



Mark Scheme (Results)

January 2019

Pearson Edexcel International
Advanced Subsidiary Level
In Chemistry (WCH02)
Paper 01 Application of Core Principles of
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.

Quality of Written Communication

Questions which involve the writing of continuous prose will expect candidates to:

- write legibly, with accurate use of spelling, grammar and punctuation in order to make the meaning clear
- select and use a form and style of writing appropriate to purpose and to complex subject matter
- organise information clearly and coherently, using specialist vocabulary when appropriate.

Full marks will be awarded if the candidate has demonstrated the above abilities. Questions where QWC is likely to be particularly important are indicated (QWC) in the mark scheme, but this does not preclude others.

Section A (multiple choice)

| Question Number | Answer | Mark |
|-----------------|---|----------|
| 1 | The only correct answer is C <i>A is not correct because the molecule has two tetrahedral carbons</i> <i>B is not correct because the molecule has a tetrahedral carbon</i> <i>D is not correct because the molecule has a tetrahedral carbon</i> | 1 |

| Question Number | Correct Answer | Mark |
|-----------------|--|----------|
| 2 | The only correct answer is B <i>A is not correct because it does not contain a 120° bond angle</i> <i>C is not correct because it does not contain a 90° bond angle</i> <i>D is not correct because it contains neither bond angle</i> | 1 |

| Question Number | Correct Answer | Mark |
|-----------------|--|----------|
| 3 | The only correct answer is B <i>A is not correct because the N-H bond is less polar than the O-H bond</i> <i>C is not correct because the C-Cl bond is less polar than the O-H bond</i> <i>D is not correct because the C-I bond is less polar than the O-H bond</i> | 1 |

| Question Number | Correct Answer | Mark |
|-----------------|--|----------|
| 4 | The only correct answer is D <i>A is not correct because the molecule is non-polar</i> <i>B is not correct because the bond is polar</i> <i>C is not correct because the bond is polar and the molecule is non-polar</i> | 1 |

| Question Number | Correct Answer | Mark |
|-----------------|---|----------|
| 5 | <p>The only correct answer is A</p> <p>B is not correct because both effects are incorrect</p> <p>C is not correct because the effect of increasing chain length is to increase the boiling temperature</p> <p>D is not correct because the effect of increasing branching is to decrease the boiling temperature</p> | 1 |

| Question Number | Correct Answer | Mark |
|-----------------|---|----------|
| 6 | <p>The only correct answer is A</p> <p>B is not correct because HF has the highest boiling temperature</p> <p>C is not correct because HF has the highest boiling temperature and HCl the lowest</p> <p>D is not correct because the trend for HI, HBr and HCl is incorrect</p> | 1 |

| Question Number | Correct Answer | Mark |
|-----------------|---|----------|
| 7 | <p>The only correct answer is D</p> <p>A is not correct because metal nitrites only form with some Group 1 nitrates</p> <p>B is not correct because metal oxides do not form with some Group 1 nitrates</p> <p>C is not correct because nitrogen dioxide only forms with Group 2 and lithium nitrates</p> | 1 |

| Question Number | Correct Answer | Mark |
|-----------------|---|----------|
| 8 | <p>The only correct answer is D</p> <p>A is not correct because hydrogen bromide usually forms first</p> <p>B is not correct because bromine forms</p> <p>C is not correct because sulfur dioxide forms</p> | 1 |

| Question Number | Correct Answer | Mark |
|-----------------|--|----------|
| 9 | <p>The only correct answer is C</p> <p>A is <i>not correct</i> because chlorine disproportionates from 0 to +1 and -1</p> <p>B is <i>not correct</i> because chlorine disproportionates from 0 to +5 and -1</p> <p>D is <i>not correct</i> because chlorine disproportionates from +5 to +7 and -1</p> | 1 |

| Question Number | Correct Answer | Mark |
|-----------------|---|----------|
| 10 | <p>The only correct answer is A</p> <p>B is <i>not correct</i> because this is the effect of lowering the temperature</p> <p>C is <i>not correct</i> because this is the effect of increasing the temperature</p> <p>D is <i>not correct</i> because the area under the curve does not change</p> | 1 |

| Question Number | Correct Answer | Mark |
|-----------------|--|----------|
| 11(a) | <p>The only correct answer is B</p> <p>A is <i>not correct</i> because both effects are incorrect</p> <p>C is <i>not correct</i> because the yield increases</p> <p>D is <i>not correct</i> because the rate decreases</p> | 1 |

