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# **INTERNATIONAL A-LEVEL CHEMISTRY (9620) CH03**

Unit 3 Inorganic 2 and Physical 2

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Mark scheme

January 2019

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Version 1.0 Final

Mark schemes are prepared by the Lead Assessment Writer and considered, together with the relevant questions, by a panel of subject teachers. This mark scheme includes any amendments made at the standardisation events which all associates participate in and is the scheme which was used by them in this examination. The standardisation process ensures that the mark scheme covers the students' responses to questions and that every associate understands and applies it in the same correct way. As preparation for standardisation each associate analyses a number of students' scripts. Alternative answers not already covered by the mark scheme are discussed and legislated for. If, after the standardisation process, associates encounter unusual answers which have not been raised they are required to refer these to the Lead Assessment Writer.

It must be stressed that a mark scheme is a working document, in many cases further developed and expanded on the basis of students' reactions to a particular paper. Assumptions about future mark schemes on the basis of one year's document should be avoided; whilst the guiding principles of assessment remain constant, details will change, depending on the content of a particular examination paper.

Further copies of this mark scheme are available from [aqa.org.uk](http://aqa.org.uk)

## A-level Chemistry

### Mark Scheme Instructions for Examiners

#### 1. General

The mark scheme for each question shows:

- the marks available for each part of the question
- the total marks available for the question
- the typical answer or answers which are expected
- extra information to help the examiner make his or her judgement and help to delineate what is acceptable or not worthy of credit or, in discursive answers, to give an overview of the area in which a mark or marks may be awarded.

The extra information in the 'Comments' column is aligned to the appropriate answer in the left-hand part of the mark scheme and should only be applied to that item in the mark scheme.

You should mark according to the contents of the mark scheme. If you are in any doubt about applying the mark scheme to a particular response, consult your Team Leader.

At the beginning of a part of a question a reminder may be given, for example: where consequential marking needs to be considered in a calculation; or the answer may be on the diagram or at a different place on the script.

In general the right-hand side of the mark scheme is there to provide those extra details which might confuse the main part of the mark scheme yet may be helpful in ensuring that marking is straightforward and consistent.

The use of M1, M2, M3 etc in the right-hand column refers to the marking points in the order in which they appear in the mark scheme. So, M1 refers to the first marking point, M2 the second marking point etc.

#### 2. Emboldening

- 2.1** In a list of acceptable answers where more than one mark is available 'any **two** from' is used, with the number of marks emboldened. Each of the following bullet points is a potential mark.
- 2.2** A bold **and** is used to indicate that both parts of the answer are required to award the mark.
- 2.3** Alternative answers acceptable for a mark are indicated by the use of **OR**. Different terms in the mark scheme are shown by a / ; eg allow smooth / free movement.

### 3. Marking points

#### 3.1 Marking of lists

This applies to questions requiring a set number of responses, but for which students have provided extra responses. The general 'List' principle to be followed in such a situation is that 'right + wrong = wrong'.

Each error / contradiction negates each correct response. So, if the number of error / contradictions equals or exceeds the number of marks available for the question, no marks can be awarded.

However, responses considered to be neutral (often prefaced by 'Ignore' in the mark scheme) are not penalised.

For example, in a question requiring 2 answers for 2 marks:

| Correct answers | Incorrect answers (i.e. incorrect rather than neutral) | Mark (2) | Comment                                                                                                     |
|-----------------|--------------------------------------------------------|----------|-------------------------------------------------------------------------------------------------------------|
| 1               | 0                                                      | 1        |                                                                                                             |
| 1               | 1                                                      | 1        | They have not exceeded the maximum number of responses so there is no penalty.                              |
| 1               | 2                                                      | 0        | They have exceeded the maximum number of responses so the extra incorrect response cancels the correct one. |
| 2               | 0                                                      | 2        |                                                                                                             |
| 2               | 1                                                      | 1        |                                                                                                             |
| 2               | 2                                                      | 0        |                                                                                                             |
| 3               | 0                                                      | 2        | The maximum mark is 2                                                                                       |
| 3               | 1                                                      | 1        | The incorrect response cancels out one of the two correct responses that gained credit.                     |
| 3               | 2                                                      | 0        | Two incorrect responses cancel out the two marks gained.                                                    |
| 3               | 3                                                      | 0        |                                                                                                             |

**3.2 Marking procedure for calculations**

Full marks should be awarded for a correct numerical answer, without any working shown, unless the question states 'Show your working' or 'justify your answer'. In this case, the mark scheme will clearly indicate what is required to gain full credit.

If an answer to a calculation is incorrect and working is shown, process mark(s) can usually be gained by correct substitution / working and this is shown in the 'Comments' column or by each stage of a longer calculation.

**3.3 Errors carried forward, consequential marking and arithmetic errors**

Allowances for errors carried forward are most likely to be restricted to calculation questions and should be shown by the abbreviation ECF or consequential in the marking scheme.

An arithmetic error should be penalised for one mark only unless otherwise amplified in the marking scheme. Arithmetic errors may arise from a slip in a calculation or from an incorrect transfer of a numerical value from data given in a question.

