

Mark Scheme (Results)

Summer 2013

GCE Chemistry 6CH05/01
General Principles of Chemistry II

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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.
- Mark schemes will indicate within the table where, and which strands of QWC, are being assessed. The strands are as follows:
 - i) Ensure that text is legible and that spelling, punctuation and grammar are accurate so that meaning is clear
 - ii) Select and use a form and style of writing appropriate to purpose and to complex subject matter
 - iii) Organise information clearly and coherently, using specialist vocabulary when appropriate

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

| Question Number | Correct Answer | Mark |
|-----------------|----------------|----------|
| 1 | C | 1 |

| Question Number | Correct Answer | Mark |
|-----------------|----------------|----------|
| 2 | D | 1 |

| Question Number | Correct Answer | Mark |
|-----------------|----------------|----------|
| 3 | A | 1 |

| Question Number | Correct Answer | Mark |
|-----------------|----------------|----------|
| 4 | C | 1 |

| Question Number | Correct Answer | Mark |
|-----------------|----------------|----------|
| 5 | C | 1 |

| Question Number | Correct Answer | Mark |
|-----------------|----------------|----------|
| 6 | C | 1 |

| Question Number | Correct Answer | Mark |
|-----------------|----------------|----------|
| 7 | A | 1 |

| Question Number | Correct Answer | Mark |
|-----------------|----------------|----------|
| 8 | D | 1 |

| Question Number | Correct Answer | Mark |
|-----------------|----------------|----------|
| 9 | D | 1 |

| Question Number | Correct Answer | Mark |
|-----------------|----------------|----------|
| 10 | D | 1 |

| Question Number | Correct Answer | Mark |
|-----------------|----------------|----------|
| 11 | A | 1 |

| Question Number | Correct Answer | Mark |
|-----------------|----------------|----------|
| 12 | B | 1 |

| Question Number | Correct Answer | Mark |
|-----------------|----------------|----------|
| 13 | B | 1 |

| Question Number | Correct Answer | Mark |
|-----------------|----------------|----------|
| 14 | D | 1 |

| Question Number | Correct Answer | Mark |
|-----------------|----------------|----------|
| 15 | B | 1 |

| Question Number | Correct Answer | Mark |
|-----------------|----------------|----------|
| 16 | B | 1 |

| Question Number | Correct Answer | Mark |
|-----------------|----------------|----------|
| 17 | B | 1 |

| Question Number | Correct Answer | Mark |
|-----------------|----------------|----------|
| 18 | A | 1 |

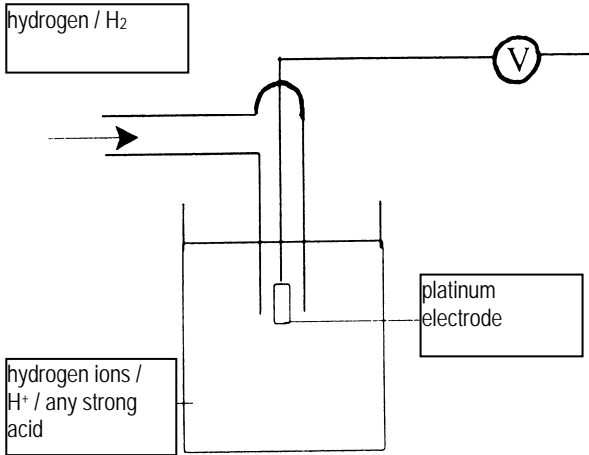
| Question Number | Correct Answer | Mark |
|-----------------|----------------|----------|
| 19 | B | 1 |

| Question Number | Correct Answer | Mark |
|-----------------|----------------|----------|
| 20 | C | 1 |

Total for Section A = 20 Marks

Section B

| Question Number | Acceptable Answers | Reject | Mark | | | | | | | | | | |
|-----------------|--|---------------|------------------------|--|--|--|--|--|---------|--|-------|--------------|----------|
| 21(a) | <table border="1"> <thead> <tr> <th>Half-equation</th> <th>E^\ominus / V</th> </tr> </thead> <tbody> <tr> <td></td> <td></td> </tr> <tr> <td></td> <td></td> </tr> <tr> <td></td> <td>+0.4(0)</td> </tr> <tr> <td></td> <td>+1.23</td> </tr> </tbody> </table> <p>(1) for each correct value Penalise omission of + once only</p> | Half-equation | E^\ominus / V | | | | | | +0.4(0) | | +1.23 | +2.46 | 2 |
| Half-equation | E^\ominus / V | | | | | | | | | | | | |
| | | | | | | | | | | | | | |
| | | | | | | | | | | | | | |
| | +0.4(0) | | | | | | | | | | | | |
| | +1.23 | | | | | | | | | | | | |

