Coimisiún na Scrúduithe Stáit
State Examinations Commission

Leaving Certificate 2021

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.

Coimisiún na Scrúduithe Stáit

State Examinations Commission

LEAVING CERTIFICATE EXAMINATION, 2021

CHEMISTRY – HIGHER LEVEL

MARKING SCHEME

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 the 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 obtain more than 75% of the total marks.

Candidates are required to answer any SIX questions.

All questions carry equal marks (50).

Coimisiún na Scrúduithe Stáit

Marcanna Breise as ucht freagairt trí Ghaeilge

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

N.B. Ba chóir marcanna de réir an ghnáthráta a bhronnadh ar iarrthóirí nach ngnóthaíonn níos mó ná 75% d'iomlán na marcanna don scrúdú. Ba chóir freisin an marc bónais sin **a shlánú síos**.

Tábla 300 @ 10%

Bain úsáid as an tábla seo i gcás na n-ábhar a bhfuil 300 marc san iomlán ag gabháil leo agus inarb é 10% gnáthráta an bhónais.

Bain úsáid as an ngnáthráta i gcás 225 marc agus faoina bhun sin. Os cionn an mharc sin, féach an tábla thíos.

Bunmharc	Marc Bónais
226	22
227 - 230	21
231 - 233	20
234 - 236	19
237 - 240	18
241 - 243	17
244 - 246	16
247 - 250	15
251 - 253	14
254 - 256	13
257 - 260	12
261 - 263	11

Bunmharc	Marc Bónais
264 - 266	10
267 - 270	9
271 - 273	8
274 - 276	7
277 - 280	6
281 - 283	5
284 - 286	4
287 - 290	3
291 - 293	2
294 - 296	1
297 - 300	0

Annotations used in (online) marking Chemistry 2021

For a fully correct response examiners may award one total mark, e.g. six marks or a number of partial marks, e.g. 2 marks, 3 marks, 1 mark that add to the same total.

For partially correct responses examiners should place the apropriate marks near the correct part of the response and/or use 0 marks to indicate the part of the answer that is incorrect or insufficient.

Examiners should annotate fully incorrect responses or responses of no merit with a 0 mark.

Colours of annotations may vary.

Annotation	Meaning
 n	n marks awarded
	Mathematical slip error or other penalty as per scheme
	No marks awarded. Answer incorrect or insufficient
	Reverse order
	Surplus answer or part of answer
	Blank page or part of page
	Cancellation / contradiction
	Part of answer of significance
	Incorrect charge, subscript, etc
	Key word, phrase omitted
	Correct – e.g. used where item attempted more than once
	Incorrect

QUESTION 1

(*a*) DESCRIBE: use **funnel** to **transfer** original bleach (contents of beaker) to correctly prepared 500 cm^3 **volumetric flask** (3)

rinse beaker funnel and glass rod **into** volumetric **flask //**
with **deionised (distilled, pure) water //**
make up (fill, add deionised water**)** *flask* to 500.0 cm^3 with **bottom of meniscus on mark** with deionised water **//**
stopper and invert several times

ANY TWO: (2 × 3)

[No marks for rinsing *a pipette* with deionised (distilled, pure) water or reference to bottom of meniscus *of a pipette*.]

(*b*) WHY: **to ensure all hypochlorite (bleach, ClO^-) reacts (is reduced, detected, forms Cl^-, forms iodine) /**
to ensure iodine remains in solution / to form soluble **I_3^- (triiodide** ion**, KI_3)** (6)
[Allow (6) for KI acts as reducing agent.]
[Allow 'to make **hypochlorite (bleach, ClO^-) limiting** reagent'.]
[*Note KI or I^- excess reagent or not limiting only repeats question.*]

(*c*) STATE: *first:* **colourless //**
second: **brown (golden-brown, yellow-brown, red-brown, orange)** (2 × 3)
[correct colours reversed (3)]

(*d*) IDENTIFY: (*i*) **starch** solution (3)

WHAT: (*ii*) from pale yellow (straw yellow) to **blue / black / blue-black //**
to **colourless** (2 × 3)
[correct colours reversed (3)]

[Marks for (ii) available even if marks for (i) not awarded.]

(*e*) FIND: (*i*) 0**.001926** (**1.926 × 10^{-3}, 963/500000**) moles sodium thiosulfate on average (3)

$\frac{21.4 \times 0.09}{1000}$ = 0**.001926** (**1.926 × 10^{-3}, 963/500000**) moles sodium thiosulfate (3)

(*ii*) 0**.000963** (**9.63 × 10^{-4}**) moles of I_2 in 25.0 cm^3 in conical flask (3)

$Na_2S_2O_3 : I_2 = 2 : 1 \Rightarrow 0.001926\ (1.926 \times 10^{-3}, 963/500000) \div 2$
= 0**.000963** (**9.63 × 10^{-4} , 963/1000000**) moles of I_2 in 25.0 cm^3 in conical flask (3)
[Divide by 2 essential.]

or

$\frac{25.0 \times M}{1} = \frac{21.4 \times 0.09}{2} \Rightarrow M$ = 0.03852 (3.852 × 10^{-2}, 963/25000) moles/l (M) of I_2

0.03852 (3.852 × 10^{-2}, 963/25000) ÷ 40
= 0**.000963** (**9.63 × 10^{-4}, 963/1000000**) moles of I_2 in 25.0 cm^3 in conical flask (3)
[Divide by 40 essential.]

(*iii*) 0.**77**04 **(963/1250)** moles ClO^- per litre original bleach (6)

0.000963 (9.63×10^{-4}) moles of I_2 in 25.0 cm^3 in conical flask
0.000963 (9.63×10^{-4}) moles of diluted ClO^- in 25.0 cm^3 in conical flask

0.000963 (9.63×10^{-4}) moles per 25.0 $cm^3 \times 40$
= 0**.03852 (3.852×10^{-2}, 963/25000)** moles ClO^- per litre diluted bleach (3)
[Multiply by 40 essential.]

0.03852 (3.852×10^{-2}, 963/25000) moles per litre diluted bleach × 20 (dilution factor)
= 0.**77**04 **(963/1250)** moles ClO^- per litre original bleach (3)
[Multiply by 20 essential.]

or

0.000963 (9.63×10^{-4}) moles of I_2 in 25.0 cm^3 in conical flask
0.000963 (9.63×10^{-4}) moles of diluted ClO^- in 25.0 cm^3 in conical flask

0.000963 (9.63×10^{-4}) moles per 25.0 $cm^3 \times 20$ (dilution factor)
= 0**.01926 (1.926×10^{-2}, 963/50000)** moles ClO^- per 25.0 cm^3 original bleach (3)
[Multiply by 20 essential.]

