

**AS  
CHEMISTRY  
7404/2**

Paper 2 Organic and Physical Chemistry

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**Mark scheme**

June 2021

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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 Examiner.

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)

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## AS and 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 (ie 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, eg 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, eg 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.

|             |             |             |             |             |
|-------------|-------------|-------------|-------------|-------------|
|             |             |             |             |             |
| allowed     | allowed     | not allowed | not allowed | not allowed |
|             |             |             |             |             |
| allowed     | allowed     | allowed     | allowed     | not allowed |
|             |             |             |             |             |
| not allowed | not allowed | not allowed | not allowed | not allowed |
|             |             |             |             |             |
| not allowed | not allowed | not allowed | not allowed | not allowed |

- Representation of  $\text{CH}_2$  by  $\text{C}-\text{H}_2$  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  |
| $\text{CH}_2.\text{CH}_2$         | 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 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 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.

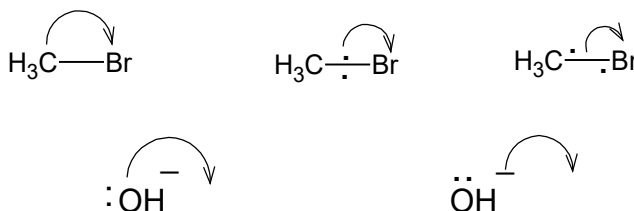
Unnecessary but not wrong numbers will **not** be penalised such as the number ‘2’ in 2-methylpropane or the number ‘1’ in 2-chlorobutan-1-oic acid.

|                         |                                                                    |
|-------------------------|--------------------------------------------------------------------|
| 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>                           |

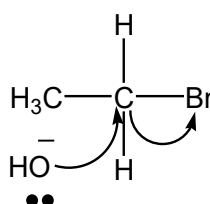
**3.14 Organic reaction mechanisms**

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.

**3.15 Extended responses**

**For questions marked using a 'Levels of Response' mark scheme:**

Level of response mark schemes are broken down into three levels, each of which has a descriptor. Each descriptor contains two statements. The first statement is the Chemistry content statement and the second statement is the communication statement.

**Determining a level**

Start at the lowest level of the mark scheme and use it as a ladder to see whether the answer meets the Chemistry content descriptor for that level. The descriptor for the level indicates the qualities that might be seen in the student's answer for that level. If it meets the lowest level, then go to the next one and decide if it meets this level, and so on, until you have a match between the level descriptor and the answer.

When assigning a level you should look at the overall quality of the answer and not look to pick holes in small and specific parts of the answer where the student has not performed quite as well as the rest. If the answer covers different aspects of different levels of the mark scheme you should use a best fit approach for defining the level.

Once the level has been decided, the mark within the level is determined by the communication statement:

- If the answer completely matches the communication descriptor, award the higher mark within the level.
- If the answer does not completely match the communication descriptor, award the lower mark within the level.

The exemplar materials used during standardisation will help you to determine the appropriate level. There will be an exemplar in the standardising materials which will correspond with each level of the mark scheme and for each mark within each level. This answer will have been awarded a mark by the Lead Examiner. You can compare the student's answer with the exemplar to determine if it is the same standard, better or worse than the example. You can then use this to allocate a mark for the answer based on the Lead Examiner's mark on the exemplar.

You may well need to read back through the answer as you apply the mark scheme to clarify points and assure yourself that the level and the mark are appropriate.

Indicative content in the mark scheme is provided as a guide for examiners. It is not intended to be exhaustive and you must credit other chemically valid points. Students may not have to cover all of the points mentioned in the indicative content to reach the highest level of the mark scheme. The mark scheme will state how much chemical content is required for the highest level.

An answer which contains nothing of relevance to the question must be awarded no marks.

**For other extended response answers:**

Where a mark scheme includes linkage words (such as 'therefore', 'so', 'because' etc), these are optional. However, a student's marks for the question may be limited if they do not demonstrate the ability to construct and develop a sustained line of reasoning which is coherent, relevant, substantiated and logically structured. In particular answers in the form of bullet pointed lists may not be awarded full marks if there is no indication of logical flow between each point or if points are in an illogical order.