| Question Number | Acceptable Answers | Reject | Mark |
|-----------------|--|--|----------|
| 21(b)(i) |  <p>First mark: Hydrogen / $\text{H}_2(\text{g})$ / H_2 (1) IGNORE Any pressure value quoted</p> <p>Second mark: Name or formula of any strong acid (e.g. HCl / H_2SO_4) (1) ALLOW hydrogen ions / $\text{H}^+(\text{aq})$ / H^+ IGNORE Any acid concentration value quoted IGNORE State symbols for ANY formula of hydrogen and / or acid, even if incorrect IGNORE any references to platinum</p> | <p>$\text{H}(\text{g})$ / H for hydrogen gas</p> <p>'HCL' / HSO_4 Just 'acidic'</p> | 2 |

| Question Number | Acceptable Answers | Reject | Mark |
|------------------|---|---|----------|
| 21(b)(ii) | <ul style="list-style-type: none"> • 1 atm / 100 kPa / 101 kPa / 1 bar • 1 mol dm⁻³ ([H⁺] / [HCl]) <p>ALLOW '1 molar' / '1M'</p> <ul style="list-style-type: none"> • 298 K / 25 °C <p>ALLOW "°K"</p> <p>All THREE conditions correct = 2 marks</p> <p>Any TWO conditions correct = 1 mark</p> <p>IGNORE References to 'standard conditions' References to Pt/catalyst</p> <p>ALLOW 0.5 mol dm⁻³ H₂SO₄ INSTEAD of the 1 mol dm⁻³ ([H⁺] / [HCl])</p> | <p>Wrong pressure units</p> <p>Incorrect concentration units (eg '1 mol' / 1 mol⁻¹ dm³ for [H⁺])</p> <p>273 K / 0°C / 'room temperature'</p> | 2 |

| Question Number | Acceptable Answers | Reject | Mark |
|-----------------|--|--|----------|
| 21(c) | <p>First mark: Mentions / some evidence for the use of BOTH equations 1 AND 3 from the table in any way, even if reversed or left unbalanced eg $O_2(g) + 2H_2O(l) + 4e^- \rightarrow 4OH^-(aq)$ AND $4OH^-(aq) + 2H_2(g) \rightarrow 4H_2O(l) + 4e^-$ (1) ALLOW \rightleftharpoons for \rightarrow</p> <p>Second mark: (Adds the above half-equations cancelling $4e^-$ to get) $2H_2(g) + O_2(g) \rightarrow 2H_2O(l)$ OR $H_2(g) + \frac{1}{2}O_2(g) \rightarrow H_2O(l)$ (1) ALLOW \rightleftharpoons for \rightarrow but must have H_2 and O_2 on left</p> <p>Mark the second scoring point independently</p> <p>Award this mark if the correct equation is seen, no matter how it is derived</p> <p>ALLOW MULTIPLES OF EQUATIONS IN ALL CASES</p> <p>IGNORE any state symbols, even if incorrect</p> <p>ALLOW equilibrium sign \rightleftharpoons used in ANY of the above equations instead of the full arrows</p> | <p>Equations involving H^+</p> <p>If e^- / OH^- / H^+ / two surplus H_2O molecules remain in this final equation (0) for 2nd mark</p> | 2 |

| Question Number | Acceptable Answers | Reject | Mark |
|-----------------|---|-----------|----------|
| 21(d) | $E^{\ominus}_{\text{cell}} = +0.40 - (-0.83) \text{ (V)}$ $= (+)1.23 \text{ (V)}$ <p>+ sign NOT required in final answer</p> <p>Correct answer with or without working scores (1)</p> <p>No ECF from any incorrect E^{\ominus} values used</p> | -1.23 (V) | 1 |

| Question Number | Acceptable Answers | Reject | Mark |
|-----------------|---|--|----------|
| 21(e) | <p>Reaction / equation is the same OR Reaction / equation for both is $2\text{H}_2(\text{g}) + \text{O}_2(\text{g}) \rightarrow 2\text{H}_2\text{O}(\text{l})$ ALLOW \rightleftharpoons for \rightarrow</p> <p>IGNORE state symbols even if incorrect</p> <p>ALLOW statements such as 'they both produce water from hydrogen and oxygen' / 'reactants and products are the same'</p> <p>ALLOW multiples of the equation</p> | <p>'Electrode potentials don't change' Just same product / water is produced Just same reactants are oxidized and reduced</p> <p>Same reaction but in reverse scores (0)</p> | 1 |

