Coimisiún na Scrúduithe Stáit
State Examinations Commission

Leaving Certificate 2023

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 1 mark for each arithmetical slip made by a candidate in a calculation, e.g. rounding error, transposing numbers. This deduction applies to incorrect M_r values but only where the addition of all the correct atomic masses is shown and the error is clearly an arithmetical slip. If the addition of atomic masses is not shown, the candidate loses the marks for an incorrect M_r.

7. For calculation questions where units are specified for that question, if the candidate work is correct and a correct answer is given using valid alternative units, apply no penalty.

8. 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 eight questions in all.

All questions carry equal marks (50).

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 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% gnáthráta an bhónais.
Bain úsáid as an ngnáthráta i gcás 300 marc agus faoina bhun sin. Os cionn an mharc sin, féach an tábla thíos.

Bunmharc	Marc Bónais
301 - 303	29
304 - 306	28
307 - 310	27
311 - 313	26
314 - 316	25
317 - 320	24
321 - 323	23
324 - 326	22
327 - 330	21
331 - 333	20
334 - 336	19
337 - 340	18
341 - 343	17
344 - 346	16
347 - 350	15

Bunmharc	Marc Bónais
351 - 353	14
354 - 356	13
357 - 360	12
361 - 363	11
364 - 366	10
367 - 370	9
371 - 373	8
374 - 376	7
377 - 380	6
381 - 383	5
384 - 386	4
387 - 390	3
391 - 393	2
394 - 396	1
397 - 400	0

Annotations used in marking Chemistry 2023

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
$\boxed{-1}$	Mathematical slip error or other penalty as per scheme
$\boxed{0}$	No marks awarded. Answer incorrect or insufficient
$\boxed{R}$	Reverse order
[	Surplus answer or part of answer
	Blank page or part of page
$\boxed{C}$	Cancellation / contradiction
	Part of answer of significance
	Incorrect charge, subscript, etc
λ	Key word, phrase omitted
✓	Correct – e.g. used where item attempted more than once
✗	Incorrect

QUESTION 1

(*a*) STATE: **pure / solid / soluble / stable** on storage **/ does not absorb water (hygroscopic) / not** easily air **oxidised / not efflorescent / high molecular mass / low toxicity / inexpensive / readily available** ANY TWO: (2 × 4)

(*b*) (*i*) DESCRIBE: **dissolve** in **beaker** containing dilute sulfuric acid **//**
add **rinsings** of clock glass to **beaker //**
transfer to 250 cm^3 **volumetric flask //**
transfer solution to flask using a **funnel //**
add **rinsings** of beaker, funnel, glass rod to **flask //**
add **deionised (distilled, pure) water** and dilute sulfuric acid **//**
slowly (carefully) near the mark using pipette or dropper **//**
until **bottom of meniscus is on mark //**
stopper and **invert (mix) several times (more than once)**
ANY THREE: (6 + 3 + 3)

(*ii*) WHY: to **prevent** air **oxidation of Fe^{2+} {Fe(II)} /**
to **prevent** air **oxidation to Fe^{3+} {to Fe(III)} /**
to **prevent hydrolysis (reaction with water) of Fe^{2+} {Fe(II)}** (3)

(*c*) (*i*) HOW: faint (pale) permanent **pink** colour remains (3)

(*ii*) WHAT: **brown precipitate (solid)** (3)

EXPLAIN: **MnO_2 {Mn^{4+}, Mn(IV)}** formed (3)
[WHAT (*ii*) must be correct for EXPLAIN (*ii*) to be awarded marks.]

(*d*) CALCULATE:

(*i*) 0.**095** (**9.5 × 10^{-2}, 19/200**) moles $(NH_4)_2SO_4 \cdot FeSO_4 \cdot 6H_2O$ per litre (9)

M_r $(NH_4)_2SO_4 \cdot FeSO_4 \cdot 6H_2O$ = **392**	(3)
9.31 × 4 = **37.24** g/l $(NH_4)_2SO_4 \cdot FeSO_4 \cdot 6H_2O$	(3)
$\frac{37.24}{392}$ = 0.**095** (**9.5 × 10^{-2}, 19/200**) moles $(NH_4)_2SO_4 \cdot FeSO_4 \cdot 6H_2O$ per litre	(3)

or

M_r $(NH_4)_2SO_4 \cdot FeSO_4 \cdot 6H_2O$ = **392**	(3)
$\frac{9.31}{392}$ = 0.**02375** (**2.375 × 10^{-2}, 19/800**) moles $(NH_4)_2SO_4 \cdot FeSO_4 \cdot 6H_2O$ in flask	(3)
0.02375 × 4 = 0.**095** (**9.5 × 10^{-2}, 19/200**) moles $(NH_4)_2SO_4 \cdot FeSO_4 \cdot 6H_2O$ per litre	(3)

(*ii*) 0.**002375** (**2.375 × 10^{-3}, 19/8000**) moles Fe^{2+} in 25.0 cm^3 (3)

$\frac{25.0 \times 0.095}{1000}$ = 0.**002375** (**2.375 × 10^{-3}, 19/8000**) moles Fe^{2+} in 25.0 cm^3	(3)
[Divide (*i*) by **40** essential.]	