**3.4 Equations**

In questions requiring students to write equations, state symbols are generally ignored unless otherwise stated in the 'Comments' column.

Examiners should also credit correct equations using multiples and fractions unless otherwise stated in the 'Comments' column.

**3.5 Oxidation states**

In general, the sign for an oxidation state will be assumed to be positive unless specifically shown to be negative.

**3.6 Interpretation of 'it'**

Answers using the word 'it' should be given credit only if it is clear that the 'it' refers to the correct subject.

**3.7 Phonetic spelling**

The phonetic spelling of correct scientific terminology should be credited **unless** there is a possible confusion with another technical term or if the question requires correct IUPAC nomenclature.

### 3.8 Brackets

(.....) are used to indicate information which is not essential for the mark to be awarded but is included to help the examiner identify the sense of the answer required.

### 3.9 Ignore / Insufficient / Do **not** allow

Ignore or insufficient is used when the information given is irrelevant to the question or not enough to gain the marking point. Any further correct amplification could gain the marking point.

Do **not** allow means that this is a wrong answer which, even if the correct answer is given, will still mean that the mark is not awarded.

### 3.10 Marking crossed out work

Crossed out work that **has not been** replaced should be marked as if it were not crossed out, if possible. Where crossed out work **has been** replaced, the replacement work and not the crossed out work should be marked.

### 3.11 Reagents

The command word "Identify", allows the student to choose to use **either** the name or the formula of a reagent in their answer. In some circumstances, the list principle may apply when both the name and the formula are used. Specific details will be given in mark schemes.

The guiding principle is that a reagent is a chemical which can be taken out of a bottle or container. Failure to identify complete reagents **will be penalised**, but follow-on marks (e.g. for a subsequent equation or observation) can be scored from an incorrect attempt (possibly an incomplete reagent) at the correct reagent. Specific details will be given in mark schemes.

For example, **no credit** would be given for

- the cyanide ion or  $\text{CN}^-$  when the reagent should be potassium cyanide or KCN;
- the hydroxide ion or  $\text{OH}^-$  when the reagent should be sodium hydroxide or NaOH;
- the  $\text{Ag}(\text{NH}_3)_2^+$  ion when the reagent should be Tollens' reagent (or ammoniacal silver nitrate). In this example, no credit is given for the ion, but credit could be given for a correct observation following on from the use of the ion. Specific details will be given in mark schemes.

In the event that a student provides, for example, **both** KCN and cyanide ion, it would be usual to ignore the reference to the cyanide ion (because this is not contradictory) and credit the KCN. Specific details will be given in mark schemes.

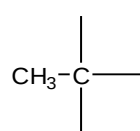
### 3.12 Organic structures

Where students are asked to draw organic structures, unless a specific type is required in the question and stated in the mark scheme, these may be given as displayed, structural or skeletal formulas or a combination of all three as long as the result is unambiguous.

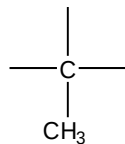
In general

- Displayed formulae must show all of the bonds and all of the atoms in the molecule, but need not show correct bond angles.
- Skeletal formulae must show carbon atoms by an angle or suitable intersection in the skeleton chain. Functional groups must be shown and it is essential that all atoms other than C atoms are shown in these (except H atoms in the functional groups of aldehydes, secondary amines and N-substituted amides which do not need to be shown).
- Structures must not be ambiguous, e.g. 1-bromopropane should be shown as  $\text{CH}_3\text{CH}_2\text{CH}_2\text{Br}$  and not as the molecular formula  $\text{C}_3\text{H}_7\text{Br}$  which could also represent the isomeric 2-bromopropane.
- Bonds should be drawn correctly between the relevant atoms. This principle applies in all cases where the attached functional group contains a carbon atom, e.g nitrile, carboxylic acid, aldehyde and acid chloride. The carbon-carbon bond should be clearly shown. Wrongly bonded atoms will be penalised **on every occasion**. (see the examples below)
- The same principle should also be applied to the structure of alcohols. For example, if students show the alcohol functional group as  $\text{C} - \text{HO}$ , they should be penalised **on every occasion**.
- Latitude should be given to the representation of  $\text{C} - \text{C}$  bonds in alkyl groups, given that  $\text{CH}_3-$  is considered to be interchangeable with  $\text{H}_3\text{C}-$  even though the latter would be preferred.
- Similar latitude should be given to the representation of amines where  $\text{NH}_2-\text{C}$  will be allowed, although  $\text{H}_2\text{N}-\text{C}$  would be preferred.
- Poor presentation of vertical  $\text{C} - \text{CH}_3$  bonds or vertical  $\text{C} - \text{NH}_2$  bonds should **not** be penalised. For other functional groups, such as  $-\text{OH}$  and  $-\text{CN}$ , the limit of tolerance is the half-way position between the vertical bond and the relevant atoms in the attached group.

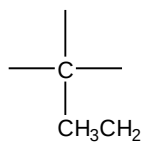
By way of illustration, the following would apply.