= 0.01926 (1.926×10^{-2}, 963/50000) moles per 25.0 cm^3 original bleach × 40
= 0.**77**04 **(963/1250)** moles ClO^- per litre original bleach (3)
[Multiply by 40 essential.]

or

$\frac{25.0 \times M}{1} = \frac{21.4 \times 0.09}{2} \Rightarrow M$ = 0.03852 (3.852×10^{-2}, 963/25000) moles/l (M) I_2
$\Rightarrow M$ = 0**.03852 (3.852×10^{-2}, 963/25000)** moles/l (M) of diluted bleach (3)

0.03852 (3.852×10^{-2}, 963/25000) moles per litre diluted bleach × 20 (dilution factor)
= 0.**77**04 **(963/1250)** moles ClO^- per litre original bleach (3)
[Multiply by 20 essential.]

(*iv*) **4** % (w/v) ClO^- in original bleach (8)

*M*r ClO^- = **51.5***
0.7704 (963/1250) × 51.5 = **39.9655** – **39.6756** g ClO^- per litre original bleach (3)
*[Multiply by 51.5 essential.]

39.6756 ÷ 10 =
3.9655 – 4 g ClO^- per 100 cm^3 original bleach $\Rightarrow$ 3.9655 – **4** % (w/v) ClO^- in original bleach (2)
[Divide by 10 essential.]

or

*M*r ClO^- = **51.5***
0.7704 ÷ 10 = 0**.077**04 moles per 100 cm^3 original bleach (2)
[Divide by 10 essential.]

0.07704 (963/12500) × 51.5 = 3.9655 – **4** % (w/v) ClO^-original bleach (3)
*[Multiply by 51.5 essential.]

[**Addition must be shown for error to be treated as slip. Mr of 51.45 and subsequent work based on Ar values in Formula and Tables booklet acceptable*.]
[*Final answer not a whole number to be treated as slip.*]
[*1 mark to be deducted for incorrect or inappropriate **rounding** but deduction to be made once only in (e).*] [*1 mark to be deducted for **each** of any other mathematical slips, e.g. transposing numbers, addition error in M_r where atomic masses shown to be added incorrectly, etc*].

QUESTION 2

(*a*) (*i*) WHY: **speeds up reaction / brings reaction to completion** in shorter time **/ helps mix reactants / allows heating without loss of material / allows heating without** flask **boiling dry / maximise yield / to help reaction reach activation energy** (5)

(*ii*) SUGGEST: **oil (water) bath (beaker)** heated with Bunsen or hotplate **/ heating mantle / Bunsen with wire gauze** (3)
[Information given clearly in diagram acceptable.]

(*iii*) JUSTIFY: *heated oil (water) bath:* **gentle heating** possible **/ temperature (rate of heating) easily controlled / safe (no** direct **flame, no** naked **flame) //**

heating mantle: **temperature (rate of heating) easily controlled / safe (no flame) / convenient / quick / easy to use**

Bunsen with wire gauze: **gentle heating** possible **/ temperature (rate of heating) easily controlled / flask not heated directly** (3)

[JUSTIFY marks only available if SUGGEST marks awarded.]

(*iv*) WHY: **improves yield / to get more (the most) soap / makes soap less soluble in brine /** helps **precipitate (separate) soap /** ethanol (would) **dissolve**s **soap / for re-use** (3)

(*b*) (*i*) NAME: **propane-1,2,3-triol / 1,2,3-propanetriol / glycerol / glycerine** (6)

(*ii*) WHAT: saturated (concentrated) **solution of salt (NaCl)** in water **/ salt water** (3)

(*iii*) EXPLAIN: **to precipitate (separate) soap / to dissolve (wash away, wash out) components other than soap (NaOH, glycerol)** (3)

(*c*) (*i*) DESCRIBE: **filter (filtration) / decant (pour) off brine (liquid)** (6)

(*ii*) WHERE: **in brine (**salt **solution, liquid, filtrate) / in** the filtration **flask /** some **mixed with soap** (3)
[Information given clearly in diagram acceptable.]

(*d*) EXPLAIN: **COONa (COO$^-$Na$^+$,** $CH_3(CH_2)_{10}$**COO$^-$, COO$^-$, Na$^+$) /** one end **ionic (polar)** (6)

(*e*) WHAT: **19.98** g (**19.98 – 20** g) $CH_3(CH_2)_{10}COONa$ (9)

0.03 moles tri-ester $\Rightarrow$ 0**.09** moles soap	(3)
M_r soap = **222***	(3)
0.09 × 222* = **19.98** g (**19.98 – 20** g) $CH_3(CH_2)_{10}COONa$	(3)

[**Addition must be shown for error to be treated as slip. Mr of 222.294 and subsequent work based on Ar values in Formula and Tables booklet acceptable.*]

QUESTION 3

(*a*) DESCRIBE: (5 × 3)

Method 1	Method 2	Method 3	
clean a **platinum (nichrome) wire* (rod, probe) in HCl (concentrated hydrochloric acid)**	**soak wood (splint, stick)** overnight in water **/ use damp (wet) wood (splint, stick)**	prepare a **solution of** the given **salt**	(3)
dip wet rod **in salt (sample)**	**dip**** splint (stick) **in salt (sample)**	**in water and ethanol (propanol)**	(3)
hold salt in or over hot (blue) part of Bunsen **flame**	**hold** salt in or over hot (blue) part of Bunsen **flame**	**spray** salt solution onto (into) hot (blue) part of Bunsen **flame**	(3)
yellow (amber, orange) colour is a positive result for **sodium** sulfite	**yellow (amber, orange)** colour is a positive result for **sodium** sulfite	**yellow (amber, orange)** colour is a positive result for **sodium** sulfite	(3)
yellow-**green** colour is a positive result for **barium** chloride	yellow-**green** colour is a positive result for **barium** chloride	yellow-**green** colour is a positive result for **barium** chloride	(3)

*[Allow 'metal inoculating loop', or 'metal spatula' for 'platinum (nichrome) wire'.]
[Clear labelled diagram for some or all points acceptable.]
[**Method 2: 'Soak splint (stick) in salt solution' merits (6).]

(*b*) (*i*) DESCRIBE: **add (mix)** drops **barium chloride ($BaCl_2$)** solution to (with) small volume of sodium sulfite solution **//**
white precipitate (white solid) formed //
add (mix) drops **hydrochloric acid (HCl)** and all **precipitate (solid, barium sulfite, $BaSO_3$) dissolves /**
add (mix) drops **hydrochloric acid (HCl)** and **no precipitate (no solid, no barium sulfite, no $BaSO_3$) remains** (3 × 3)
[Some of this information may be given in equation form.]

(*ii*) WHAT: **red (red-brown, yellow-brown, brown, orange, yellow) disappears / colour disappears /** solution **becomes colourless** (3)
[Clear unacceptable instead of colourless.]