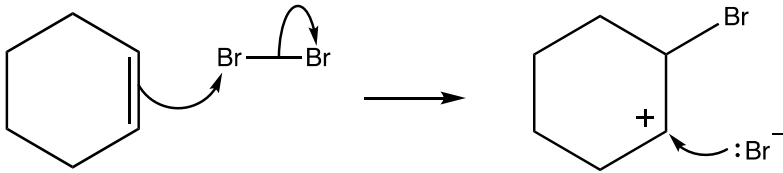
The mark schemes for some questions state that the maximum mark available for an extended response answer is limited if the answer is not coherent, relevant, substantiated and logically structured. During the standardisation process, the Lead Examiner will provide marked exemplar material to demonstrate answers which have not met these criteria. You should use these exemplars as a comparison when marking student answers.

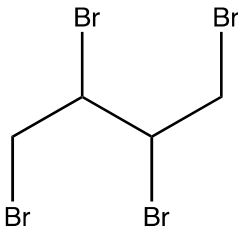
| Question | Marking guidance                               | Additional Comments/Guidelines                                                | Mark |
|----------|------------------------------------------------|-------------------------------------------------------------------------------|------|
| 01.1     | Number of molecules (with a particular energy) | Ignore particles / atoms<br>Allow amount or fraction or proportion for number | 1    |

| Question | Marking guidance                      | Additional Comments/Guidelines                                        | Mark |
|----------|---------------------------------------|-----------------------------------------------------------------------|------|
| 01.2     | There are no molecules with no energy | All molecules / particles have some energy<br>Allow particles / atoms | 1    |

| Question | Marking guidance                      | Additional Comments/Guidelines | Mark |
|----------|---------------------------------------|--------------------------------|------|
| 01.3     | Most probable / common / modal energy |                                | 1    |

| Question | Marking guidance                                                                                                                          | Additional Comments/Guidelines                      | Mark |
|----------|-------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------|------|
| 01.4     | <b>M1</b> Peak should be at same energy (i.e. in line with X)                                                                             | <b>M1</b> and <b>M2</b> marked independently        | 1    |
|          | <b>M2</b> Overall area should be half the original area; after diverging from the origin, the second line should not touch the first line | <b>M2</b> area should be about half of the original | 1    |

| Question | Marking guidance                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | Additional Comments/Guidelines                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | Mark                                         |
|----------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------|
| 02.1     | <p><b>M1</b> electrophilic addition</p>  <p><b>M2</b> must show an arrow from the double bond towards a Br atom in a Br–Br molecule</p> <p><b>M3</b> must show the breaking of the Br–Br bond</p> <p><b>M4</b> is for the structure of the correct carbocation</p> <p><b>M5</b> must show an arrow from the lone pair of electrons on the Br<sup>–</sup> towards the positively charged atom of <u>their</u> carbocation</p> | <p>All arrows are double-headed. Penalise one mark from the total for <b>M2-5</b> if half headed arrows are used.</p> <p>Do not penalise the “correct” use of “sticks”</p> <p>Penalise only once in any part of the mechanism for a line and two dots to show a bond</p> <p><b>M2</b> ignore partial negative charges on the double bond</p> <p><b>M3</b> penalise incorrect partial charges on the Br–Br bond and penalise formal charges</p> <p>Penalise <b>M4</b> if there is a bond drawn to the positive charge</p> <p><b>Max 3 of 4 marks (M2-5)</b> for wrong organic reactant or wrong carbocation (ignore structure of product)</p> <p>For <b>M5</b>, credit attack on a partially positively charged carbocation structure, but penalise <b>M4</b> for the structure of the carbocation</p> | <p>1</p> <p>1</p> <p>1</p> <p>1</p> <p>1</p> |
| Question | Marking guidance                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | Additional Comments/Guidelines                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | Mark                                         |
| 02.2     | <p><b>M1</b> C=C electron rich / area of high electron density</p> <p><b>M2</b> Br-Br becomes polarised</p> <p><b>M3</b> δ+ Br attracted to C=C</p>                                                                                                                                                                                                                                                                                                                                                            | <p><b>M1</b> ignore idea that C=C is negative or highly electronegative</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | <p>1</p> <p>1</p> <p>1</p>                   |