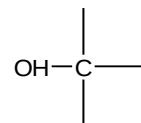
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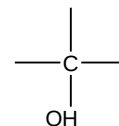
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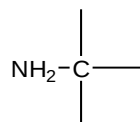
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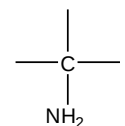
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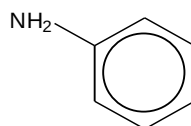
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**allowed**



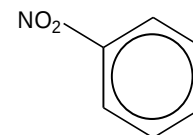
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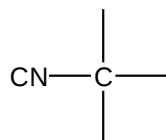
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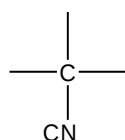
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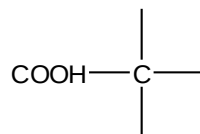
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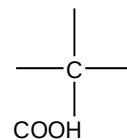
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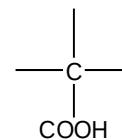
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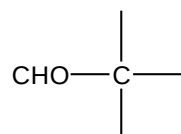
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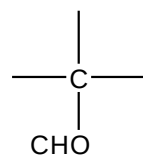
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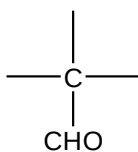
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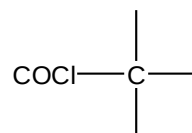
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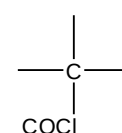
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- Representation of  $\text{CH}_2$  by  $\text{C-H}_2$  will be penalised
- Some examples are given here of **structures** for specific compounds that should **not** gain credit (but, exceptions may be made in the context of balancing equations)

$\text{CH}_3\text{COH}$  for ethanal

$\text{CH}_3\text{CH}_2\text{HO}$  for ethanol

$\text{OHCH}_2\text{CH}_3$  for ethanol

$\text{C}_2\text{H}_6\text{O}$  for ethanol

$\text{CH}_2\text{CH}_2$  for ethene

$\text{CH}_2\cdot\text{CH}_2$  for ethene

$\text{CH}_2:\text{CH}_2$  for ethene

- Each of the following **should gain credit** as alternatives to correct representations of the structures.

$\text{CH}_2 = \text{CH}_2$  for ethene,  $\text{H}_2\text{C}=\text{CH}_2$

$\text{CH}_3\text{CHOHCH}_3$  for propan-2-ol,  $\text{CH}_3\text{CH}(\text{OH})\text{CH}_3$

- In most cases, the use of “sticks” to represent  $\text{C-H}$  bonds in a structure should **not** be penalised. The exceptions to this when “sticks” will be penalised include
  - structures in mechanisms where the  $\text{C-H}$  bond is essential (e.g. elimination reactions in halogenoalkanes and alcohols)
  - when a displayed formula is required
  - when a skeletal structure is required or has been drawn by the candidate

### 3.13 Organic names

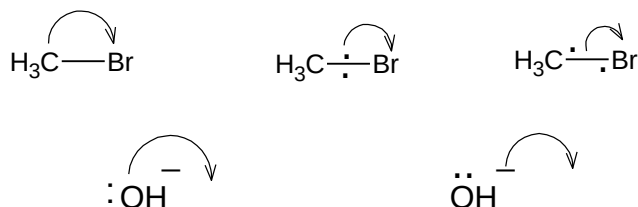
As a general principle, non-IUPAC names or incorrect spelling or incomplete names should **not** gain credit. Some illustrations are given here.

|                         |                                                                    |
|-------------------------|--------------------------------------------------------------------|
| but-2-ol                | should be <b>butan-2-ol</b>                                        |
| 2-hydroxybutane         | should be <b>butan-2-ol</b>                                        |
| butane-2-ol             | should be <b>butan-2-ol</b>                                        |
| 2-butanol               | should be <b>butan-2-ol</b>                                        |
| ethan-1,2-diol          | should be <b>ethane-1,2-diol</b>                                   |
| 2-methpropan-2-ol       | should be <b>2-methylpropan-2-ol</b>                               |
| 2-methylbutan-3-ol      | should be <b>3-methylbutan-2-ol</b>                                |
| 3-methylpentan          | should be <b>3-methylpentane</b>                                   |
| 3-mythylpentane         | should be <b>3-methylpentane</b>                                   |
| 3-methypentane          | should be <b>3-methylpentane</b>                                   |
| propanitrile            | should be <b>propanenitrile</b>                                    |
| aminethane              | should be <b>ethylamine</b> (although aminoethane can gain credit) |
| 2-methyl-3-bromobutane  | should be <b>2-bromo-3-methylbutane</b>                            |
| 3-bromo-2-methylbutane  | should be <b>2-bromo-3-methylbutane</b>                            |
| 3-methyl-2-bromobutane  | should be <b>2-bromo-3-methylbutane</b>                            |
| 2-methylbut-3-ene       | should be <b>3-methylbut-1-ene</b>                                 |
| difluorodichloromethane | should be <b>dichlorodifluoromethane</b>                           |

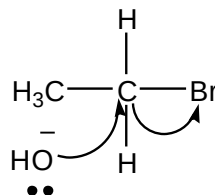
**3.14 Organic reaction mechanisms**

Curly arrows should originate either from a lone pair of electrons or from a bond.