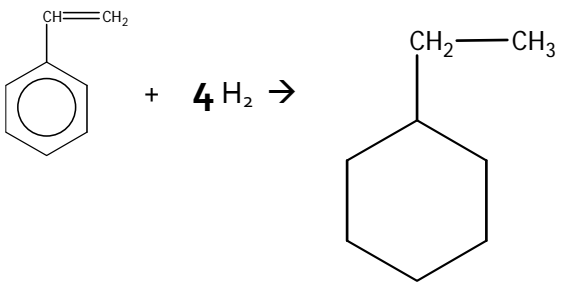
| Question Number | Acceptable Answers | Reject | Mark |
|-----------------|--|--------|----------|
| 21(f) | To increase the surface area /to increase the number of active sites | | 1 |

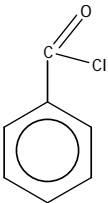
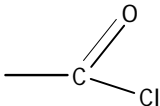
| Question Number | Acceptable Answers | Reject | Mark |
|-----------------|--|--|----------|
| 21(g) | <p>Storage (problems) OR hydrogen / oxygen / the gases have to be stored under pressure OR Leakage (of hydrogen / of oxygen / of gas) OR Transport(ation) problems OR Hard to carry / lack of portability OR Hydrogen flammable / inflammable OR Hydrogen explosive OR (Fuel cell) costly / expensive OR Needs (regular) re-filling OR Needs continual replenishment of H₂ and O₂ OR Lack of availability (of hydrogen / fuel) OR Hydrogen is made from fossil fuels / hydrogen is made by electrolysis / hydrogen is made from Natural Gas / hydrogen is made from non-renewable resources</p> <p>ALLOW water is a Greenhouse gas / Fuel cell(s) have short(er) life-span / Fuel cells have to be (regularly) replaced</p> <p>IGNORE references to just 'danger' or just 'safety' or just 'hazardous'</p> <p>Any arguments in terms of voltage output</p> <p>References to cannot be recharged</p> | <p>'Fuel cell can only be used once' scores (0)</p> | 1 |

Total for Question 21 = 12 Marks

| Question Number | Acceptable Answers | Reject | Mark |
|-----------------|---|--|----------|
| 22(a)(i) | Addition / reduction / free-radical addition IGNORE references to 'hydrogenation' | 'redox' 'electrophilic addition' 'nucleophilic addition' | 1 |

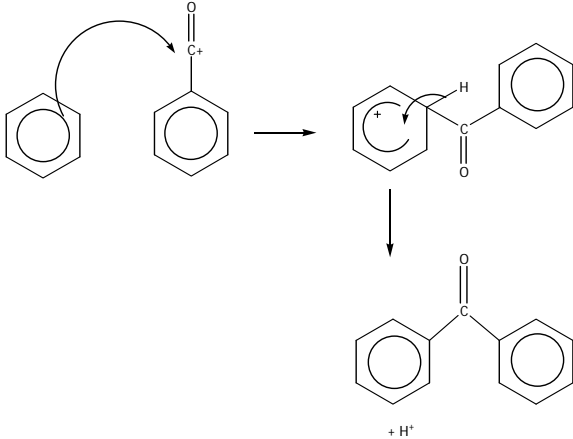
| Question Number | Acceptable Answers | Reject | Mark |
|------------------|---|--------|----------|
| 22(a)(ii) | <p>First mark: Delocalization (of π/p electrons in benzene ring) (1)</p> <p>IGNORE reference to 'resonance'</p> <p>Second mark: Results in more energy needed to break the bonds in benzene (compared with three separate π bonds) (1)</p> <p>ALLOW confers stability on the molecule / makes benzene more stable (than expected)</p> <p>IGNORE Reference to carbon-carbon bond lengths Values of any enthalpy changes</p> <p>Mark the two points independently</p> | | 2 |

| Question Number | Acceptable Answers | Reject | Mark |
|-------------------|--|--------|----------|
| 22(a)(iii) |  <p style="text-align: center;">($\Delta H =$) – 328 (kJ mol⁻¹)</p> <p>First mark: For “4”</p> <p>Second mark: Product as above / correct skeletal formula of product</p> <p>ALLOW Side chain written as –C₂H₅</p> <p>Third mark: –328 (kJ mol⁻¹)</p> <p>NOTE</p> <p>One H₂ added showing a CQ correct product with only side chain reduced and cq $\Delta H = -120$ (kJ mol⁻¹) scores (2)</p> <p>Three H₂ added showing a CQ correct product with only the benzene ring reduced and cq $\Delta H = -208$ (kJ mol⁻¹) scores (2)</p> <p>Five H₂ added with fully correct product drawn and $\Delta H = -448$ (kJ mol⁻¹) scores (2)</p> <p>Three and a half H₂ added showing a fully correct product and $\Delta H = -268/-293(.3)$(kJ mol⁻¹) scores (2)</p> <p>NOTE Mark scoring points independently</p> | | 3 |

| Question Number | Acceptable Answers | Reject | Mark |
|-----------------|--|--------|----------|
| 22(b)(i) |  <p>Mark awarded for displaying</p>  | | 1 |