(*iii*) 0.**000475 (4.75 × 10^{-4}, 19/40000)** moles of $KMnO_4$ reduced (3)

Fe^{2+} : potassium manganate(VII) = 5 : 1	
⇒ 0.**000475 (4.75 × 10^{-4}, 19/40000)** moles of $KMnO_4$ reduced	(3)
[Divide (*ii*) by **5** essential.]	

(*iv*) 0.**02** – 0.**022** M $KMnO_4$ (3)

0.000475 (4.75 × 10^{-4}, 19/40000) = $\frac{22.6 \times M}{1000}$	
⇒ M = $\frac{1000 \times 0.000475}{22.6}$ = 0.**02** – 0.**022** M $KMnO_4$	(3)

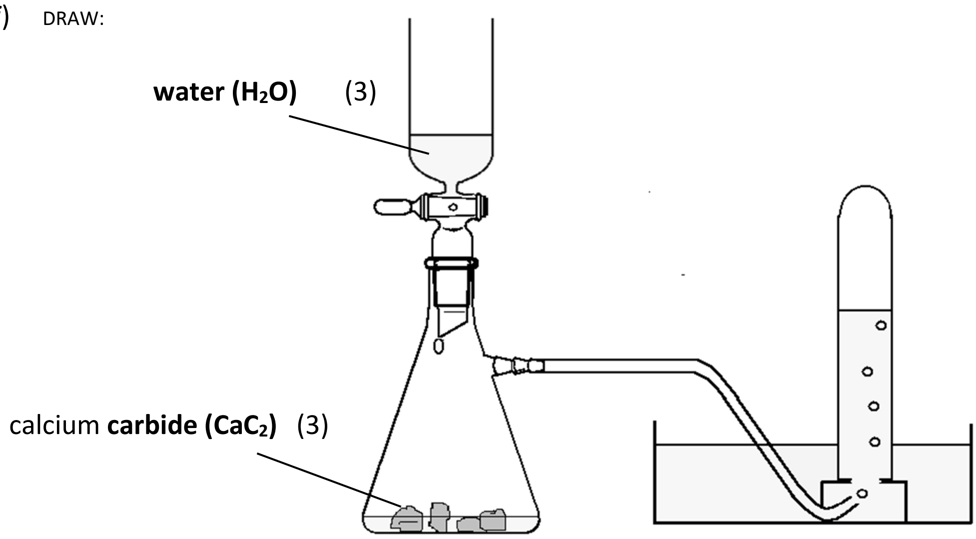
or

$\frac{22.6 \times M}{1} = \frac{25.0 \times 0.095}{5}$ ⇒ M = 0.**02** – 0.**022** M $KMnO_4$	(3)

[Do <u>not</u> award all 18 marks for correct answer to part (*iv*) only.]

QUESTION 2

(*a*) (*i*) DRAW:



correct arrangement of apparatus (3)

(*ii*) WHY: **air (oxygen, nitrogen)** present (5)

(*b*) (*i*) WHAT: **brown (red, orange, yellow) decolourises (to colourless)** (3)
[Correct order essential.]
[Decolourises alone insufficient; clear not acceptable instead of colourless.]

(*ii*) WHAT: **purple (lilac, violet, pink) decolourises (to colourless)** (3)
[Correct order essential.]
[Decolourises alone insufficient; clear not acceptable instead of colourless.]

(*iii*) WHAT: **unsaturated / multiple bond /** undergoes **addition reaction** (6)
[Allow double/triple bond; allow oxidised.]

(*c*) (*i*) DESCRIBE: insert **lighting taper** into (over) test-tube (3)

(*ii*) DESCRIBE: **bright (luminous) / yellow / sooty (smutty, smoky)** (3)

(*iii*) WRITE: $C_2H_2 + 2\frac{1}{2}O_2 \rightarrow 2CO_2 + H_2O$ /
$2C_2H_2 + 5O_2 \rightarrow 4CO_2 + 2H_2O$ FORMULAE: (3) BALANCING: (3)

(*iv*) HOW: **hot**ter **/ clean**er **(less sooty, less smoky, no soot, no smoke) / less bright / blue** (3) (*d*) WHAT: 0.**6** litres ethyne (9)

M_r calcium carbide (CaC_2) = 64

80% of 2.0 = **1.6** g calcium carbide (3)

$\frac{1.6}{64}$ = 0**.025** moles pure calcium carbide (3)

$\Rightarrow$ 0.025 moles ethyne

$\Rightarrow$ 0.025 × 24.0 = 0.**6** litres ethyne (3)

or

M_r calcium carbide (CaC_2) = 64

$\frac{2.0}{64}$ = 0**.03125** moles impure calcium carbide (3)

80% of 0.3125 $\Rightarrow$ 0**.025** moles calcium carbide (3)

$\Rightarrow$ 0.025 moles ethyne

$\Rightarrow$ 0.025 × 24.0 = 0.**6** litres ethyne (3)

or

M_r calcium carbide (CaC_2) = 64

$\frac{2.0}{64}$ = 0**.03125** moles impure calcium carbide (3)

$\Rightarrow$ 0.03125 moles ethyne with impurities

$\Rightarrow$ 0.03125 × 24.0 = 0.**75** litres ethyne with impurities (3)

80% of 0.75 $\Rightarrow$ 0.**6** litres ethyne (3)

[If zero marks awarded, allow (3) for M_r = 64.]