| Question | Marking guidance                                                                  | Additional Comments/Guidelines | Mark |
|----------|-----------------------------------------------------------------------------------|--------------------------------|------|
| 02.3     |  | Must be skeletal structure     | 1    |

| Question | Marking Guidance                                                                                                                                 |                                                                                                                                                                                                                                                                                                                                                                                                                  | Additional Comments/Guidelines                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | Mark |
|----------|--------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|
| 03.1     | This question is marked using levels of response. Refer to the Mark Scheme Instructions for Examiners for guidance on how to mark this question. |                                                                                                                                                                                                                                                                                                                                                                                                                  | <b>Stage 1</b><br>Anti-bumping granules<br>1a no anti-bumping granules / add anti-bumping granules<br>1b to create smaller bubbles / to prevent large bubbles / to prevent mixture jumping into condenser<br><br><b>Stage 2</b><br>Open system with no thermometer<br>2a system should be closed (above flask) to prevent gases escaping<br>2b should be closed with (bung +) thermometer<br>2c to allow collection of propanone (only) / to prevent distillation of other components / to stay in suitable temperature range<br><br><b>Stage 3</b><br>The water direction in the condenser<br>3a water flows in wrong direction through condenser / change water direction<br>3b condenser not cool enough / not full of water<br>3c product may not condense / comes through as gas | 6    |
|          | <b>Level 3<br/>(5–6 marks)</b>                                                                                                                   | <b>All stages are covered and each stage is generally correct and virtually complete</b><br><br>(6 v 5) Answer is well structured, with no repetition or irrelevant points, and covers all aspects of the question. Accurate and clear expression of ideas with no errors in use of technical terms.                                                                                                             |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |      |
|          | <b>Level 2<br/>(3–4 marks)</b>                                                                                                                   | <b>All stages are covered but stage(s) may be incomplete or may contain inaccuracies OR two stages are covered and are generally correct and virtually complete</b><br><br>(4 v 3) Answer has some structure and covers most aspects of the question. Ideas are expressed with reasonable clarity with, perhaps, some repetition or some irrelevant points. If any, only minor errors in use of technical terms. |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |      |
|          | <b>Level 1<br/>(1–2 marks)</b>                                                                                                                   | <b>Two stages are covered but stage(s) may be incomplete or may contain inaccuracies OR only one stage is covered but is generally correct and virtually complete</b><br><br>(2 v 1) Answer includes statements which are presented in a logical order and/or linked.                                                                                                                                            |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |      |
|          | <b>0 marks</b>                                                                                                                                   | Insufficient correct chemistry to gain a mark.                                                                                                                                                                                                                                                                                                                                                                   |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |      |

| Question | Marking guidance                                                                       | Additional Comments/Guidelines                                                        | Mark |
|----------|----------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------|------|
| 03.2     | <b>M1</b> mass of propan-2-ol = $2.0 \times 0.786$ (= 1.572 g to at least 2sf)         | <b>Alternative for M3/4</b>                                                           | 1    |
|          | <b>M2</b> amount of propan-2-ol = $\frac{1.572}{60.0}$ (= 0.0262 to at least 2 sf) mol | <b>M3</b> amount of propanone formed = $\frac{0.954}{58.0}$ (= 0.0164) mol            | 1    |
|          | <b>M3</b> mass of propanone expected = $0.0262 \times 58.0$ (= 1.52 g to at least 2sf) | <b>M4</b> % yield = $\left(\frac{0.0164}{0.0262} \times 100\right) = 63\%$ (2sf only) | 1    |
|          | <b>M4</b> % yield = $\left(\frac{0.954}{1.52} \times 100\right) = 63\%$ (2sf only)     | Allow ECF at each step                                                                | 1    |