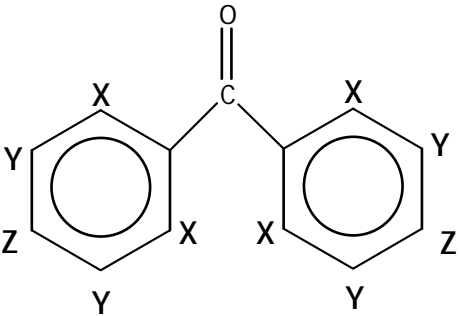
| Question Number | Acceptable Answers | Reject | Mark |
|------------------|--|--------|----------|
| 22(b)(ii) | <p>Electrophilic substitution</p> <p>BOTH words needed</p> <p>IGNORE references to 'acylation' and /or 'Friedel-Crafts'</p> | | 1 |

| Question Number | Acceptable Answers | Reject | Mark |
|-------------------|--|--------|----------|
| 22(b)(iii) | <p>Friedel and Crafts</p> <p>BOTH names are needed for this mark</p> | | 1 |

| Question Number | Acceptable Answers | Reject | Mark |
|-----------------|--|--------|----------|
| 22(b)(iv) | <p>First mark: $\text{C}_6\text{H}_5\text{COCl} + \text{AlCl}_3 \rightarrow \text{C}_6\text{H}_5\text{CO}^+ + \text{AlCl}_4^-$ (1)</p> <p>+ can be anywhere on the $\text{C}_6\text{H}_5\text{CO}$ in the equation for the first mark</p> <div style="text-align: center;">  <p style="text-align: center;">+ H⁺</p> </div> <p style="text-align: center;">(AlCl₄⁻ + H⁺ → HCl + AlCl₃)</p> <p>NOTE: If ethanoyl chloride or any other acid chloride or the generic RCOCl is used instead of benzoyl chloride, no first mark can be awarded but the 2nd, 3rd and 4th marks can be awarded consequentially</p> <p>Second mark: First curly arrow, as shown, to start from inside the hexagon to the correct C⁺ carbon (i.e. not to the benzene ring) Note the + must be on the C of the C=O/CO for this mark (1)</p> <p>Third mark: Intermediate correctly drawn (1)</p> <p>NOTE + can be shown anywhere in the ring or at the C atom where electrophile is bonded. The 'horseshoe' in the intermediate to cover at least three carbon atoms</p> <p>Fourth mark: Second curly arrow as shown from C—H bond to reform the ring, not from the H atom in this bond (1)</p> <p>NOTE Products do not have to be shown nor the equation for regeneration of the catalyst given</p> | | 4 |

| Question Number | Acceptable Answers | Reject | Mark |
|-----------------|--|-------------------------|----------|
| 22(b)(v) | Absorbs / reflects / blocks / protects from / shields against / uv (light/ radiation) IGNORE 'non-toxic' / references to IR | adsorbs uv light | 1 |

| Question Number | Acceptable Answers | Reject | Mark | | | | | | | | | | |
|-----------------|--|--------|---|-----|--|-----|-------------|-----|------|-----|--|--|----------|
| 22(c)(i) | <p>Any TWO of the following</p> <p>(1) for identifying the bond by formula as shown and (1) for wavenumber in each matching pair</p> <p>UNITS are not required</p> <table border="1" data-bbox="316 840 997 1243"> <thead> <tr> <th>Bond</th> <th>Wavenumber range/wavenumber (cm⁻¹)</th> </tr> </thead> <tbody> <tr> <td>C=C</td> <td>1600 / 1580 / 1500 / 1450 All four values needed</td> </tr> <tr> <td>C=O</td> <td>1700 - 1680</td> </tr> <tr> <td>C-H</td> <td>3030</td> </tr> <tr> <td>C-H</td> <td>750 / 700 Both values needed</td> </tr> </tbody> </table> <p>NOTE ALLOW Correct wavenumber range, or any number within the correct range, for C=O</p> <p>Mark identification of the bond and the wavenumber independently (eg a correct bond with a wrong wavenumber, or vice-versa, scores one of the two marks in each case)</p> <p>IGNORE nmr values / chemical shifts</p> | Bond | Wavenumber range/wavenumber (cm ⁻¹) | C=C | 1600 / 1580 / 1500 / 1450 All four values needed | C=O | 1700 - 1680 | C-H | 3030 | C-H | 750 / 700 Both values needed | | 4 |
| Bond | Wavenumber range/wavenumber (cm ⁻¹) | | | | | | | | | | | | |
| C=C | 1600 / 1580 / 1500 / 1450 All four values needed | | | | | | | | | | | | |
| C=O | 1700 - 1680 | | | | | | | | | | | | |
| C-H | 3030 | | | | | | | | | | | | |
| C-H | 750 / 700 Both values needed | | | | | | | | | | | | |