QUESTION 3

(*a*) DEFINE: **heat (energy) change (involved, released, absorbed) //**
when a **reaction takes place according to a balanced equation /**
when the **numbers of moles** of reactants **in a balanced equation** describing a reaction **react** completely (3 + 2)

(*b*) STATE: (*i*) advantage: **accurate**
(*ii*) disadvantage: **not quick / slow / allows heat loss** to surroundings (2 × 3)

(*c*) (*i*) WHY: **exothermic** reaction **/ heat given out (generated) /** ΔH **negative** (3)

(*ii*) SUGGEST: **heat loss** to the surroundings **/ polystyrene is not a perfect insulator /**
the solution is **hotter than** the **room (surroundings)** (3)

(*iii*) EXPLAIN: **better insulator (doesn't get hot, doesn't absorb heat) / low heat capacity /**
glass not as good an insulator / glass gets hot / glass absorbs heat /
specific **heat capacity of glass (beaker)** would have to be allowed for in calculations (3)

(*d*) CALCULATE: (*i*) 0**.05** moles (3)

$M = \frac{50 \times 1.0}{1000}$ = 0**.05** moles (3)

(*ii*) **2.856** kJ [**2.856 to 2.9** kJ] (9)

m = 0.**1** kg (3)	/
H = $\boldsymbol{mc\Delta T}$ ($\boldsymbol{mc\Delta\theta}$) (3)	
H = 0.1 × 4.2 × 6.8 = **2.856** kJ [**2.856 to 2.9** kJ] (3)	

c = 0.**0042** kJ g^{-1} K^{-1} (3)	
H = $\boldsymbol{mc\Delta T}$ ($\boldsymbol{mc\Delta\theta}$) (3)	
H = 100 × 0.0042 × 6.8 = **2.856** kJ[**2.856 to 2.9** kJ](3)	

(*iii*) **–57.1 to –58** kJ mol^{-1} (6)

2.856 ÷ 0.05 = **57.12** kJ mol^{-1} (3)
ΔH **= –57.12** kJ mol^{-1} [**–57.1 to –58** kJ mol^{-1}] (3)

[–1 if incorrect rounding results in candidate's final answer lying outside given range, but deduction to be made once only in (*d*).]
[Ignore negative signs used in work in (*ii*), but final answer in (*iii*) must be negative.]

(*e*) (*i*) EXPLAIN: **big**ger **temperature rise** recorded **/**
less percentage error /
temperature rise easier to measure accurately (6)
[Allow (3) for **more HCl neutralised / more heat released**.]

(*ii*) WHY: three times **more heat produced /** three times **more** moles **(**0.**15) neutralised //**
three times **more solution (water) absorbing heat /**
three times **more solution (greater mass** of water, **more water,** 0.**3** kg**) being heated** (2 × 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*) DEFINE: (*i*) **number of protons** in nucleus of an atom **//**
(*ii*) **number of protons and neutrons** in nucleus of an atom (2 × 3)

(*b*) WRITE: (*i*) **GaN //**
(*ii*) **Ga_2O_3** (2 × 3)

(*c*) PREDICT: **v**-shape **/ bent / angular //**
linear (2 × 3)

(*d*) IDENTIFY: **second //**
ionisation energy (2 × 3)

(*e*) WHAT: **spreading (movement) of a substance (compound, molecules) //**
from high to low concentration / to fill a container (volume) (2 × 3)

(*f*) IDENTIFY: 2: **ionisation //**
4: **separation** (2 × 3)
[Take order of question unless answers clearly labelled.]

(*g*) FIND: 0.**1** M (6)

$\frac{25.0 \times 0.12}{1000}$ = 0.**003** moles (3)

$\Rightarrow 0.003 = \frac{30.0 \times M}{1000}$

$\Rightarrow M$ = 0.**1** M (3)

or

25.0 × 0.12 = 30.0 × *M* /
$\frac{\mathbf{25.0 \times 0.12}}{\mathbf{30}} = M$ (3)

$\Rightarrow M$ = 0.**1** M (3)

$\frac{30}{25}$ = **1.2** dilution factor (3)

$\Longrightarrow \frac{\mathbf{0.12}}{\mathbf{1.2}}$ = 0.**1** M (3)

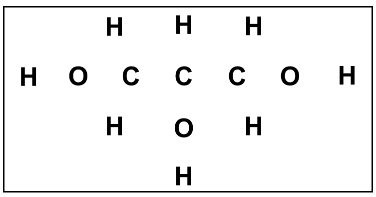
$\frac{25}{30}$ = 0.**8333** dilution factor (3)

$\Rightarrow$ 0.12 × 0.8333= 0.**1** M (3)

[Allow $\frac{30}{25}$ or $\frac{25}{30}$ for first (3) marks.]

(*h*) WHAT: **catalyst / substance which alters rate of reaction //**
of **biological (living)** origin **/** that is **protein** in nature (2 × 3)

(*i*) DRAW:



[Allow OH instead of O–H.] (6)
[$CH_2OHCHOHCH_2OH$ for (3).]