| Question Number | Correct Answer | Mark |
|-----------------|--|----------|
| 11(b) | <p>The only correct answer is D</p> <p>A is <i>not correct</i> because the yield increases</p> <p>B is <i>not correct</i> because the rate increases</p> <p>C is <i>not correct</i> because both effects are incorrect</p> | 1 |

| Question Number | Correct Answer | Mark |
|-----------------|--|----------|
| 11(c) | <p>The only correct answer is C</p> <p><i>A is not correct because the quantities have been doubled</i></p> <p><i>B is not correct because the quantities have been doubled</i></p> <p><i>D is not correct because the quantities have been doubled</i></p> | 1 |

| Question Number | Correct Answer | Mark |
|-----------------|--|----------|
| 12 | <p>The only correct answer is D</p> <p><i>A is not correct because the volume of H₂O gas has been ignored</i></p> <p><i>B is not correct because the volume of carbon dioxide has been ignored</i></p> <p><i>C is not correct because the volume of excess oxygen has been ignored</i></p> | 1 |

| Question Number | Correct Answer | Mark |
|-----------------|---|----------|
| 13 | <p>The only correct answer is A</p> <p><i>B is not correct because it is a primary alcohol</i></p> <p><i>C is not correct because it is a secondary alcohol</i></p> <p><i>D is not correct because it is a secondary alcohol</i></p> | 1 |

| Question Number | Correct Answer | Mark |
|-----------------|--|----------|
| 14 | <p>The only correct answer is A</p> <p><i>B is not correct because butane is not formed</i></p> <p><i>C is not correct because butane is not formed</i></p> <p><i>D is not correct because butene is not formed</i></p> | 1 |

| Question Number | Correct Answer | Mark |
|-----------------|---|----------|
| 15(a) | <p>The only correct answer is C</p> <p><i>A is not correct because it is not an addition reaction nor electrophilic</i></p> <p><i>B is not correct because it is not an addition reaction nor nucleophilic</i></p> <p><i>D is not correct because it is not nucleophilic</i></p> | 1 |

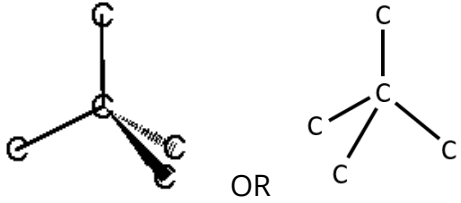
| Question Number | Correct Answer | Mark |
|-----------------|--|----------|
| 15(b) | <p>The only correct answer is D</p> <p><i>A is not correct because it is not an addition reaction</i></p> <p><i>B is not correct because it is not an addition reaction</i></p> <p><i>C is not correct because it does not involve a free radical</i></p> | 1 |

| Question Number | Correct Answer | Mark |
|-----------------|--|----------|
| 16 | <p>The only correct answer is A</p> <p><i>B is not correct because it is emitted in smaller amounts</i></p> <p><i>C is not correct because it is emitted in smaller amounts</i></p> <p><i>D is not correct because it is emitted in smaller amounts</i></p> | 1 |

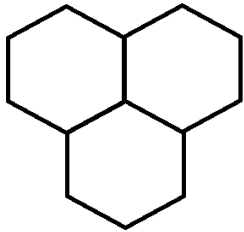
| Question Number | Correct Answer | Mark |
|-----------------|--|----------|
| 17 | <p>The only correct answer is B</p> <p><i>A is not correct because neither water vapour nor carbon dioxide depletes the ozone layer</i></p> <p><i>C is not correct because carbon dioxide does not deplete the ozone layer</i></p> <p><i>D is not correct because water vapour does not deplete the ozone layer</i></p> | 1 |

(Total for Section A = 20 marks)