| Question | Marking guidance                                     | Additional Comments/Guidelines                                                   | Mark |
|----------|------------------------------------------------------|----------------------------------------------------------------------------------|------|
| 03.3     | <b>M1</b> propan-2-ol: tetrahedral and $109.5^\circ$ | <b>M1</b> allow $104\text{--}110^\circ$                                          | 1    |
|          | <b>M2</b> propanone: trigonal planar and $120^\circ$ | <b>M2</b> allow $115\text{--}123^\circ$<br>Any two correct boxes scores one mark | 1    |

| Question | Marking guidance                                                          | Additional Comments/Guidelines                                                                             | Mark |
|----------|---------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------|------|
| 03.4     | <b>M1</b> propan-2-ol has stronger intermolecular forces                  | Penalise <b>M1</b> and <b>M2</b> for any reference to breaking covalent bonds, (but <b>M3</b> could score) | 1    |
|          | <b>M2</b> propan-2-ol has hydrogen bonds between molecules                | For <b>M2</b> ignore reference to dipole-dipole forces in propan-2-ol                                      | 1    |
|          | <b>M3</b> propanone has dipole-dipole forces and/or van der Waals' forces |                                                                                                            | 1    |

| Question | Marking guidance       | Additional Comments/Guidelines | Mark |
|----------|------------------------|--------------------------------|------|
| 04.1     | trichlorofluoromethane |                                | 1    |

| Question | Marking guidance | Additional Comments/Guidelines                                                                                        | Mark |
|----------|------------------|-----------------------------------------------------------------------------------------------------------------------|------|
| 04.2     |                  | $\text{CCl}_3\text{F} \rightarrow \cdot\text{CCl}_2\text{F} + \cdot\text{Cl}$<br>radical dot anywhere on each radical | 1    |

| Question | Marking guidance                                                                                               | Additional Comments/Guidelines                                                                                    | Mark |
|----------|----------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------|------|
| 04.3     | <b>M1</b> amount of CFC-11 = $\frac{500}{137.5}$ (= 3.64) mol                                                  | Allow ECF from <b>M1</b> to <b>M2</b>                                                                             | 1    |
|          | <b>M2</b> molecules of O <sub>3</sub> = 3.64 x 100,000 x 6.022 x 10 <sup>23</sup><br>= 2.19 x 10 <sup>29</sup> | Allow answers in range 2 x 10 <sup>29</sup> to 2.20 x 10 <sup>29</sup> (1sf is acceptable as this is an estimate) | 1    |

| Question | Marking guidance                                       | Additional Comments/Guidelines                                             | Mark |
|----------|--------------------------------------------------------|----------------------------------------------------------------------------|------|
| 04.4     | Absorbs (harmful) ultraviolet / uv (light / radiation) | Protects us from (harmful) uv<br>Ignore other wavelengths / types of light | 1    |

| Question | Marking guidance                                                                                                                                                                                                                                                          | Additional Comments/Guidelines | Mark |
|----------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------|------|
| 04.5     | One of these reasons: <ul style="list-style-type: none"> <li>• lack of evidence that ozone was being depleted</li> <li>• lack of alternatives to CFCs</li> <li>• commercial interest to continue to use CFCs</li> <li>• hard to obtain international agreement</li> </ul> |                                | 1    |

| Question | Marking guidance                     | Additional Comments/Guidelines      | Mark |
|----------|--------------------------------------|-------------------------------------|------|
| 04.6     | <b>M1</b> absorbs infrared radiation | <b>M1</b> idea of IR being taken in | 1    |
|          | <b>M2</b> molecule has polar bonds   | <b>M2</b> accept polar molecule     | 1    |