(*j*) GIVE: (*i*) **6 (VI) //**

(*ii*) **two** S = **2, two** S = **3 /** accept **2.5** (2 × 3)

(*k*) CALCULATE: **1×10^{18}** per jar (6)

M_r 2-methoxybenzoic acid = 152
0.001 ÷ **152** = **6.6×10^{-6}** moles per kg (3)
6.6×10^{-6} **× 6.0×10^{23}** = **3.96×10^{18}** molecules per kg (2)
3.96×10^{18} **÷ 4** = **1×10^{18}** molecules per jar (1)

or

M_r 2-methoxybenzoic acid = 152
0.001 ÷ **152** = **6.6×10^{-6}** moles per kg (3)
6.6×10^{-6} **÷ 4** = **1.65×10^{-6}** moles per jar (1)
1.65×10^{-6} **× 6.0×10^{23}** = **1×10^{18}** molecules per jar (2)

or

M_r 2-methoxybenzoic acid = 152
0.001 **÷ 4** = 0**.00025** g per jar (1)
0.00025 ÷ **152** = **1.64×10^{-6}** moles per jar (3)
1.64×10^{-6} **× 6.0×10^{23}** = **1×10^{18}** molecules per jar (2)

[–1 if final answer expressed as 9.87×10^{17} molecules per jar.]

(*l*) **A** WRITE: **$CaCO_3 + SO_2 \rightarrow CaSO_3 + CO_2$ /**

$CaCO_3 \rightarrow CaO + CO_2$ and **$CaO + SO_2 \rightarrow CaSO_3$**

FORMULAE: (3) BALANCING: (3)

or

B EXPLAIN: **valence electrons //**

free to move through (shared by, delocalised amongst) positive (metal) ions (2 × 3)

QUESTION 5

(*a*) (*i*) HOW: **plum-pudding** model of atom **/ electrons (negatives) embedded in sphere of positive** matter **/ balancing charge of positive matter** in atom **/**
same number of negative charges (electrons) as positive charges (protons) in atom (3)

(*ii*) STATE: **atomic (line, emission, absorption) spectra (e.g. Balmer series) / flame tests / ionisation energy (energies)** of the elements **/ periodic table** layout (3)

(*iii*) STATE: **only works for hydrogen** atom **(**He^+ ion**) / doesn't work for multi-electron atoms (ions) //**
wave-particle duality not included **/ wave nature of electron** not included **//**
uncertainty (Heisenberg) principle not included **//**
did not explain **high resolution spectra (splitting of spectral lines, Zeemann effect) //**
did not explain **sublevels (orbitals) / only accounted for main energy levels (shells)**
ANY TWO: (2 × 3)

(*iv*) 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.]

(*v*) WRITE: $1s^2\,2s^2\,2p^6\,3s^2\,3p^6$ / $1s^2\,2s^2\,2p_x^2 2p_y^2\,2p_z^2\,3s^2\,3p_x^2 3p_y^2\,3p_z^2$ **//**
$4s^2\,3d^{10}\,4p^5$ / $4s^2\,3d^{10}\,4p_x^2 4p_y^2\,4p_z^1$ (2 × 3)
or
[Allow **[Ar] //** $4s^2\,3d^{10}\,4p^5$ or **[Ar] //** $4s^2\,3d^{10}\,4p_x^2 4p_y^2\,4p_z^1$ for (2 × 3)]
[Allow subscripts instead of superscripts.]
[Arrows to represent numbers of electrons acceptable, but sublevel labels must be given.]

(*b*) (*i*) DEFINE: number expressing the **relative (measure of) attraction** of a nucleus (atom) **//**
for shared pair(s) of **electrons / for electrons in a covalent bond** (2 × 3)

(*ii*) ACCOUNT: effective **nuclear charge increasing //**
atomic radius decreasing / shared (outer, valence) electrons drawn **closer to nucleus**
(2 × 3)

(*iii*) EXPLAIN: **atomic radius increasing / shared (outer, valence) electrons farther from nucleus / more shells (**main **energy levels) //**
more **screening (shielding)** of nucleus by electrons in inner shells **/**
effective nuclear charge almost **constant /**
influence of nuclear charge decreasing (2 × 3)

(*iv*) PREDICT: almost **pure covalent / non-polar covalent /** very **slightly polar covalent** (3)

(*v*) WHICH: **F (fluorine)** (3)

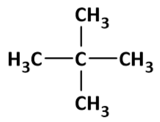
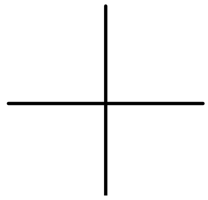
JUSTIFY: F (fluorine) **more (most) electronegative** than O (2)
[JUSTIFY marks only available if WHICH marks have been awarded.]

QUESTION 6

(*a*) (*i*) WHAT: compound of **carbon (C)** and **hydrogen (H)** only (6)

(*ii*) WHY: contain **only single** carbon carbon (C–C) **bonds /**
contain **no double (multiple)** carbon carbon (C–C) **bonds /**
do not participate in addition reactions with hydrogen (6)

(*b*) GIVE: 2,2-**dimethylpropane** (3)

DRAW: **$CH_3C(CH_3)_2CH_3$ /**  **/**  (6)

[Accept for (6) if Hs <u>not</u> shown explicitly in expanded structure.]