Section B

| Question Number | Acceptable Answers | Reject | Mark |
|-----------------|--|---|----------|
| 18(a)(i) |  <p>OR</p> <p>ALLOW Open/solid circles for C atoms Skeletal structures</p> <p>IGNORE Number of tetrahedral units Fewer than four bonds to peripheral C atoms Stated bond angles</p> | <p>Bonds at right angles only</p> <p>Atoms of any other element</p> <p>Any C atom with 5 (or more) bonds</p> | 1 |

| Question Number | Acceptable Answers | Reject | Mark |
|------------------|---|----------------------------------|----------|
| 18(a)(ii) | <p>Mark all points independently</p> <p>Shape: tetrahedral</p> <p>ALLOW Tetrahedron Any reasonable attempt at spelling (1)</p> <p>Bond angle: 109.5°</p> <p>ALLOW 109° (1)</p> <p>Explanation: minimum repulsion / maximum separation and (between) four (bonding) pairs of electrons</p> <p>ALLOW As far apart as possible for maximum separation Four bond pairs / regions of electron density / covalent bonds (1)</p> | <p>Four bonds Four atoms</p> | 3 |

| Question Number | Acceptable Answers | Reject | Mark |
|-----------------|---|--------------------------------------|----------|
| 18(b)(i) | <p>Diagram showing 2, 3, 4 or 5 interlocking hexagons with 13 to 19 carbons inclusive</p> <p>ALLOW 11 to 21 carbons</p> <p>e.g.</p>  <p>ALLOW Non skeletal diagrams (1)</p> <p>IGNORE Number of bonds to peripheral carbons Additional layers</p> <p>Bond angle 120° (1)</p> | Any carbon with four (or more) bonds | 2 |

| Question Number | Acceptable Answers | Reject | Mark |
|------------------|---|---|----------|
| 18(b)(ii) | <p>London/dispersion force(s) / van der Waals'</p> <p>ALLOW Any reasonable attempt at spelling</p> <p>Instantaneous dipole-induced dipole Induced dipole-induced dipole Temporary dipole-induced dipole</p> <p>IGNORE Intermolecular forces</p> | <p>Hydrogen bond</p> <p>(Permanent) dipole-dipole</p> | 1 |

| Question Number | Acceptable Answers | Reject | Mark |
|-------------------|--|---|----------|
| 18(b)(iii) | <p>Graphite has delocalised electrons (and diamond does not)</p> <p>ALLOW Delocalised / free moving electron per atom or if linked to every carbon having three bonds</p> <p>Sea of delocalised electrons</p> <p>Graphite has some free moving electrons</p> <p>Electrons can move between layers</p> <p>Diamond does not contain delocalised electrons</p> <p>IGNORE Just free electrons Reference to charge carriers</p> | <p>Just one / a delocalised electron</p> <p>Lone pair of electrons</p> <p>Free moving electron</p> <p>Electrons move perpendicular to layers</p> <p>Any reference to graphite molecules</p> | 1 |

| Question Number | Acceptable Answers | Reject | Mark |
|------------------|---|--------|----------|
| 18(b)(iv) | <p>Heat is not conducted at right angles to the layers</p> <p>OR</p> <p>Heat is conducted well in the direction of / within the layers</p> <p>ALLOW</p> <p>Heat is conducted well between the layers / spread out evenly across the spacecraft (1)</p> <p>Graphite has a high melting / boiling temperature</p> <p>ALLOW</p> <p>Graphite can withstand high temperatures / is thermally stable / is inert (1)</p> <p>IGNORE</p> <p>Soft / slippery / layers can slide</p> <p>Reference to reduced friction</p> <p>Malleable/mouldable</p> <p>Low density/weight</p> | | 2 |

| Question Number | Acceptable Answers | Reject | Mark |
|-----------------|--|---------------------------------------|----------|
| 18(c) | <p>(Buckminster)fullerene(s) / (carbon/fullerene) nanotubes / graphene</p> <p>ALLOW</p> <p>Buckyball(s)</p> <p>Any reasonable attempt at spelling</p> <p>IGNORE</p> <p>'Carbon sixty'/C₆₀</p> <p>Amorphous carbon</p> | Charcoal / soot / coal / carbon fibre | 1 |

(Total for Question 18 = 11 marks)