**The following representations** should not gain credit **and will be penalised each time** within a clip.



For example, the following would score zero marks



When the curly arrow is showing the formation of a bond to an atom, the arrow can go directly to the relevant atom, alongside the relevant atom or **more than half-way** towards the relevant atom.

In free-radical substitution

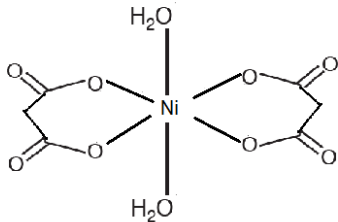
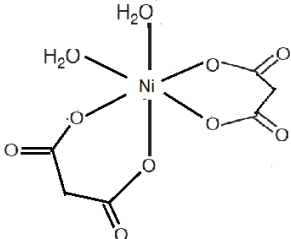
- the absence of a radical dot should be penalised **once only** within a clip.
- the use of half-headed arrows is not required, but the use of double-headed arrows or the incorrect use of half-headed arrows in free-radical mechanisms should be penalised **once only** within a clip

The correct use of skeletal formulae in mechanisms is acceptable, but where a C-H bond breaks both the bond and the H must be drawn to gain credit.

| Question | Marking guidance                                                                                                                       | Mark       | Comments                                                                                                                                                                                                                                                                  |
|----------|----------------------------------------------------------------------------------------------------------------------------------------|------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 01.1     | $P_4 + 5O_2 \rightarrow P_4O_{10}$                                                                                                     | 1          | allow multiples or fractions<br>ignore state symbol<br><br>allow<br>$4P + 5O_2 \rightarrow P_4O_{10}$<br>reject any formula for phosphorous that is not P or $P_4$                                                                                                        |
| 01.2     | Formulae:<br>$H_2SO_3$ <b>AND</b> $H_2SO_4$<br><br>pH values<br>$SO_2$ any in range 2 to 5<br><b>AND</b><br>$SO_3$ any in range 0 to 1 | 1<br><br>1 | If no mark awarded then award 1 mark for correct formula<br><b>and</b> pH for one oxide                                                                                                                                                                                   |
| 01.3     | $Al_2O_3 + 2NaOH + 3H_2O \rightarrow 2NaAl(OH)_4$                                                                                      | 1          | ignore state symbols<br>Allow any of:<br>$Al_2O_3 + 2OH^- + 3H_2O \rightarrow 2Al(OH)_4^-$<br>$Al_2O_3 + 6OH^- + 3H_2O \rightarrow 2Al(OH)_6^{3-}$<br>$Al_2O_3 + 6NaOH + 3H_2O \rightarrow 2Na_3Al(OH)_6$<br><br>Reject reactions with carbonates and hydrogen carbonates |

|       |                                                                                                                                                                                                                                                                                                                                                                                        |                                     |                                                                                                                                                                                                                                                                                                                                                           |
|-------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 01.4  | <p><b>M1</b> SiO<sub>2</sub> giant (lattice) and covalent</p> <p><b>M2</b> strong (covalent) bonds (between atoms) / require lots of energy to overcome - break</p> <p><b>M3</b> SiCl<sub>4</sub> (simple) molecular</p> <p><b>M4</b> weak forces between molecules / weak van der Waal's forces / weak intermolecular forces<br/><b>and</b><br/>require little energy to overcome</p> | <p>1</p> <p>1</p> <p>1</p> <p>1</p> | <p>Allow “macromolecular” for “giant lattice” and “giant covalent” for M1</p> <p>If SiO<sub>2</sub> is not covalent, lose M2</p> <p>if breaking covalent bonds in SiCl<sub>4</sub> then do not award M4</p> <p>If SiO<sub>2</sub> stated as not covalent, do not award M1 or M2<br/>If SiCl<sub>4</sub> stated as not covalent, do not award M3 or M4</p> |
| Total |                                                                                                                                                                                                                                                                                                                                                                                        | 8                                   |                                                                                                                                                                                                                                                                                                                                                           |

| Question | Marking guidance                                                                                                                                                                                                  | Mark   | Comments                                                             |
|----------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------|----------------------------------------------------------------------|
| 02.1     | <b>equation 1:</b> $2\text{Fe}^{2+} + \text{S}_2\text{O}_8^{2-} \rightarrow 2\text{Fe}^{3+} + 2\text{SO}_4^{2-}$<br><b>equation 2:</b> $2\text{Fe}^{3+} + 2\text{I}^- \rightarrow 2\text{Fe}^{2+} + \text{I}_2$   | 1<br>1 | allow one mark for two correct equations in wrong order              |
| 02.2     | <b>M1</b> (iron(II) in) <u>haemoglobin</u><br><b>M2</b> co-ordinate bond forms between oxygen and iron(II)                                                                                                        | 1<br>1 | Allow $\text{Fe}^{2+}$                                               |
| 02.3     | CO takes the place of $\text{O}_2$<br>in haemoglobin <b>OR</b> joined to $\text{Fe}^{2+}$                                                                                                                         | 1      | ignore statement of formation of carboxyhaemoglobin                  |
| 02.4     | <b>M1</b> brown precipitate<br><b>M2</b><br>$2[\text{Fe}(\text{H}_2\text{O})_6]^{3+} + 3\text{CO}_3^{2-} \rightarrow 2\text{Fe}(\text{OH})_3(\text{H}_2\text{O})_3 + 3\text{CO}_2 + 3\text{H}_2\text{O}$          | 1<br>1 |                                                                      |
| 02.5     | <b>M1</b> $\text{Fe}^{3+}$ is highly charged <b>OR</b> high charge:size ratio<br><br><b>M2</b> (this pulls electron density out of the O-H bond and) weakens the O-H bond so $\text{H}^+$ ions are (readily) lost | 1<br>1 | allow $\text{Fe}^{3+}$ is highly polarising<br>Allow "larger charge" |
| Total    |                                                                                                                                                                                                                   | 9      |                                                                      |

