Coimisiún na Scrúduithe Stáit
State Examinations Commission

Leaving Certificate 2017

Marking Scheme

Chemistry

Higher Level
Note to teachers and students on the use of published marking schemes

Marking schemes published by the State Examinations Commission are not intended to be standalone documents. They are an essential resource for examiners who receive training in the correct interpretation and application of the scheme. This training involves, among other things, marking samples of student work and discussing the marks awarded, so as to clarify the correct application of the scheme. The work of examiners is subsequently monitored by Advising Examiners to ensure consistent and accurate application of the marking scheme. This process is overseen by the Chief Examiner, usually assisted by a Chief Advising Examiner. The Chief Examiner is the final authority regarding whether or not the marking scheme has been correctly applied to any piece of candidate work.

Marking schemes are working documents. While a draft marking scheme is prepared in advance of the examination, the scheme is not finalised until examiners have applied it to candidates’ work and the feedback from all examiners has been collated and considered in light of the full range of responses of candidates, the overall level of difficulty of the examination and the need to maintain consistency in standards from year to year. This published document contains the finalised scheme, as it was applied to all candidates’ work.

In the case of marking schemes that include model solutions or answers, it should be noted that these are not intended to be exhaustive. Variations and alternatives may also be acceptable. Examiners must consider all answers on their merits, and will have consulted with their Advising Examiners when in doubt.

Future Marking Schemes

Assumptions about future marking schemes on the basis of past schemes should be avoided. While the underlying assessment principles remain the same, the details of the marking of a particular type of question may change in the context of the contribution of that question to the overall examination in a given year. The Chief Examiner in any given year has the responsibility to determine how best to ensure the fair and accurate assessment of candidates’ work and to ensure consistency in the standard of the assessment from year to year. Accordingly, aspects of the structure, detail and application of the marking scheme for a particular examination are subject to change from one year to the next without notice.
Introduction

In considering the marking scheme, the following should be noted.

1. In many cases only key phrases are given which contain the information and ideas that must appear in the candidate’s answer in order to merit the assigned marks.

2. The descriptions, methods and definitions in the scheme are not exhaustive and alternative valid answers are acceptable.

3. The detail required in any answer is determined by the context and the manner in which the question is asked, and by the number of marks assigned to the answer in the examination paper and, in any instance, therefore, may vary from year to year.

4. The bold text indicates the essential points required in the candidate’s answer. A double solidus (//) separates points for which separate marks are allocated in a part of the question. Words, expressions or statements separated by a solidus (/) are alternatives which are equally acceptable for a particular point. A word or phrase in bold, given in brackets, is an acceptable alternative to the preceding word or phrase. Note, however, that words, expressions or phrases must be correctly used in context and not contradicted, and, where there is incorrect use of terminology or contradiction, the marks may not be awarded. Cancellation may apply when a candidate gives a list of correct and incorrect answers.

5. In general, names and formulas of elements and compounds are equally acceptable except in cases where either the name or the formula is specifically asked for in the question. However, in some cases where the name is asked for, the formula may be accepted as an alternative.

6. There is a deduction of one mark for each arithmetical slip made by a candidate in a calculation. This deduction applies to incorrect $M_r$ values but only if a candidate shows the addition of all the correct atomic masses and the error is clearly an addition error. If the addition of atomic masses is not shown, the candidate loses 3 marks for an incorrect $M_r$.

7. Bonus marks at the rate of 10% of the marks obtained will be given to a candidate who answers entirely through Irish and who obtains less than 75% of the total marks. In calculating the bonus to be applied decimals are always rounded down, not up e.g., 4.5 becomes 4; 4.9 becomes 4, etc. The bonus table given on the next page applies to candidates who answer entirely through Irish and who obtained more than 75% of the total marks.

Candidates are required to answer eight questions in all.

These must include at least two questions from Section A.

All questions carry equal marks (50).
Marcanna Breise as ucht freagairt trí Ghaeilge

Léiríonn an tábla thíos an méid marcanna breise ba chóir a bhronnadh ar iartróirí a ghnóthaíonn níos mó ná 75% d’iomlán na marcanna.

N.B. Ba chóir marcanna de réir an ghnáthráta a bhronnadh ar iartróirí nach ngnóthaíonn níos mó ná 75% d’iomlán na marcanna don scrúdú. Ba chóir freisin an marc bónais sin a shíl an mháthair céard a bhfuil 75% d’iomlán.

Tábla 400 @ 10%

Bain úsáid as an tábla seo i gcás na n-ábhar a bhfuil 400 marc san iomlán ag gabháil leo agus inarb é 10% ghnáthráta an bhónais.

Bain úsáid as an ngán a bháis i gcás 300 marc agus faoina bhun sin. Os cionn an mharc sin, féach an tábla thíos.

<table>
<thead>
<tr>
<th>Bunmharc</th>
<th>Marc Bónais</th>
</tr>
</thead>
<tbody>
<tr>
<td>301 - 303</td>
<td>29</td>
</tr>
<tr>
<td>304 - 306</td>
<td>28</td>
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<td>307 - 310</td>
<td>27</td>
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<td>311 - 313</td>
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<td>331 - 333</td>
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<td>337 - 340</td>
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<td>341 - 343</td>
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<td>344 - 346</td>
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<tr>
<td>347 - 350</td>
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</table>

<table>
<thead>
<tr>
<th>Bunmharc</th>
<th>Marc Bónais</th>
</tr>
</thead>
<tbody>
<tr>
<td>351 - 353</td>
<td>14</td>
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<tr>
<td>354 - 356</td>
<td>13</td>
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<td>357 - 360</td>
<td>12</td>
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<td>367 - 370</td>
<td>9</td>
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<td>371 - 373</td>
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<td>381 - 383</td>
<td>5</td>
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<td>384 - 386</td>
<td>4</td>
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<tr>
<td>387 - 390</td>
<td>3</td>
</tr>
<tr>
<td>391 - 393</td>
<td>2</td>
</tr>
<tr>
<td>394 - 396</td>
<td>1</td>
</tr>
<tr>
<td>397 - 400</td>
<td>0</td>
</tr>
</tbody>
</table>
QUESTION 1

(a) (i) **EXPLAIN:** solution of known concentration (molarity) (5)

(ii) **GIVE:**

pure // water soluble // solid // high molecular mass // stable in air (not oxidised by air, does not effloresce (lose water of crystallisation), does not deliquesce (absorb water from air), is not hygroscopic) // mass true (accurate) representation of number of moles present // anhydrous (not hydrated, does not have water of crystallisation) **ANY TWO:** (2 × 3)

[Allow one of either ‘non-toxic’ or ‘cheap’ or ‘readily available’ for 3 if no other marks awarded]

[Allow 3 marks for enables accurately known concentration to be obtained if no other marks awarded]

(b) **EXPLAIN:** (i) to prevent air oxidation of the Fe²⁺ in solution / to prevent Fe²⁺ in solution reacting with dissolved oxygen (air) / to avoid formation of Fe³⁺ / to stabilise Fe²⁺ (3)

[Allow ‘to prevent hydrolysis of Fe²⁺’ and ‘to prevent Fe²⁺ reacting with water’.]