| Question | Marking guidance                                                                                     | Additional Comments/Guidelines                                                                                      | Mark |
|----------|------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------|------|
| 05.1     | <b>Step 1</b>                                                                                        | For each step the two marks are independent                                                                         |      |
|          | <b>M1</b> fractional distillation                                                                    |                                                                                                                     | 1    |
|          | <b>M2</b> separated into mixtures of compounds with similar boiling points / similar sized molecules | <b>M2</b> to separate naphtha from other compounds;<br>to separate compounds by chain length / size / boiling point | 1    |
|          | <b>Step 2</b>                                                                                        |                                                                                                                     |      |
|          | <b>M3</b> (thermal) cracking                                                                         | <b>M3</b> not catalytic cracking                                                                                    | 1    |
|          | <b>M4</b> to make alkenes / propene / shorter molecules                                              |                                                                                                                     | 1    |
|          | <b>Step 3</b>                                                                                        |                                                                                                                     |      |
|          | <b>M5</b> (addition) polymerisation                                                                  | <b>M5</b> not condensation polymerisation                                                                           | 1    |
|          | <b>M6</b> molecules joined together or to produce long chain molecule                                |                                                                                                                     | 1    |

| Question | Marking guidance                      | Additional Comments/Guidelines                        | Mark |
|----------|---------------------------------------|-------------------------------------------------------|------|
| 05.2     | no polar bonds (in chain) / non-polar | Do not allow if only C-H bonds mentioned as non polar | 1    |

| Question | Marking guidance                                                                           | Additional Comments/Guidelines | Mark |
|----------|--------------------------------------------------------------------------------------------|--------------------------------|------|
| 05.3     | to prevent build-up of waste (in landfill) OR they can be broken down by natural processes |                                | 1    |

| Question | Marking guidance                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | Additional Comments/Guidelines                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | Mark                                         |
|----------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------|
| 06.1     | <p><b>METHOD 1</b></p> <p><b>Stage 1</b></p> <p><b>M1</b> <math>n = \frac{PV}{RT}</math></p> <p><b>M2</b> converting P to <math>51.0 \times 10^3</math>, V to <math>482 \times 10^{-6}</math></p> <p><b>M3</b> <math>= \frac{51.0 \times 10^3 \times 482 \times 10^{-6}}{8.31 \times 297}</math> (= 0.00996)</p> <p><b>Stage 2</b></p> <p><b>M4</b> converting mass to 0.717</p> <p><b>M5</b> <math>M_r \left( = \frac{\text{mass}}{\text{moles}} \right) = \frac{\text{M4}}{\text{M3}} = 72.0</math> (at least 2 sf)</p> <p><b>METHOD 2</b></p> <p><b>M1</b> <math>n = \frac{PV}{RT}</math></p> <p><b>M2</b> <math>M_r = \frac{mRT}{PV}</math></p> <p><b>M3</b> converting P to <math>51.0 \times 10^3</math>, V to <math>482 \times 10^{-6}</math></p> <p><b>M4</b> converting mass to 0.717</p> <p><b>M5</b> <math>M_r = \left( \frac{0.717 \times 8.31 \times 297}{51.0 \times 10^3 \times 482 \times 10^{-6}} \right) = 72.0</math> (at least 2 sf)</p> | <p><b>Both methods:</b></p> <p>72.0 can be achieved with incorrect working and may not score because individual steps need to be assessed as correct</p> <p>72.0 with no working scores no marks</p> <p>If expression not written out, <b>M1</b> could score from a substituted correct expression later on (even if any unit conversions are incorrect)</p> <p><b>METHOD 1</b></p> <ul style="list-style-type: none"> <li>• ECF from <b>M2</b> to <b>M3</b></li> <li>• ECF from <b>M3</b> to <b>M4</b></li> <li>• ECF from <b>M4</b> to <b>M5</b></li> <li>• Ignore units for <b>M3</b></li> </ul> <p><b>METHOD 2</b></p> <ul style="list-style-type: none"> <li>• ECF from <b>M3</b> to <b>M4</b></li> <li>• ECF from <b>M2</b> to <b>M4</b></li> <li>• ECF from <b>M4</b> to <b>M5</b></li> </ul> | <p>1</p> <p>1</p> <p>1</p> <p>1</p> <p>1</p> |

| Question | Marking guidance                                                                                                                                                      | Additional Comments/Guidelines        | Mark   |
|----------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------|--------|
| 06.2     | <b>M1</b> amount of CO <sub>2</sub> formed in flask = 0.008 mol<br><b>M2</b> amount of gas in flask<br>= 0.0075 (O <sub>2</sub> ) + 0.0080 ( <b>M1</b> ) = 0.0155 mol | Allow ECF from <b>M1</b> to <b>M2</b> | 1<br>1 |