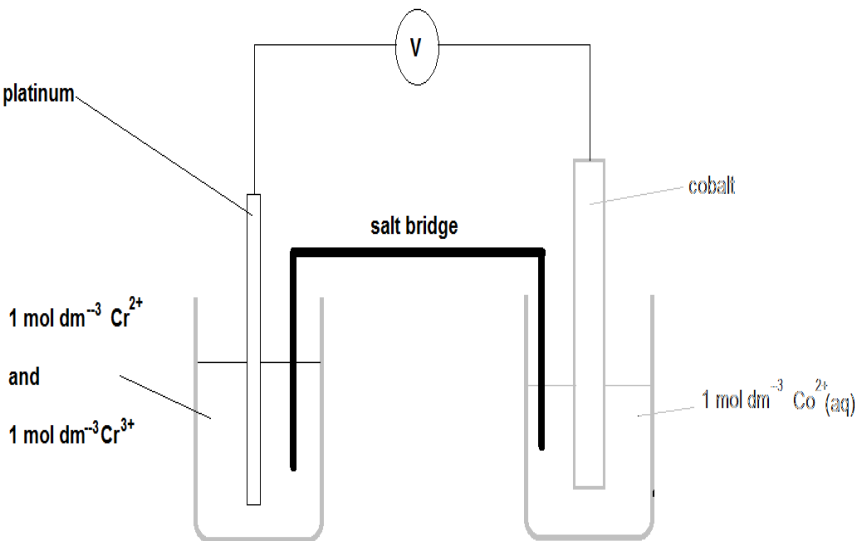
| Question                                                                           | Marking guidance                                                                                                  | Mark | Comments |       |   |         |   |   |  |
|------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------|------|----------|-------|---|---------|---|---|--|
| 03.1                                                                               | M1 donates an electron pair (to a metal atom/ion) from two different atoms                                        | 1    |          |       |   |         |   |   |  |
| 03.2                                                                               |                                  | 1    |          |       |   |         |   |   |  |
|                                                                                    | <table><tr><td>cis</td><td></td></tr><tr><td>trans</td><td>✓</td></tr><tr><td>optical</td><td></td></tr></table>  | cis  |          | trans | ✓ | optical |   | 1 |  |
|                                                                                    | cis                                                                                                               |      |          |       |   |         |   |   |  |
|                                                                                    | trans                                                                                                             | ✓    |          |       |   |         |   |   |  |
| optical                                                                            |                                                                                                                   |      |          |       |   |         |   |   |  |
|  | 1                                                                                                                 |      |          |       |   |         |   |   |  |
|                                                                                    | <table><tr><td>cis</td><td>✓</td></tr><tr><td>trans</td><td></td></tr><tr><td>optical</td><td>✓</td></tr></table> | cis  | ✓        | trans |   | optical | ✓ | 1 |  |
| cis                                                                                | ✓                                                                                                                 |      |          |       |   |         |   |   |  |
| trans                                                                              |                                                                                                                   |      |          |       |   |         |   |   |  |
| optical                                                                            | ✓                                                                                                                 |      |          |       |   |         |   |   |  |
| Total                                                                              |                                                                                                                   | 5    |          |       |   |         |   |   |  |

| Question | Marking guidance                                                                                                                                                | Mark   | Comments                                                                                                      |
|----------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------|--------|---------------------------------------------------------------------------------------------------------------|
| 04.1     | $(5\text{FeC}_2\text{O}_4 + 3\text{MnO}_4^-) + 24\text{H}^+ \rightarrow 10\text{CO}_2 + 3\text{Mn}^{2+} + 12\text{H}_2\text{O} + 5\text{Fe}^{3+}$               | 1      |                                                                                                               |
| 04.2     | the reaction is slow (at room temperature)                                                                                                                      | 1      | allow the activation energy is high<br>allow “to increase the rate of the reaction”<br>reject to remove water |
| 04.3     | <b>M1</b> no effect<br><b>M2</b> moles of iron(II) ethanedioate do not change                                                                                   | 1<br>1 | If <b>M1</b> incorrect, CE = 0/2<br>allow only water lost                                                     |
| 04.4     | <b>Explanation</b> when all of the iron(II) ethanedioate has reacted<br>manganate(VII) remains unreacted <b>OR</b> self indicating<br><b>Colour</b> (pale) pink | 1<br>1 | ignore purple                                                                                                 |

