / HBr / Br₂ for Cl₂ once only</p> <p>Penalise incorrect alkene once only</p> <p>Penalise missing H atom once only</p> <p>Penalise use of curly half-arrows once only</p> <p>Do not award full charges</p> <p>Do not award 'open bond' on C⁺</p> <p>Do not award Cl^{δ^-}</p> <p>Do not award curly arrow from negative charge</p>	(4)

Question Number	Answer	Additional Guidance	Mark
21(c)(ii)	<p>An explanation that makes reference to the following points:</p> <ul style="list-style-type: none"> • identification of hazard (1) • suitable precaution (1) 	<p>Mark M1 and M2 independently</p> <p>(in)flammable</p> <p>avoid (naked) flames / fire</p> <p>Ignore just take care with flames / fire</p> <p>Ignore fire extinguishers etc</p> <p>Allow use heating mantle / (electric) water bath etc</p> <p>Ignore keep away from heat source / do not heat</p> <p>Ignore Bunsen burner</p> <p>Allow heat in an inert atmosphere / nitrogen / argon</p> <p>Ignore just exclude oxygen / heat in absence of oxygen</p> <p>Allow use small amounts</p> <p>Ignore fume cupboard</p> <p>Ignore gloves / tie hair back / safety goggles / laboratory coat</p>	(2)

Question Number	Answer	Additional Guidance	Mark
21(d)(i)	<p>Method 1</p> <ul style="list-style-type: none"> calculation of mass C, H and O calculation of moles C, H and O <p>and</p> <p>empirical formula</p> <p>Method 2</p> <ul style="list-style-type: none"> calculation of moles C₂H₄ and O <p>or</p> <p>calculation of moles C₂H₄ and O₂</p> <ul style="list-style-type: none"> empirical formula 	<p>Ignore SF except 1 SF for all methods Example of calculation:</p> <p>(1) mass C = $\frac{24}{28} \times 10.0 = 8.5714$ (g) mass H = $\frac{4}{28} \times 10.0 = 1.4286$ (g) mass O = $15.7 - 10.0 = 5.70$ (g)</p> $\begin{array}{ccc} \text{C} & : & \text{H} & : & \text{O} \\ \hline 8.5714 & : & 1.4286 & : & 5.7 \\ 12 & & 1 & & 16 \\ \hline 0.71429 & : & 1.4286 & : & 0.36 \end{array}$ <p>(1) empirical formula is C₂H₄O TE on M1 only if mass(C + H + O) = 15.7 (g)</p> <p>(moles C₂H₄ = $\frac{10.0}{28}$ =) 0.35714 (moles O = $\frac{15.7 - 10.0}{16}$ =) 0.35625</p> <p>(moles C₂H₄ = $\frac{10.0}{28}$ =) 0.35714 (1) (moles O₂ = $\frac{15.7 - 10.0}{32}$ =) 0.17813</p> <p>(1) M2 dependent on M1 empirical formula is C₂H₄O</p>	

	<p>Method 3</p> <ul style="list-style-type: none"> calculation of moles C₂H₄ <p>and</p> <p><i>M_r</i> product</p> <ul style="list-style-type: none"> empirical formula <p>and</p> <p>calculation of <i>M_r</i> of empirical formula</p>	<p>(moles C₂H₄ =) $\frac{10.0}{28} = 0.35714$</p> <p>(1) (<i>M_r</i> product =) $\frac{15.7}{0.35714} = 43.96$</p> <p>M2 dependent on M1 empirical formula is C₂H₄O (1) $2 \times 12 + 4 \times 1 + 1 \times 16 = 44$</p>	(2)
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Question Number	Answer	Additional Guidance	Mark
21(d)(ii)	<ul style="list-style-type: none"> displayed formula of ethane-1,2-diol 	<p>Example of displayed formula:</p> $ \begin{array}{ccccccc} & & \text{H} & & \text{H} & & \\ & & & & & & \\ \text{H} & - & \text{O} & - & \text{C} & - & \text{C} & - & \text{O} & - & \text{H} \\ & & & & & & \\ & & \text{H} & & \text{H} & & \end{array} $ <p>Ignore skeletal or structural formulae Allow non-displayed OH groups Ignore bond lengths and angles</p> <p>Do not award horizontal OH-C connectivity</p> <p>Ignore connectivity of pendant / vertical non-displayed OH groups</p> <p>Do not award missing H atoms</p>	(1)

Question Number	Answer	Additional Guidance	Mark
21(e)	<ul style="list-style-type: none"> correct equation and skeletal formulae 	<p>Example of equation:</p>  <p>Allow molecules in any orientation Ignore bond lengths and angles</p> <p>Allow multiples</p> <p>Ignore molecular, structural or displayed formulae Do not award if additional products given</p>	(1)

Question Number	Answer	Additional Guidance	Mark
21(f)(i)	<ul style="list-style-type: none"> addition or reduction or hydrogenation 	<p>Ignore additional Do not award electrophilic / nucleophilic addition</p> <p>Ignore redox</p> <p>Do not award hydration</p> <p>Do not award cracking</p> <p>Do not award reforming</p>	(1)

Question Number	Answer	Additional Guidance	Mark
21(f)(ii)	<ul style="list-style-type: none"> • steam or water and heat • acid catalyst 	<p>Mark M1 and M2 independently</p> <p>Accept H₂O(g) / water vapour</p> <p>(1) Allow any stated temperature $100^{\circ}\text{C} \leq T \leq 400^{\circ}\text{C}$ Ignore stated temperatures $< 100^{\circ}\text{C}$ Ignore high temperature Do not award stated temperatures $> 400^{\circ}\text{C}$ Do not award (heat under) reflux</p> <p>(1) Accept (concentrated) phosphoric acid / H₃PO₄ Allow (concentrated) sulfuric acid / H₂SO₄ Do not award dilute acid catalysts</p> <p>Ignore reference to pressure</p> <p>Accept react with concentrated H₂SO₄ followed by hydrolysis (2)</p>	(2)

Question Number	Answer	Additional Guidance	Mark
21(f)(iii)	<p>An explanation that makes reference to the following points:</p> <ul style="list-style-type: none"> • (angle b is) 104.5° • four bond pairs (of electrons around C) for angle a <p>and</p> <p>two bond pairs and two lone pairs (of electrons around O) for angle b</p> <ul style="list-style-type: none"> • lone pairs (of electrons) repel more than bond pairs 	<p>Mark all points independently</p> <p>(1) Allow 103° to 106°</p> <p>Allow four pairs of electrons (around the central atom) for both angles</p> <p>Ignore covalent bond for bond pair</p> <p>(1) Ignore just two lone pairs for angle b and no lone pairs for angle a</p> <p>(1) Allow each lone pair reduces the bond angle by 2.5°</p> <p>Allow lone pair-lone pair / lone pair-bond pair repulsion greater than bond pair-bond pair repulsion</p> <p>Allow just lone pairs repel more / lone pair repulsion greatest</p> <p>Ignore (electron) pairs repel to maximum separation / minimum repulsion</p> <p>Do not award (electron) pairs repel to minimum separation / maximum repulsion</p>	(3)

(Total for Question 21 = 23 marks)
TOTAL FOR SECTION B = 60 MARKS
TOTAL FOR PAPER = 80 MARKS