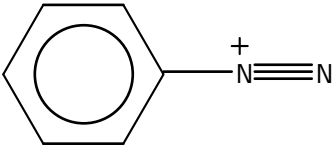
| Question Number | Acceptable Answers | Reject | Mark |
|------------------|---|--------|----------|
| 22(c)(ii) | <div style="text-align: center;">  </div> <p>First mark</p> <p>EITHER Identifies correctly the three different proton environments</p> <p>ALLOW If the three different proton environments are only shown on one of the benzene rings</p> <p>NOTE On right-hand ring, clockwise from C=O, positions 2, 3 and 4 And /or 2,4 and 5 are shown as different environments and /or On left-hand ring, anti-clockwise from C=O, positions 2, 3 and 4 And /or 2,4 and 5 are shown as different environments</p> <p>OR</p> <p>Identifies proton Z correctly on both benzene rings (1)</p> <p>Second mark Fully correct labelling both rings using the letters X, Y and Z</p> <p>NOTE X and Y labels are interchangeable, Z is not (1)</p> | | 2 |

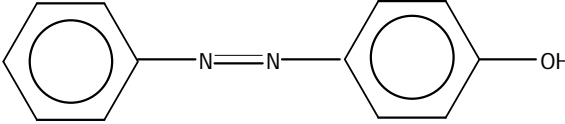
Total for Question 22 = 20 Marks

| Question Number | Acceptable Answers | Reject | Mark |
|-----------------|---|--|----------|
| 23(a)(i) | Lone pair (of electrons on the nitrogen atom) ALLOW non-bonded pair (of electrons on the nitrogen atom) | Lone pairs Spare pair | 1 |

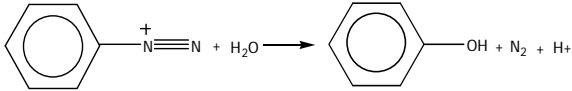
| Question Number | Acceptable Answers | Reject | Mark |
|------------------|--|--------|----------|
| 23(a)(ii) | <p>(with H₂SO₄)</p> <p>$(\text{C}_4\text{H}_9\text{NH}_3^+)_2\text{SO}_4^{2-}$ (1)</p> <p>ALLOW</p> <p>$\text{C}_4\text{H}_9\text{NH}_3^+\text{HSO}_4^-$</p> <p>(with CH₃COOH)</p> <p>$\text{C}_4\text{H}_9\text{NH}_3^+\text{CH}_3\text{COO}^-$ (1)</p> <p>CHARGES not essential</p> <p>Cation and anion can be in either order</p> <p>Max (1) if formula of the amine is incorrect in either case</p> <p>ALLOW (1) if only the correct cation is given in each case (i.e. the anion has been omitted in both cases)</p> <p>NOTE The correct ions can be shown separately Eg $(\text{C}_4\text{H}_9\text{NH}_3^+)_2 + \text{SO}_4^{2-}$</p> | | 2 |

| Question Number | Acceptable Answers | Reject | Mark |
|-----------------|--|--|----------|
| 23(b) | Tin / Sn ALLOW Iron / Fe (1) (concentrated) hydrochloric acid NOTE If they write 'HCl', there must be some indication of concentrated Eg 'conc HCl' / 'concentrated HCl' ALLOW HCl(aq) (Followed by addition of alkali to liberate the free amine) (1) Mark the two points independently NOTE Do not allow 2 nd mark if there is a suggestion that the acid and alkali are added together simultaneously | LiAlH ₄ Just 'HCl' 'dilute' hydrochloric acid / sulfuric acid | 2 |