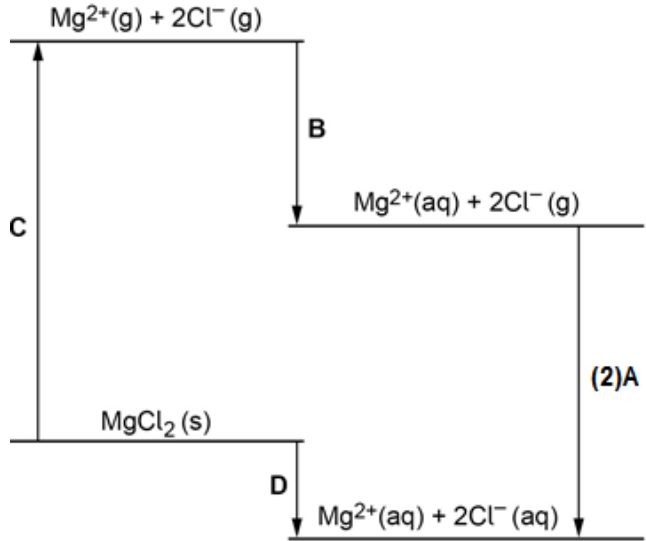


|       |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                                              |                                                                                                                                                                                                                                                                                            |
|-------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 04.5  | <p><b>M1</b> amount <math>\text{MnO}_4^-</math> (<math>= 6.40 \times 10^{-3} \times 12.45/1000</math>) <math>= 7.968 \times 10^{-5}</math> mol</p> <p><b>M2</b> amount <math>\text{FeC}_2\text{O}_4</math> (<math>= 7.968 \times 10^{-5} \times 5/3</math>) <math>= 1.328 \times 10^{-4}</math> mol</p> <p><b>M3</b> = amount <math>\text{FeC}_2\text{O}_4</math> in <math>1 \text{ dm}^3</math> (<math>= 1.328 \times 10^{-4} \times 1000/25</math>) <math>= 5.312 \times 10^{-3}</math> mol</p> <p><b>M4</b> solubility <math>= 5.312 \times 10^{-3} \times 179.8</math></p> <p><b>M5</b> = <u>0.955</u> (<math>\text{g dm}^{-3}</math>)</p> <p>OR</p> <p><b>M1</b> amount <math>\text{MnO}_4^-</math> (<math>= 6.40 \times 10^{-3} \times 12.45/1000</math>) <math>= 7.968 \times 10^{-5}</math> mol</p> <p><b>M2</b> amount <math>\text{FeC}_2\text{O}_4</math> (<math>= 7.968 \times 10^{-5} \times 5/3</math>) <math>= 1.328 \times 10^{-4}</math> mol</p> <p><b>M3</b> mass <math>\text{FeC}_2\text{O}_4</math> <math>= (1.328 \times 10^{-4} \times 179.8) = 0.02388</math></p> <p><b>M4</b> solubility <math>= 0.02388 \times 1000/25</math></p> <p><b>M5</b> = <u>0.955</u> (<math>\text{g dm}^{-3}</math>)</p> | <p>1</p> <p>1</p> <p>1</p> <p>1</p> <p>1</p> | <p>M2=M1 <math>\times</math> 5/3</p> <p>M3 = M2 <math>\times</math> 40</p> <p>M4 = M3 <math>\times</math> 179.8</p> <p>If arithmetic error only, allow max 4/5</p><br><p>M2 =M1 <math>\times</math> 5/3</p> <p>M3 = M2 <math>\times</math> 179.8</p> <p>M4 = M3 <math>\times</math> 40</p> |
| 04.6  | <p><b>M1</b> (make up solutions of known concentrations and) find absorbance of known concentrations</p> <p><b>M2</b> read concentration of unknown from calibration graph</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | 2                                            |                                                                                                                                                                                                                                                                                            |
| Total |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | 13                                           |                                                                                                                                                                                                                                                                                            |