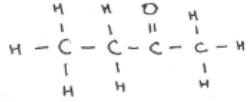
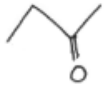
| Question Number | Acceptable Answers | Reject | Mark |
|-----------------|---|--------|----------|
| 19(a)(i) | <ul style="list-style-type: none"> • Hydrogen bonding <p>ALLOW H-bond(ing)</p> <ul style="list-style-type: none"> • London/dispersion / van der Waals' / instantaneous dipole-induced dipole / temporary dipole-induced dipole • Permanent dipole(-permanent dipole) <p>IGNORE Just dipole-dipole</p> <p>All three (2)</p> <p>Any two (1)</p> <p>Any reference to a covalent bond with one or two correct intermolecular forces scores (0)</p> <p>Any reference to a covalent bond with three correct intermolecular forces scores (1)</p> | | 2 |

| Question Number | Acceptable Answer | Reject | Mark |
|------------------|--|---------------------------------------|----------|
| 19(a)(ii) | <p>Butan-2-ol forms hydrogen bonds with water (making some dissolve)</p> <p>ALLOW Butan-2-ol cannot form H-bonds with water easily / forms H-bonds with water less easily than ethanol (1)</p> <p>IGNORE Just butan-2-ol can/forms/has H-bonds</p> <p>London/dispersion forces between butan-2-ol molecules are relatively strong / stronger than in ethanol (limiting solubility)</p> <p>ALLOW London/dispersion forces in butan-2-ol are strong(er)</p> <p>ACCEPT van der Waals' / instantaneous dipole-induced dipole / temporary dipole-induced dipole forces for London/dispersion forces (1)</p> <p>Energy released from intermolecular forces formed between butan-2-ol and water less than that required to break intermolecular forces (within butan-2-ol and water) scores (1)</p> <p>IGNORE Comparison of strength of London forces in butan-2-ol to H-bonding in water</p> <p>Reference to the number of H-bonds formed / in water/butan-2-ol/ethanol</p> <p>Reference to polarity of water/butan-2-ol/ ethanol / hydrophobic/hydrophilic properties</p> | <p>Cannot form H-bonds with water</p> | 2 |

| Question Number | Acceptable Answers | Reject | Mark |
|-----------------|---|--|----------|
| 19(b)(i) | <p>Sodium disappears</p> <p>ALLOW Dissolves for disappears Solid for sodium White solid (forming) (1)</p> <p>IGNORE White precipitate forms Heat produced Sodium sinks/floats Sodium decreases in mass Sodium melts</p> <p>Bubbles / fizzing / effervescence (1)</p> <p>IGNORE Gas/vapour/hydrogen/H₂ produced</p> | <p>Yellow flame</p> <p>Any other gas eg CO₂/O₂</p> | 2 |

| Question Number | Acceptable Answer | Reject | Mark |
|------------------|--|---|----------|
| 19(b)(ii) | $\text{C}_2\text{H}_5\text{OH} + \text{Na} \rightarrow \begin{array}{c} \text{H} \quad \text{H} \\ \quad \\ \text{H}-\text{C}-\text{C}-\text{O}^{(-)}\text{Na}^{(+)} \\ \quad \\ \text{H} \quad \text{H} \end{array} / \text{CH}_3\text{CH}_2\text{O}^{(-)}\text{Na}^{(+)} + \frac{1}{2}\text{H}_2$ <p>Correct formula of sodium ethoxide</p> <p>ALLOW $\text{C}_2\text{H}_5\text{O}^{(-)}\text{Na}^{(+)}$ (1)</p> <p>Rest of equation (1)</p> <p>M2 dependent on M1 or O-Na/CH₃CH₂NaO/C₂H₅NaO</p> <p>ALLOW Multiples</p> <p>Fully correct equation for alcohol other than ethanol eg CH₃OH/C₃H₇OH scores (1)</p> <p>IGNORE state symbols even if incorrect</p> | O-Na CH ₃ CH ₂ NaO C ₂ H ₅ NaO C ₂ H ₆ O | 2 |

| Question Number | Acceptable Answer | Reject | Mark |
|-----------------|---|--|----------|
| 19(c)(i) | <p>Ethanoic acid (1)</p> <p>IGNORE CH_3COOH Displayed/skeletal formula Carboxylic acid Just ethanoic</p> <p>Any one from:</p> <ul style="list-style-type: none"> • Fizzes / effervesces / bubbles / with sodium carbonate/ hydrogencarbonate / calcium carbonate • Neutralises (a significant volume of) sodium carbonate/ hydrogencarbonate solution • Fizzes / effervesces / bubbles with Mg/magnesium • Fruity smell (when heated) with an alcohol (in the presence of an acid catalyst) (1) <p>No TE on M1 unless near miss e.g. CH_3COOH/carboxylic acid</p> <p>IGNORE Tests involving indicators eg litmus</p> | <p>PCl_5/phosphorus(V) chloride</p> <p>Na/sodium</p> | 2 |

| Question Number | Acceptable Answer | Reject | Mark |
|------------------|---|-------------------|----------|
| 19(c)(ii) | $\text{CH}_3\text{CH}_2\text{COCH}_3 / \text{C}_2\text{H}_5\text{COCH}_3$ OR  OR  | Molecular formula | 1 |