(*c*) WHAT: **C_6H_{12}** (6)

(*d*) CALCULATE: **–10046.5** kJ mol^{-1} (12)

$\Delta H_{\text{reaction}} = \Sigma\Delta H_{\text{formation products}} - \Sigma\Delta H_{\text{formation reactants}}$

$\Delta H_{\text{reaction}} = (15 \times -393.5)$ kJ + (16×-285.8) kJ $-(\Delta H_{\text{formation } C_{15}H_{32}})$ kJ

$\Delta H_{\text{reaction}} =$ (**–5902.5**) kJ (3) + (**–4572.8**) kJ (3) **– (–428.8)** kJ (3) **/**
$\Delta H_{\text{reaction}} =$ (**–5902.5**) kJ (3) + (**–4572.8**) kJ (3) **+ 428.8** kJ (3) **/**
$\Delta H_{\text{combst}} =$ **–10475.3** (6) **– (–428.8)** (3) **/**
$\Delta H_{\text{combst}} =$ **–10475.3** (6) **+ 428.8** (3) **/**

$\Delta H_{\text{combst}} =$ **–10046.5** (3) kJ mol^{-1}

3 Δ*H*s must be added for the consequential award of the last 3 marks.

or

$C_{15}H_{32} \rightarrow 15C + 16H_2$	ΔH =	**428.8** kJ	(3)
$15C + 15O_2 \rightarrow 15CO_2$	ΔH =	**–5902.5** kJ	(3)
$16H_2 + 8O_2 \rightarrow 16H_2O$	ΔH =	**–4572.8** kJ	(3)
$C_{15}H_{32} + 23O_2 \rightarrow 15CO_2 + 16H_2O$	ΔH_{combst} =	**–10046.5** kJ mol^{-1}	(3)

3 Δ*H*s must be added for the consequential award of the last 3 marks.

[Mixing and matching from different boxes <u>not</u> acceptable.]
[Where final answer for ΔH = +**10046.5** kJ mol^{-1} apply the marking scheme, but the max. mark is 9.]

(*e*) (*i*) WHAT: **CH_2** (6)
[Allow (3) for **14**.]

(*ii*) ESTIMATE: **600 – 700** kJ mol^{-1} (5)

QUESTION 7

(*a*) (*i*) DEFINE: **proton (hydrogen ion, H^+) donor** (3)

(*ii*) WHAT: 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** (3)

(*iii*) IDENTIFY: **OCl^-** (3)

(*iv*) IDENTIFY: **H_2SO_4** (3)

(*b*) CALCULATE: (*i*) pH = **1.1** (6)

$[H^+] = 0.08$	(2)
pH = **– $\log_{10}[H^+]$ /** pH = **– $\log_{10}[H_3O^+]$**	(2)
pH = **1.1**	(2)

CALCULATE: (*ii*) pH = **4.5** (6)

pH = $-\log\sqrt{K_a[\mathrm{HA}]}$ $\left(\text{pH} = -\log\sqrt{1.2 \times 10^{-9}}\text{, pH} = -\log(3.5 \times 10^{-5})\right)$	(3)
pH = **4.5**	(3)

(*c*) (*i*) IDENTIFY: **sedimentation (settlement) / flocculation / filtration / decanting / screening**

ANY TWO: (2 × 3)

(*ii*) CALCULATE: **1550** p.p.m. (6)

1.24 g in 800 cm^3 $\Rightarrow$ **1.55×10^{-3}** g per cm^3 / **1.55** mg per cm^3	(3)
$\Rightarrow$ **1550** p.p.m.	(3)

or

1.24 g in 800 cm^3 $\Rightarrow$ **1.55** g per litre	(3)
$\Rightarrow$ **1550** p.p.m.	(3)

or

$\frac{1.24 \times 1000}{800}$ $\Rightarrow$ **1.55** g per litre	(3)
$\Rightarrow$ **1550** p.p.m.	(3)

(*d*) (*i*) WRITE: **$Al_2(SO_4)_3 + 2Na_3PO_4 \rightarrow 2AlPO_4 + 3Na_2SO_4$** FORMULAE: (3) BALANCING: (3)

(*ii*) DESCRIBE: add **iron(II) sulfate ($FeSO_4$) /** add ammonium **iron(II) sulfate (**$(NH_4)_2SO_4$.**$FeSO_4$**$\cdot 6H_2O$**) //** add **conc**entrated **sulfuric acid (H_2SO_4)** dropwise (gently, with a dropper) **//** **brown ring**

(3 + 3 + 2)

QUESTION 8

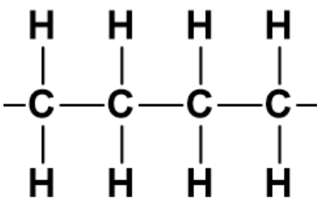
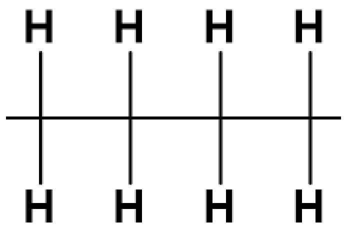
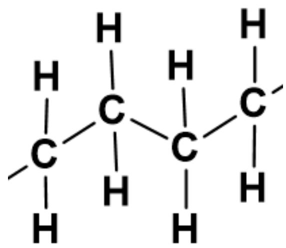
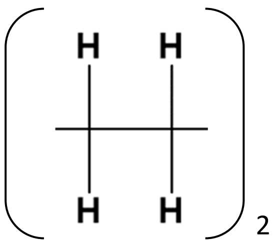
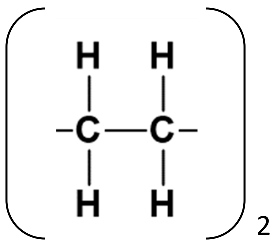
(*a*) (*i*) WHAT: **small molecule (number of atoms) removed** from substrate **/**
named small molecule (e.g. water) removed from substrate **(dehydration) /**
reverse of addition reaction **/**
double bond (triple bond, ring) formed in molecule (4)

(*ii*) IDENTIFY: **D (ethanol to ethene)** (4)

(*b*) (*i*) IDENTIFY: **H_2 (hydrogen** gas**)** (3)

(*ii*) IDENTIFY: **platinum (Pt) / palladium (Pd) / nickel (Ni) / copper (Cu) / rhodium (Rh) / ruthenium (Ru)** (3)

(*c*) (*i*) DRAW: (6)

		
		[Correct carbon skeleton (4 Cs) essential, shape not required.] [Hs need not be shown explicitly where CH bond is shown.]