| Question Number | Acceptable Answers | Reject | Mark |
|-----------------|--|-------------------------------------|----------|
| 23(c)(i) |  NOTE If the above structure is drawn, the + charge must be on the N connected directly to the benzene ring ALLOW —N=N ⁺ on ring IGNORE Cl ⁻ | N ₂ ⁺ on ring | 1 |

| Question Number | Acceptable Answers | Reject | Mark |
|------------------|---|--------|----------|
| 23(c)(ii) |  | | 1 |

| Question Number | Acceptable Answers | Reject | Mark |
|-------------------|--|--------|----------|
| 23(c)(iii) | <p>(Conditions) (Presence of) NaOH / KOH / alkali / OH⁻ (1)</p> <p>ALLOW 'Alkaline (conditions)' or 'base' or 'high pH'</p> <p>IGNORE Any references to temperature</p> <p>(Use) Dye / pigment / colouring / indicator / in foodstuff / in paint / methyl orange (1)</p> <p>IGNORE Any reference to medicines</p> | | 2 |

| Question Number | Acceptable Answers | Reject | Mark |
|-----------------|---|--------|----------|
| 23 (d) | <div style="text-align: center;">  </div> <p>ALLOW The + sign to be on either N atom in the benzenediazonium ion</p> <p>OR</p> $\text{C}_6\text{H}_5\text{N}_2^+ + \text{H}_2\text{O} \rightarrow \text{C}_6\text{H}_5\text{OH} + \text{N}_2 + \text{H}^+$ <p>OR</p> $\text{C}_6\text{H}_5\text{N}_2\text{Cl} + \text{H}_2\text{O} \rightarrow \text{C}_6\text{H}_5\text{OH} + \text{N}_2 + \text{HCl}$ <p>OR</p> $\text{C}_6\text{H}_5\text{N}_2^+ + 2\text{H}_2\text{O} \rightarrow \text{C}_6\text{H}_5\text{OH} + \text{N}_2 + \text{H}_3\text{O}^+$ <p>OR</p> $\text{C}_6\text{H}_5\text{N}_2^+\text{Cl}^- + \text{H}_2\text{O} \rightarrow \text{C}_6\text{H}_5\text{OH} + \text{N}_2 + \text{HCl}$ <p>NOTE —C₆H₅ can be written or drawn</p> <p>First mark for N₂ (1)</p> <p>Second mark for rest of the equation correct (1)</p> <p>IGNORE State symbols, even if incorrect</p> | | 2 |

| Question Number | Acceptable Answers | Reject | Mark |
|-----------------|--|--------|----------|
| 23(e)(i) | <p>(Otherwise) too much (product) remains in solution OR If excess (solvent) is used, crystals might not form</p> <p>ALLOW To avoid losing (too much) product (in the filtrate when crystallization occurs) / 'to maximize the yield'/ 'will crystallize better from a concentrated solution'/ 'will recrystallize (better) when cold'</p> <p>IGNORE References to a 'saturated solution' or references to 'dilution' or references to the time taken for crystals to form</p> | | 1 |

| Question Number | Acceptable Answers | Reject | Mark |
|------------------|--|--------|----------|
| 23(e)(ii) | <p>(Insoluble impurities removed) By hot filtration / During the first filtration / During the second step in the process (1)</p> <p>(Soluble impurities removed) By remaining in solution / Left in filtrate / Removed when washed (with cold solvent) (1)</p> | | 2 |

| Question Number | Acceptable Answers | Reject | Mark |
|-------------------|---|---|----------|
| 23(e)(iii) | Measure the melting temperature / melting point and compare with data / known value (from a data book / literature / Internet /data base) (BOTH points needed for the mark) OR The melting point is sharp (Just this statement is needed for the mark) ALLOW Any form of chromatography IGNORE References to any types of spectroscopy | (0) if reference to determination of the boiling point is made | 1 |

Total for Question 23 = 15 Marks

| Question Number | Acceptable Answers | Reject | Mark |
|-----------------|--|--------|----------|
| 24(a)(i) | $\text{TiCl}_4 + 4\text{Na} \rightarrow 4\text{NaCl} + \text{Ti}$ IGNORE State symbols, even if incorrect ALLOW Multiples Reversible arrows | | 1 |

| Question Number | Acceptable Answers | Reject | Mark |
|------------------|--|--------|----------|
| 24(a)(ii) | <p>Ti reduced as oxidation number decreases from +4 to 0/ changes from +4 to 0</p> <p style="text-align: right;">(1)</p> <p>Na oxidized as oxidation number increases from 0 to +1 /changes from 0 to +1</p> <p style="text-align: right;">(1)</p> <p>ALLOW Correct oxidation numbers only for one mark</p> <p>NOTE Max (1) if no + sign included</p> <p>ALLOW '4+' and/or '1+' given instead of +4 and +1</p> <p>NOTE If any of the oxidation numbers are wrong, award max (1) for the idea that during oxidation the oxidation number increases AND during reduction the oxidation number decreases</p> <p>IGNORE References to loss and /or gain of electrons</p> | | 2 |