EXPLAIN: (ii) to ensure MnO₄⁻ {Mn(VII)} reduced to (produces, forms) colourless Mn²⁺ {Mn(II)} / to prevent formation of MnO₂ {Mn(IV), brown precipitate} in solution (6)

[Allow Mn²⁺ for Mn(VII) and Mn⁴⁺ for Mn(IV).]

[Allow MnO₄⁻ {Mn(VII), Mn⁷⁺, MnO₂/, Mn(IV), brown precipitate} ‘fully reduced’ or ‘to ensure reaction goes to completion’.]

[Allow 3 marks only for oxidation of MnO₄⁻ {Mn(VII), Mn⁷⁺, MnO₂/, Mn(IV)} to Mn²⁺ {Mn(II)}.]

(c) **DESCRIBE** swirl flask while adding manganate(VII) (solution from burette) //

**PROCEDURE:** rinse down inside walls (sides, inside) of flask (container, vessel) with deionised (distilled, pure) water at intervals //

add manganate(VII) dropwise (slowly) as end point is approached //

read burette at eye-level //

keep burette vertical //

read top of meniscus //

carry out a rough titration //

repeat to find two or more titres (readings) that agree to within 0.1 cm³ //

use a white tile (surface, paper) to see colour changes in flask clearly **ANY FOUR:** (4 × 3)

[Allow ‘beaker’ for ‘flask’.]

**WHAT OBS:** faint (pale) pink colour remains (3)

[‘Pink to colourless’ not acceptable.]
(d) **CALCULATE:**  

(i) \[ M = \frac{8.82 \times 4}{392^*} = 0.09** \text{ M} \quad (3) \]

\[ \frac{25 \times 0.09}{1000} = 0.00225\ (2.25 \times 10^{-3}) \text{ moles} \quad (3) \]

(ii) \[ M = \frac{1.26 \times 4}{56} = 0.09** \text{ M} / \frac{1.26}{56} = 0.0225\ (2.25 \times 10^{-2}) \text{ moles in 250 cm}^3 \quad (3) \]

\[ \frac{25 \times 0.09}{1000} / 0.0225 = 0.00225\ (2.25 \times 10^{-3}) \text{ moles} \quad (3) \]

[*Addition must be shown for error to be treated as slip.*]  
[**Only figure to be used as molarity in (d) (iii)**]

(ii) \[ 0.00045\ (4.5 \times 10^{-4}) \text{ moles} \quad (3) \]

\[ 0.00225 \div 5 = 0.00045\ (4.5 \times 10^{-4}) \text{ moles} \quad (3) \]

(iii) \[ 0.022 \text{ M} \]

\[ \frac{0.00045}{20.45} = 0.000220 = 0.000022 \text{ moles / cm}^3 \quad (3) \]

\[ 0.000220 \times 1000 = 0.0220 = 0.022 \text{ M} \quad (3) \]

\[ \frac{20.45 \times M}{1} = \frac{25 \times 0.09**}{5} \quad (3) \]

\[ M = 0.0220 = 0.022 \text{ M} \quad (3) \]

[1 mark to be deducted for incorrect rounding off resulting in candidate’s final numerical answer lying outside given value but deduction to be made once only in (d).]
QUESTION 2

(a) (i) **WHAT:** reaction mixture turns milky (white) / bubbling / vapour (steam, smoke) / effervescence (fizzing) / solid (CaC₂, calcium dicarbide) reacts / flask gets hot

(ii) **EXPLAIN:** contain air (nitrogen, oxygen, argon, carbon dioxide)
[Allow impure.]

(b) (i) **DRAW:** heat applied to aluminium oxide (alumina, Al₂O₃) // ethanol (C₂H₅OH)

(ii) **STATE AND EXPLAIN:**

<table>
<thead>
<tr>
<th>State Precaution</th>
<th>Explain Precaution</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>remove delivery tube from water (loosen test-tube stopper) before removing heat at end</strong></td>
<td><strong>avoid suckback into hot test-tube / avoid flying glass (chemical splash) / avoid test-tube (apparatus) cracking</strong></td>
</tr>
<tr>
<td><strong>keep ethanol (ethene, stopper) away from flame / keep test-tube stopper tightly fitted</strong></td>
<td><strong>ethanol (ethene, stopper) flammable / avoid fumes from burning stopper</strong></td>
</tr>
<tr>
<td><strong>use Pyrex (boiling, stout-walled) test-tube / apply heat to test-tube gently before heating strongly / avoid prolonged heating of test-tube at the same place</strong></td>
<td><strong>avoid test-tube cracking / avoid fire (burns)</strong></td>
</tr>
<tr>
<td><strong>keep long hair tied back</strong></td>
<td><strong>avoid burns (contact with chemicals)</strong></td>
</tr>
<tr>
<td><strong>wear eye-protection (goggles) / use safety screen)</strong></td>
<td><strong>avoid burns (cuts from flying glass, contact with chemicals)</strong></td>
</tr>
<tr>
<td><strong>wear gloves / use tongs (forceps) / do not touch glass wool</strong></td>
<td><strong>avoid burns (cuts from flying glass, contact with chemicals)</strong></td>
</tr>
<tr>
<td><strong>wear mask (lab coat)</strong></td>
<td><strong>avoid contact with chemicals</strong></td>
</tr>
</tbody>
</table>

[Correct, linked, specific, chemical hazard, e.g. ‘glass wool irritating’ acceptable.]
(c) (i) **COMPARE:**

ethyne flame smokier (sootier, brighter, more luminous, yellower) than ethene’s / ethene flame cleaner (not as bright, less luminous, bluer) than ethyne’s / statement:

ethyne smoky (sooty, yellow, bright) / ethene clean (blue, bluish, yellowish)  

(ii) **WRITE:**

\[
\text{C}_2\text{H}_2 + 2\frac{1}{2} \text{O}_2 \rightarrow 2\text{CO}_2 + \text{H}_2\text{O} / 2\text{C}_2\text{H}_2 + 5\text{O}_2 \rightarrow 4\text{CO}_2 + 2\text{H}_2\text{O}
\]

**FORMULAE:** (3) **BALANCING:** (3)

(d) **NAME:**

bromine (Br$_2$) solution (water) / acidified potassium manganate(VII) {permanganate} / (KMnO$_4$/H$^+$) / (MnO$_4$$^-$/H$^+$)  

(3)

(e) **CALCULATE:**

\[3.0 \times 10^{22} \text{ molecules}\]

\[
\frac{3.2}{64^*} = 0.05 \text{ moles calcium carbide} \quad (3)
\]

\[
\Rightarrow 0.05 \text{ moles ethyne / 1:1 CaC}_2:\text{ethyne} \quad (3)
\]

\[
0.05 \times 6.0 \times 10^{23} = 3.0 \times 10^{22} \text{ molecules} \quad (2)
\]

[*Addition must be shown for error to be treated as slip.*]
QUESTION 3

(a) **DEFINE:**
change in concentration per unit time / rate of change of concentration / change in concentration
of one (a) reactant (product)