| Question | Marking guidance                                                                                                                                                                                                                                                                                                          | Mark   | Comments                                                                                                                                         |
|----------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------|--------------------------------------------------------------------------------------------------------------------------------------------------|
| 05.1     | $K_p = \frac{p \text{ CH}_3\text{OH}}{p \text{ CO} \times (p \text{ H}_2)^2}$                                                                                                                                                                                                                                             | 1      | ignore curved brackets, do not accept [ ]<br>allow $p^2 \text{ H}_2$ etc.                                                                        |
| 05.2     | kPa <sup>-2</sup> (second box)                                                                                                                                                                                                                                                                                            | 1      |                                                                                                                                                  |
| 05.3     | <b>M1</b> (forward) reaction is exothermic<br><br><b>M2</b> Equilibrium moves left to give out heat <b>OR</b> position of equilibrium moves left to reduce the temperature/oppose the increase in temperature                                                                                                             | 1      | allow equilibrium moves in endothermic direction                                                                                                 |
|          |                                                                                                                                                                                                                                                                                                                           | 1      | Not just 'oppose the change'                                                                                                                     |
| 05.4     | moles hydrogen = 2(.0)<br>moles CH <sub>3</sub> OH = 14(.0)                                                                                                                                                                                                                                                               | 1<br>1 |                                                                                                                                                  |
| 05.5     | <b>M1</b> mole fractions of all three gases<br>CO = 0.2727...; H <sub>2</sub> = 0.0909....; CH <sub>3</sub> OH = 0.6363....<br><br><b>M2</b> partial pressures of all three gases<br>CO = 1363.63...kPa H <sub>2</sub> = 454.545... kPa CH <sub>3</sub> OH = 3181.81.... kPa<br><br><b>M3</b> $K_p = 1.13 \times 10^{-5}$ | 1      | fall back values give:<br><b>M1</b> mole fractions of all three gases<br>CO = 0.2727...; H <sub>2</sub> = 0.363636 CH <sub>3</sub> OH = 0.363636 |
|          |                                                                                                                                                                                                                                                                                                                           | 1      | <b>M2</b> partial pressures of all three gases<br>CO = 1363(.63 .kPa H <sub>2</sub> = 1818(.18) kPa<br>CH <sub>3</sub> OH=1818(.18) kPa          |
|          |                                                                                                                                                                                                                                                                                                                           | 1      | <b>M3</b> $K_p = 4.03 \times 10^{-7}$                                                                                                            |
| Total    |                                                                                                                                                                                                                                                                                                                           | 9      |                                                                                                                                                  |

| Question | Marking guidance                                                                                                                                                                                                                                                                                                                                                             | Mark | Comments                                                                                                                                                                                |
|----------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 06.1     | Temperature: 298 K <b>OR</b> 25 °C<br><b>AND</b><br>Pressure 100 kPa                                                                                                                                                                                                                                                                                                         | 1    | ignore 1 atmos<br>reject 101kPa                                                                                                                                                         |
| 06.2     |  <p> <b>M1</b> labelled salt bridge<br/> <b>M2</b> left hand solution contains both 1 mol dm<sup>-3</sup> Cr<sup>2+</sup> and 1 mol dm<sup>-3</sup> Cr<sup>3+</sup><br/> <b>M3</b> platinum electrode on left<br/> <b>M4</b> electrodes connected using a voltmeter.                 </p> | 4    | <p>for M1 allow a description of a salt bridge</p> <p>M2 allow equimolar, Ignore solubility of any compounds. allow missing concentration but do not allow incorrect concentrations</p> |

|                                 |                                                                                                                                                                                              |           |                                                                                      |
|---------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------|--------------------------------------------------------------------------------------|
| <b>06.3</b>                     | Platinum<br><b>AND</b><br>(Cr <sup>3+</sup> /Cr <sup>2+</sup> half cell) has more negative (standard) electrode potential<br>(and so is better reducing agent)                               | 1         | allow Chromium / left-hand side                                                      |
| <b>06.4</b>                     | 0.13(V)                                                                                                                                                                                      | 1         |                                                                                      |
| <b>06.5</b><br>clip with<br>6.3 | Pt Cr <sup>2+</sup> (aq),Cr <sup>3+</sup> (aq)    Co <sup>2+</sup> (aq)  Co(s)                                                                                                               | 1         | allow reverse if Cobalt identified as negative electrode.<br>state symbols required. |
| <b>06.6</b>                     | <b>M1</b> as oxidising agent<br>2Cr <sup>3+</sup> (aq) + Mg(s) → 2Cr <sup>2+</sup> (aq) + Mg <sup>2+</sup> (aq)                                                                              | 1         | ignore state symbols throughout this part                                            |
|                                 | <b>M2</b> as a reducing agent<br>2Cr <sup>3+</sup> (aq) + H <sub>2</sub> O(l) + 6HCl(aq) + → Cr <sub>2</sub> O <sub>7</sub> <sup>2-</sup> (aq) + 8H <sup>+</sup> (aq) + 3I <sub>2</sub> (aq) | 1         | Allow 1 mark for both equations correct but in wrong order                           |
| <b>Total</b>                    |                                                                                                                                                                                              | <b>10</b> |                                                                                      |

| Question | Marking guidance                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | Mark             | Comments                                                          |
|----------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------|-------------------------------------------------------------------|
| 07.1     | (Enthalpy change when) 1 mole of gaseous ions (dissolve in water) to form 1 mole of aqueous ions.                                                                                                                                                                                                                                                                                                                                                                                                                  | 1                | 1 mole need only be mentioned once                                |
| 07.2     |  <p> <b>M1</b> <math>\text{Mg}^{2+}(\text{g}) + 2\text{Cl}^{-}</math><br/> <b>M2</b> <math>\text{Mg}^{2+}(\text{aq}) + 2\text{Cl}^{-}(\text{g})</math> <b>OR</b> <math>\text{Mg}^{2+}(\text{g}) + 2\text{Cl}^{-}(\text{aq})</math><br/> <b>M3</b> <math>\text{Mg}^{2+}(\text{aq}) + 2\text{Cl}^{-}(\text{aq})</math><br/> <b>M4</b> <b>A</b>, <b>B</b> and <b>D</b> labels, B and A may be either way round                 </p> | 1<br>1<br>1<br>1 | full marks can only be awarded if species match letters of steps. |