HOW: **add (mix)** drops **barium chloride ($BaCl_2$)** solution to (with) solution in test tube **// precipitate (solid) remains (does not dissolve)** when **hydrochloric acid (HCl) added (mixed)** (2 × 3)
[Only where **all** 9 marks awarded in (*b*) (*i*) DESCRIBE award **6** marks in (*ii*) HOW for **repeat** sulfite **test** and this time **precipitate remains when HCl added.**]

(*c*) WHAT: (*i*) **magnesium (Mg)** has **better (stronger)** reducing ability than copper (Cu) **/**
magnesium (Mg) more easily oxidised than copper (Cu) **/**
magnesium (Mg) loses electrons more easily than copper (Cu) **/**
Mg reduces copper(II) / Mg reduces Cu^{2+} / magnesium ions **displace(s) copper** ions (3)

(*ii*) **zinc** has **better (stronger)** reducing ability than copper (Cu) **/**
zinc more easily oxidised than copper (Cu) **/**
zinc (Zn) loses electrons more easily than copper (Cu) **/**
Zn reduces copper(II) / Zn reduces Cu^{2+} / zinc ions **displace(s) copper** ions (3)

(*iii*) WRITE: **$Mg + Cu^{2+} \rightarrow Mg^{2+} + Cu$ / $Mg + CuSO_4 \rightarrow MgSO_4 + Cu$ /**
$Zn + Cu^{2+} \rightarrow Zn^{2+} + Cu$ / $Zn + CuSO_4 \rightarrow ZnSO_4 + Cu$ (6)

(*iv*) SUGGEST: **magnesium in excess (more moles {atoms} magnesium) /**
zinc limiting (fewer moles {atoms} zinc) / copper sulfate (Cu(II), Cu^{2+}) limiting in magnesium (first) reaction / all copper sulfate (Cu(II), Cu^{2+}) used up in magnesium (first) reaction / all zinc used up / copper sulfate (Cu(II), Cu^{2+}) in excess (left over, unreacted) in zinc (second) reaction

or accept

magnesium reacts quickly / magnesium more easily oxidised than zinc **/**
zinc reacts slowly / zinc not oxidised as easily as magnesium **/**
zinc not sandpapered (cleaned) (5)

QUESTION 4

Eight items to be answered.

Six marks to be allocated to each item and one additional mark to be added for each of the first two items attempted.

(*a*) HOW: (*i*) **18** electrons
(*ii*) **16** neutrons (2 × 3)
[Take order of question unless answers clearly labelled.]

(*b*) DEFINE: **space (volume, region)** around nucleus of an atom **//**
where there is a relatively **high probability (possibility) of finding an electron / where an electron is likely to be found** (2 × 3)
['Area' around nucleus not acceptable.]

(*c*) WRITE: **$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2\ 3d^8$ /**
$1s^2\ 2s^2\ 2p_x^2 2p_y^2\ 2p_z^2\ 3s^2\ 3p_x^2 3p_y^2\ 3p_z^2 4s^2\ 3d^8$ /
[Ar] $4s^2\ 3d^8$ (6)
[*Allow subscripts instead of superscripts.*]
[*Arrows to represent numbers of electrons acceptable but sub-level labels must be given.*]

(*d*) WHICH: **CO_2** container **/ last (third) one //**
EXPLAIN: **equal numbers of molecules (moles) /** according to **Avogadro's law /**
CO_2 triatomic (three atoms in CO_2 molecule**) / CO_2 molecule has more atoms** (2 × 3)
[Award second (3) only if first (3) is given.]

(*e*) DEFINE: number expressing the **relative (measure of)** force of **attraction (affinity) of an atom (nucleus** of an atom**)** of an element **//**
for shared pair(s) of **electrons / for electrons in a covalent bond** (2 × 3)

(*f*) WHY: **C-C is a sigma** bond and **C≡C is a sigma and 2 pi** bonds **//**
sigma stronger than pi **/ pi weaker** than sigma (2 × 3)

(*g*) DEDUCE: **N_2O** (6)

(*h*) FIND: **3 / $KBrO_3$** (6)

$\frac{80}{39+80+16x}$ **= 0.479** * / $\frac{80}{119+16x} \times 100$ **= 47.9** * (3)

80 = 57.001 + 7.664*x* ⇒ *x* = **3** (3)

or

$\frac{39}{80} \times 47.9$ = 23.35% (23.4%) K* and
100 – (47.9 + 23.4) = **28.7**% **(28.8%, 29%)** O (3)

$\frac{47.9}{80}$ = 0.598 $\frac{23.4}{39}$ = 0.6 $\frac{28.7}{16}$ = 1.794
0.598 : 0.6 : 1.794 = 1 : 1 : 3 ⇒ *x* = **3** (3)

or

80 = 47.9 % ⇒ **167**.01 = 100 = M_r (3)

167.01 – 80 – 39 = 48.01 = 16*x*

⇒ *x* = **3** (3)

[**Work based on Ar values in Formula and Tables booklet acceptable.*]

(*i*) SHOW: **$H_2O + H_2O \rightleftharpoons H_3O^+ + OH^-$ / $2H_2O \rightleftharpoons H_3O^+ + OH^-$** FORMULAE: (3) BALANCED (3)
Allow $H_2O \rightleftharpoons H^+ + OH^-$
[non equilibrium arrow unacceptable….(–1)]

(*j*) GIVE: **preservative (antifungal** agent**, pH adjuster) / food additive / flavour**ing agent (6)

(*k*) WHAT: (*i*) **2** (3)
(*ii*) **3** (3)
[Take order of question unless answers clearly labelled.]

(*l*) **A** GIVE: *advantage:* **suits slower reactions / suits pharmaceutical industry (research) / flexible (adaptable)** reaction vessels **/ suits small quantities / capital (building, installation) costs** of plant **small / loss isolated to single batch / etc**

disadvantage: **contamination** from previous batch **possible / labour costs high / costly (unit cost higher) / filling (emptying, cleaning, recharging, calibration, maintenance of)** reaction vessel takes **time / etc**

(2 × 3)

or

B WHAT: **low-**density poly(ethene) **(L**DPE**)** carbon chains **more branched (has branching) / high**-density poly(ethene) **(H**DPE**)** carbon chains have **less (no) branching** (6)

QUESTION 5

(*a*) (*i*) HOW: listed elements **according to** increasing **atomic weight (atomic mass) //**
properties varying periodically / in columns (groups) of similar properties (3 + 2)

(*ii*) SUGGEST: **noble gases were unknown (undiscovered, not in Mendeleev's** first **table) /**
inertness (unreactivity) of argon **/ inertness (unreactivity)** of **noble gases /**
no group obviously **missing /**
no gap for argon (3)

(*iii*) HOW: **no gaps** in modern periodic table **/**
elements **known for all (lower) atomic numbers /**
all other (lighter) elements known /
all elements up to about Z = **117 (118) known** (3)