$\frac{d[\text{reactant}]}{dt}$ / $\frac{d[\text{product}]}{dt}$

$\frac{-d[\text{reactant}]}{dt} / \frac{d[\text{product}]}{dt}$

(b) **DESCRIBE:**
cross (print) under (behind) flask // obscured (no longer visible, no longer legible) //
when viewed through same (constant) depth (height) of solution in each run /
using same or identical flask (vessel) in each run

or

light meter reading //
reaches same value //
when viewed through same (constant) depth (height) of solution in each run /
using same or identical flask (vessel) in each run

or

pH meter (probe) reading / conductivity meter (probe) reading //
reaches same value

(c) **COPY X:**

<table>
<thead>
<tr>
<th>Concentration Na$_2$S$_2$O$_3$ (g /L)</th>
<th>Marks</th>
</tr>
</thead>
<tbody>
<tr>
<td>30.0</td>
<td></td>
</tr>
<tr>
<td>30 × 0.8 = 24.0 (24)</td>
<td>(3)</td>
</tr>
<tr>
<td>30 × 0.6 = 18.0 (18)</td>
<td>(3)</td>
</tr>
<tr>
<td>30 × 0.4 = 12.0 (12)</td>
<td></td>
</tr>
<tr>
<td>30 × 0.2 = 6.0 (6)</td>
<td></td>
</tr>
<tr>
<td>0</td>
<td></td>
</tr>
</tbody>
</table>

(d) (i) **COPY Y:**

0.020 s$^{-1}$

0.016, 0.012, 0.008, 0.004 s$^{-1}$

<table>
<thead>
<tr>
<th>Column Y</th>
<th>Marks</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>$r$ (s$^{-1}$)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.020</td>
<td>(3)</td>
<td></td>
</tr>
<tr>
<td>0.016</td>
<td>(3)</td>
<td>1 mark to be deducted for any one of these four values incorrectly rounded but make at most one deduction.</td>
</tr>
<tr>
<td>0.012</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.008</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.004</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
(ii) **PLOT:** both axes correctly labelled concentration (g/L) and rate ($r$, s$^{-1}$) (3) appropriate scales on both axes (3) five points plotted correctly (3) straight line through origin / 6th point plotted correctly and line (curve) through them (3) [Not plotted on graph paper (–3).] [Where concentration versus time plotted, maximum (6) marks.]

![Graph 1](image1.png)  ![Graph 2](image2.png)

(iii) **WHAT:** concentration of sodium thiosulfate is directly proportional to (varies directly with) rate ($r$, 1/t) (3) [Allow ‘direct relationship between concentration and rate ($r$, 1/t)’, and ‘straight line through origin’ and ‘linear relationship between concentration and rate ($r$, 1/t)’ and ‘rate increases as concentration increases’.] [‘Inversely’ cancels ‘proportional’, ‘varies indirectly’ cancels ‘varies directly’.]

(e) **DESCRIBE:** repeat using water baths / repeat heating solutions using hotplate (Bunsen burner) // at a number of (several) different (stated) temperatures // with same (fixed) volume(s) and concentration(s) of sodium thiosulfate and HCl / repeat a specified run from examination question, e.g. repeat Run 3 // record reaction times (rates) / analyse data collected / plot graph of temperature versus reaction rates (inverse times)

ANY THREE: (3 × 3)
QUESTION 4
Eight items to be answered. Six marks to be allocated to each item and one additional mark to be added to each of the first two items for which the highest marks are awarded.

(a) **WHY:** chemical properties matched (fitted) better in that order / to ensure periodic recurrence of chemical properties / elements with similar chemical properties were listed in columns (groups) / listing these by atomic mass (weight) did not group them with elements of similar chemical properties
[Allow ‘Mendeleev thought tellurium’s atomic mass had been incorrectly measured’.]

(b) **IDENTIFY:** 3 and // 2
[Order not important.][Allow orbitals if given, e.g. 3s and 2s.]

(c) **IDENTIFY:** X = Ba //
Z = 56

(d) **WRITE:**
(i) 2 / +2 //
(ii) 4 /+4

(e) **STATE:** equal (same) volumes of gases contain equal (same) numbers of molecules (particles, moles) //
at the same (constant) temperature and pressure
[‘Amounts’ unacceptable instead of ‘volumes’; ‘all temperatures and pressures’ and ‘at s.t.p.’ unacceptable instead of ‘at the same (constant) temperature and pressure’.]

(f) **CALCULATE:** 4.5 g per 500 cm³

| 0.9 (w/v) ⇒ 0.9 g per 100 cm³ / 9 g per litre | (3) |
| 4.5 g per 500 cm³ | (3) |

(g) **IDENTIFY:**
(i) intramolecular: polar (covalent) bonds within ammonia molecule(s) //
(ii) intermolecular: hydrogen bonds (dipole-dipole, van der Waals forces) between ammonia molecules
[Take order of question unless statements clearly identified as intermolecular or intramolecular]

(h) (i) **WRITE:** C₁₀H₁₂O₂
[Allow condensed formula with 10C, 12H, 2O.]

(ii) **NAME:** IR (ir, infrared) spectrometry or spectroscopy / uv-visible (UV-vis) spectrometry or spectroscopy / MS {mass spectrometry (spectroscopy)} / nmr (nuclear magnetic resonance spectroscopy) / x-ray crystallography (diffraction), etc

(i) **WRITE:** Cu + 2AgNO₃ → Cu(NO₃)₂ + 2Ag
**FORMULAE:** (3) **BALANCING:** (3)
(j) **HOW:** calcium hydrogen carbonate decomposes (breaks down, reacts) / calcium hydrogen carbonate converted to calcium carbonate (CaCO₃, limescale, limestone) / a precipitate (an insoluble product) is formed

[Information can be conveyed in a chemical equation.]

(k) **A EXPLAIN:**

\[ \text{SO}_2 + \frac{1}{2} \text{O}_2 \rightarrow \text{SO}_3 \]
\[ \text{SO}_3 + \text{H}_2\text{O} \rightarrow \text{H}_2\text{SO}_4 \]  

(2 × 3)

or
\[ \text{SO}_2 + \text{H}_2\text{O} \rightarrow \text{H}_2\text{SO}_3 \]
\[ \text{H}_2\text{SO}_3 + \frac{1}{2} \text{O}_2 \rightarrow \text{H}_2\text{SO}_4 \]  

(2 × 3)

or
\[ \text{SO}_2 + \frac{1}{2} \text{O}_2 + \text{H}_2\text{O} \rightarrow \text{H}_2\text{SO}_4 \]  

(6)

**B HOW:** aluminium object to be anodised (it) is made anode (positive electrode, +) // in dilute sulfuric acid electrolyte / in acidified water electrolyte  

(2 × 3)
QUESTION 5

(a) DEFINE: space (volume, region) around the nucleus of an atom // where there is a relatively high probability (possibility) of finding an electron / where an electron is likely to be found ['Area' around nucleus not acceptable.]

or

approximate solution // to a Schrödinger wave equation (2 × 3)

WRITE:  
\[
1s^2 2s^2 2p^2 / 1s^2 2s^2 2p_y^1
\]

[Allow subscripts instead of superscripts.]

[Arrows to represent numbers of electrons acceptable but sublevel symbols must be given.]