[Allow end bonds shown or not shown but end H’s not acceptable, i.e. butane not acceptable.]

(*ii*) HOW: **planar to //**
tetrahedral (2 × 3)
[correct order essential]

(*d*) (*i*) IDENTIFY: **HCl (hydrogen chloride)** (3)
[hydrochloric acid not acceptable]

(*ii*) WHAT: evidence for **substitution (free radical)** reaction (mechanism) /
evidence for **termination** (3)

(*e*) (*i*) DEDUCE: **D** (3)

(*ii*) DEDUCE: **C** (3)

(*iii*) WHY: **increasing molecular mass (M_r) / increasing molecular size /**
increasing number of electrons / stronger intermolecular (van der Waals, London, dispersion) forces (bonds, interactions) (6)
[Any reference to breaking more <u>intra</u>molecular bonds incorrect and cancels.]

(*iv*) ACCOUNT: **ethanal has stronger intermolecular (dipole-dipole) forces (bonds, interactions) /**
C = O is polar in ethanal / propane has weaker intermolecular (van der Waals, London, dispersion, temporary) forces (bonds, interactions) /
propane is non-polar / ethanal is polar (3)

(*v*) ACCOUNT: **ethanoic acid has stronger hydrogen bonding /**
ethanoic acid forms dimers /
propanol has weaker hydrogen bonding (3)

QUESTION 9

(*a*) (*i*) EXPLAIN: **stage reached when / after a while /**
rate of forward reaction decreases until **/** only **PCl_3 and Cl_2 react at first /**
rate of reverse reaction increases until **/ PCl_5 reacts when it is formed /**
both reactions continue / dynamic equilibrium **/ reactions do not stop //**

at equilibrium **rates of forward and reverse reactions** are **equal ($r_f = r_r$) /**
at equilibrium **unchanging concentration**s

(4 + 4)

(*ii*) WOULD: **less** (3)

(*ii*) EXPLAIN: **one mole (molecule) of product (PCl_5) replaces two moles (molecules) of reactants / one mole (molecule) of PCl_5 replaces one mole (molecule) PCl_3 and one mole (molecule) Cl_2 / fewer moles (molecules)** present in the container (on RHS) (3)
[WOULD (*ii*) must be correct for EXPLAIN (*ii*) to be awarded marks.]

(*b*) (*i*) WRITE: $K_c = \dfrac{[\mathbf{PCl_5}]}{[\mathbf{PCl_3}][\mathbf{Cl_2}]}$ (6)
[Square brackets are essential.]
[Note: marks for (*b*) (*i*) may be awarded for this expression given in (*b*) (*ii*).]

(*ii*) CALCULATE: $[PCl_3]$ = **2.**0 mol/l, $[Cl_2]$ = 0**.2** mol/l and $[PCl_5]$ = **1.**0 mol/l (12)

	$PCl_{3\,(g)}$	+	$Cl_{2\,(g)}$	$\rightleftharpoons$	$PCl_{5(g)}$	
Initially:	3.00 mol/l		1.20 mol/l		0 mol/l	
Change:	- x mol/l		- x mol/l		+ x mol/l	
Equil:	**3.0**0 **- x** mol/l		**1.2**0 **- x** mol/l		**x** mol/l	(3)

$$\frac{\boldsymbol{x}}{(\mathbf{3.}00 - \boldsymbol{x})(\mathbf{1.2}0 - \boldsymbol{x})} = \mathbf{2.5}$$ (3)

$\Rightarrow$ ***x* = 1.**00 or 3.6 (3)

$\Rightarrow$ At equilibrium $[PCl_3]$ = **2.0** mol/l
$[Cl_2]$ = 0**.2** mol/l
$[PCl_5]$ = **1.**0 mol/l (3 × 1)

[For work where only one of the three equilibrium concentrations is expressed in terms of ***x*** and a quadratic equation is not formed, allow a maximum mark of 0, 0, 3, 1.]

(*c*) WHAT: **smaller / lower / less than 2.5 / decreases** (3)

EXPLAIN: **less product (PCl_5)** at equilibrium **/ more reactants (PCl_3 and Cl_2)** at equilibrium **/ larger denominator** in Kc expression **/ smaller numerator** in Kc expression **/** equilibrium **shifts to reactant side (left hand side, LHS, endothermic side, side that absorbs heat) / favours reverse reaction** (3)
[WHAT must be correct for EXPLAIN to be awarded marks.]