(*b*) (*i*) WHY: **uncertainty (Heisenberg) principle / electron's position and velocity**
(speed, momentum) not known at same time / wave nature of electron /
wave-particle duality of electron / electrons occupy orbitals not orbits (6)

(*ii*) HOW: **half the internuclear distance (half the distance between the nuclei {centres})**
of two **atoms of same element (**two **identical atoms) //**
joined by **a single** covalent **bond** (2 × 3)
or
half the internuclear distance between two **atoms //**
joined by **a single homonuclear bond** (2 × 3)

(*iii*) PREDICT: 0**.0995 –** 0**.1**0 nm (3)

(*iv*) ACCOUNT: effective **nuclear charge increasing /** number **protons increases /**
atomic number increases (3)

(*v*) WHY: **Ar-Ar bonds unlikely to (do not) exist / argon monatomic** (3)

(*c*) (*i*) DEFINE: minimum **energy required to** completely **remove //**
the **most loosely bound electron /** the **outermost electron** (2 × 3)

(*ii*) WHY: **outer**most **electron** of potassium **farther from nucleus /**
outermost **electron** of potassium **belongs to 4th (higher) energy level (shell) /**
atomic radius of potassium **greater /**
outermost **electrons of chlorine and argon closer to nucleus /**
outermost **electrons of chlorine and argon belong to 3rd (lower) energy level (shell) //**
[Allow K = $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^1$]

greater degree of **shielding (screening)** from electrons in inner main energy levels
(shells) in potassium **/ lower effective nuclear charge** (2 × 3)

(*iii*) WHY: **more difficult (requires more energy) to remove electron from a positive ion** than from the neutral atom **/**
greater attraction between **nucleus (ion) and electron /**
effective nuclear charge of potassium ion **increased /**
more protons than electrons in the ion **/**
ionic **radius smaller /** second (outer, next) **electron closer to nucleus** (3)

(*iv*) WHY: second **electron comes from new* shell (full** outer 3**p subshell, full** outer 3**p sublevel) / first electron easily removed as it is the only electron in outer (4th) shell /** second outermost **electron removed from 3rd** main **energy level (shell) while first removed from 4th /**
second outermost **electron removed from a stable (full, closed) octet (noble gas configuration) /**
second outermost **electron closer to nucleus** than first **/**
second outermost **electron less shielded (screened)** than first (3)
*[Full shell incorrect here but do not cancel other correct indicator].

QUESTION 6

(*a*) (*i*) GIVE: **steam reforming** of natural gas **(coal gasification) //**
electrolysis of water //
dehydrocyclization (reforming) of hydrocarbons ANY TWO: (3 + 2)

(*ii*) STATE: **low polluting (**almost **non-polluting, clean) /** non-toxic **water only product /**
non-toxic product of combustion **/ no harmful** combustion **product /**
no CO_2 (soot, carbon monoxide) produced /
eco-friendly (low **carbon footprint,** low **greenhouse effect contribution) //**

efficient / high energy produced per kg / high kilogram calorific value //

high octane number (rating) / resistant to autoignition //

supply effectively **limitless (plentiful, abundant) /** production can be **renewable**

ANY TWO: (2 × 3)

(*b*) (*i*) WHAT: **propane / $CH_3CH_2CH_3$ / C_3H_8 //**
butane / $CH_3CH_2CH_2CH_3$ / C_4H_{10} (2 × 3)

(*ii*) EXPLAIN: **separation on basis of boiling point (molecular size, number of carbons) indicated or stated /**
smaller or lower b.p. molecules at top indicated or stated /
larger or higher b.p. molecules at base indicated or stated (3)

heated crude oil (furnace) at base of column shown or stated //
column with levels or outlets shown //
temperature decreases as mixture rises **up column shown or stated**
ANY TWO: (2 × 3)

[Points of information can be taken from labelled diagram]
[No diagram (–3)]

(*iii*) SHOW: **refinery gas (LPG) above gas oil (diesel) shown** in part (*ii*) diagram (3)

(*c*) WHAT: **safety / to give** gas **a smell / to enable leaks to be detected** (6)

(*d*) USE: **–73.7** kJ mol^{-1} (15)

$\Delta H_{combustion}$ = $\Sigma\Delta H_{formation\ products}$ – $\Sigma\Delta H_{formation\ reactants}$

$\Delta H_{combustion}$ = (**–787.**0) kJ mol^{-1} (3) + (**–857.4**) mol^{-1} (3) + **(–296.8)** kJ mol^{-1} (3) – $\Delta H_{formation}$
($\Delta H_{combustion}$ = **(–1941.2**) kJ mol^{-1} (9) **–** $\Delta H_{formation}$**)**

$\Delta H_{formation}$ = (–787.0) kJ mol^{-1} + (–857.4) k mol^{-1} + (–296.8) kJ mol^{-1} + **1867.5** (3) kJ mol^{-1}

$\Delta H_{formation}$ = –1941.2 + 1867.5 = **–73.7** (3) kJ mol^{-1}

or

$2CO_2 + 3H_2O + SO_2 \rightarrow C_2H_5SH + 4½O_2$	ΔH =	**1867.5** kJ		(3)
$2C + 2O_2 \rightarrow 2CO_2$	ΔH =	**–787.**0 kJ		(3)
$3H_2 + 1½O_2 \rightarrow 3H_2O$	ΔH =	**–857.4** kJ	= **–1941.2** (9)	(3)
$S + O_2 \rightarrow SO_2$ / $\frac{1}{8}S_8 + O_2 \rightarrow SO_2$	ΔH =	**–296.8** kJ		(3)

$2C + 3H_2 + S \rightarrow C_2H_5SH$	$\Delta H_{formation}$ =	**–73.7** kJ mol^{-1} **/**	
$2C + 3H_2 + \frac{1}{8}S_8 \rightarrow C_2H_5SH$	$\Delta H_{formation}$ =	**–73.7** kJ mol^{-1}	(3)

Mixing and matching from different boxes not acceptable.
Equations not essential in second box, however:

Final Answer ΔH = +**73.7** kJ mol^{-1} and **$C_2H_5SH \rightarrow 2C + 3H_2 + S$ / $C_2H_5SH \rightarrow 2C + 3H_2 + \frac{1}{8}S_8$** worth 12 marks **only when clearly associated** with this equation.
Scheme above applies.