HOW MANY: 4

(b) WHY: orbitals do not have defined volumes / Heisenberg’s uncertainty principle / it is impossible (difficult) to measure accurately both position and momentum (velocity) of an electron in an atom simultaneously / wave-particle duality of electron / electrons have wave nature / electrons have wave motion / distance between electron in an atom and nucleus always changing / probability of finding an electron in an atom non-zero except at infinity / probability exists of finding an electron in an atom anywhere (3)

[‘Distance between electron and nucleus difficult to measure’ insufficient on its own.]

STATE: half the distance between the nuclei (centres) // of two atoms of (an, the, the same) element joined by a single covalent bond / of two identical atoms joined by a single covalent bond (2 × 3)

[Accept information given in a labelled diagram.]

(c) (i) DESCRIBE: increases (increasing) // ACCOUNT: additional shell(s) {main energy level[s]} overcome(s) increasing nuclear charge (2 × 3)

[DESCRIBE and ACCOUNT are linked.]

(ii) ACCOUNT: effective nuclear charge increasing / number protons (nuclear charge, atomic number) increasing with same screening effect by electrons in first shell (3)

(d) DEFINE: minimum energy to remove // most loosely bound electron completely (to infinity) (2 × 3)

WHY: increasing effective nuclear charge / increasing number protons (atomic number) with same screening effect by electrons in first shell // smaller atomic radius / atomic size decreasing (2 × 3)
(e) **HOW:**

(i) six values $\Rightarrow$ six electrons / each value $\Rightarrow$ one electron

(ii) gradual (steady) increase for first four values $\Rightarrow$ four electrons in the outer (second) main energy level (shell) / first four values numerically close (all low, all lower) $\Rightarrow$ four electrons in the outer (second) main energy level (shell) /

last two values very high (higher) $\Rightarrow$ two electrons in the inner (first) main energy level (shell) /

large jump (large increase) after 4th value (after 6223, before 5th value, before 37831) $\Rightarrow$ two (four) electrons of the six in one level (shell) and four (two) in the other
QUESTION 6

(a) IDENTIFY: methane (CH₄)

GIVE: fuel / production of hydrogen / steam reforming / production of ammonia / production of fertilizer

WHY: global warming / enhanced greenhouse gas (effect) / traps heat that should escape to atmosphere / climate change / rising sea levels / melting polar ice-caps / destruction of some wildlife habitats / threat to survival of some wildlife species / affects crop yields, etc [‘Damages ozone’ cancels correct response.]

(5 + 3 + 3)

(b) EXPLAIN: stronger (more) intermolecular (van der Waals, London (dispersion)) bonds (forces, interactions) / more electrons present to create intermolecular forces

(6)

(c) (i) WRITE: C₇H₁₆ → C₆H₅CH₃ + 4H₂ / C₇H₁₆ → C₇H₈ + 4H₂ / C₇H₁₆ → C₆H₅CH₃ + 4H₂

FORMULAE: (3) BALANCING: (3)

(ii) WHAT: increase (improve) octane rating (number, value) of a fuel / reduces tendency of fuel to cause knocking / make more fuel (compounds, hydrocarbons, molecules) of higher demand / increase value of products / make more efficient fuel / makes molecules (compounds, hydrocarbons) that are cyclic

(3)

(d) (i) DRAW:

<table>
<thead>
<tr>
<th></th>
<th>but-2-ene</th>
<th>2-methylbutane</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>[H₃C\overset{\text{C}}{\text{C}}\overset{\text{C}}{\text{C}}\overset{\text{CH₃}}{\text{CH₃}}]</td>
<td>[\overset{\text{CH₃}}{\text{C}}\overset{\text{C}}{\text{C}}\overset{\text{H}}{\text{H}}\overset{\text{H}}{\text{CH₃}}]</td>
</tr>
</tbody>
</table>

[In expanded structures the Hs need not be explicitly written.]

(ii) DEDUCE: C₃H₆

[Accept structure] (3)
(e) **STATE:**

heat change for a reaction //

depends only on initial and final states / is same whether reaction takes place in one or
more stages / is independent of path taken / is sum of heat changes for all stages

\[(2 \times 3)\]

**CALCULATE:**

\[
\Delta H_{\text{cracking}} = \sum \Delta H_{\text{formation products}} - \sum \Delta H_{\text{formation reactants}}
\]

\[
= \left[(-9.3) + (-178.4) + (20.0)\right] \text{kJ} \quad (3) - (-350.9) \text{kJ} \quad (3)
\]

or

\[
= \left[(-9.3) + (-178.4) + (20.0)\right] \text{kJ} \quad (3) + 350.9 \text{kJ} \quad (3)
\]

\[
= -167.7 \text{kJ} \quad (3) + 350.9 \text{kJ} \quad (3)
\]

and

\[
= 183.2 \text{kJ} \quad (3)
\]

or

\[
\begin{align*}
\text{C}_{12}\text{H}_{26} & \rightarrow 12\text{C} + 13\text{H}_2 & \Delta H &= 350.9 \text{kJ} \quad (3) \\
4\text{C} + 4\text{H}_2 & \rightarrow \text{C}_4\text{H}_8 & \Delta H &= -9.3 \text{kJ} \quad (3) \\
5\text{C} + 6\text{H}_2 & \rightarrow \text{C}_5\text{H}_{12} & \Delta H &= -178.4 \text{kJ} \quad (3) \\
3\text{C} + 3\text{H}_2 & \rightarrow \text{C}_3\text{H}_6 & \Delta H &= 20.0 \text{kJ} \quad (3)
\end{align*}
\]

\[
\begin{align*}
\text{C}_{12}\text{H}_{26} & \rightarrow \text{C}_4\text{H}_8 + \text{C}_5\text{H}_{12} + \text{C}_3\text{H}_6 & \Delta H &= 183.2 \text{kJ} \quad (3)
\end{align*}
\]

or

\[
\begin{align*}
\text{C}_{12}\text{H}_{26} & \rightarrow 12\text{C} + 13\text{H}_2 & \Delta H &= 350.9 \text{kJ} \quad (3) \\
12\text{C} + 13\text{H}_2 & \rightarrow \text{C}_4\text{H}_8 + \text{C}_5\text{H}_{12} + \text{C}_3\text{H}_6 & \Delta H &= -167.7 \text{kJ} \quad (3) \\
\text{C}_{12}\text{H}_{26} & \rightarrow \text{C}_4\text{H}_8 + \text{C}_5\text{H}_{12} + \text{C}_3\text{H}_6 & \Delta H &= 183.2 \text{kJ} \quad (3)
\end{align*}
\]

[Final Answer \( \text{C}_4\text{H}_8 + \text{C}_5\text{H}_{12} + \text{C}_3\text{H}_6 \rightarrow \text{C}_{12}\text{H}_{26} \quad \Delta H = -183.2 \text{kJ} \) is worth (6) marks.]

[Equations not essential, however final answer \(-183.2 \text{kJ} \) is worth only (3) marks if not accompanied by an equation or if accompanied by an equation other than that for cracking in reverse.]
QUESTION 7
(a) WHAT: state in which rate of forward reaction is equal to rate of reverse reaction / state reached at which concentrations of reactants and products are constant (5)
[Allow \( r_i = r_r \) or \( r_i = r_{f} \).]