|              |                                                                                 |           |                                                                         |
|--------------|---------------------------------------------------------------------------------|-----------|-------------------------------------------------------------------------|
| <b>07.3</b>  | $-155 = 2493 + X + (2 \times -364)$<br>OR<br>$X = -155 - 2493 + (2 \times 364)$ | 1         | If the “2x” is missing, then CE=0                                       |
|              | enthalpy of hydration = $-1920 \text{ kJ mol}^{-1}$                             | 1         |                                                                         |
| <b>07.4</b>  | <b>M1</b> amount $\text{MgCl}_2 (= 10.0 / 95.3) = 0.1049317\text{mol}$          | 1         | M2 = M1 x 155<br><br>M3 = their Q over mc<br><br>accept 3 sig figs only |
|              | <b>M2</b> $q = (0.1049317 \times 155) = 16.264428 \text{ kJ}$                   | 1         |                                                                         |
|              | <b>M3</b> $\Delta T = 16264.4286 / (150 \times 4.18) = 25.94\dots$              | 1         |                                                                         |
|              | <b>M4</b> max temp = $25.94 + 20.0 = 45.94\dots = 45.9^\circ\text{C}$           | 1         |                                                                         |
| <b>Total</b> |                                                                                 | <b>11</b> |                                                                         |

| Question | Marking guidance                                                                                                                                     | Mark                           | Comments                                                                                                                                          |
|----------|------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------|
| 08.1     | $[H^+] = \sqrt{5.48 \times 10^{-14}} = 2.34 \times 10^{-7}$<br>$pH = -\log_{10} 2.34 \times 10^{-7} = 6.63$                                          | 1<br>1                         |                                                                                                                                                   |
| 08.2     | $[H^+] = [OH^-]$                                                                                                                                     | 1                              |                                                                                                                                                   |
| 08.3     | pH changes by only a small amount <b>OR</b> pH is approximately constant<br><b>and</b><br>when a <u>small</u> amount of acid or base/alkali is added | 1                              | do not allow “stays constant” or “does not change”<br>Allow “or the solution diluted”<br>Allow resist change in pH / stays approximately the same |
| 08.4     | <b>M1</b><br>$[H^+] = K_a \times [acid]/[salt]$<br><b>OR</b><br>$[H^+] = 1.35 \times 10^{-5} \times 0.500/1.00$<br><br><b>M2</b><br>$pH = 5.17$      | 1<br><br><br><br><br><br><br>1 | or $pH = pK_a + \log [salt]/[acid]$<br><br>allow $[H^+] = 1.35 \times 10^{-5} \times 0.100 / 0.200$<br><br>answer must be to 2 dp                 |

|       |                                                                                                |   |  |
|-------|------------------------------------------------------------------------------------------------|---|--|
| 08.5  | <b>M1</b><br>amount acid left = $0.100 - 0.020 = 0.080$ mol                                    | 1 |  |
|       | <b>M2</b><br>amount salt = $0.200 + 0.020 = 0.220$ mol                                         | 1 |  |
|       | <b>M3</b><br>$[H^+] = 1.35 \times 10^{-5} \times (0.080/0.220) / (0.220 / 0.220)$<br>pH = 5.31 | 1 |  |
| Total |                                                                                                | 9 |  |



| Question | Marking guidance                                                                                                                                | Mark | Comments                                                                                                           |
|----------|-------------------------------------------------------------------------------------------------------------------------------------------------|------|--------------------------------------------------------------------------------------------------------------------|
| 09.1     | <b>M1</b> $(2 \times 12) + (3 \times -394) - ((3 \times -111) + -822)$ <b>OR</b> correct Hess cycle                                             | 1    | Allow 1 mark for (+)3                                                                                              |
|          | <b>M2</b> $-3 \text{ (kJ mol}^{-1}\text{)}$                                                                                                     | 1    |                                                                                                                    |
| 09.2     | <b>M1</b> $(2 \times 35) + (3 \times 214) - (3 \times 198) - 90$ <b>OR</b> $\sum \text{entropy of products} - \sum \text{entropy of reactants}$ | 1    |                                                                                                                    |
|          | <b>M2</b> $(+28 \text{ J K}^{-1} \text{ mol}^{-1})$                                                                                             | 1    |                                                                                                                    |
| 09.3     | <b>M1</b> as temperature increases $T\Delta S$ gets bigger <b>or</b> more positive                                                              | 1    | allow becomes “more feasible or feasibility increases” for becomes feasible<br>An explanation is required to score |
|          | <b>M2</b> When $T\Delta S$ is $> \Delta H$ , $\Delta G$ becomes negative and so reaction becomes feasible.                                      | 1    |                                                                                                                    |
| Total    |                                                                                                                                                 | 6    |                                                                                                                    |