QUESTION 7

(*a*) DEFINE: (*i*) **dissociates in water (aqueous solution) //**
to produce protons (hydrogen ions, H^+) (2 × 2)
[Allow H_3O^+ (hydronium ions)]

(*ii*) **proton (hydrogen ion, H^+) donor** (4)

(*iii*) STATE: **protons (H^+** ions**) do not exist** alone in solution **/**
protons (H^+ ions**)** from dissociation **donated (become attached, transferred) to water (some other species) /**
protons (H^+ ions**) become H_3O^+ (hydronium ions) /**
water must always be **involved (**theory **confined to aqueous solutions) /**
NH_3 can**not** be considered **a base /**
water can**not** be considered **amphoteric (amphoteric substances not explained)** (6)

(*iv*) WHAT: two species (two substances, an acid and a base) that **differ by a proton (H^+) /**
base accepts proton to become its conjugate acid /
acid donates proton to become its conjugate base (3)

(*b*) DISTINGUISH: **greater the tendency of** an **acid to donate protons (more** the **acid tends to dissociate into ions) the stronger it is /**
less the tendency of an **acid to donate protons (less** the **acid tends to dissociate into ions) the weaker it is** (6)

or

***strong** acid:*
is a **good proton (H^+) donor /** has a **weak conjugate base / fully dissociated /**
has **large (complete) degree of dissociation** into ions **/ K_a value large //**

***weak** acid*:
is a **poor proton (H^+) donor /** has a **strong conjugate base /**
dissociated into ions **to small extent / slightly* dissociated / K_a value small**
(2 × 3)

[*Accept **weak** acid only **partly dissociated.**]

(*c*) WRITE: **$HSO_4^- + H_2O \rightleftharpoons SO_4^{2-} + H_3O^+$**
FORMULAE: (3) BALANCING: (3)

[non equilibrium arrow acceptable here]

(*d*) (*i*) WRITE: **$HA + H_2O \rightleftharpoons H_3O^+ + A^-$** FORMULAE: (3) BALANCING: (3)
[non equilibrium arrow unacceptable….(–1)]

(*ii*) FIND: $[H_3O^+] = [A^-] =$ **1.5×10^{-3} (3/2000, 0.0015)** M (3)

$[H_3O^+] = [A^-]$
1.5% of 0.1 = **1.5×10^{-3} (3/2000, 0.0015)** M (3)

(*iii*) CALCULATE: pH = **2.8**2 (6)

pH = **– log**$_{10}$**[H$^+$] /** pH = **– log**$_{10}$**[H$_3$O$^+$] /** pH = **– log**$_{10}$**(1.5 × 10^{-3})** (3)

pH = **2.8**2 (3)

(*iv*) CALCULATE: K_a = **2.25 × 10^{-5} – 2.55 × 10^{-5}** (6)

$K_a = \frac{[\mathbf{H_3O^+}][\mathbf{A^-}]}{[\mathbf{HA}]}$ / Allow $K_a = \frac{[\mathbf{H^+}][\mathbf{A^-}]}{[\mathbf{HA}]}$ (3)

$= \frac{(1.5\times10^{-3})^2}{0.10}$ = **2.25 × 10^{-5}** (3)

or

pH = –log$\sqrt{K_a[\mathbf{HA}]}$ **/ antilog(– pH) =** $\sqrt{K_a[\mathbf{HA}]}$ **/**
2.82 **= –log**$\sqrt{K_a[\mathbf{HA}]}$ **/ antilog(–2.8**2**) =** $\sqrt{K_a[\mathbf{HA}]}$ **/ 10$^{-2.82}$ =** $\sqrt{K_a[\mathbf{HA}]}$ **/**
2.82 **= –log**$\sqrt{K_a[0.\mathbf{10}]}$ **/ antilog(–2.8**2**) =** $\sqrt{K_a[0.\mathbf{10}]}$ **/ 10$^{-2.82}$ =** $\sqrt{K_a[0.\mathbf{10}]}$ **/**

[H$_3$O$^+$] = $\sqrt{K_a[\mathbf{HA}]}$ **/ 1.5 × 10^{-3} =** $\sqrt{K_a[\mathbf{HA}]}$ **/** Allow **[H$^+$] =** $\sqrt{K_a[\mathbf{HA}]}$ **/**
[H$_3$O$^+$] = $\sqrt{K_a[0.\mathbf{10}]}$ **/ 1.5 × 10^{-3} =** $\sqrt{K_a[0.\mathbf{10}]}$ **/** Allow **[H$^+$] =** $\sqrt{K_a[\mathbf{HA}]}$ (3)

$2.29 \times 10^{-6} = K_a \times 0.10$
$\Rightarrow K_a$ = **2.25 × 10^{-5} – 2.51 × 10^{-5}** (3)

Accept [HA] after dissociation taken as $0.10 - 1.5 \times 10^{-3} = 0.0985$ M

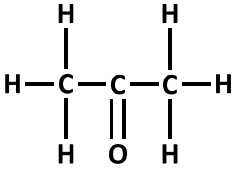
QUESTION 8

(*a*) (*i*) WHAT NAME: **propan-2-ol / 2-propanol**

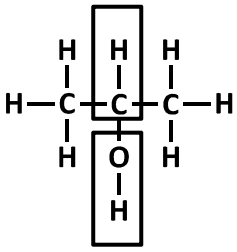
(*ii*) CLASSIFY: **secondary / 2°**

JUSTIFY: **two carbon** atoms **attached to carbon (C) with OH /**
OH (alcohol functional **group) attached to carbon in middle of chain (carbon 2, C2, carbon with only one H atom attached to it) /**
OH (alcohol functional **group) not on terminal (end, first, third) carbon** atom **/**
OH (alcohol functional **group) not on C1 (C3)**
[CLASSIFY marks must be correct if JUSTIFY to be awarded marks.] (3 + 3 + 2)

(*b*) (*i*) IDENTIFY: **propanone /acetone / CH_3COCH_3 /** (3)



(*ii*) DRAW:



(3)

INDICATE: **OH** bond **//**
CH bond of **carbon to which OH is attached** (2 × 3)
[C-O formed unacceptable but cancellation not applied.]
[Hs attached to carbon atoms need not be shown explicitly but all CH bonds must be indicated and the H of OH **must** be shown]
[DRAW must be correct for INDICATE to be awarded marks.]

(*iii*) HOW: central carbon (carbon 2, C2, carbonyl carbon) changes from trigonal **planar to tetrahedral** and no other change (3)

(*c*) (*i*) WHAT: **addition / hydration** (3)

(*ii*) IDENTIFY: **propanol / propan-1-ol** (3)

(*d*) (*i*) WRITE: **$CH_3CH(OH)CH_3 + Na \rightarrow CH_3CH(ONa)CH_3 + ½H_2$ / $C_3H_7OH + Na \rightarrow C_3H_7ONa + ½H_2$ /**
$2CH_3CH(OH)CH_3 + 2Na \rightarrow 2CH_3CH(ONa)CH_3 + H_2$ /
$2C_3H_7OH + 2Na \rightarrow 2C_3H_7ONa + H_2$ FORMULAE: (3) BALANCING: (3)

(*ii*) WHAT: **acidic / loses proton** (3)

(*e*) (*i*) EXPRESS: **9.3** moles per litre (mol l^{-1}, M) (9)

70 cm^3 $CH_3CH(OH)CH_3$ per 100 cm^3	
$\Rightarrow$ **700** cm^3 $CH_3CH(OH)CH_3$ per litre	(3)
700 × 0.8 = **560** g $CH_3CH(OH)CH_3$ per litre	(3)
$\frac{560}{60^*}$ = **9.3**33 moles per litre (mol l^{-1}, M)	(3)

[**Addition must be shown for error to be treated as slip. Mr of 60.094 and subsequent work based on Ar values in Formula and Tables booklet acceptable.*]

(*ii*) WHAT: **dipole-dipole** interactions **/ van der Waals** forces (3)

QUESTION 9

(*a*) SELECT: (*i*) **A** (3)

(*ii*) **B** (3)

[Take order of question unless answers clearly labelled.]