WHY: both reaction(s) continue(s) / reaction doesn’t stop (3)

STATE: systems in (at) equilibrium // react to oppose (minimise, relieve) applied stress(es) {disturbance(s)} (2 × 3)
[Instead of 'stress(es){disturbance(s)}' accept 'change in temperature, pressure or number of moles (concentrations)' if all three {temperature, pressure and moles (concentrations)} are given.]

(b) WRITE: \[ K_c = \frac{[\text{NO}_2]^2}{[\text{N}_2\text{O}_4]} \] (6)
[Do not accept inverted expression.]

(c) CALCULATE: 0.05 mol per litre \( \text{N}_2\text{O}_4 \) and 0.1 mol per litre \( \text{NO}_2 \) (18)
Candidate working with 2x moles NO₂ at equilibrium

\[ \text{N}_2\text{O}_4 (g) \rightleftharpoons 2\text{NO}_2 (g) \]

Start: 1 mol \hspace{1cm} 0 mol

Equil: \( 1 - x \) mol \hspace{0.5cm} 2x mol \hspace{1cm} (3)
Equil: \( (1 - x) \div 10 \) mol/l \hspace{0.5cm} 2x \div 10 \) mol/l \hspace{1cm} (3)

\[
\frac{4x^2 + 100}{(1-x) \div 10} = \frac{2}{0.2} / \frac{(2x)^2}{(1-x)} = \frac{4x^2}{(1-x)} = 2 / \\
4x^2 + 2x - 2 = 0 / \\
2x^2 + x - 1 = 0 / x^2 + 0.5x - 0.5 = 0 \hspace{1cm} (3)
\]

\[
x = \frac{-(2) \pm \sqrt{(2)^2 - 4(4)(-2)}}{2 \times 4} / \\
x = \frac{-(1) \pm \sqrt{(1)^2 - 4(2)(-1)}}{2 \times 2} / \\
x = \frac{-(0.5) \pm \sqrt{(0.5)^2 - 4(-0.5)}}{2}
\]

or \((2x + 2)(2x - 1) = 0 / (2x - 1)(x + 1) = 0 / (x + 1)(x - 0.5) = 0\)

\[
x = 0.5 \text{ mol} \hspace{1cm} (3)
\]

\[
[N_2O_4] = (1 - x) \div 10 = 0.05 \text{ mol/l} \hspace{1cm} (3) \\
[NO_2] = 2x \div 10 = 0.1 \text{ mol/l} \hspace{1cm} (3)
\]

Candidate working with y moles NO₂ at equilibrium

\[ \text{N}_2\text{O}_4 (g) \rightleftharpoons 2\text{NO}_2 (g) \]

Start: 1 mol \hspace{1cm} 0 mol

Equil: \( 1 - ½y \) mol \hspace{0.5cm} y mol \hspace{1cm} (3)
Equil: \( (1 - ½y) \div 10 \) mol/l \hspace{0.5cm} y \div 10 \) mol/l \hspace{1cm} (3)

\[
\frac{y^2 \div 100}{(1-½y) \div 10} = \frac{2}{0.2} / \frac{y^2}{1-½y} = 2 / \\
y^2 + y - 2 = 0 \hspace{1cm} (3)
\]

\[
y = \frac{-(1) \pm \sqrt{1^2 - 4(-2)}}{2}
\]

or \((y + 2)(y - 1) = 0\)

\[
y = 1 \text{ mol} \hspace{1cm} (3)
\]

\[
[N_2O_4] = (1 - ½y) \div 10 = 0.05 \text{ mol/l} \hspace{1cm} (3) \\
[NO_2] = y \div 10 = 0.1 \text{ mol/l} \hspace{1cm} (3)
\]

[Chemically impossible solution of correct quadratic equation also used to find concentrations, deduct (1) mark.]
[Do not award last (6) marks for quadratic equation with two chemically impossible solutions.]
[Do not allow mixing and matching of marks within boxes.]
[Where inverted \( K_c \) expression used, do not award (3) marks for setting up quadratic.]

(a) EXPLAIN: low(er) temperature (decrease in temperature) favours (results in, produces more) N₂O₄ (left side, reverse, exothermic (heat producing) reaction) /

high(er) temperature would favour (result in, produce more) NO₂ (right side, forward, endothermic (heat absorbing) reaction) \hspace{1cm} (3)

DEDUCE: decomposition endothermic \hspace{1cm} (3)
[Linkage here. EXPLAIN marks only available if DEDUCE marks awarded but order of answering parts unimportant]

(e) WOULD: no change (effect) / none \hspace{1cm} (3)

EXPLAIN: \( K_c \) constant at given temperature even if concentrations change / only change in temperature will result in change in \( K_c \) \hspace{1cm} (3)
[WOULD and EXPLAIN linked; order of answering parts unimportant; WOULD marks may be awarded if correct response to WOULD is inferred in correct EXPLAIN statement.]
QUESTION 8

(a) WHAT: colourless to purple (pink) to brown to colourless (white) / colourless to purple (pink) to brown to colourless (white) (3)

EXPLAIN: MnO₄⁻ {Mn(VII)} changes to / MnO₂ {Mn(IV)} changes to Mn²⁺ {Mn(II)} (3)
[Allow Mn³⁺ for Mn(VII) and Mn⁴⁺ for Mn(IV)]
[Oxidation of MnO₄⁻ {Mn(VII), Mn⁷⁺} instead of reduction not acceptable.]
[WHAT and EXPLAIN linked]

MARK CLEARLY:

(i)

(ii)

(b) GIVE: A = propanal //
B = propanone (2 × 3)
[Correct order essential unless substances clearly labelled A and B.]

DRAW:

<table>
<thead>
<tr>
<th>propanal</th>
<th>propanone</th>
</tr>
</thead>
<tbody>
<tr>
<td>CH₃CH₂CHO</td>
<td>CH₃COCH₃</td>
</tr>
<tr>
<td>C₂H₅CHO</td>
<td>(CH₃)₂CO</td>
</tr>
</tbody>
</table>

[Aldehyde H must be explicitly shown, other Hs need not be explicit.]

(c) IDENTIFY: hydrogen / H₂ //
nickel (Ni, platinum, Pt, palladium, Pd, copper, Cu, rhodium, Rh, ruthenium, Ru) catalyst (2 × 3)
[Allow any order of response here.]
(d) SUGGEST: Tollens’ reagent / ammoniacal silver nitrate / silver(I) oxide (Ag₂O) / Fehling’s reagent / Benedict’s reagent / copper(II) hydroxide {Cu(OH)₂} (6)

(e) NAME: methyl ethanoate / ethyl methanoate (6)
[Full or condensed ester formula acceptable here. Molecular formula C₃H₆O₂ insufficient.]