| Question | Marking guidance          | Additional Comments/Guidelines | Mark |
|----------|---------------------------|--------------------------------|------|
| 07.1     | nucleophilic substitution |                                | 1    |

| Question | Marking guidance                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | Additional Comments/Guidelines                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | Mark                       |
|----------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------|
| 07.2     | <p><b>M1</b> elimination</p> <p> <math display="block">\text{H}-\ddot{\text{O}}-\text{CH}_2-\text{CH}_2-\text{CH}_2-\text{OH} \xrightarrow{\text{H}^+} \text{H}-\text{O}^+-\text{CH}_2-\text{CH}_2-\text{CH}_2-\text{OH} \xrightarrow{(-\text{H}_2\text{O})} \text{CH}_2=\text{CH}-\text{CH}_2-\text{OH} \xrightarrow{(-\text{H}^+)} \text{CH}_2=\text{CH}-\text{CH}_3</math> </p> <p><b>M2</b> arrow from lone pair on O to <math>\text{H}^+</math></p> <p><b>M3</b> 1<sup>st</sup> intermediate <b>and</b> arrow from <math>\text{C}-\text{O}^+\text{H}_2</math> bond to O</p> <p><b>M4</b> 2nd intermediate (carbocation) <b>and</b> arrow from a correct C–H bond to correct C–C to form <math>\text{C}=\text{C}</math></p> | <p><b>Max 2 of 3 marks (M2-4)</b> for wrong organic reactant (ignore structure of product)</p> <p><b>M3</b> and <b>M4</b> can be scored in one concurrent step:</p> <p><b>M3</b> for correct intermediate and arrow from <math>\text{C}-\text{O}^+\text{H}_2</math> bond to O</p> <p><b>M4</b> for arrow from a correct C–H bond to correct C–C to form <math>\text{C}=\text{C}</math></p> <p> <math display="block">\text{H}-\ddot{\text{O}}-\text{CH}_2-\text{CH}_2-\text{CH}_2-\text{OH} \xrightarrow{\text{H}^+} \text{H}-\text{O}^+-\text{CH}_2-\text{CH}_2-\text{CH}_2-\text{OH} \xrightarrow{(-\text{H}_2\text{O})} \text{CH}_2=\text{CH}-\text{CH}_2-\text{OH} \xrightarrow{(-\text{H}^+)} \text{CH}_2=\text{CH}-\text{CH}_3</math> </p> | <p>1</p> <p>1</p> <p>1</p> |

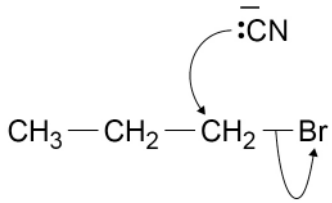
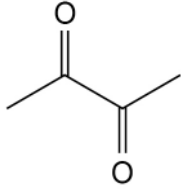
| Question | Marking guidance                                                                                                                                            | Additional Comments/Guidelines                                                   | Mark |
|----------|-------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------|------|
| 07.3     | $  \begin{array}{cc}  \text{H} & \text{H} \\    &   \\  -\text{C} & -\text{C}- \\    &   \\  \text{H} & \text{CH}_2 \\  &   \\  & \text{OH}  \end{array}  $ | <p>Any correct structural representation</p> <p>Ignore any brackets and/or n</p> | 1    |

| Question | Marking guidance                                                                                                                                                                                           | Additional Comments/Guidelines | Mark |
|----------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------|------|
| 07.4     | $  \begin{array}{ccccc}  & \text{H} & \text{H} & \text{O} & \\  &   &   &    & \\  \text{H} & -\text{C} & -\text{C} & -\text{C} & -\text{H} \\  &   &   & & \\  & \text{H} & \text{H} & &   \end{array}  $ | Structure in any form          | 1    |