(*b*) USE: **exothermic** (3)

JUSTIFY: **less ammonia (low**er **yield) at high**er **temperature /**
more ammonia (higher **yield) at low**er **temperature /**
reverse reaction favoured when temperature increases (to absorb heat) /
forward heat releasing **reaction not favoured when temperature increases** (6)

[USE must be correct for JUSTIFY to be awarded marks]

(*c*) (*i*) WRITE: $K_c = \dfrac{[\mathbf{NH_3}]^{\mathbf{2}}}{[\mathbf{N_2}][\mathbf{H_2}]^{\mathbf{3}}}$ (6)

[Square brackets **ESSENTIAL**.][Award marks for this expression given in part (*ii*).]

(*ii*) CALCULATE: $\frac{25}{243}$ / 0.**1**03 (12)

Let x = number of moles of N_2 that reacted

	$N_{2\,(g)}$	+	$3H_{2\,(g)}$	⇌	$2NH_{3\,(g)}$	
Initially:	9.0 mol		27.0 mol		0 mol	
Change:	**– *x*** mol		**– 3*x*** mol		+ **2*x*** mol **/**	
Equil:	**9**.0 **– *x*** mol		**27**.0 **– 3*x*** mol		**2*x*** mol	(3)

But $2x = 6 \Rightarrow x = 3$

Equil: 9.0 – 3 = **6** mol N_2 27.0 – 9 = **18** mol H_2 **6** mol NH_3 (3)

Divide by 10.0

Equil: $\frac{9.0-3}{10}$ = 0.**6** mol/l N_2 $\frac{27.0-9}{10}$ = **1.8** mol/l H_2 $\frac{6}{10}$ = 0.**6** mol/l NH_3 (3)

Relate K_c to equilibrium concentrations

$K_c = \frac{0.\mathbf{6}^2}{0.\mathbf{6}(\mathbf{1.8})^3}$ = $\frac{25}{243}$ / 0.**1**03 (3)

or

Let x = number of moles per litre of N_2 that reacted

	$N_{2\,(g)}$	+	$3H_{2\,(g)}$	⇌	$2NH_{3\,(g)}$	
Initially:	9.0 mol		27.0 mol		0 mol	
Divide by 10.0						
Initially:	0.**9** mol/l N_2		**2.7** mol/l H_2		0 mol/l NH_3	(3)
Change:	**– *x*** mol/l		**– 3*x*** mol/l		+ **2*x*** mol/l **/**	
Equil:	0.**9 – *x*** mol/l N_2		**2.7 – 3*x*** mol/l H_2		**2*x*** mol/l NH_3	(3)

But $2x = 0.6 \Rightarrow x = 0.3$

Equil: 0.9 – 0.3 = 0.**6** mol/l N_2 2.7 – 0.9 = **1.8** mol/l H_2 0.**6** mol/l NH_3 (3)

Relate K_c to equilibrium concentrations

$K_c = \frac{0.\mathbf{6}^2}{0.\mathbf{6}(\mathbf{1.8})^3}$ = $\frac{25}{243}$ / 0.**1**03 (3)

[No mixing and matching of contents of boxes above.]

(*iii*) FIND: **20**% (3)

$\frac{\mathbf{6}}{\mathbf{30}} \times 100 = \mathbf{20}\%$ **/** $\frac{\mathbf{0.6}}{\mathbf{3}} \times 100 = \mathbf{20}\%$ (3)

(*d*) STATE: (*i*) **larger (increased)** yield of ammonia / **more** ammonia (4)

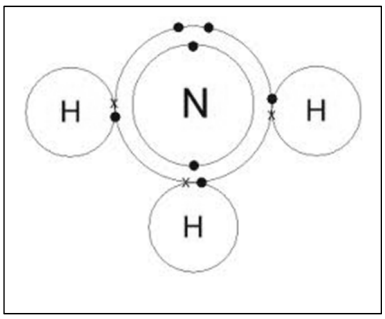
EXPLAIN: (*i*) reaction which produces **fewer** gaseous **moles (molecules)** favoured (3)
[STATE (*i*) and EXPLAIN (*i*) linked.] [STATE must be correct for EXPLAIN to be awarded marks.]

STATE: (*ii*) **no effect / none** (4)

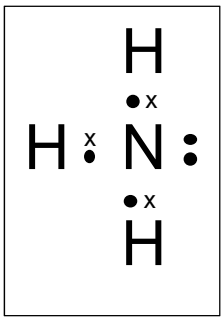
EXPLAIN: (*ii*) any catalyst **only affects (speeds up) rate (time to reach equilibrium) /**
catalyst **does not affect equilibrium concentration**s **(yield**s**) /**
any catalyst **affects (speeds up) forward and reverse reactions equally** (3)
[STATE (*ii*)and EXPLAIN (*ii*) linked.] [STATE must be correct for EXPLAIN to be awarded marks.]

QUESTION 10

(*a*) (*i*) DRAW: **1 lone pair shown //**
3 bond pairs shown



/



(4 + 3)

(*ii*) WHY: **lone pair (lp)** present in ammonia **/ 4 electron pairs** present in ammonia **/**
trigonal planar possible **if only** three **bond pairs (bp's)** (3)

(*iii*) WHAT: **linear** and
bent (**v**-shaped) (2 × 3)
[Clear diagrams acceptable]

(*iv*) EXPLAIN: **centres of negative and positive charge coincide /**
distribution of polar **bonds (dipoles)** is **highly symmetric** about central atom **/**
high degree of symmetry in arrangement of polar **bonds (dipoles) /**
3 or 4 **electron pairs in perfect 3 dimensional (3-d) spatial** arrangement **/**
3 **bonds (bond pairs, bp's) of BF_3 in perfect trigonal planar** arrangement and
4 **bonds (bond pairs, bp's) of CH_4 in perfect tetrahedral** arrangement **/**
vector **sum of dipole moments zero / no overall dipole moment /**
dipole moments cancel / only bond pairs present / no lone pairs present (3)
['no dipole moment' on its own unacceptable]

(*v*) WHAT: **NH_3** bond **angle smaller than** that of **CH_4 /**
107° in NH_3 smaller than **109.5**° in CH_4 (6)