| Question Number | Acceptable Answers | Reject | Mark |
|-----------------|---|--------|----------|
| 24(b) | <p>(Ti [Ar]) $3d^2 4s^2 / 4s^2 3d^2$ (1)</p> <p>(Ti³⁺ [Ar]) $3d^1 / 3d^1 4s^0$ (Ti⁴⁺ [Ar]) 'nil' / $3d^0 4s^0 / 3d^0$ space left blank by candidate</p> <p>BOTH Ti³⁺ and Ti⁴⁺ correct for second mark (1)</p> <p>Mark CQ on Ti electron configuration for the second mark</p> <p>ALLOW Upper case (e.g. 'D' for 'd' in electronic configurations) Subscripts for numbers of electrons</p> <p>Full correct electronic configurations $1s^2, 2s^2, \dots$</p> | | 2 |

| Question Number | Acceptable Answers | Reject | Mark |
|-----------------|---|--|----------|
| 24(c)(i) | <p>(d-block element)</p> <p>EITHER Ti has (two) electrons in the 3d subshell / Ti has a partially filled d-subshell / Ti has a partially filled d-orbital / Ti has electrons in d-orbital(s) / Ti has electrons in d-subshell (During the build up of its atoms) last added / valence electron is in a d-subshell / d-orbital</p> <p>OR (During the build up of its atoms) last added / valence electron is in a d-subshell / d-orbital</p> | <p>Outer / highest energy electrons are in a d-orbital / Outer / highest energy electrons are in a d-subshell</p> <p>Electrons in the 'd-block' / 'electrons in the d-shell'</p> | 1 |

| Question Number | Acceptable Answers | Reject | Mark |
|------------------|---|--------|----------|
| 24(c)(ii) | <p>(transition element)</p> <p>Forms one (or more stable) ions / forms Ti³⁺ (ions) which have</p> <p>incomplete d-orbital(s) / an incomplete d-subshell / a partially filled d-subshell / an unpaired d electron</p> <p>IGNORE References to variable oxidation states</p> | | 1 |

| Question Number | Acceptable Answers | Reject | Mark |
|-----------------|---|--|----------|
| 24(d)(i) | <p>First mark: d-subshell splits /d-orbitals split (in energy by ligands) /d energy level(s) split(s) (1)</p> <p>Second mark: absorbs light (in visible region) (1)</p> <p>Third mark: Electron transitions from lower to higher energy / electron(s) jump from lower to higher energy</p> <p>OR</p> <p>Electron(s) promoted (within d) (1)</p> <p>Mark independently</p> <p>NOTE Maximum of (1) mark (i.e. the first mark only) if refers to electrons falling back down again</p> | <p>d-orbital / d-shell splits</p> <p>absorbs purple light</p> | 3 |

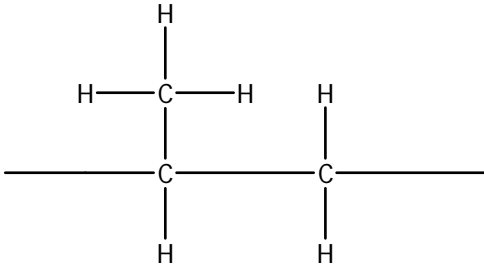
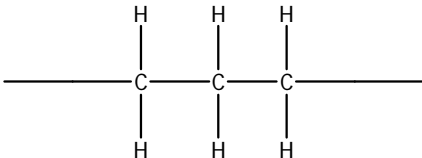
| Question Number | Acceptable Answers | Reject | Mark |
|------------------|-----------------------------------|--------|----------|
| 24(d)(ii) | No d-electrons / empty d-subshell | | 1 |