<table>
<thead>
<tr>
<th>NAME:</th>
<th>methyl ethanoate</th>
<th>ethyl methanoate</th>
</tr>
</thead>
<tbody>
<tr>
<td>IDENTIFY:</td>
<td>methanol / CH₃OH</td>
<td>methanol / C₂H₅OH</td>
</tr>
</tbody>
</table>
|               | ethanoic acid / CH₃COOH | methanoic acid / HCOOH | (3 + 2)

[NAME and IDENTIFY are linked and IDENTIFY marks only available where NAME marks awarded.]
[Alcohol and carboxylic acid may be identified by name, condensed formula or structure.]
QUESTION 9

(a) DEFINE: 

(i) proton (H⁺) acceptor //
(ii) two species that differ by a proton (H⁺) 
[Examples insufficient on their own.]

WHAT:  
H₃O⁺ / hydronium ion

(b) DEFINE:  
pH = −\log_{10}[H⁺] / −\log_{10}[H₂O⁺] / minus log base 10 hydrogen ion concentration expressed in moles per litre

ACCOUNT:  
[Allow ‘hydrochloric’ for HCl, ‘sulfuric’ for H₂SO₄ and ‘methanoic’ for HCOOH. Allow H⁺, proton, H₂O⁺ or hydronium ion for ‘hydrogen ion’.]

(i) & (ii) First (9) marks available from one of the boxes below.

<table>
<thead>
<tr>
<th>RELEVANT HCl information</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.10 M HCl produces 0.10 M H⁺ ion / pH HCl = −log (0.10)</td>
</tr>
<tr>
<td>or</td>
</tr>
<tr>
<td>HCl monoprotic (monobasic) / one molecule HCl produces one H⁺ ion //</td>
</tr>
<tr>
<td>HCl is strong (fully dissociated into H⁺ ions, a good proton donor)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>RELEVANT H₂SO₄ information</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.10 M H₂SO₄ produces 0.20 M H⁺ ion /</td>
</tr>
<tr>
<td>pH H₂SO₄ = −log (0.20) /</td>
</tr>
<tr>
<td>H₂SO₄ diprotic (dibasic) /</td>
</tr>
<tr>
<td>one molecule H₂SO₄ produces two H⁺ ions /</td>
</tr>
<tr>
<td>H₂SO₄ produces (has) more (twice as many) H⁺ ions as HCl</td>
</tr>
</tbody>
</table>

or

<table>
<thead>
<tr>
<th>RELEVANT H₂SO₄ information</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.10 M H₂SO₄ produces 0.20 M H⁺ ion / pH H₂SO₄ = −log (0.20)</td>
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<td>or</td>
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<tr>
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</tbody>
</table>

and

<table>
<thead>
<tr>
<th>RELEVANT HCl information</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.10 M HCl produces 0.10 M H⁺ ion / pH HCl = −log (0.10)</td>
</tr>
</tbody>
</table>

and

<table>
<thead>
<tr>
<th>RELEVANT HCOOH information</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.10 M methanoic acid (HCOOH) solution produces 4.27 × 10⁻³ M (less than 0.10 M) H⁺ ion /</td>
</tr>
<tr>
<td>pH HCOOH = inverse log (−2.37) (antilog (−2.37)) /</td>
</tr>
<tr>
<td>HCOOH is weak (slightly (not fully) dissociated into H⁺ ions, a poor proton donor) /</td>
</tr>
<tr>
<td>HCOOH weaker than HCl</td>
</tr>
</tbody>
</table>

3 marks
USE: 

\[ K_a = 1.82 \times 10^{-4} \] 

\[ [H^+] = \text{inverse log} \, (-2.37) \div \text{antilog} \, (-2.37) \div 4.27 \times 10^{-3} \div 10^{-2.37} \] 

\[ \Rightarrow K_a = \frac{[H^+][A^-]}{[HA]} = \frac{[H^+]^2}{[HA]} \div \frac{[H^+]^2}{[0.1]} \] 

\[ [H^+] = \sqrt{K_a[HA]} \div 4.27 \times 10^{-3} = \sqrt{K_a[0.1]} \div [H^+]^2 = K_a[HA] \div (4.27 \times 10^{-3})^2 = K_a(0.1) \] 

\[ K_a = 1.82 \times 10^{-4} \] 

(iv) \( \text{pH} = 2.52 \) 

\[ \text{pH} = -\log \sqrt{K_a[HA]} = -\log \sqrt{1.82 \times 10^{-4}[0.05]} = 2.52 \] 

\[ \text{Any three: (3 × 3)} \] 

(c) DRAW: 
axes labelled (pH and volume) // 
curve of correct shape with steep rise at 25 cm³ // 
vertical part mostly above pH = 7 // 
steep rise coincides with 25 cm³ NaOH 

\[ \text{ANY THREE: (3 × 3)} \] 

NAME: phenolphthalein 

EXPLAIN: 

\text{colour change (indicator range) coincides with sharp rise on graph} / 
\text{colour change occurs > 7} / \text{colour change occurs between 7 and 10} / 
\text{indicator range is 8.3 – 10} \] 

\[ \text{name and explain linked} \]
QUESTION 10

(a) DRAW: conical flask containing vapour (liquid) // aluminium foil lid with pinhole (bung with small hole) // rubber band (only acceptable with the foil option) // immersed in beaker of boiling (hot) water // thermometer (temperature probe, temperature sensor) shown in water // heat source / symbol for heat source

[At least one correct label essential; unlabelled diagram maximum (3 x 2).] [No diagram = maximum (3 x 2).]

ANY FOUR POINTS: 4 + (3 x 2)

or

vapour in gas syringe // liquid injected into large syringe via rubber seal // by needle of small syringe // gas syringe in oven (water bath, steam jacket) / heat source indicated // thermometer (temperature probe, temperature sensor) shown in oven (water bath, steam jacket)

[Syringes should be recognisable; injection shown or mentioned.] [At least one correct label essential; unlabelled diagram maximum (3 x 2).] [No diagram = maximum (3 x 2).]

ANY FOUR POINTS: 4 + (3 x 2)
(i) **CALCULATE:**

\[ n = \frac{pV}{RT} \]

\[ n = \frac{101 \times 10^5 \times 268 \times 10^{-6}}{8.3 \times 371.15} / \frac{1.01 \times 10^5 \times 268 \times 10^{-6}}{n \times 8.3 \times 371.15} = n \times 8.3 \times 371.15 \quad (6) \]

\[ n = 8.787 \times 10^{-3} \text{ moles} \quad [8.7 \times 10^{-3} \text{ to } 9 \times 10^{-3} \text{ moles}] \quad (3) \]

[Treat an incorrect multiple of any of the possible answers allowed by the range above as a mathematical slip. Treat use of temperature in °C as another slip.]

\[ \frac{p_1V_1}{T_1} = \frac{p_2V_2}{T_2} \Rightarrow \frac{V_1}{T_1} = \frac{V_2}{T_2} \]

\[ \frac{101 \times 268}{371.15} = \frac{101 \times 268 \times 273.15}{273.15} \Rightarrow \frac{V_2}{T_2} = \frac{268 \times 273.15}{371.15} \Rightarrow V_2 = 196.60 \text{ cm}^3 \quad (6) \]

\[ n = \frac{196.60}{22400} = 8.787 \times 10^{-3} \text{ moles} \quad [8.7 \times 10^{-3} \text{ to } 9 \times 10^{-3} \text{ moles}] \quad (3) \]

[Treat an incorrect multiple of any of the possible answers allowed by the range above as a mathematical slip. Treat use of temperature in °C as another slip.]