(*b*) (*i*) DEFINE: **change in concentration per unit (over) time (rate of change of concentration,** $\frac{\textbf{change in concentration}}{\textbf{time}}$) of one reactant or product

or

$\frac{d[reactant]}{dt}$ / $\frac{-d[reactant]}{dt}$ / $\frac{d[product]}{dt}$ (6)

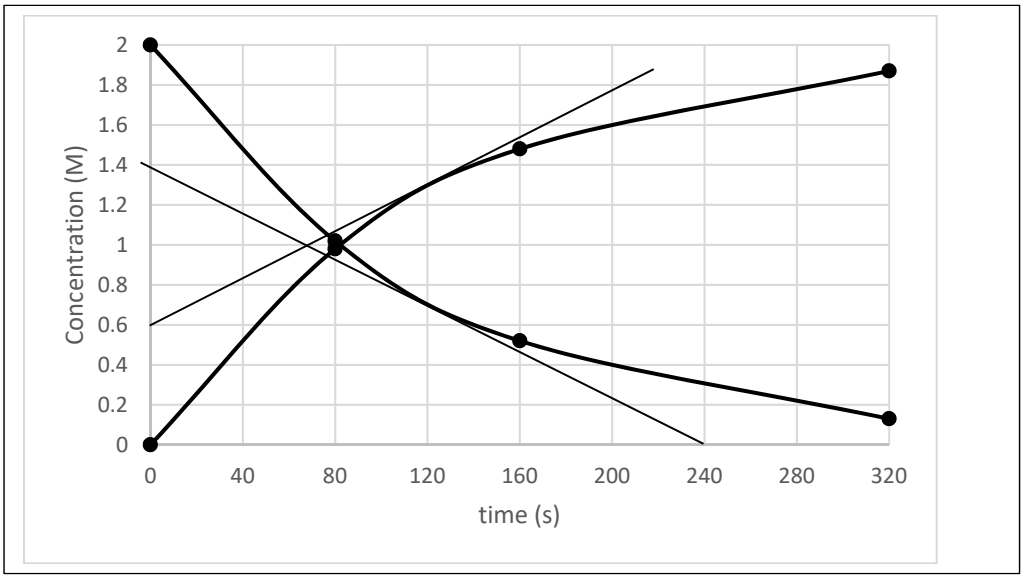
(*ii*) USE: **axes labelled time (seconds, s) and concentration (M, moles per litre) //**

appropriate correct numeric scales on both axes //

careful plotting of 7 points excluding origin //
[(–1) for each of first three incorrectly plotted points]

two smooth curves of correct shape through 8 points including origin (4 × 3)
[Marks not available if points joined by straight lines]

[Time versus concentration graphs acceptable]
[Deduct (6) marks for each of the following:
if different scales used for the two curves;
graph paper not used;
graphs on different sheets of graph paper;
graphs side by side with separate axes on same sheet of graph paper]



(*iii*) FIND: **good tangent drawn to either curve at 120 s** (4)
any two points from tangent read correctly, e.g. (0, 0.6) and (200, 1.78) /
rise and run correctly read from tangent, e.g. 1.4 M , 240 s

slope = 0**.0064** M s^{-1} HCl **[**0**.004 –** 0**.009]** M s^{-1} HCl (3)

$\frac{\textbf{1.78}-\textbf{0.6}}{\textbf{200}-\textbf{0}} = \frac{\textbf{1.28}}{\textbf{200}}$ **=** 0**.0064** M s^{-1} HCl **[**0**.004 –** 0**.009]** M s^{-1} HCl (3)

[Negative sign not required for rate of decomposition of chloroethene.]
[Tangent must be drawn for work on instantaneous rate to be awarded full marks.]
[Last 3 marks can be awarded for rate within stated range with no tangent drawn or consequentially for work done on a poor tangent or a tangent placed at an incorrect time.]

(*c*) (*i*) FIND: **68.58** g Ag (12)

M_r $Cu(NO_3)_2$ = **187.5***	(3)
$\frac{22.50}{187.5}$ = 0.12 (3/25) moles copper(II) nitrate ⇒ 0.**12 (3/25)** moles Cu	(3)
0.12 × 63.5 = **7.62** g Cu	(3)
76.20 – 7.62 = **68.58** g Ag	(3)

[**Addition must be shown for error to be treated as slip. Mr of 187.52 and subsequent work giving 68.57 g Ag based on Ar values in Formula and Tables booklet acceptable.]*

WHAT RATIO: **9 : 1** = Ag : Cu or **9/10 Ag** or **1/10 Cu** (3)

$\frac{68.58}{7.62}$ ⇒ **9 : 1** = Ag : Cu / $\frac{7.62}{76.20}$ ⇒ **1/10 Cu /** ⇒ **9/10 Ag**	(3)
1 : 9 = **Cu : Ag** …..acceptable	
1 : 9 unlabelled or labelled incorrectly treat as mathematical slip (–1)	

(*ii*) WHAT VOLUME: **19.6** litres NO_2 / **19,600** cm^3 NO_2 (10)

$\frac{68.58}{108}$ = 0.635 moles silver	⇒	0**.635** moles NO_2 from silver	(3)
0.12 moles copper	⇒	0**.24** moles NO_2 from copper	(3)
0.635 + 0.24 = 0**.875** moles NO_2 total			(1)
0.875 × **22.4**** = **19.6** litres NO_2 / 0.875 × **22,400**** = **19,600** cm^3 NO_2			(3)

[*A*r of 107.9 from in Formula and Tables booklet and subsequent work acceptable. giving 19.611 litres.]

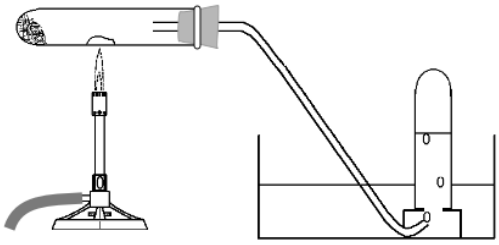
[**24 litres or 24,000 cm^3 unacceptable for molar volume here.]

QUESTION 11

(*a*) (*i*) GIVE: **ripening fruit / plant growth (regulator, inhibitor, promoter) /**
monomer for **polythene (polymer, plastic) manufacture /**
industrial **ethanol manufacture / manufacture antifreeze /**
precursor for **organic chemical synthesis** (4)

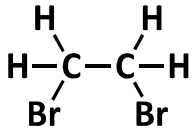
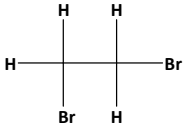
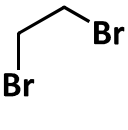
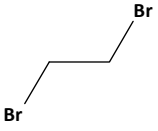
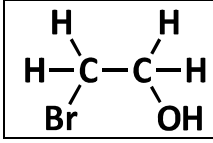
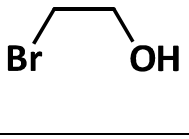
(*ii*) DRAW: **horizontal (slanting) test tube with** delivery **tube emerging** //
ethanol in **glass (steel, cotton) wool at end** //
heat source shown under catalyst (Al_2O_3) in **centre of test-tube** //
collection ethene (gas, bubbles) **over water** or in gas syringe **shown**

ANY THREE: (3 × 3)



[Diagram essential; at least one chemical or item of apparatus labelled]
[Unlabelled diagram (–3)]

(*iii*) DRAW:

				**CH_2BrCH_2Br / $BrCH_2CH_2Br$**
				**CH_2BrCH_2OH**

ANY ONE: (6)

[1,1-dibromoethane unacceptable and 1-bromoethanol unacceptable.]