(*d*) (*i*) EXPLAIN: adding chlorine (Cl_2) is a **stress //**
relieved when chlorine (Cl_2) reacts forming **more PCl_5 (favouring forward reaction, right hand side, greater yield of product)** (2 × 3)

(*ii*) WHY: because **only temperature** change **affects (changes)** K_c **/**
because K_c **temperature constant (unchanged) /**
because K_c **unaffected (unchanged) by changes in concentration /**
because **concentrations (amounts) of other** equilibrium **substances (chemicals, PCl_3 and PCl_5) also change keeping** K_c **constant** (6)

QUESTION 10

(*a*) (*i*) WHY: **carcinogen(ic) /** causes **cancer / mutagenic /**
breaks (damages) DNA (chromosomes) / toxic / harmful (4)

(*ii*) NAME: **dehydrocyclisation (reforming)** (6)

(*iii*) HOW MANY: **12** (3)

(*iv*) HOW MANY: **12** (3)

(*v*) HOW MANY: **6** (3)

(*vi*) HOW MANY: **18** (3)

(*vii*) HOW MANY: **12** (3)

(*b*) (*i*) WRITE: $(CH_2)_n(COOH)_2$: $\mathbf{14n + 90}$ (3)
$(CH_2)_n(COONa)_2$: $\mathbf{14n + 134}$ (3)
[Take order of question unless answers clearly labelled.]

(*ii*) WRITE: $\frac{1.77}{14n+90}$ moles $(CH_2)_n(COOH)_2$ (3)
$\frac{2.43}{14n+134}$ moles $(CH_2)_n(COONa)_2$ (3)
[Take order of question unless answers clearly labelled.]

(*iii*) FIND:

$\frac{1.77}{14n+90} = \frac{2.43}{14n+134}$ **/**	
$24.78n + 237.18 = 34.02n + 218.7$ **/**	
$\Rightarrow 18.48 = 9.24n$ **//**	(2)
$\Rightarrow n = \mathbf{2}$ **//**	(2)
molar mass of $(CH_2)_n(COOH)_2$ = **118** g	(3)

[Allow correct answers obtained by trial and error method below, i.e. letting *n* = 2 and showing *n* = 2 gives equal moles of succinic acid and disodium succinate as shown below. Do not allow mixing and matching of marks between boxes.]

Letting $n = \mathbf{2} \Rightarrow M_r$ $(CH_2)_n(COOH)_2$ = **118** and M_r $(CH_2)_n(COONa)_2$ = 162	(2 + 3)
Show moles $(CH_2)_n(COOH)_2$ = moles $(CH_2)_n(COONa)_2$	
$\frac{1.77}{118}$ = 0.**015** moles $(CH_2)_n(COOH)_2$ = $\frac{2.43}{162}$ = 0.**015** moles $(CH_2)_n(COONa)_2$	(2)

(*iv*) WHAT: **250** cm^3 (6)

$\frac{1.77}{118}$ = 0.**015** moles $(CH_2)_n(COOH)_2$	(2)
$\Rightarrow$ 0.**03** moles NaOH	(2)
$0.03 = \frac{0.12 \times V}{1000}$ $\Rightarrow V = \mathbf{250}$ cm^3	(2)

(*c*) (*i*) WHAT: atoms with **same atomic number (same Z**, **equal numbers protons) /**
atoms of the same element //
different number of neutrons (different A) / different mass numbers (2 × 3)

(*ii*) WHAT: spontaneous **decay (disintegration, break-up, splitting)** of an unstable atomic **nucleus** (**of** atomic **nuclei**) **//**
with emission of radiation (2 × 3)

(*iii*) COPY & COMPLETE: ${}^{131}_{53}\mathrm{I} \rightarrow \ \mathbf{{}^{131}_{54}Xe} \quad + \ {}^{0}_{-1}e$ (3)

(*iv*) EXPLAIN: **neutron //**
changes into proton and electron (2 × 3)

(*v*) ARE: **more** (4)

QUESTION 11

(*a*) (*i*) STATE: **volume (V) of a fixed mass of gas at constant pressure //**
proportional ($\propto$) to temperature (T) in kelvins
or
for a fixed mass of gas at constant pressure //
$\frac{V}{T}$ **= constant (k) /** $\frac{V_1}{T_1} = \frac{V_2}{T_2}$ (2 × 3)

(*ii*) EXPLAIN: $pV = nRT \Rightarrow \frac{V}{T} = \frac{nR}{p}$ **= constant /**
n **and** ***R*** **constant** for a fixed mass of gas and ***p*** also **constant** (3)

(*iii*) UNDER: **high temperature //**
low pressure (2 × 2)

(*iv*) CALCULATE: 0.**3 –** 0.**31** m^3 / **300 – 310 litres** (6)

$pV = nRT$ / $n = \frac{pV}{RT} \Rightarrow$	
10000 × ***V*** **=** 1.0 × **8.3 × 373 /** $V = \frac{1.0 \times 8.3 \times 373}{10000}$	(3)
V = 0.**31** m^3	(3)

(*v*) GIVE: strong **H bonding (intermolecular forces)** between its molecules **/ polar** molecule **//**
molecules (particles) not point masses / particles (molecules, atoms) occupy volume //
collisions not elastic ANY TWO: (2 × 3)

(*b*) (*i*) IDENTIFY: **carbon (C, graphite) / platinum (Pt)** (4)

(*ii*) DEFINE: **loss** of electrons (3)

(*iii*) WRITE: $\mathbf{I^- \rightarrow \tfrac{1}{2}I_2 + e^- \;/\; 2I^- \rightarrow I_2 + 2e^-}$
FORMULAE: (3) BALANCING: (3)