(ii) **FIND:**

32 or 31

\[ n = \frac{m}{M_m} = \frac{m}{n} = \frac{0.28}{8.787 \times 10^{-3}} \quad (3) \]

31.9 = 32 \quad [Accept 32 or 31] \quad (3)

*Deduct 1 mark if answer not rounded correctly to a whole number. No penalty if relative molecular mass is given units of mass.*
(b) WHAT: \(^{4}_2\text{He} \quad / \quad \text{helium (He) nucleus / particle consisting of two protons and two neutrons /} \quad \text{He}^2+ \quad (6)

(i) WHAT: alpha particles were expected to \textbf{pass straight through} / alpha particles passing through expected to be \textbf{undeflected (no more than slightly deflected) / small angles of deflection (repulsion)} for some alpha particles passing through \((6)\) [Reference to ‘large angles’ or ‘straight back’ contradicts another correct statement.]

(ii) HOW: some (a few) alpha particles were \textbf{deflected (repelled) at large angles} // a few (some) alpha particles were \textbf{reflected (deflected back, repelled back along original path)} \((2 \times 3)\)

(iii) HOW: large \textbf{electron cloud} surrounding / atoms mostly empty space with small (dense) // nucleus / positive core (centre) \((2 \times 2)\)

[Marks in (i), (ii), and (iii) are available for separate, clear, labelled diagrams.]

(c) (i) WHAT: \textit{mono} \textit{chloroethane} / \textit{1-chloroethane} / \textit{ethyl chloride} / \textit{C}_2\text{H}_5\text{Cl} \quad (2)

NAME: ionic addition / electrophilic addition \((2)\)

DESCRIBE: polar bond in \textit{hydrogen chloride breaks into ions} / \textit{hydrogen chloride undergoes heterolytic fission} / \textit{HCl} \rightarrow \textit{H}^+ + (and) \textit{Cl}^– // \textit{double bond} in \textit{ethene breaks with H}^+ \textit{adding to} (with H^+ forming a bond with) one carbon atom giving \textit{carbononium ion (carbocation, C+, intermediate)} / \textit{double bond breaks and new C-H bond formed with H}^+, \textit{giving carbonium ion (carbocation, C+, intermediate)} // addition of \textit{Cl}^– to \textit{carbonium ion (carbocation, C+, intermediate)} gives \textit{product (chloroethane)} \((3 \times 3)\)

\[\begin{align*}
\text{HCl} & \rightarrow \text{H}^+ + (\text{and}) \text{Cl}^– \\
\text{C}_2\text{H}_5\text{Cl} & \rightarrow \text{C}_2\text{H}_5\text{H} + \text{Cl}^– \\
\end{align*}\]

[Allow cyclic carbocation.]

[allow correct use of curly arrows (but not half-arrows (fishhooks).]

[Deduct (3) marks for each of the following errors: H^+—Cl^–, addition of Cl^- instead of Cl^- in third step, each reference to radicals, reference to Cl^- adding first and H^+ adding in third step.]
hydrogen of hydrogen chloride approaches double bond end-on / hydrogen chloride (HCl) highly polarised with hydrogen nearest double bond / hydrogen chloride (HCl) becomes (→) H⁺—Cl⁻ with hydrogen nearest double bond / partially charged hydrogen atom (H⁺) from HCl is attracted to double bond // double bond breaks and new C-H bond formed (with H⁺ adding) giving carbononium ion (carbocation, C⁺, intermediate) and Cl⁻ / double bond breaks and new C-H bond formed, giving carbonium ion (carbocation, C⁺, intermediate) and Cl⁻ // addition of Cl⁻ to carbonium ion (carbocation, C⁺, intermediate) gives product (chloroethane)

\[\text{(3 × 3)}\]

<table>
<thead>
<tr>
<th>(3)</th>
<th>(3)</th>
<th>(3)</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1.png" alt="Diagram 1" /></td>
<td><img src="image2.png" alt="Diagram 2" /></td>
<td><img src="image3.png" alt="Diagram 3" /></td>
</tr>
</tbody>
</table>

[Allow cyclic carbocation.] [Cl⁻ not essential in second diagram.]

[Marks available for diagrams, allow correct use of curly arrows (but not half-arrows (fishhooks).]

[Deduct (3) marks for each of the following errors: H⁺—Cl⁻, addition of Cl⁶⁻ instead of Cl⁻ in third step, each reference to radicals, reference to Cl⁻ adding first and H⁺ adding in third step.]

or

polar bond in hydrogen chloride breaks into ions / HCl → H⁺ + (and) Cl⁻ (3) double bond breaks with H⁺ adding to ethene and simultaneous (followed very rapidly by) breaking of bond in nearby HCl molecule to then allow addition of Cl⁻ giving product (chloroethane) and regenerating a H⁺ (6)

<table>
<thead>
<tr>
<th>(3)</th>
<th>(6)</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image4.png" alt="Diagram 4" /></td>
<td><img src="image5.png" alt="Diagram 5" /></td>
</tr>
</tbody>
</table>

[Marks available for diagrams, allow correct use of curly arrows (but not half-arrows (fishhooks).]

[Deduct (3) marks for each of the following errors: H⁺—Cl⁻, addition of Cl⁶⁻ instead of Cl⁻ in third step, each reference to radicals, reference to Cl⁻ adding first and H⁺ adding thereafter.]
(ii) **HOW:** planar around carbons in ethene to //
   tetrahedral around carbons in chloroethane

   [Take order of question unless geometries clearly assigned to ethene and chloroethane]

(III) **HOW:** chlorine (Cl₂) / chlorination //
   ultraviolet (uv) light

   [Allow 3 for ‘free radical substitution’ or ‘radical chlorination’.]
QUESTION 11

(a) (i) **WHAT:** \(6.8896 - 6.89\) g azurite

\[
M_r \text{ azurite} = 344.5^* \quad (3)
\]

\[
\frac{3.81}{63.5} = 0.06 \text{ moles Cu} \Rightarrow 0.02 \text{ (1/50) moles azurite} \quad (3)
\]

\[
\frac{m}{344.5} = 0.02 \text{ moles}
\]

\[
m = 6.89 \text{ g azurite} \quad (3)
\]

**CALCULATE:** 6.63 g malachite

\[
M_r \text{ malachite} = 221^{**} \quad (3)
\]

0.06 moles Cu or 0.02 moles azurite

\[
\Rightarrow 0.03 \text{ (3/100) moles malachite} \quad (3)
\]

0.03 \times 221 = 6.63 g malachite \quad (3)

\[
M_r \text{ azurite} = 344.5^* \quad (3)
\]

\[
\frac{3 \times 63.5}{344.5} \times 100 = 55.2975 - 55.30\% \text{ Cu} \quad (3)
\]

\[
\frac{3.81}{0.5530} = m
\]

\[
m = 6.8896 - 6.89 \text{ g azurite} \quad (3)
\]

\[
M_r \text{ malachite} = 221^{**} \quad (3)
\]

\[
2 \times 63.5 \text{ g Cu in 221 g malachite} / 127 \text{ g Cu in 221 g malachite} \quad (3)
\]

\[
\frac{3.81 \text{ g Cu} \Rightarrow \frac{221 \times 3.81}{2 \times 63.5} / \frac{221 \times 3.81}{127} = 6.63 \text{ g malachite}}{3} \quad (3)
\]

[*Addition must be shown for error to be treated as slip.]