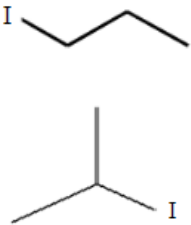
| Question Number | Acceptable Answer | Reject | Mark |
|-------------------|---|--|----------|
| 19(c)(iii) | <p>Any two from:</p> <ul style="list-style-type: none"> Butan-2-ol has O-H peak/absorption/trough <p>ALLOW OH⁻/-OH/hydroxyl for O-H C-O/C-OH peak Wavenumber/stretch/vibration for peak etc Reverse argument for oxidation product</p> <p>IGNORE Alcohol absorption</p> <ul style="list-style-type: none"> Oxidation product has C=O peak/absorption/trough <p>ALLOW Carbonyl bond peak Butan(-2-)one/ketone/product for oxidation product Reverse argument for butan-2-ol</p> <ul style="list-style-type: none"> Both have different fingerprint regions <p style="text-align: right;">(2)</p> <p>IGNORE Different C-H absorptions Different C-C absorptions Wavenumbers, even if incorrect</p> | <p>Penalise omission of peak once only</p> <p>OH⁻/hydroxide C=O</p> <p>Aldehyde C=O C-O</p> <p>Aldehyde C-H</p> | 2 |

(Total for Question 19 = 13 marks)

| Question Number | Acceptable Answer | Reject | Mark |
|-----------------|--|--------|----------|
| 20(a)(i) | $2\text{I}^- + \text{Cl}_2 \rightarrow \text{I}_2 + 2\text{Cl}^-$ ALLOW Multiples Spectator ions if crossed out IGNORE Full equation (as working) Half equations (as working) State symbols even if incorrect | | 1 |

| Question Number | Acceptable Answer | Reject | Mark |
|------------------|---|--|----------|
| 20(a)(ii) | Any suitable named liquid organic solvent e.g. hexane / cyclohexane ALLOW Tetra / trichloro(m)ethane Hydrocarbon solvent (1) Pink / purple / violet / mauve (1) IGNORE Modifiers eg pale M2 dependent on M1 | Any alcohol / alkene / arene Halogenoalkane | 2 |

| Question Number | Acceptable Answer | Reject | Mark |
|-------------------|--|--|----------|
| 20(a)(iii) | <p>Sulfur / S oxidised from (+)2 to (+)2½ (1)</p> <p>Iodine / I / I₂ reduced from 0 to -1 (1)</p> <p>OR</p> <p>Sulfur / S from (+)2 to (+)2½ (1)</p> <p>Iodine / I / I₂ from 0 to -1</p> <p>and</p> <p>Sulfur / S oxidised</p> <p>Iodine / I / I₂ reduced (1)</p> <p>ALLOW</p> <p>Oxidation states from annotated equation</p> | <p>S₂O₃²⁻ oxidised</p> <p>S₂O₃²⁻</p> <p>S₂O₃²⁻ oxidised</p> | 2 |

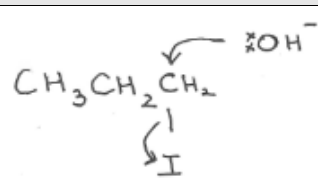
| Question Number | Acceptable Answer | Reject | Mark |
|-----------------|--|--------|----------|
| 20(b)(i) |  <p>IGNORE</p> <p>Bond angles and bond lengths</p> <p>Displayed / structural formulae even if incorrect</p> | | 1 |

| Question Number | Acceptable Answer | Reject | Mark |
|------------------|---|--------|----------|
| 20(b)(ii) | <p>There is only one (stable) isotope of iodine</p> <p>ALLOW</p> <p>No isotopes of iodine</p> <p>(Both) chlorine and bromine have two isotopes</p> <p>Chlorine has ³⁵Cl and ³⁷Cl and / or bromine has ⁷⁹Br and ⁸¹Br</p> <p>ACCEPT</p> <p>Chloro- / chloride for chlorine</p> <p>Bromo- / bromide for bromine</p> | Isomer | 1 |