| Question | Marking guidance                                        | Additional Comments/Guidelines | Mark |
|----------|---------------------------------------------------------|--------------------------------|------|
| 08.1     | <u>Heat</u> (energy) <u>change at constant pressure</u> | allow transfer for change      | 1    |

| Question | Marking guidance                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | Additional Comments/Guidelines                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | Mark                                |
|----------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------|
| 08.2     | <p><b>M1</b> correctly showing how many of which types of bonds are broken / made<br/> (broken) <math>2(\text{C}-\text{C}) + 8(\text{C}-\text{H}) + 5(\text{O}=\text{O})</math> (5776 + 2(C-C))<br/> (made) <math>6(\text{C}=\text{O}) + 8(\text{O}-\text{H})</math> (8162)</p> <p><b>M2</b> including 4(41) for vaporisation of water</p> <p><b>M3</b> <math>2(\text{C}-\text{C})</math><br/> <math>= 6(\text{C}=\text{O}) + 8(\text{O}-\text{H}) + 4(41) - 2046 - 8(\text{C}-\text{H}) - 5(\text{O}=\text{O})</math><br/> <math>= 6(743) + 8(463) + 4(41) - 2046 - 8(412) - 5(496)</math><br/> <math>= 504</math></p> <p><b>M4</b> <math>(\text{C}-\text{C}) = \frac{\text{M3}}{2} = 252 \text{ (kJ mol}^{-1}\text{)}</math></p> | <p>252 scores 4<br/> 170 scores 3 (omits vaporisation of water)<br/> 168 scores 3 (3 C-C bonds)<br/> 113 scores 2 (3 C-C bonds &amp; omits vaporisation of water)<br/> 88 scores 3 (vaporisation of water on wrong side)</p> <p><b>M1</b> is for identifying the number and type of bonds broken / made (does not have to explicit if they are broken or made, it is just which bonds and the number of each)</p> <p><b>M2</b> is for including 4(41) in some way in the calculation</p> <p><b>M3</b> is for calculating total for C-C bonds; allow 340 for 2 marks for omitting 4(41)</p> <p><b>M4</b> is for dividing their <b>M3</b> by two (ie allow ECF from <b>M3</b> to <b>M4</b>; ECF for 3(C-C) to divide their <b>M3</b> by three)</p> <p>Ignore units</p> | <p>1</p> <p>1</p> <p>1</p> <p>1</p> |

| Question | Marking guidance                                                | Additional Comments/Guidelines | Mark |
|----------|-----------------------------------------------------------------|--------------------------------|------|
| 08.3     | Oxygen / O <sub>2</sub> is the only substance that has O=O bond |                                | 1    |

| Question | Marking Guidance | Mark | Comments                                                                               |
|----------|------------------|------|----------------------------------------------------------------------------------------|
| 9        | B                | 1    | 4-methylpent-2-ene                                                                     |
| 10       | C                | 1    | $\text{C}_2\text{H}_4\text{O}_2$                                                       |
| 11       | B                | 1    | $1.74 \times 10^{-2}$                                                                  |
| 12       | D                | 1    | $\bullet\text{CH}_3 + \text{Cl}_2 \rightarrow \text{CH}_3\text{Cl} + \text{Cl}\bullet$ |
| 13       | B                | 1    | 3-methylhex-1-ene                                                                      |
| 14       | D                | 1    | butanenitrile                                                                          |
| 15       | B                | 1    |     |
| 16       | A                | 1    | 1-bromopropane, C–Br bond weaker than C–Cl bond                                        |
| 17       | A                | 1    |   |
| 18       | D                | 1    | $(\text{CH}_3)_2\text{CHCH}=\text{CH}_2$                                               |

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|    |   |   |                                                                    |
|----|---|---|--------------------------------------------------------------------|
| 19 | D | 1 | An increase in pressure increases the value of $K_c$               |
| 20 | C | 1 | The rate of the reverse reaction increases.                        |
| 21 | B | 1 |                                                                    |
| 22 | A | 1 | It can be removed from car exhaust gases by a catalytic converter. |
| 23 | C | 1 | 51.1%                                                              |