(*iv*) DESCRIBE: **positive (+)** (3)

(*v*) EXPLAIN: **OH$^-$** ions formed at this electrode (6)

(*vi*) WHAT: **brown (red, yellow)** (3)

(*c*) (*i*) EXPLAIN: minimum **energy of reacting (colliding) molecules (particles, reactants) //**
for product molecule(s) **to be formed / for reaction to occur /**
for (of) effective collisions / for intermediate (transition state) to be formed /
for internal **bonds to be broken** (2 × 2)

(*ii*) HOW: **increased / speeded up / faster /**
decreases energy required for reaction to occur /
provides alternative mechanism (pathway) (3)

(*iii*) HOW: using a **catalyst / changing the** reaction **mechanism /**
providing an alternate pathway (intermediate) for reaction (3)

(*iv*) WHY: **energy (time) required to break covalent bonds** before new bonds formed **/**
covalent bonds must be broken before they can react **//**
ions dissociated already **/ ions ready to react /**
ions react when they collide (meet) / ionic bonds already broken in solution
(2 × 3)

(*v*) SUGGEST: add **catalyst (Co^{2+}, cobalt(II)** ions**) //**
increase temperature //
increase concentration hydrogen peroxide //
increase concentration sodium potassium tartrate ANY THREE: (3 × 3)
[Allow (3) for increase concentration, but once only if neither hydrogen peroxide nor sodium potassium tartrate specified.]

(*d*)

A (*i*) WRITE: $\mathbf{N_2 + O_2 \rightarrow 2NO}$ FORMULAE: (2) BALANCING: (2)

$\mathbf{2NO + O_2 \rightarrow 2NO_2}$ **/** $\mathbf{NO + \frac{1}{2}O_2 \rightarrow NO_2}$ FORMULAE: (2) BALANCING: (2)

(*ii*) WHY: **triple bond** in N_2 **(N≡N)** must be broken / **high bond energy** (3)
[Accept non-polar bond]

(*iii*) CALCULATE: 0.**0027** – 0.**003** moles guideline or 0.**029 –** 0.**02944** mg present (6)

M_r NO_2 = 46
$3.2 \times 10^{-3} \times 46$ = 0.**1472** g in 5000 m^3 (3)

$0.1472 \div 5000 = 2.944 \times 10^{-5}$ g per m^3

⇒ 0.**02944** mg present per m^3 (3)

⇒ guideline exceeded

or

M_r NO_2 = 46
$3.2 \times 10^{-3} \div 5000$ = $\mathbf{6.4 \times 10^{-7}}$ moles per m^3 (3)

$6.4 \times 10^{-7} \times 46 = 2.944 \times 10^{-5}$ g per m^3
⇒ 0.**02944** mg per m^3 (3)

⇒ guideline exceeded

or

M_r NO_2 = 46
0.025 × 5000 = **125** mg in 5000 m^3 max (3)

⇒ 0.125 g in 5000 m^3 max

$\Rightarrow \frac{0.125}{46}$

= $\mathbf{2.7 \times 10^{-3}}$ **–** $\mathbf{3.0 \times 10^{-3}}$ moles max (3)

⇒ guideline exceeded

or

M_r NO_2 = 46
0.025 mg ⇒ 2.5×10^{-5} g per m^3
$\Rightarrow \frac{2.5 \times 10^{-5}}{46}$ = $\mathbf{5.4 \times 10^{-7}}$ moles per m^3 max (3)

⇒ $5.4 \times 10^{-7} \times 5000$

= $\mathbf{2.7 \times 10^{-3}}$ **–** $\mathbf{3.0 \times 10^{-3}}$ moles max (3)
⇒ guideline exceeded

[If <u>zero marks</u> awarded, allow (2) for M_r = 46.]

(*iv*) IDENTIFY: **burning fossil fuels / transport / heating / agriculture / making fertiliser (nylon, etc.)** (3)

(*v*) EXPLAIN: **absorbs (retains) heat** energy **(infrared** radiation**) in** Earth's **atmosphere / contributes to global warming (climate change)** (5) *or*

B (*i*) WRITE: $\mathbf{Al_2O_3{\cdot}3H_2O + 2NaOH \rightarrow 2NaAlO_2 + 4H_2O}$ FORMULAE: (3) BALANCING: (3)

(*ii*) IDENTIFY: **sludge (red mud, iron oxide)** byproduct (produced, separated, stored) **/**
waste water could cause contamination if not treated **/**
dust unsightly (harmful to health, harmful to environment) if released **/**
gaseous emissions filtered to avoid health environment) damage /
fossil fuel consumption has global warming effects **/ etc.** (3)

(*iii*) WHAT: availability of **cheap electricity (cost of electricity)** (3)

(*iv*) WHY: **ions free to move** when molten or dissolved **/**
alumina (Al_2O_3) **conducts electricity** when molten or dissolved **/**
solid alumina (Al_2O_3) **does not (cannot) conduct electricity** (3)

(*v*) WRITE: $\mathbf{Al^{3+} + 3e^{-} \rightarrow Al}$ **/** $\mathbf{2Al^{3+} + 6e^{-} \rightarrow 2Al}$ FORMULAE: (3) BALANCING: (3)

(*vi*) EXPLAIN: **cryolite (Na_3AlF_6, impurity, solvent,aluminium fluoride, AlF_3 , calcium fluoride, CaF_2) added** (4)