(*iv*) EXPLAIN: ethene is **soluble in cyclohexane, insoluble in water //**

cyclohexane non-polar /
water polar /

no partial charges (dipoles) in ethene to interact with **partial charges (dipoles) in water) /**
ethene cannot disrupt **hydrogen bonding** of **water** molecules **/**
ethene cannot form hydrogen bonds with water /
ethene and cyclohexane have similar intermolecular forces (2 × 3)
['Like dissolves like' unacceptable.]

(*b*) (*i*) EXPLAIN: **amount** of **(measure** of**, number** of **ppm, number** of **moles, number** of **grams, concentration, molarity)** dissolved **oxygen consumed by biochemical (biological, chemical) process //**
in a water sample over **five days in the dark at 20 ^{o}C** (2 × 3)
[Allow 20 ± 1 ^{o}C]

(*ii*) WHY: would cause (lead to, result in) **algal bloom (eutrophication, de-oxygenation, fish kill) /** would cause **pollution /** would makes **water unfit for drinking (leisure activities), etc** (3)

(*iii*) HOW: **oxidation (breakdown, digestion)** of organic matter (effluent, sewage) **//**
by biological (biochemical) process **/ involving (by) microorganisms (bacteria)** (2 × 3)
['Removal of nutrients' insufficient but does not cancel.]

(*iv*) WHY: all (any) **oxygen would be consumed between analyses (in storage, in the 5 days, before second test) /**
BOD greater than oxygen available (dissolved) / BOD too high to measure **/**
oxygen has low solubility in water /
no oxygen present (remaining) in original sample /
to ensure oxygen present during storage (for testing, **throughout the 5 days) /**
to avoid oxygen level falling to zero (too low, below 2 p.p.m.) during storage (before testing, **during the 5 days)** (6)

(*v*) CALCULATE: **27,000** p.p.m. / **2.7 × 10^{4}** p.p.m. (4)

2.7 × 100 × 100 = **27,000** p.p.m. **/ 2.7 × 10^{4}** p.p.m. (4)

(*c*) (*i*) WHAT: **matter composed of atoms (tiny particles, small particles) /**
atoms are tiny particles (small particles) //

atoms (particles) indivisible (cannot be split, cannot be broken into simpler particles) //

atoms (particles) cannot be created (destroyed) /
fixed number of **atoms (particles)** in universe (exist) **//**

atoms (particles) of same element identical ANY TWO: (2 × 3)

(*ii*) NAME: J.J. **Thomson** (3)

(*iii*) WHAT: **neutron changes into a proton /** $\mathbf{{}_{0}^{1}n \rightarrow {}_{1}^{1}p}$ **//**
and an electron which is emitted **/** $+\ {}_{-1}^{0}e$ (2 × 3)
[Accept 'proton changes into positron and neutron' / $\mathbf{{}_{1}^{1}p \rightarrow {}_{0}^{1}n + {}_{1}^{0}e}$ (6)]

(*iv*) WHAT: *neon-20:* **10 protons (p), 10 neutrons (n)** in nucleus**, 10 electrons (e)** in electron cloud **//**
neon-22: **10 protons (p), 12 neutrons (n)** in nucleus**, 10 electrons (e)** in electron cloud (2 × 3)

[Take order of question unless labelled clearly]

(*v*) CALCULATE: **20.2**0 (4)

(90.0 × 20) + (10.0 × 22) = **2020 /** 1800 + 220 = **2020** (2)
2020 ÷ 100 = **20.2**0 (2)

(*d*)

A (*i*) WHY: very strong (high energy) **triple bond / N≡N //**
non-polar / high degree of **symmetry / no dipole moment /**
no unpaired electrons (2 × 2)

(*ii*) DESCRIBE: **$N_2 + O_2 \rightarrow 2NO$ /**
nitrogen and oxygen combine to form NO (nitrogen(II) oxide) //
$2NO + O_2 \rightarrow 2NO_2$ / $NO + ½O_2 \rightarrow NO_2$ /
NO (nitrous oxide, nitrogen(II) oxide) combines with oxygen to form NO_2 (nitrogen(IV) oxide, nitric oxide) //
lightning provides energy
ANY TWO: (2 × 3)

[Equations in part (*ii*) need not be balanced where given]

(*iii*) WRITE: **$H_2O + 2NO_2 \rightarrow HNO_2 + HNO_3$ /**
$H_2O + 3NO_2 \rightarrow 2HNO_3 + NO$ FORMULAE: (3) BALANCING: (3)

(*iv*) WHAT: manufacture of **protein (amino acids)** (3)

(*v*) DESCRIBE: death and **decay (decomposition)** of animal (animal waste) **/**
ammonium compounds (ammonia) formed (excreted, egested) //
bacteria convert nitrogen compounds (nitrates, nitrites, ammonia) to nitrogen (N_2) / denitrification
(2 × 3)

or

B (*i*) EXPLAIN: **using electricity //**
to break down a chemical (substance) / to cause a chemical **reaction** (2 × 2)

(*ii*) WHY: **ions are free to move** (3)

(*iii*) WRITE: **$Al^{3+} + 3e^- \rightarrow Al$ / $2Al^{3+} + 6e^- \rightarrow 2Al$ //**
$O^{2-} \rightarrow ½O_2 + 2e^-$ / $2O^{2-} \rightarrow O_2 + 4e^-$ / $3O^{2-} \rightarrow 1½O_2 + 6e^-$ //
$Al_2O_3 \rightarrow 2Al + 1½O_2$ / $2Al_2O_3 \rightarrow 4Al + 3O_2$
(3 × 3)

(*iv*) IDENTIFY: **reduction (reaction with CO, reaction with C, reaction with coke)** in blast furnace (3)

(*v*) SUGGEST: **no electricity / electricity undiscovered / too reactive / too difficult to reduce** (3)

(*vi*) EXPLAIN: **metals lower down (at bottom of)** electrochemical series more **difficult to oxidise (more unreactive) /**
metals lower down (at bottom of) electrochemical series have salts more (very) **easily reduced /**
metals lower down (at bottom of) electrochemical series **less electropositive** (3)