| Question Number | Acceptable Answer | Reject | Mark |
|-------------------|---|--|----------|
| 20(b)(iii) | $\text{CH}_3\text{CH}_2\text{CH}_2^+$ ALLOW C_3H_7^+ Displayed formula (1) IGNORE Position of positive charge The C-I bond breaks (may be shown on a diagram) (1) IGNORE Loses iodine | Omission of charge $\text{CH}_3\text{CHCH}_3^+$ Just fragmentation | 2 |

| Question Number | Acceptable Answer | Reject | Mark |
|-----------------|--|-------------|----------|
| 20(c)(i) | Yellow ALLOW Bright yellow (1) Silver iodide (1) IGNORE AgI | Pale yellow | 2 |

| Question Number | Acceptable Answer | Reject | Mark |
|------------------|---|--------|----------|
| 20(c)(ii) | $\text{Ag}^+(\text{aq}) + \text{I}^-(\text{aq}) \rightarrow \text{AgI}(\text{s})$ TE on silver chloride / silver bromide in (c)(i) | | 1 |

| Question Number | Acceptable Answer | Reject | Mark |
|-----------------|---|--|----------|
| 20(d) |  <p>Curly arrow from lone pair on OH⁻ to carbon (of C-I) (1)</p> <p>Curly arrow from C-I bond to the iodine or just beyond (can be scored from a transition state) (1)</p> <p>Correct S_N1 mechanism scores (2)</p> <p>IGNORE Dipoles even if incorrect Transition state / intermediate in S_N2 mechanism Products, even if incorrect</p> | <p>Penalise incorrect carbon chain / missing hydrogens once only</p> <p>From Na-OH OH:⁻</p> <p>Full charges</p> | 2 |

| Question Number | Acceptable Answer | Reject | Mark |
|-----------------|-------------------|--------|----------|
| 20(e)(i) | Elimination | | 1 |

| Question Number | Correct Answer | Reject | Mark |
|------------------|---|--------|----------|
| 20(e)(ii) | <p>Propene</p> <p>ALLOW Prop-1-ene</p> <p>IGNORE Alkene</p> | | 1 |

(Total for Question 20 = 16 marks)
(Total for Section B = 40 marks)

Section C

| Question Number | Acceptable Answer | Reject | Mark |
|-----------------|---|--|----------|
| 21(a)(i) | <p>Electrons excited / promoted (to higher energy levels / orbitals by heat)</p> <p>ALLOW Raised/move / jump for excited (1)</p> <p>(Electrons) relax to lower energy levels / orbitals</p> <p>ALLOW Return / drop / fall / de-excite for relax Ground state for lower energy levels (1)</p> <p>To score both M1 and M2 energy levels / orbitals must be mentioned somewhere</p> <p>IGNORE Reference to stability of excited / ground state</p> <p>Energy / photons emitted as (visible) light</p> <p>ALLOW Wavelength / frequency / radiation for energy Given out / released for emitted Visible range / region / spectrum for light (1)</p> <p>IGNORE ion or atom throughout</p> | <p>...by electricity / combustion / burning</p> <p>Pushed</p> <p>Reflected</p> | 3 |

| Question Number | Acceptable Answer | Reject | Mark |
|------------------|--|---|----------|
| 21(a)(ii) | <p>Yellow-red</p> <p>ALLOW Brick-red / red</p> | <p>Just yellow</p> <p>Any mention of orange</p> | 1 |

| Question Number | Acceptable Answer | Reject | Mark |
|-------------------|---|------------------------------|----------|
| 21(a)(iii) | Energy / frequency / wavelength (emitted) is outside the visible range / region / spectrum ALLOW Photon / radiation / light for energy etc Too high / low / in the ultraviolet for outside Energy etc cannot be detected by the eye | ..of the ions White light | 1 |

| Question Number | Acceptable Answer | Reject | Mark |
|-----------------|--|--------|----------|
| 21(b) | $\text{CaCO}_3 + \text{CO}_2 + \text{H}_2\text{O} \rightarrow \text{Ca}(\text{HCO}_3)_2$ ALLOW H_2CO_3 for $(\text{CO}_2 + \text{H}_2\text{O})$ Multiples IGNORE state symbols even if incorrect | | 1 |

| Question Number | Acceptable Answer | Reject | Mark |
|-----------------|---|--------|----------|
| 21(c) | Barium sulfate is (much) less soluble (in water) or reverse argument ALLOW Barium sulfate is insoluble Solubility of sulfates decreases down group IGNORE Reference to hydration/lattice enthalpy Reference to reactivity | | 1 |