| Question Number | Acceptable Answers | Reject | Mark |
|-----------------|--|--|------|
| 24(e)(i) | <p>TiO₂ 'Structure' mark</p> <p>EITHER</p> <p>Giant (structure) OR Lattice (structure)</p> <p>IGNORE Whether stated as ionic or covalent for this mark (1)</p> <p>TiO₂ 'Bonding' mark</p> <p>EITHER</p> <p>Strong (electrostatic) attraction between ions</p> <p>ALLOW Strong ionic bonds / ionic bonds require a lot of energy to break</p> <p>OR</p> <p>Strong covalent bonds/covalent bonds require a lot of energy to break (1)</p> <p>TiCl₄ 'Structure' mark</p> <p>(Simple) molecules / (small) molecules /molecular (1)</p> <p>TiCl₄ 'Bonding' mark</p> <p>Weak London / dispersion / van der Waals' forces (between molecules) / London /dispersion / van der Waals' forces (between molecules) require little energy to break</p> | <p>TiO₂ (small) molecules / simple molecular</p> <p>For TiO₂ mention of any type of intermolecular forces between molecules of TiO₂</p> <p>TiCl₄ giant structure</p> <p>Covalent bonds broken (on melting) in TiCl₄</p> <p>Ionic bonding in TiCl₄</p> <p>Hydrogen bonding (0) for this mark</p> | 4 |

| | | | |
|--|---|--|--|
| | <p>NOTE</p> <p>If candidates assumes TiO_2 and TiCl_4 are both simple molecular, can score last mark for saying that the named intermolecular forces in TiO_2 are stronger than those in TiCl_4</p> <p>IGNORE (Permanent) dipole-dipole forces (1)</p> <p>Mark the four scoring points independently</p> | | |
|--|---|--|--|

| Question Number | Acceptable Answers | Reject | Mark |
|------------------|---|--------|----------|
| 24(e)(ii) | Amphoteric ALLOW Recognisable spellings | | 1 |

| Question Number | Acceptable Answers | Reject | Mark |
|-------------------|--|--------|----------|
| 24(e)(iii) | $\text{TiO}_2 + 2\text{H}_2\text{O} + 2\text{KOH} \rightarrow \text{K}_2\text{Ti}(\text{OH})_6$ OR $\text{TiO}_2 + 2\text{H}_2\text{O} + 2\text{OH}^- \rightarrow \text{Ti}(\text{OH})_6^{2-}$ IGNORE state symbols even if incorrect | | 1 |

| Question Number | Acceptable Answers | Reject | Mark |
|------------------|---|---|----------|
| 24(e)(iv) |  <p>MUST have continuation bonds at each end ALLOW CH₃ IGNORE n and any brackets</p> |  <p>Two (or more) repeat units shown</p> | 1 |

| Question Number | Acceptable Answers | Reject | Mark |
|-----------------|---|--------|----------|
| 24(f)(i) | $(\text{H}_2\text{O}_2 + 2\text{H}^+ +) \mathbf{2e^{(-)}} \rightarrow \mathbf{2\text{H}_2\text{O}}$ BOTH $2e^{(-)}$ and $2\text{H}_2\text{O}$ needed for the mark | | 1 |

| Question Number | Acceptable Answers | Reject | Mark |
|------------------|---|--------|----------|
| 24(f)(ii) | <p>(Moles H₂O₂ = $\frac{0.0200 \times 22.50}{1000}$ $\Rightarrow 4.5 \times 10^{-4}$ mol H₂O₂ (1)</p> <p>(Moles Ti³⁺ reacting in 25.0 cm³) = 9.0×10^{-4} mol Ti³⁺</p> <p>(Moles Ti³⁺ in 250 cm³) = 9.0×10^{-3} mol Ti³⁺ (1)</p> <p>(Original concentration of Ti³⁺) $= \frac{9.0 \times 10^{-3}}{0.00500}$ $\Rightarrow 1.8$ (mol dm⁻³) (1)</p> <p>1.8 (mol dm⁻³) with or without working scores (3)</p> <p>NOTES: If mole ratio H₂O₂ : Ti³⁺ is 1:1 final answer for concentration of Ti³⁺ is 0.9 (mol dm⁻³) scores (2) overall</p> <p>If mole ratio H₂O₂ : Ti³⁺ is 2:1 final answer for concentration of Ti³⁺ is 0.45 (mol dm⁻³) scores (2) overall</p> <p>If candidate forgets to multiply no. of moles of Ti³⁺ by 10 then answer is 0.18 (mol dm⁻³) this scores (2)</p> <p>If volume of H₂O₂ used is 25.0 no first mark, but can score (2) if final answer CQ is 2(.0) (mol dm⁻³)</p> | | 3 |

| Question Number | Acceptable Answers | Reject | Mark |
|------------------------|---|------------|----------|
| 24 (f)(iii) | (It/titanium(III)/Ti ³⁺) oxidized (by oxygen in the air) ALLOW 'It is a strong reducing agent' | Hydrolysis | 1 |

Total for Question 24 = 23 Marks

Total for Paper = 90 Marks

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