(ii) **CALCULATE:** 6.63 g malachite

\[
M_r \text{ azurite} = 344.5^* \quad (3)
\]

\[
3 \times 63.5 \text{ g Cu in 344.5 g azurite} / 190.5 \text{ g Cu in 344.5 g azurite} \quad (3)
\]

\[
3.81 \text{ g Cu} \Rightarrow \frac{344.5 \times 3.81}{3 \times 63.5} / \frac{344.5 \times 3.81}{190.5} = 6.89 \text{ g azurite} \quad (3)
\]

\[
M_r \text{ malachite} = 221^{**} \quad (3)
\]

\[
2 \times 344.5 \text{ g / 689 g azurite} \Rightarrow 3 \times 221 \text{ g / 663 g malachite} \quad (3)
\]

\[
6.89 \text{ g azurite} \Rightarrow \frac{663 \times 6.89}{689} = 6.63 \text{ g malachite} \quad (3)
\]

[**Addition must be shown for error to be treated as slip.]

[Where candidate’s work clearly shows one incorrect \(A_r\) used to get \(M_r\) of azurite and \(M_r\) of malachite consistent with this error, award no marks for \(M_r\) of azurite and apply slip (–1) for the error in \(M_r\) of malachite.]

(iii) **WHAT:** 0.224 litres / 224 cm³

\[
0.01 (1/100) \text{ moles CO}_2 \text{ gas} \quad (3)
\]

0.01 \times 22.4 = 0.224 litres / 224 cm³ \quad (3)

\[
689 (2 \times 344.5) \text{ g azurite} / 663 (3 \times 221) \text{ g malachite} \Rightarrow 22.4 \text{ l (22400 cm³)} \text{ CO}_2 \text{ gas} \quad (3)
\]

\[
6.89 \text{ g azurite} / 6.63 \text{ g malachite} \Rightarrow 0.224 \text{ litres / 224 cm³} \quad (3)
\]

[Use of 24 litres as molar volume not acceptable here.]

(iv) **SUGGEST:**

keep it dry / low humidity / use waterproof varnish (coating) / keep it cool / protect from heat / protect from light \( (1) \)
(b) **DEFINE:** number expressing the relative attraction of an atom for / measure of tendency for atom to attract / shared pair(s) of electrons / electrons in a covalent bond / bonding pair of electrons

\[ (2 \times 3) \]

**DRAW:**

<table>
<thead>
<tr>
<th>(i)</th>
<th>NF(_3)</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1" alt="Diagram" /></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>(ii)</th>
<th>BF(_3)</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image2" alt="Diagram" /></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>(iii)</th>
<th>ClF</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image3" alt="Diagram" /></td>
<td></td>
</tr>
</tbody>
</table>

[Only bond pairs required for each molecule.]
[BF\(_3\) ionic unacceptable but cancellation not applied.]

**USE:** trigonal (triangular) planar

[Diagram alone insufficient, name essential]

\[ (3) \]

(iv) **INDICATE:** partial positive charge on chlorine // partial negative charge on fluorine

\[ (2 \times 2) \]

[See original diagram in (iii) above or accept new diagram; only bond pair required.]
[Full charges not acceptable.]

(v) **PREDICT:** polar covalent

\[ (3) \]
(c) A (i) **GIVE:** packaging food to prevent oxidation (keep food fresh) // packaging to prevent crushing of food (delicate items) // flushing (purging) tanks of flammable liquids (gases, vapours) // freezing (preserving) food (biological specimens, sperm, semen) // remove unwanted skin cells // remove skin cancer (warts, verrucae) // feedstock for ammonia (fertilizer) industry, // etc

**ANY TWO:** \((4 + 3)\)

(ii) **NAME:** carbon dioxide // water vapour // dust // oil particles

**ANY TWO:** \((2 \times 3)\)

[Allow CO\(_2\) and H\(_2\)O.]

(iii) **EXPLAIN:**

cooled //

compressed (placed under pressure)

*or*

compressed (placed under pressure) //

and allowed to expand

\((2 \times 3)\)

(iv) **WHICH:** A

(v) **WHICH:** B

B (i) **DRAW:**

\[
\begin{align*}
\text{H} & \quad \text{H} \\
\text{H} & \quad \text{H} \\
\text{H} & \quad \text{H} \\
\text{C} & \quad \text{C} \\
\end{align*}
\]

\[
\begin{align*}
\text{H} & \quad \text{H} \\
\text{H} & \quad \text{H} \\
\text{H} & \quad \text{H} \\
\text{C} & \quad \text{C} \\
\end{align*}
\]

\[
\begin{align*}
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\text{H} & \quad \text{H} \\
\text{H} & \quad \text{H} \\
\text{C} & \quad \text{C} \\
\end{align*}
\]

\[
\begin{align*}
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\text{H} & \quad \text{H} \\
\text{H} & \quad \text{H} \\
\text{C} & \quad \text{C} \\
\end{align*}
\]

\[
\begin{align*}
\text{H} & \quad \text{H} \\
\text{H} & \quad \text{H} \\
\text{H} & \quad \text{H} \\
\text{C} & \quad \text{C} \\
\end{align*}
\]

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\begin{align*}
\text{H} & \quad \text{H} \\
\text{H} & \quad \text{H} \\
\text{H} & \quad \text{H} \\
\text{C} & \quad \text{C} \\
\end{align*}
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\[
\begin{align*}
\text{H} & \quad \text{H} \\
\text{H} & \quad \text{H} \\
\text{H} & \quad \text{H} \\
\text{C} & \quad \text{C} \\
\end{align*}
\]

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\begin{align*}
\text{H} & \quad \text{H} \\
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\text{H} & \quad \text{H} \\
\text{C} & \quad \text{C} \\
\end{align*}
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\[
\begin{align*}
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\text{H} & \quad \text{H} \\
\text{H} & \quad \text{H} \\
\text{C} & \quad \text{C} \\
\end{align*}
\]

\[
\begin{align*}
\text{H} & \quad \text{H} \\
\text{H} & \quad \text{H} \\
\text{H} & \quad \text{H} \\
\text{C} & \quad \text{C} \\
\end{align*}
\]

[Three repeating units of poly(ethene), i.e. six carbons in a chain, two hydrogen atoms attached to each carbon, single bonds.]

[End bonds not required.]

[Where 2 ethenes make a carbon chain with four carbon atoms, award (3) for ethenes and (2) for chain.]

(ii) **GIVE:** 

LDPE: more branched / lower melting point / shorter chain length / softer (more flexible, not as strong)

**ANY TWO:** \((6 + 3)\)

[Accept equivalent opposites about HDPE]

(iii) **WHAT:**

HDPE: organometallic (Ziegler-Natta) catalyst

LDPE: high(er) pressure(s) / LDPE: high(er) temperature(s)

HDPE: low(er) temperature(s) / HDPE: low(er) pressure(s)

\((3)\)
Blank Page