| Question Number | Acceptable Answer | Reject | Mark |
|-----------------|--|--------|----------|
| 21(d)(i) | <p>Calcium ions / Ca^{2+} are larger than magnesium ions / Mg^{2+}</p> <p>ALLOW Calcium ions / Ca^{2+} have a lower charge density than magnesium ions / Mg^{2+} (1)</p> <p>The calcium ions / Ca^{2+} polarise the C-O bond / carbonate ion less</p> <p>ALLOW The calcium ions / Ca^{2+} distort (the electron cloud in) the carbonate ion less (1)</p> <p>The C-O bond is less easily broken</p> <p>ALLOW More energy needed to break the bonds in the carbonate ion Bonds in the carbonate ion are less easily broken (1)</p> <p>ALLOW Reverse arguments for magnesium ions / Mg^{2+} throughout</p> | | 3 |

| Question Number | Acceptable Answer | Reject | Mark |
|------------------|--|-------------|----------|
| 21(d)(ii) | <p>moles of CO₂ = $\frac{1.626}{24}$ (= 0.06775) (1)</p> <p>Then</p> <p>Route 1</p> <p>M_r metal carbonate = $\frac{10.0}{0.06775}$</p> <p>= 147.6 (1)</p> <p>TE on moles CO₂</p> <p>A_r metal (= 147.6 - 60)</p> <p>= 87.6</p> <p>So the metal (ion) is Sr⁽²⁺⁾/strontium (1)</p> <p>TE on M_r metal carbonate provided nearest A_r is that of a group 2 element</p> <p>$M_r = \frac{10.00 \times 24}{1.626} = 147.6$ scores M1 and M2</p> <p>$A_r = \frac{10.00 \times 24}{1.626} - 60 = 87.6$ and Sr scores (3)</p> <p>OR</p> <p>Route 2</p> <p>Mass metal = $10.00 - 0.06775 \times 60$</p> <p>= 5.935 (g) (1)</p> <p>TE on moles CO₂</p> <p>A_r metal = $\frac{5.935}{0.06775} = 87.6$</p> <p>So the metal (ion) is Sr⁽²⁺⁾/strontium (1)</p> <p>TE on M_r metal carbonate provided nearest A_r is that of a group 2 element</p> <p>Correct metal with no working scores (1)</p> <p>IGNORE SF except 1SF Units</p> | Ra / radium | 3 |

| Question Number | Acceptable Answer | Reject | Mark |
|-------------------|--|---------------------------------|----------|
| 21(d)(iii) | $\text{Ca(OH)}_2(\text{aq}) + \text{CO}_2(\text{g}) \rightarrow \text{CaCO}_3(\text{s}) + \text{H}_2\text{O}(\text{l})$ ALLOW $\text{CO}_2(\text{aq})$ | $\text{H}_2\text{O}(\text{aq})$ | 1 |

| Question Number | Acceptable Answer | Reject | Mark |
|-----------------|---|---|----------|
| 21(e)(i) | Methyl orange (1) From yellow to orange (1) M2 dependent on M1 ALLOW Any acid-alkali titration indicators with correct colour change e.g. Phenolphthalein (1) From pink to colourless (1) ALLOW Any recognisable spelling of indicator | Litmus and universal indicator ...to red / pink From red... From purple... | 2 |

| Question Number | Acceptable Answer | Reject | Mark |
|------------------|--|--------|----------|
| 21(e)(ii) | Mols of HCl = $\frac{8.90 \times 0.05}{1000}$ = $4.45 \times 10^{-4} / 0.000445$ (1) Mols of Ca(OH) ₂ = $4.45 \times 10^{-4} \times \frac{1}{2}$ = $2.225 \times 10^{-4} / 0.0002225$ (1) [Ca(OH) ₂] = $2.225 \times 10^{-4} \times 100$ = $2.225 \times 10^{-2} / 0.02225$ (1) Concentration of calcium hydroxide = $2.225 \times 10^{-2} \times 74.1$ = $1.648725 \text{ (g dm}^{-3}\text{)}$ (1) ALLOW TE at each stage IGNORE units, even if incorrect IGNORE SF except 1SF Correct answer with no working scores (4) | | 4 |

(Total for Section C = 20 marks)

(TOTAL FOR PAPER = 80 MARKS)